# Ionizing particle beam fluence and position micro-pattern detector array with multi-coordinate readout

## DOE SBIR Phase II project update and the outlook past closing

**2019** Radiation Detection and Imaging (RDI) Technologies LLC, Arizona State University, and Mayo Clinic Arizona
E. Galyaev, M. Bues, D. Blyth, J. Holmes, R.-A. Briceno, N. Mullins, K. Scheuer

**2020** Radiation Detection and Imaging (RDI) Technologies LLC, Mayo Clinic Arizona, Texas A&M Cyclotron Institute
E. Galyaev, M. Bues, R.-A. Briceno, G. Rogachev, T.Ahn, J. Bishop

# Introduction and recap of the RDI projects

"High-density ionizing particle beam fluence and position detector array using the Micromegas technology with multi-coordinate readout" - DOE STTR Phase I (2016) / Phase II (2017-2019)

- Micro-pattern gas ionization arrays
  micromegas... with a few new twists:
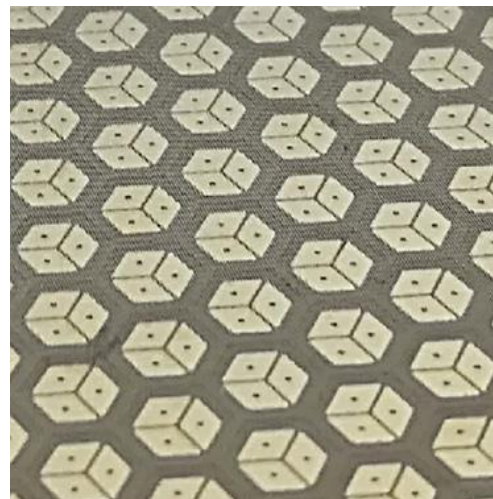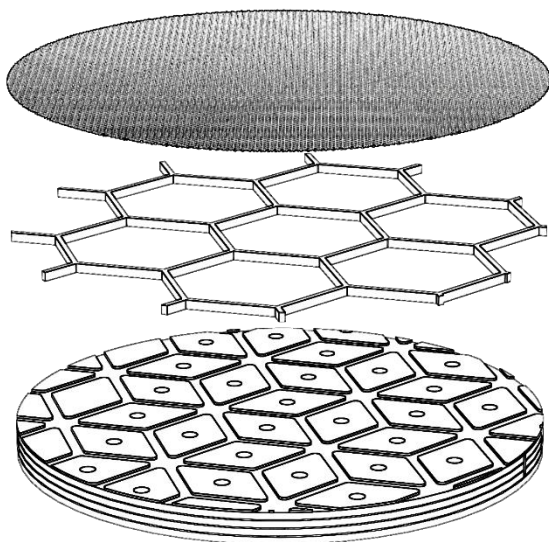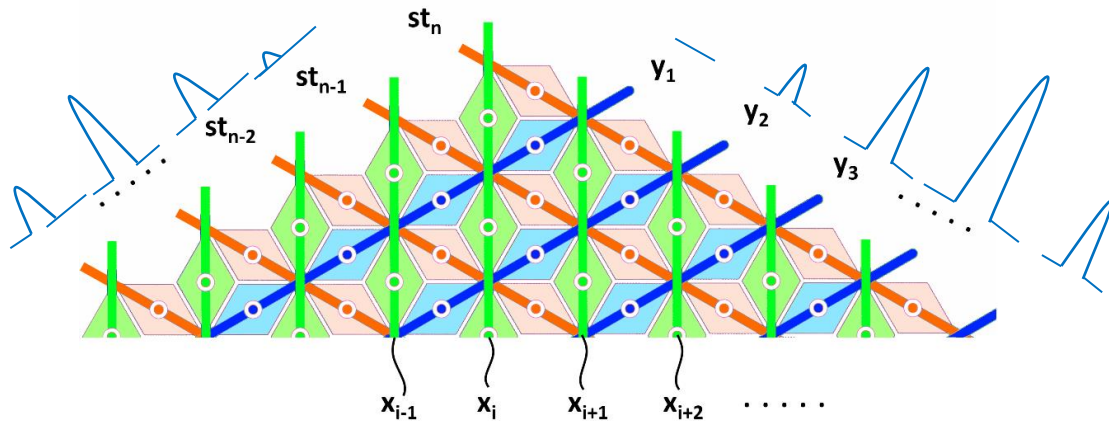
- A high-resolution air ionization array
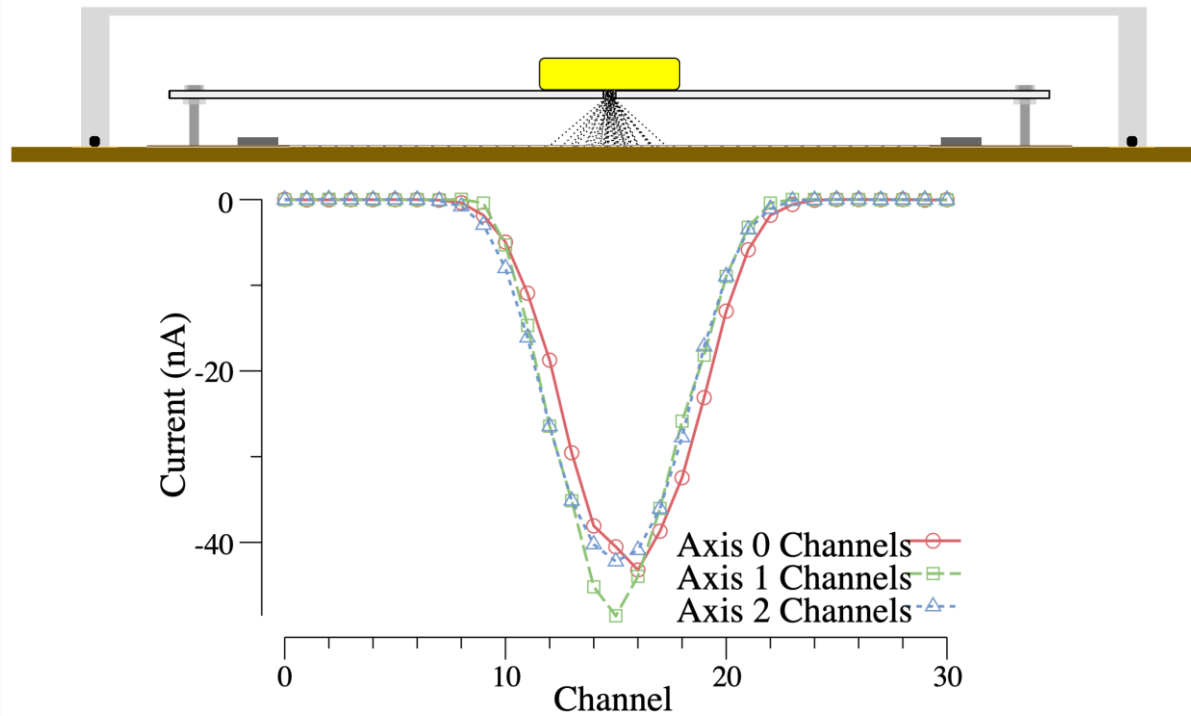  for pencil-scanning beam proton radiotherapy
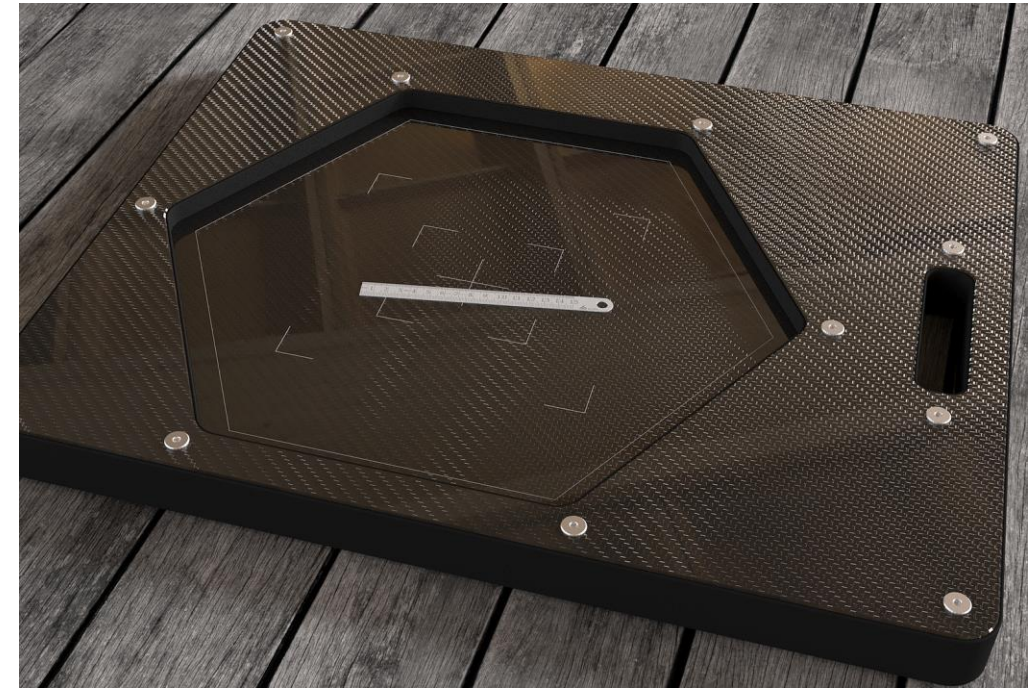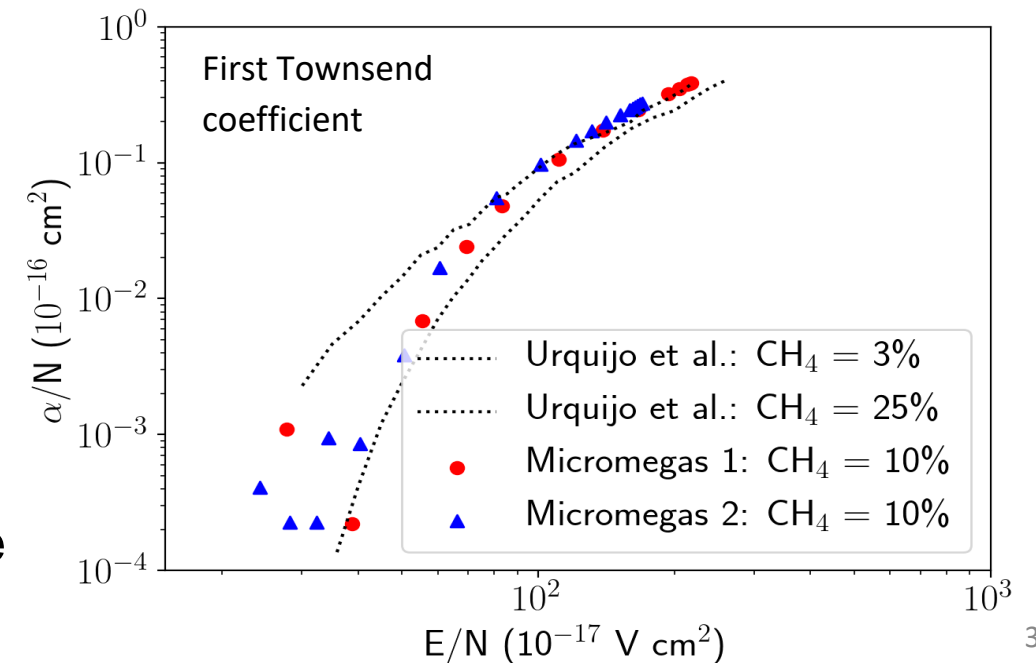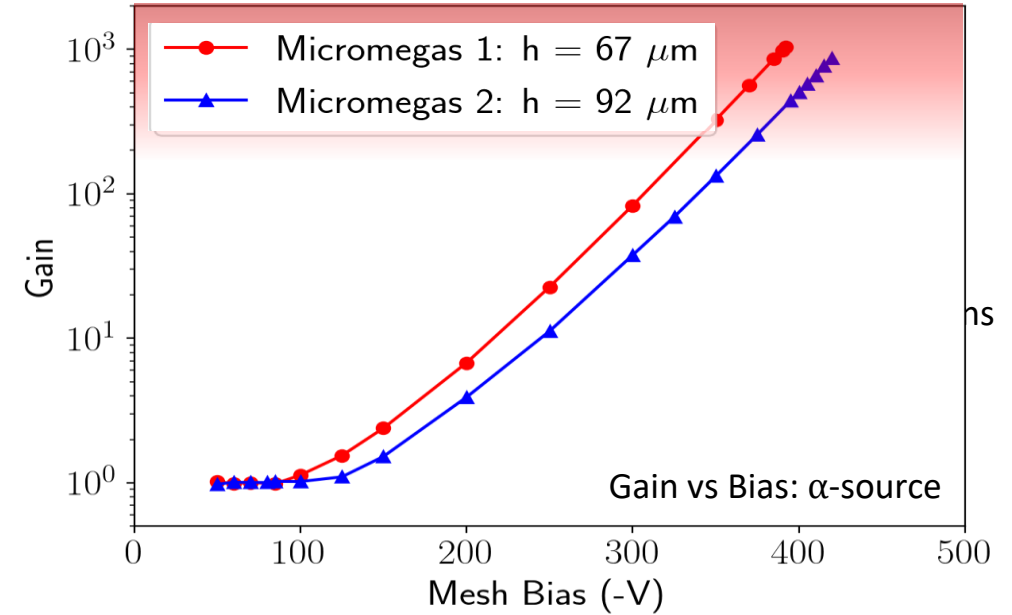


- Partners:

