Development of a Plasma Panel Radiation Detector

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Plasma detector design characteristic (lateral discharge detector)

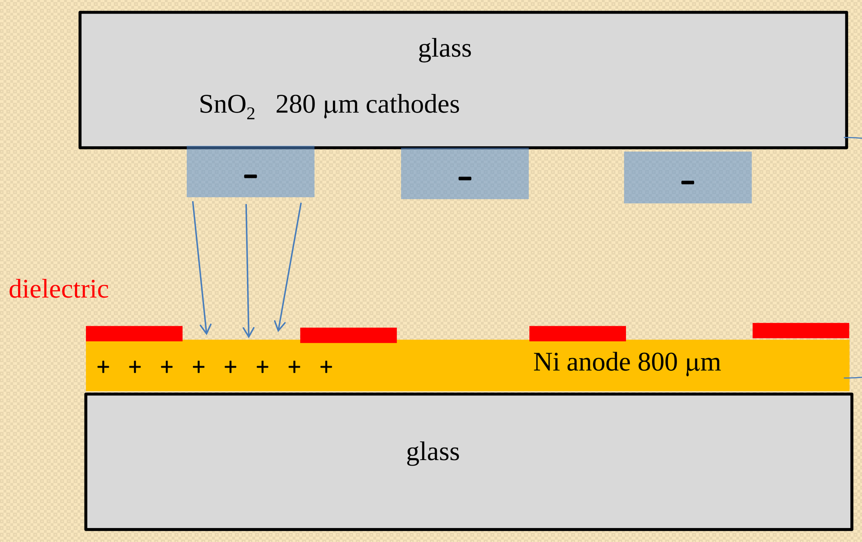
- Drift region of ~3 mm
- Generation of ~20-30 ion-pairs for high MIP efficiency
- Avalanche initiated by free drift electrons
- Avalanche across a transverse gap on substrate
- Field lines converge on sense electrodes
- High fields (MV/m) to initiate discharge at few hundred volts
- Cells defined by localized capacitance & discharge resistor in the HV line
- Discharge resistor formed by embedded resistance or resistive layer
- Resistance limits and localizes the discharge
- Drift electrode is being perforated with windows to maximize the viewing of possible light emission

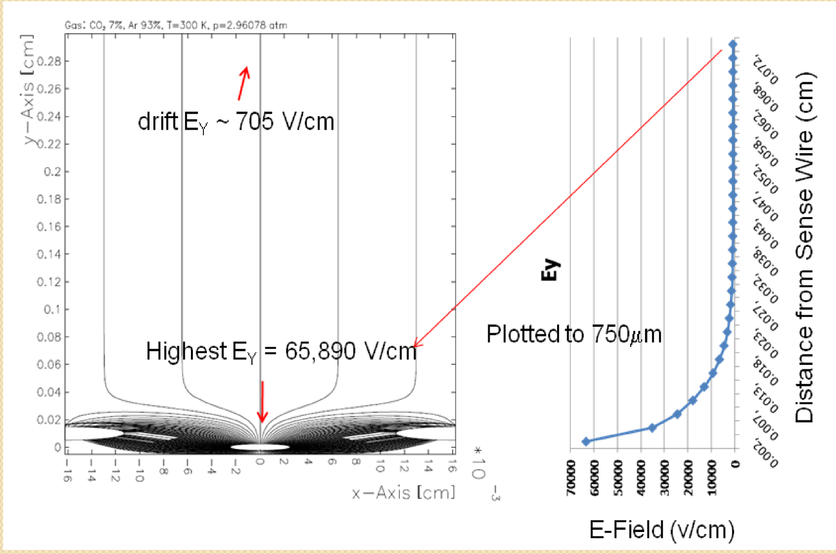
Plasma Panel Sensors key attributes

- Arrays of electrodes forming gas discharge regions
- Electrode deposition: photolithography on glass
- Small electrode gaps
  ➔high electric fields at low voltage
- Gas: Non-reactive, inert Penning mixtures
- Large panels (60") produced. Scalable detector sizes
- Glass < 1 mm, low Multiple Coulomb Scattering
- Hermetically sealed panels at 200-700 Torr
  ➔No gas supply system!
- Established industrial infrastructure
- Low fabrication costs: ~ \$0.30 inch^{-2}
  (current market sale price, including electronics)

