Novel Readout Design for Hi-Resolution Tracking TPCs

NGUYEN PHAN | UNIVERSITY OF NEW MEXICO

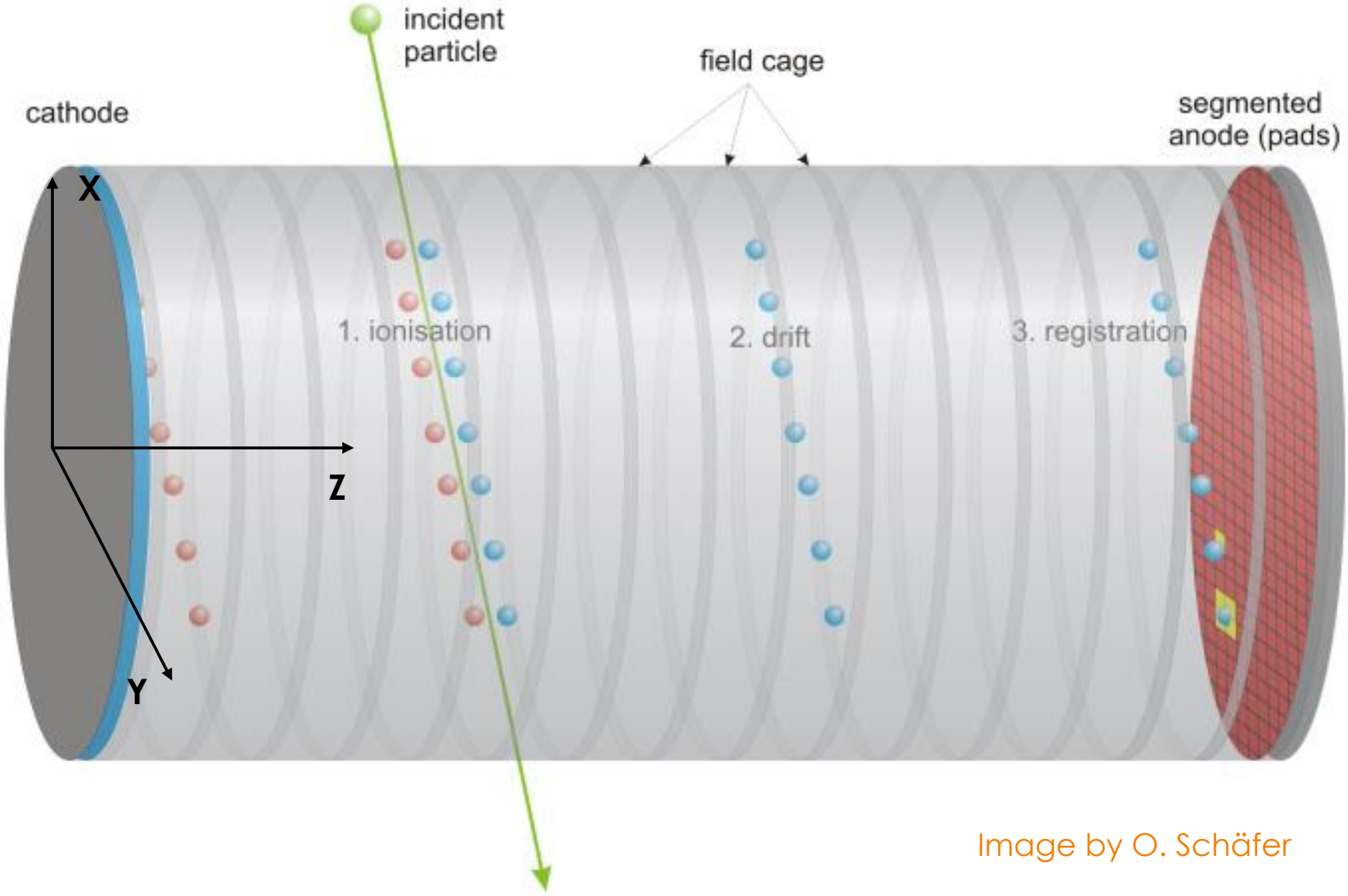


Image by O. Schäfer

Track imaging technologies

Wires

Strip Boards

Pixels

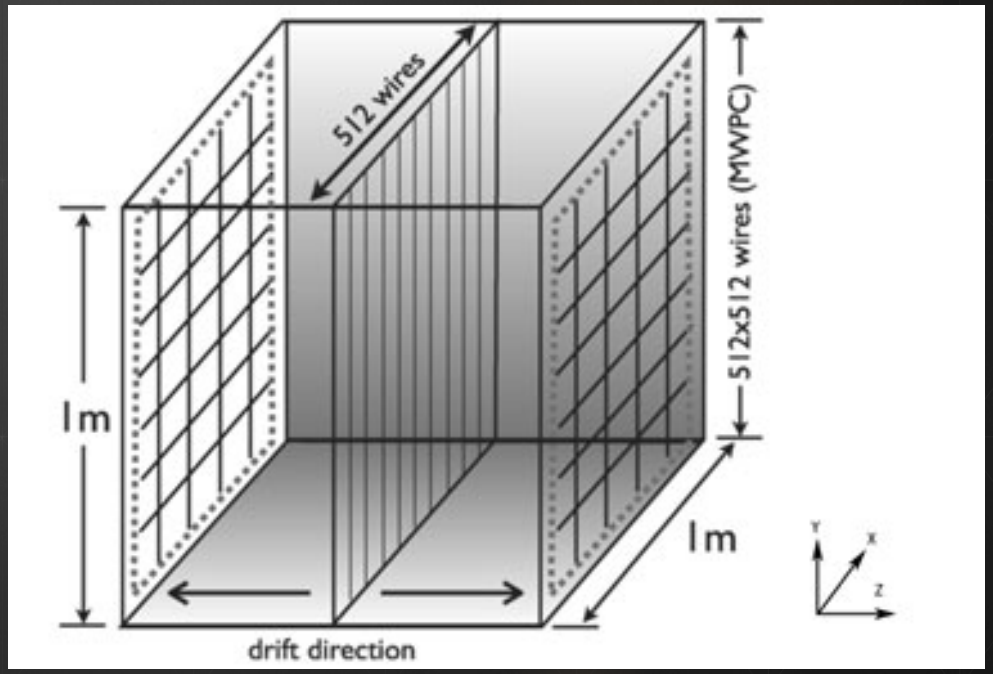
CCD/CMOS

X-Y Hi-Resolution Tracking

- X-Y resolution limited by the pitch of the readout
  - ~ 1mm for wires
  - 0.1's mm for strips
  - 0.01's mm for pixels but small area
- Many channels are required
  - Higher cost
  - Importantly, greater complexity

Z Hi-Resolution Tracking

- Requires only 1 channel
- For slow electron and negative ion drift gases, resolution only limited by diffusion.
- For example, DRIFT detector
  - Z resolution ~ 50 um
  - X, Y resolution = 2 mm



