Digitization: induction & electronics

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With a lot of discussions with
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Digitization: induction & electronics

Goal 1 -
Have compatible results with
1. **full induction**, *i.e.* Ramo & weighting field
2. **fast induction**, *i.e.* collected charge

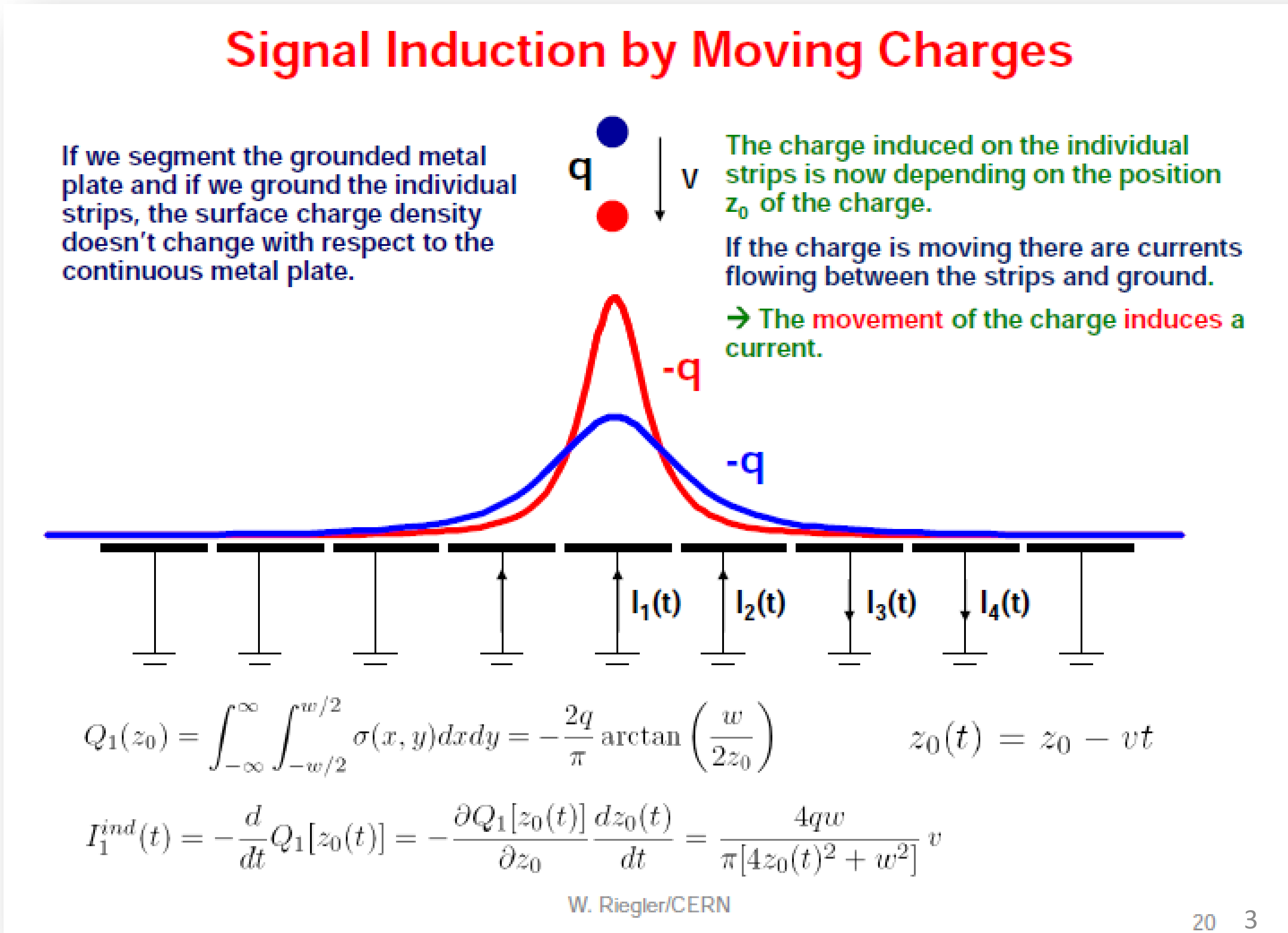
• rewrite the weighting field according to Riegler calculations
• improve the charge collection calculation in GTS

