High-Performance Plasma Panel Based Micropattern Detector

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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***)

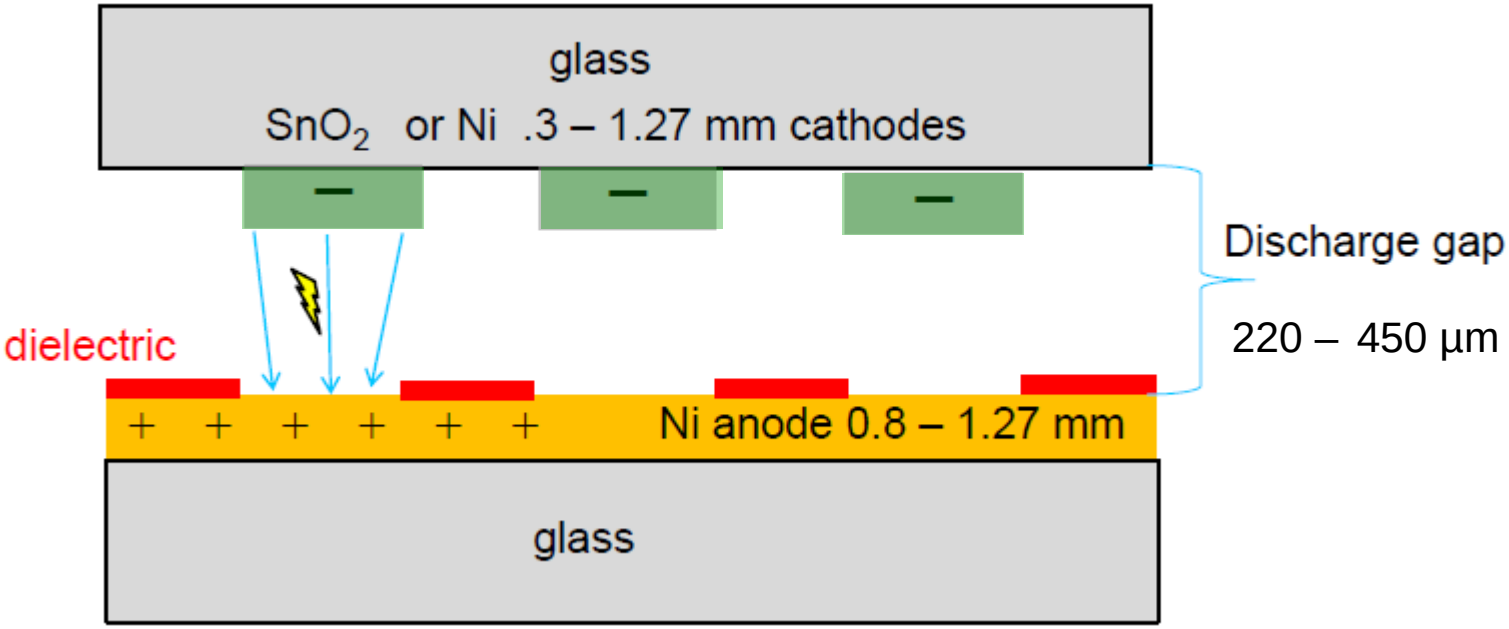
Neutrons: Thermal neutrons (***neutron scattering & homeland security***)

