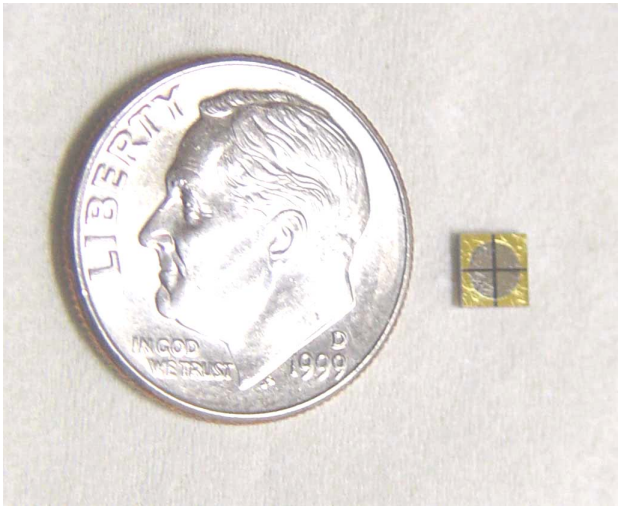
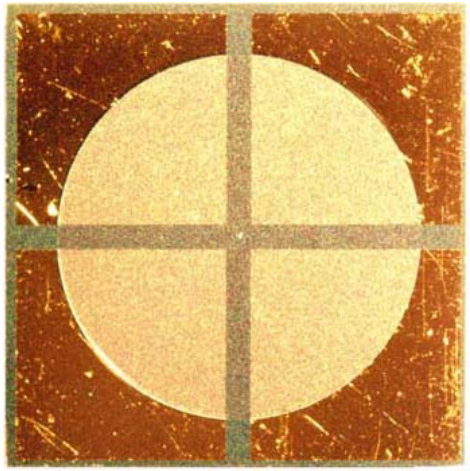
Hydrogen sensor diagnostic

Bob Bastasz, Dmitry Rudakov, Adam McLean, Josh Whaley, Clement Wong
Sandia National Laboratories and General Atomics

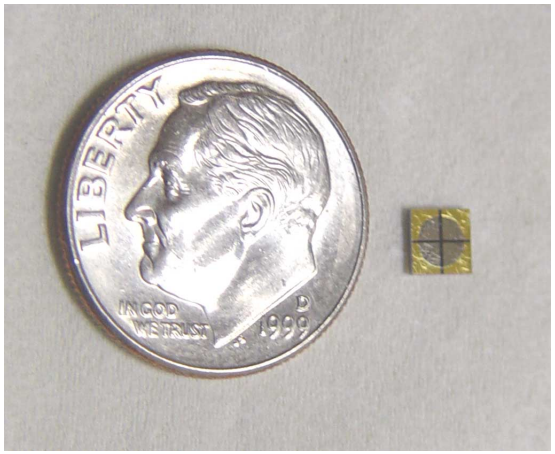


outline

- **H sensors**
- **DiMES diagnostic**
- **DIII-D test**
- **data analysis**
- **status & plans**



Metal-Insulator-Semiconductor (MIS) sensors



4 element hydrogen sensor chip
4 mm × 4 mm

- MIS gas sensors are solid-state devices that detect hydrogen.
- The sensors are small, low-power devices that have good sensitivity and selectivity to H.

- MIS sensors detect hydrogen using a catalytically-active metal incorporated into a semiconductor device.

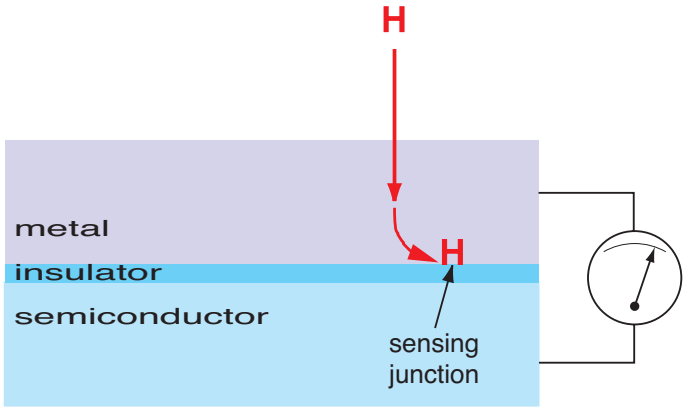
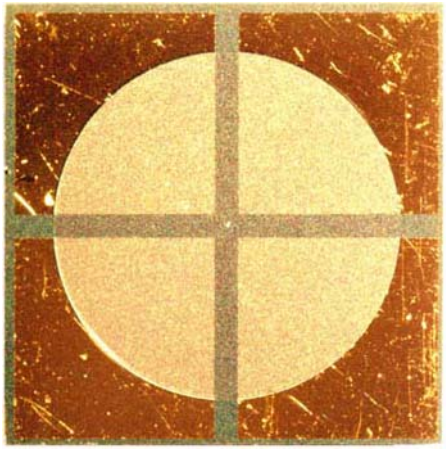


