High-Performance Plasma Panel Based Micropattern Detector

August 7, 2015
DOE-NP SBIR/STTR Exchange Meeting
Gaithersburg, MD

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Plasma Panel Sensor (PPS)

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

- **Each pixel operates like an independent *micro-Geiger counter,* activated by *direct* ionization in the gas, or *indirect* ionization via 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 glass & foil*** 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**
  - Response range: ≈ **1 Hz/cm^2** to *at least* **10^6 Hz/cm^2**
  - Gas pressure operational range: ≈ 760 to < **100 Torr**
- **Primary Applications – *Particle Tracking & Active Pixel Beam Monitors*****
  - Research: Nuclear physics / high energy physics
  - 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 for late-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***)

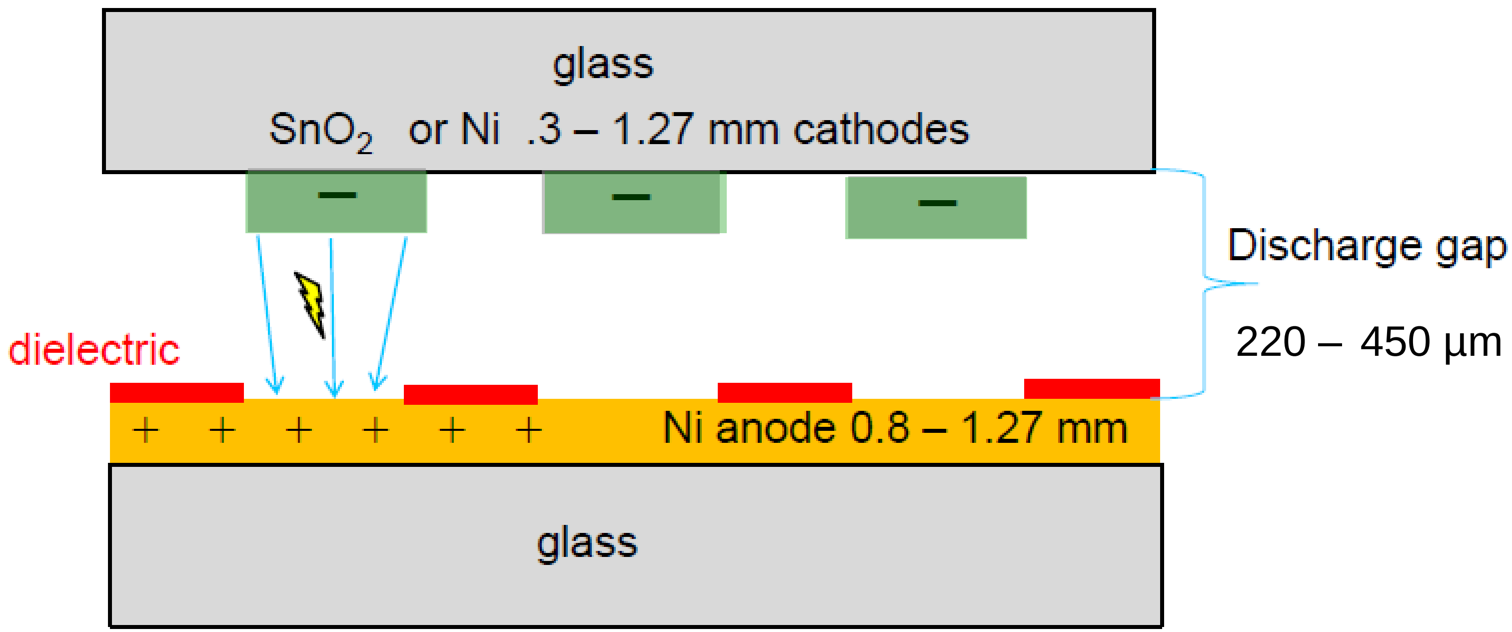
Neutrons: Thermal neutrons (***neutron scattering & homeland security***)

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

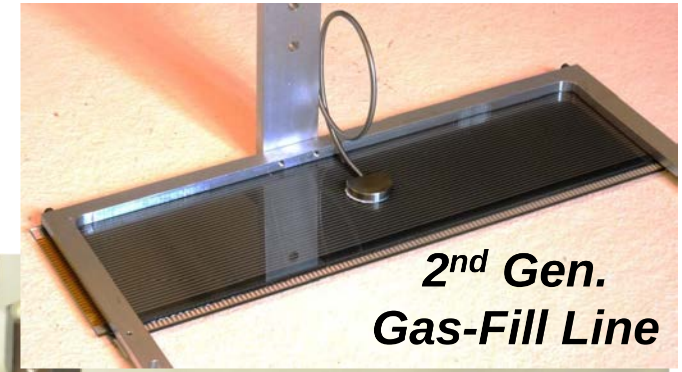
- Columnar Discharge (**CD**) – Pixels at intersections of orthogonal electrode array
    - Electrode sizes and pitch vary between different panels