X, Y

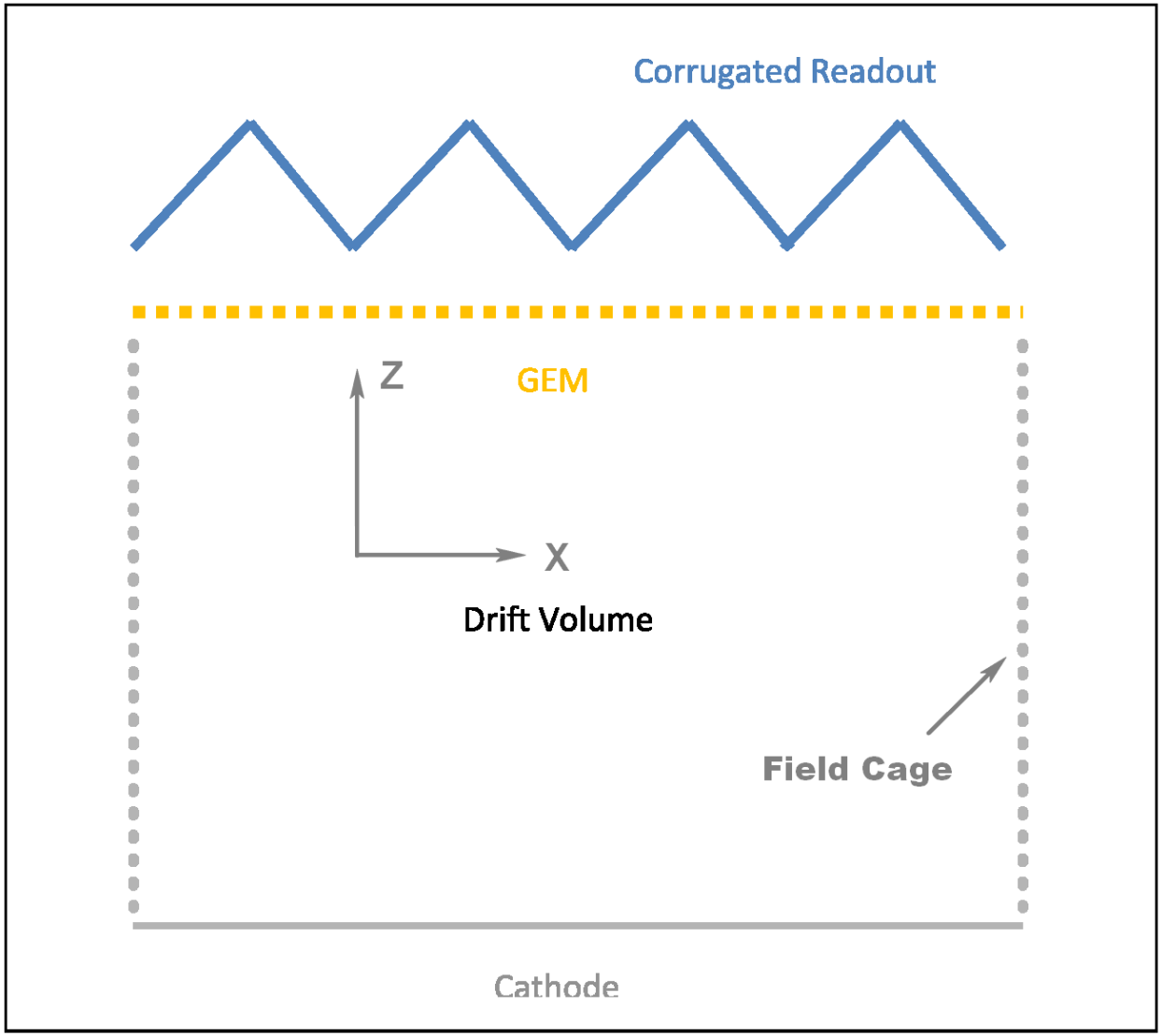
Spatial measurements

Z

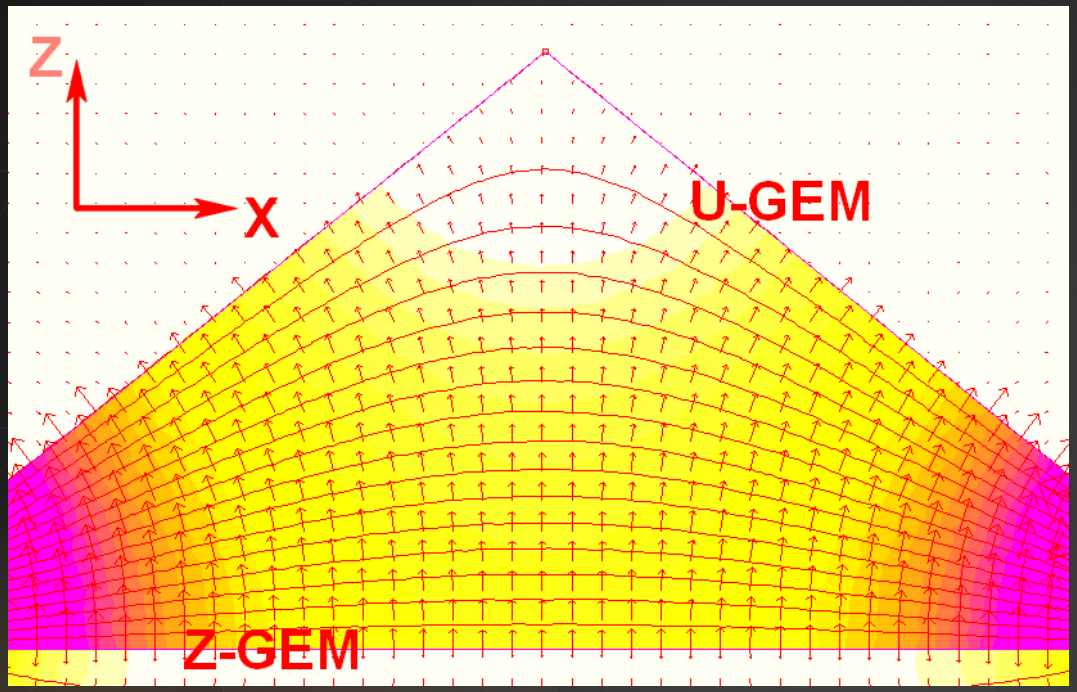
Time measurement

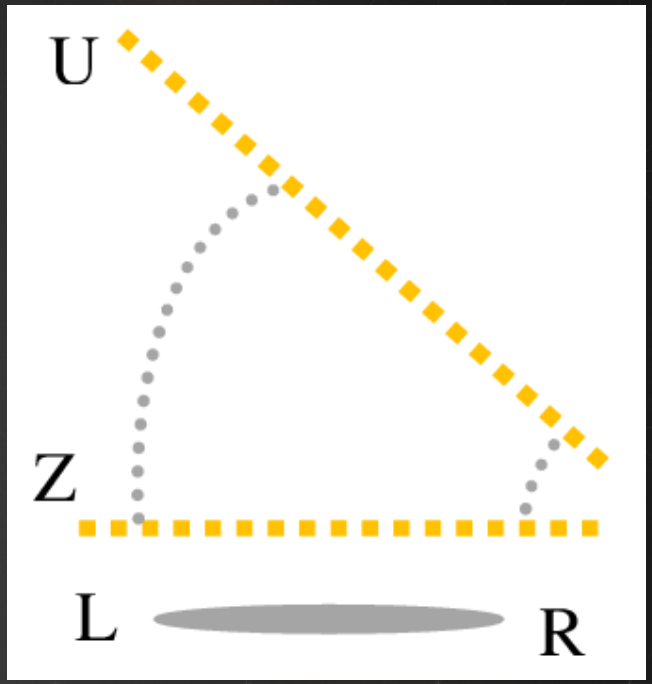
- Can we measure X and Y via timing as well?
- Many channels -> 3 channels (1 for each dimension), lower detector complexity, cost and high resolution.
- How can this be done?
- For the remainder of this talk, I will only focus on how to measure one other dimension (X) in addition to Z via timing.

