High-Performance Plasma Panel Based Micropattern Detector

August 6, 2014
DOE-NP SBIR/STTR Exchange Meeting
Gaithersburg, MD

P. S. Friedman

Integrated Sensors, LLC, Ottawa Hills, Ohio (419-536-3212)
www.isensors.net

Program Subcontractors/Collaborators:

R. L. Varner Jr.
Oak Ridge National Laboratory, Physics Division, Oak Ridge, TN, USA

R. Ball, J. W. Chapman, C. Ferretti, D. S. Levin, C. Weaverdyck, B. Zhou
University of Michigan, Department of Physics, Ann Arbor, Michigan, USA

Plasma Panel Sensor (PPS)

- The PPS, conceived as a high-performance, low-cost, particle detector, is based on ***plasma-TV display*** panel technology.

- Each pixel operates like an independent ***micro-Geiger counter*** and can be activated either by ***direct*** ionization in the gas, or ***indirect*** ionization using a conversion layer.

- Both "***open***-cell" and "***closed***-cell" PPS devices based on ***direct*** ionization are the primary focus of our research efforts.

PPS Detector Goals

- **Scalable, low mass, long life, inexpensive**
  - ***cm*** to ***meter*** size, with ***ultrathin*** substrate capability
- **Hermetically sealed & rad-hard material structure**
  - no gas flow system & robust construction
- **Performance**
  - Pixel efficiency: ≈ **100%**
  - Time resolution: ≈ 1 ns
  - Granularity: 200 µm
  - Spatial resolution: **< 100 µm**
  - Wide response range: ≈ **1 Hz/cm^2** to *at least* **10^6 Hz/cm^2**
- **Primary Applications – *Active Pixel Beam Monitors*****
  - Research: Nuclear physics / high energy physics (LHC-upgrades)
  - Medical: Particle CT imaging (NIH) / particle beam therapy (NCI)
  - Neutron Detection: Neutron scattering (DOE-BES) / DHS-DNDO

**ANL-ATLAS "Priority-I Ranking", 2 days of testing planned in 1st half of 2015*

Sources Used for Testing

Cosmic-Ray Muons (≈ 4 GeV at sea-level)

Muon Beam: 180 GeV range (at **H8-CERN** for ***high energy physics)***

Beta Particles (max. energy): ^{137}Cs (1.2 MeV), ^{90}Sr (2.3 MeV), ^{106}Ru (3.5 MeV)

Proton Beam: 226 MeV (***proton beam cancer therapy & proton-CT***)

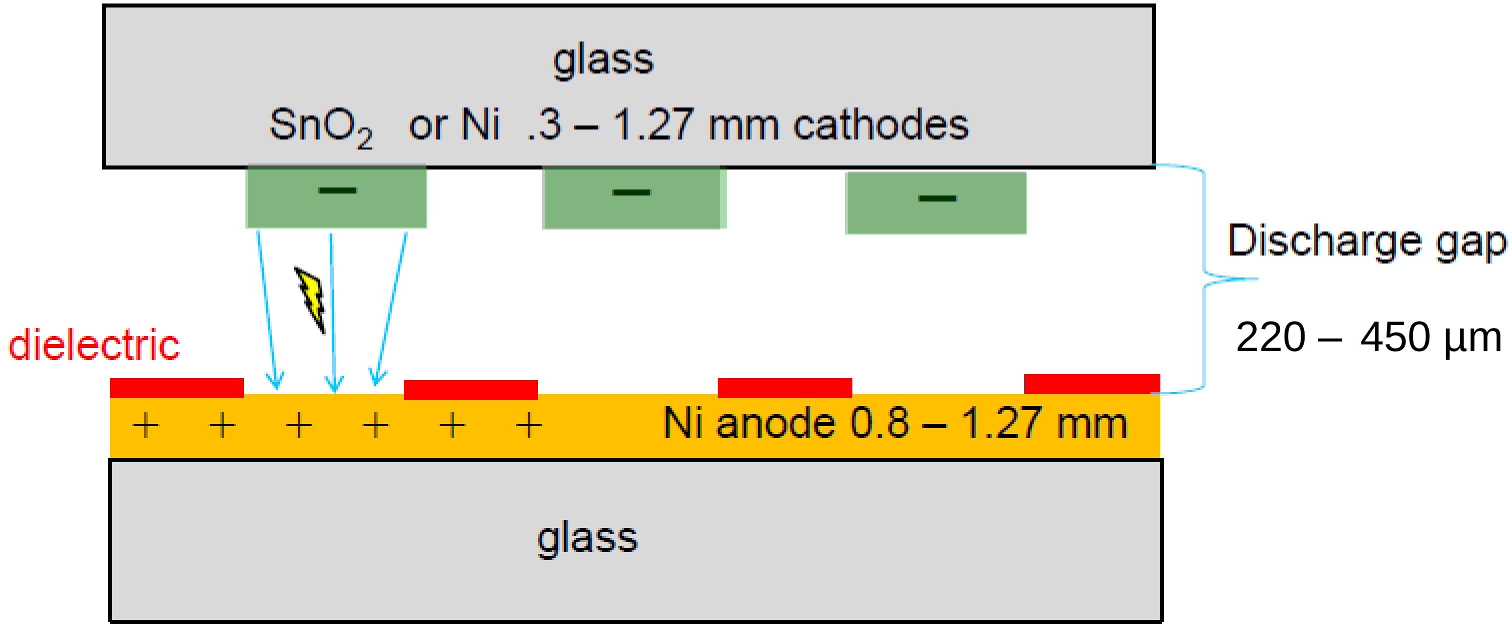
Neutrons: Thermal neutrons (***neutron scattering & homeland security***)

Gamma-Rays: ^{60}Co (1.2 MeV), ^{137}Cs (662 keV)

UV-Photons: "Black UV-lamp" with emission at 366 nm

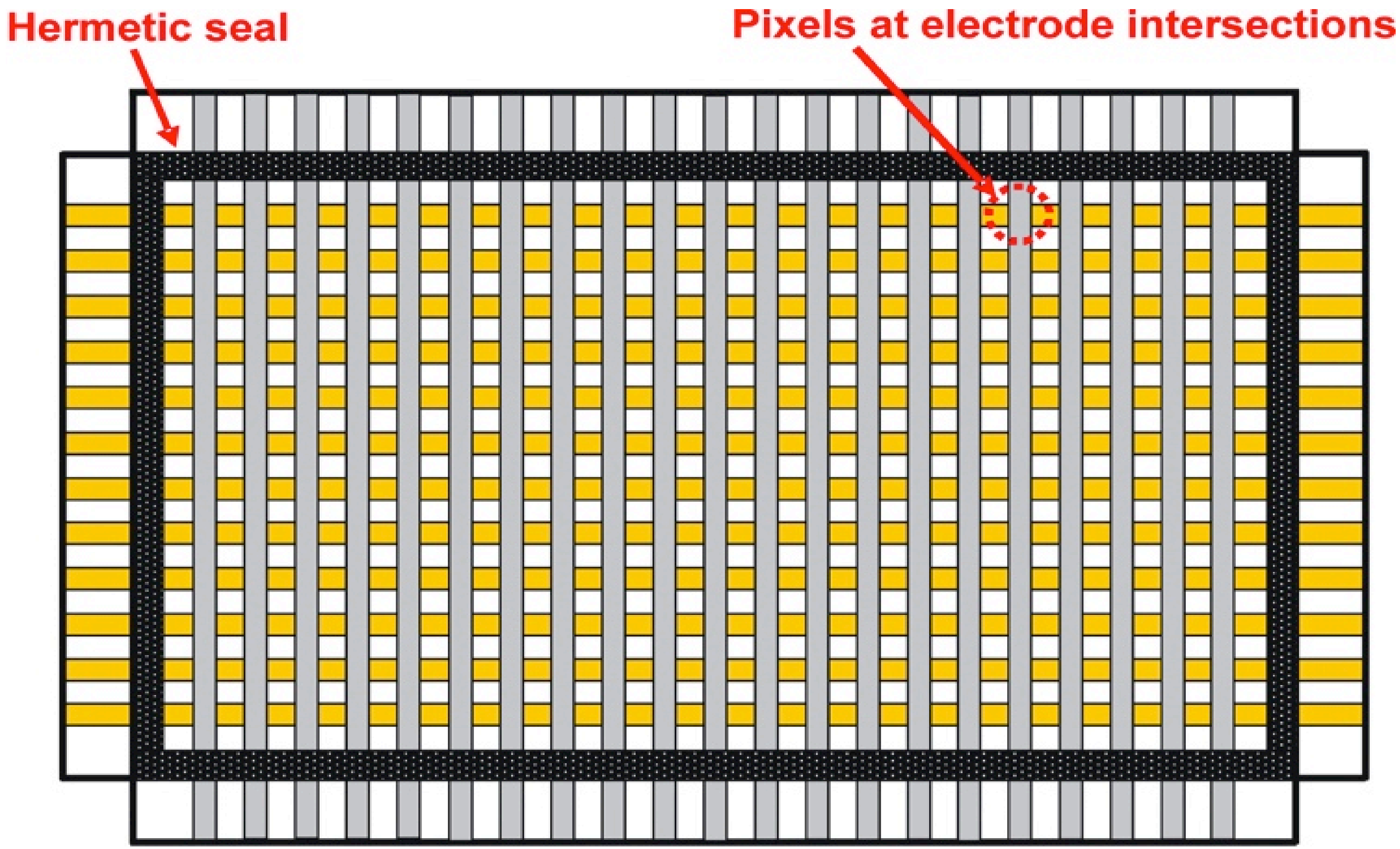
"*Open*-Cell" Commercial Plasma Panel

- Columnar Discharge (**CD**) – Pixels at intersections of orthogonal electrode array
  - Electrode sizes and pitch vary between different panels