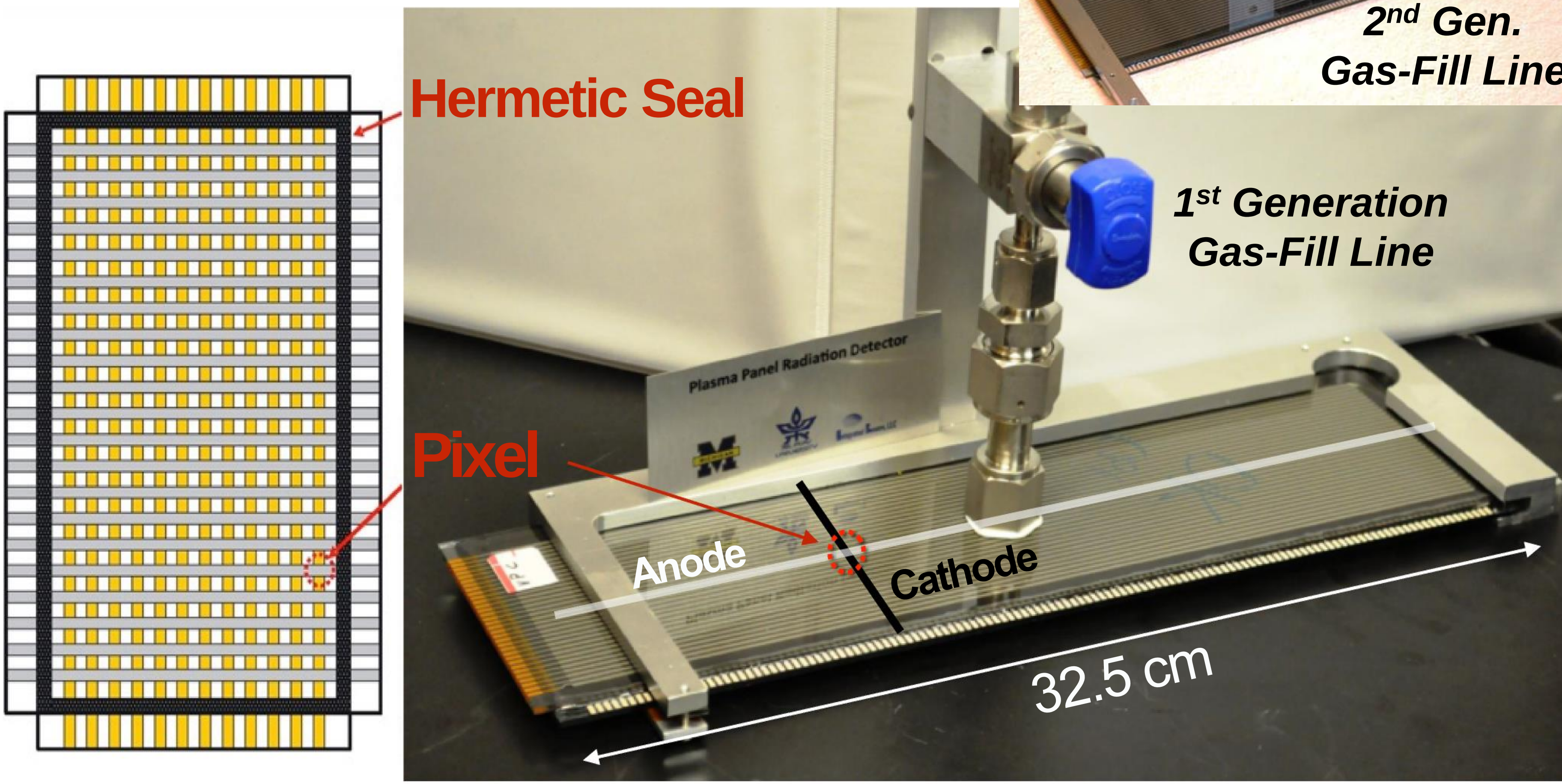


PPS with CD-Electrode Structure

"Open-Cell" Structure

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

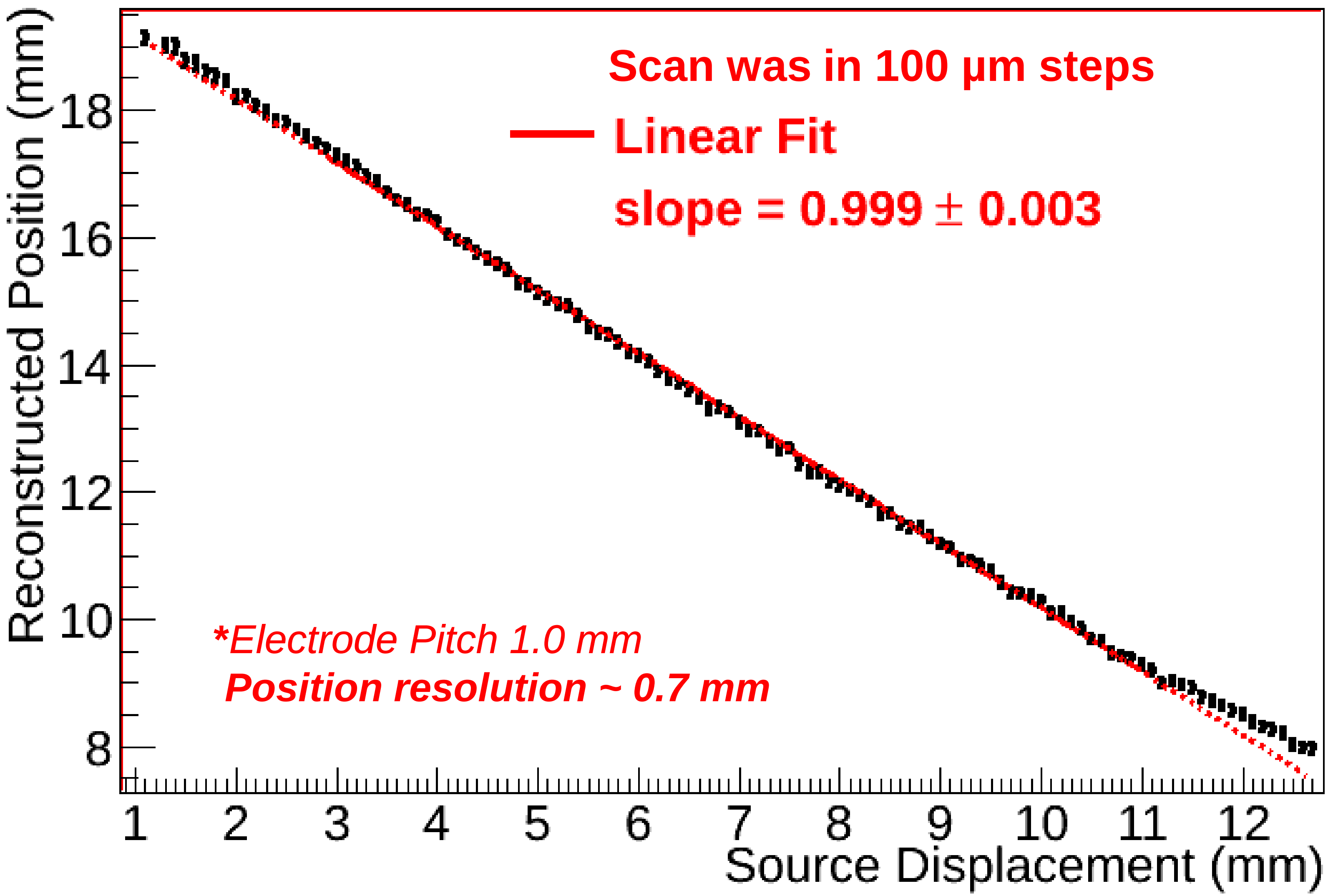




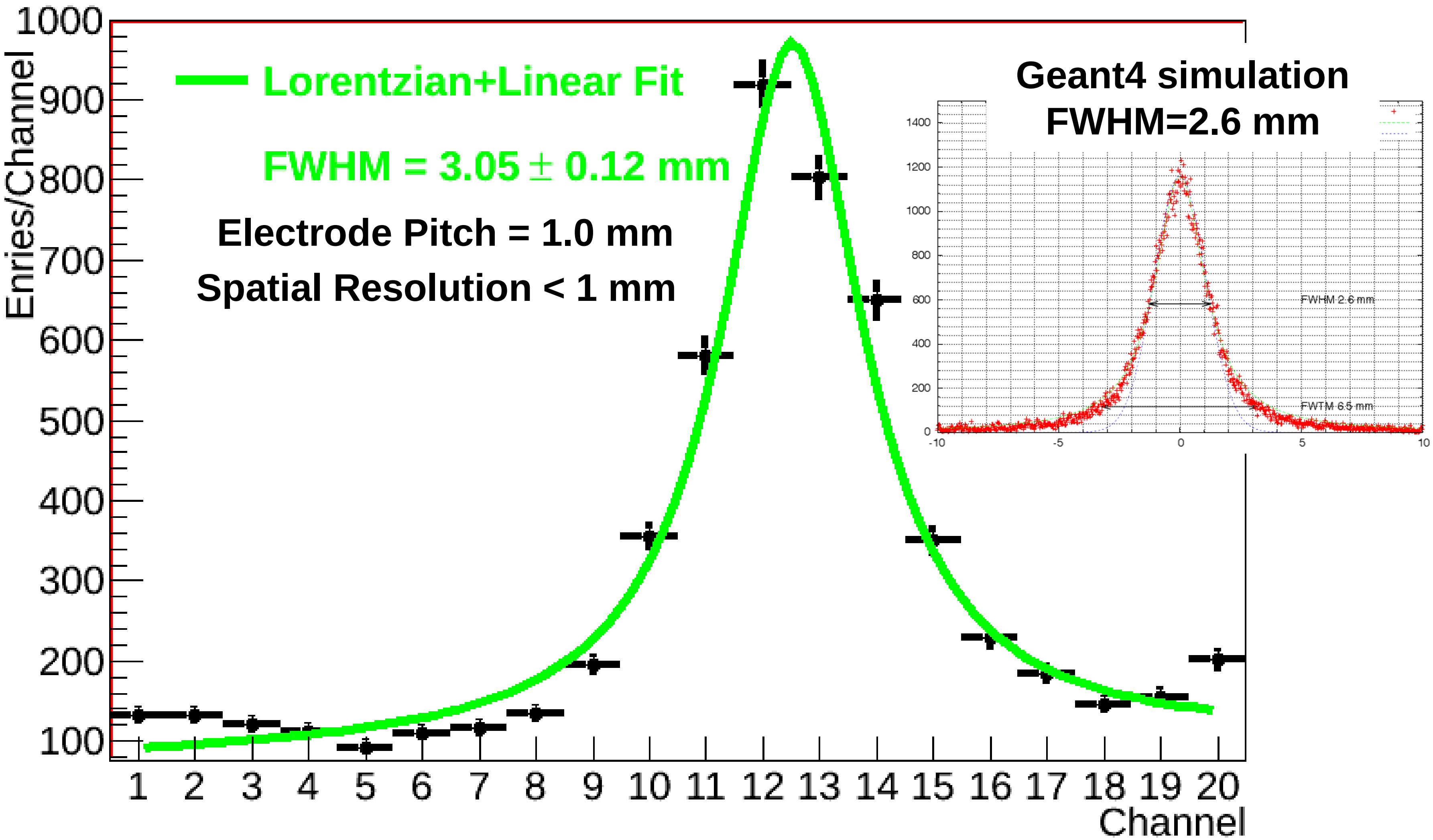
Source Moved in 0.1 mm Increments

(1 mm pitch panel)

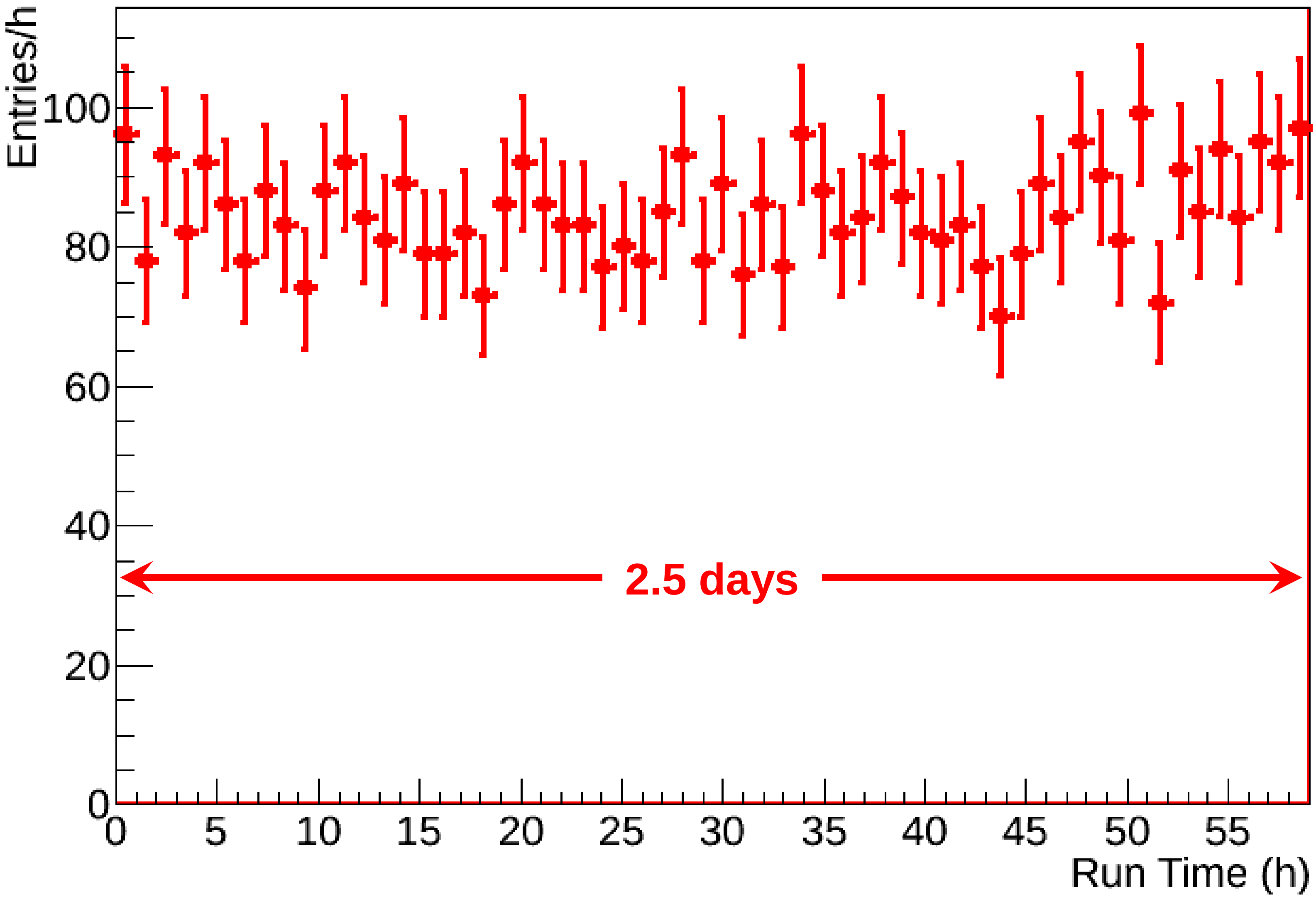
Collimated β–Source Position Scan (^{106}Ru)



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)