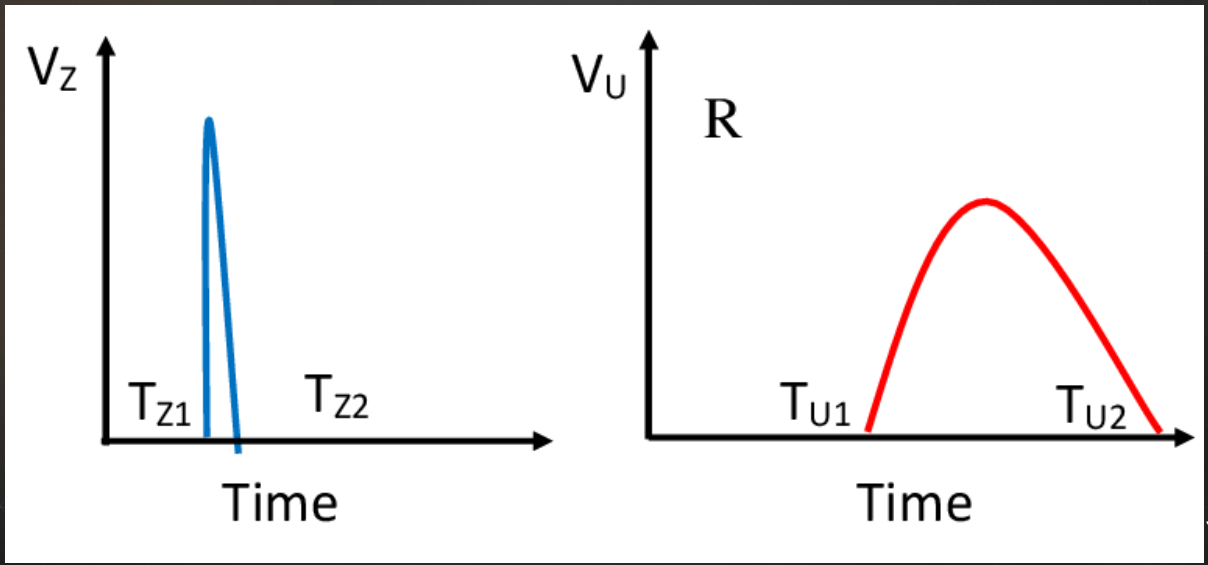
Proposed Detector Geometry



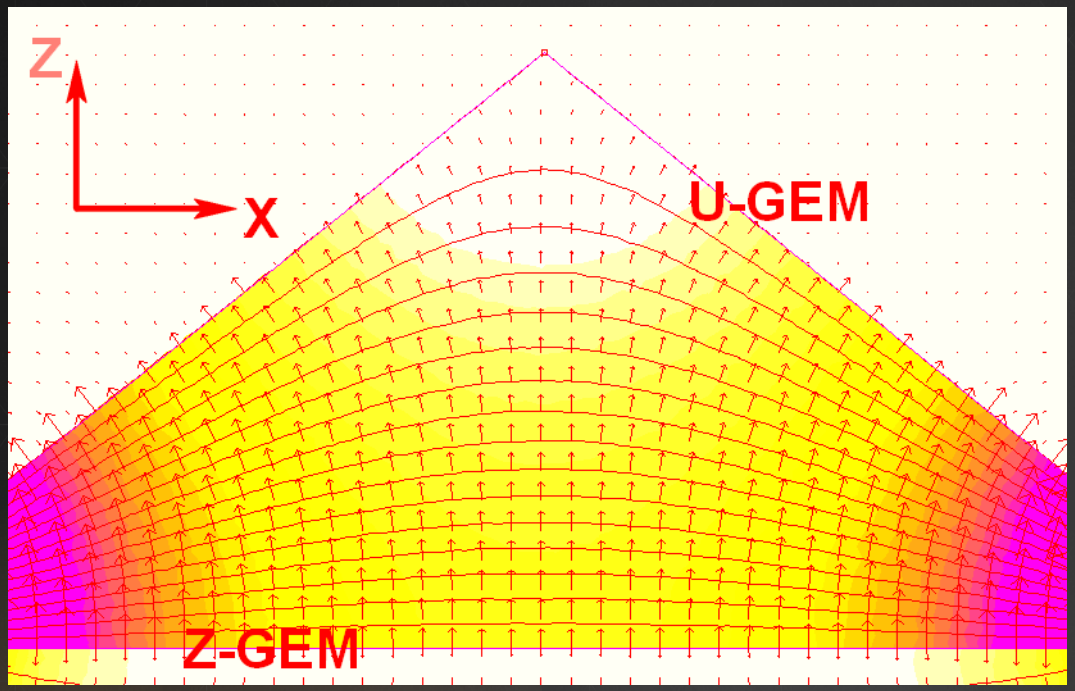
Working Principle: Horizontal Track

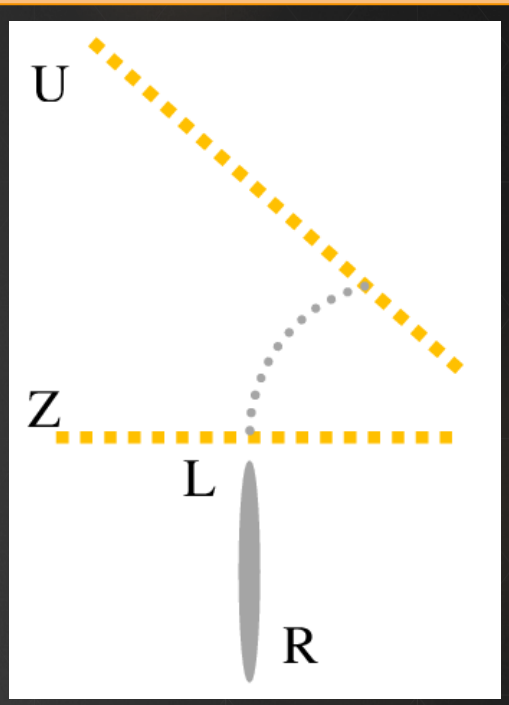


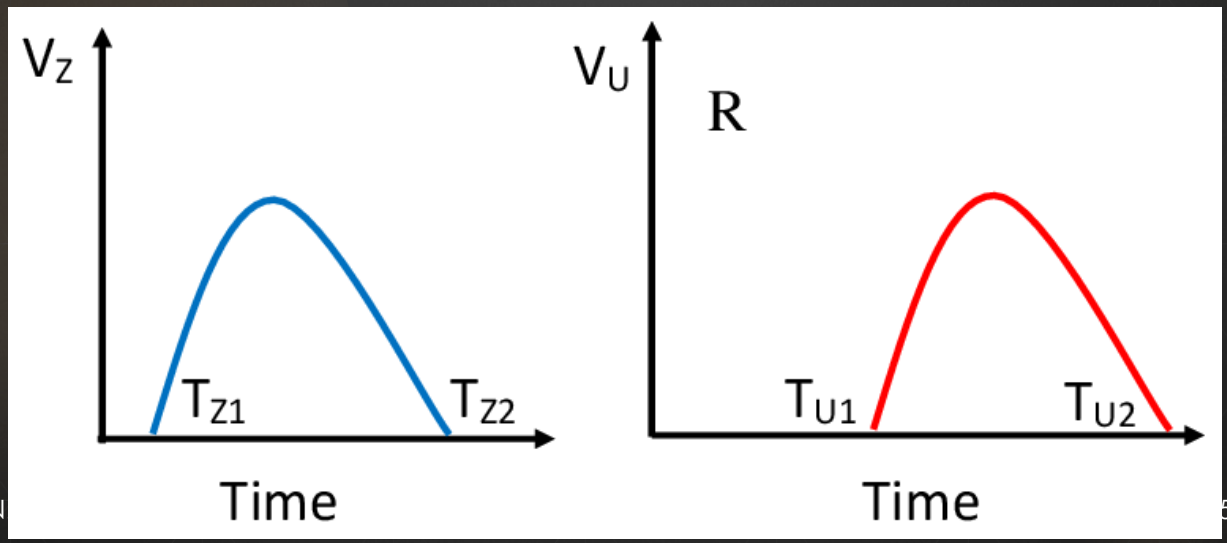




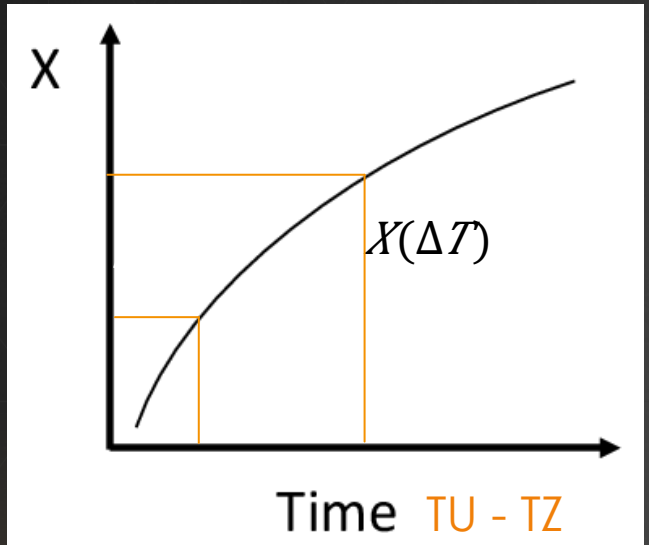
Working Principle: Vertical Track







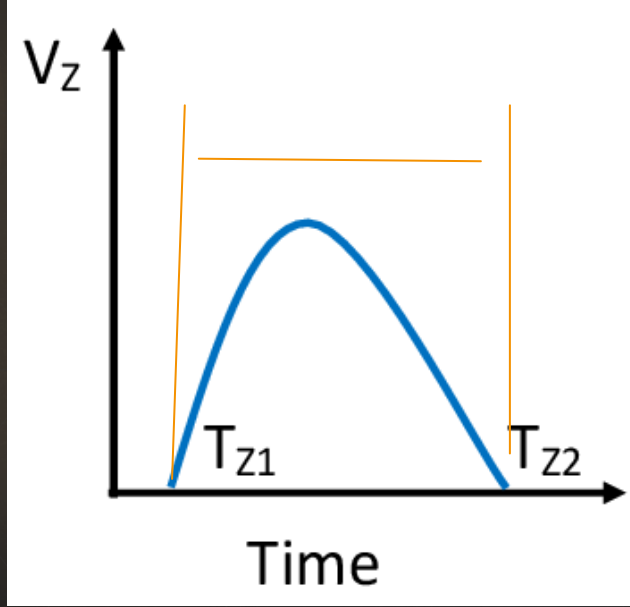
Working Principle: X Determination

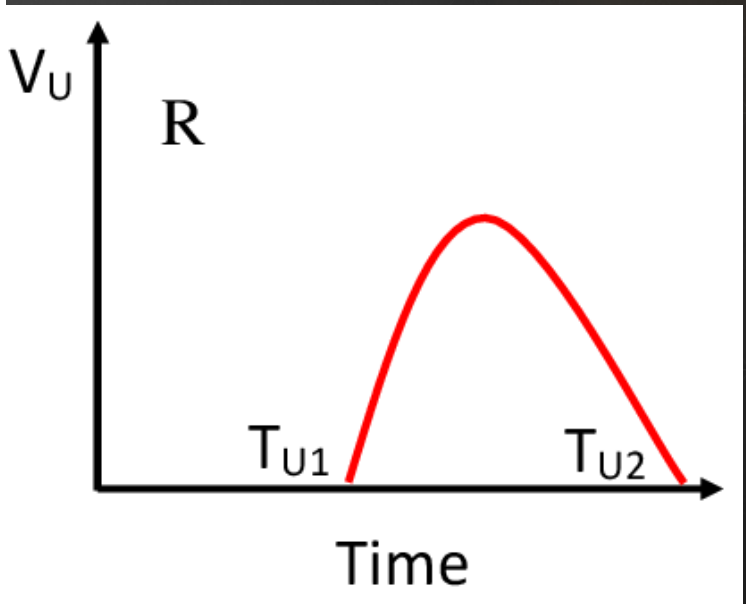


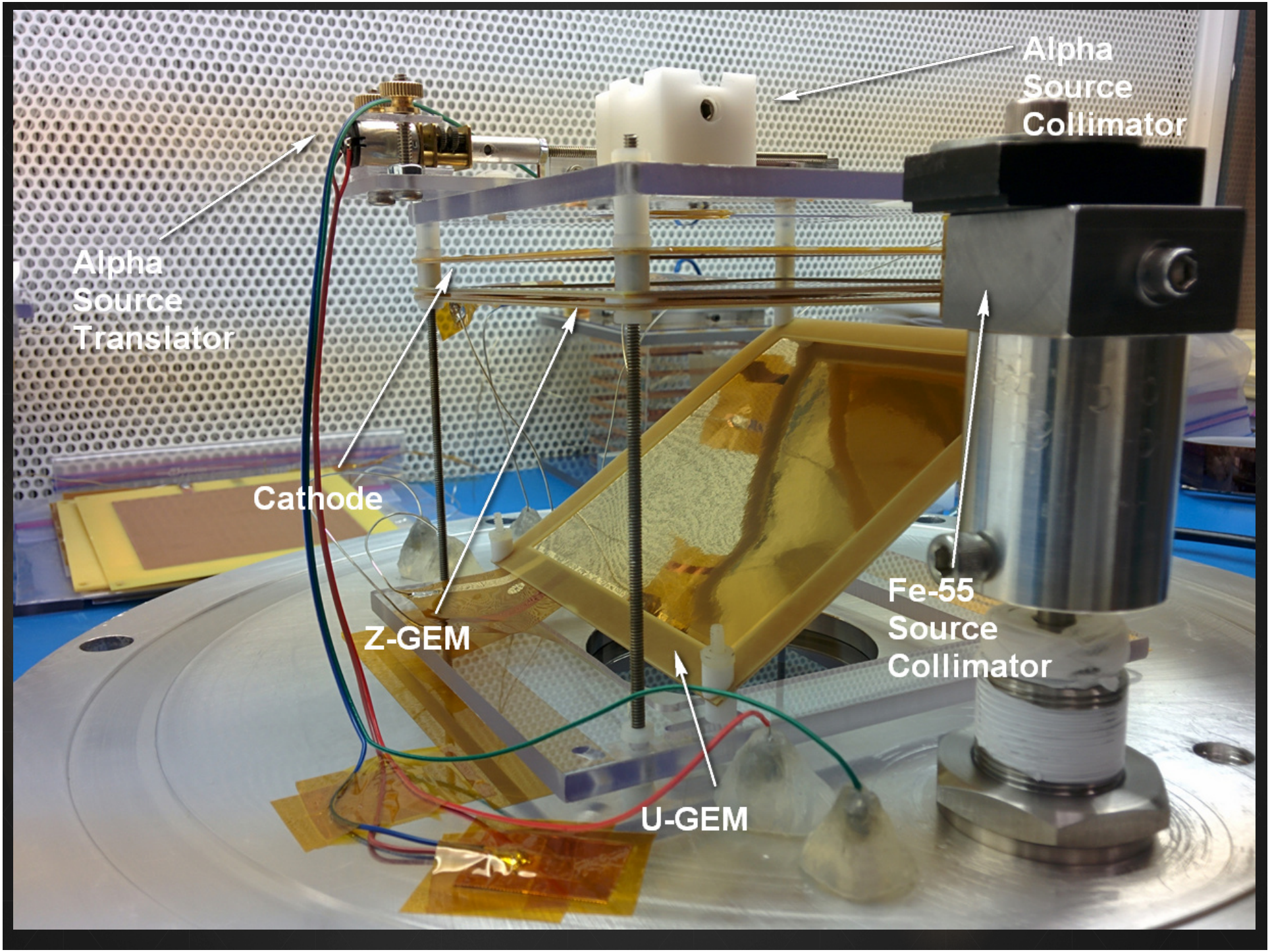
$$\Delta Z = vd \times (Tz2 - Tz1)$$

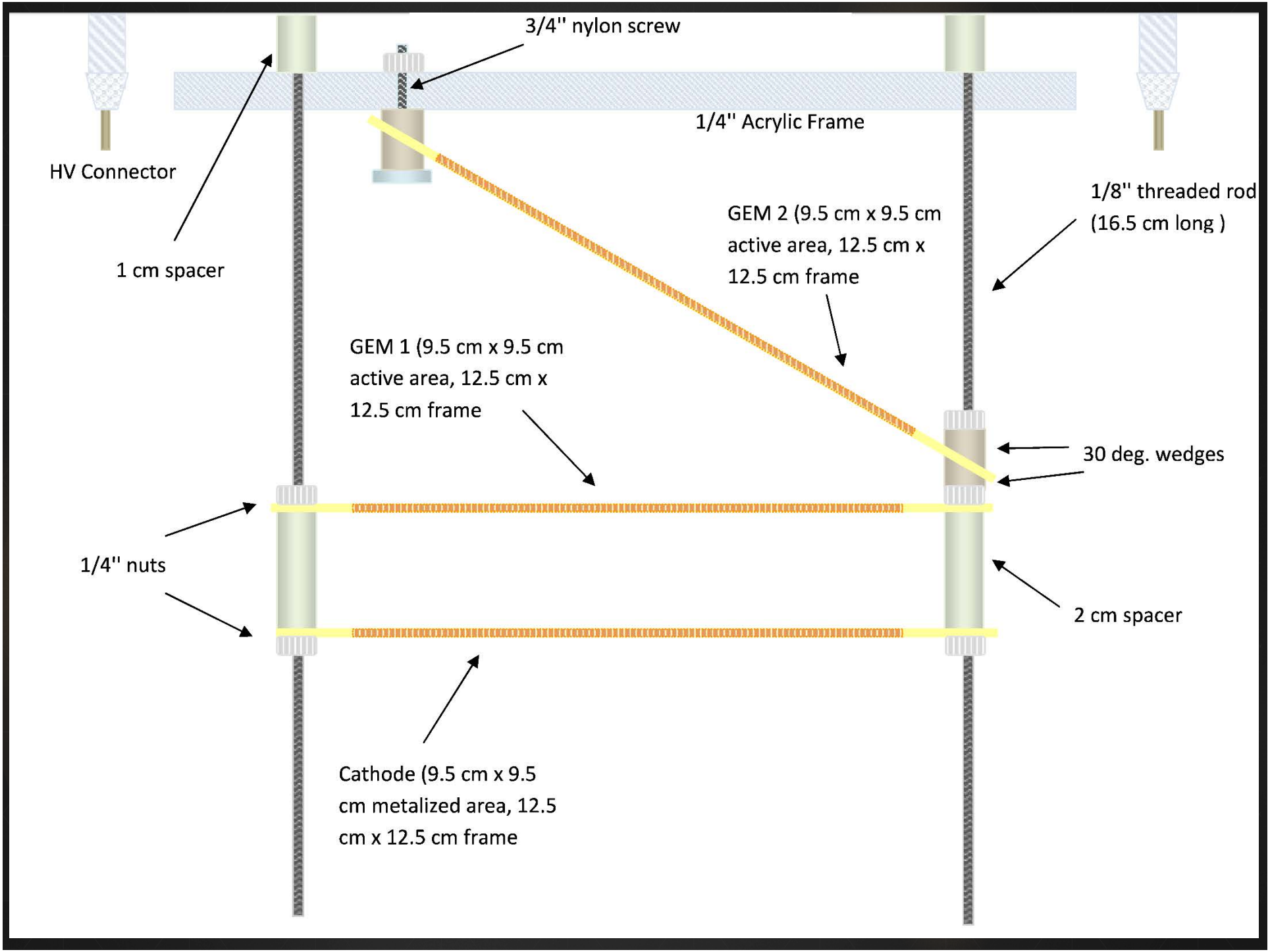
X1 = ΔT1 = Tu1 – Tz1
X2 = ΔT2 = Tu2 – Tz2