diagram of a MIS sensor structure

Solid-state H sensors for PMI diagnostics

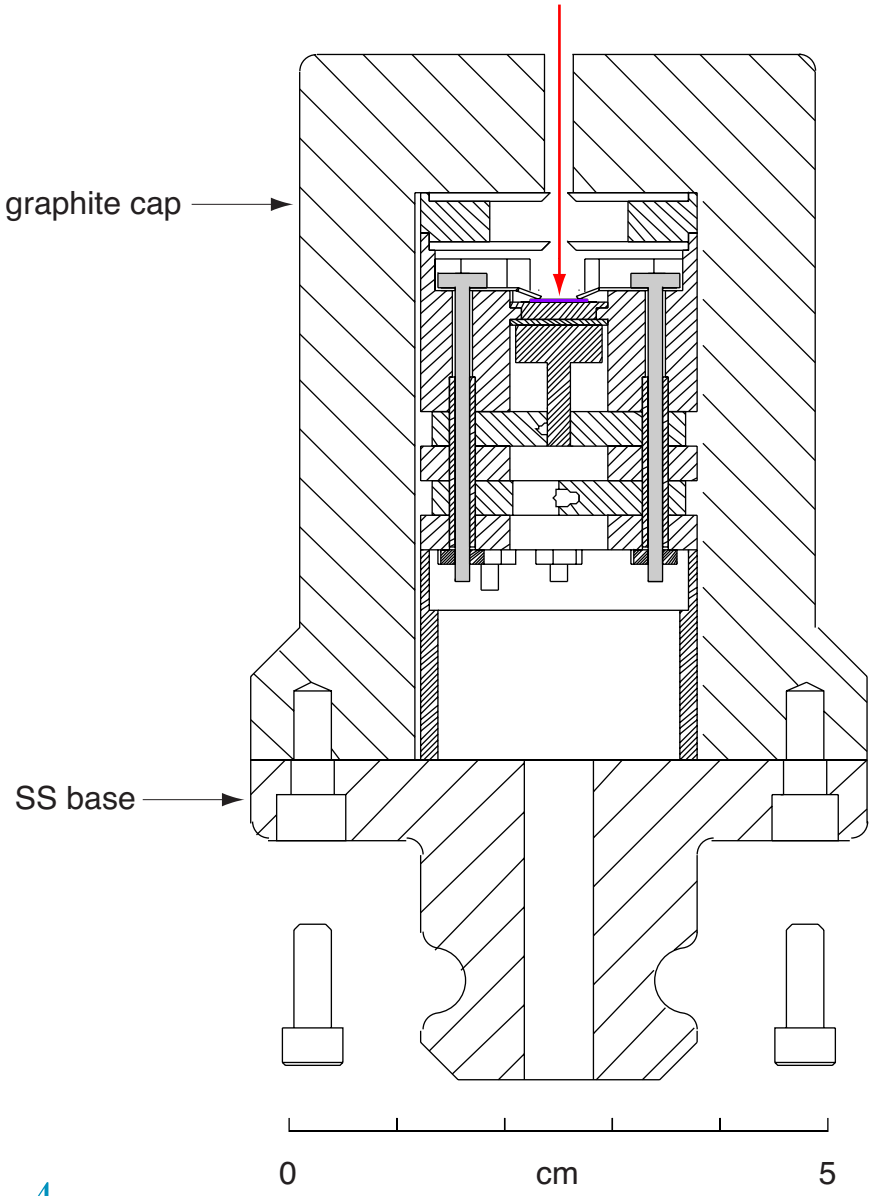
- H microsensors have several desirable properties:



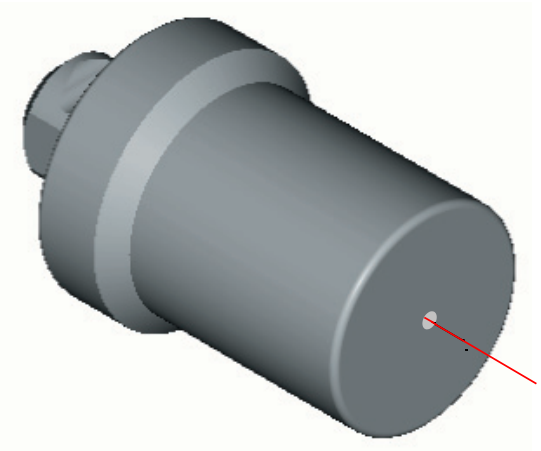
  - small, low power consumption
  - detects all H isotopes
  - compatibile with T, n, and X-rays
  - provides electrical readout.

- H microsensors can be used to:
  - monitor the particle flux to PFCs
  - study spatial and directional anisotropies
  - measure the energy of impinging particles.