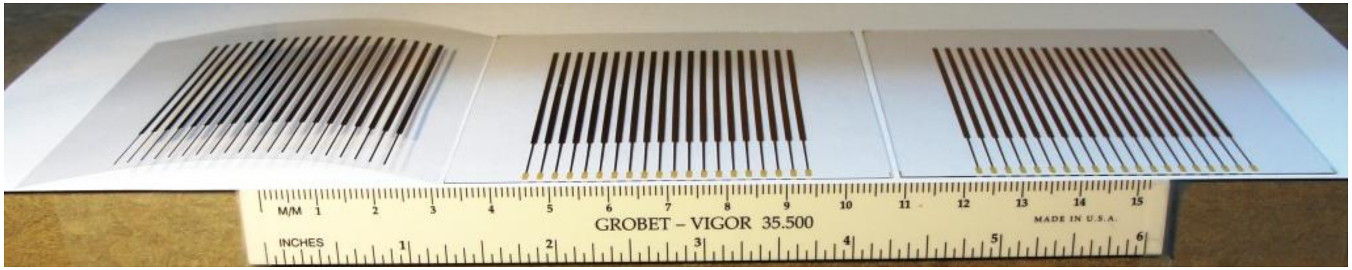
Energy Loss is 25 µm *thick glass* cover PPS for selected Ion Beams
(gas is 0.50mm of Ar at 200 Torr; *no nuclei get through the glass at 1MeV/A*)

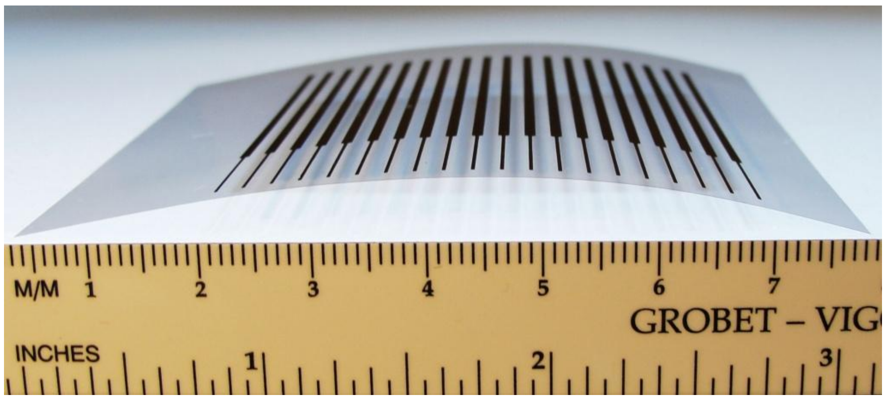
Energy (MeV)/A	**Ion Energy (MeV)**	**Energy *loss in Glass*** (MeV)	**Energy *loss in Gas*** **MeV** (# ion pairs)
3.0 (Ni-64)	192	190	0.13 (4,700)
3.0 (Sn-124)	372	348	0.57 (21,000)
3.0 (U-238)	**714**	**570**	1.52 (58,000)

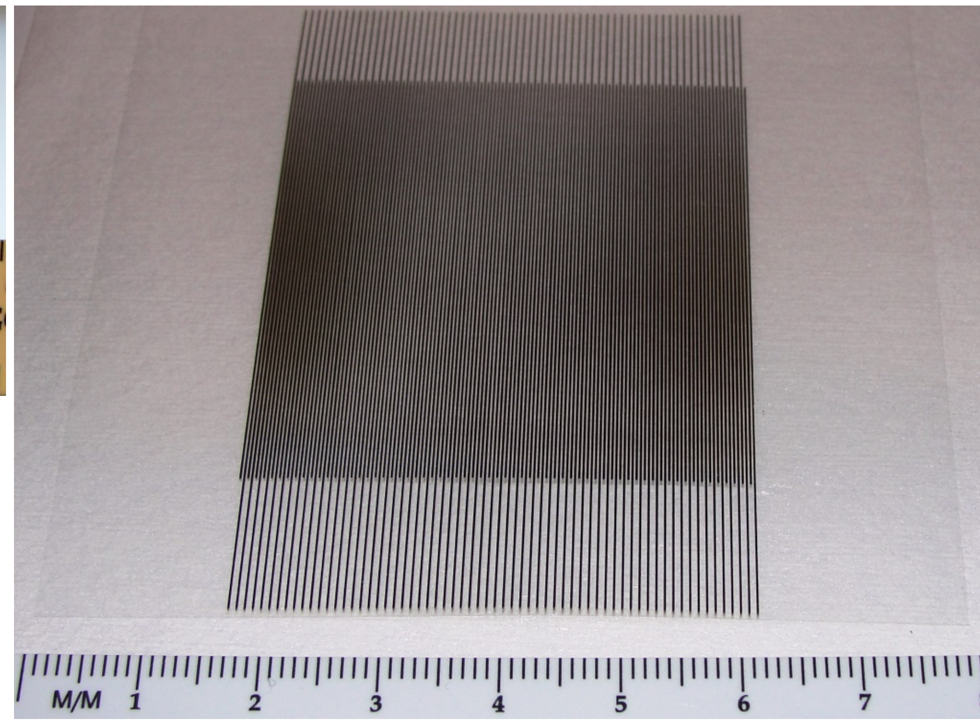
Energy Loss is 7.6 µm *thick Ti-foil* cover PPS for selected Ion Beams
(gas is 0.50mm of Ar at 200 Torr)

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	0.19 (7,300)
1.0 (Sn-124)	124	111	0.47 (17,000)
1.0 (U-238)	**238**	**199**	0.99 (37,000)
3.0 (Ni-64)	192	81.5	0.62 (23,000)
3.0 (Sn-124)	372	160	1.18 (45,000)
3.0 (U-238)	**714**	**298**	2.14 (80,000)

Commercially Available – *UltraThin* Glass







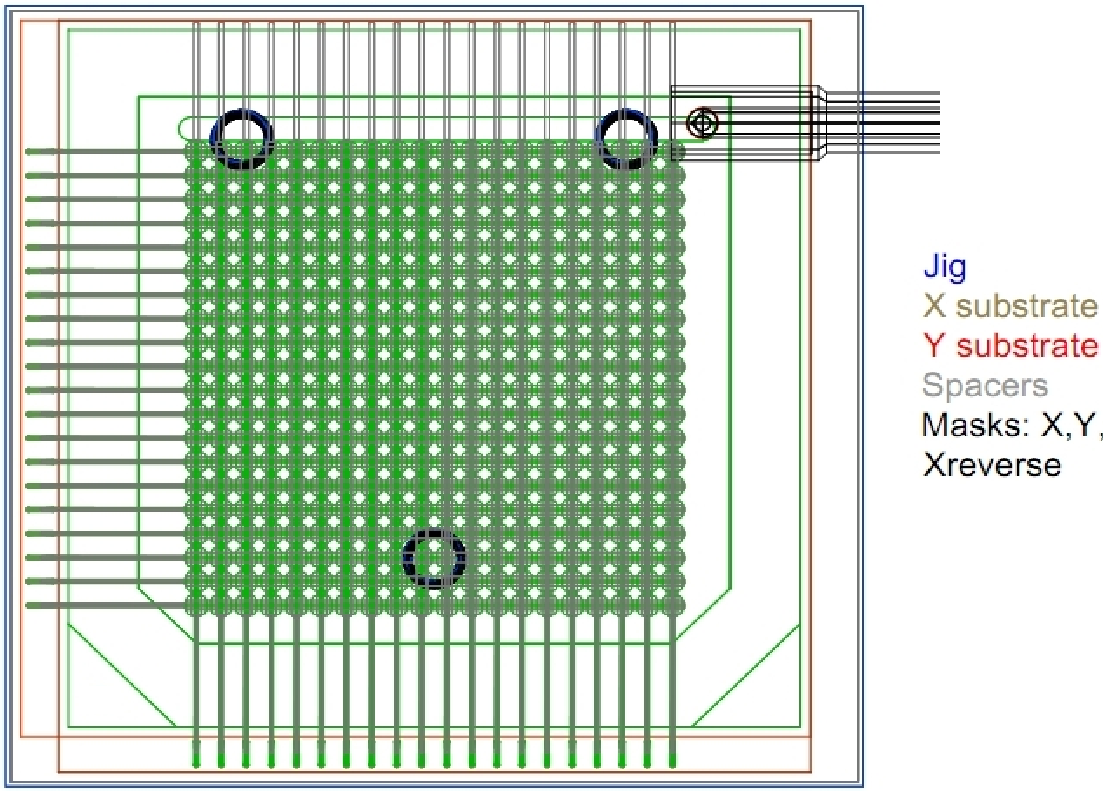
Top Row: Photos of **0.026, 0.20 & 0.30 mm** thick glass. Electrode pitch is **2.54 mm**.

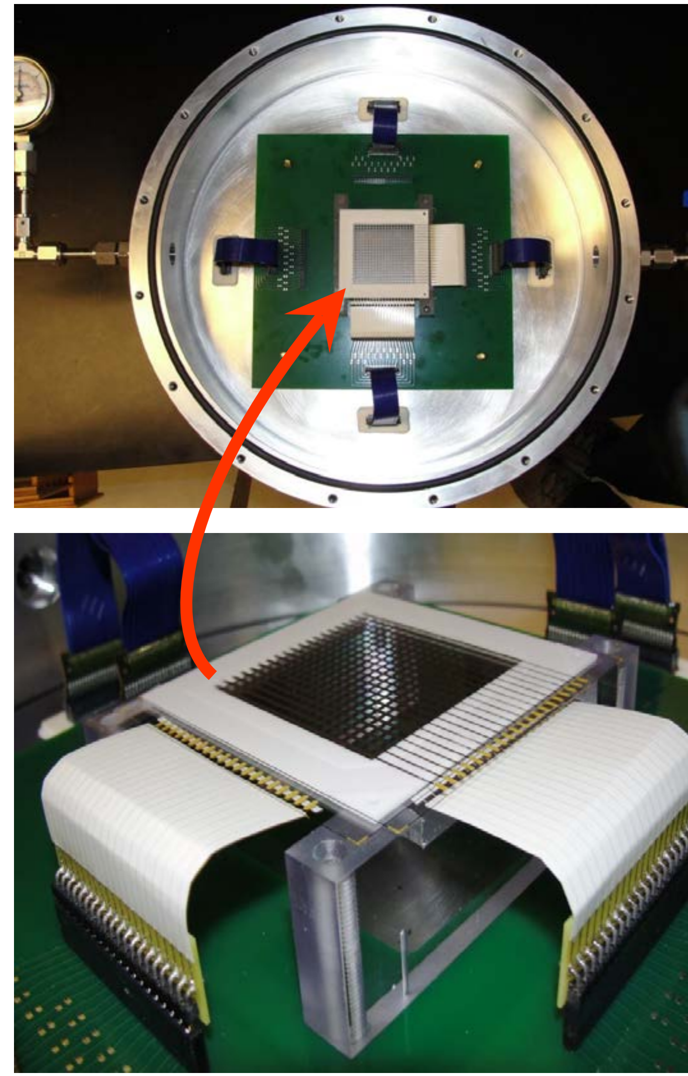
Electrode width 1.02 mm in active area, and 0.31 mm at bottom. Note 26 µm glass is 1/4 the thickness of single sheet of copy paper.