$$\Delta X = X2 - X1$$





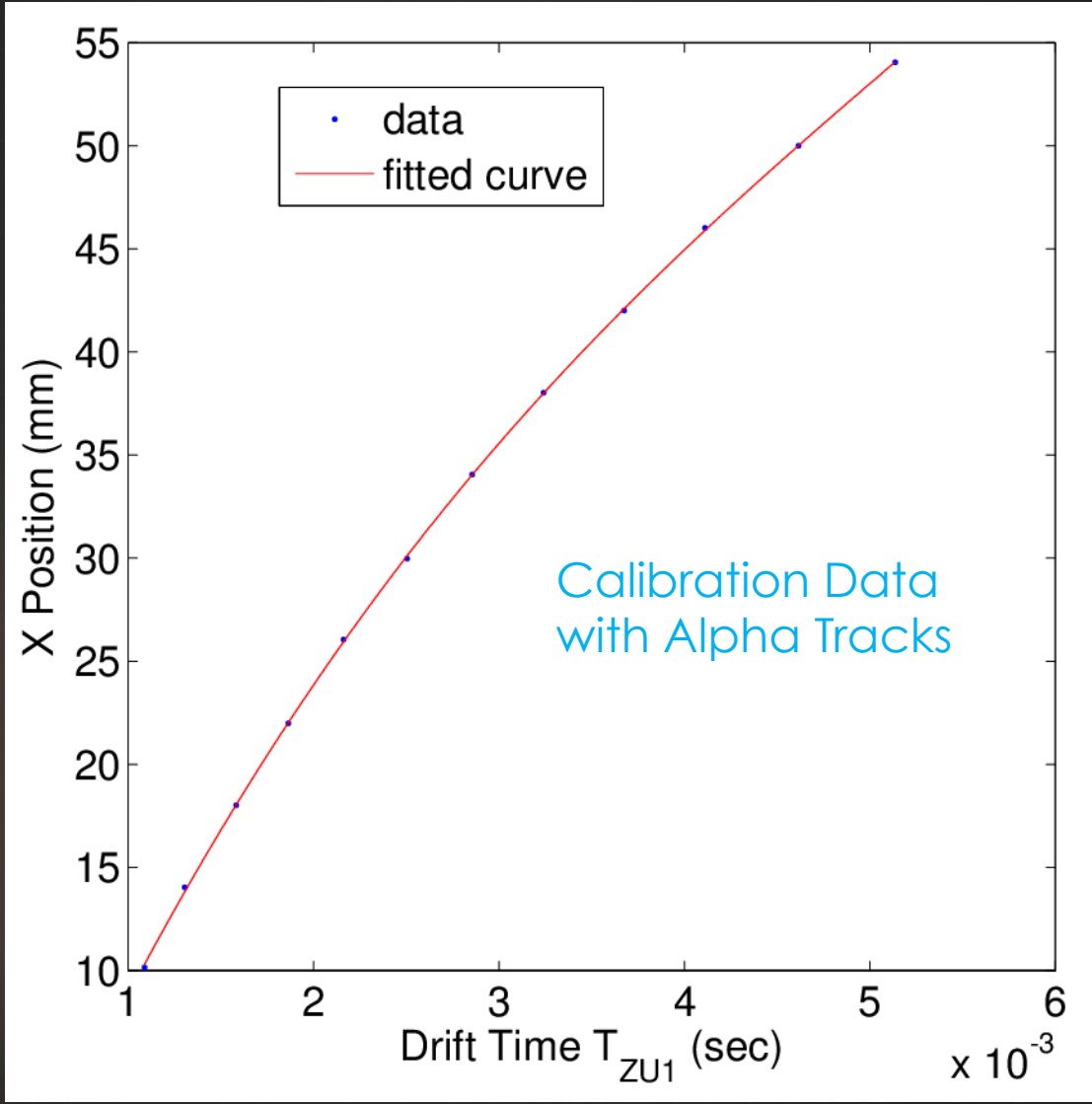

Alpha
Source
Collimator
Alpha
Source
Translator
Cathode
Z-GEM
Fe-55
Source
Collimator
U-GEM


3/4" nylon screw
1/4" Acrylic Frame
HV Connector
1 cm spacer
1/8" threaded rod
(16.5 cm long)
GEM 2 (9.5 cm x 9.5 cm
active area, 12.5 cm x
12.5 cm frame
GEM 1 (9.5 cm x 9.5 cm
active area, 12.5 cm x
12.5 cm frame
30 deg. wedges
1/4" nuts
2 cm spacer
Cathode (9.5 cm x 9.5
cm metalized area, 12.5
cm x 12.5 cm frame

Preliminary Data: X vs. Drift Time

100 Torr CF4 + 51 Torr CS2

Z, U Signals read out with two ORTEC preamps.



Errors bars ~ size of points (~ 100 um X)

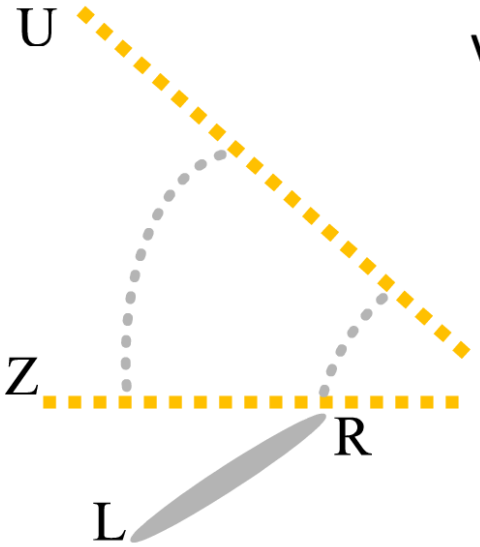
Angular Cases: Case I

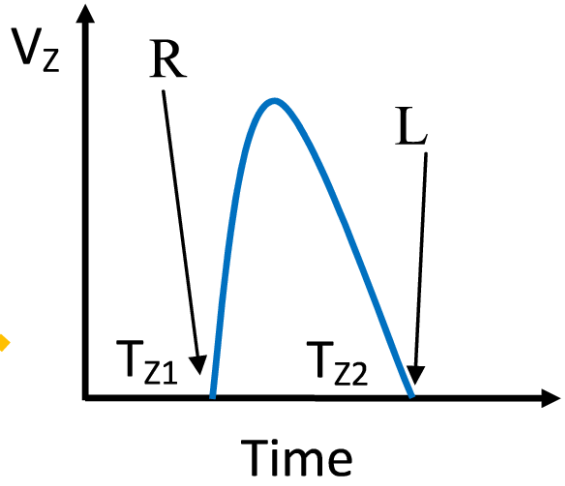
$$X_1 = X(T_{U1} - T_{Z1})$$

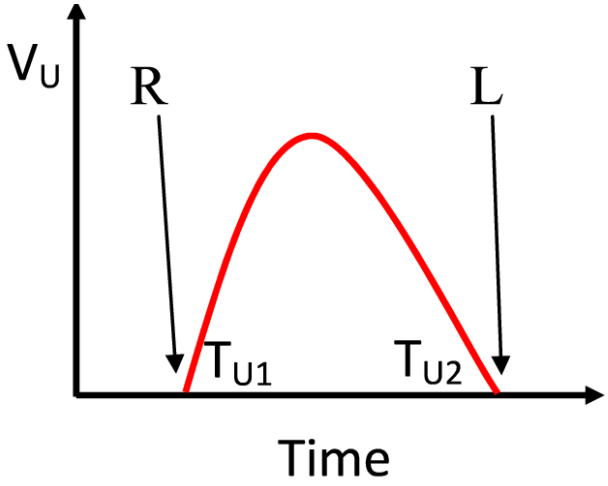
$$X_2 = X(T_{U2} - T_{Z2})$$

$$\Delta X = X_2 - X_1$$

Case I ($0^\circ \leq \phi \leq 90^\circ$):







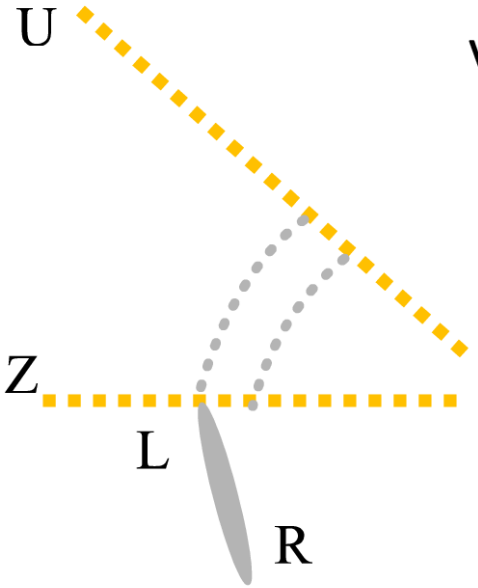
Angular Cases: Case II

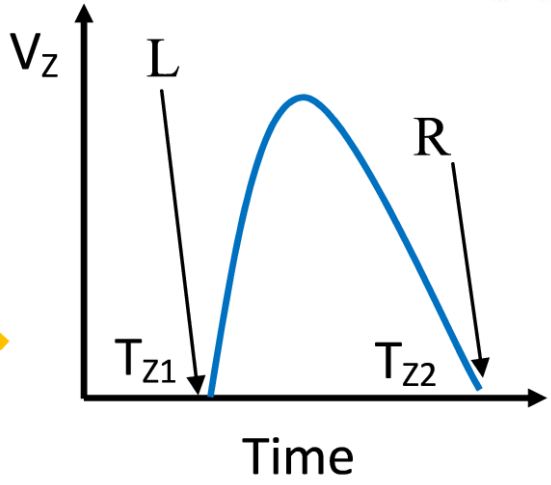
$$X_1 = X(T_{U1} - T_{Z1})$$

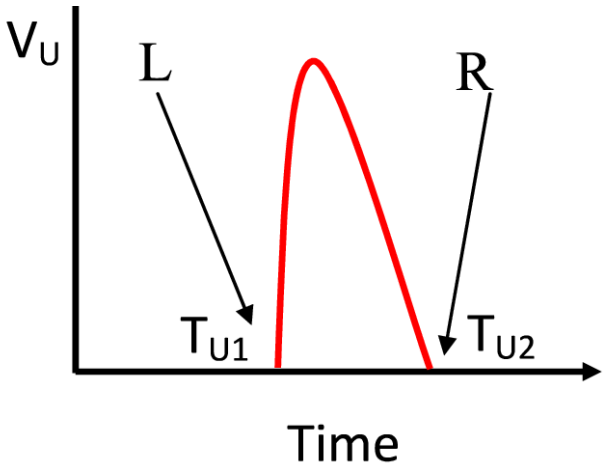
$$X_2 = X(T_{U2} - T_{Z2})$$

$$\Delta X = X_2 - X_1$$

Case II ($90^\circ < \phi < \phi_{crit}$):







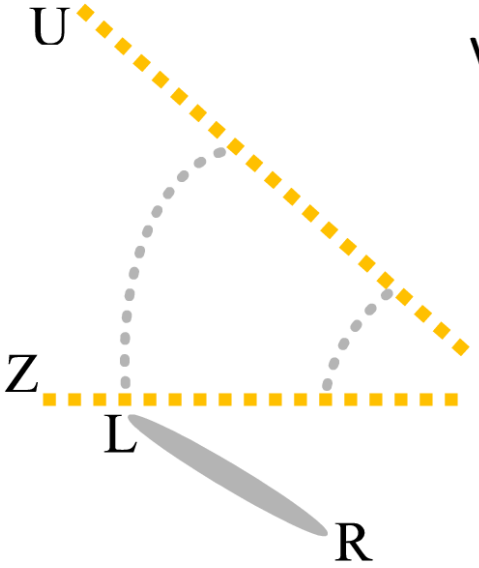
Angular Cases: Case III

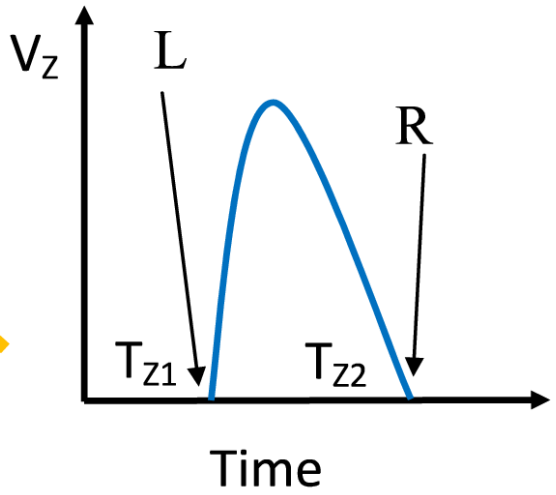
$$X_1 = X(T_{U2} - T_{Z1})$$

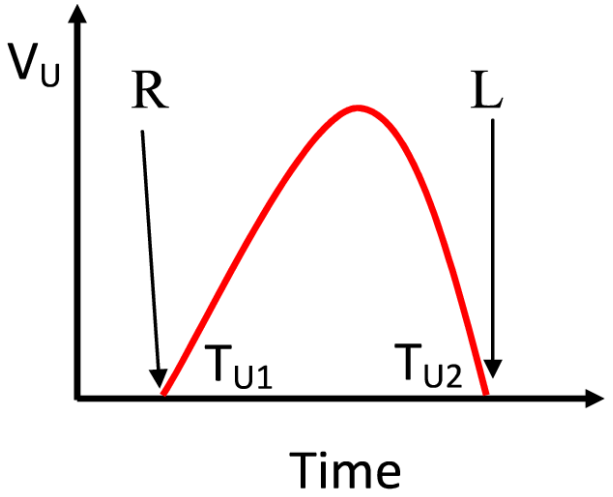
$$X_2 = X(T_{U1} - T_{Z2})$$

$$\Delta X = X_2 - X_1$$

Case III ($\phi_{crit} \leq \phi < 180^{\circ}$):

