A Pulse-dilation detector for MRSt

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MRSt presents a significant challenge for signal detection

An instantaneous proton signal leaving TCC arrives at the image plane of the dispersing magnets spread out over 200 mm and 15 ns in time.

We'd like to record the signal from each of ~40 bins with 20 ps time resolution, but skew across the image plane requires bins of width

$$\delta x = \frac{\Delta x}{\Delta t}\delta t = \frac{200\ mm}{15\ ns}\left(0.02\ ns\right) = 0.267\ mm$$

$$N_{\det} = \frac{\Delta x}{\delta x} = 750$$

Thus, we need at least 750 channels with 20 ps resolution to meet the requirement.

Need to remove time skew across energy bins to reduce required resolution: *idea is try manipulating electrons*

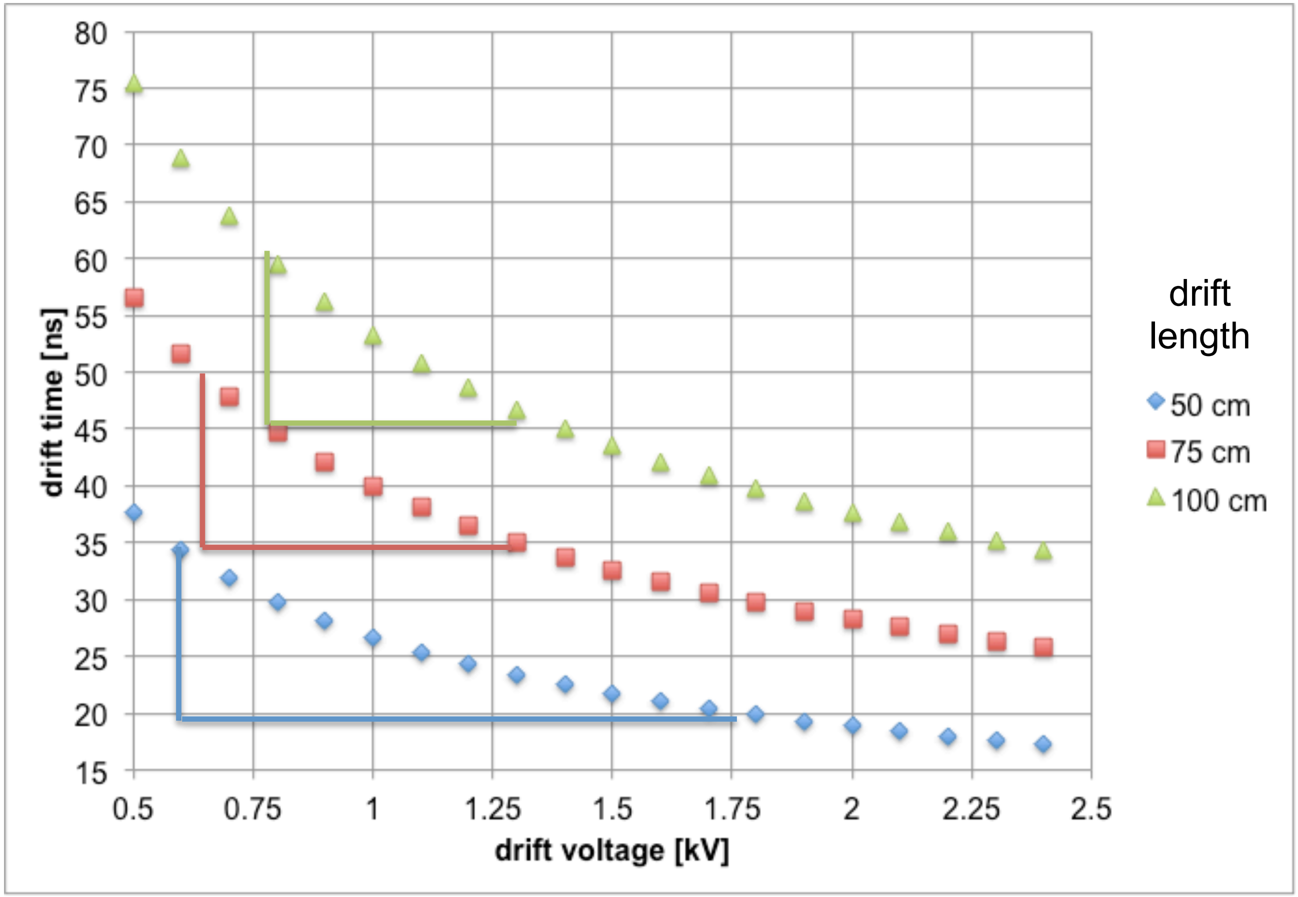
MeV protons knock electrons out of CsI with a yield of 3-4

