A novel ionizing particle beam fluence and position detector array using the Micromegas technology with multi-coordinate readout

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Table of Contents

- Project goals
- RDI Capabilities/Infrastructure
- Concept/Progress
- Results
- Nuclear physics relevance
- Schedule and deliverables/Future plans
Project Goals

To develop a cost-effective commercial MicroMegas (Micro-mesh gaseous structure) fluence detector with a high dynamic range of nearly $2^{12}$, a position resolution of greater than 1 mm, and a radiation hardness able to withstand 300 kGy (~10 years clinical use).
RDI Capabilities

- RDI LLC
- Radiation Detection & Imaging

**Beam Fluence Detector**
- DAQ Electronics (current mode)
  - 60%

**Particle Tracking Detector**
- DAQ Electronics (pulse mode)
  - More concentrated effort area

**Ongoing development cycle**
- Testing in beam at Mayo Clinic
  - 95%
- Experimentally validated Micromegas simulation loop

**Array assembly manufacturing technique/process**
- Micromegas parameters
- Array PCD + Spacers + Mic Assembly
- Scalability

**In-house testing w/isotope sources**
- Simpler layout test arrays made with cost efficient material alternatives
- Fast Turnaround Development Cycle
- Cost Efficiency of Prototyping R&D
- The Right Materials
- High-performance Analogue Electronics

- Array Test Chamber
  - Ability to quickly assemble and test ideas and improvements
- Outgassing Vacuum / Gas Chamber with Residual Gas Analyzer
  - Understanding material properties
- Own, dedicated (Class 10) clean room workspace
  - Good process, clean materials

- R&D CYCLE SUPPORTING INFRASTRUCTURE

**Project Goals**
RDI Capabilities
Micromegas
3D-Readout Imaging

Original ‘Gaussian’ distribution simulating beam intensity map

Projections as registered via 3 coordinate readout directions

6 coordinate directions

Reconstruction artifacts are present

Reconstruction artifacts are practically absent
Micromegas Array Designs

- high density (hd v1) and simple low-cost (v1-v3)
- simpler boards $\rightarrow$ rapid prototyping
Micromegas Build Process
Micromegas Build Process
Source (Po-210) Testing

Simple Array v2 (4x4 pad, 68-22 mesh)
● Goal: To improve real detector designs through accurate simulation
● Garfield++ – simulation of tracking detectors, electrons
● Geant4 - the simulation of the passage of particles through matter
● OPERA - FEA multiphysics

Kuger et al, Mesh geometry impact on micromegas performance with an exchangeable mesh prototype
Mayo Clinic Testing

- Hitachi PROBEAT proton therapy system
- Synchrotron accelerator
- 71.3 MeV - 228.8 MeV
- Increments of about 2 mm depth in water
- Delivers beam in spots
- 5 ms, $10^7$ protons
Mayo Clinic Testing

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Ionization Current for Argon-based Gas Detector in Proton Beam

![Graph showing ionization current vs beam energy](image-url)
Mayo Clinic Testing
Data Acquisition

- Analog bandwidth is 10 kHz
- 18 bit depth ADCs
- Altera FPGA/CPU-based system
- 96 channels
- Future/ongoing work: merge boards
Nuclear Physics

- New techniques for constructing Micromegas
- Studies underway with publishing plans to add to a more complete understanding of Micromegas for the scientific community
- Talks are underway with Olympus II collaboration on a new experiment that may be suitable for our detectors (trying to solve proton form factor measurement discrepancies).
- Ongoing search for more projects (suggestions welcome)
Summary

- New micromegas construction techniques are working and being optimized.
- Beam tests have begun, early results are promising.
- Complete simulation loop currently in verification stage.
- Full imaging capable DAQ is in early stages of testing.

Future

- Scalability of designs to as large as 40 cm x 40 cm.
- Pulse mode DAQ system.
- Sell lots of these detectors.
- Take over the world.