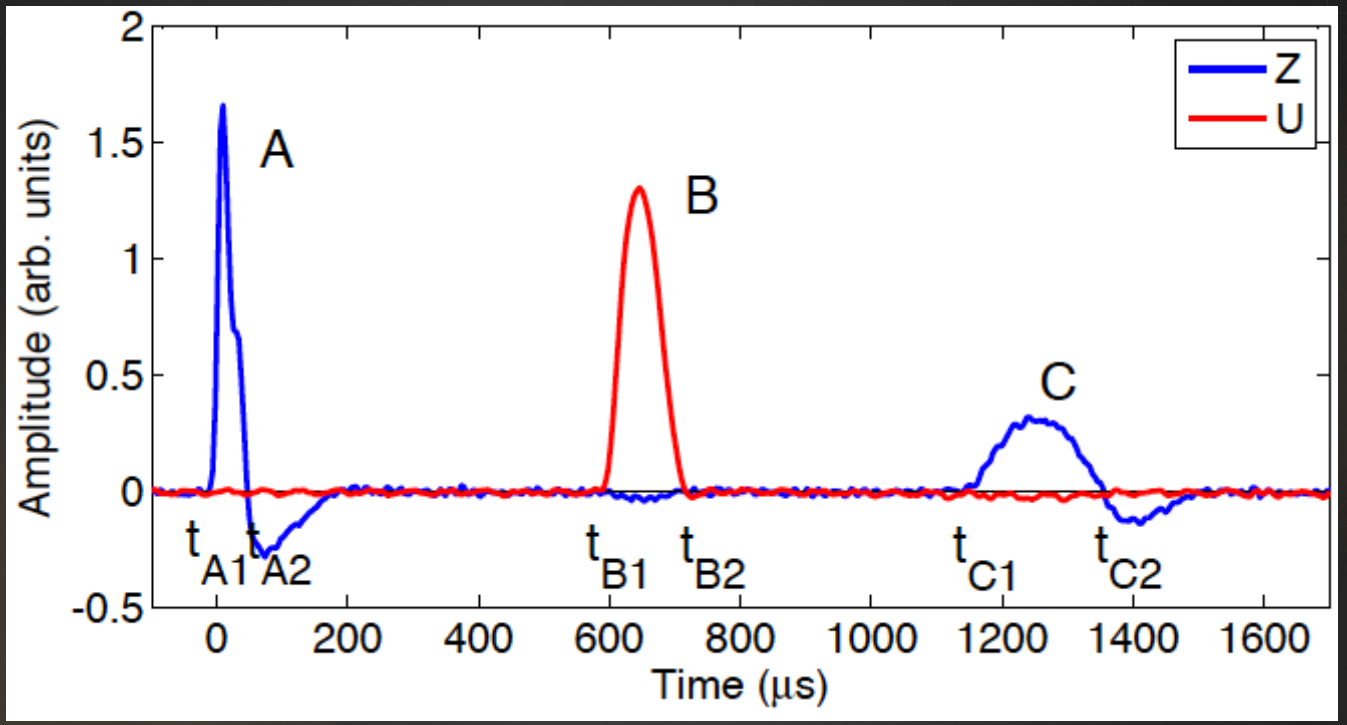






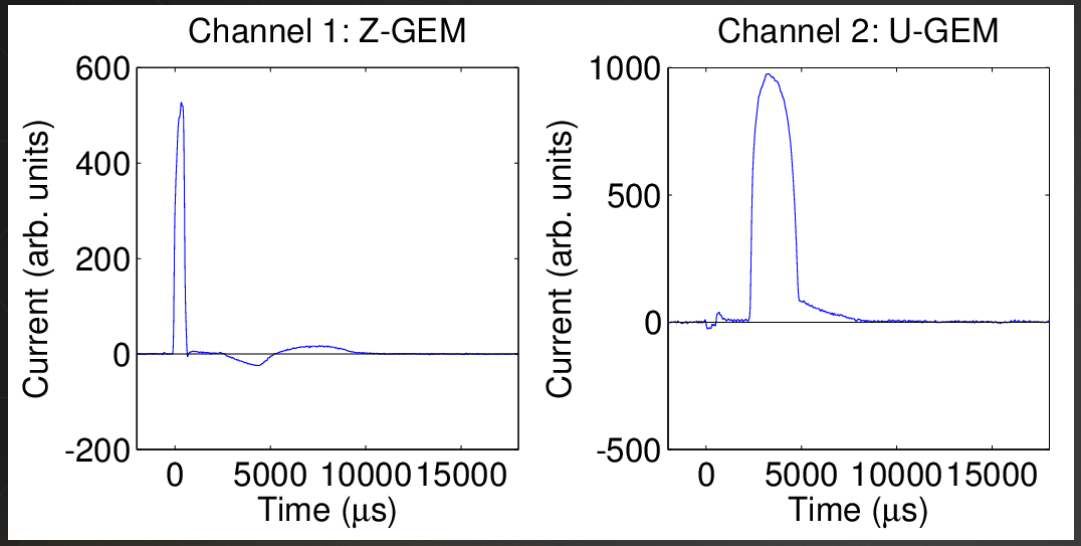
Resolving Edge Arrival Time Ambiguity

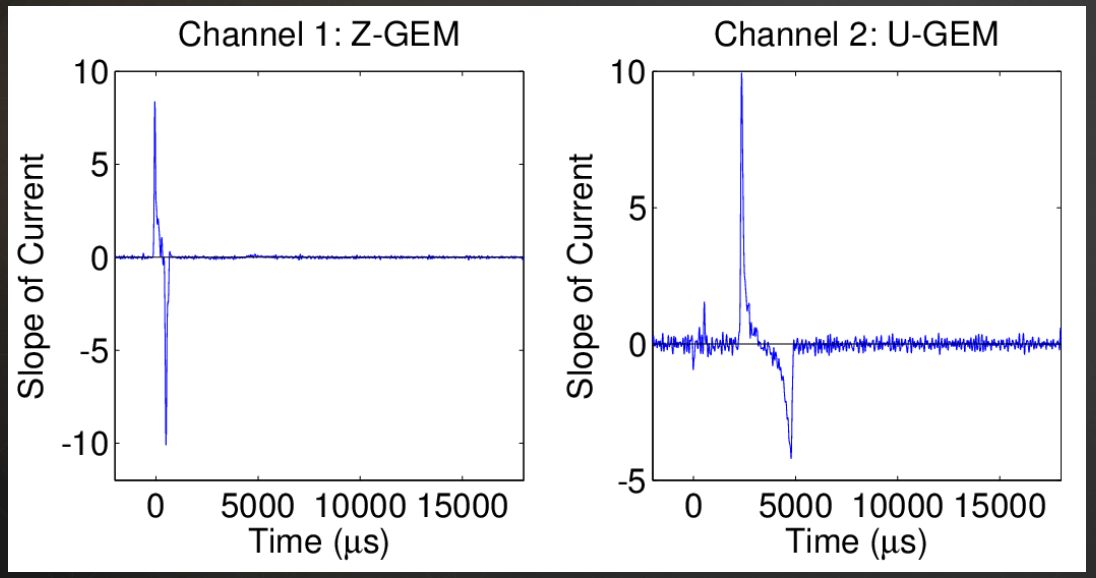
Use the return +ion signal from U- to Z-GEM!

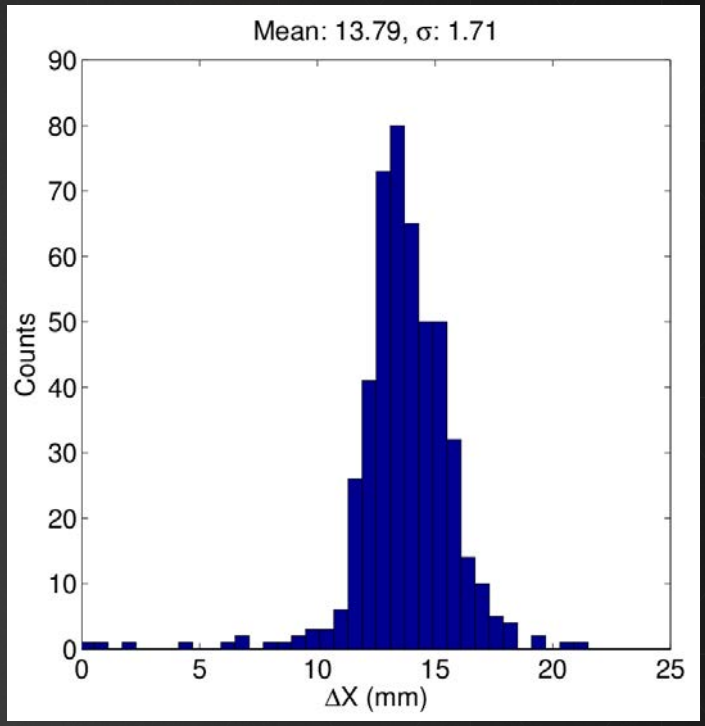


The edge tB1 ALWAYS corresponds to tC1, and tB2 to tC2. These can then be used to remove the ambiguity.