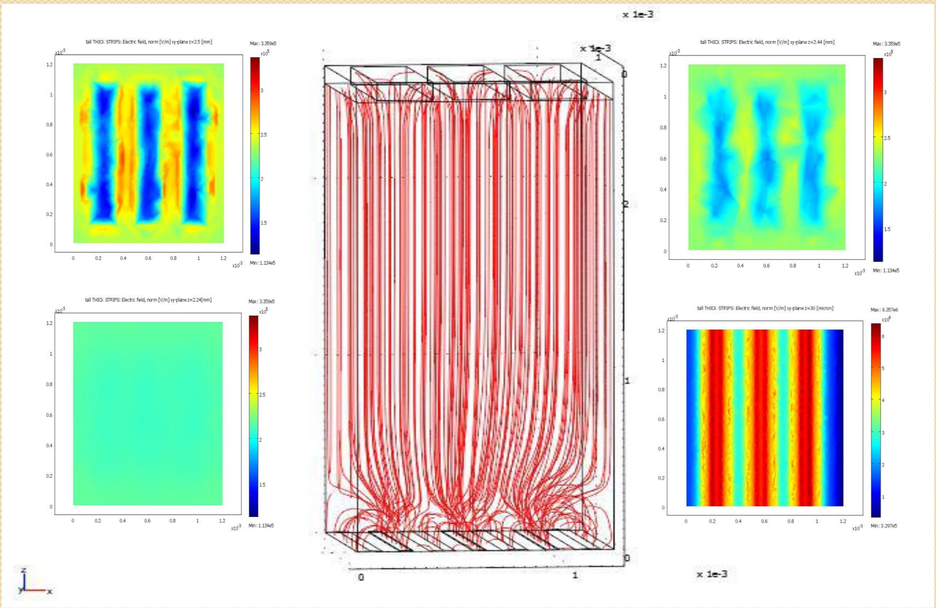
From commercial monochrome PDPs to Plasma Detector

- Columnar discharge – Matrix Configuration (ACM)
- Pixels at intersections of orthogonal electrode array
- XY Readout is possible (both sense and HV electrodes)