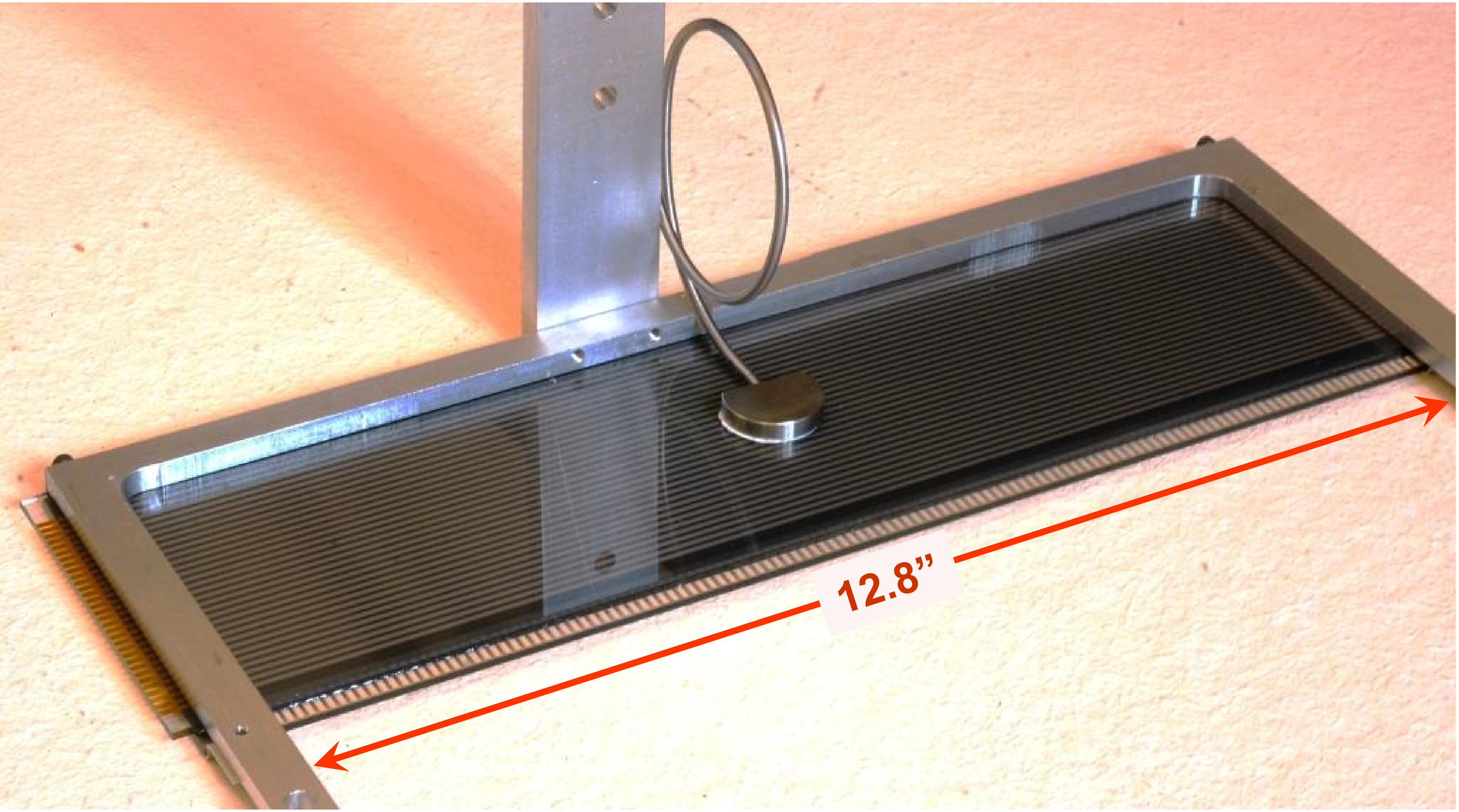


PPS with CD-Electrode Structure

(≈ 20-25% active cell/pixel fill-factor)



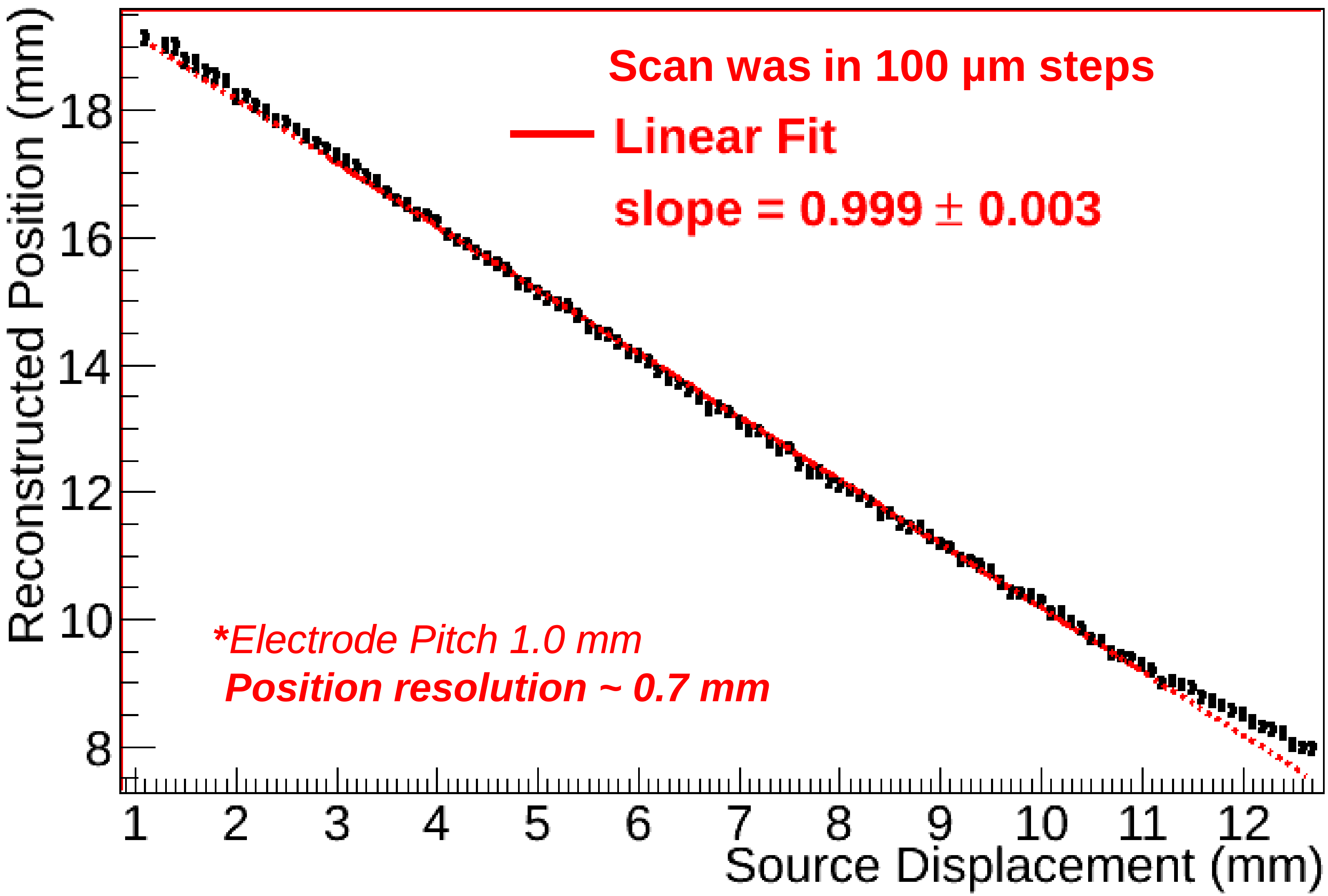
PPS "*Open* - Cell" Structure



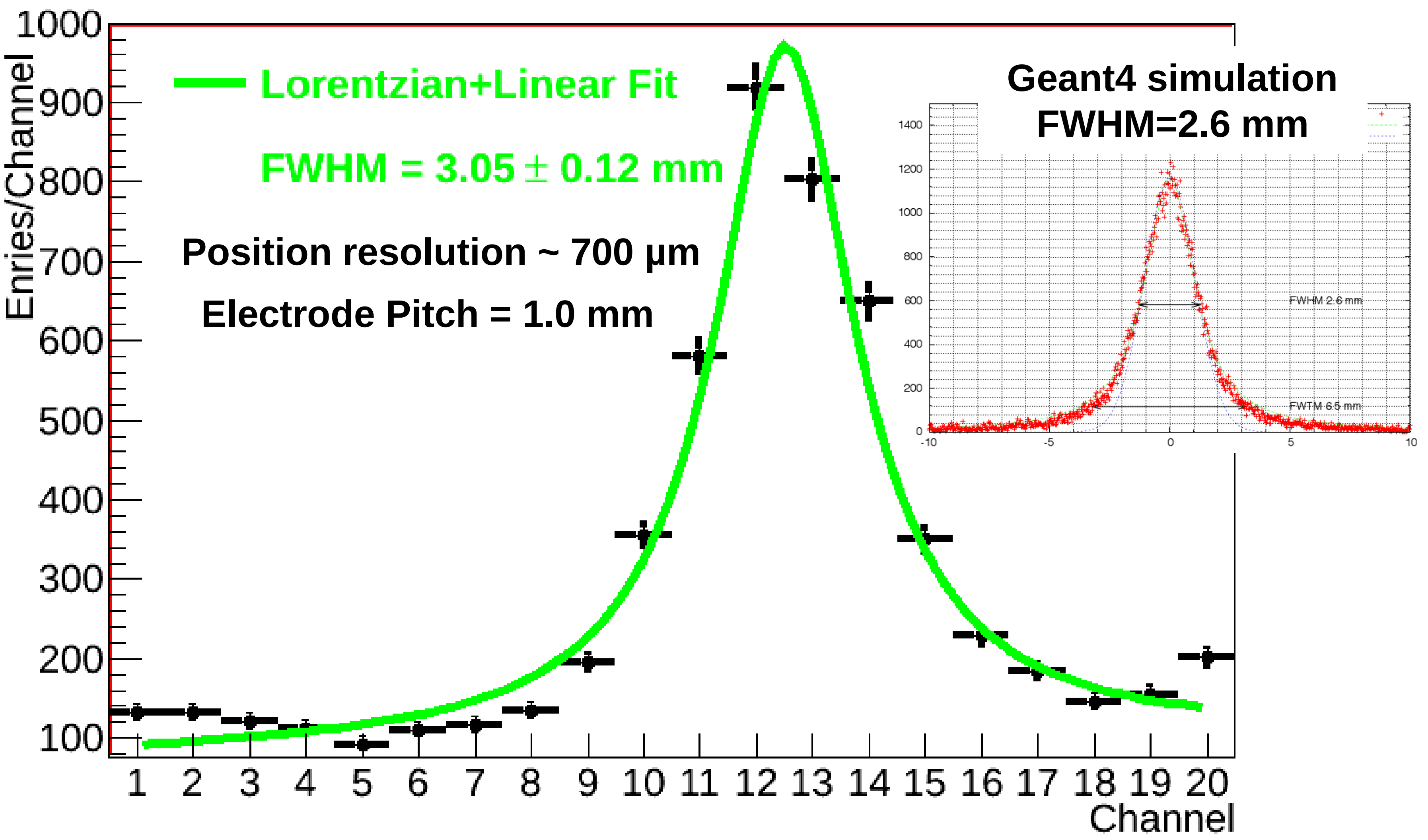
Source Moved in 0.1 mm Increments

(1 mm pitch panel)