# Experimental milestones for the RDI Micromegas (1)
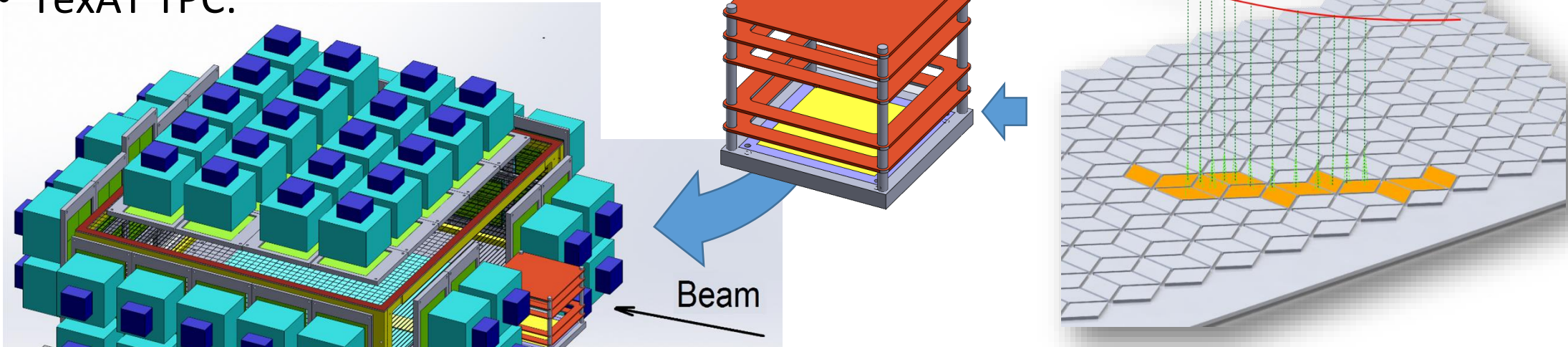


Gain vs Bias: α-source

First Townsend coefficient

- Stable operation in high-gain regime
  o Raether limit prevents high gain with protons
- Multi-channel readout via three axes
- Streaming data format
- Proven position and beam cross section shape reconstruction

# Planned validation in a physics experiment

- TexAT TPC:



Beam

- Adding entry beam position and orientation tracking
  - Requires fine spatial resolution (≤ 200um)
  - Integrated with TAMU DAQ electronics (GET)
  - RDI is to help with position reconstruction
  - RDI to try 'pulsed' own DAQ system when ready
  - Excellent compact testing platform
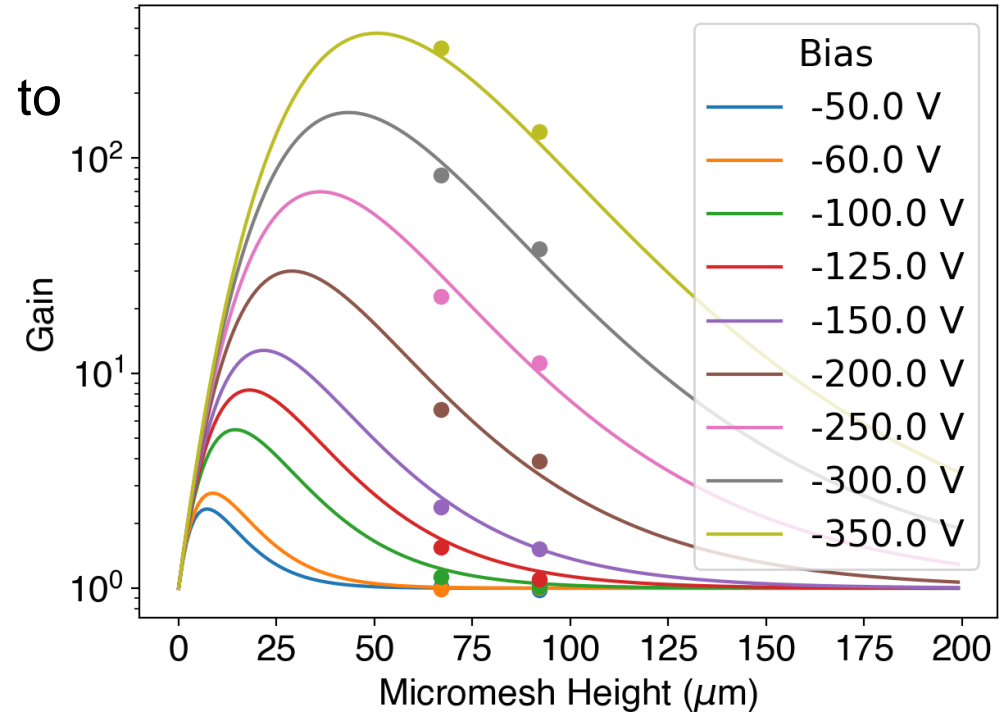
(a)          (b)          (c)
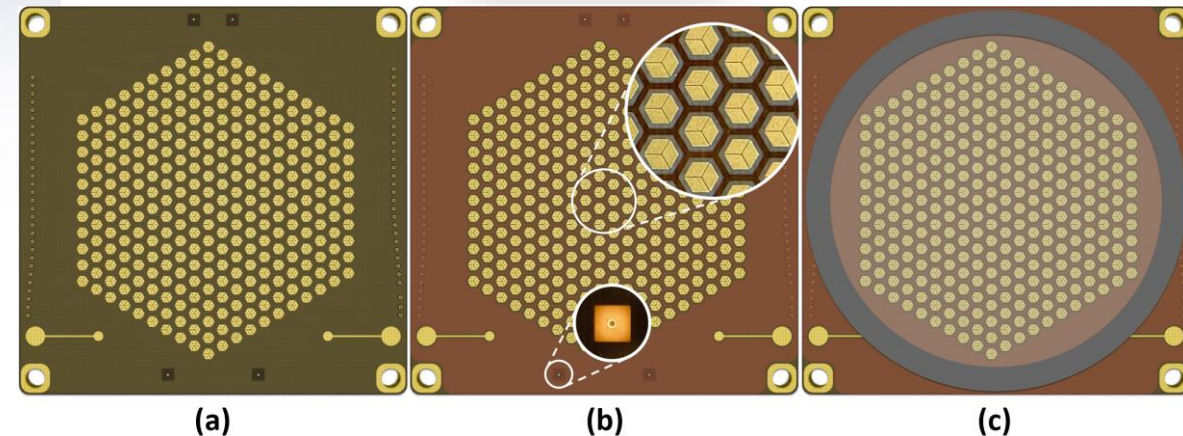
# Experimental milestones for the RDI micromegas (2)