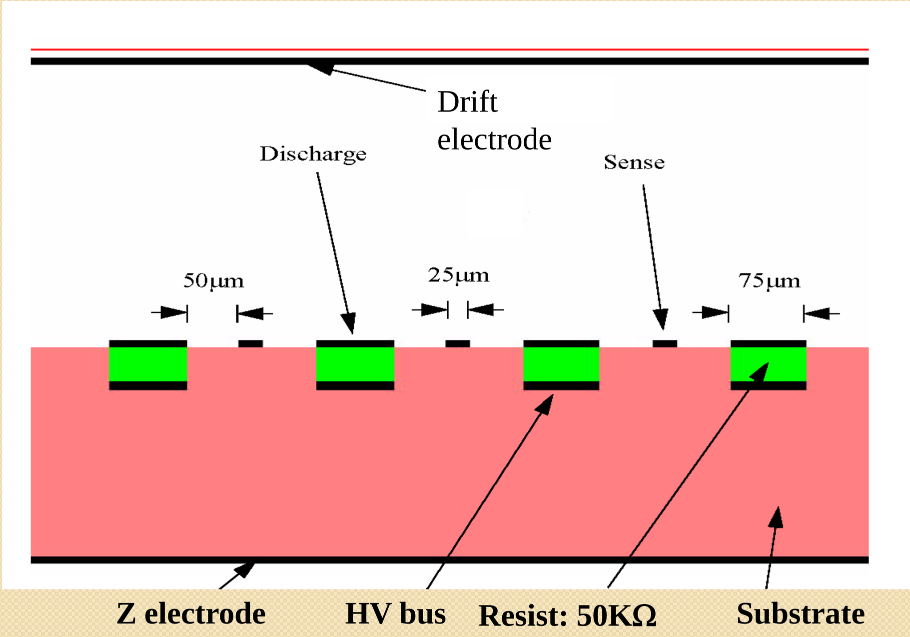




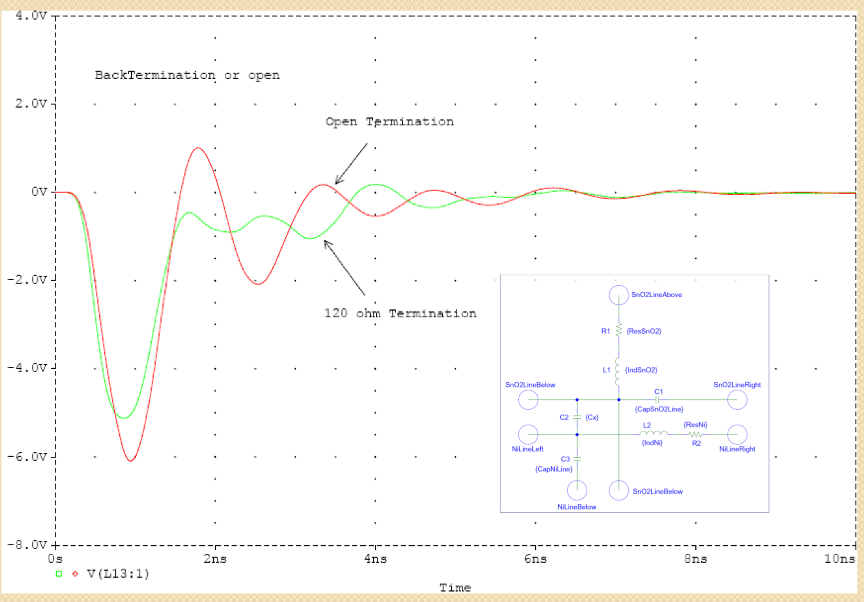
2D electrostatics (GARFIELD): Electric field lines converge to sense electrodes: MV/m at the sense electrode



Above: 3D electrostatic simulation (COMSOL): (center) convergence of the electric field lines near the electrodes, (bottom right) uniformity of the field beneath the drift electrode (40 µm-top left, 100µm-top right, 300µm- bottom left).



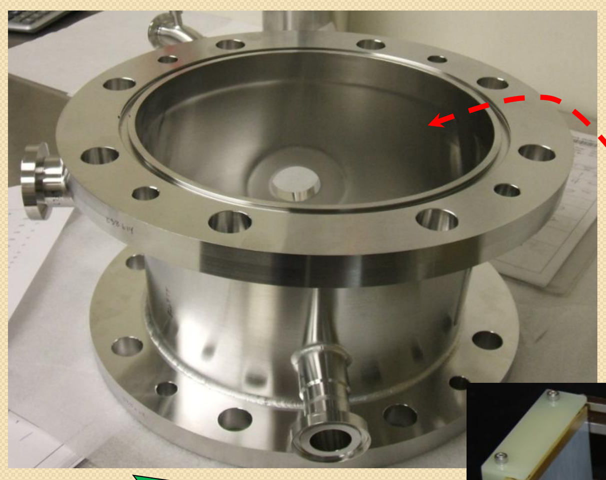
Above: 2D view of conceptual representation for test device substrate: Pixels formed by HV (discharge) and sense lines gaps. Quench resistances from resistive deposition. Signals form on sense electrodes.

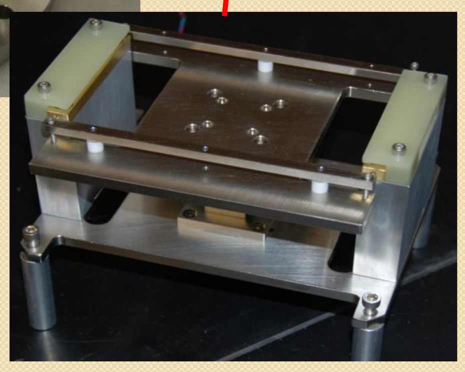


Above :SPICE simulation of signal induced in the panel by a near δ-function current source and the effect of termination resistors on the signal shape. In the square: SPICE model of one pixel.

Gas mixing system

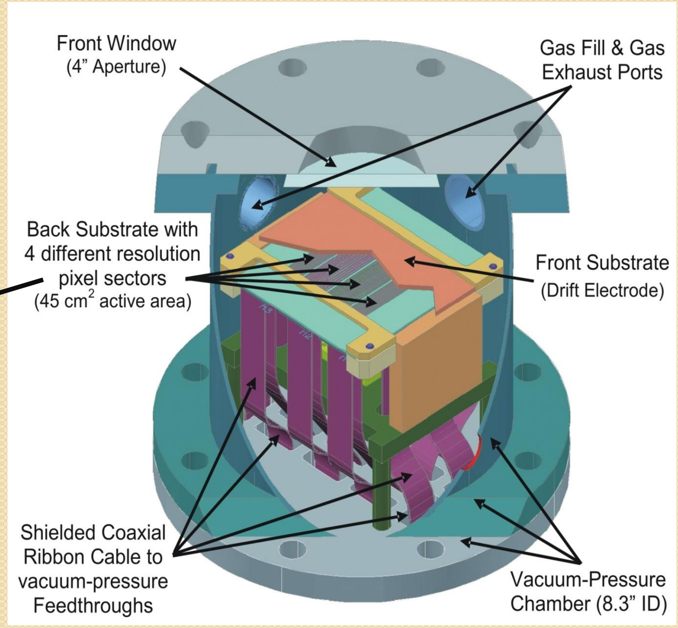
- Mixtures of five different gases
- Working Pressure of up to 4 Bar
- Mass flow controller allows high precision in gas composition