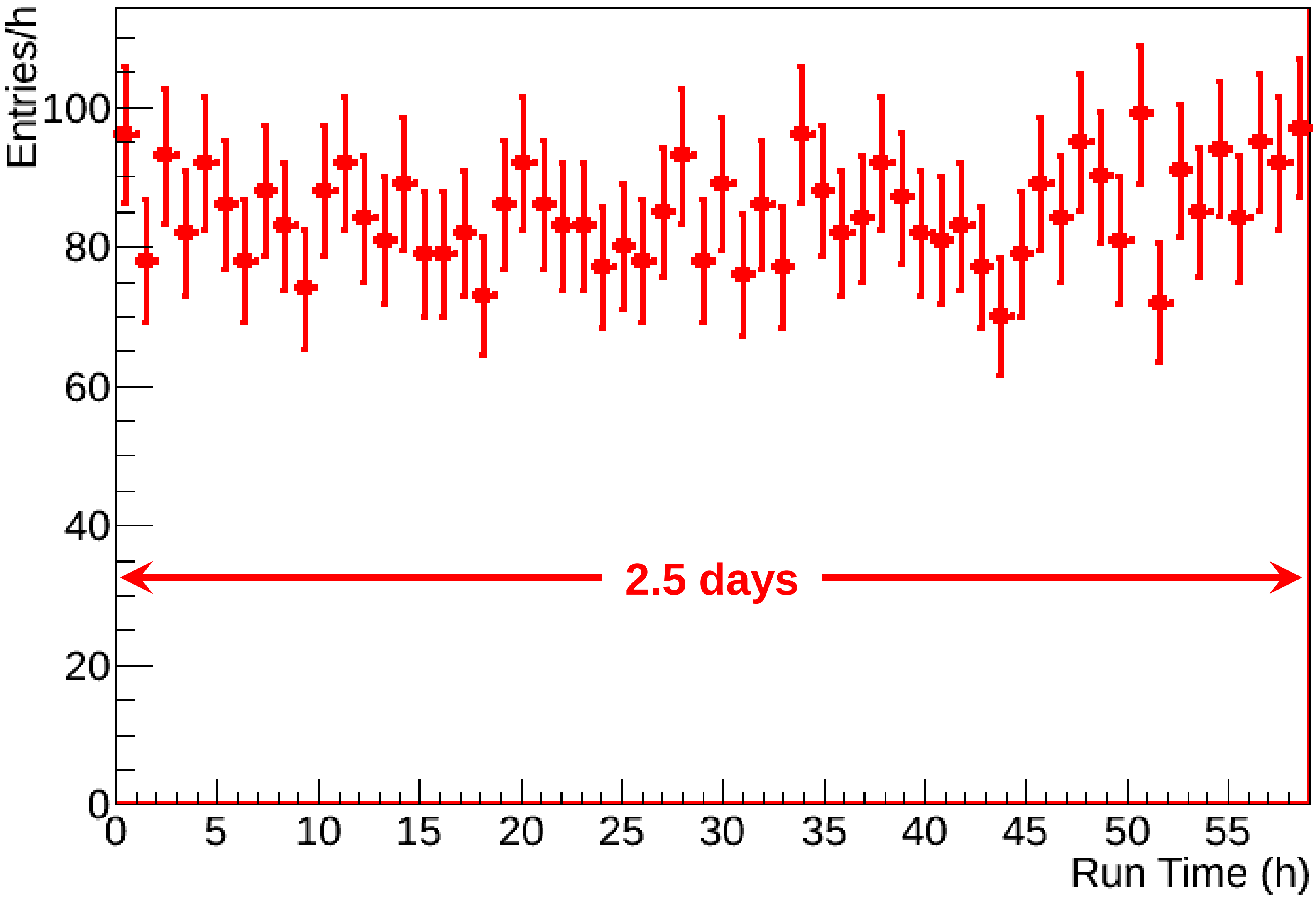
Collimated β–Source Position Scan (^{106}Ru)



Collimated β–Source Measurement (^{106}Ru)



Stability – Response to Cosmic Muons



"First" PPS Neutron Detection Results

- ^{3}**He** gas mixture at 730 Torr with 0.3 mm gas gap
- Geant4 simulation (GE) of the neutron capture rate based on source activity: **0.70 ± 0.14 Hz**
- PPS measured rate at GE: **0.67 ± 0.02 Hz**

≈ 100% of captured neutrons were detected*

*****
cannot do gamma discrimination, but can be almost gamma "blind"

Beam Energy Loss in *UltraThin* Glass vs. Ti-foil

(Application: Active Pixel Beam Monitors)

Energy Loss is 25 μm *thick glass* cover PPS for selected Ion Beams
(gas is 1mm of Ar at 760 Torr; *no nuclei get through the glass at 1MeV/A*)

Energy (MeV)/A	**Ion Energy** (**MeV**)	**Energy** ***loss in Glass*** (**MeV**)	**Energy** ***loss in Gas*** **MeV** (# ion pairs)
3.0 (Ni-64)	192	190	0.95 (36,000)
3.0 (Sn-124)	372	348	4.34 (160,000)
3.0 (U-238)	**714**	**570**	11.60 (440,000)

Energy Loss is 7.6 μm *thick Ti-foil* cover PPS for selected Ion Beams
(gas is 0.25mm of Ar + 10% CO_2 at 600 Torr)

Energy (MeV)/A	**Ion Energy** (**MeV**)	**Energy** ***loss in Ti-foil*** (**MeV**)	**Energy** ***loss in Gas*** **MeV** (# ion pairs)
1.0 (Ni-64)	64	60.5	0.29 (11,000)
1.0 (Sn-124)	124	111	0.70 (26,000)
1.0 (U-238)	**238**	**199**	1.48 (56,000)
3.0 (Ni-64)	192	81.5	0.93 (35,000)
3.0 (Sn-124)	372	160	1.77 (67,000)
3.0 (U-238)	**714**	**298**	3.21 (120,000)

Commercially Available – UltraThin Glass

CORNING

Ultra-Slim Flexible Glass

Corning Fact Sheet - 2011

The Future is Flexible

- Corning is currently proving the concept capability of thin, flexible glass - an alternative to polymer films
- The optical, thermal and dimensional stability advantages of glass benefit performance for large-area electronics, such as e-paper, flexible photovoltaics, touch panels, OLED lighting and more
- Producing large-area electronic displays will require continuous platforms, such as roll-to-roll manufacturing

Figure 1

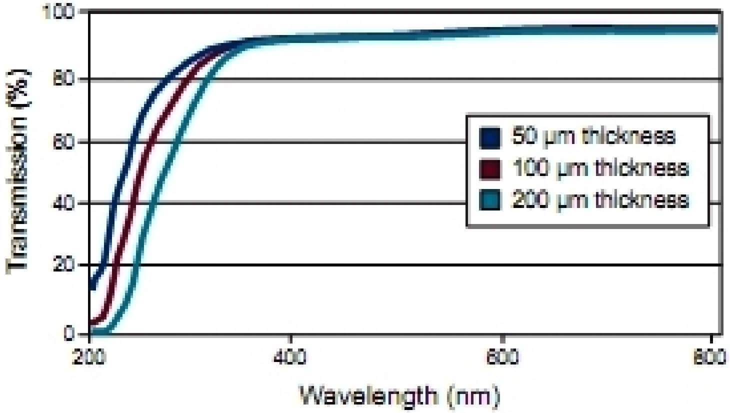
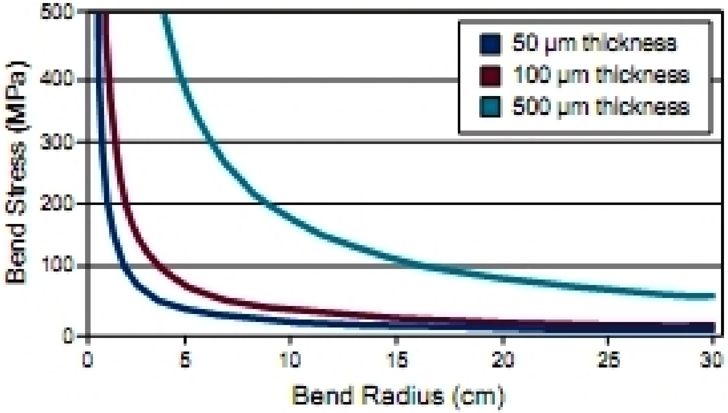
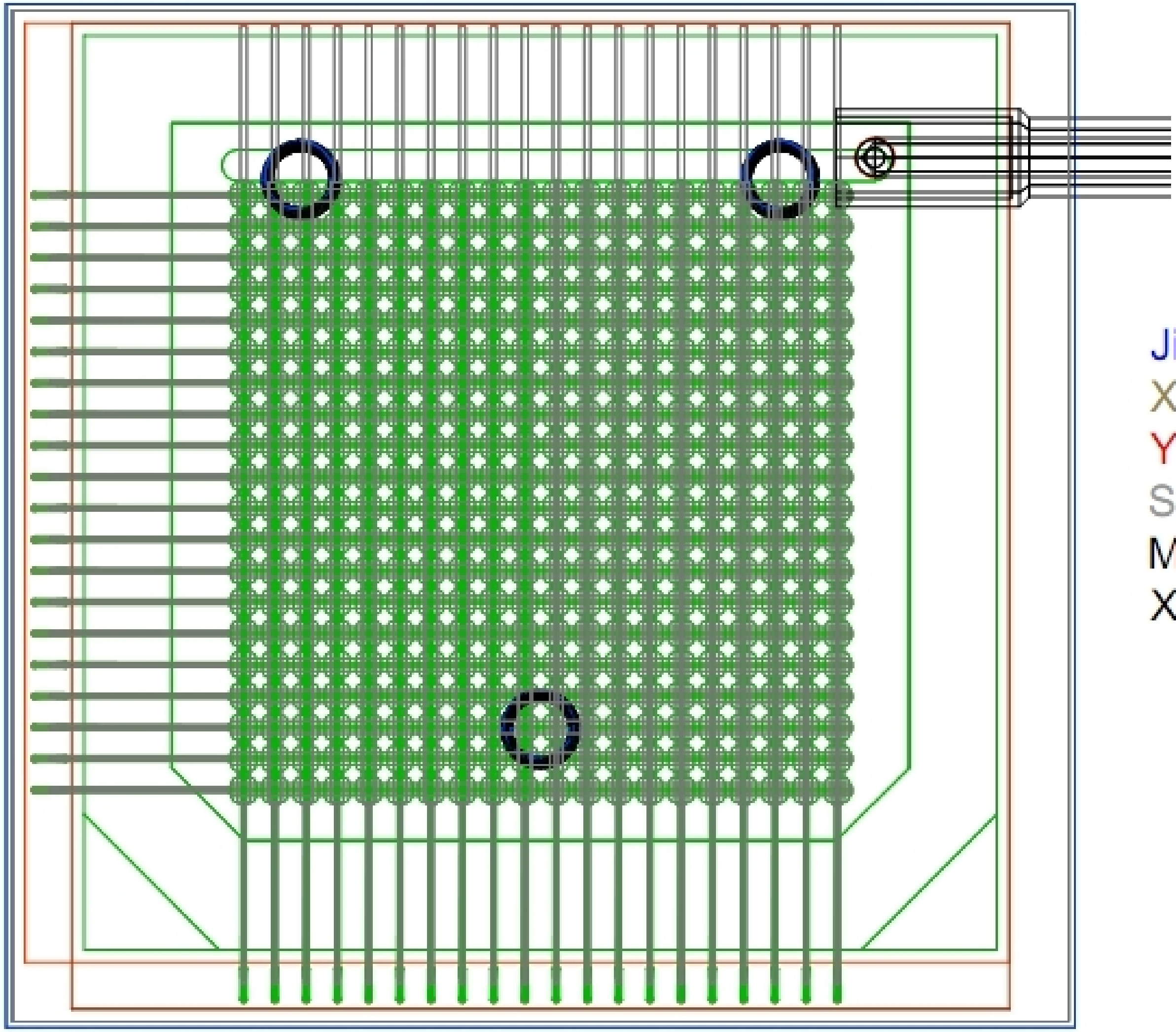