Once the signal is converted electrons, we can easily remove the temporal skew across the energy bins

A longer drift length gives a lower required voltage gradient

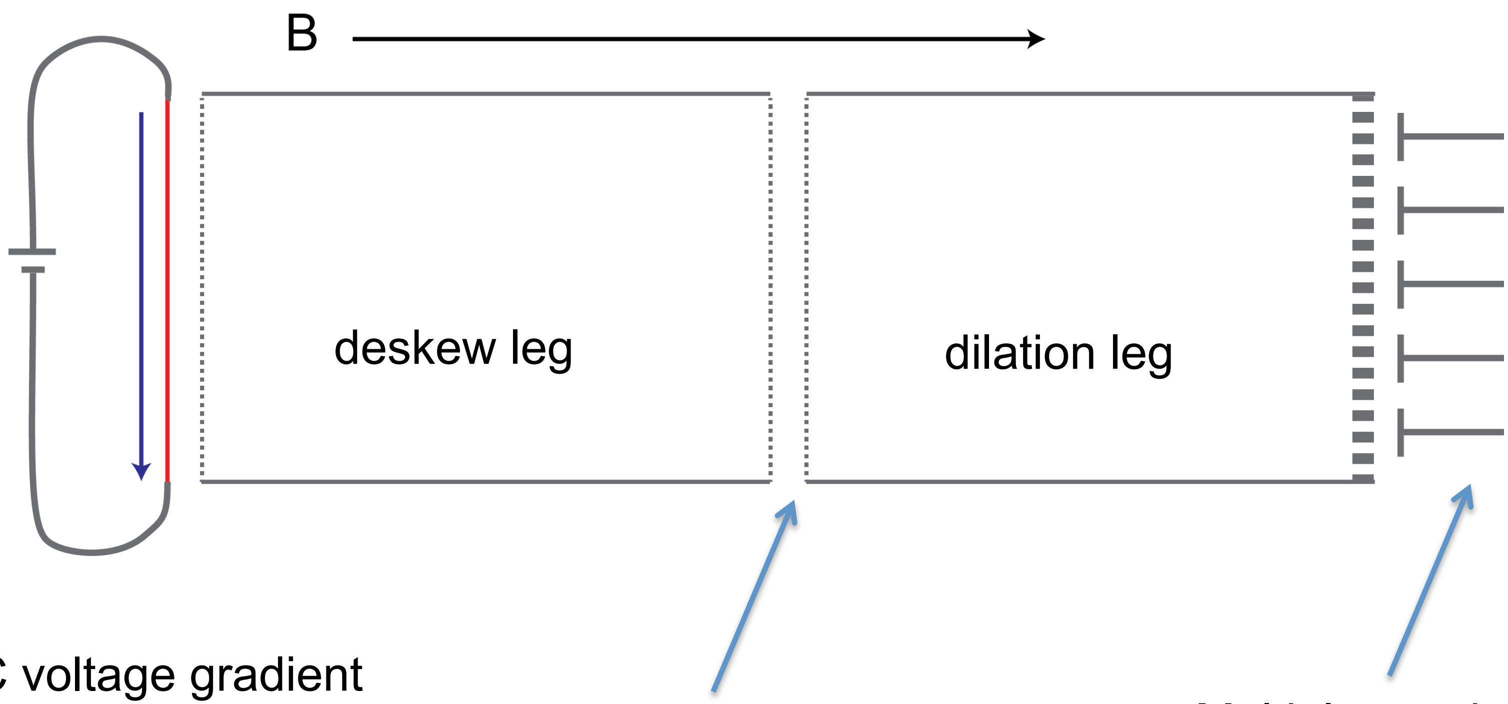
Lower voltage gradient is desirable for temporal magnification using pulse-dilation