Preliminary Data: 31°

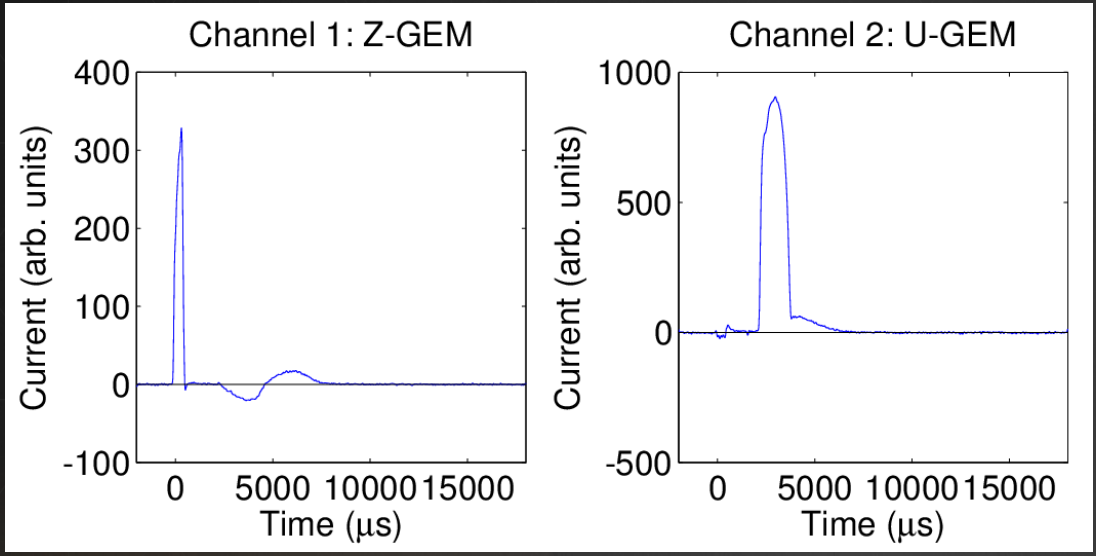


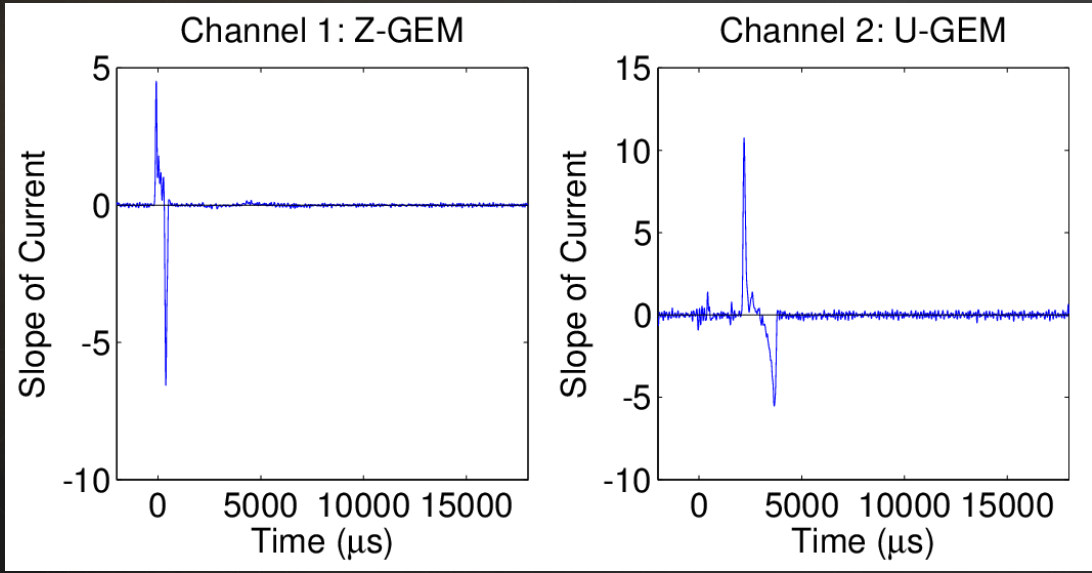


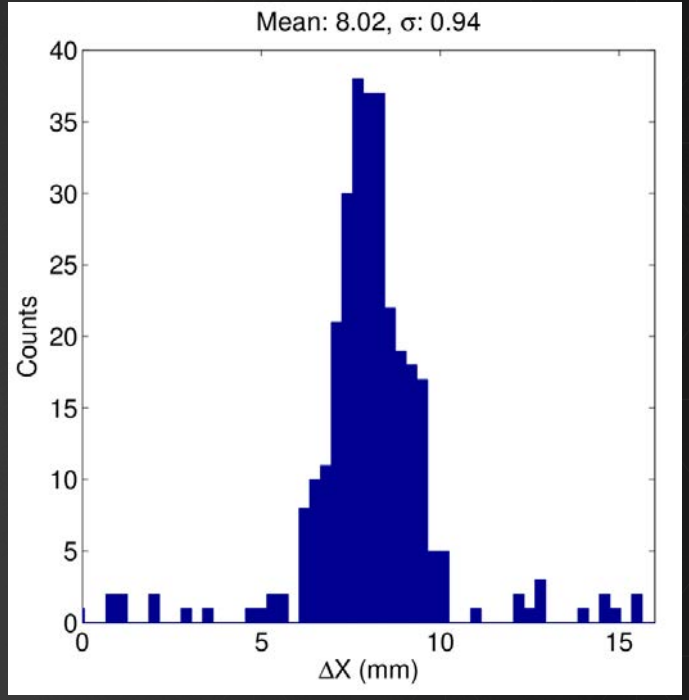


- True ΔX = 13.81 mm +- 0.5 mm
- Measured ΔX = 13.79 mm +- 0.08 mm

Preliminary Data: 45°

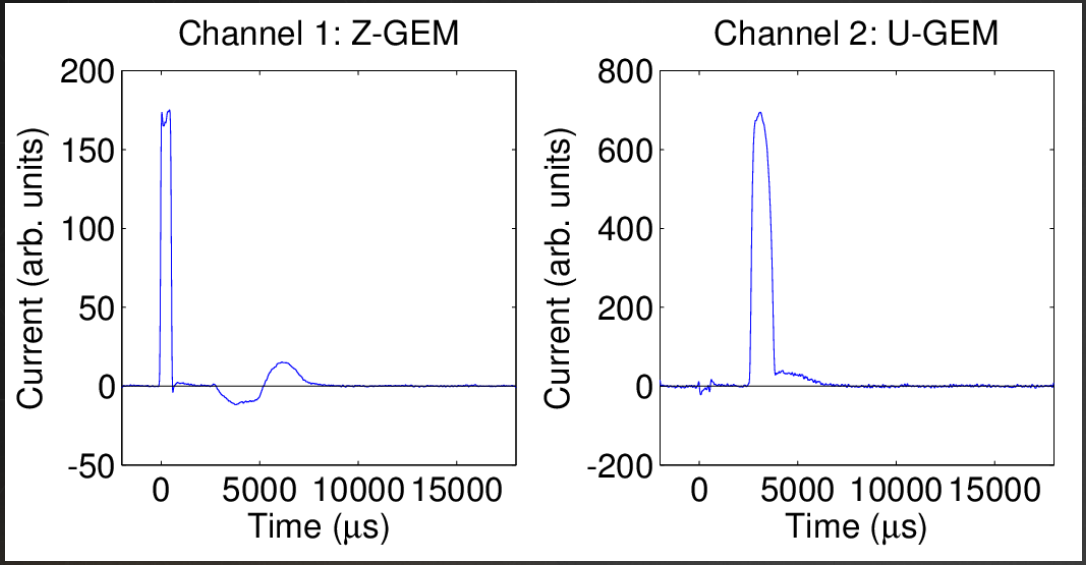


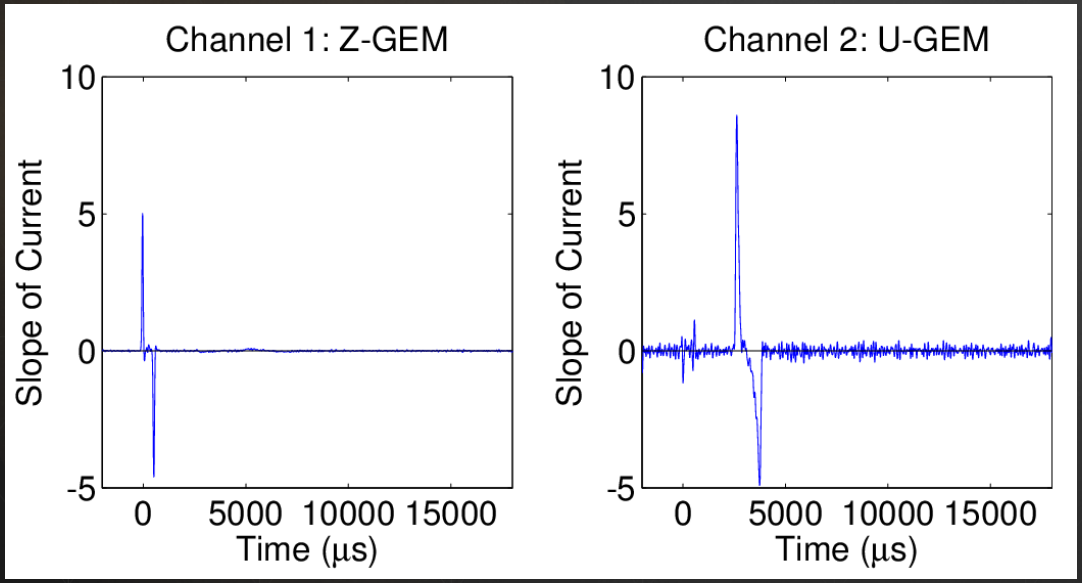


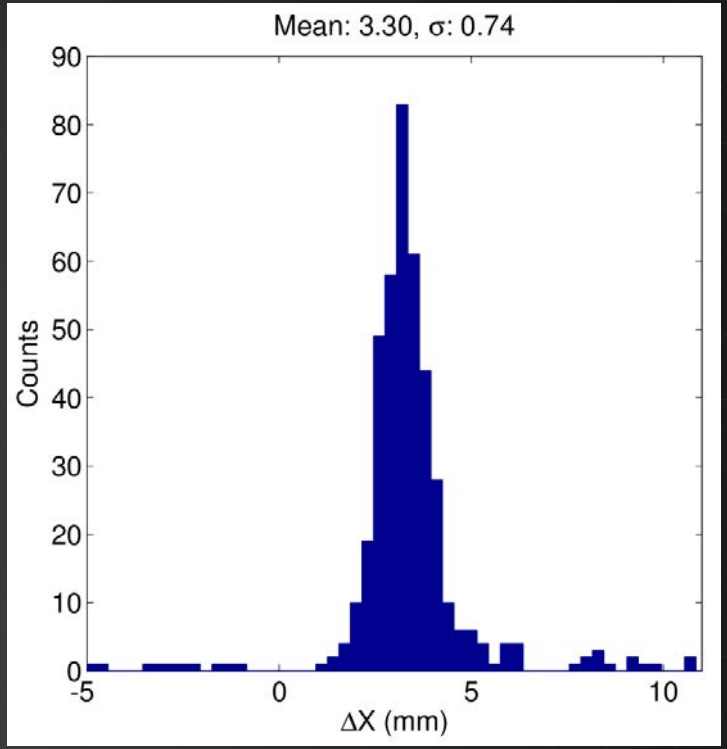


- True ΔX = 8.30 mm +- 0.3 mm
- Measured ΔX = 8.02 mm +- 0.06 mm

Preliminary Data: 70°

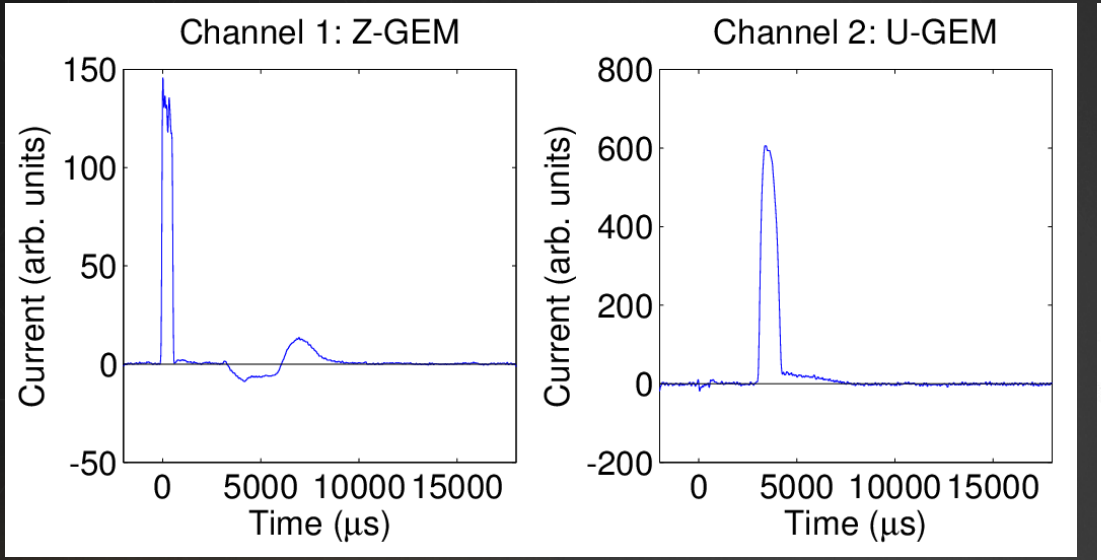


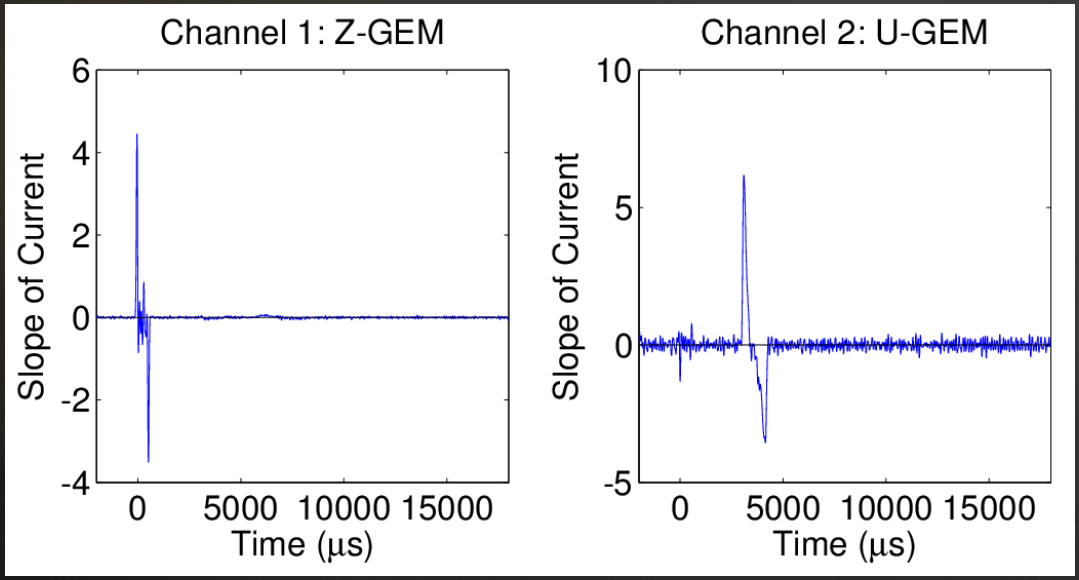


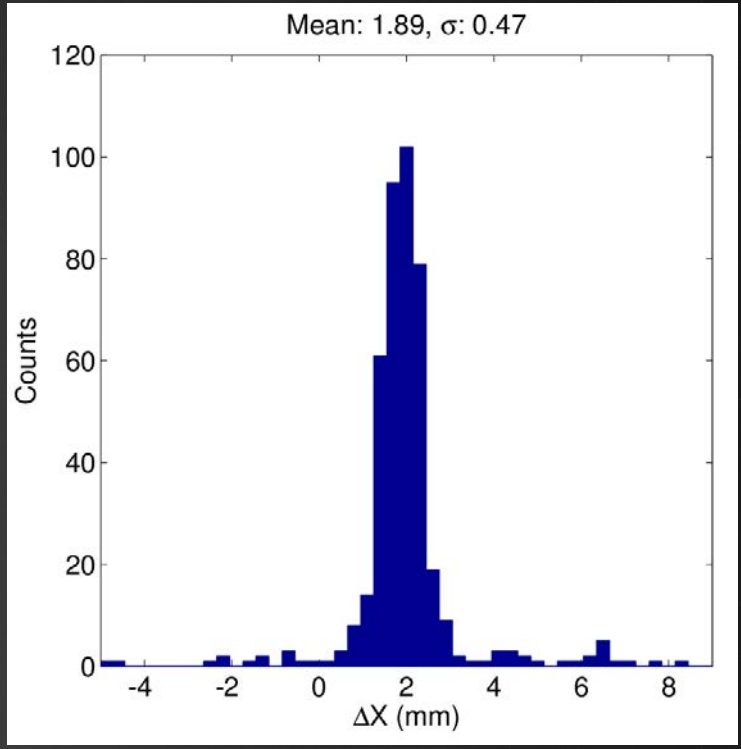


- True ΔX = 3.0 mm +- 0.2 mm
- Measured ΔX = 3.3 mm +- 0.06 mm

Preliminary Data: 80°