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

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

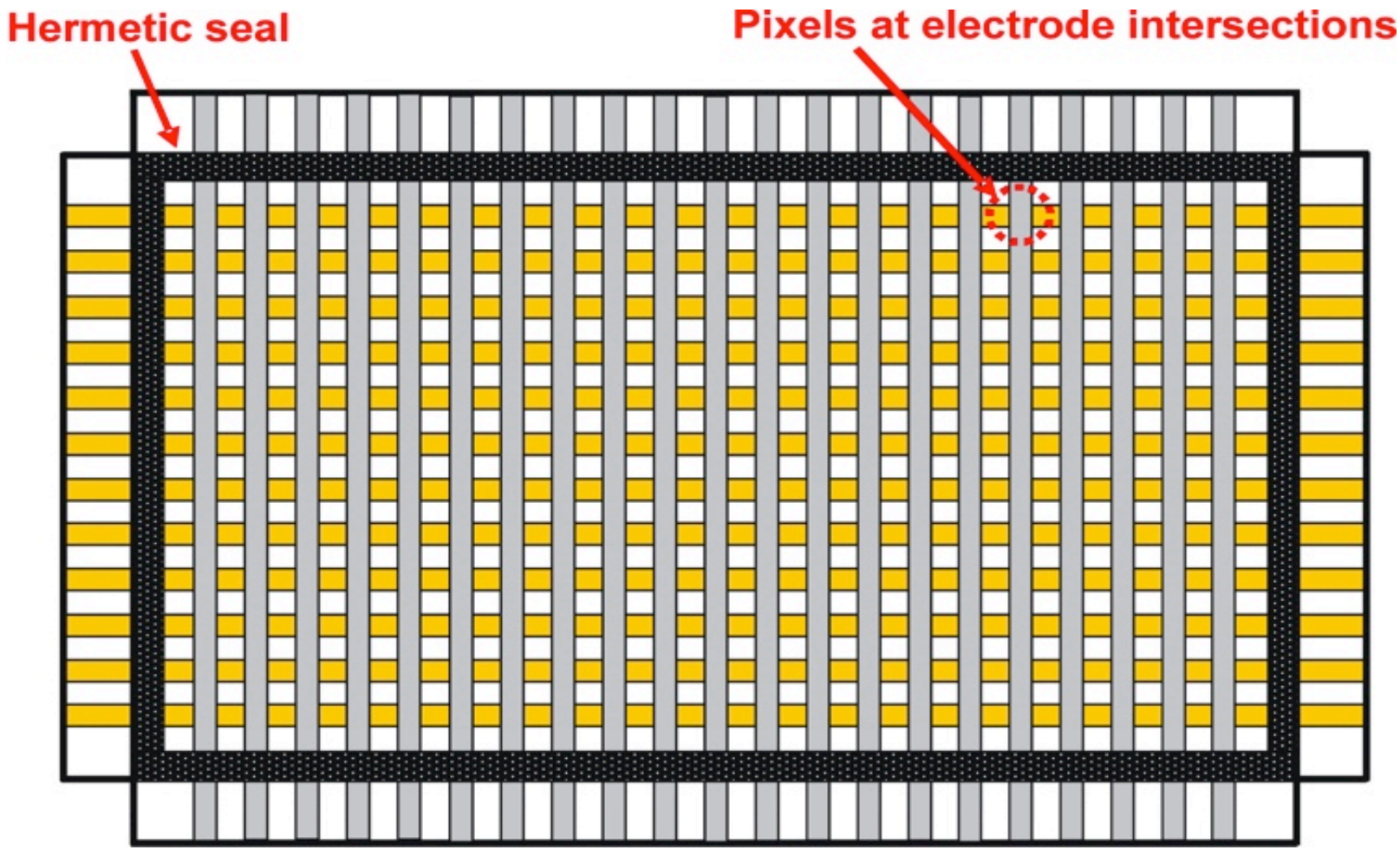
"*Open*-Cell" Commercial Plasma Panel

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

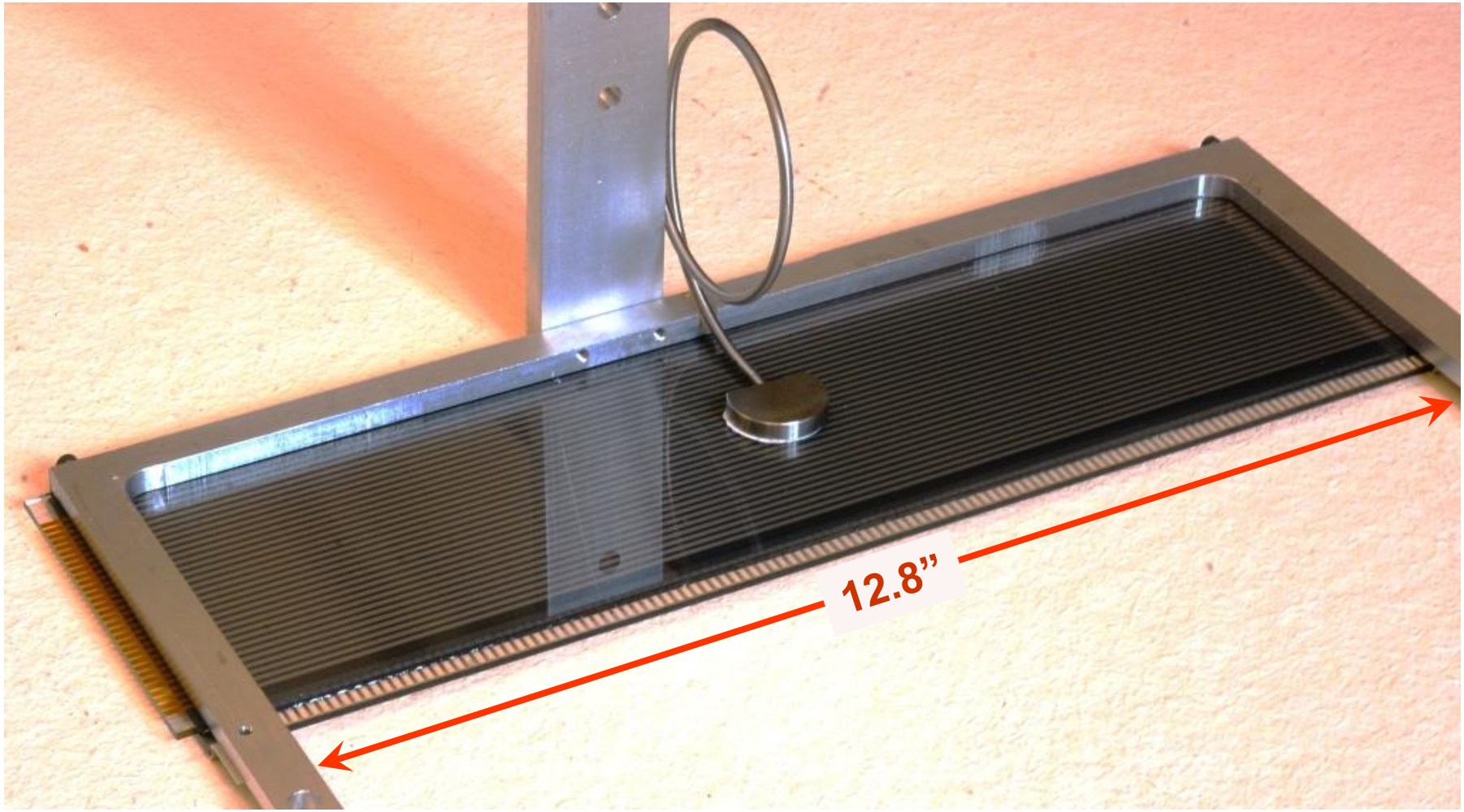


PPS with CD-Electrode Structure

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



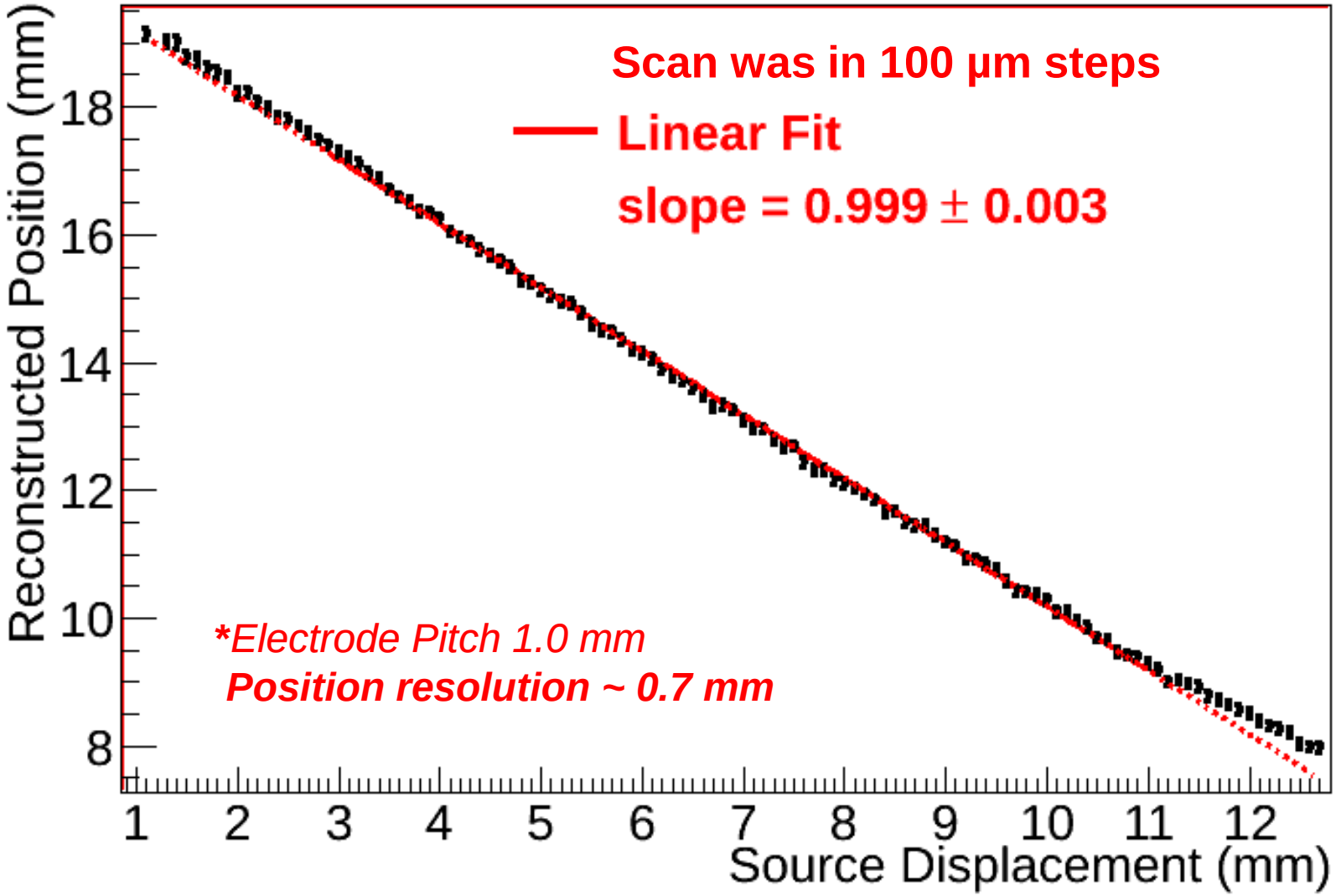
PPS "*Open* - Cell" Structure



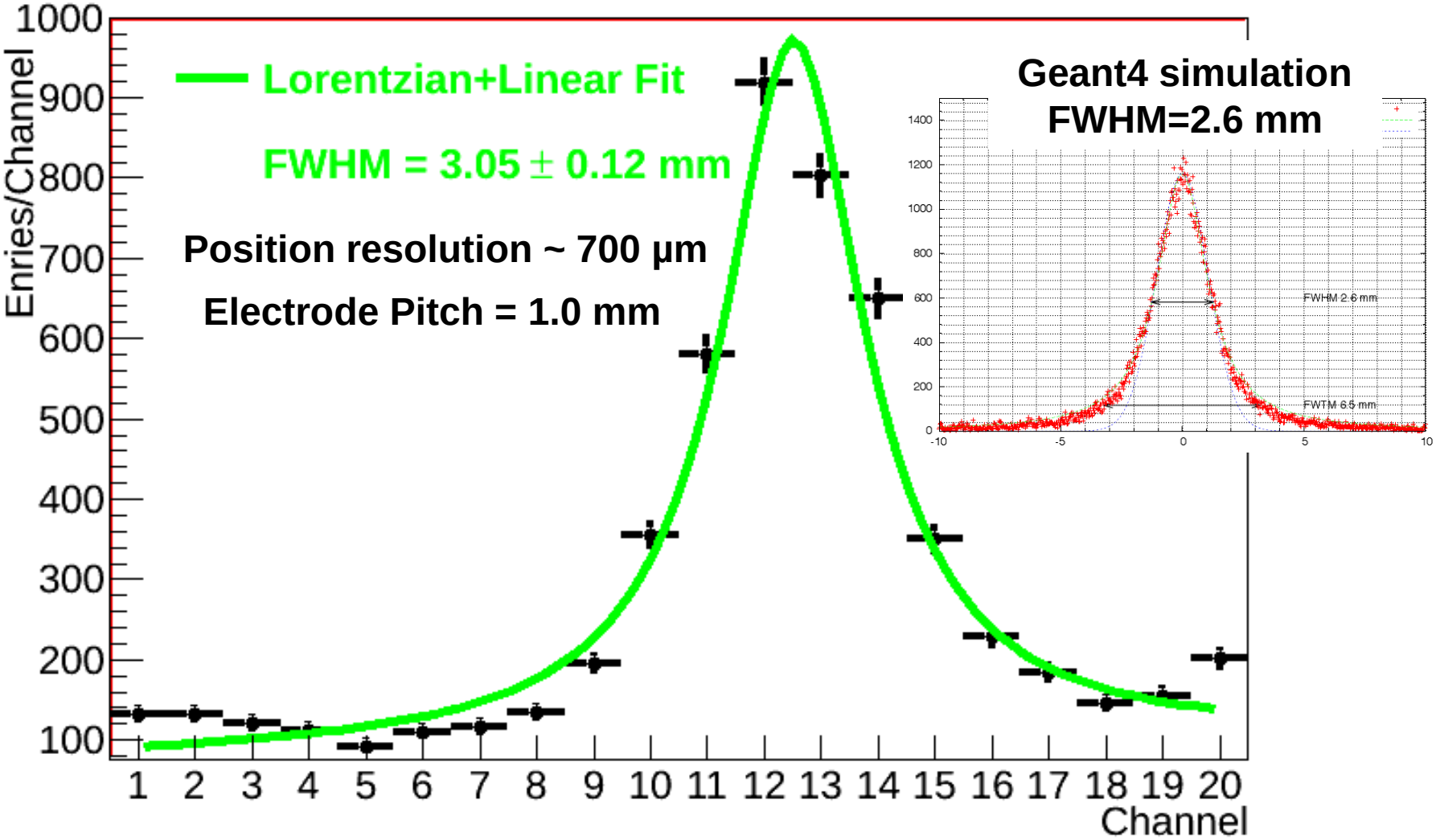
Source Moved in 0.1 mm Increments

(1 mm pitch panel)

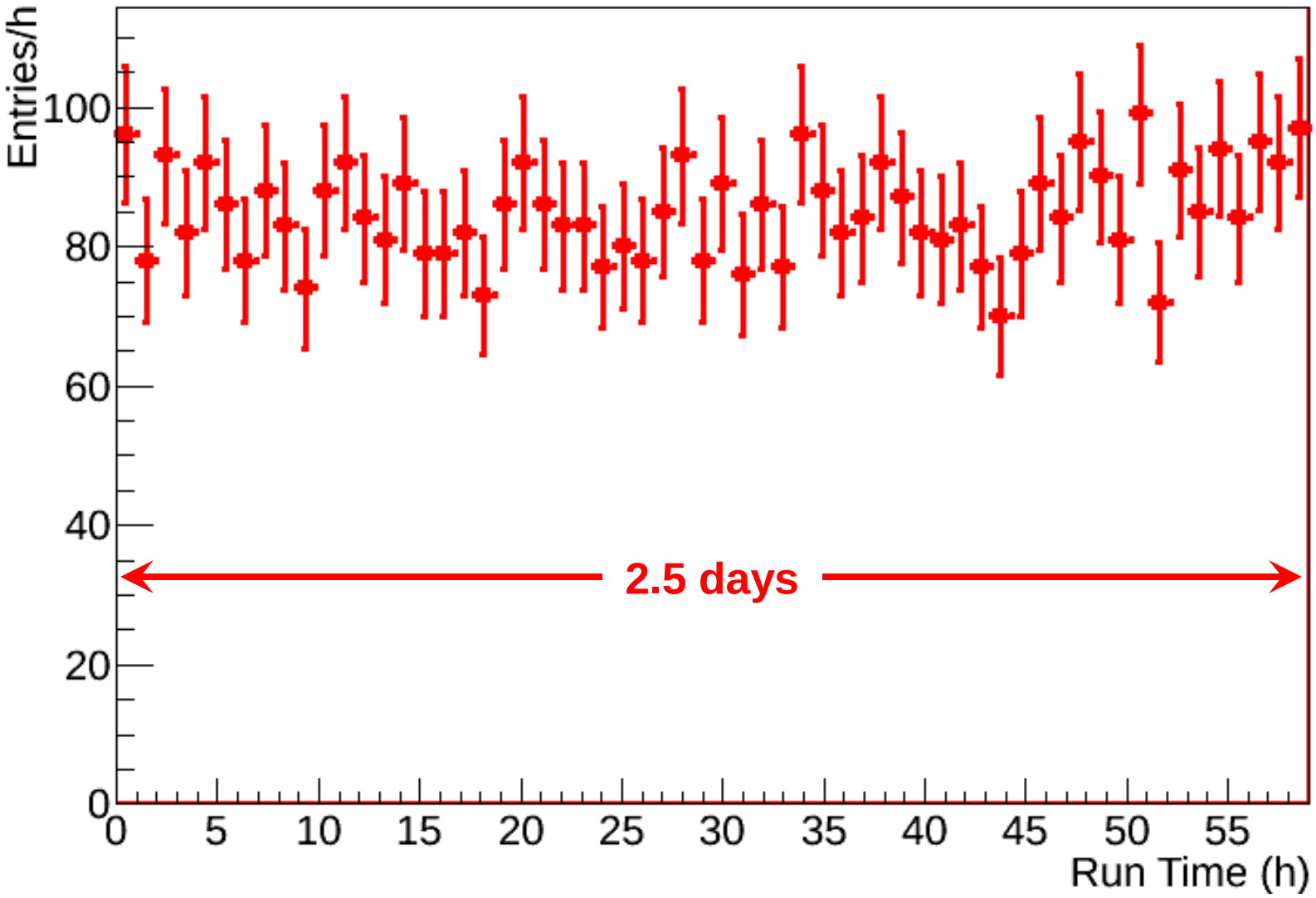
Collimated β–Source Position Scan (^{106}Ru)