$\begin{matrix}10\\14\end{matrix}$ MeV proton speed = $\begin{matrix}5.4\\7.6\end{matrix}$ keV electron speed



15 ns skew can be removed using 800-1400V drifts over a meter

Staged tube approach to deskew and pulse-dilation

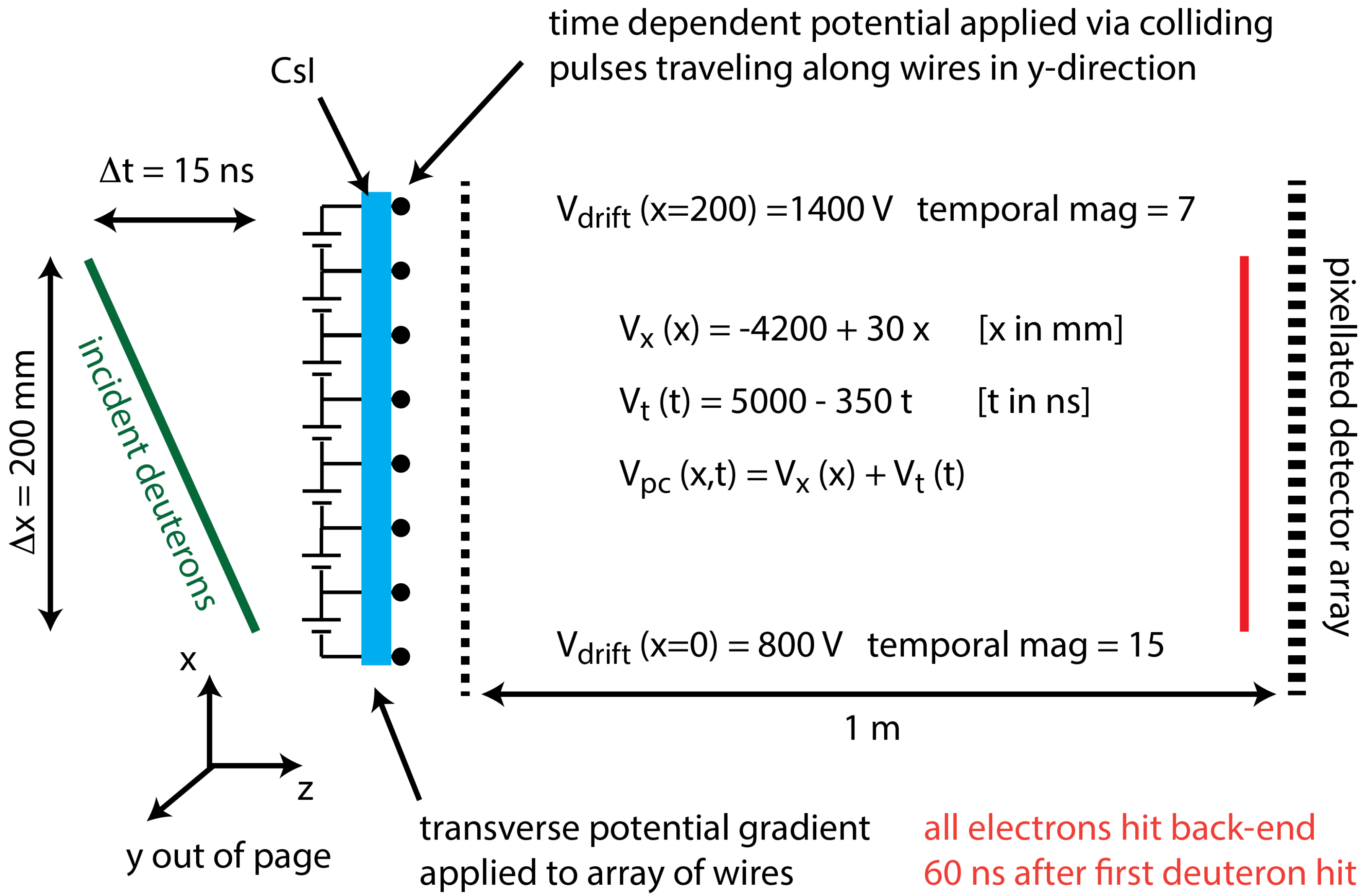


DC voltage gradient applied at cathode. Resulting velocity dispersion removes skew after appropriate drift distance.