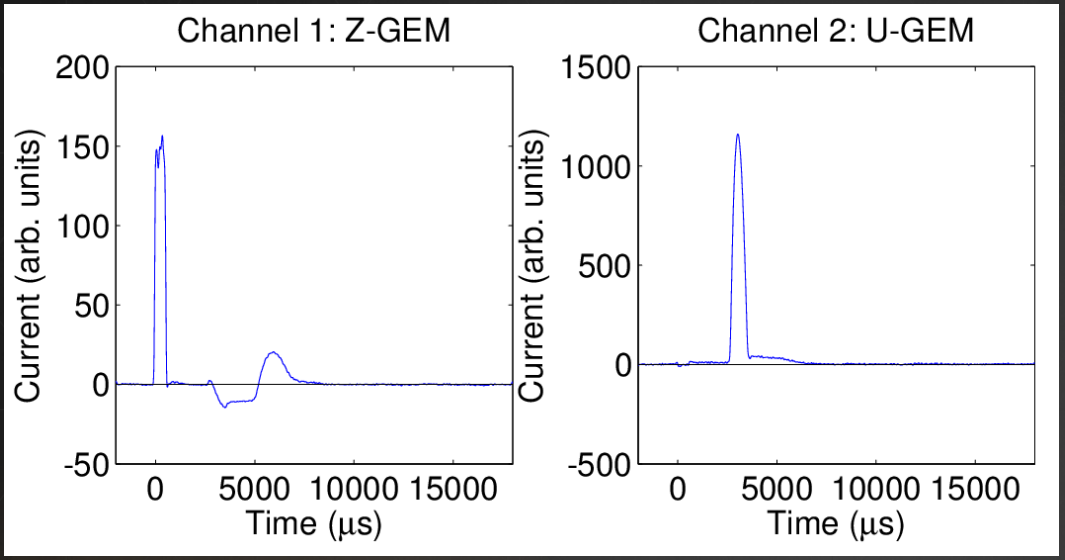


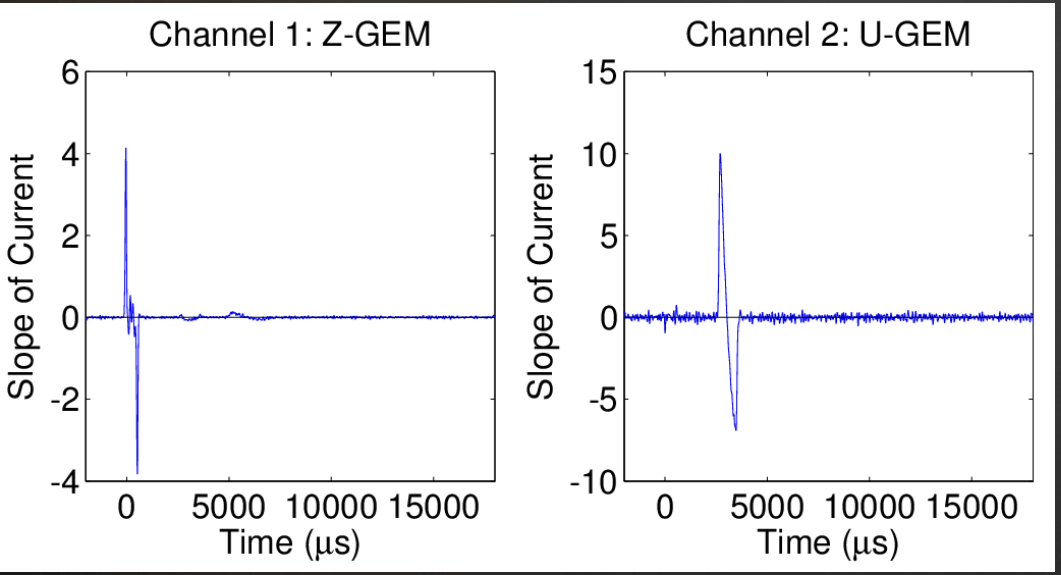


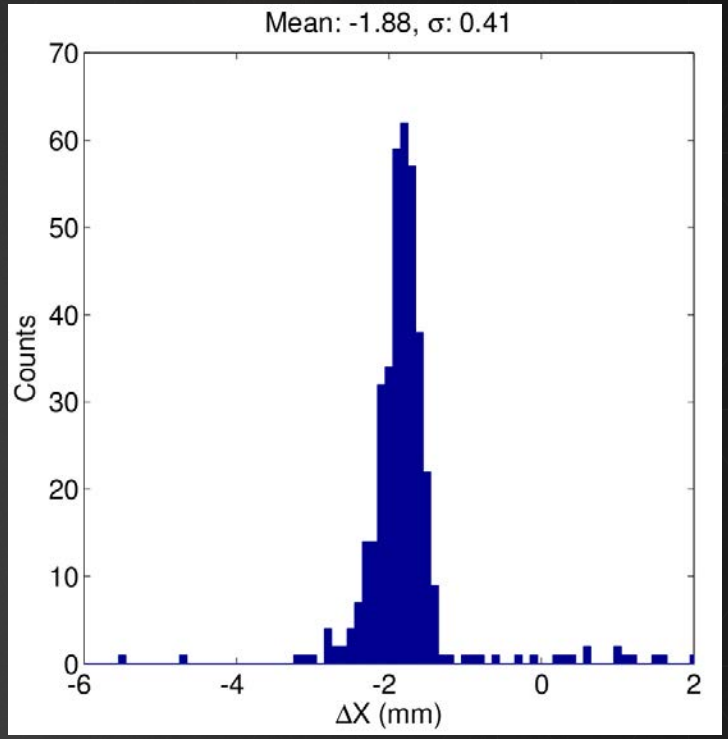


- True ΔX = 1.46 mm +- 0.15 mm
- Measured ΔX = 1.89 mm +- 0.06 mm

Preliminary Data: 100°

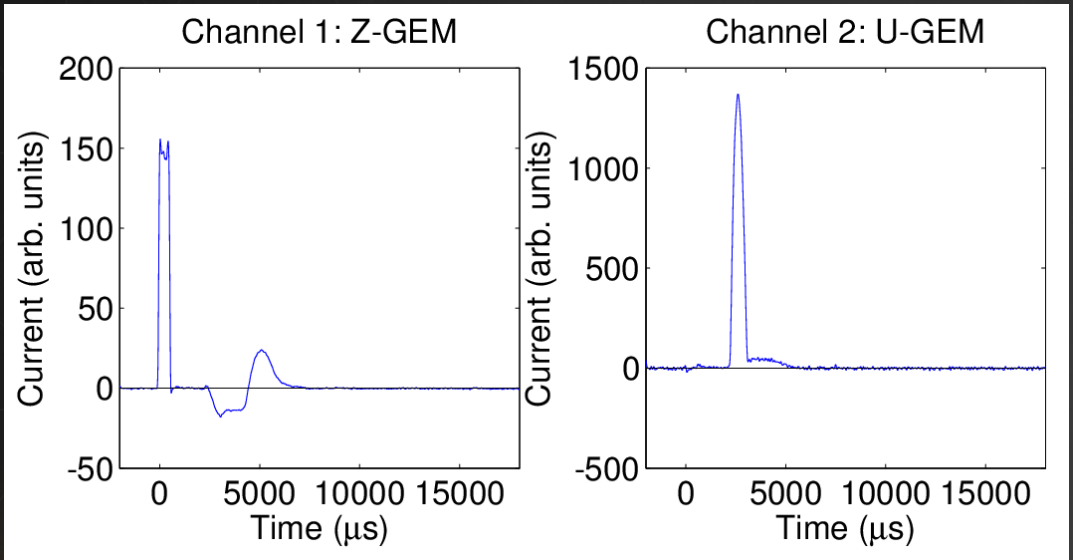


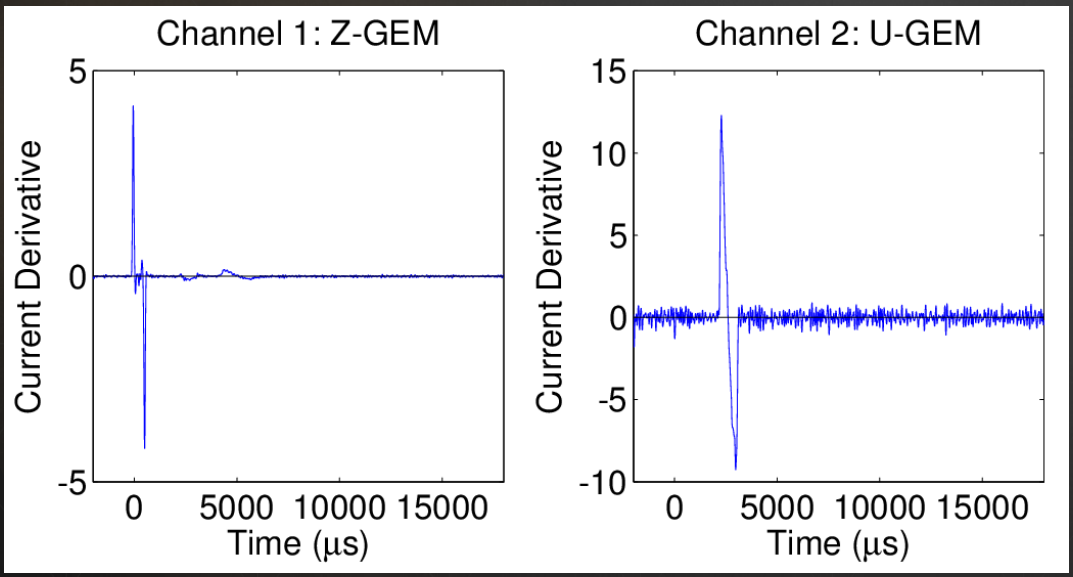


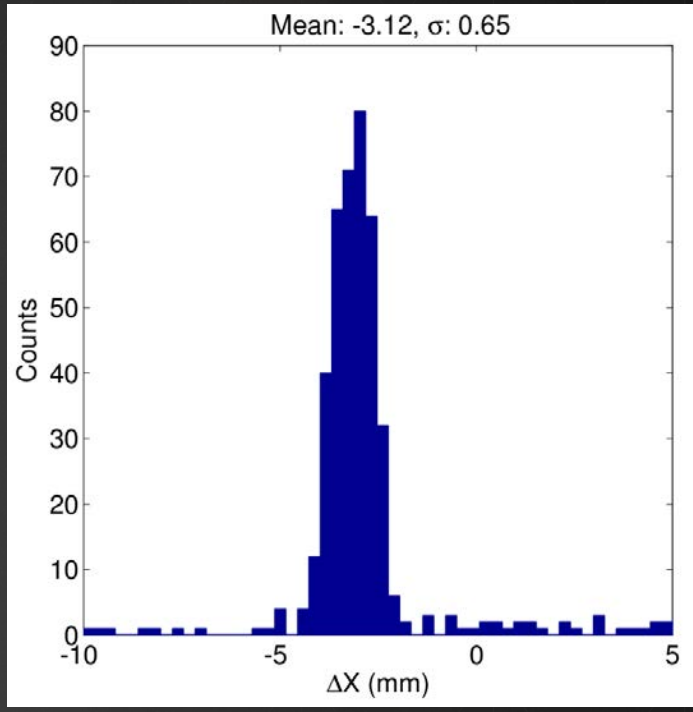


- True ΔX = - 1.46 mm +- 0.15
- Measured ΔX = -1.88 mm +- 0.02 mm

Preliminary Data: 110°

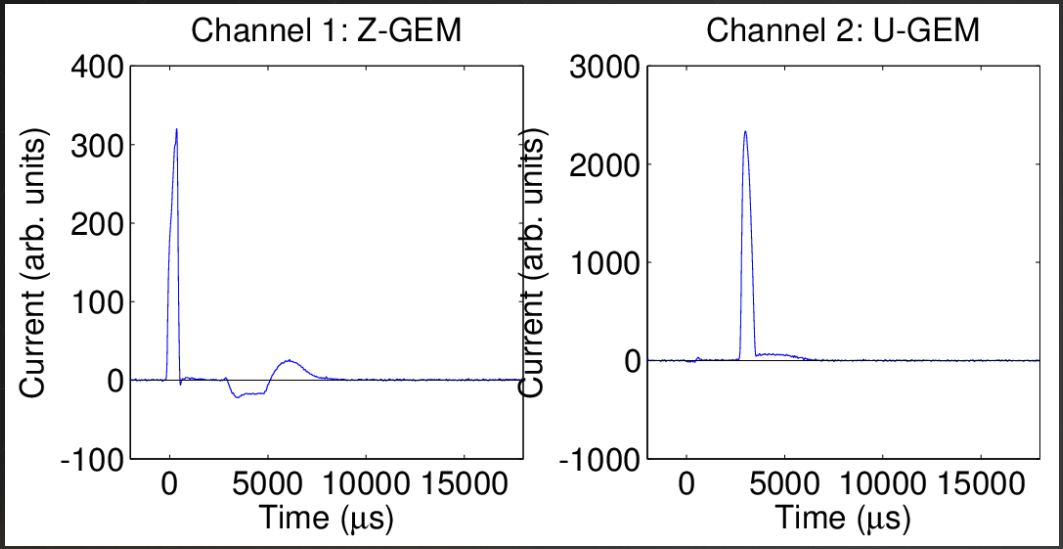


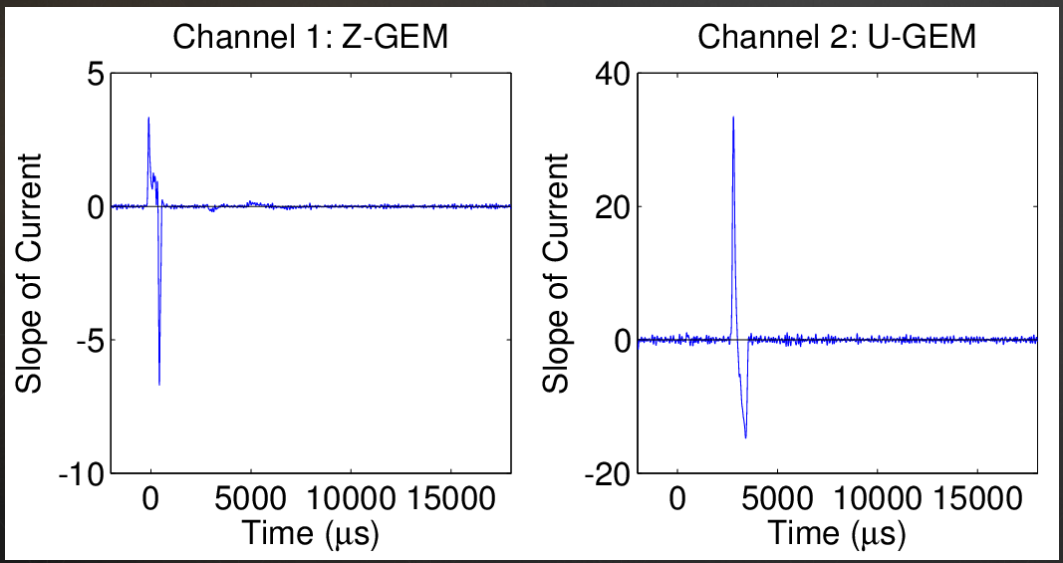


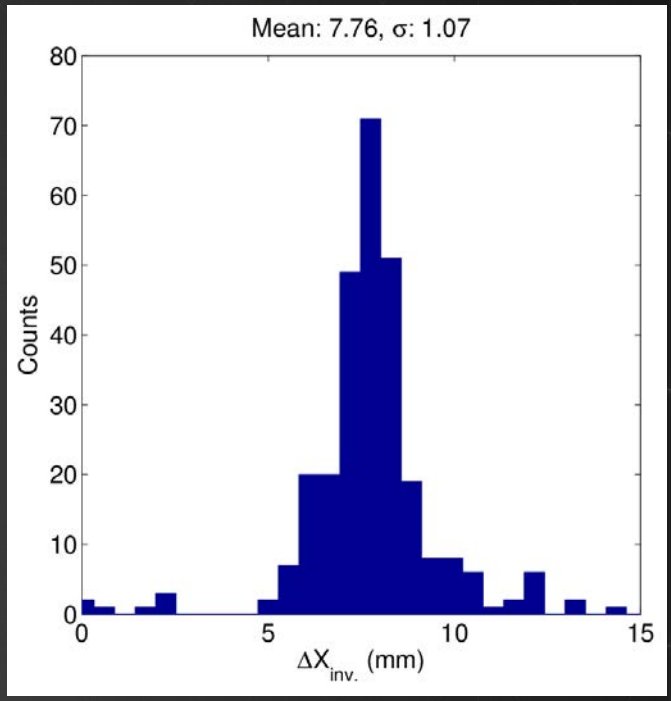


- True ΔX = - 3.0 mm +- 0.2
- Measured ΔX = -3.12 mm +- 0.03 mm

Preliminary Data: 135°

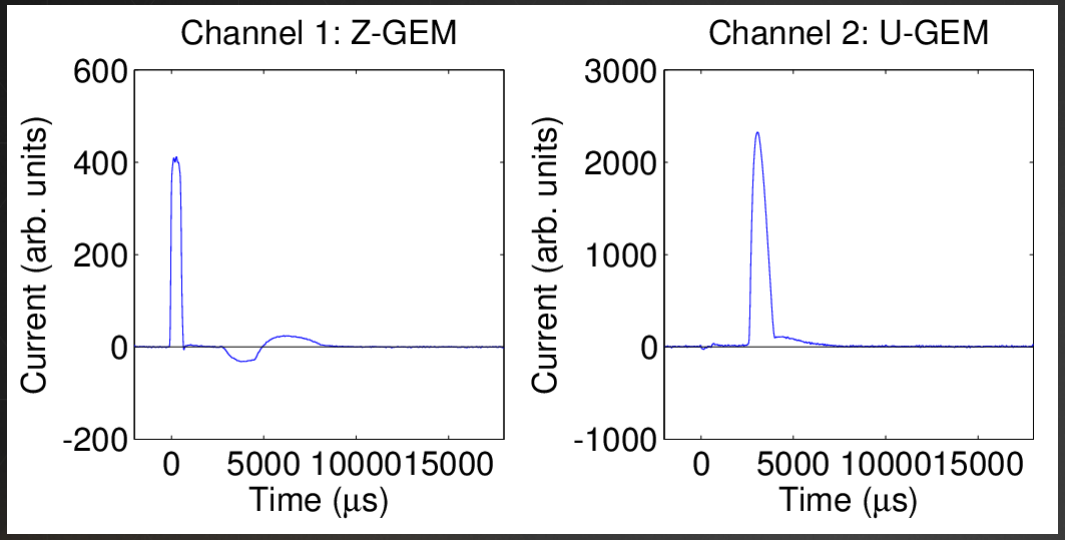