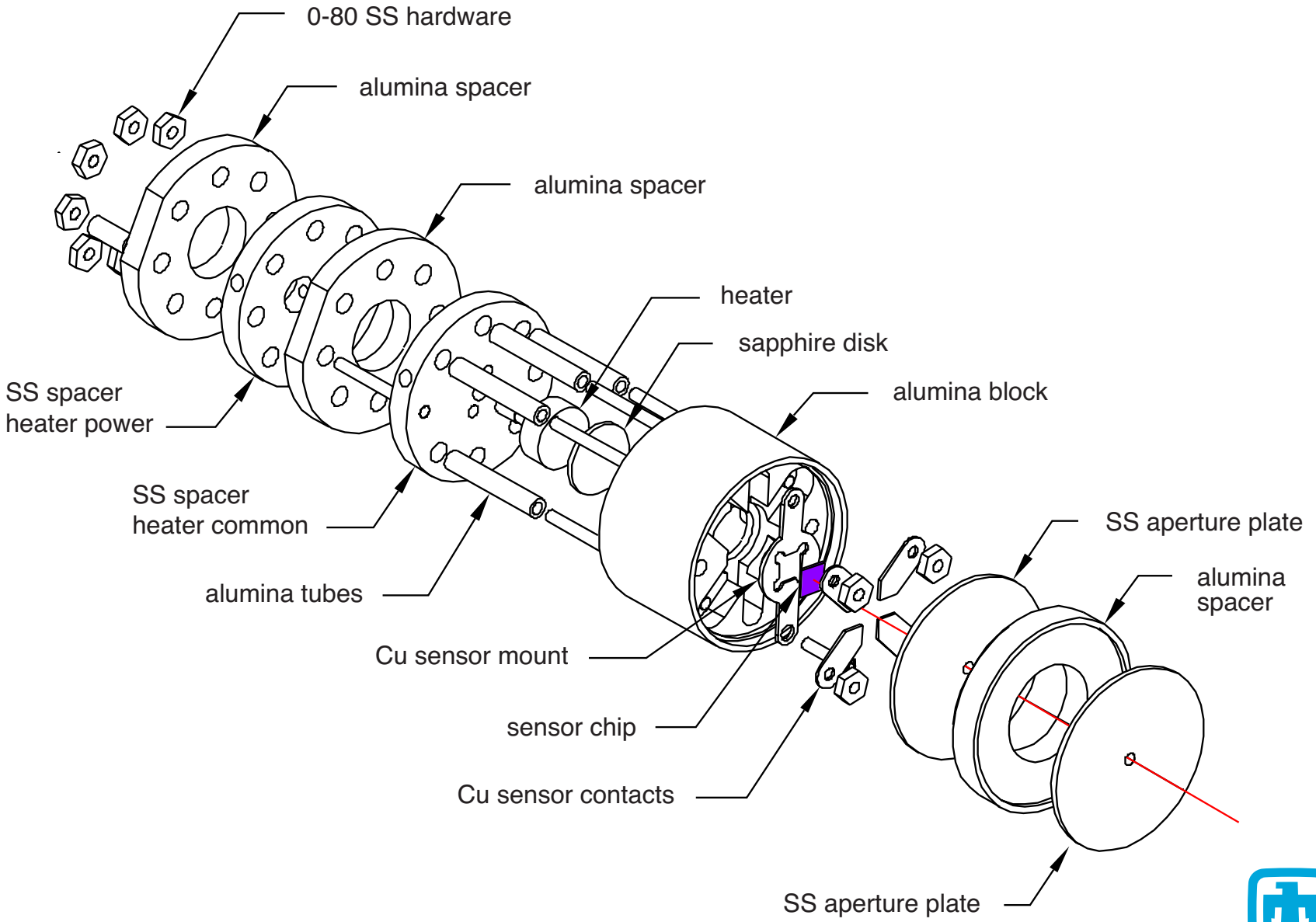
H sensor PMI diagnostic for DiMES



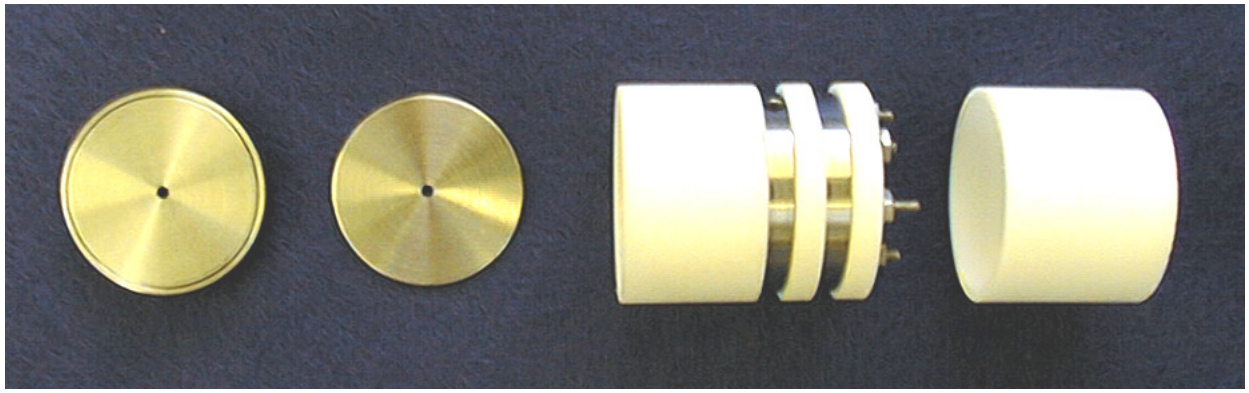
- fits inside DiMES sample
- detects energetic H (and D)
- apertures exclude ions
- integrates CX flux
- reports after shot ends