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*)

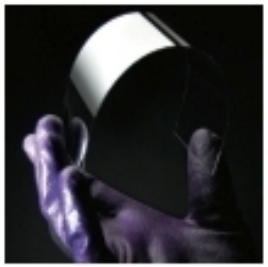
Energy (MeV)/A	**Ion Energy** (**MeV**)	**Energy** ***loss in Glass*** (**MeV**)	**Energy** ***loss in Gas*** **MeV** (# ion pairs)
3.0 (Ni-64)	192	190	0.95 (36,000)
3.0 (Sn-124)	372	348	4.34 (160,000)
3.0 (U-238)	**714**	**570**	11.60 (440,000)

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

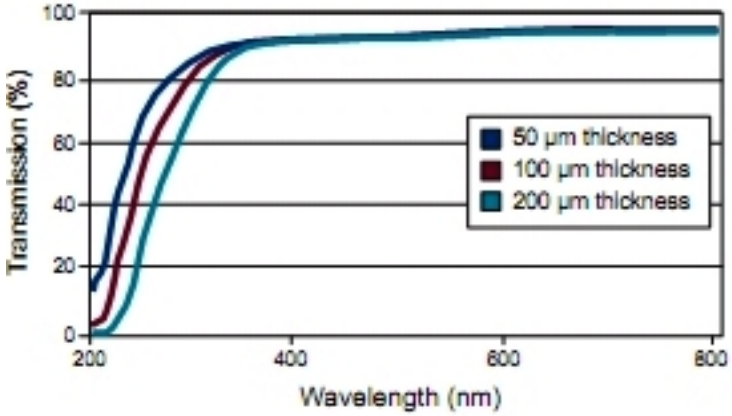
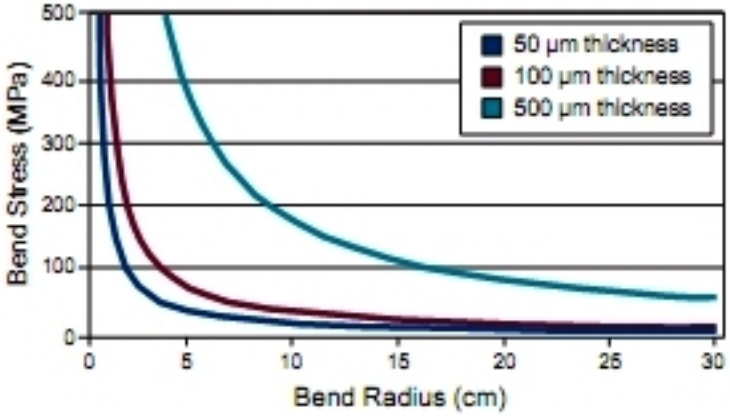
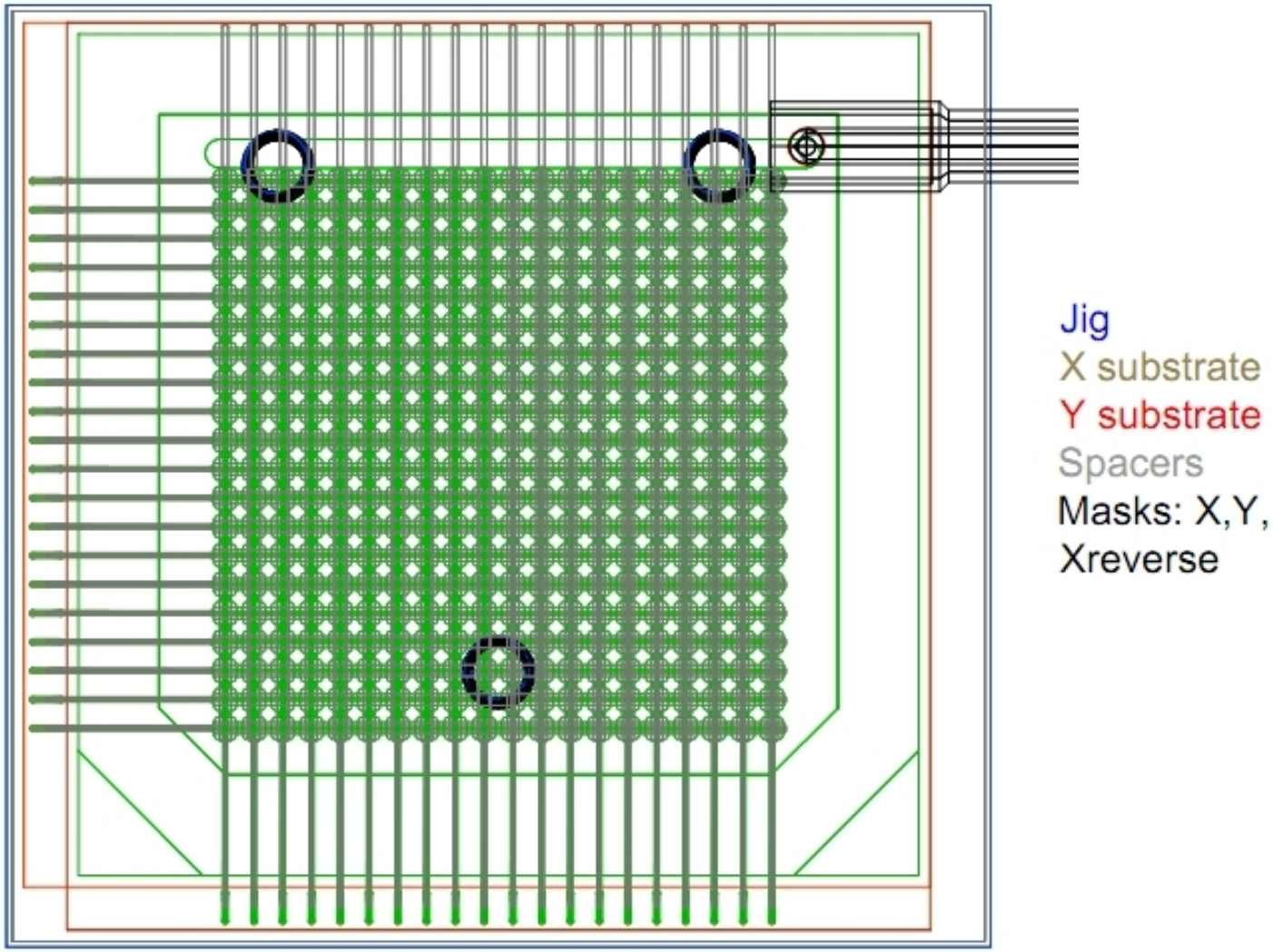