Figure 2



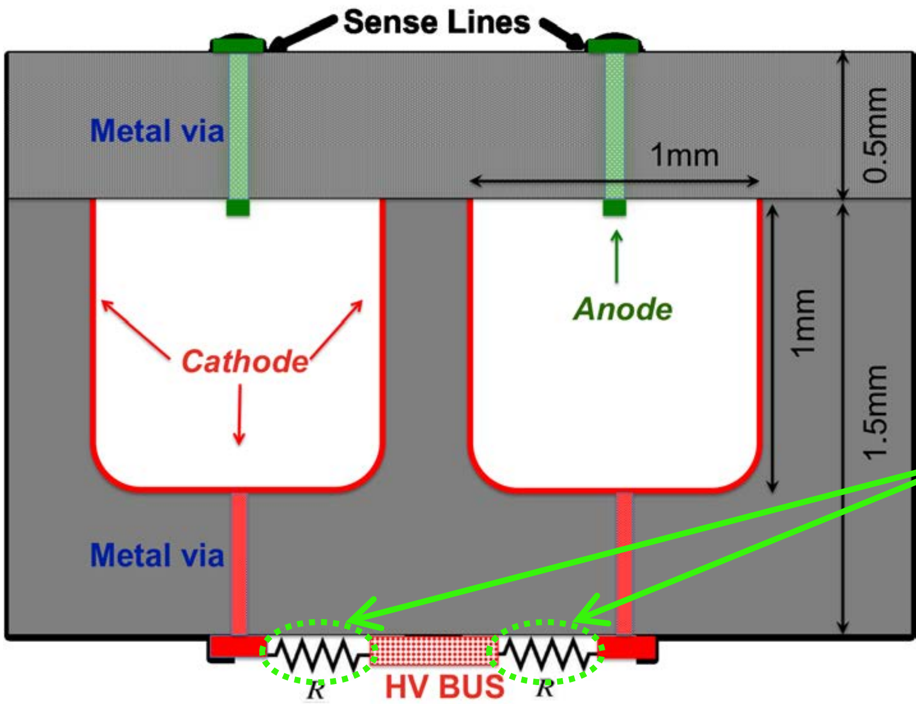
UltraThin-PPS Assembly Drawing

(≈ 60-100% active cell/pixel fill-factor)



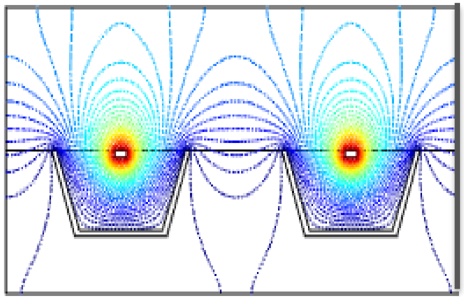
Jig
X substrate
Y substrate
Spacers
Masks: X,Y,
Xreverse

"*Closed* - Cell" Microcavity Concept



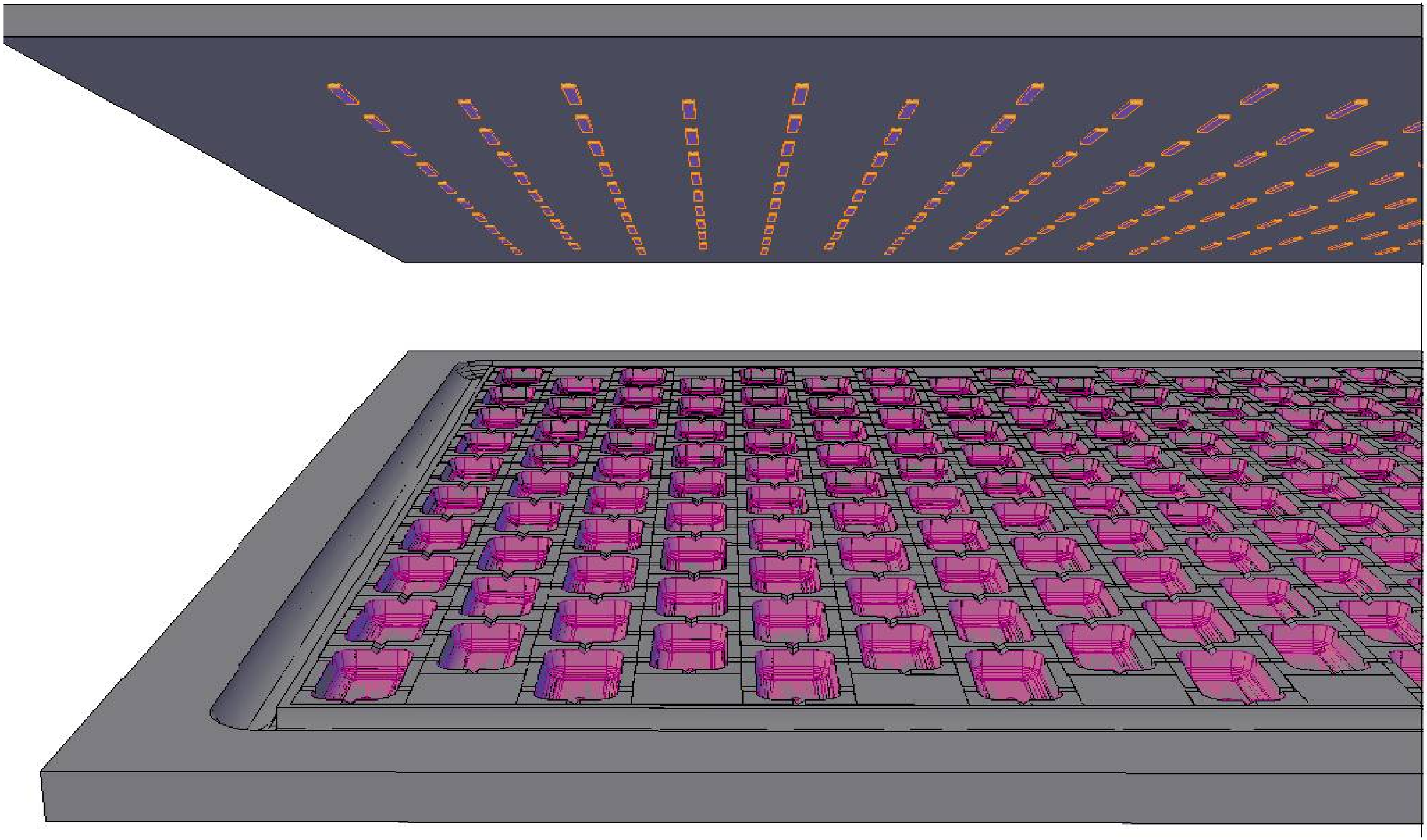
Closed gas cell individually quenched by an external resistor

Electrostatic simulations in COMSOL



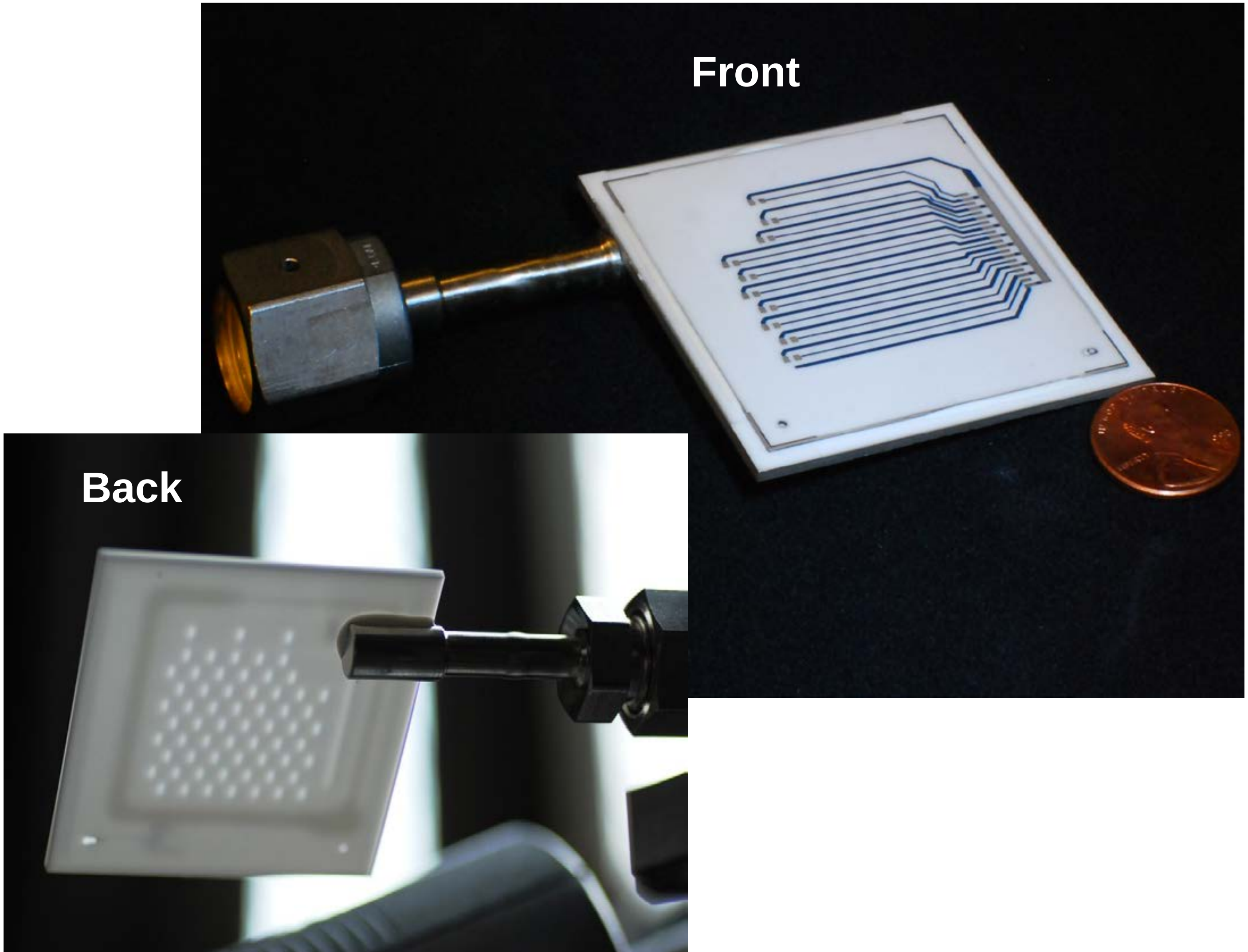
Electric field a few MV/m
→ gas breakdown