All electrons arrive here within 200ps. Fast ramp in the gap dilates the signal.

Multiple anode outputs into digitizer channels record dilated signals in ~40 energy bins

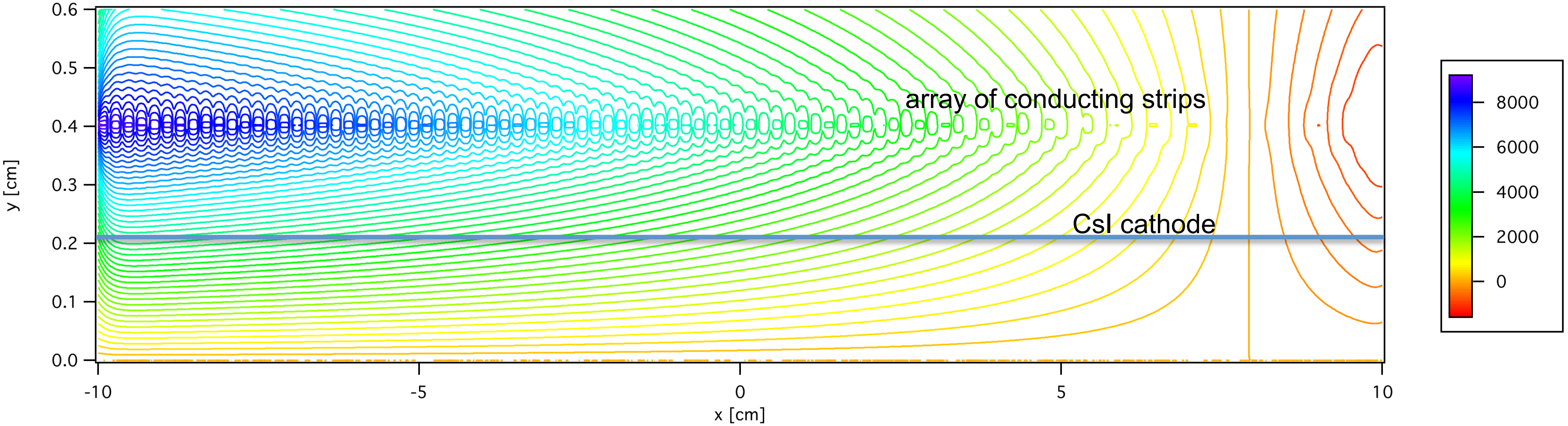
It may be possible to accomplish both functions with a single front-end