Figure 2

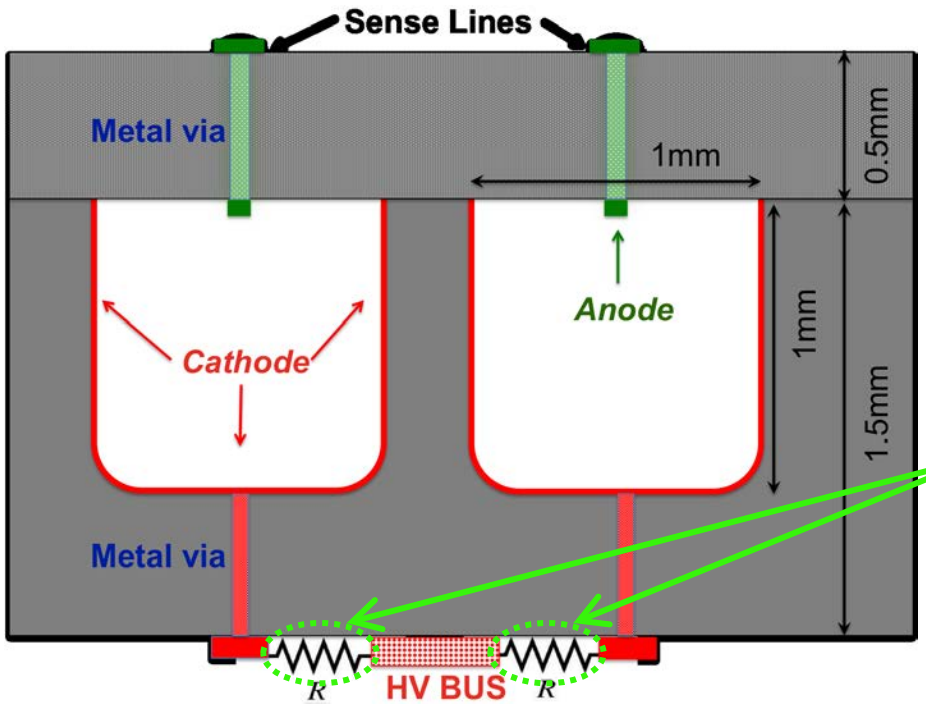


UltraThin-PPS Assembly Drawing

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

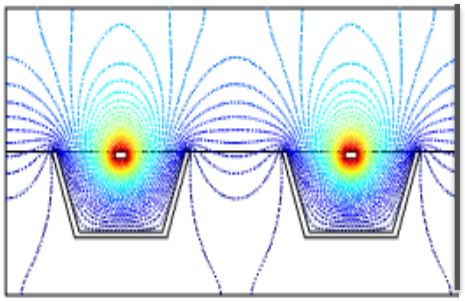


"*Closed* - Cell" Microcavity Concept



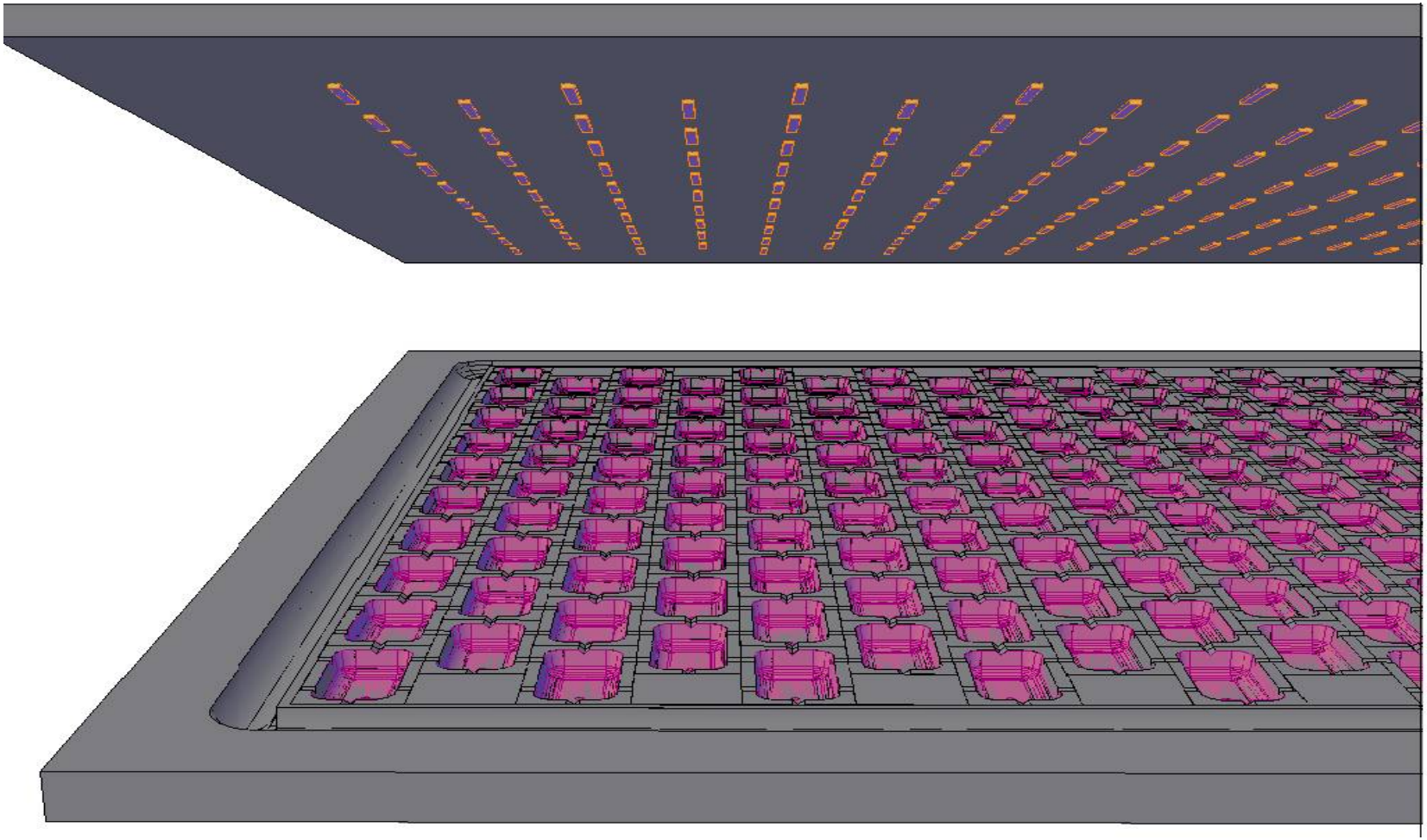
Closed gas cell individually quenched by an external resistor

Electrostatic simulations in COMSOL



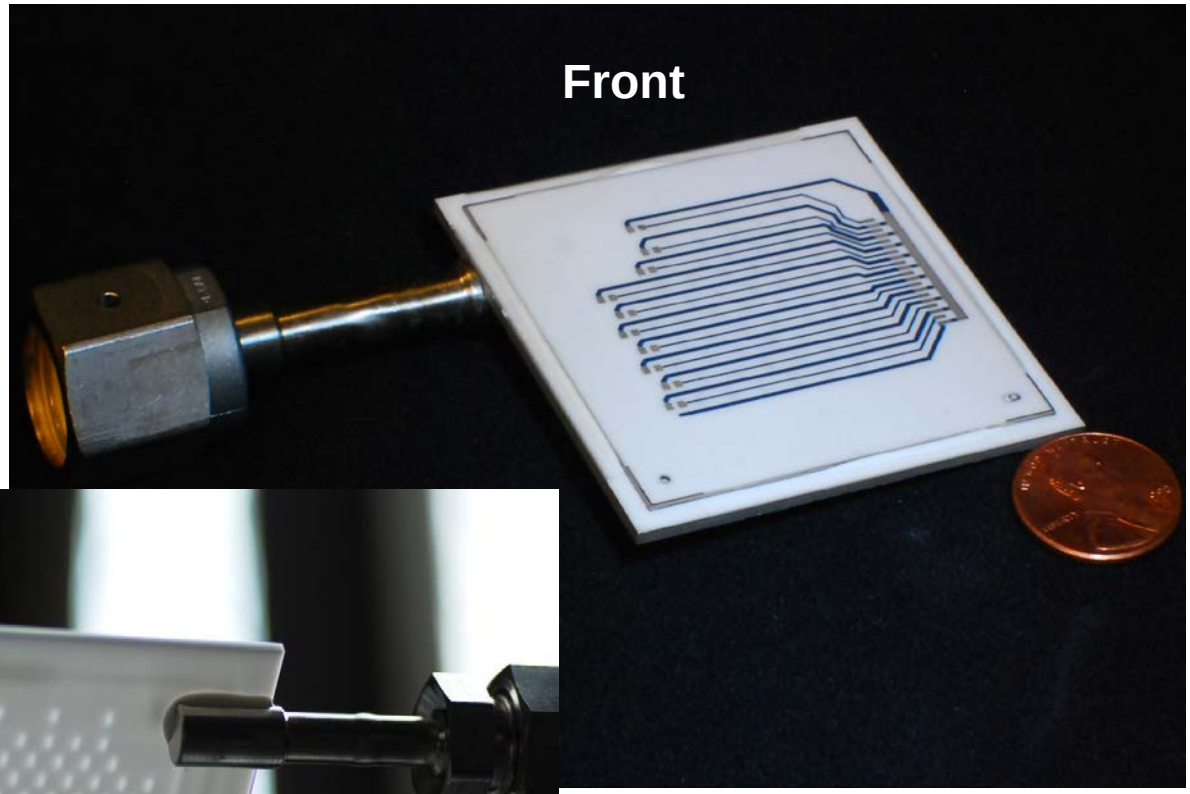
Electric field a few MV/m
→ gas breakdown

"*Closed*-Cell" Microcavity Structure

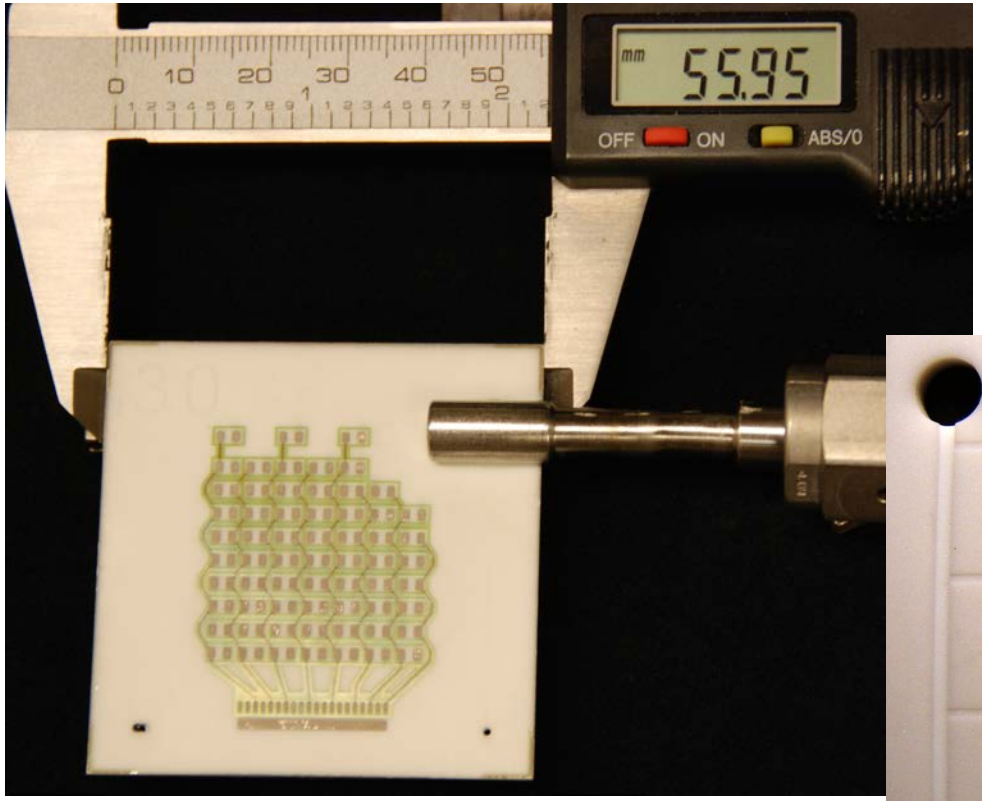


Perspective view of a pixel array with gas channels. Metallized cathode cavities on bottom plate with *vias* to HV bus. Anodes on top plate.