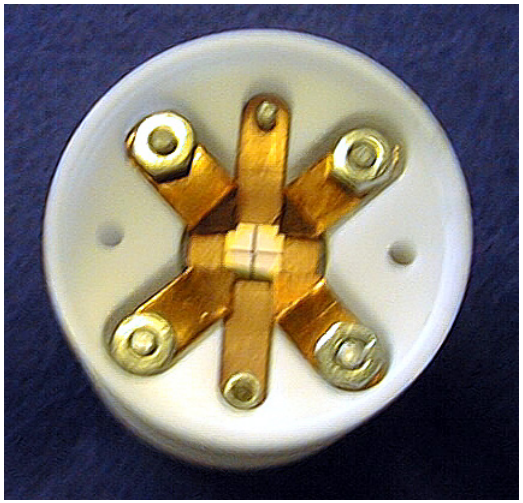


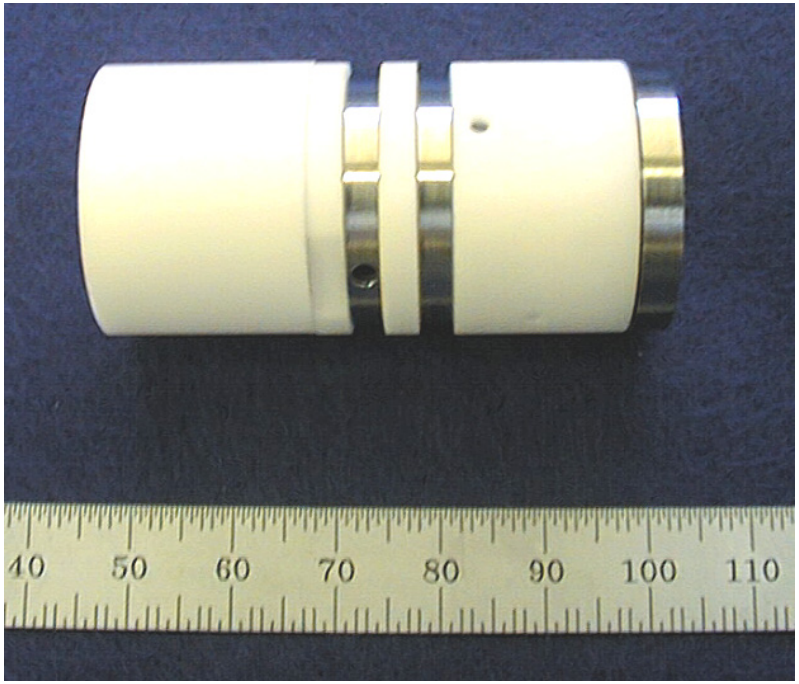
DiMES H sensor assembly



DiMES H sensor components

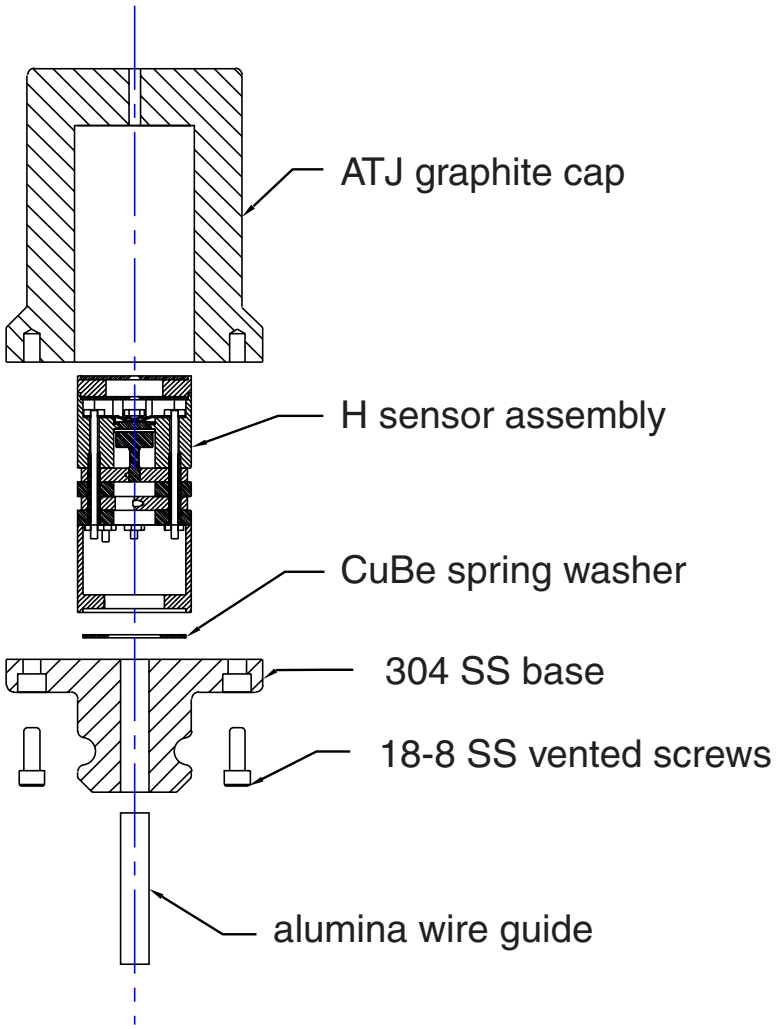






assembly holds one chip with 4 sensors

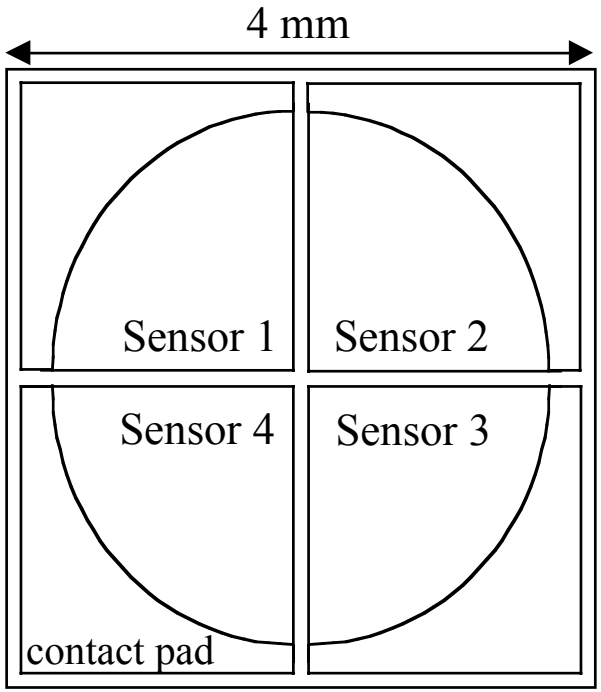
The sensor cartridge fits inside a DiMES sample.



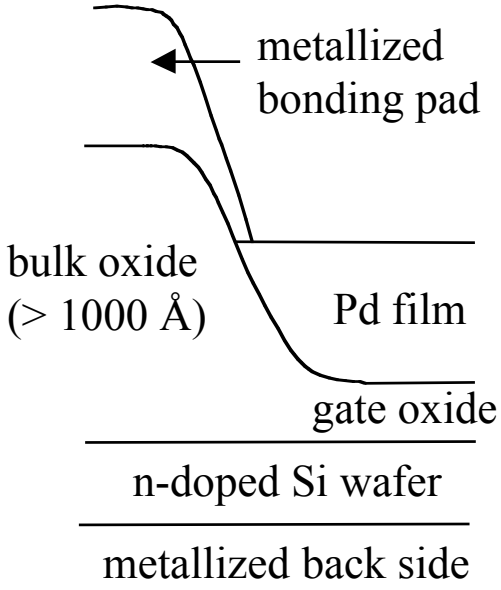
- Most of the diagnostic is made from standard vacuum materials.

Each chip contains 4 MIS hydrogen sensors.