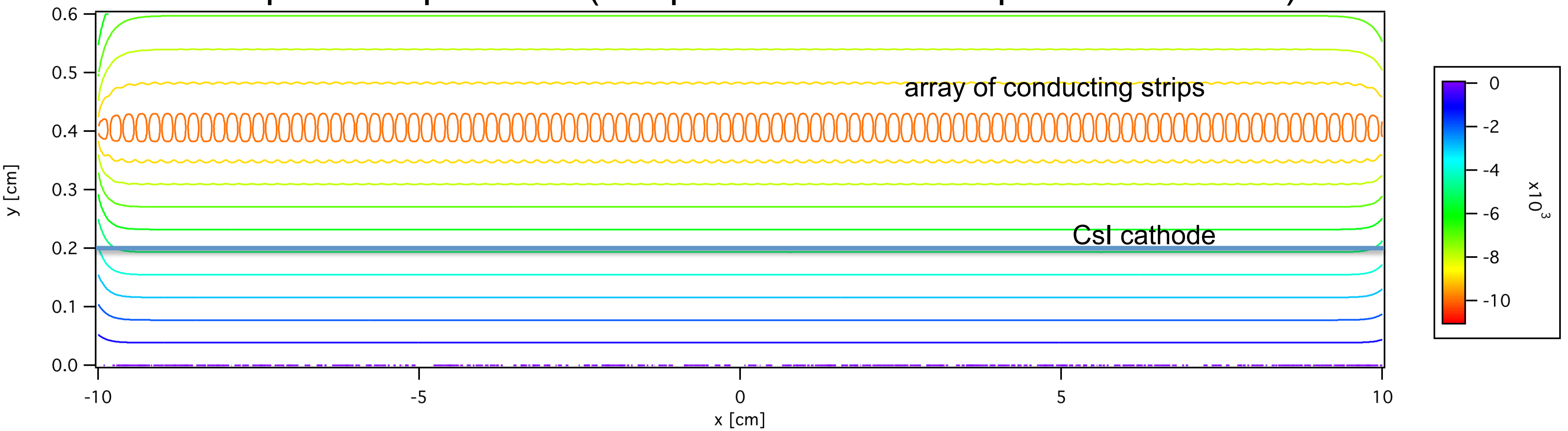
a concern is the Ex in acc. gap and its effect on electron orbits

Spatial voltage gradient can be applied with array of strips, but cathode must be stood off to smooth out wiggles