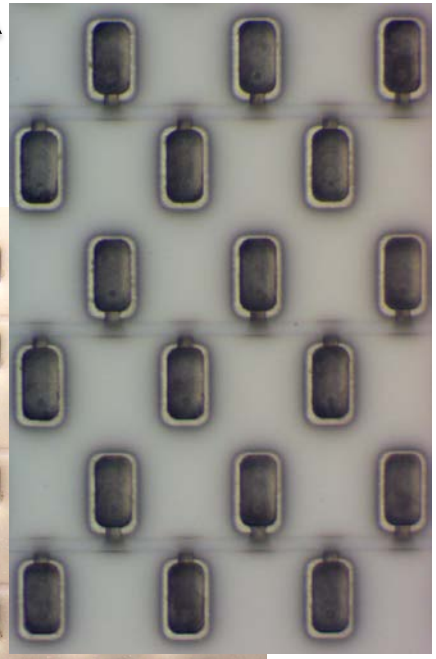
First Microcavity-PPS Panel

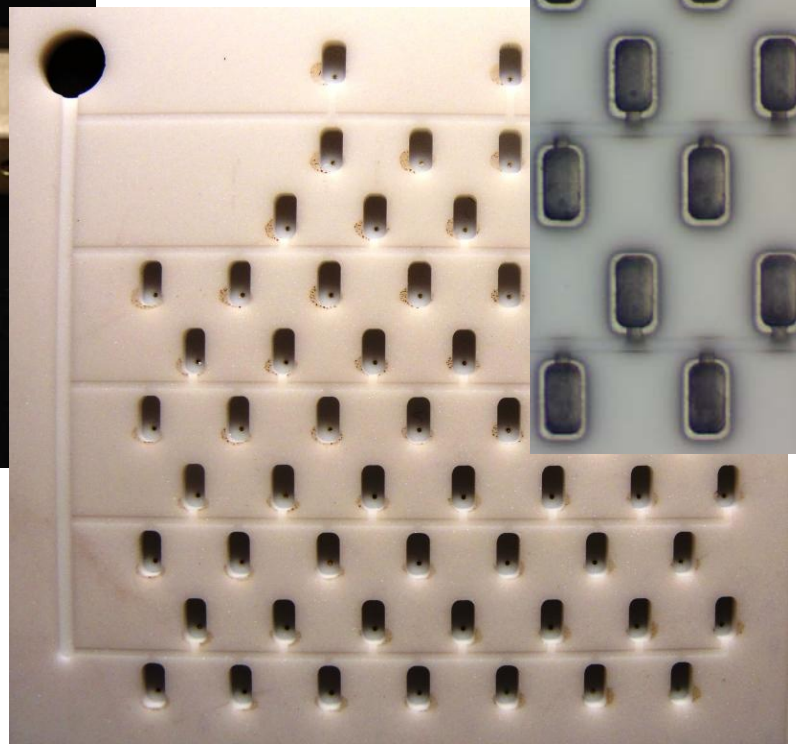


The Prototype – Back Plate



Metallized cavities
1 x 1 x 2 mm



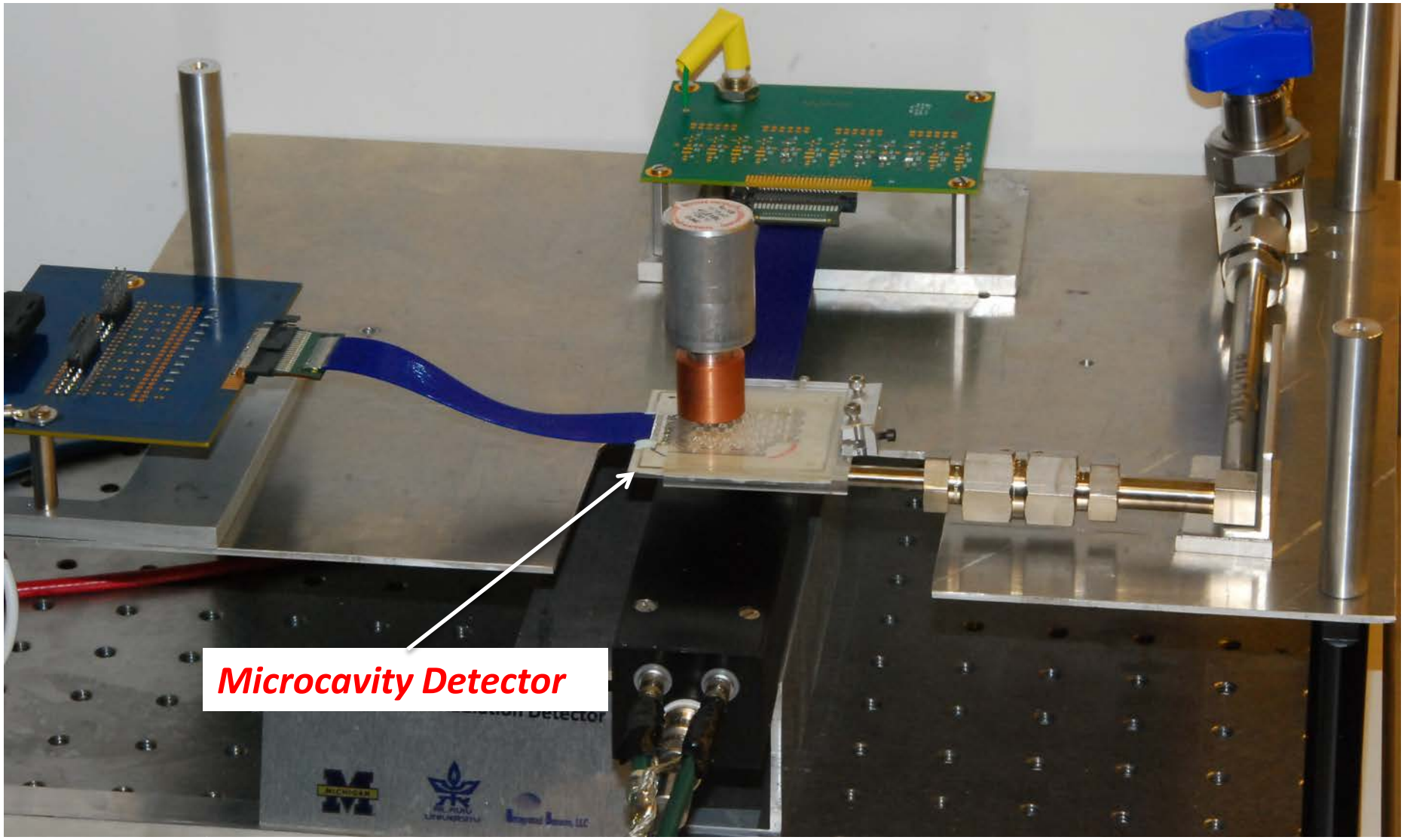


Bottom Side – quench resistor for each pixel.

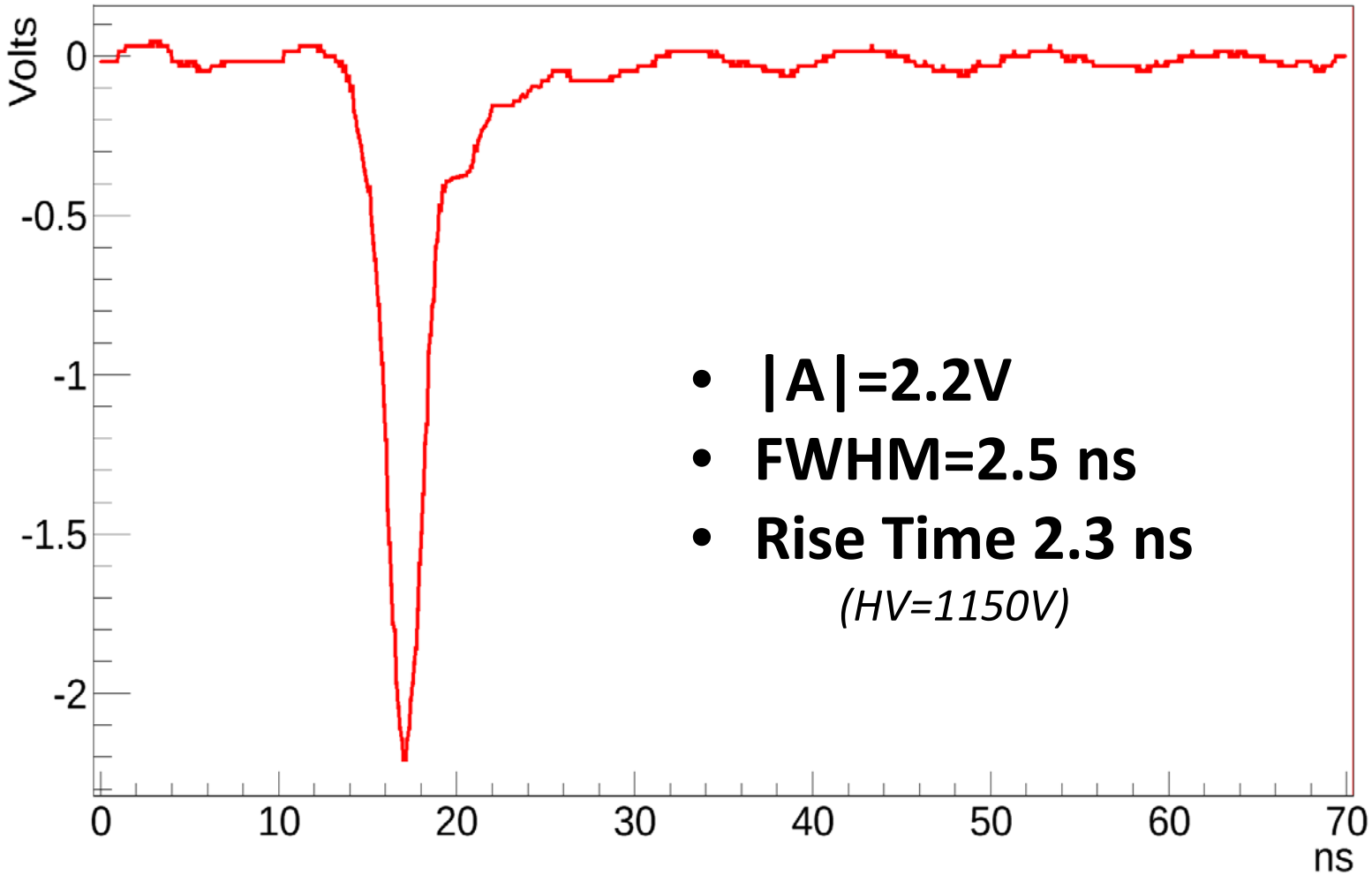
Top Cavity Side with metal vias and gas channel