Bottom Right: High resolution electrodes on 26 µm thick glass. Electrode pitch in active area (center) is **0.35 mm**, electrode width is 0.15 mm. The narrow electrode width & spacing on the slightly bowed glass created the Lissajou type interference pattern, which is an optical artifact of image magnification and viewing angle. The actual electrode pattern is very uniform.

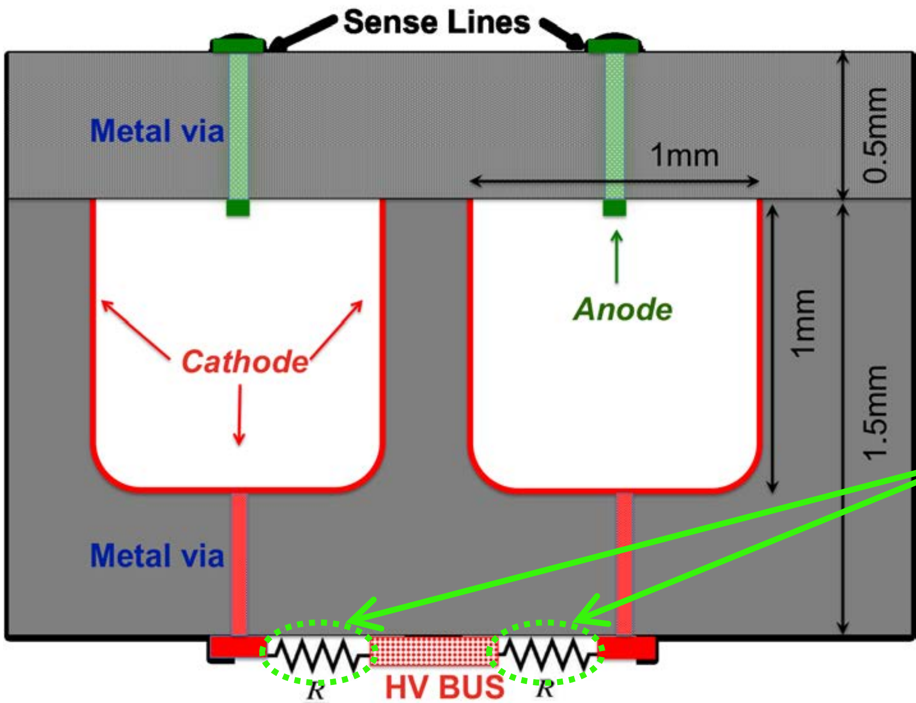
UltraThin PPS-2 (“open” panel)

(≈ 60-99% active cell/pixel fill-factor)



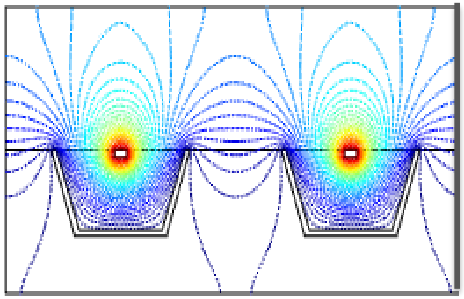


“Closed - Cell” Microcavity Concept



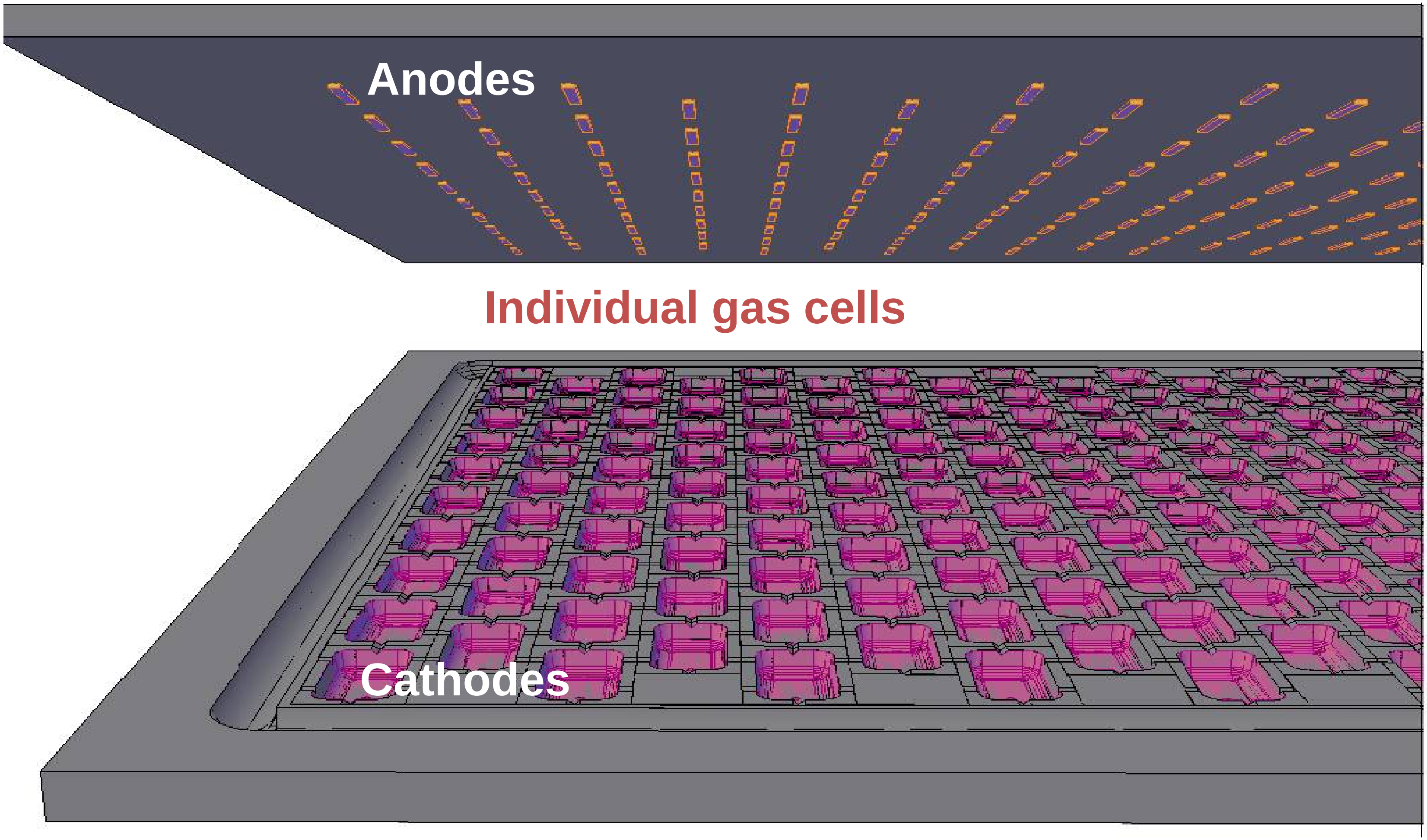
Closed gas cell individually quenched by an external resistor

Electrostatic simulations in COMSOL



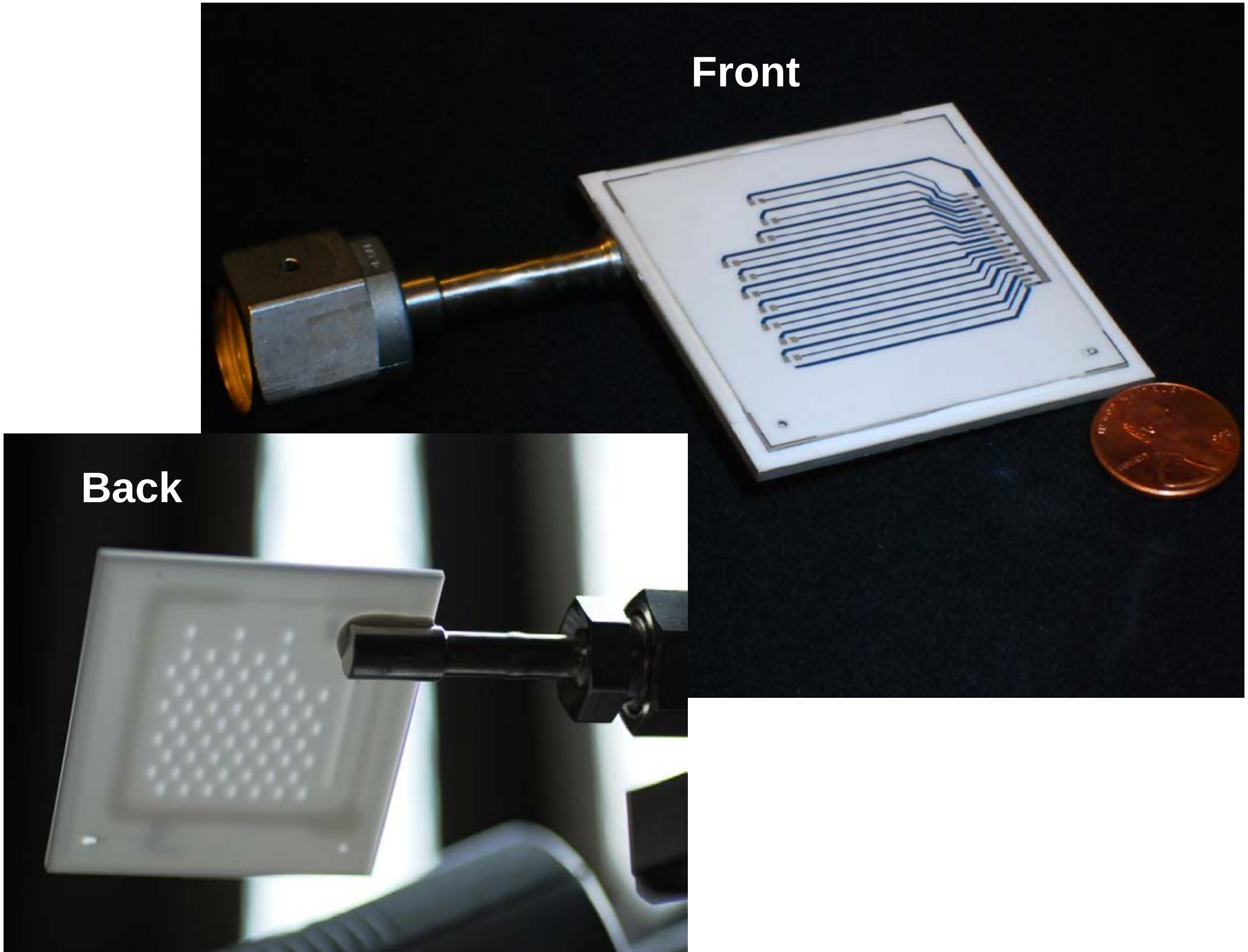
Electric field a few MV/m
→ gas breakdown