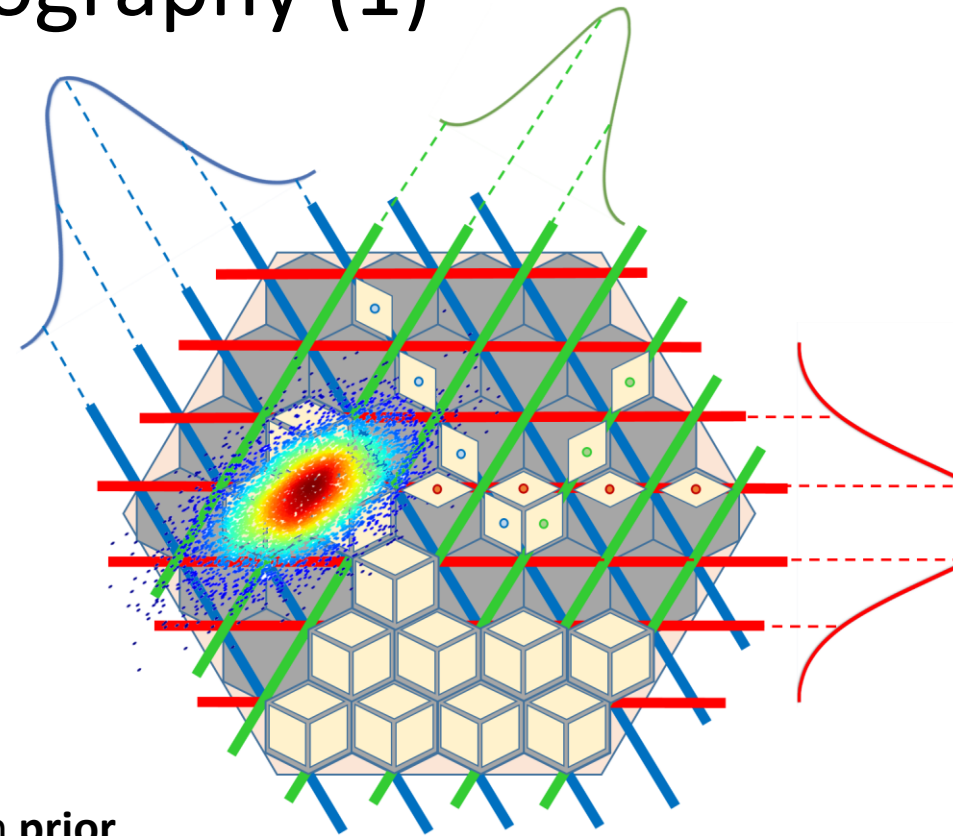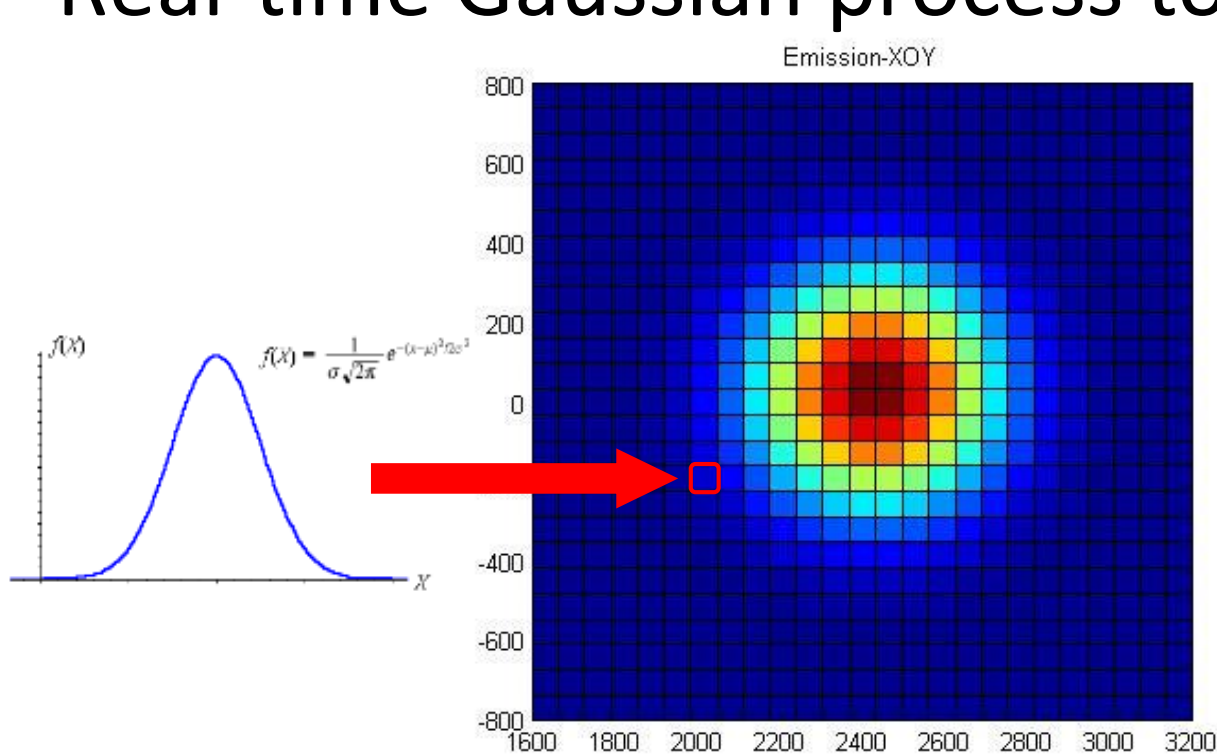x6 micromegas detector arrays have been delivered to the TAMU Cyclotron team in January 2020!





All detector arrays have been "burned out" prior to sipping and are ready to use.

RDI publication in JINST V15, 2020 (1748-0221)

# Real-time Gaussian process tomography (1)



Emission-XOY

**Ill-conditioned Non-Negative Least Squares Problem:** Many more pixels than readout channels ⇒ non-invertible rank-deficient matrix. Additionally, unphysical negative pixel intensities must be avoided.

**Regularization:** A Bayesian **prior** estimate for the image pixel probability distribution to resolve rank deficiency ⇒ Gaussian covariance between the pixel values. **Calculated ahead of time for all measurements.**
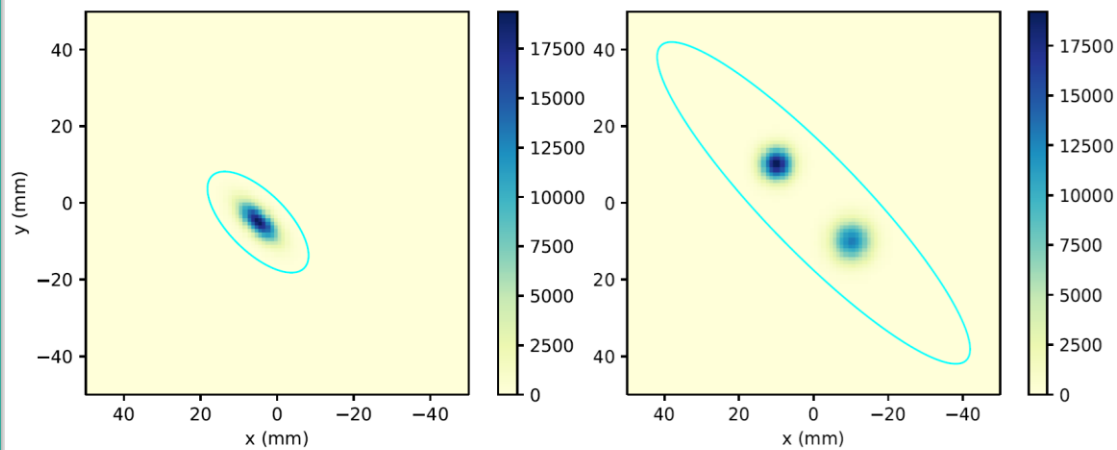
**Real-Time Application:** In real time, apply pre-computed, regularized linear estimator while enforcing inequality constraints.