Collimated β-Source Test Setup

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



Typical Microcavity-PPS Signal Pulse

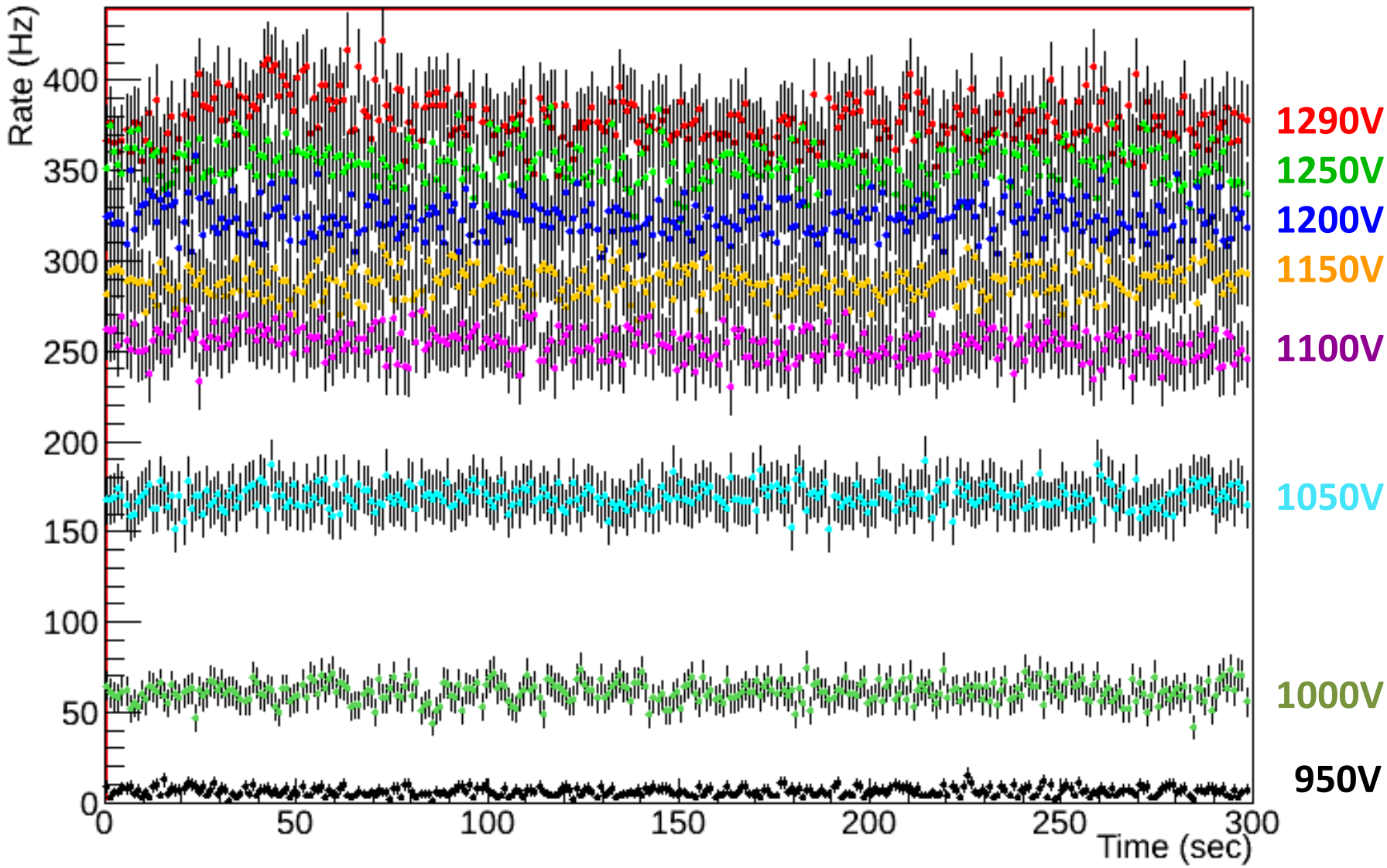


- **|A|=2.2V**
- **FWHM=2.5 ns**
- **Rise Time 2.3 ns**

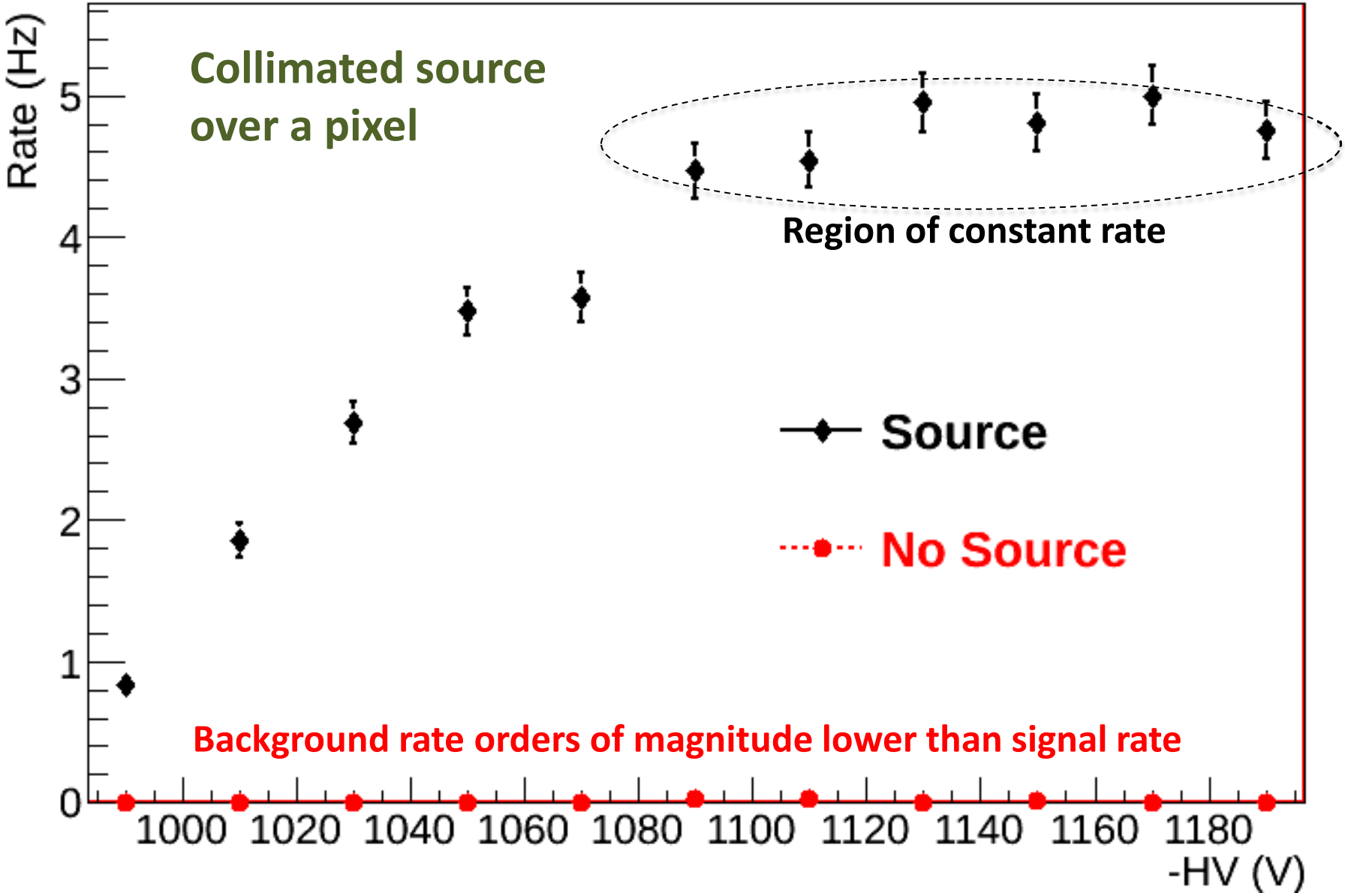
(HV=1150V)

