Charge sharing

DUNE APA consortium

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Charge splitting

Wires are read out with charge-sensitive amplifiers

- Output sampled voltage proportional to input current
- High input impedance (see all the charge)

But amplifiers are capacitively coupled to the wires

- 22 nF signal protection on FEMB
- 3.9 nF blocking on CR board for u and x wires (v is at ground)
- See diagram on following page

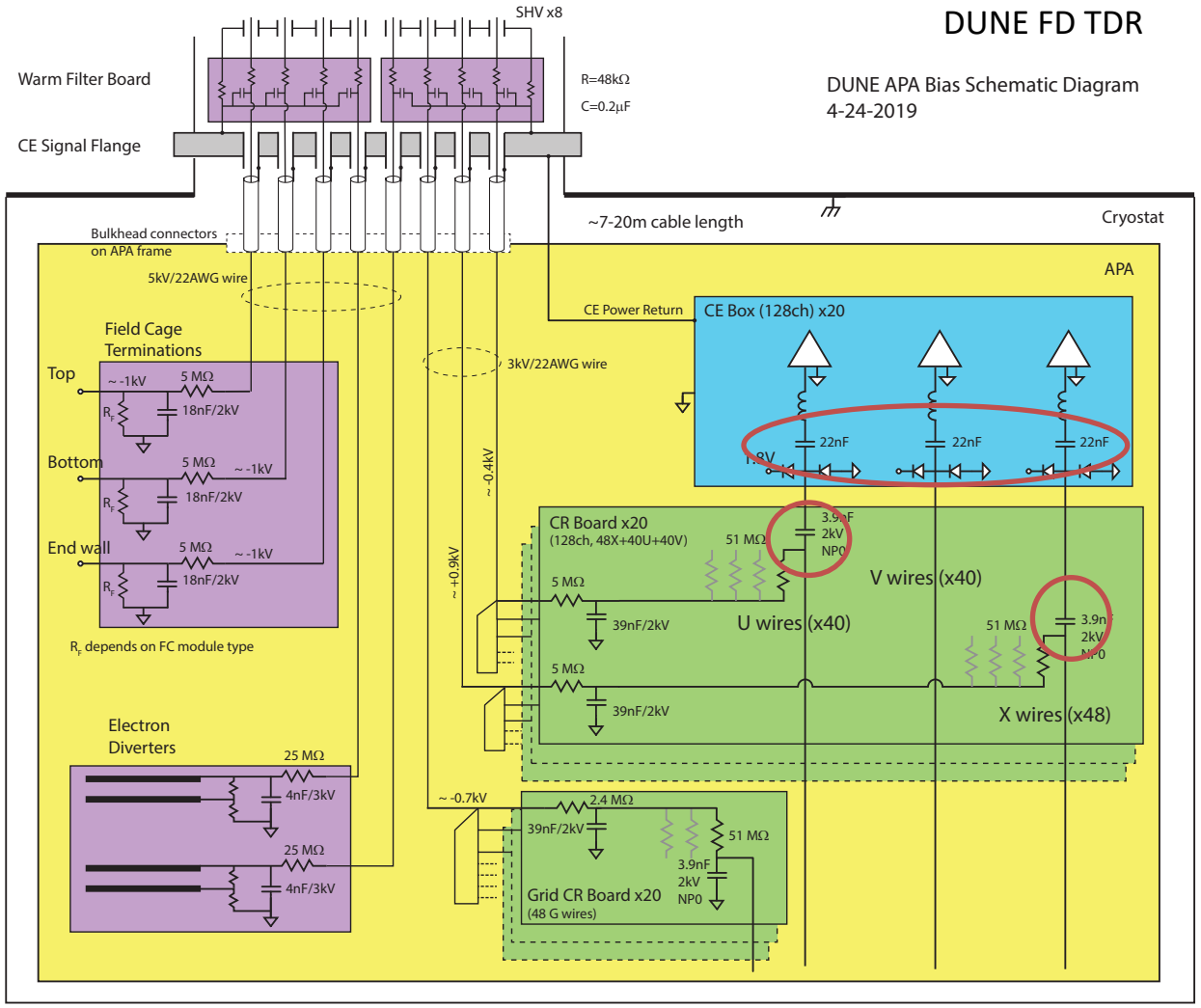
And wires have some capacitance

- To neighboring wires, other wire planes, traces, …
- Estimates based on 19 pF/m and 30 pF/trace (Bo Yu):
  - 150 ± 20 pF for collection
  - 200 ± 30 pF for induction
  - I made up the uncertainties
- Like to get measurements/calculations from the APA consortium

Together these imply charge splitting and crosstalk

- Not all charge collected on a wire is seen by the amplifier for that wire

ProtoDUNE HV



22 nF
all planes

3.9 nF
u, x only

Figure 4.3: DUNE APA wire bias schematic diagram including the CR board.

More charge splitting

Wires are capacitively coupled to many conductors

- Same plane
  - Neighboring wires directly and via traces
  - Next-neighbors, next-next-neighbors, etc.
  - Concerned both with loss from a wire and gain of signal from neighbors
    - Can be included in 2D deconvolution if we know it
- Other readout planes
  - Wires have roughly equal coupling 100s of wires so signal loss in more important than signal gain
  - Traces presumably have most sharing to (readout) neighbors
    - Not a concern for APA group?
- Anything else
  - Grid plane, field shapers, …
  - By definition, this charge is lost

Guess at division between these

- About half to each of the first two???

Charge splitting rough estimate

How important is charge splitting?

- Table summarizes the size of the charge splitting using the preceding guesses for detector capacitance
- The last columns are the protoDUNE corrections applied to convert amplified charge to charge on the wire
  - If a bit more than half of the charge is shared within the wire plane

View	C_{wir} [pF]	C_{amp} [nF]	Q_{lost}/Q	Q_{wir}/Q_{amp}	ProtoDUNE gain factor
u	200	3.31	5.7%	1.060	1.025
v	200	22.0	0.9%	1.009	1.004
x	150	3.31	4.3%	1.045	1.020

Actions to take

Want better estimates to replace my guesses

- Guesses endorsed by APA and CE consortia
- Better, analytic calculation, E-field simulation, etc.
- Best, direct measurement

What is most important to evaluate/measure?

- Anything that affects the collection plane charge
  - Induction planes have much (10X?) larger measurement uncertainty and likely have large scale uncertainty
  - Expect these to be normalized to match the collection plane

1. External capacitance for each collection wire
   - I.e. capacitance to everything but wires and traces in the same plane
   - This is used to correct the calibration gain measured with charge injection
2. Capacitance to each wire (and its traces) in the same collection plane
   - Improve 2D signal deconvolution
   - Account for charge lost to dead or noisy wires
3. Same for induction wires

Comments

Measurements on preceding page are in order of importance

1. Collection plane external charge loss
   - There are no direct measurements we can make in data to evaluate this
   - Can use physics measurements, e.g. dE/dx but these have systematic uncertainty including electron lifetime, recombination, etc.
2. Collection plane internal sharing
   - Might be able to use data to tease this out
   - Event w/o correction, sum over wires will give the correct total charge
3. Induction uncertainties like dominated by inherent APA response
   - Can be scaled to match collection
   - Charge measurements dominated by collection plane

What precision is needed for capacitance measurements?

- Aim for 1% on charge calibration scale
- 10-20% capacitance measurement/estimate is adequate if the values are close to those assumed here

Thank you