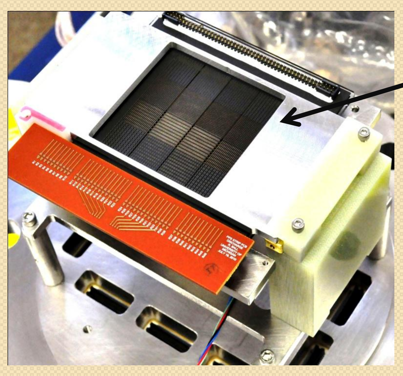




Plasma Panel Sensor (PPS) test chamber

- Ports for rapid gas removal and refill
- Stepper motor stage for test substrate (adjust drift gap)
- Signal/HV vacuum feed-throughs
- Drift electrode: metalized glass (photocathode) or metal window
- Working pressure range 0.5 - 4 bar



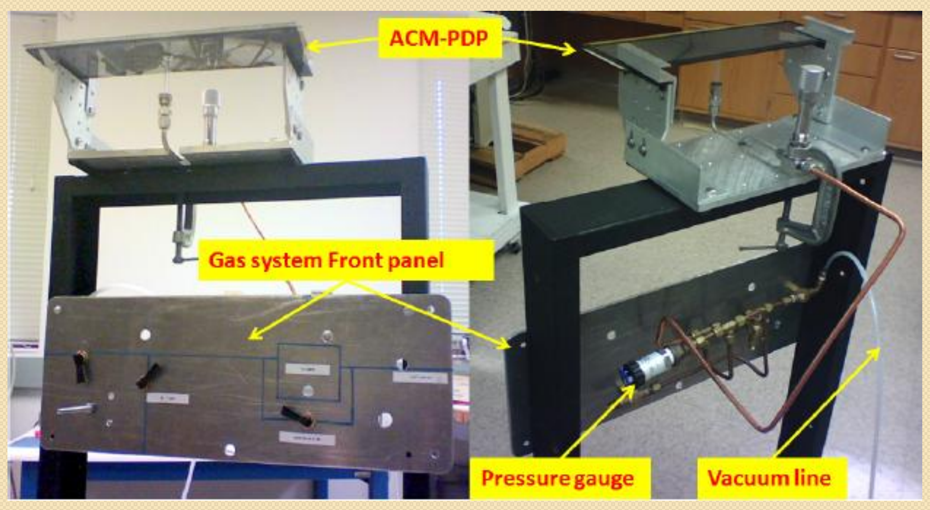


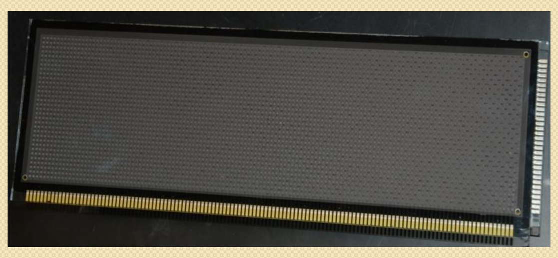
Simulation effort

- Electrostatics modeled with Maxwell-2D, COMSOL
- Drift & Avalanche properties simulated with GARFIELD
- Signal and voltage distributions computed with SPICE

First laboratory studies with columnar discharge commercial display panels which response to: UV photons, radioactive radiation (Sr^{90}) and cosmic ray muons.