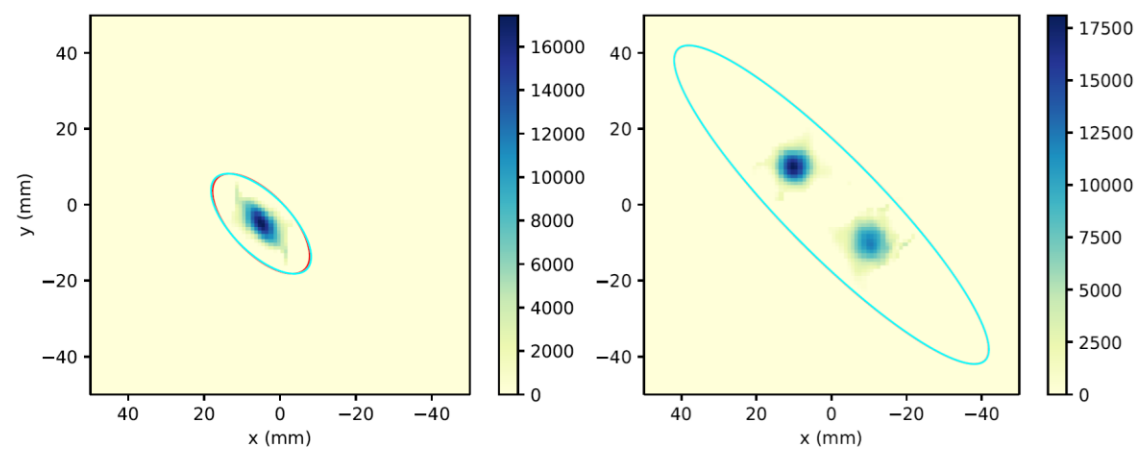The method **allows to carry out tomography in real time!**
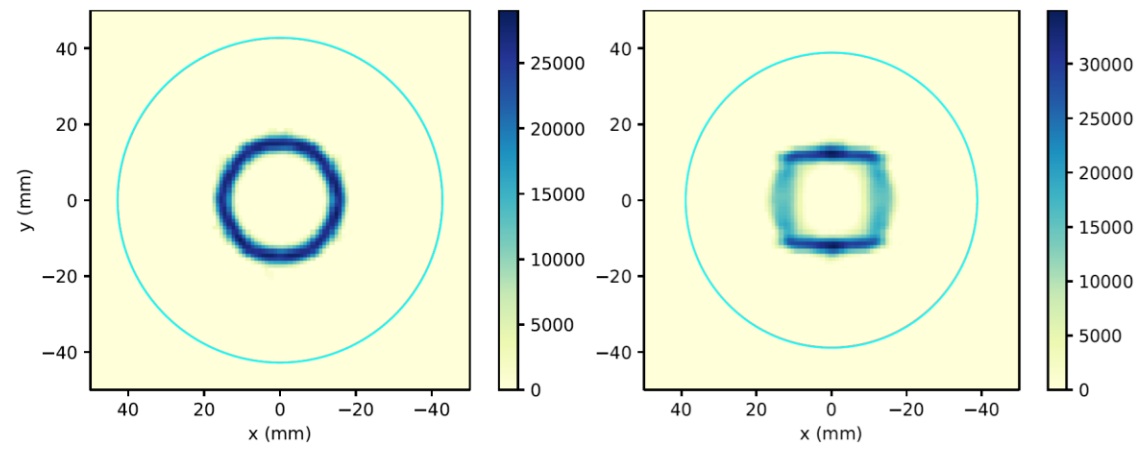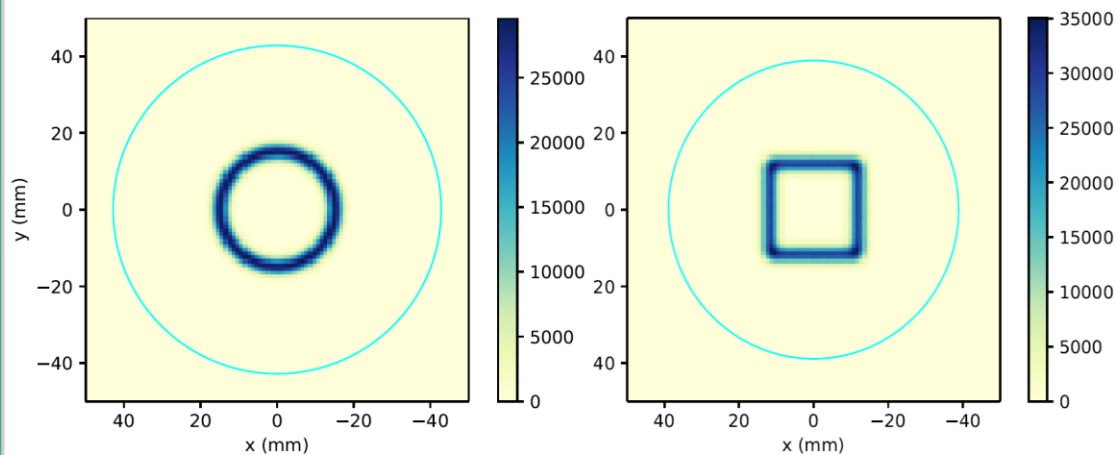See also T. Wang et al https://doi.org/10.1063/1.5023162

# Real-time Gaussian process tomography (2)
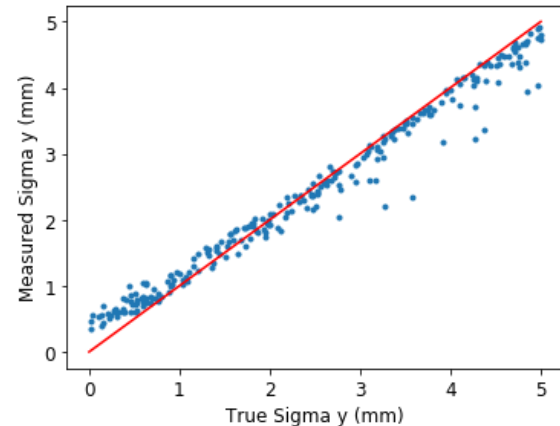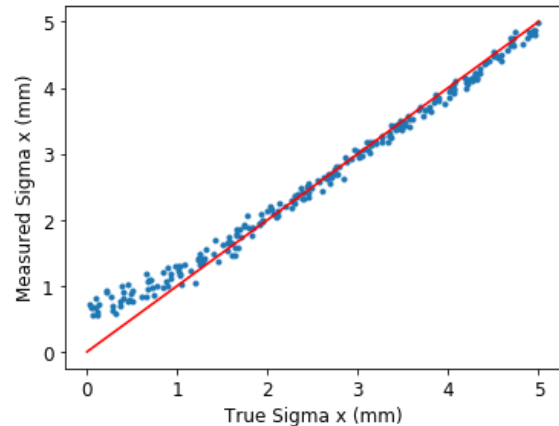


"Truth" images

Reconstructed images

Several additional interesting planar layouts are being explored in the RDI publication!

RDI Publication: JINST V15, June 2020

# Air ionization array for proton radiotherapy (1)

## PTCOG-NA (Oct-2019)

- RDI has presented (3) posters
- Strong professional interest has been generated
- Confirmed commercialization potential
- Unique chance at communication!