"*Closed*-Cell" Microcavity Concept

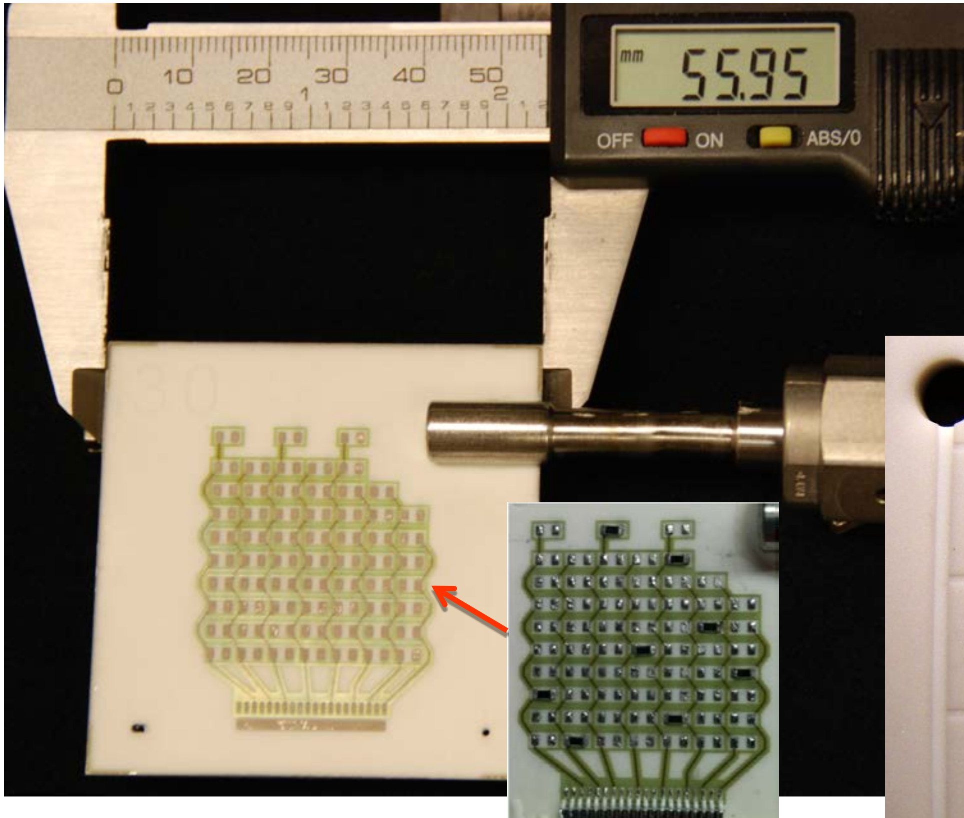


Perspective view of a pixel array with gas channels. Metallized cathode cavities on bottom plate with *vias* to HV bus. Anodes on top plate.

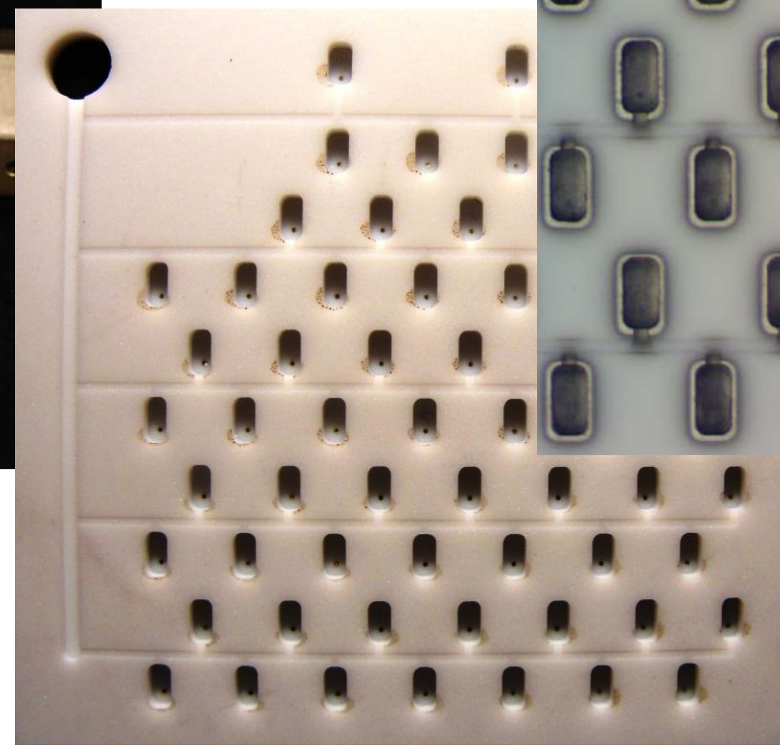
First Microcavity-PPS Panel



The Prototype – Back Plate (63 pixels)

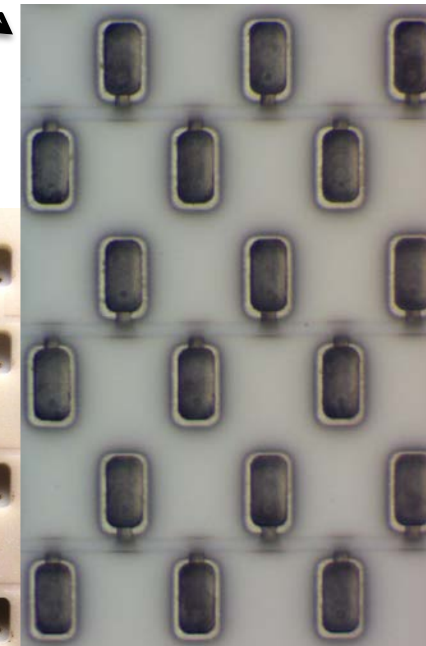


Bottom Side – quench resistor for each pixel.