Goal2 -
Refine the APV-25 simulation

• implement the different steps of APV-25 operation

Induced charge

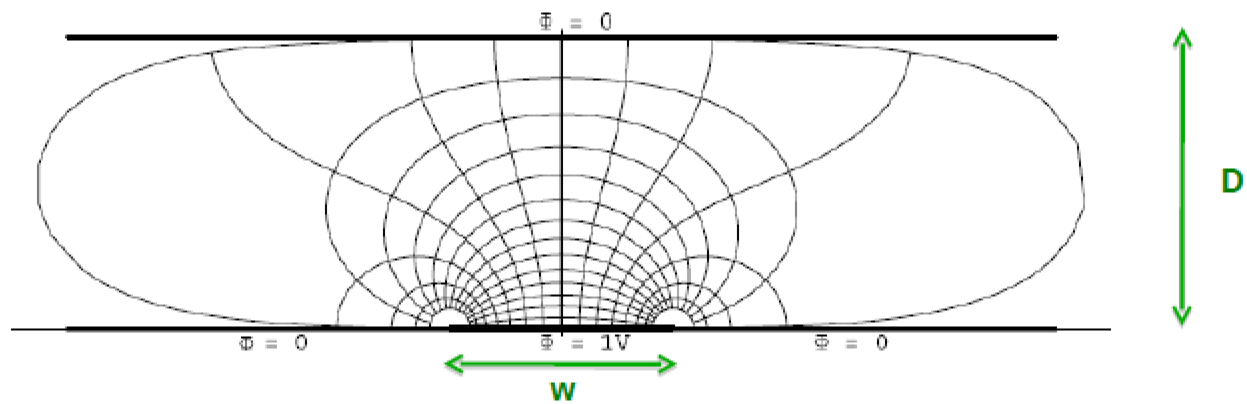
W. Riegler



Induced charge

W. Riegler

Weighting Field for a Strip in a Parallel Plate Geometry



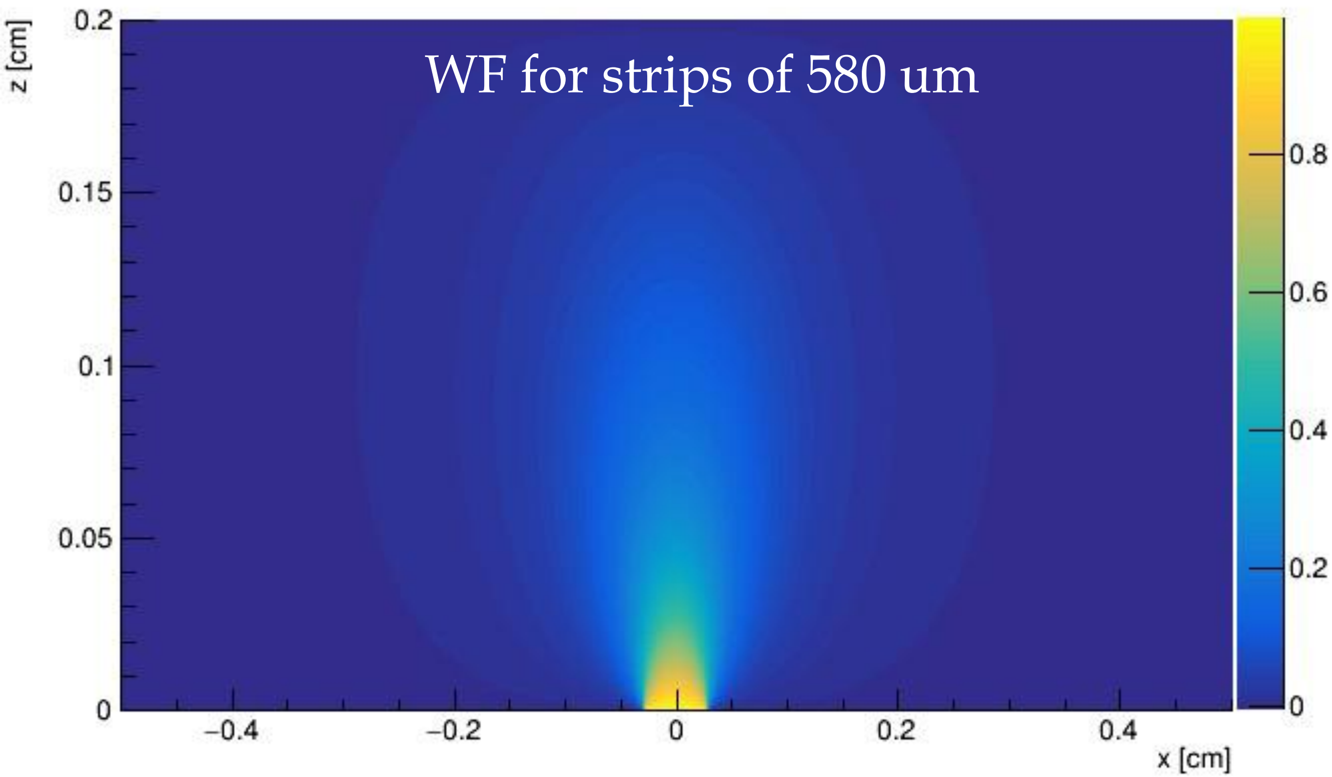
$$\Phi_1(x,z) = \frac{V_1}{\pi}\left[\arctan\left(\cot\left(\frac{z\pi}{2D}\right)\tanh\left(\pi\,\frac{x+w/2}{2D}\right)\right) - \arctan\left(\cot\left(\frac{z\pi}{2D}\right)\tanh\left(\pi\,\frac{x-w/2}{2D}\right)\right)\right]$$