The prototype array demonstrates sub-millimeter spatial resolution





Detector timing resolution

Single 'spot'          Total Current

Resolved individual pulse structure
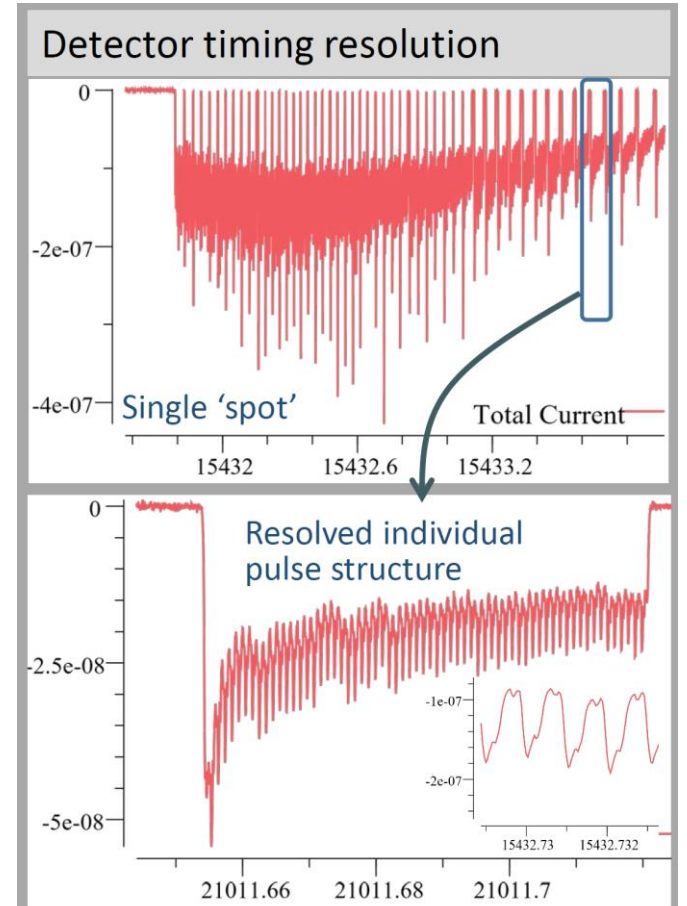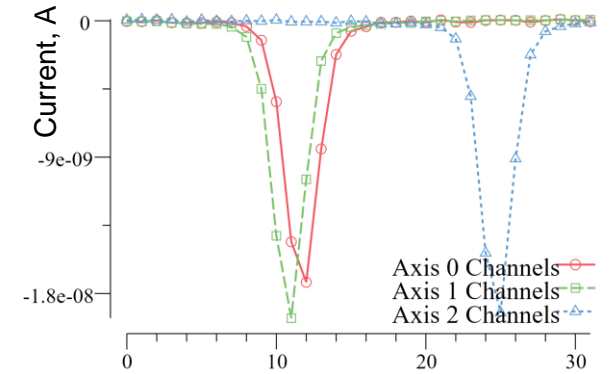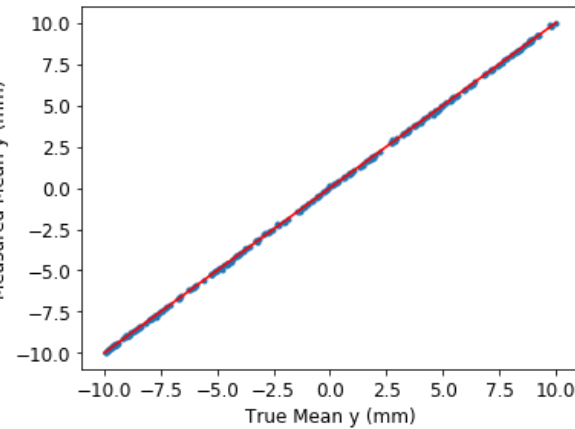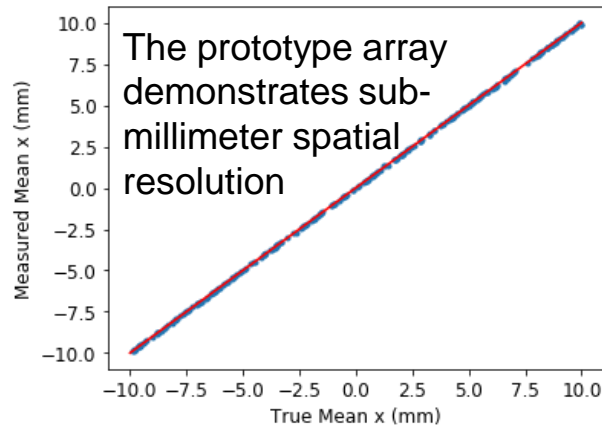
# November 2019: SBIR Phase II ends.
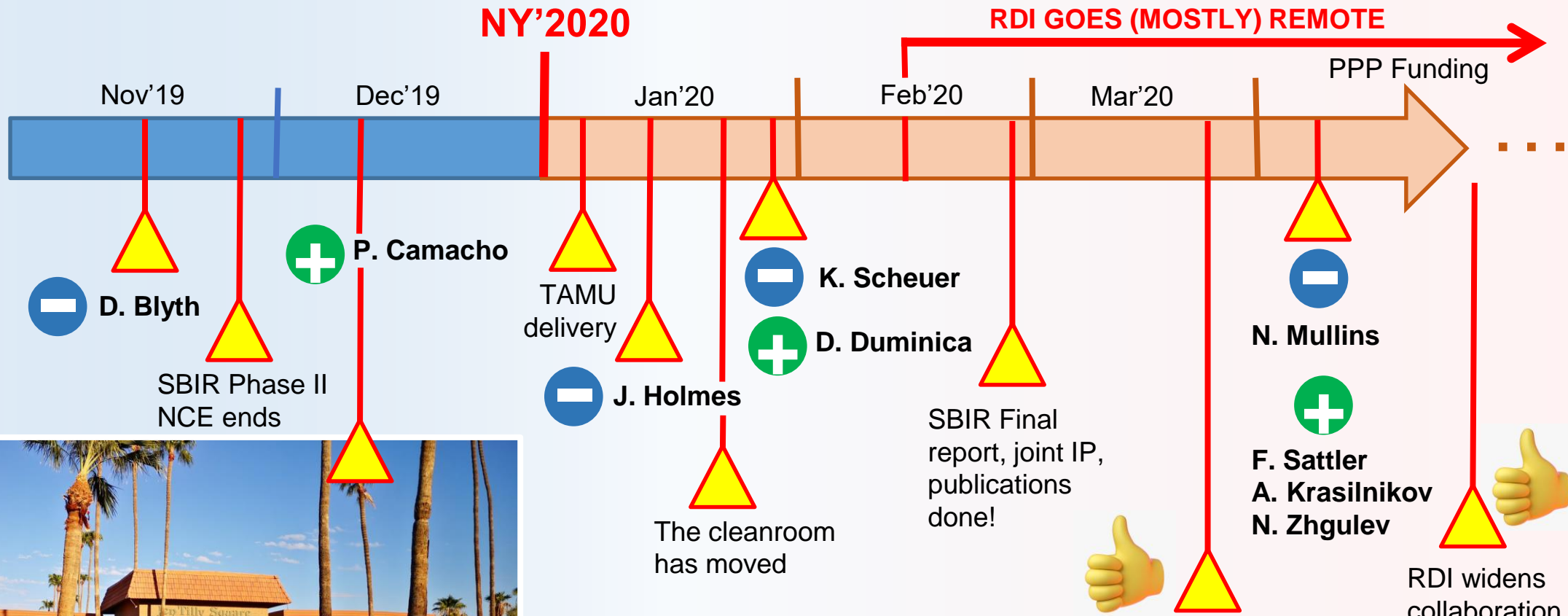
Year end team changes. RDI moves into its own offices. Year 2020 challenges.