Sensor layout



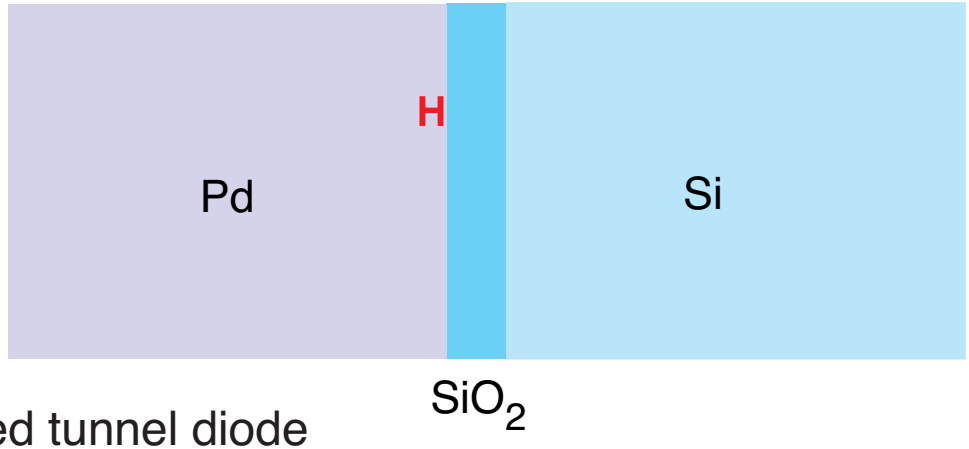
Device structure



- Devices fabricated in the CSRL at Sandia

MIS hydrogen sensors: theory of operation

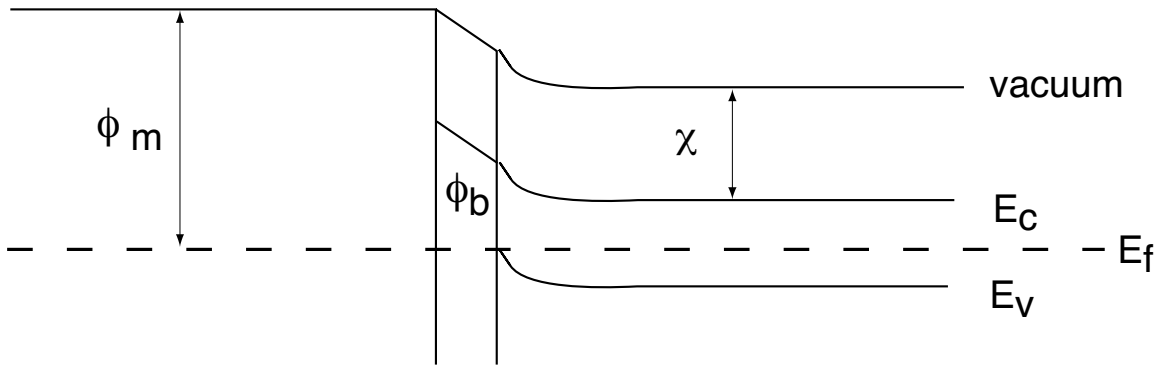
- Atomic hydrogen
  1 - filters quickly through metal
  2 - traps near interface
  3 - alters barrier height
  4 - affects electron flow across junction.