$$E_{1x} = V_1\frac{1}{2D}\left[\frac{\sin\left(\frac{z\pi}{D}\right)}{\cosh\left(\pi\,\frac{x-w/2}{D}\right)-\cos\left(\frac{z\pi}{D}\right)} - \frac{\sin\left(\frac{z\pi}{D}\right)}{\cosh\left(\pi\,\frac{x+w/2}{D}\right)-\cos\left(\frac{z\pi}{D}\right)}\right]$$

Weighting Field:

$$E_{1z} = -V_1\frac{1}{2D}\left[\frac{\sinh\left(\pi\,\frac{x-w/2}{D}\right)}{\cosh\left(\pi\,\frac{x-w/2}{D}\right)-\cos\left(\frac{z\pi}{D}\right)} - \frac{\sinh\left(\pi\,\frac{x+w/2}{D}\right)}{\cosh\left(\pi\,\frac{x+w/2}{D}\right)-\cos\left(\frac{z\pi}{D}\right)}\right]$$

Induced charge



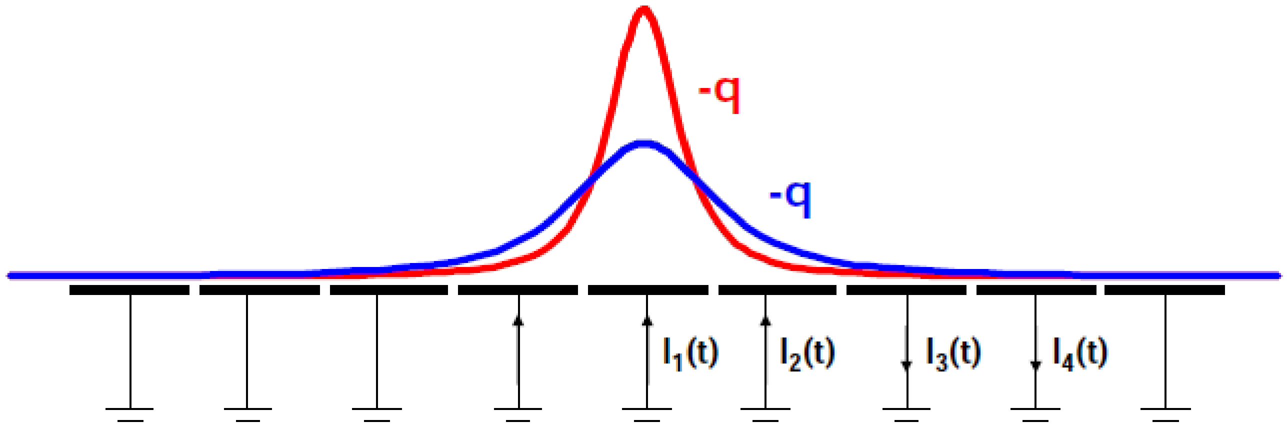
$$I(t,x) = -e_0 * Ez[x, D - v*t] * v$$

or

$$Q(t, x) = -e_0 * V_w(x, D - v*t)$$

with steps dt = 1ns

Collected charge



• For each e- in the avalanche entering the induction gap
→ compute the final position on the anode on the i-*th* strip
→ consider the electron charge as the charge collected by i-*th* strip