"*Closed*-Cell" Microcavity Structure

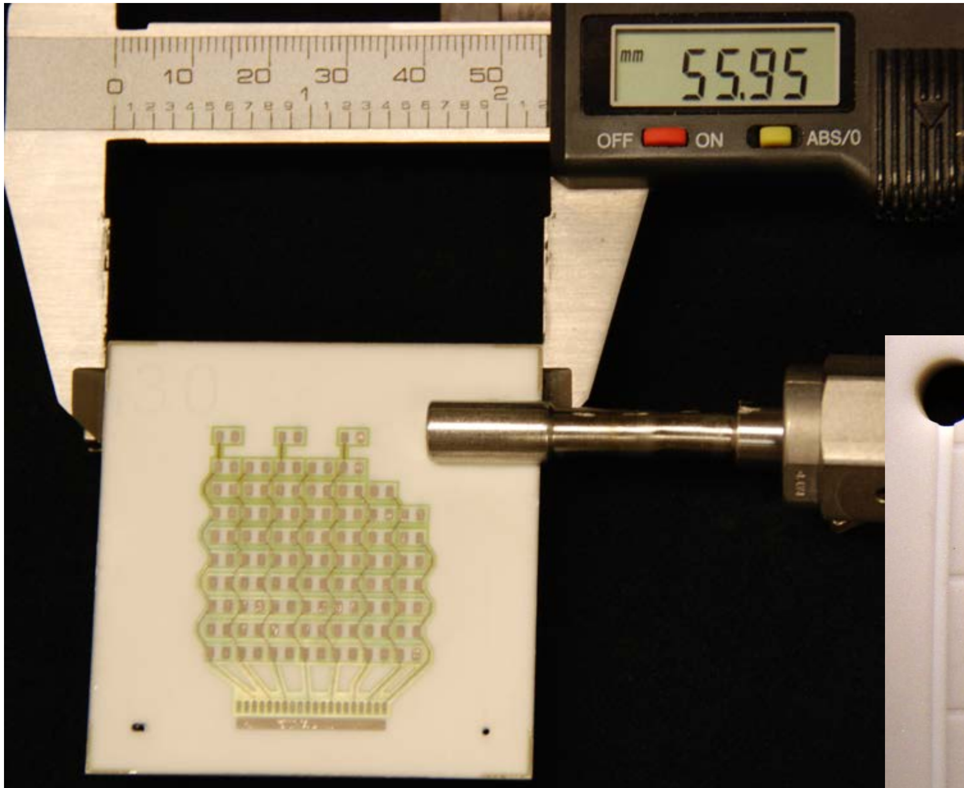


Perspective view of a pixel array with gas channels. Metallized cathode cavities on bottom plate with *vias* to HV bus. Anodes on top plate.

First Microcavity-PPS Panel

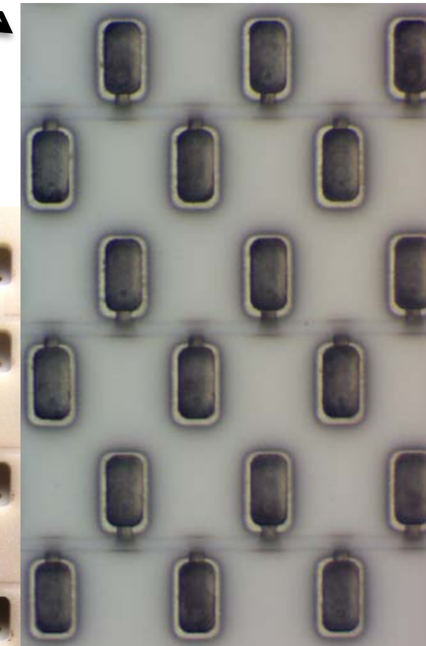


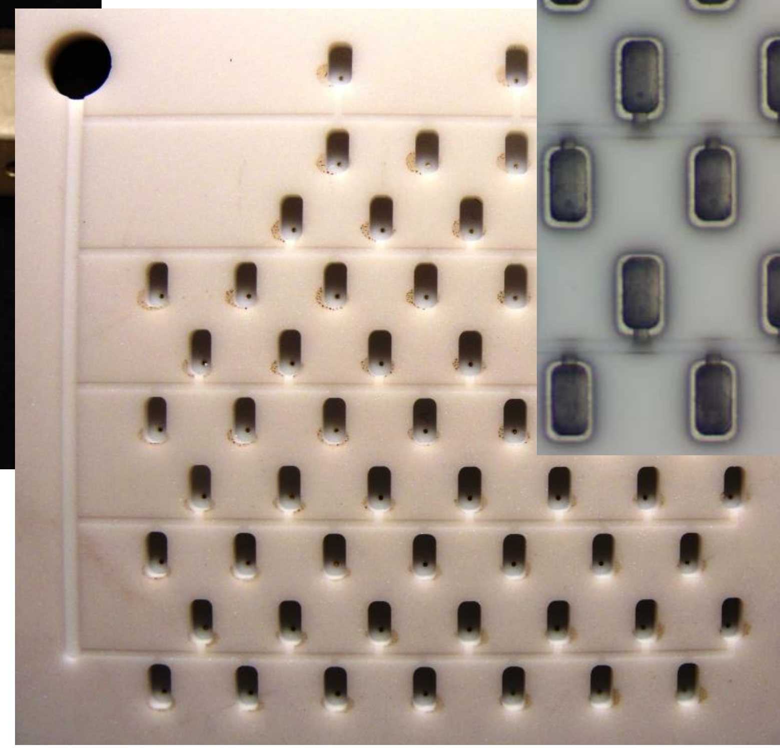
The Prototype – Back Plate



Bottom Side – quench resistor for each pixel.

Metallized cavities
1 x 1 x 2 mm

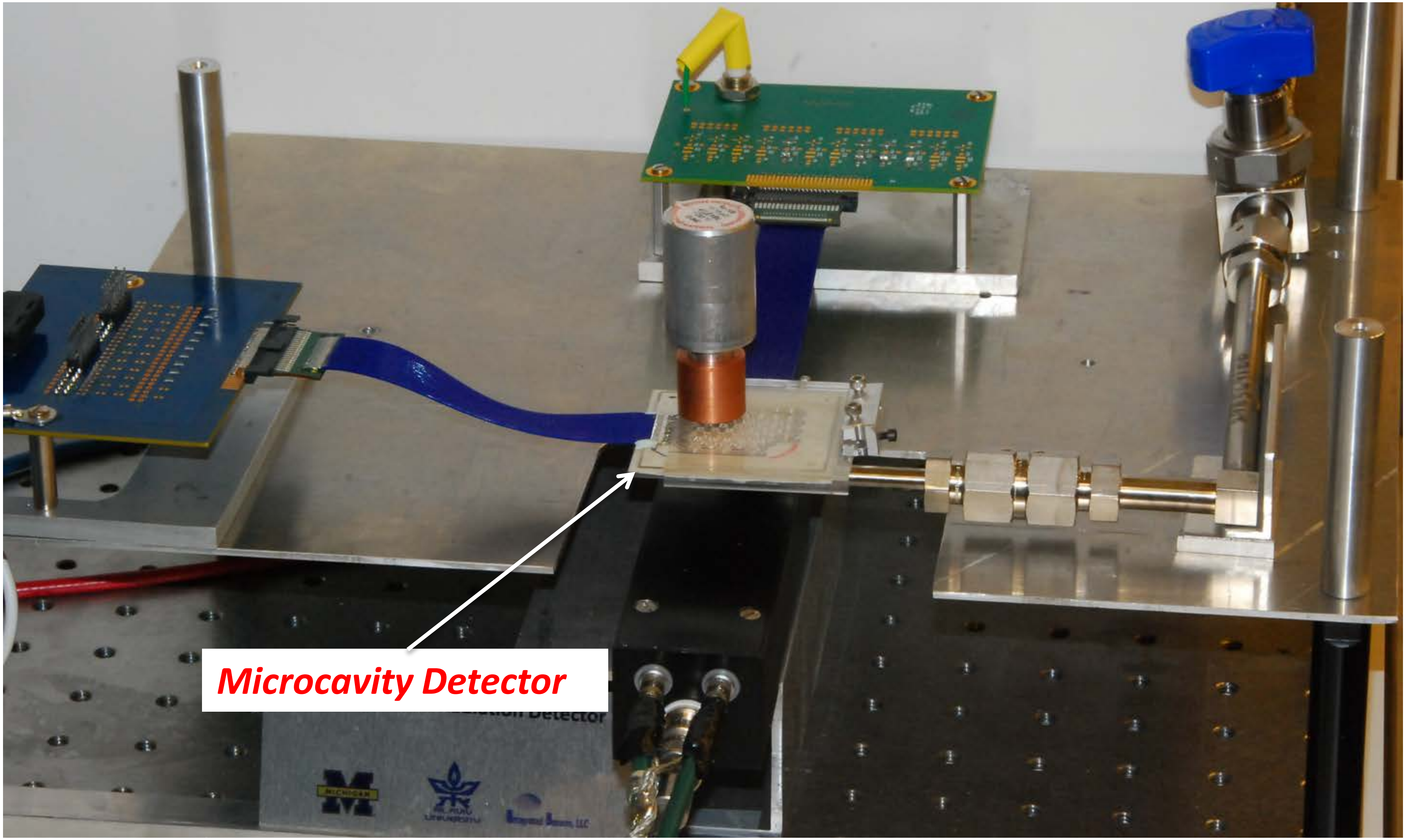




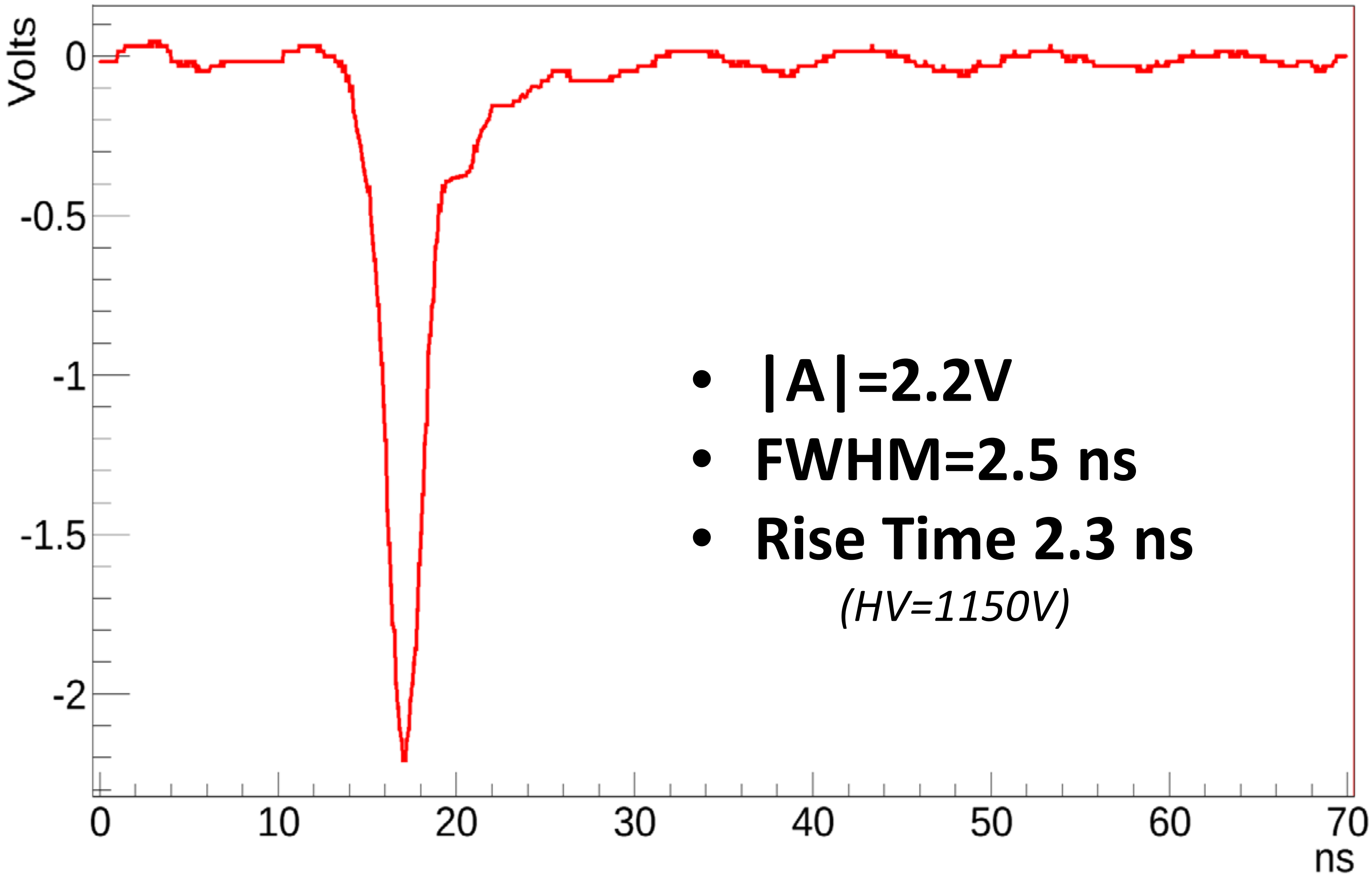
Top Cavity Side with metal vias and gas channel