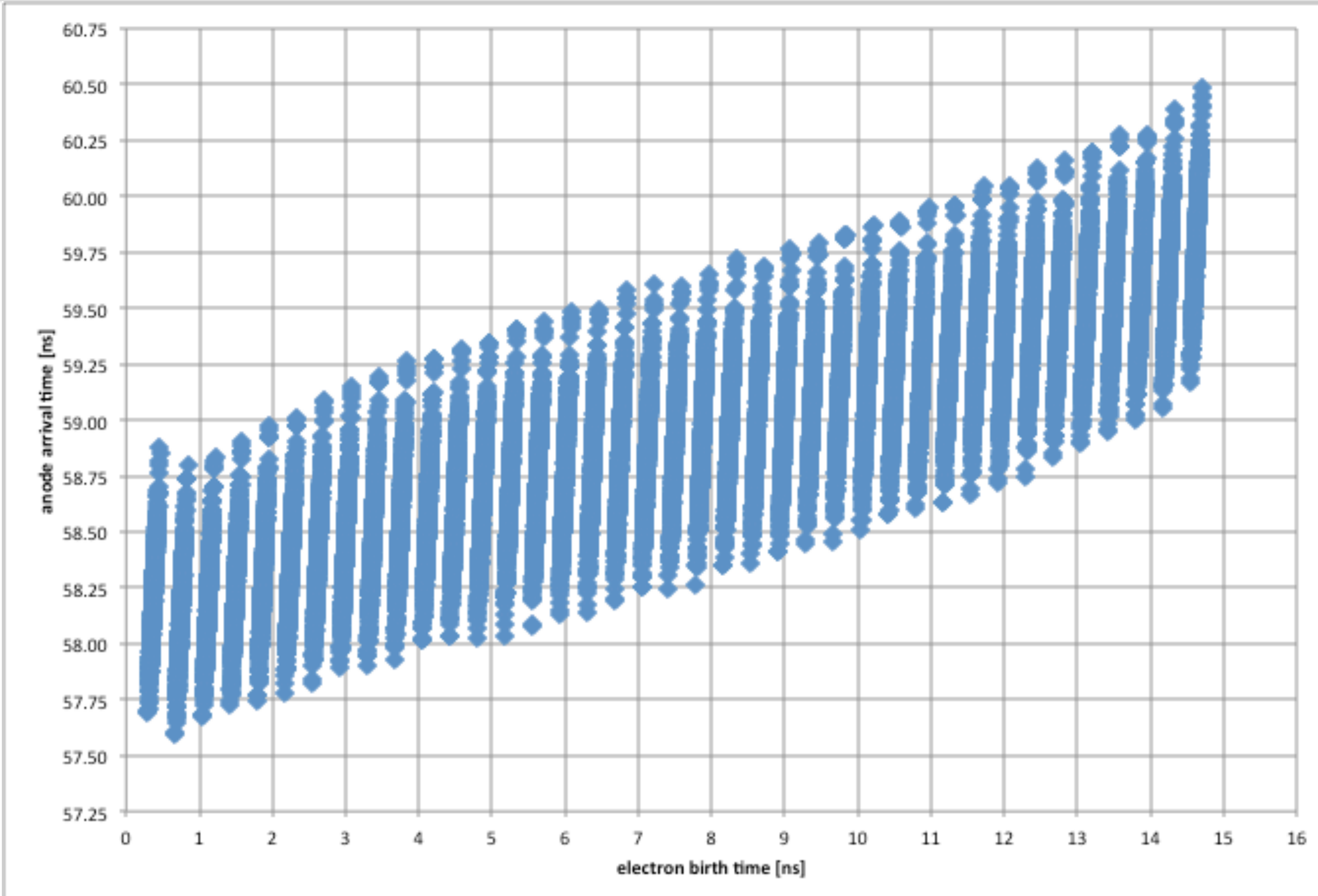
DC potential applied to strips to get gradient along cathode



Time dependent potential (ramps down from this peak over 15 ns)