• For each strip
→sum-up all the collected charges

• Use only charges ending on the active area
→580 um
→ still to be tested with 130 um

Q_{IND} *vs* Q_{COLL} comparison

W. Riegler

Total Induced Charge

If a charge is moving from point x_0 to point x_1, the induced charge is

$$Q_n^{ind} = \int_{t_0}^{t_1} I_n^{ind}(t)dt = -\frac{q}{V_w}\int_{t_0}^{t_1} E_n[x(t)]\,\dot{x}(t)dt = \frac{q}{V_w}[\psi_n(x_1) - \psi_n(x_0)]$$

If a pair of charges +q and -q is produced at point x_0 and q moves to x_1 while –q moves to x_2, the charge induced on electrode n is given by

$$Q_n^{ind} = \int_{t_0}^{t_1} I_n^{ind}(t)dt = \frac{q}{V_w}[\psi_n(x_1) - \psi_n(x_2)]$$

If the charge q moves to electrode n while the charge –q moves to another electrode, the total induced charge on electrode n is q, because the ψ_n is equal to V_w on electrode n and equal to zero on all other electrodes.

In case both charges go to different electrodes the total induced charge is zero.

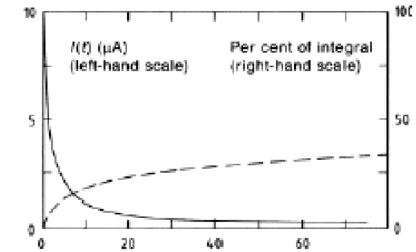
After ALL charges have arrived at the electrodes, the total induced charge on a given electrode is equal to the charge that has ARRIVED at this electrode.

Current signals on electrodes that don't receive a charge are therefore strictly bipolar.

Induced Charge, 'Collected' Charge

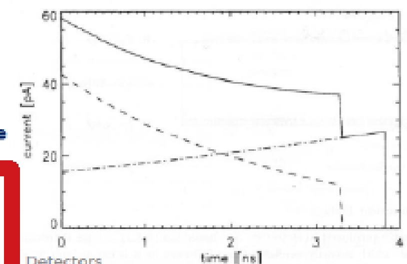
The fact that the total induced charge on an electrode, once ALL charges have arrived at the electrodes, is equal to the actual charge that has ARRIVED at the electrode, leads to very different 'vocabulary for detectors in different detectors.

In wire chambers the ions take hundreds of microseconds to arrive at the cathodes. Because the electronics 'integration time' is typically much shorter than this time, the reality that the signal is 'induced' is very well known for wire chambers, and the signal shape is dominated by the movement of the ions.



The longer the amplifier integration time, the more charge is integrated, which is sometimes called 'collected' , but it has nothing to do with collecting charge from the detector volume …

In Silicon Detectors, the electrons and holes take only a few ns to arrive at their electrodes, so e.g. for typical 'integration times' of amplifiers of 25ns, the shape is dominated by the amplifier response. The peak of the amplifier output is the proportional to the primary charge, and all the charge is 'collected'



Still, the signal is not due to charges entering the amplifier from the detector, it is due to induction by the moving charge. Once the charge has actually arrived at the electrode, the signal is over !