Collimated β-Source Test Setup

Ne-based gas mixture at 740 Torr used in all experiments



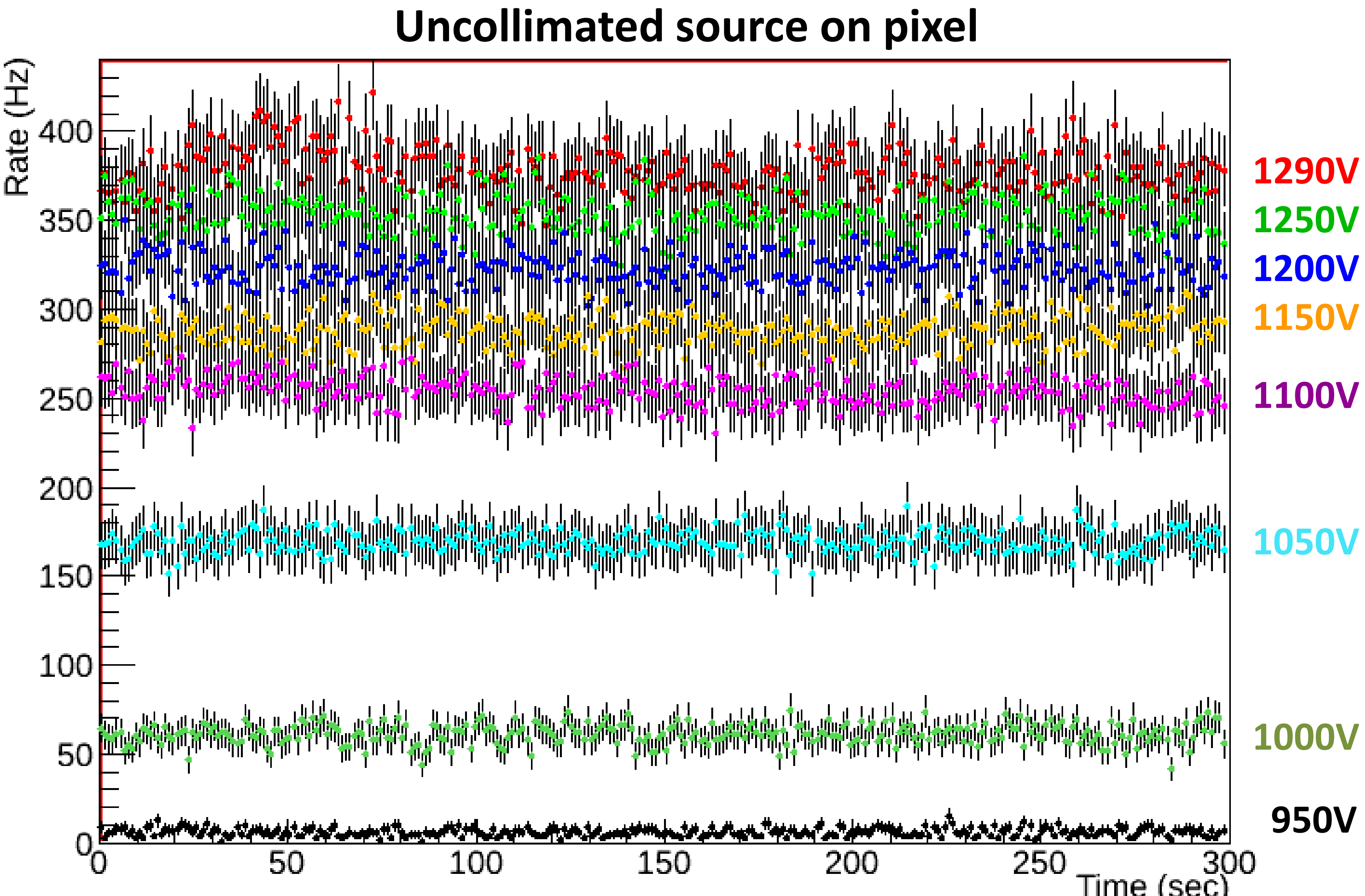
Typical Microcavity-PPS Signal Pulse



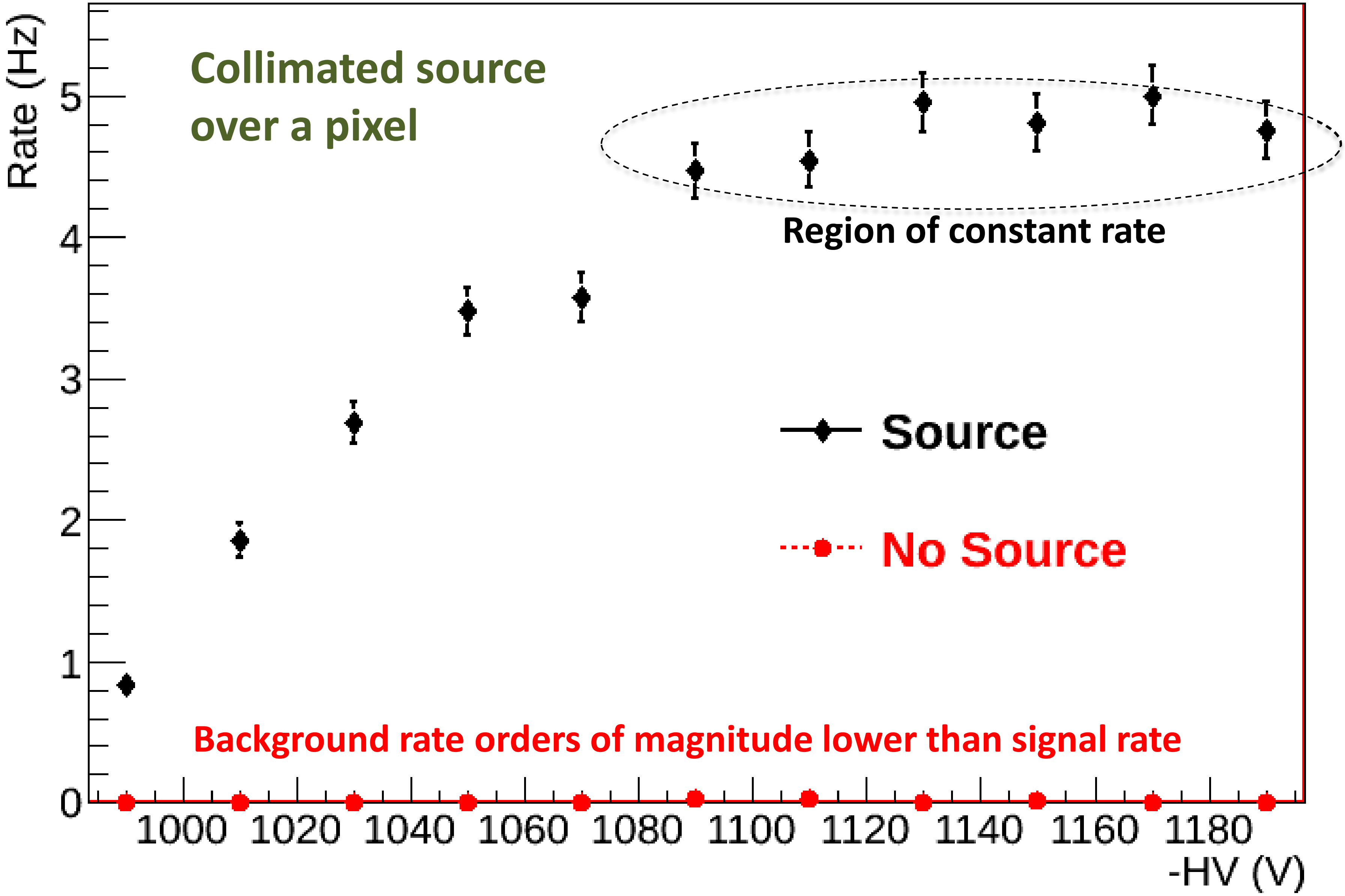
- **|A|=2.2V**
- **FWHM=2.5 ns**
- **Rise Time 2.3 ns**

(HV=1150V)