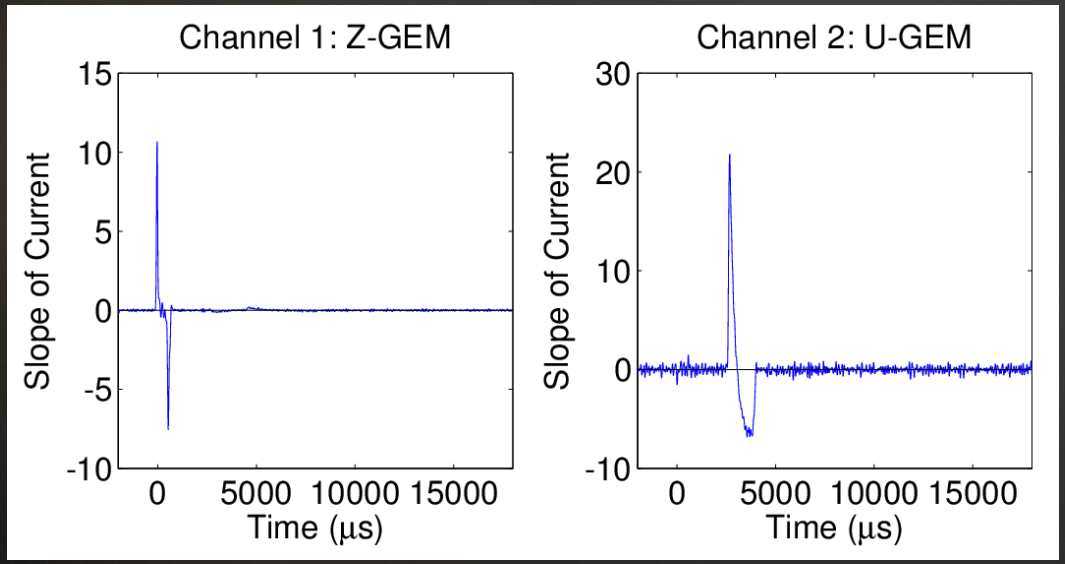


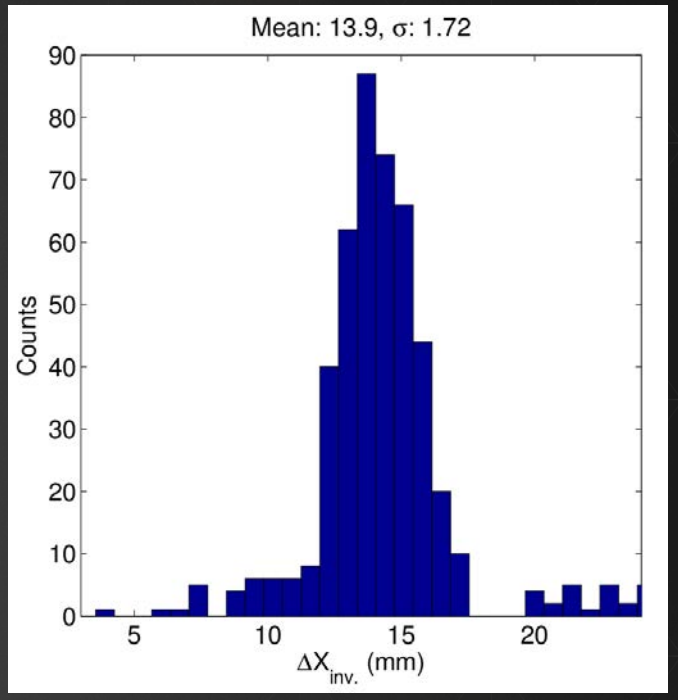


- True ΔX = 8.30 mm +- 0.3 mm
- Measured ΔX = 7.76 mm +- 0.06 mm
- Difference likely due to alignment error of source (small Y component).

Preliminary Data: 149°







- True ΔX = 13.81 mm +- 0.5 mm
- Measured ΔX = 13.90 mm +- 0.08 mm

Conclusion

- I have proposed a new approach to track readout via timing signals.
- Preliminary data shows the concept works in principle. Analysis details remain to be worked out.
- How well does this track reconstruction method work for even shorter tracks? Nuclear recoils? Electronic recoils?
- Can we measure Y in the same manner?

Thank you for your time!