- Example: a reverse-biased tunnel diode

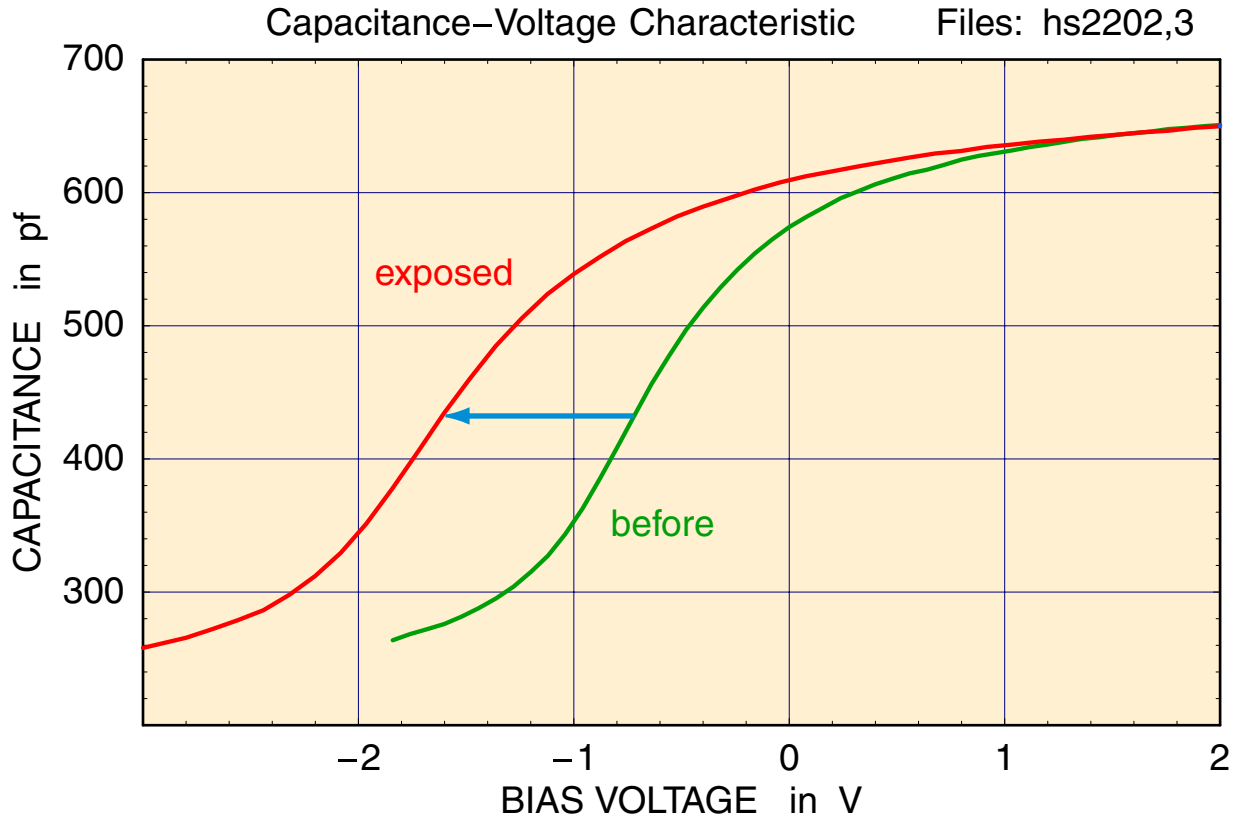
$$\phi_b \doteq \phi_m - \chi$$

$$I_r = A\, e^{-\phi_b/kT}$$



small barrier height change ⇒ large device response

Example of a Pd-MIS capacitor response to H

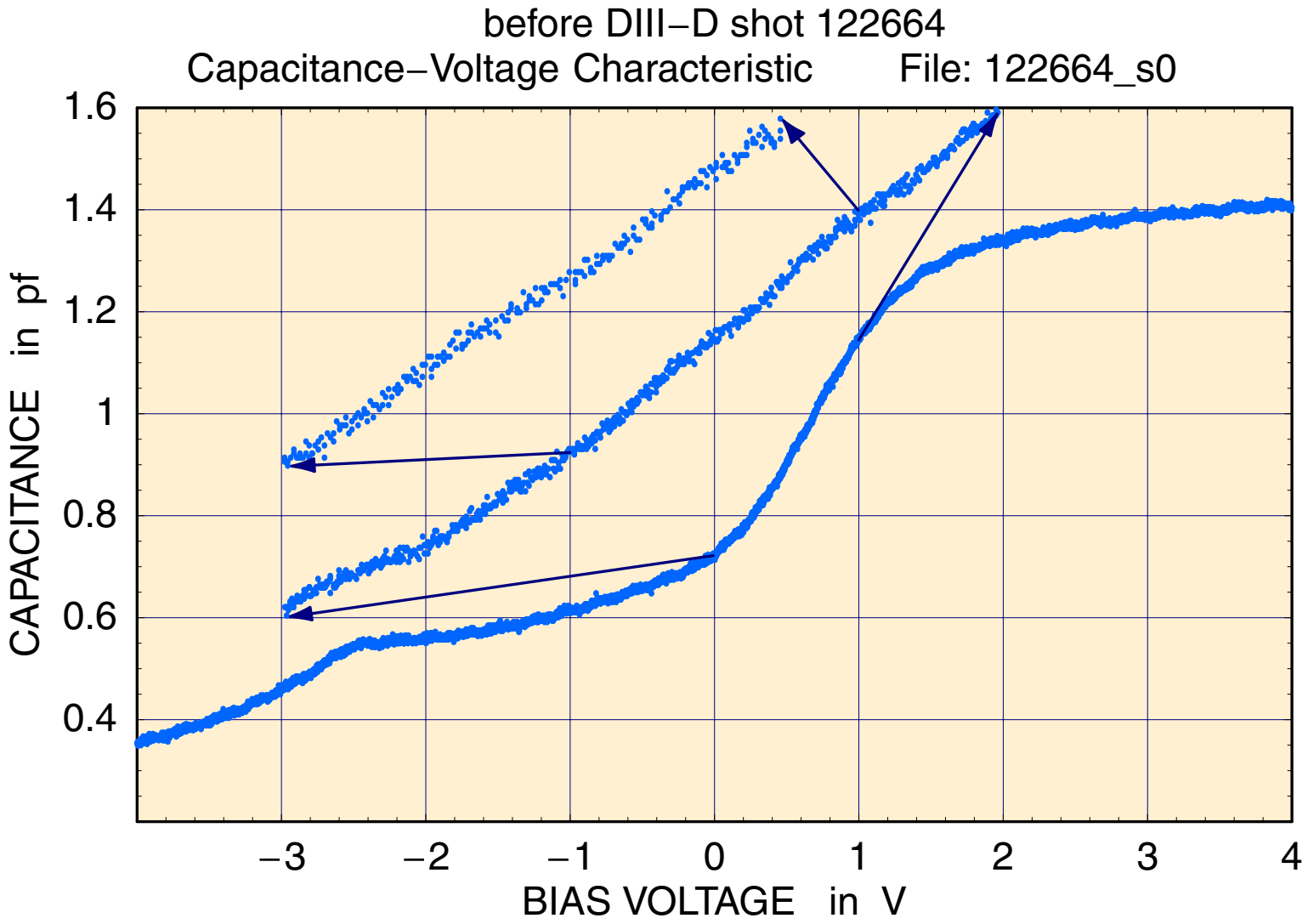


- CV curve shifts upon exposure to H.
- Monitoring the bias voltage change at the inflection point gives a measure of H dose.
- The response is fast with thin Pd films (ms).

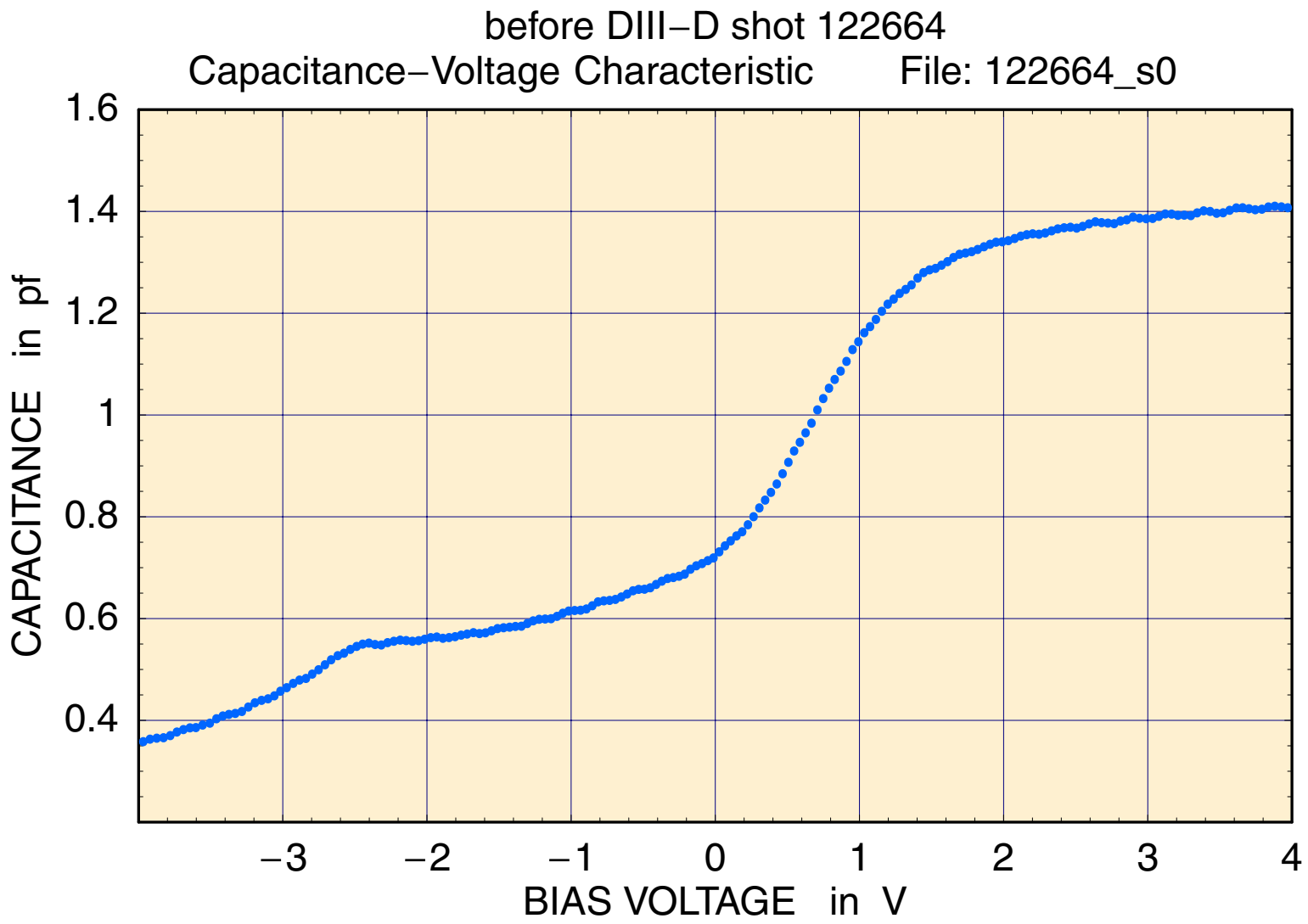
Tests in DIII-D

- The diagnostic was connected to DiMES for checkout in February, 2005.
- It was put into position in DIII-D on March 21 and monitored three days of plasma shots.
- CV curves were recorded every second from 18 sec before each shot to about 80 sec afterwards.
- The diagnostic was in place for 118 shots on 3/21,22,25, 92 of which provided data.
- 3 of the 4 sensors responded to the plasmas; the signal response changed from shot-to-shot.
- The data are currently being reduced and analyzed.