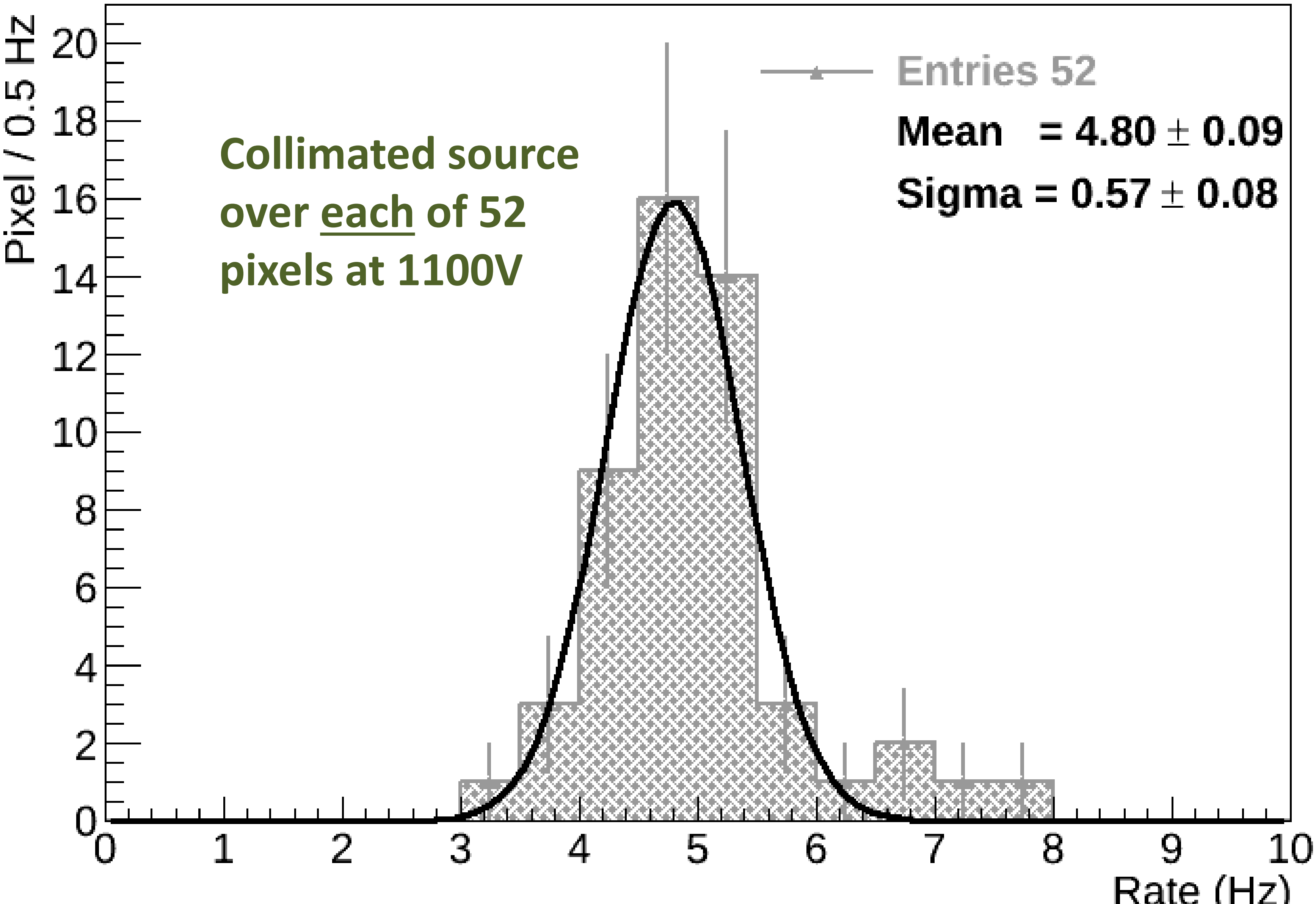
Single Pixel Rate vs. Time



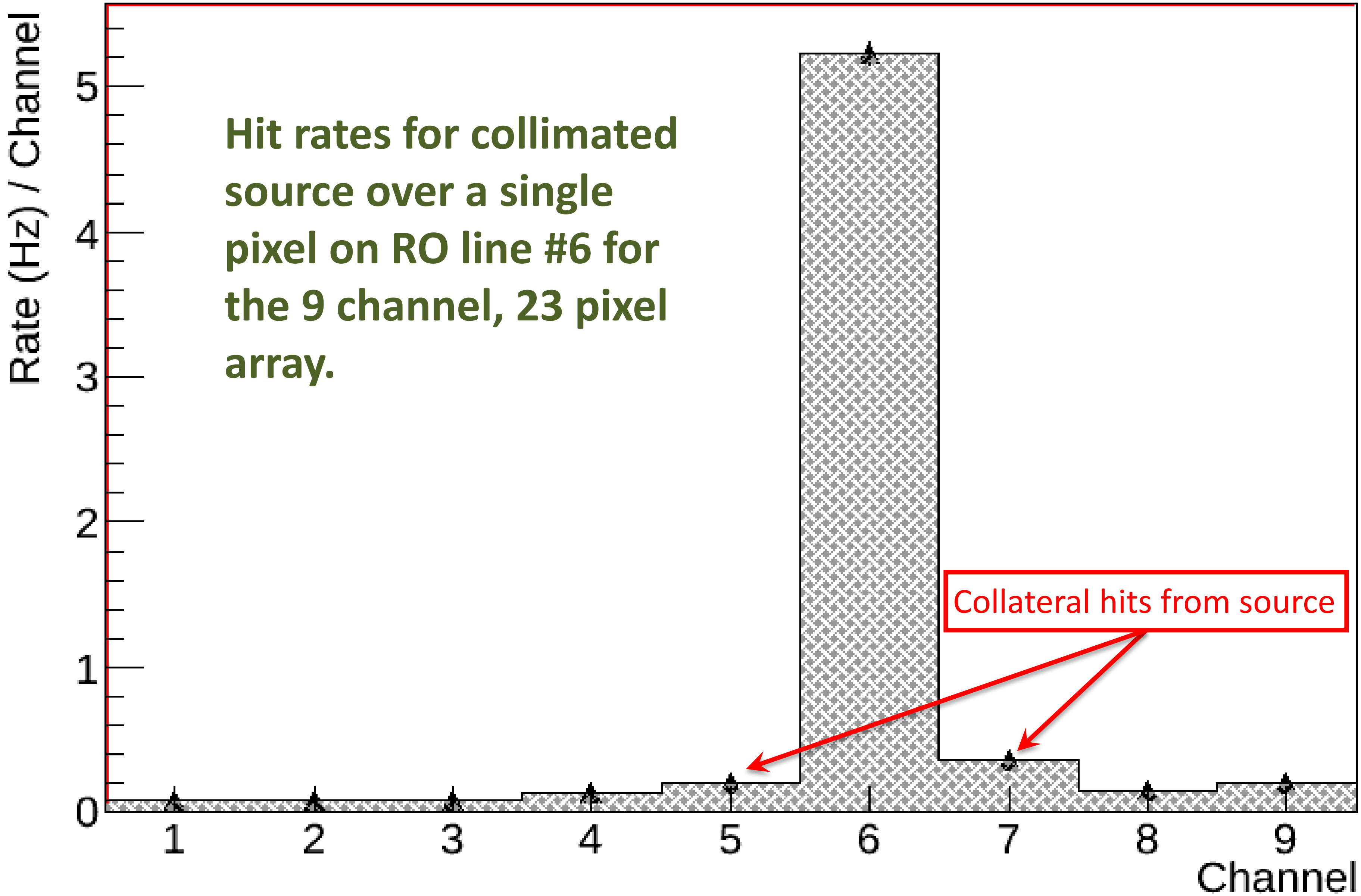
Pixel Response vs. HV



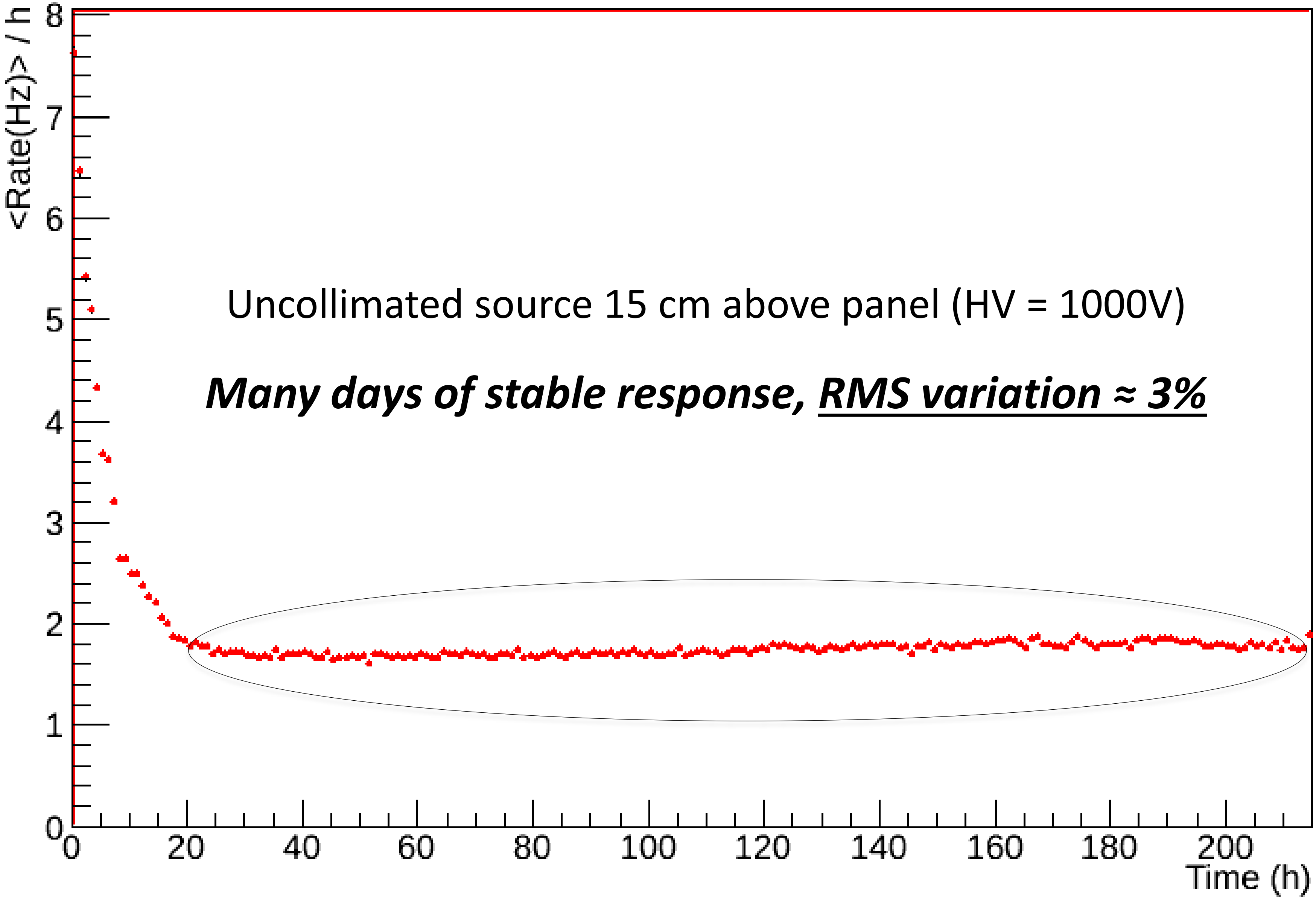
Pixel Response Uniformity



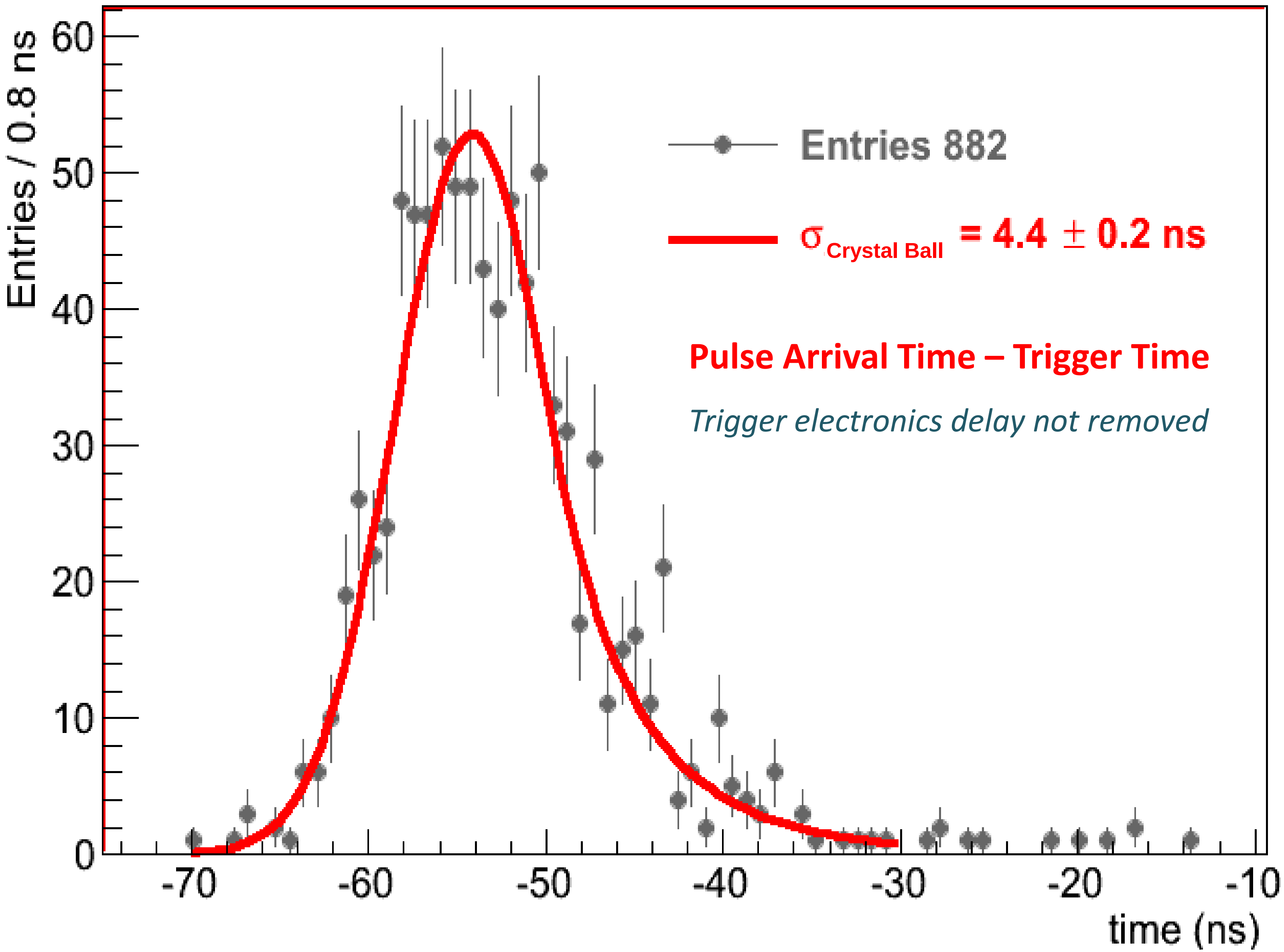
Pixel Isolation



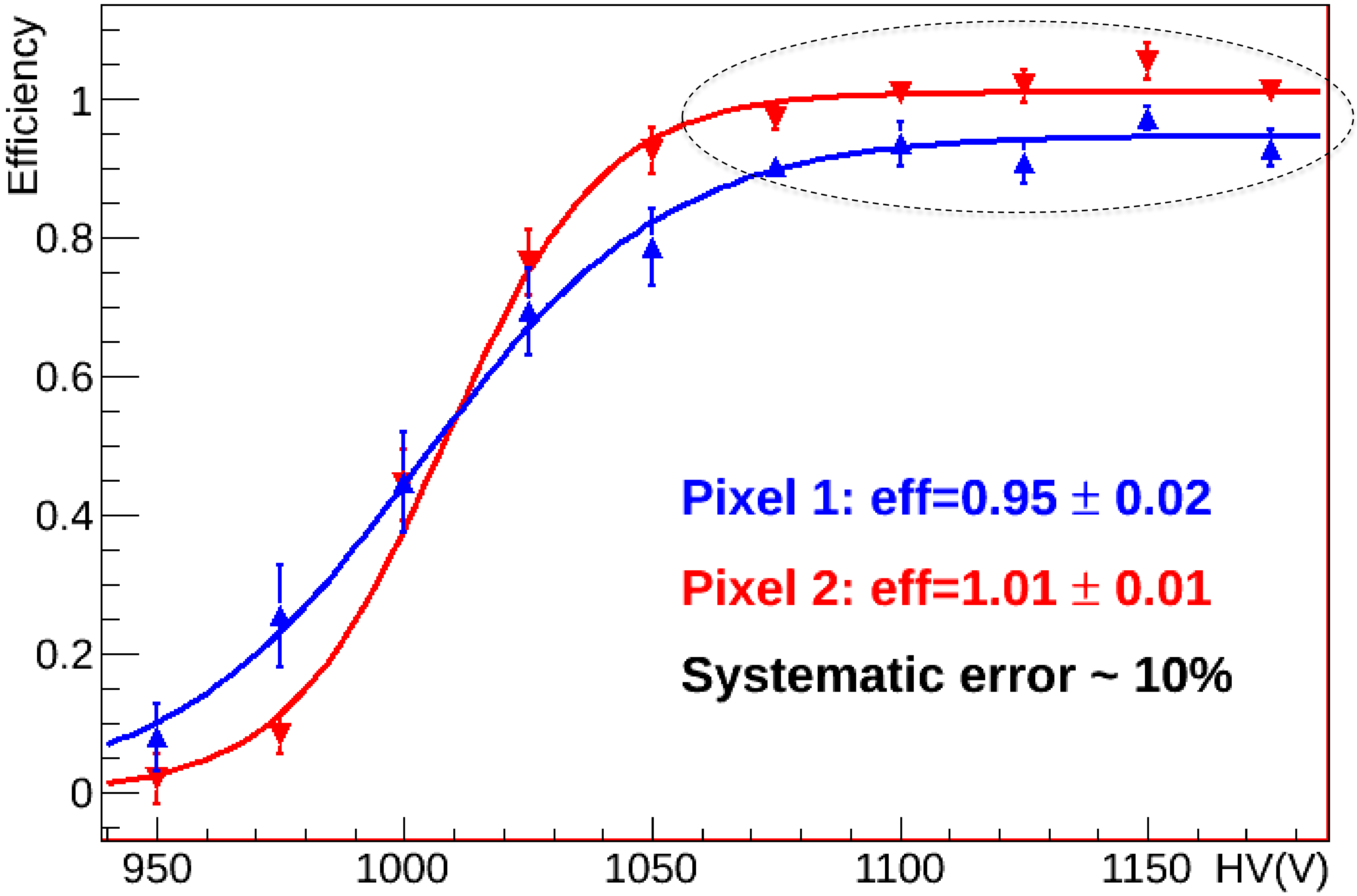
Long Term Stability (9 days)



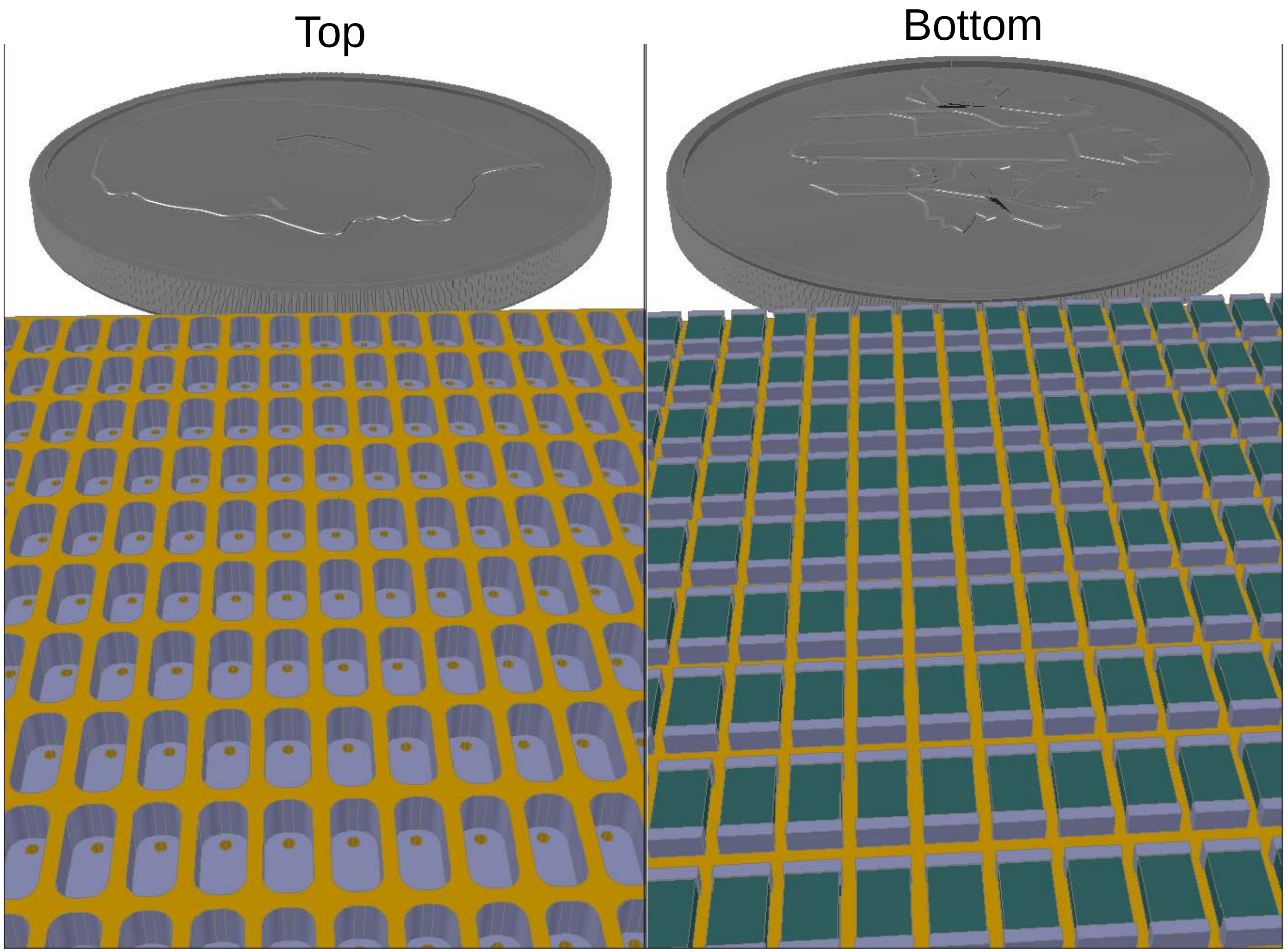
Pixel Time Resolution - Jitter



Pixel Efficiency



"Next" Microcavity-PPS (Back Plate)



Microcavity-PPS prototype for 2015 (*dime coins for scale*):
(Left) cavities with vias. (Right) surface-mount pixel resistors.

Summary

- **PPS devices have demonstrated high gain, fast timing, and high position resolution for a variety of particle sources including: betas, protons, muons and neutrons. PPS devices fabricated with *ultrathin* substrates are now under development with 2 days of testing at ANL-ATLAS planned for 1st half of 2015.**

- **The microcavity-PPS prototype shows very promising results in terms of pixel-to-pixel uniformity, time-stability of signal shape and rates, pixel response isolation, time resolutions of a few nanoseconds, excellent S/N, and efficiencies above 95% over a 100 volt range for beta particles from a ^{106}Ru source.**

- **Based on our successful Phase-II program, Integrated Sensors is seeking commercialization partners with a primarily focus on medical, scientific and homeland security applications.**