Single Pixel Rate vs. Time

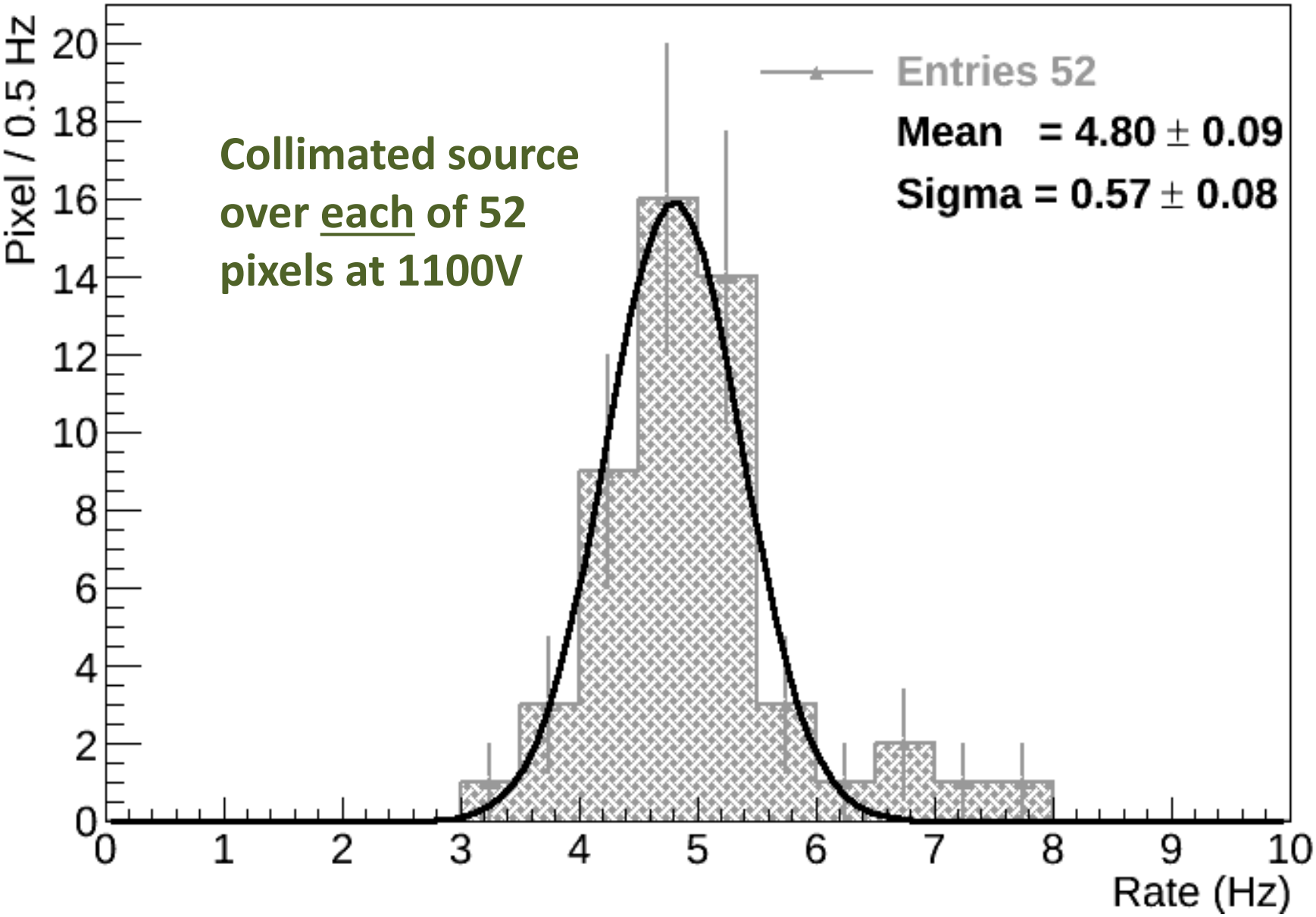
Uncollimated source on pixel



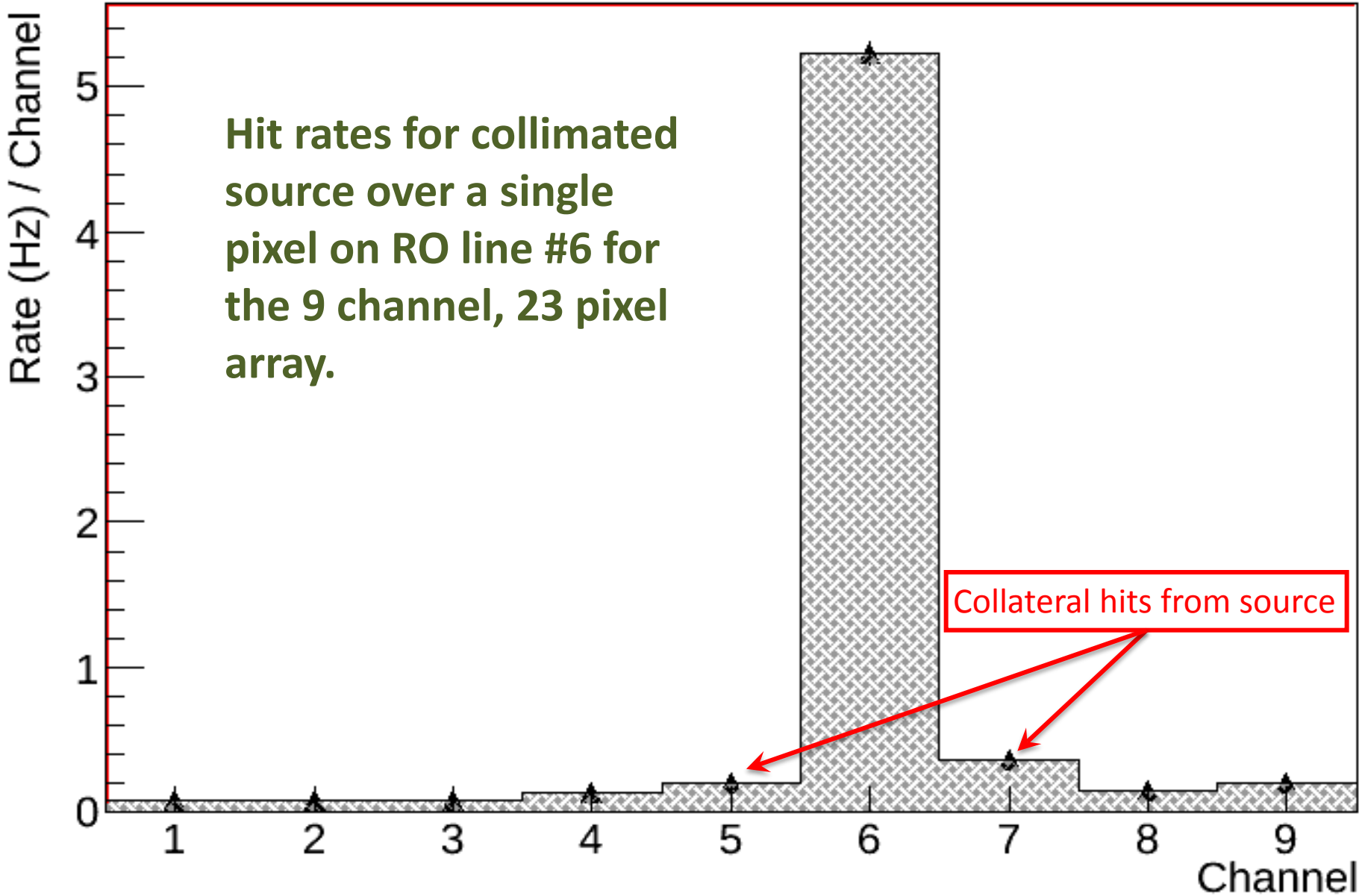
Pixel Response vs. HV



Pixel Response Uniformity

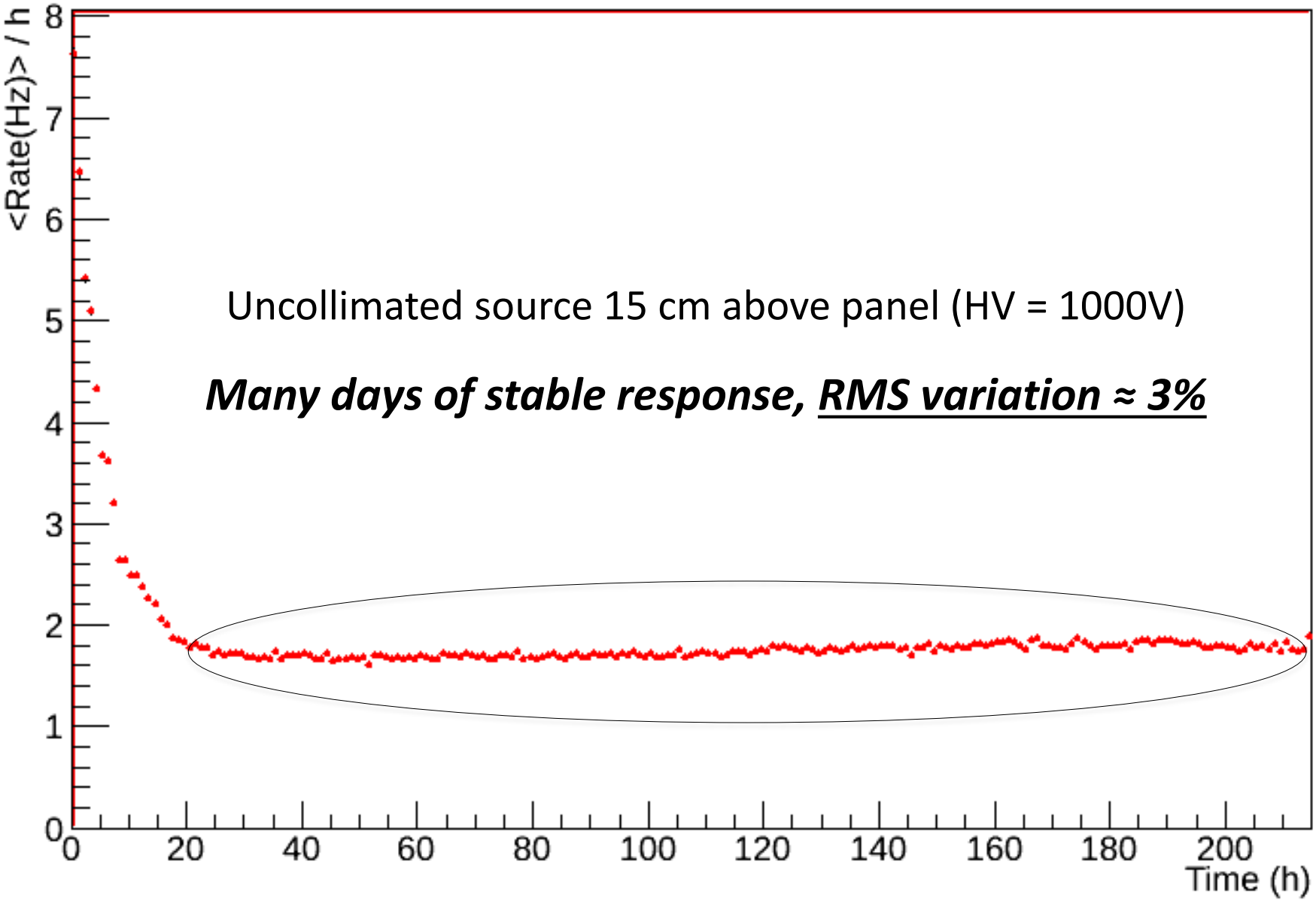


Pixel Isolation



Hit rates for collimated source over a single pixel on RO line #6 for the 9 channel, 23 pixel array.