NY'2020

RDI GOES (MOSTLY) REMOTE

PPP Funding

Nov'19    Dec'19    Jan'20    Feb'20    Mar'20

D. Blyth

SBIR Phase II NCE ends

P. Camacho

TAMU delivery

J. Holmes

The cleanroom has moved

K. Scheuer

D. Duminica

SBIR Final report, joint IP, publications done!

N. Mullins

F. Sattler
A. Krasilnikov
N. Zhgulev

RDI scores two industrial contracts

RDI widens collaboration with TAMU. P.O. from TAMU!
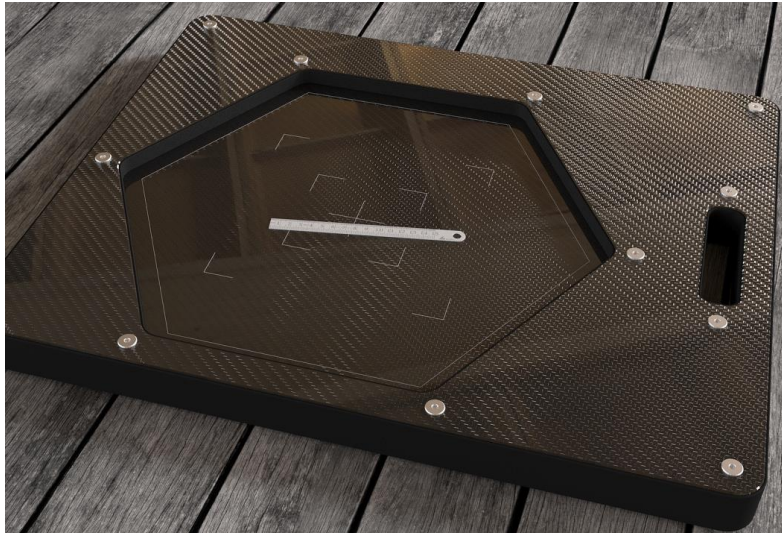
RDI moves from the ASU campus

2020 RDI LLC

- R.-A. Briceno contributes in the advisory role
- L. Jolley still contributes as contractor (since 2015!..)
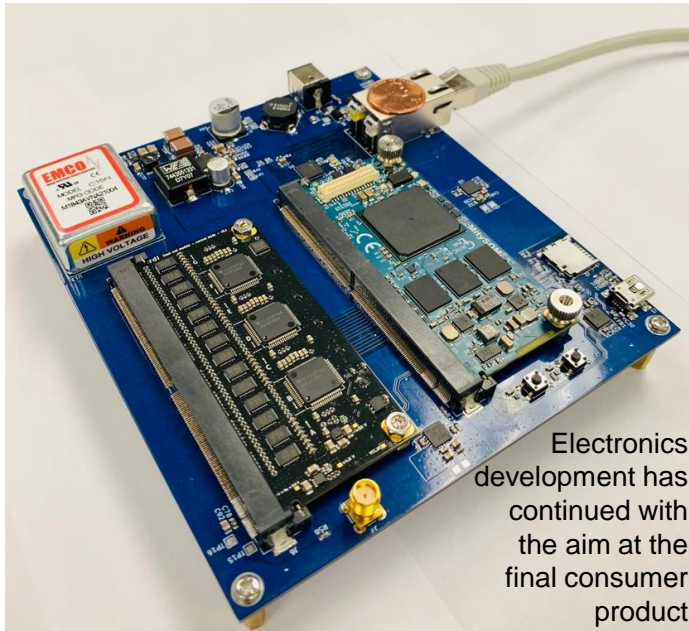
9

# Year 2020. The new RDI endures.

Air ionization array for proton radiotherapy (2)
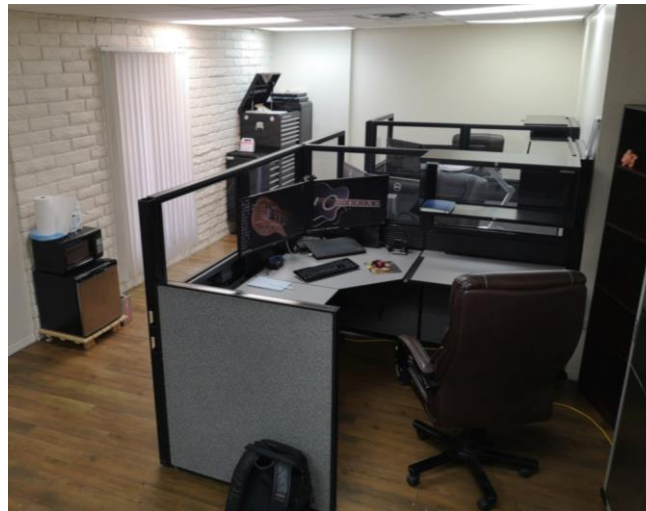


The rendering…



… becomes reality!