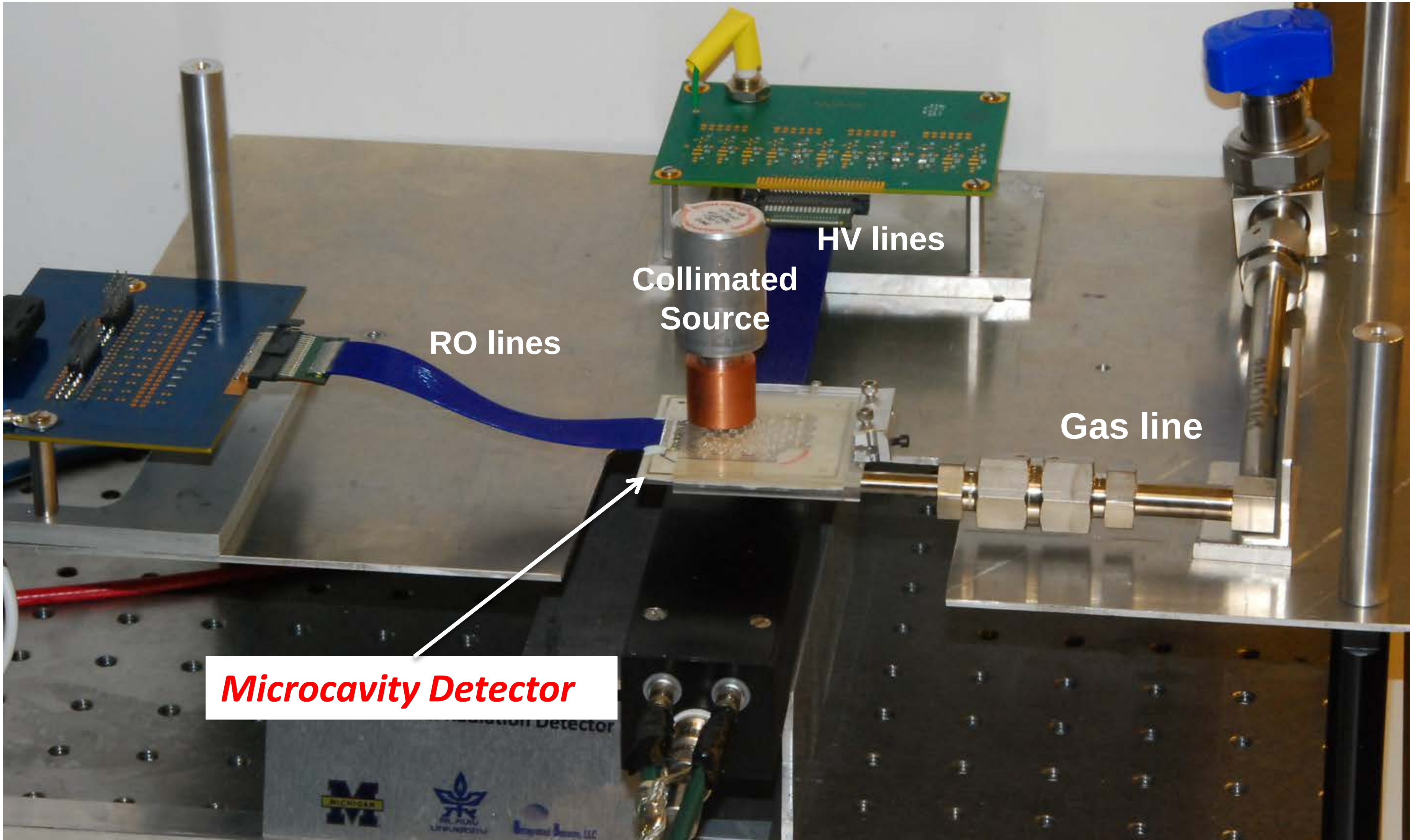


Top Cavity Side with metal vias and gas channel

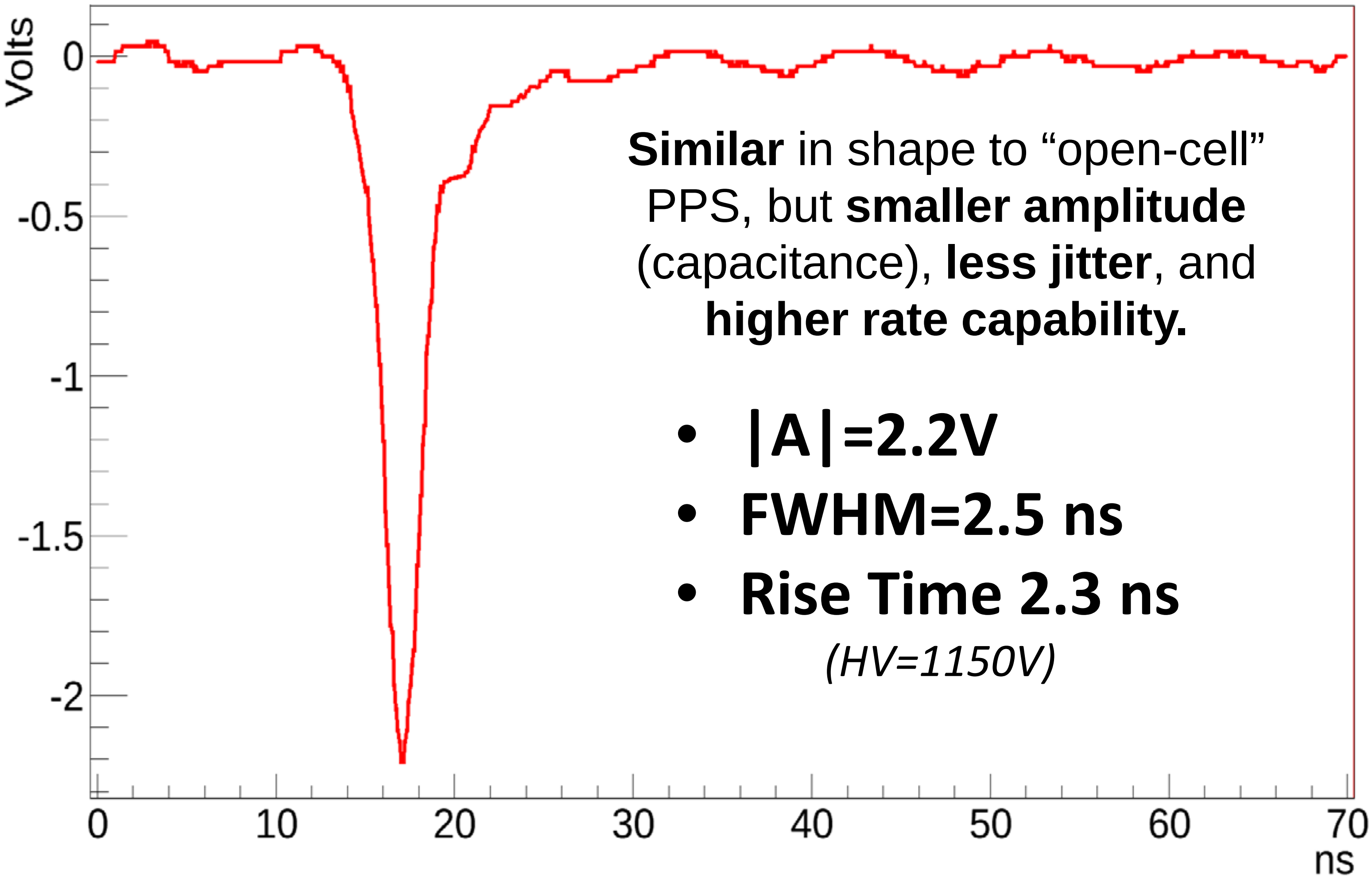
Metallized cavities 1 x 1 x 2 mm



Collimated β-Source Test Setup



Typical Microcavity-PPS Signal Pulse

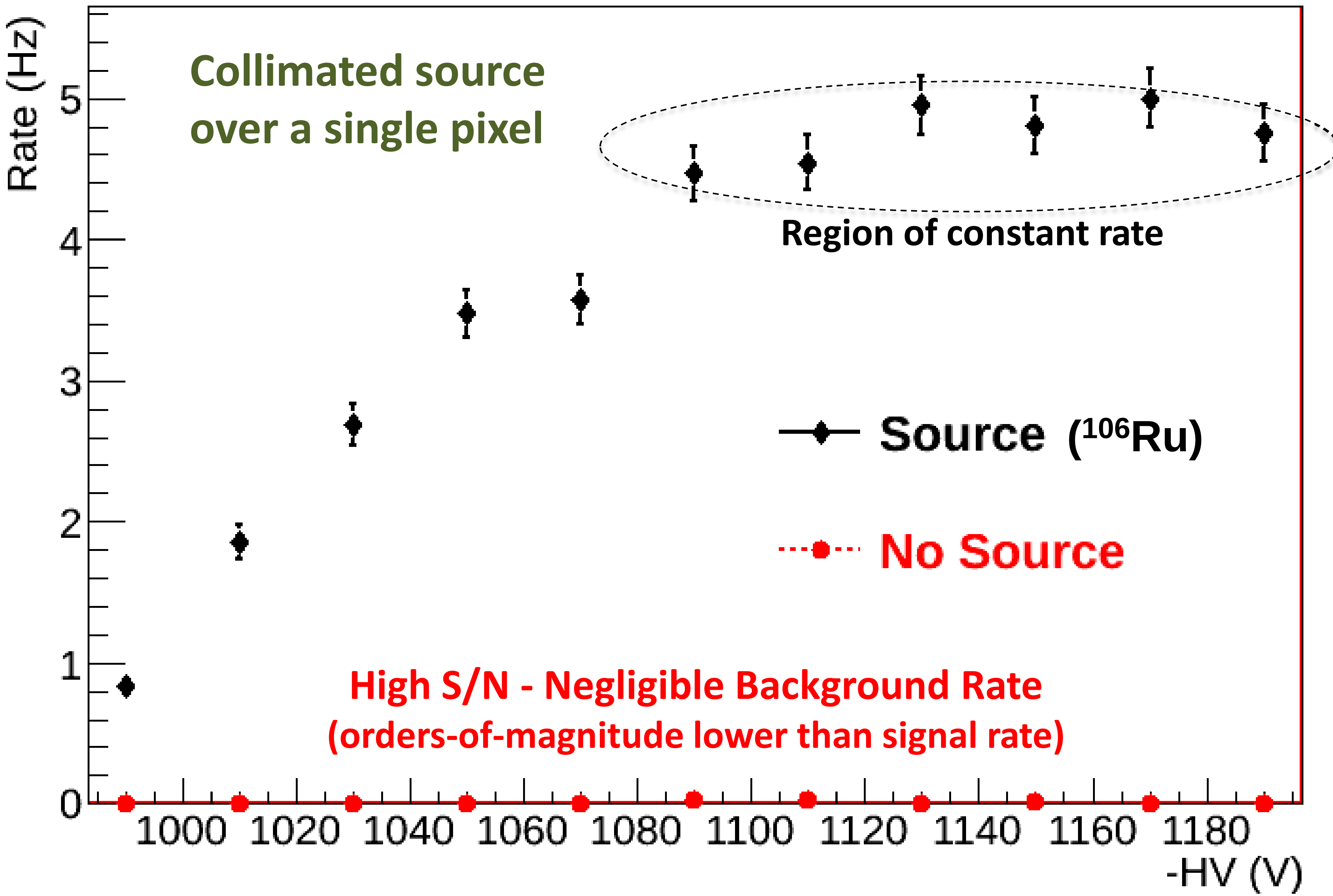


Similar in shape to "open-cell" PPS, but **smaller amplitude** (capacitance), **less jitter**, and **higher rate capability.**

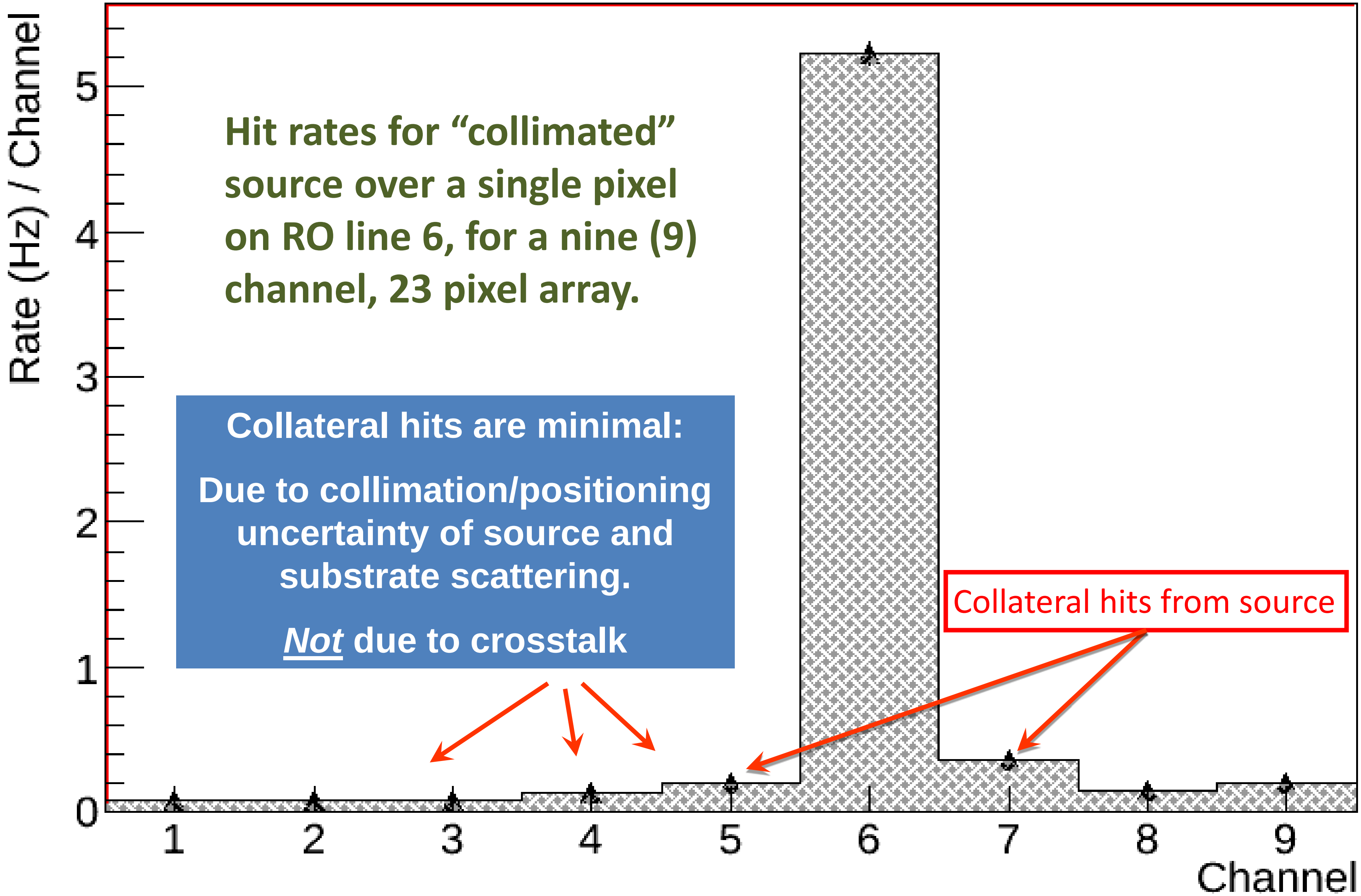
- **|A|=2.2V**
- **FWHM=2.5 ns**
- **Rise Time 2.3 ns**