- DC PDP Panel, filled with various gases at different pressures. Applied voltage varies with gas content
- Signal rise time < 10 ns
- Signal amplitude is > 5 V

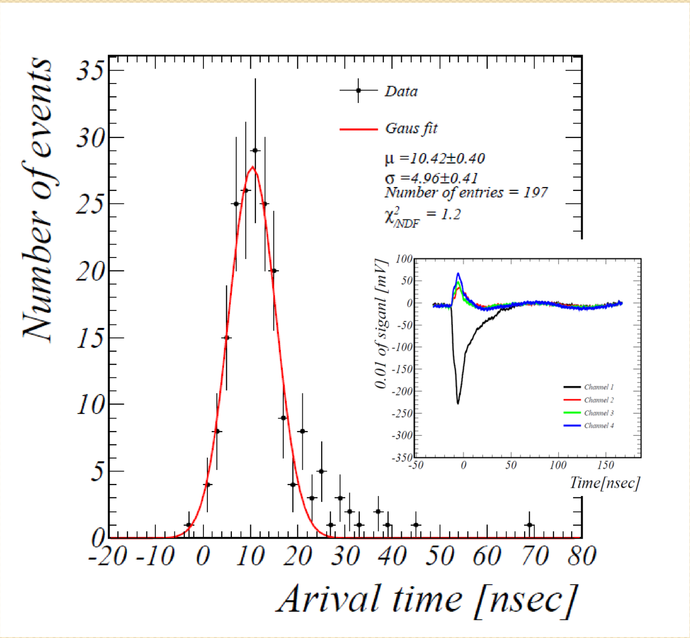




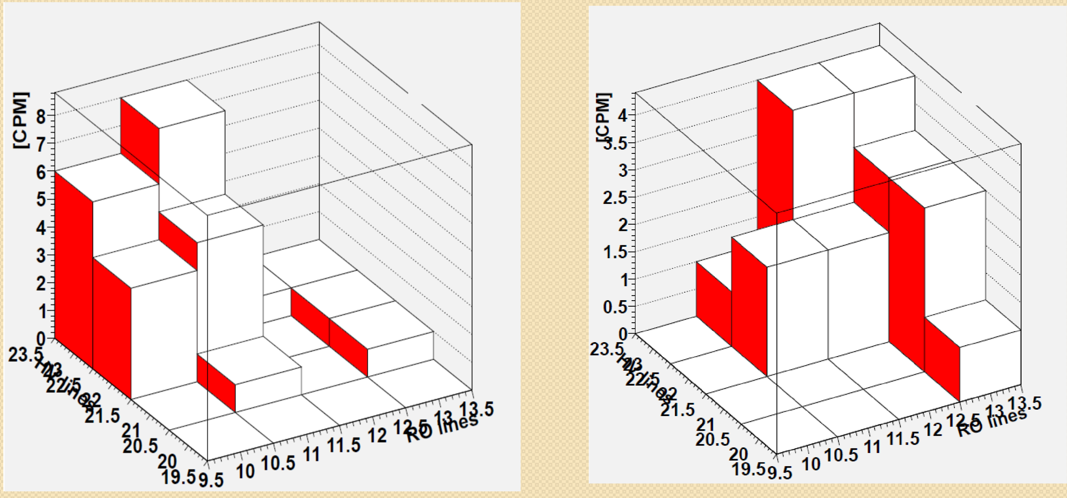
Above: A commercial display panel
Left: Laboratory test bench - Panel and gas system

Cosmic ray muons detection

- Arrival time distribution and a representative signal induced in the panel
- Gas content : SF_6 at 200 Torr and 1530 Volt

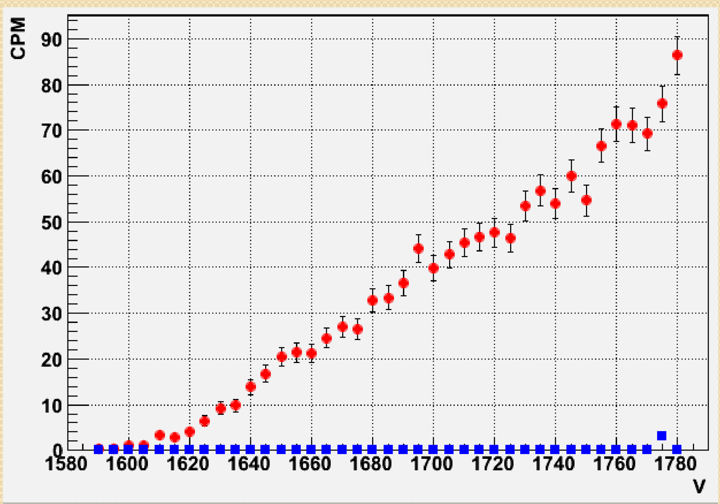


Collimated source 20cm above the panel over different parts of the active area – 4X4 pixel array



Each bin shows the hit rate on one pixel - background subtracted

Signal and background rate measurements



Red: Signal rate with the collimated source above the panel
Blue: Background (no source) rate
Gas content: CF_4 at 500 Torr