Electronics development has continued with the aim at the final consumer product



Not a lot but it's home



Software development continues. RDI is about one month away from demonstrating full quality tomography in real time. ROOT / C++ integration and analysis package for ProIO data.
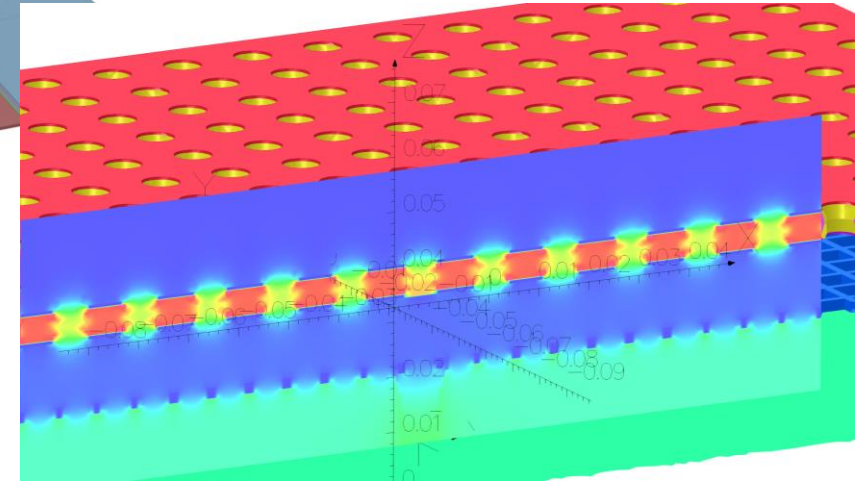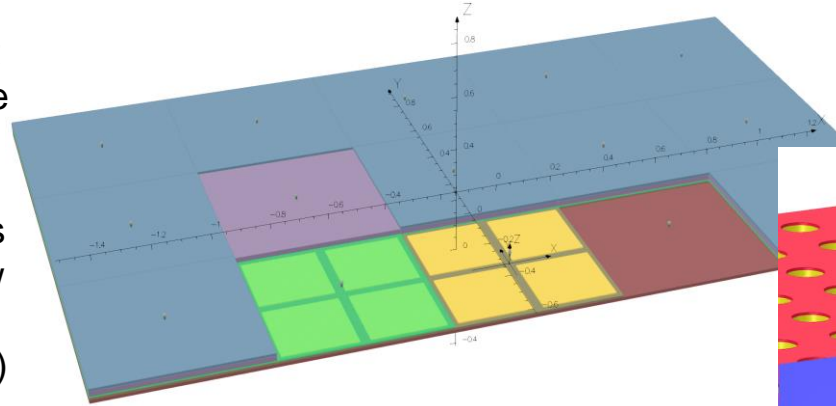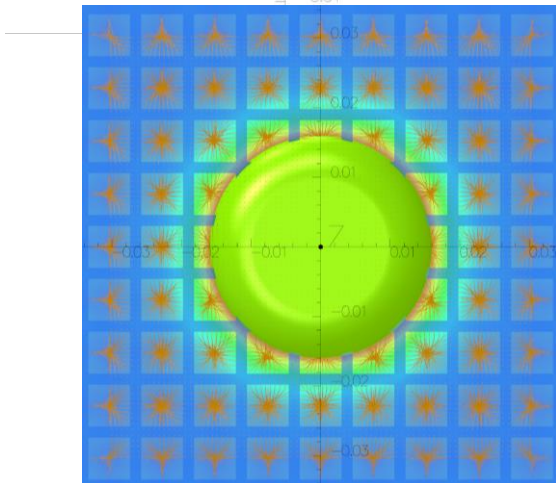
# Continued collaboration with Texas A&M

E. Pollacco
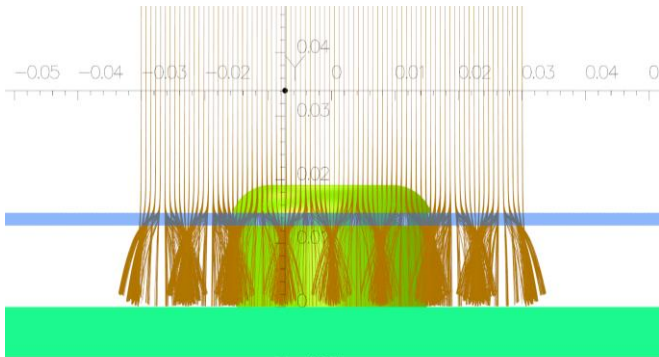G. Rogachev
T. Ahn
J. Bishop
E. Galyaev

The goal is to have one of the most comprehensive, large-area resistive micromegas simulated.
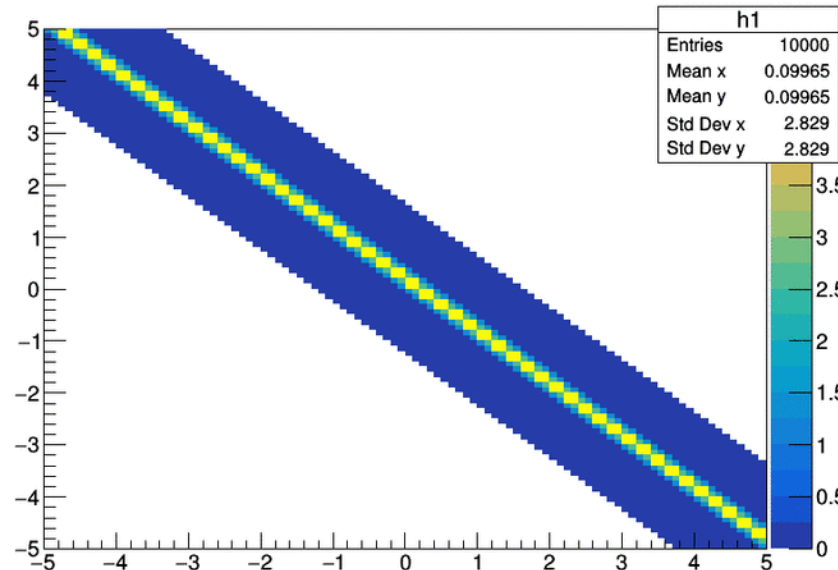
RDI and TAMU teams pulled forces together. RDI shares our know-how and skills in modeling the micromegas (OPERA & Garfield++)
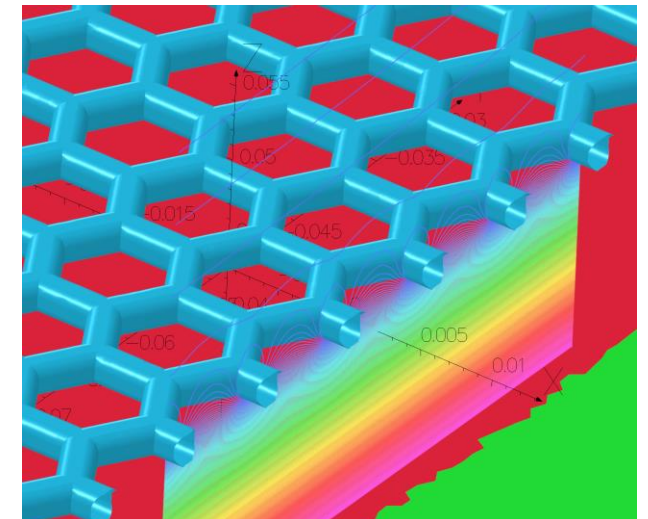
Micromegas + GEM for the TexAT is being simulated as well!

Time evolution of the charge in the resistive micromegas

β-mesh (CERN) model

# Brief summary and outlook

- ## Closing our Phase II SBIR
  - 5 publications • micromegas to TAMU and support • joint IP disclosures • final technical report available • final financial reporting • over dozen oral presentations • 3 poster presentations • PTCOG-NA proceedings

- ## Micromegas development beyond the DOE SBIR
  - Collaboration with TAMU • Unfortunate experiment delays due to COVID19 • CEA, Saclay interest in RDI methods

- ## Commercialization of the technologies
  - Commercialization of the air ionization array is the closest goal
  - About 4 months out to the first device in hand. Another 2-3 months internal validation.
  - Mayo Clinic, St. Jude: validation of the product / prep for the FDA 510k (2021)

- ## Company survival and development
  - UNMET2020 Arizona • AZ Innovation Challenge 2020 • Mayo & RDI joint NIH SBIR Phase I bid
  - Ad-hoc consulting contracts • RDI offers broad array of services • Web site & social presence
  - Bids for the new SBIR with DOE • Licensing some of our IP to our industrial partners & clients

The current situation is tough… but this is what entrepreneurship is – survival is tough, but the life is worth living ☺
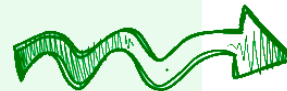
Thanks everyone at the

**U.S. DEPARTMENT OF ENERGY** | Office of Science

# THANKS to EVERYONE!



# QUESTIONS?