(HV=1150V)

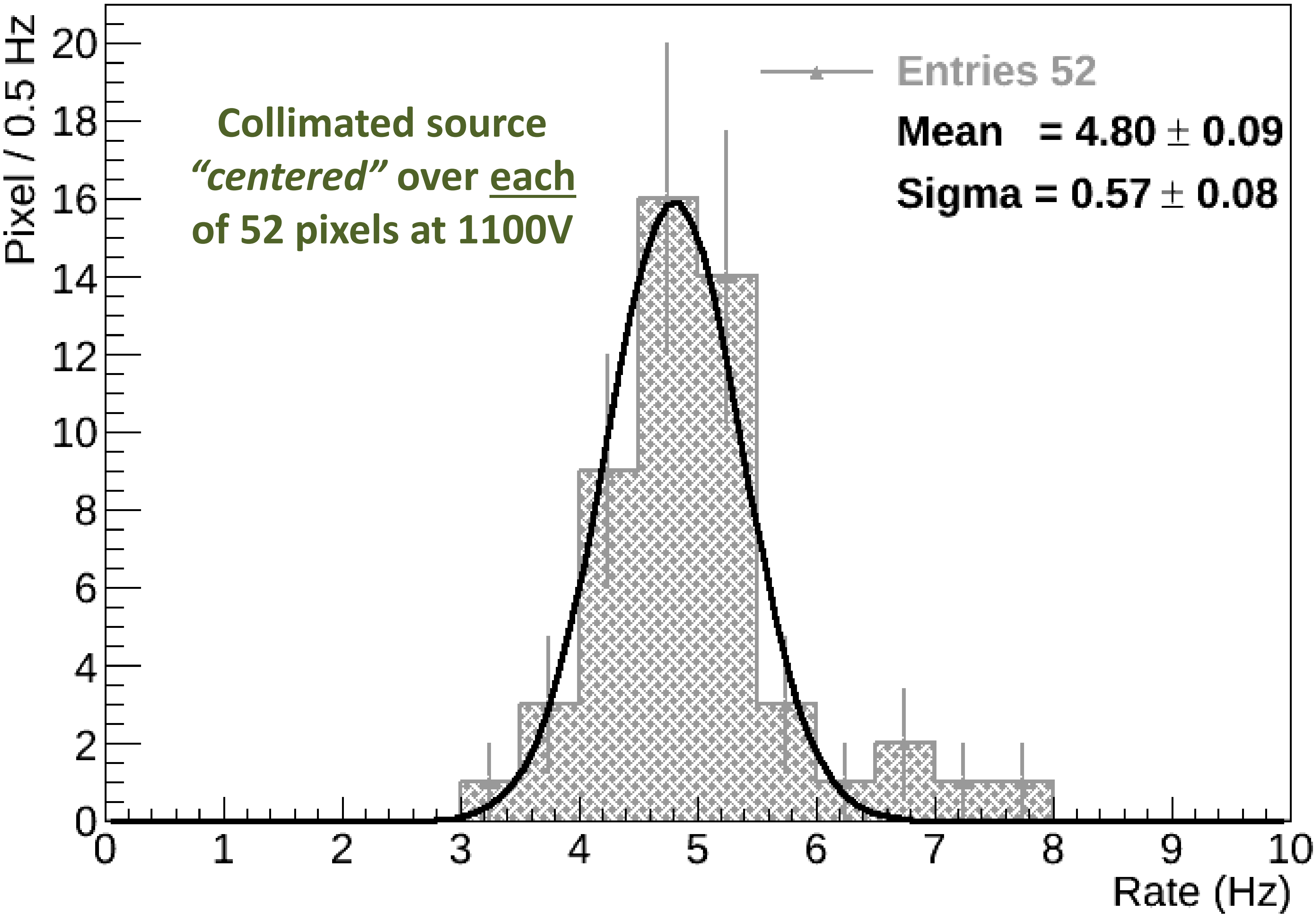
Pixel Response vs. HV



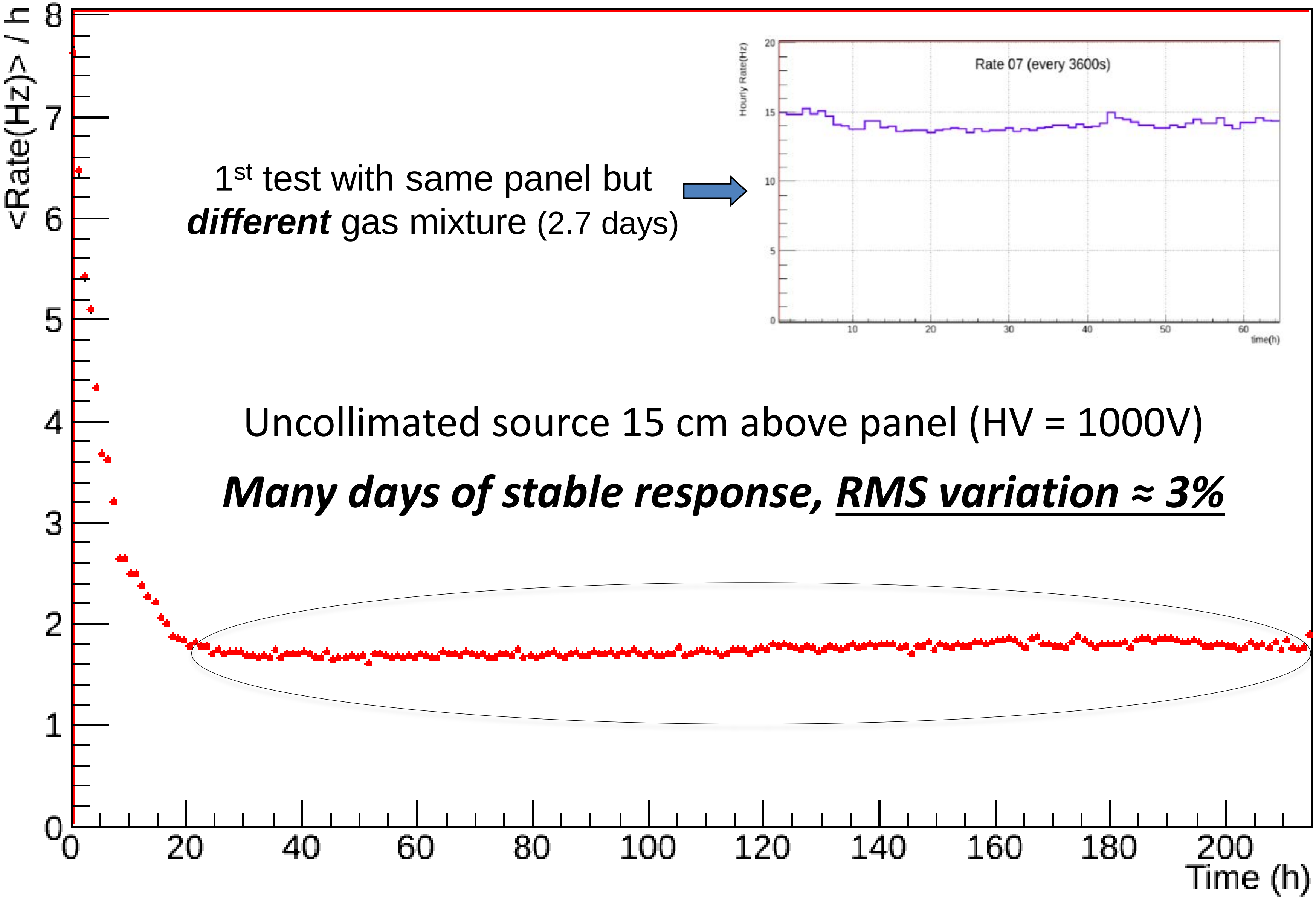
Pixel Isolation



Pixel Response Uniformity



Long Term Stability (9 days)