The induced and the collected charge on the strips **must be equal**, once all the electrons have arrived on the anode

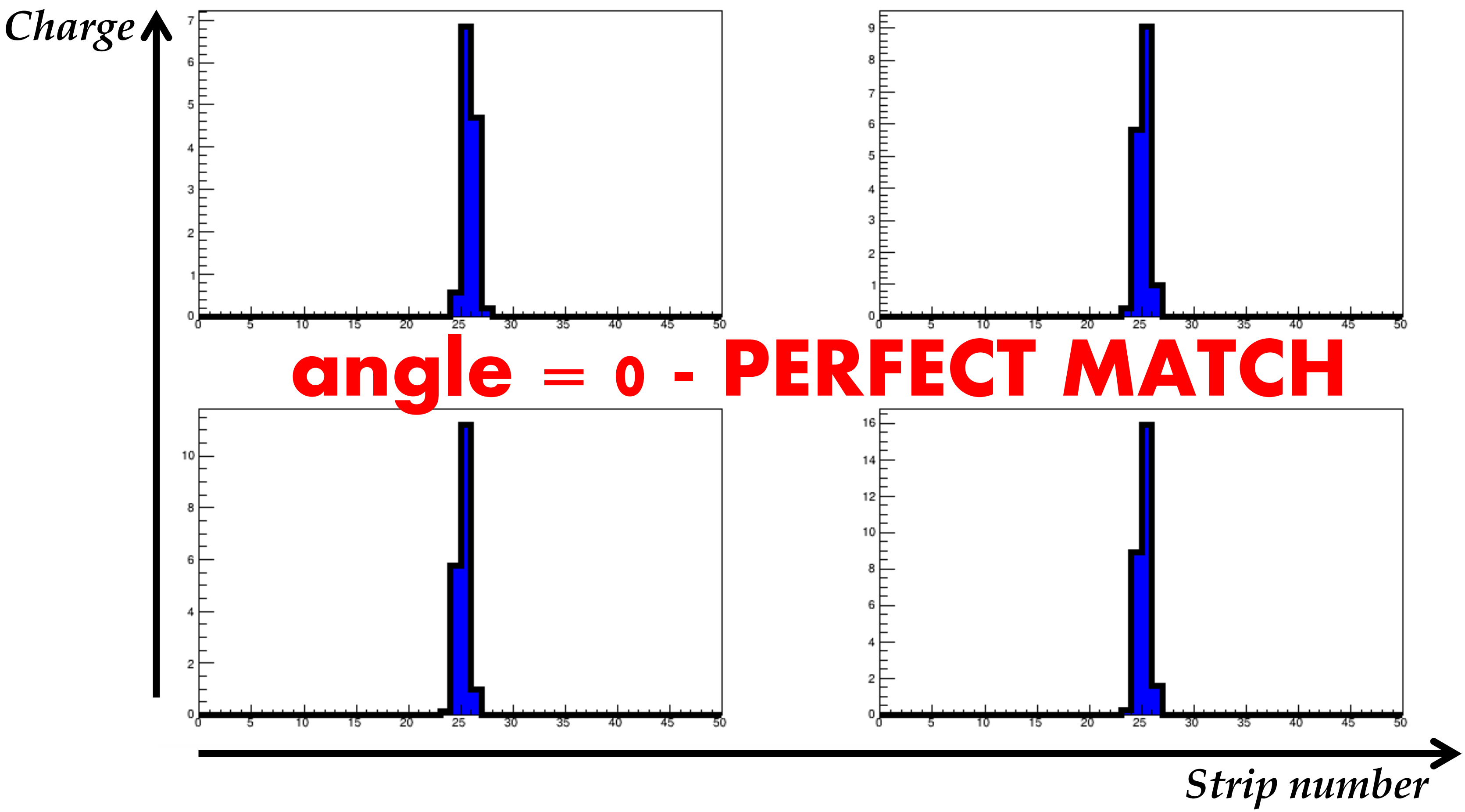
Q_{IND} *vs* Q_{COLL} comparison

Charge *vs* strip number

• Blue = collected

• Black = induced

for four different tracks with incident ***angle* = 0**

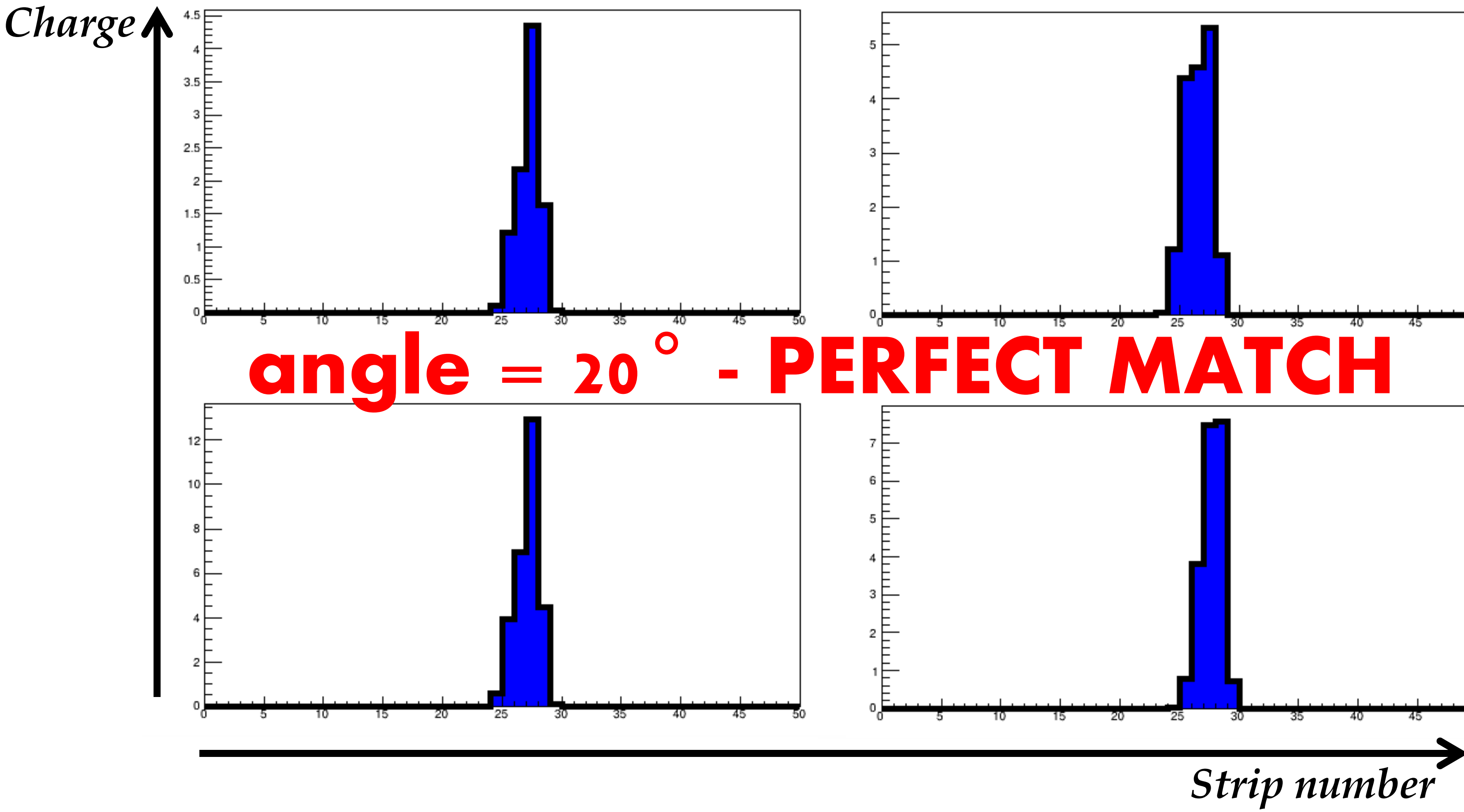


Q_{IND} *vs* Q_{COLL} comparison

Charge *vs* strip number

- Blue = collected
- Black = induced