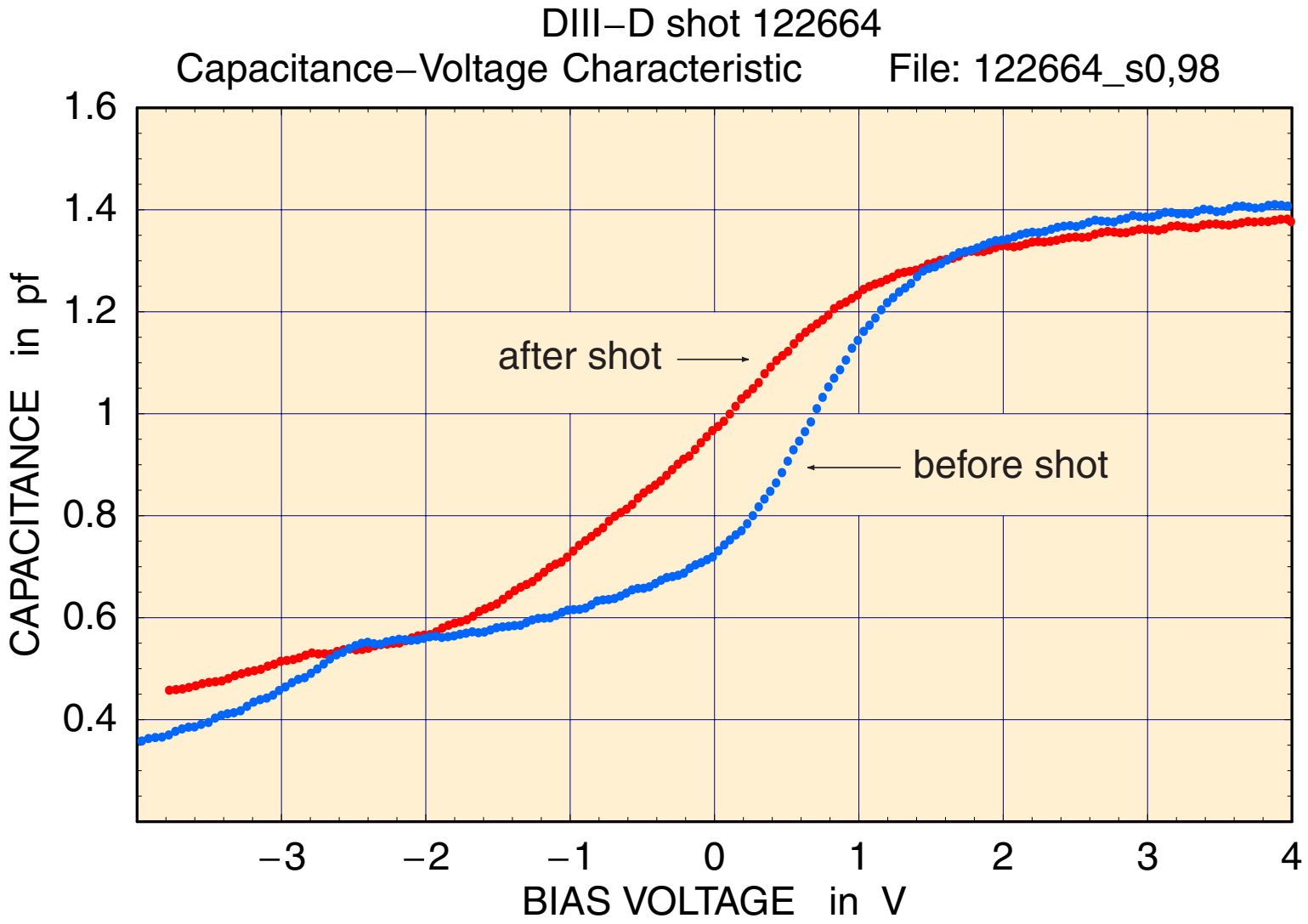
Example of raw data: a CV curve before a shot