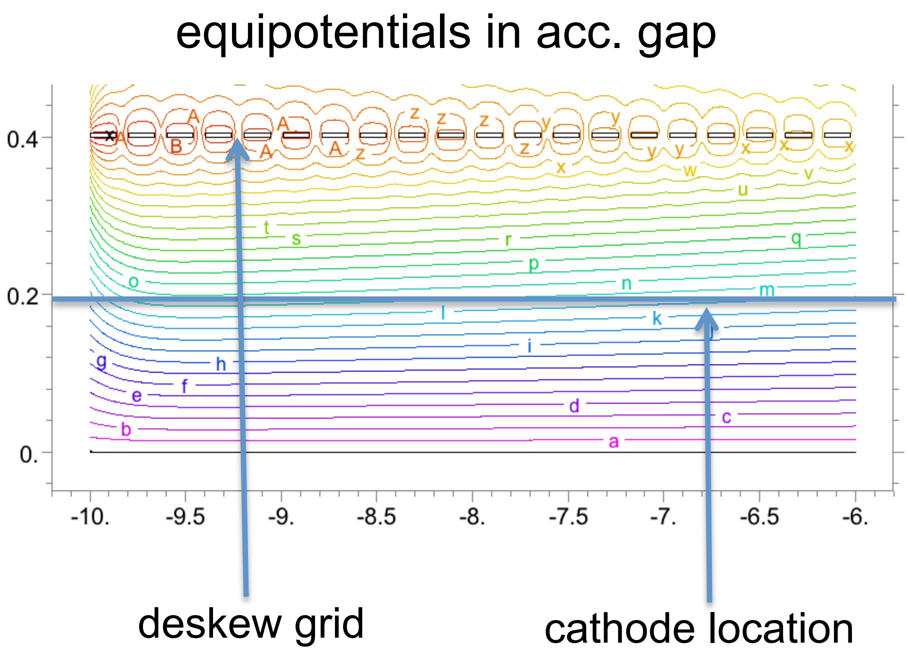


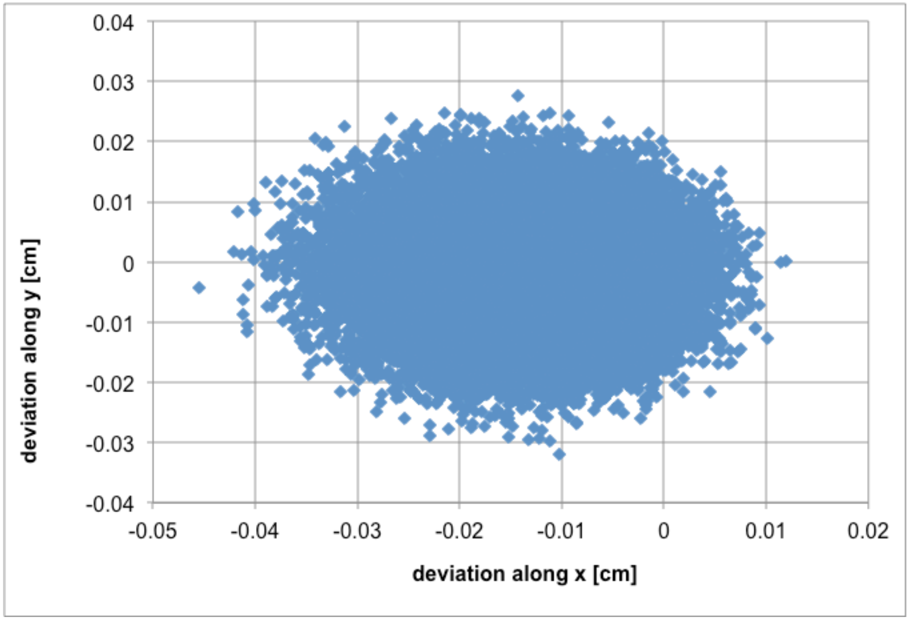
Simulation of dual function front-end electron signal drift input pulse width 100 ps, 10X temp mag, 15X deskew



Electrons strike anode within 250 μm of birth location in transverse plane for B = 500 Gauss (2X T_e contribution)

Transverse electric field due to deskew potential can pump up Larmor orbits





Here effect contributes ~100 μm to electron spreading, about same as that due to electron birth energy of 1.7 eV

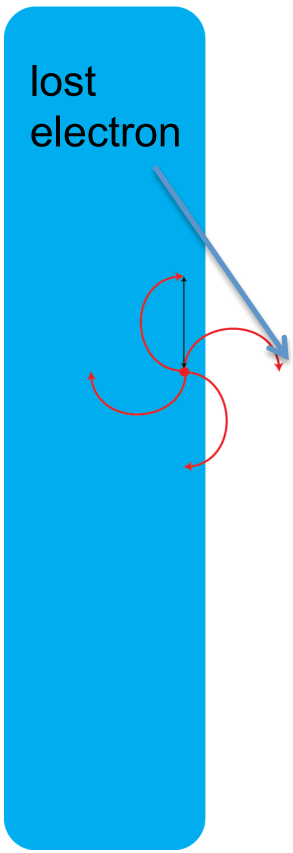
Modest magnetic field required in electron drift tube