for four different tracks with incident ***angle = 20 deg***

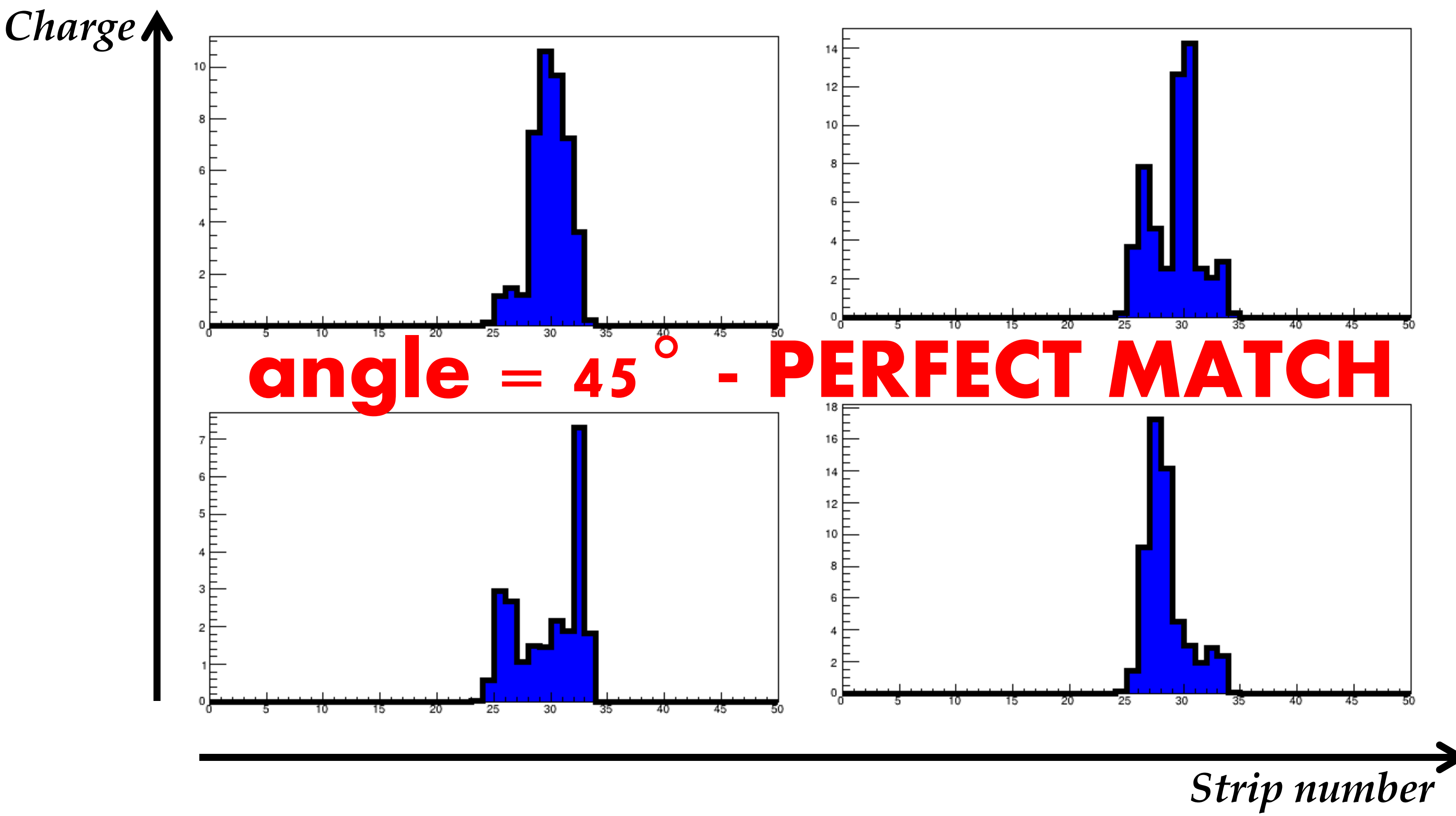


Q_{IND} *vs* Q_{COLL} comparison

Charge *vs* strip number

- Blue = collected
- Black = induced

for four different tracks with incident ***angle* = *45 deg***



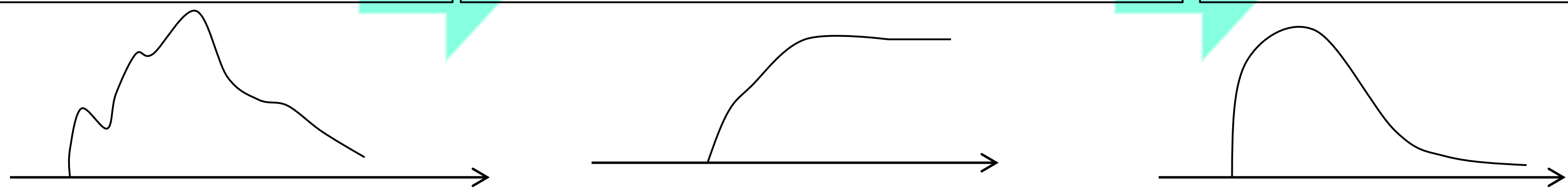
angle = 45° - PERFECT MATCH

APV-25 simulation

- CR-RC shaper
- τ = 50 ns

$$h(t) = S_p \times \frac{t-t_0}{\tau} exp(-\frac{t-t_0}{\tau}),$$