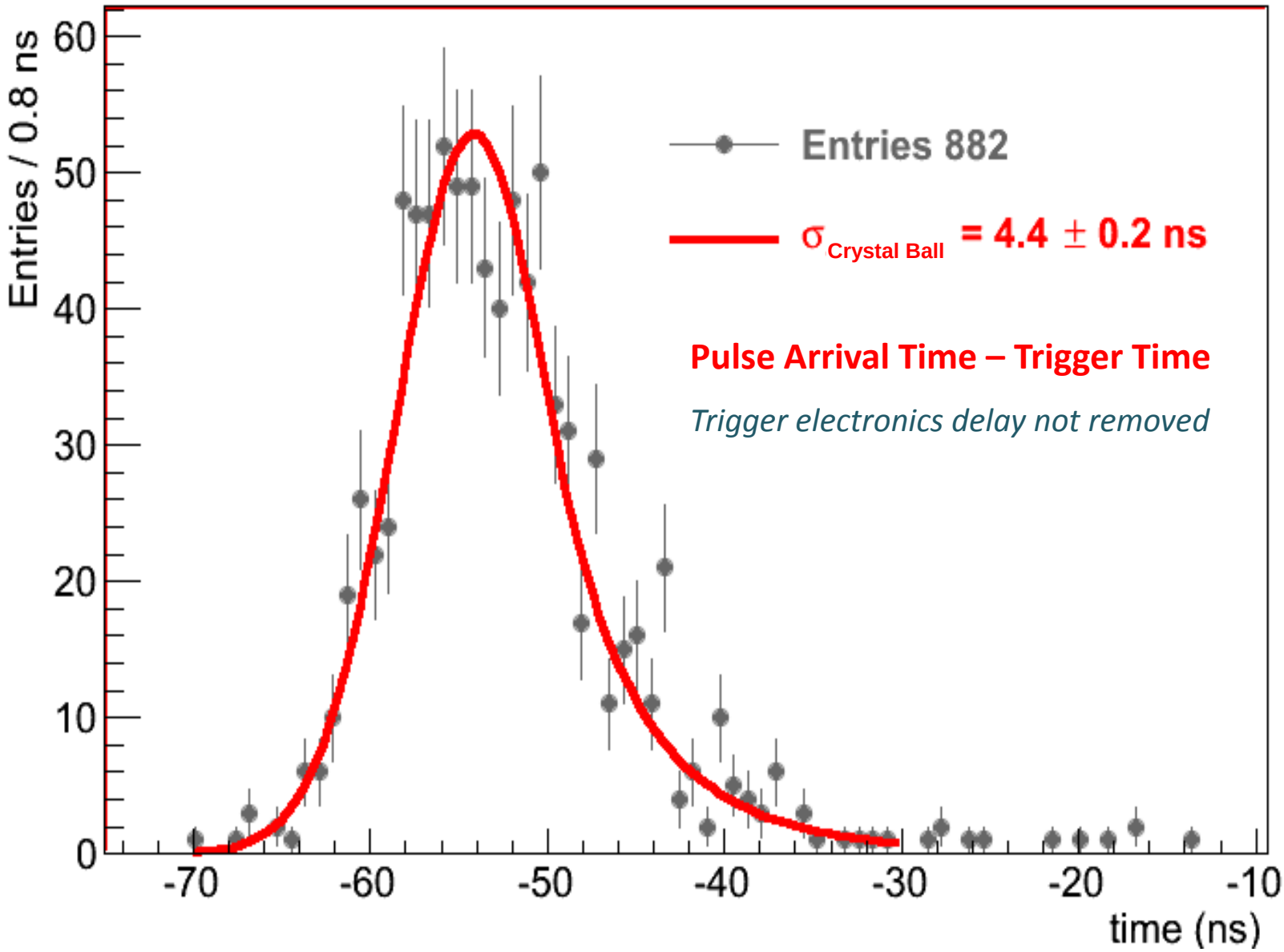
Long Term Stability (9 days)



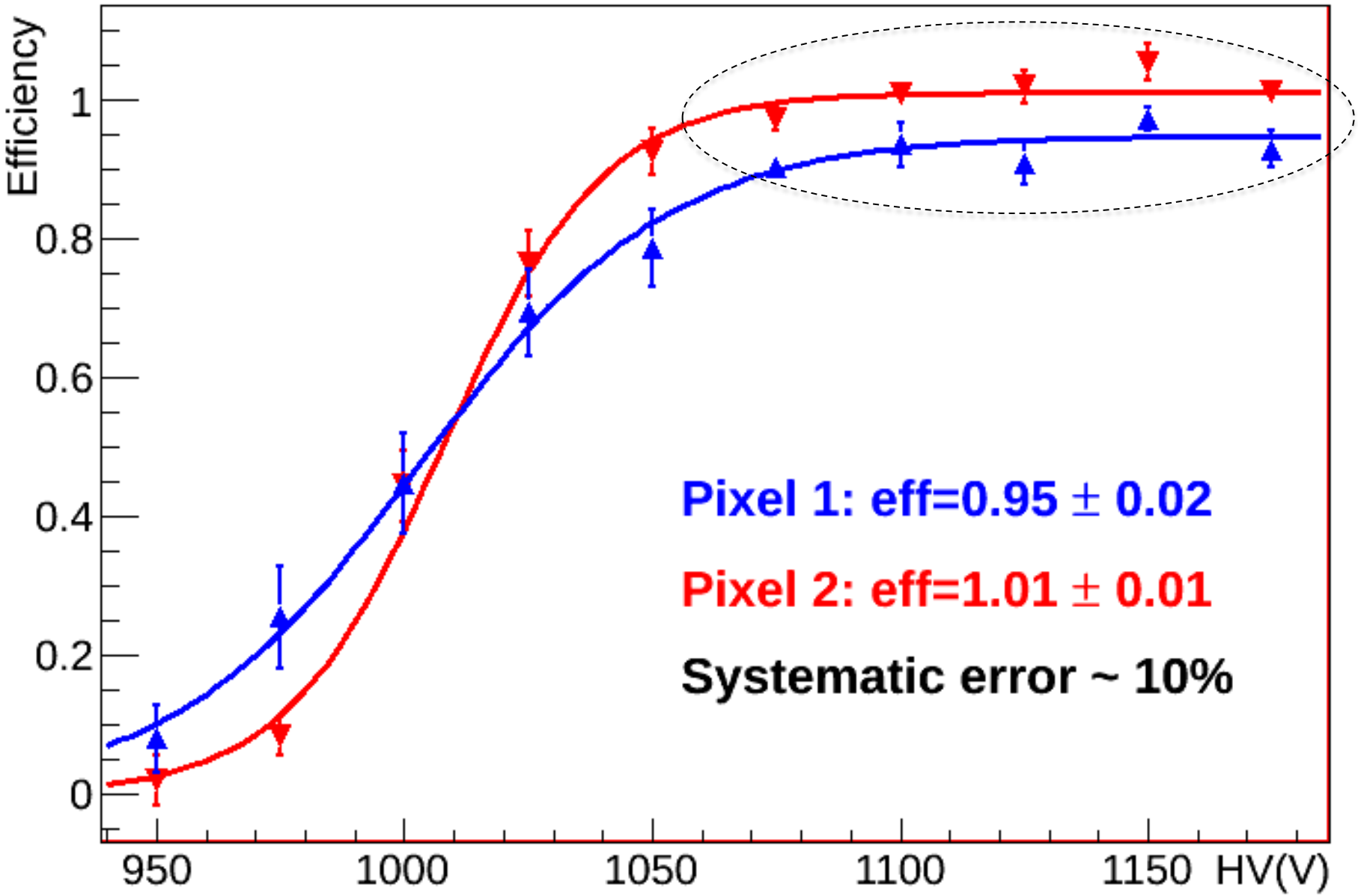
Uncollimated source 15 cm above panel (HV = 1000V)

Many days of stable response, <u>RMS variation ≈ 3%</u>

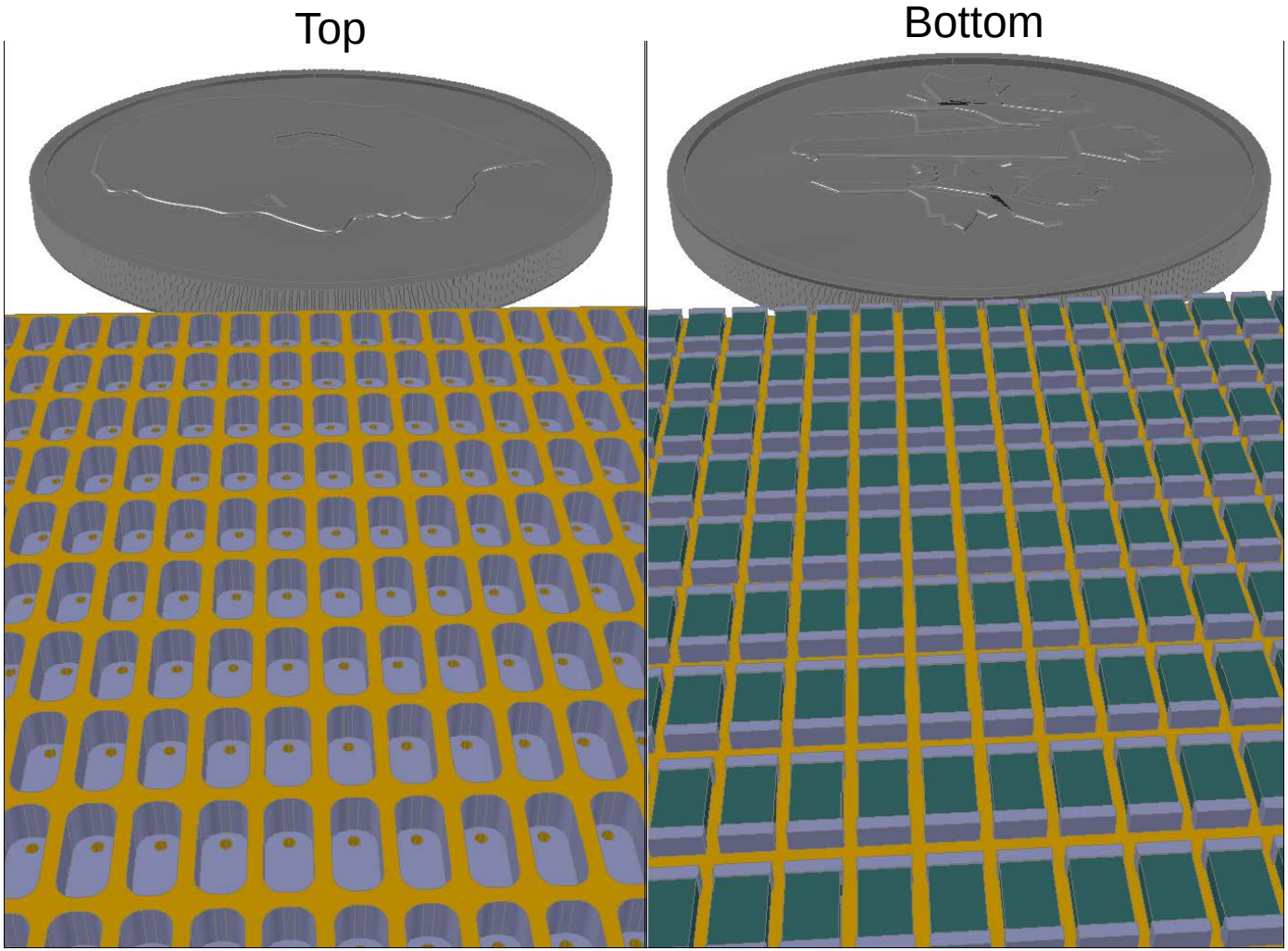
Pixel Time Resolution - Jitter



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.**