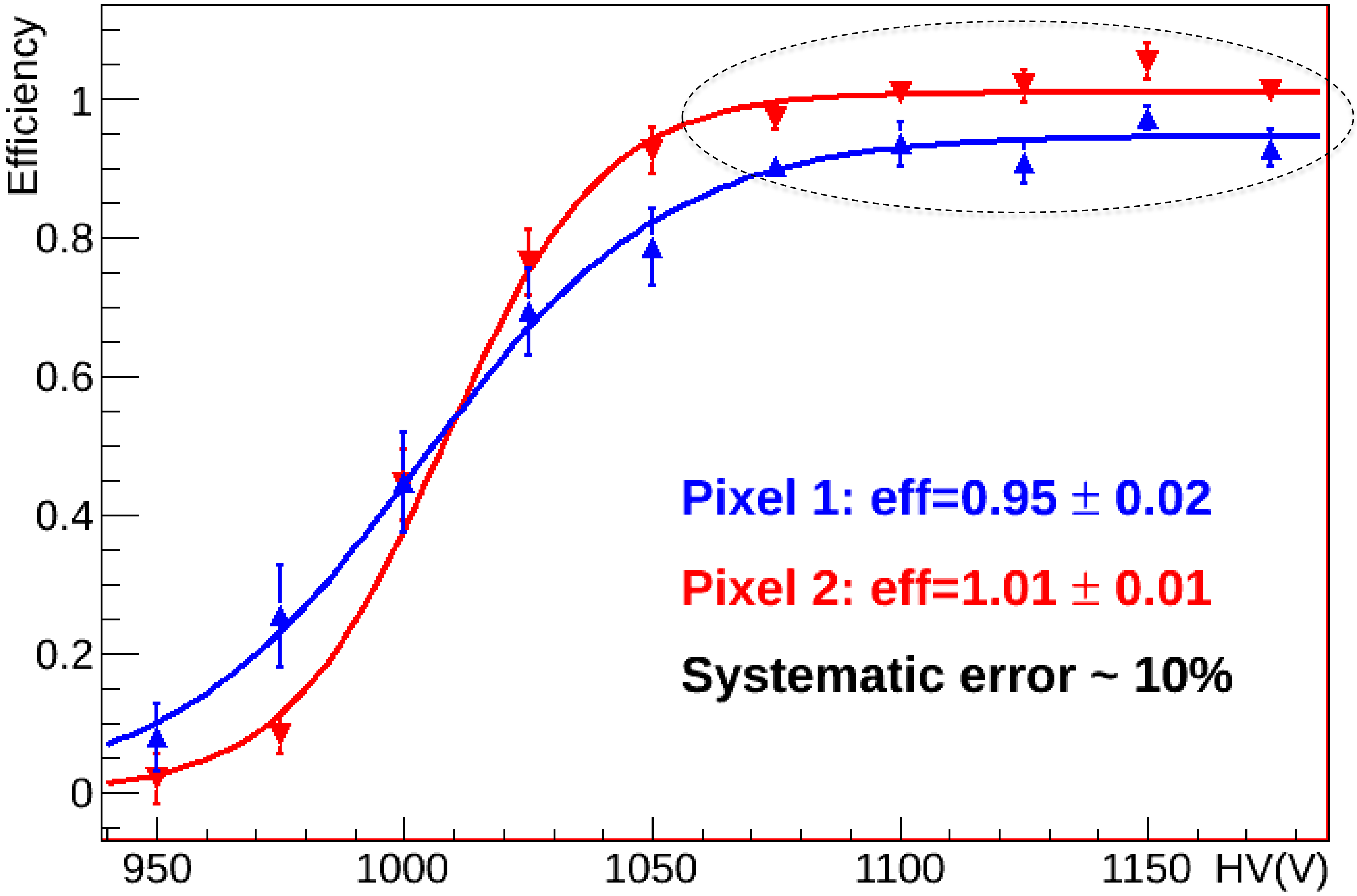


1st test with same panel but ***different*** gas mixture (2.7 days)

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

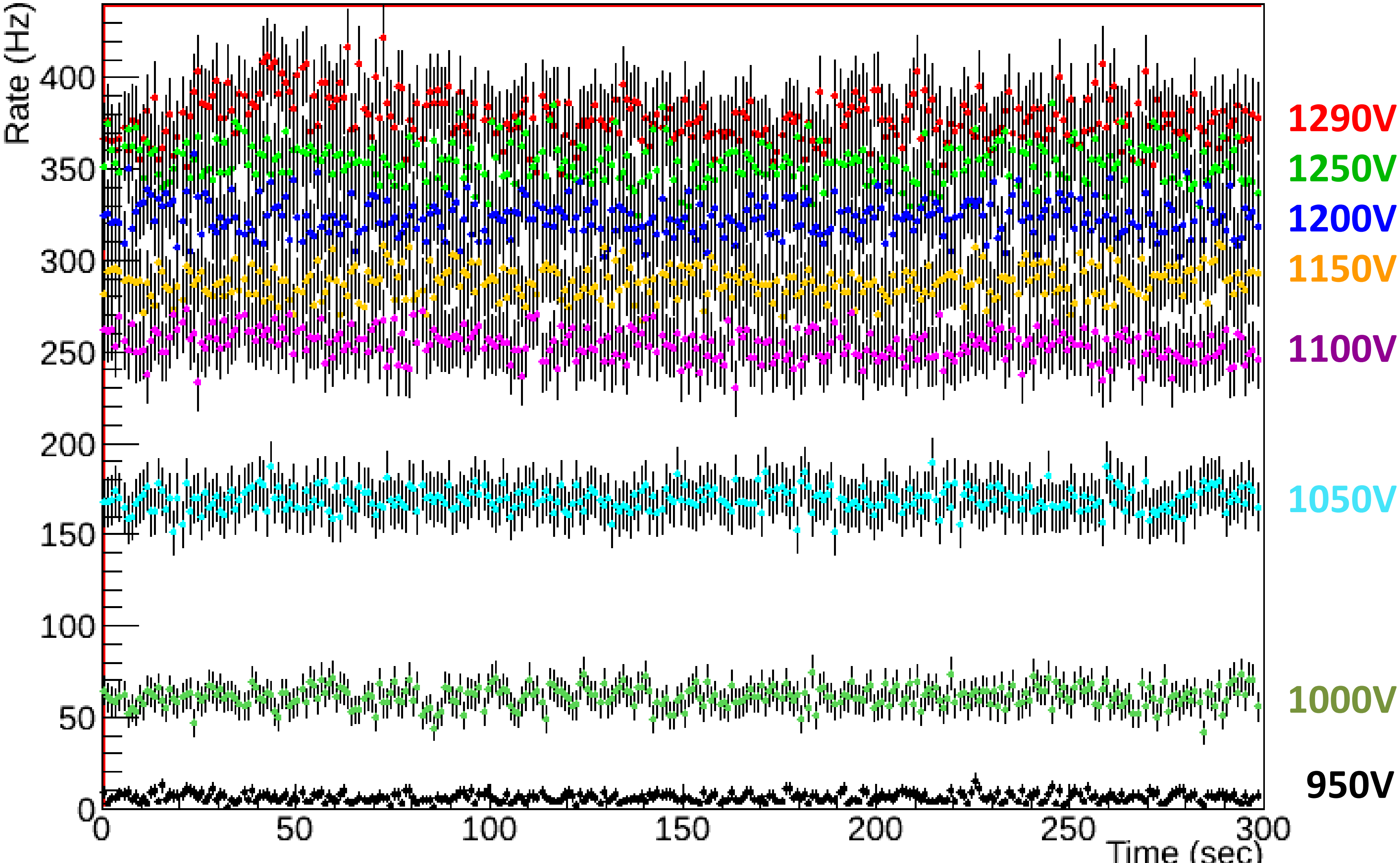
Many days of stable response, RMS variation ≈ 3%

Pixel Efficiency (β-source)

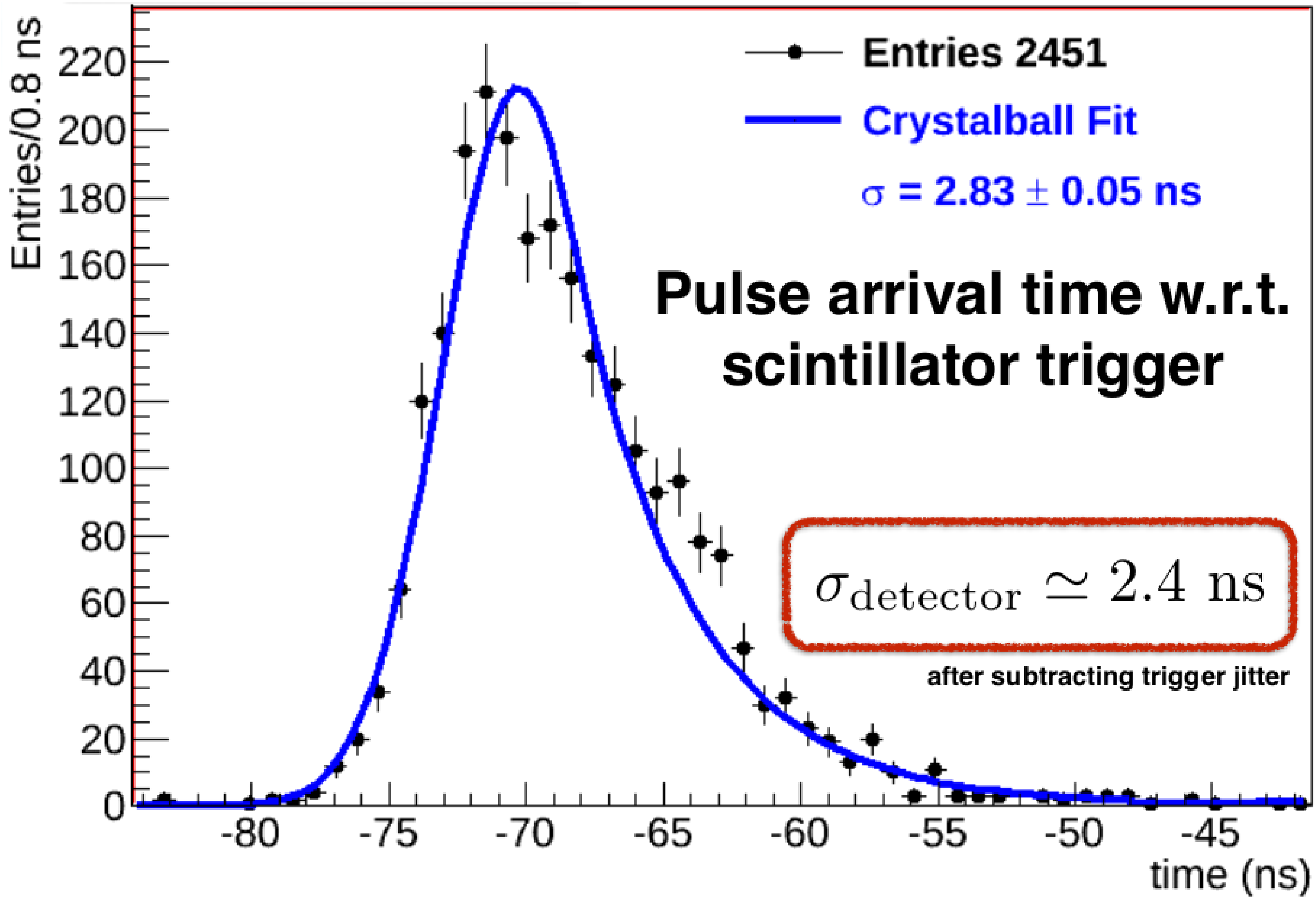


Single Pixel Rate vs. Time

Uncollimated source on pixel



Pixel Time Resolution - Jitter



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. Three (3) different *ultrathin* PPS device structures are under development – two (2) based on *glass substrates* and one (1) based on *foil cover plates*.**

- **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 sources.**

- **Based on our successful Phase-II program, Integrated Sensors is moving forward with interested parties on ultrathin-PPS particle detectors primarily for medical and scientific applications.**