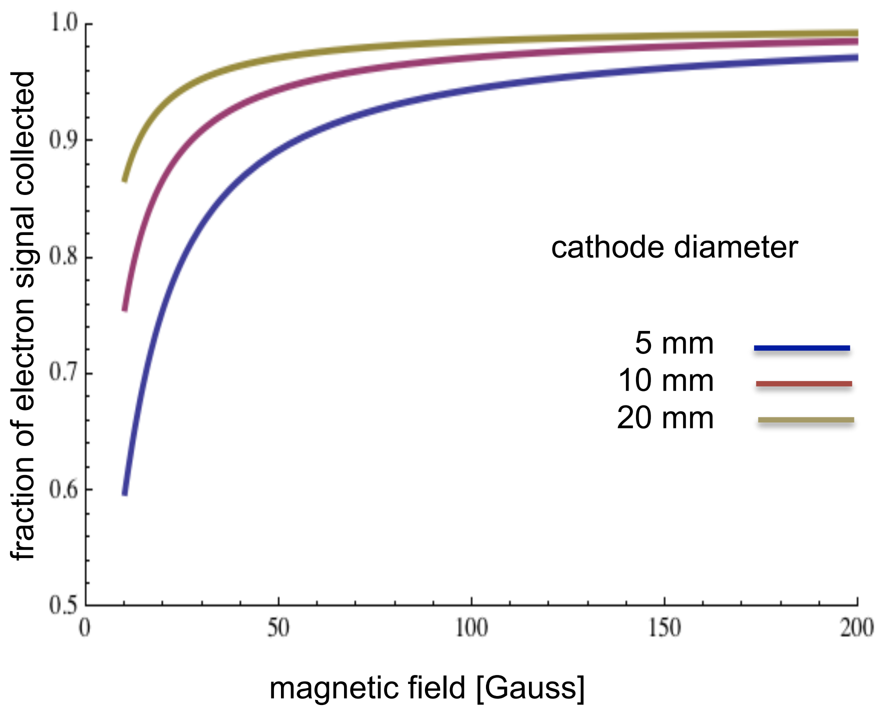
Electrons will follow magnetic field lines while executing Larmor orbits

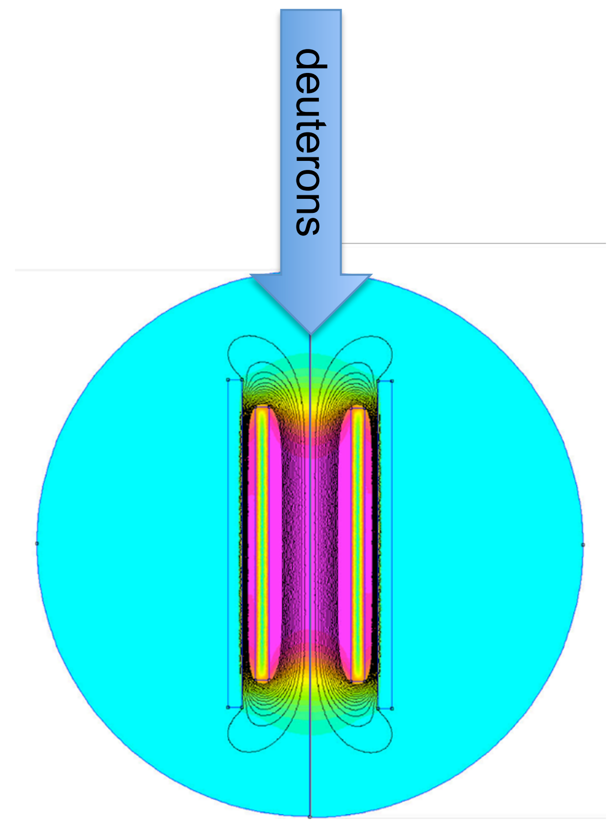
Electrons born near to the edge of the photocathode land outside the anode

protons must enter solenoidal field of electron drift tube

Need to determine if proton focusing is disturbed







Pulse-dilation MRSt detector parameters

Drift tube length	1 m
Magnetic field	~100 Gauss
Drift energy range	800 V – 1400 V
Temporal mag	~10X
Cathode ramp	5 kV in 15 ns
Deskew bias	10 kV over 200 mm
Digitizer channels	40
Digitizer bandwidth	200 ps