Induced current/charge → Pre-amplifier → INTEGRATOR → Shaper → CR-RC



induction
→ simulate charge in 1 ns time steps

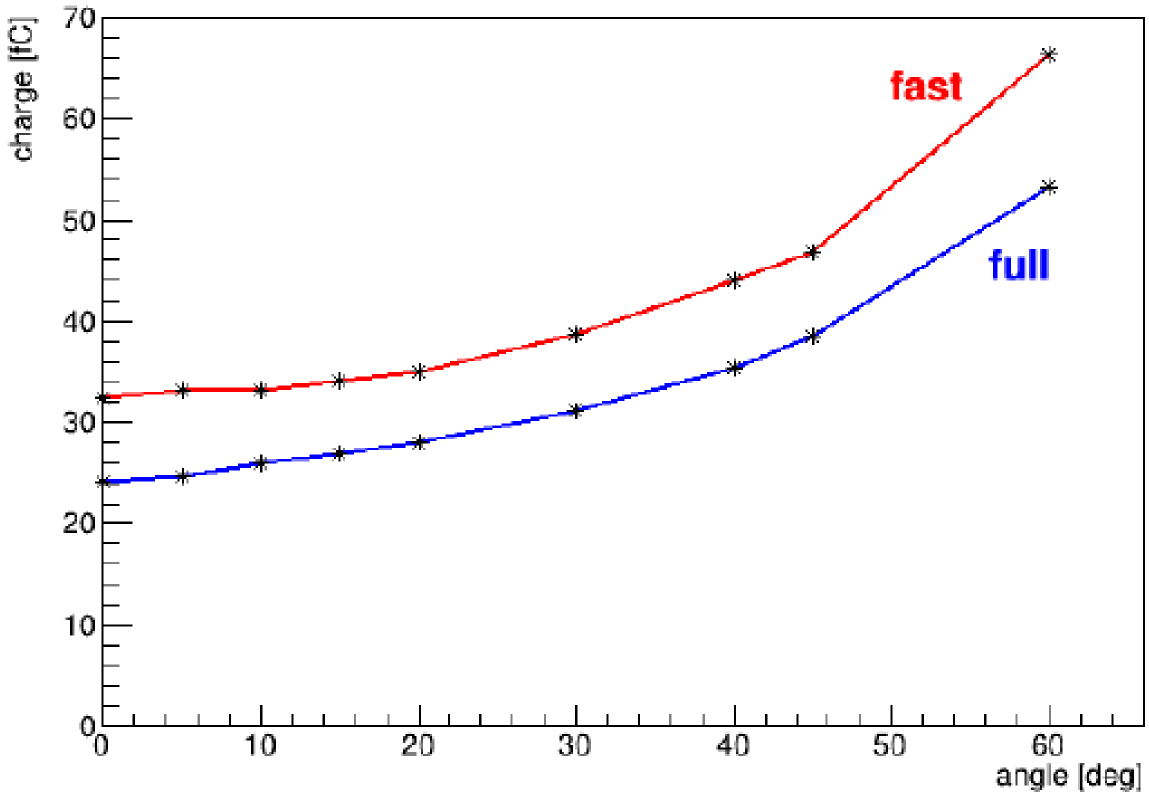
pre-amplifier
- ∀ time step get the induced charge
- ∀ time step update the integrated charge, adding the current dQ

shaper
- create 27 functions (one for each APV-25 time bin, 25 ns each)
- get the induced charge in each 25 ns and apply the transfer function of CR-RC
- for each time bin, evaluate all the previous functions and sum

APV-25 simulation

Full induction + APV-25 measures 80% of the charge

This is due to the signal time > 50 ns (APV-25 shaping time)



Next...

- we have agreement between the collected and induced charge

To do:

  - Test with 130 um strips
  - Test with magnetic field on
  - Perform tuning on updated induction

- port full and fast induction to CgemBoss

- add simulation of TIGER chip

THANK YOU FOR THE ATTENTION