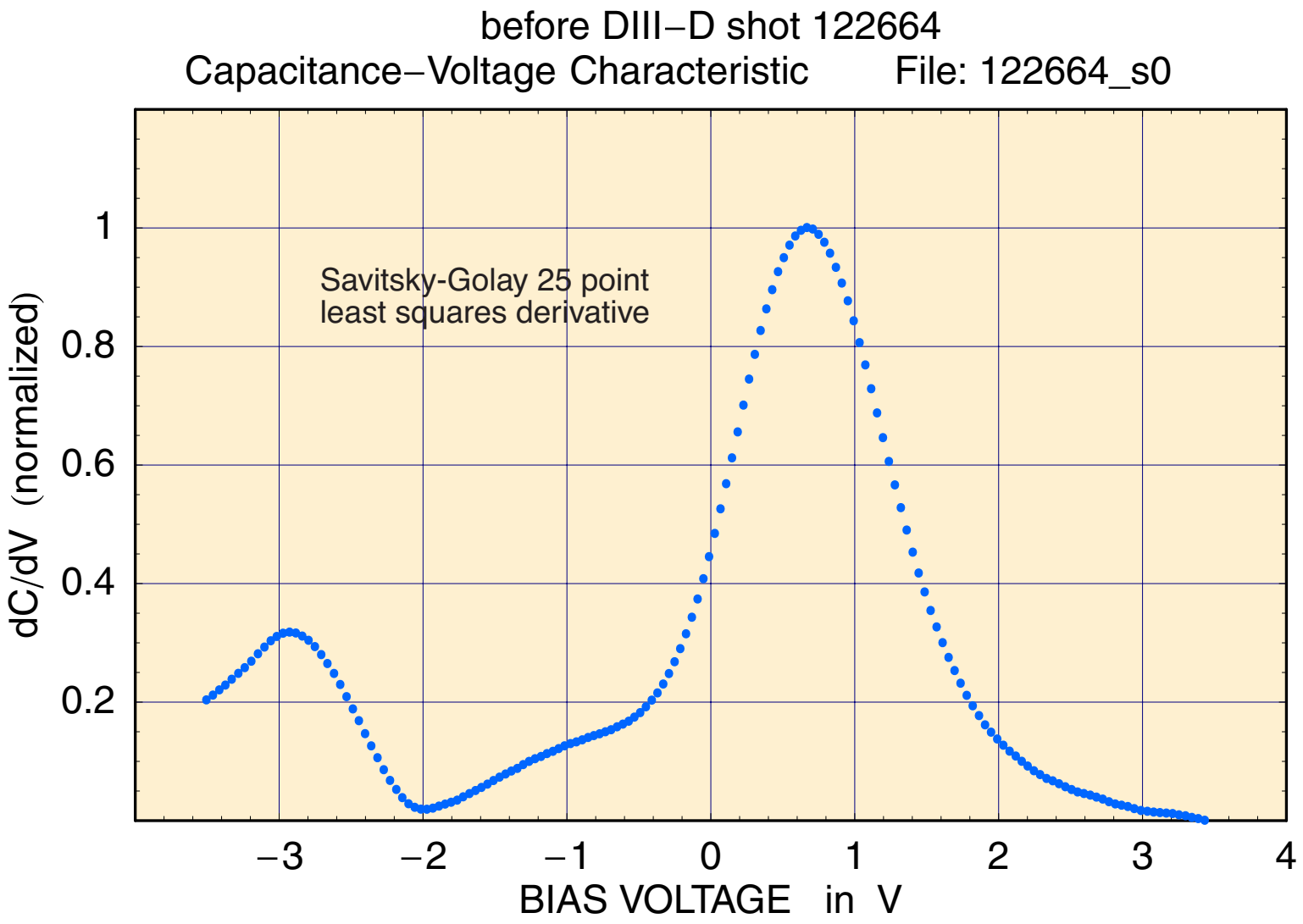
Example of data: 25 point average



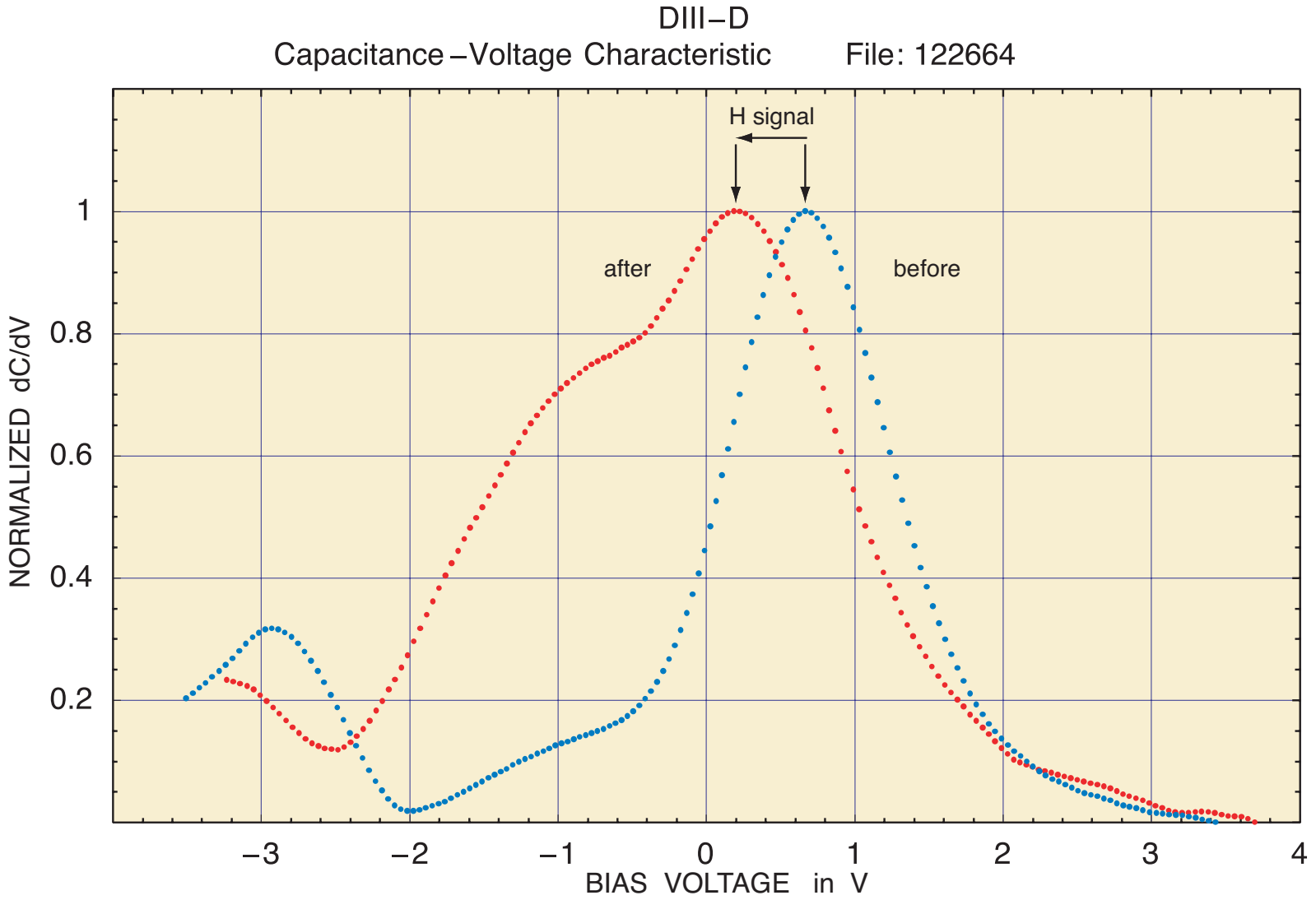
Example of data: before and after shot CV curves



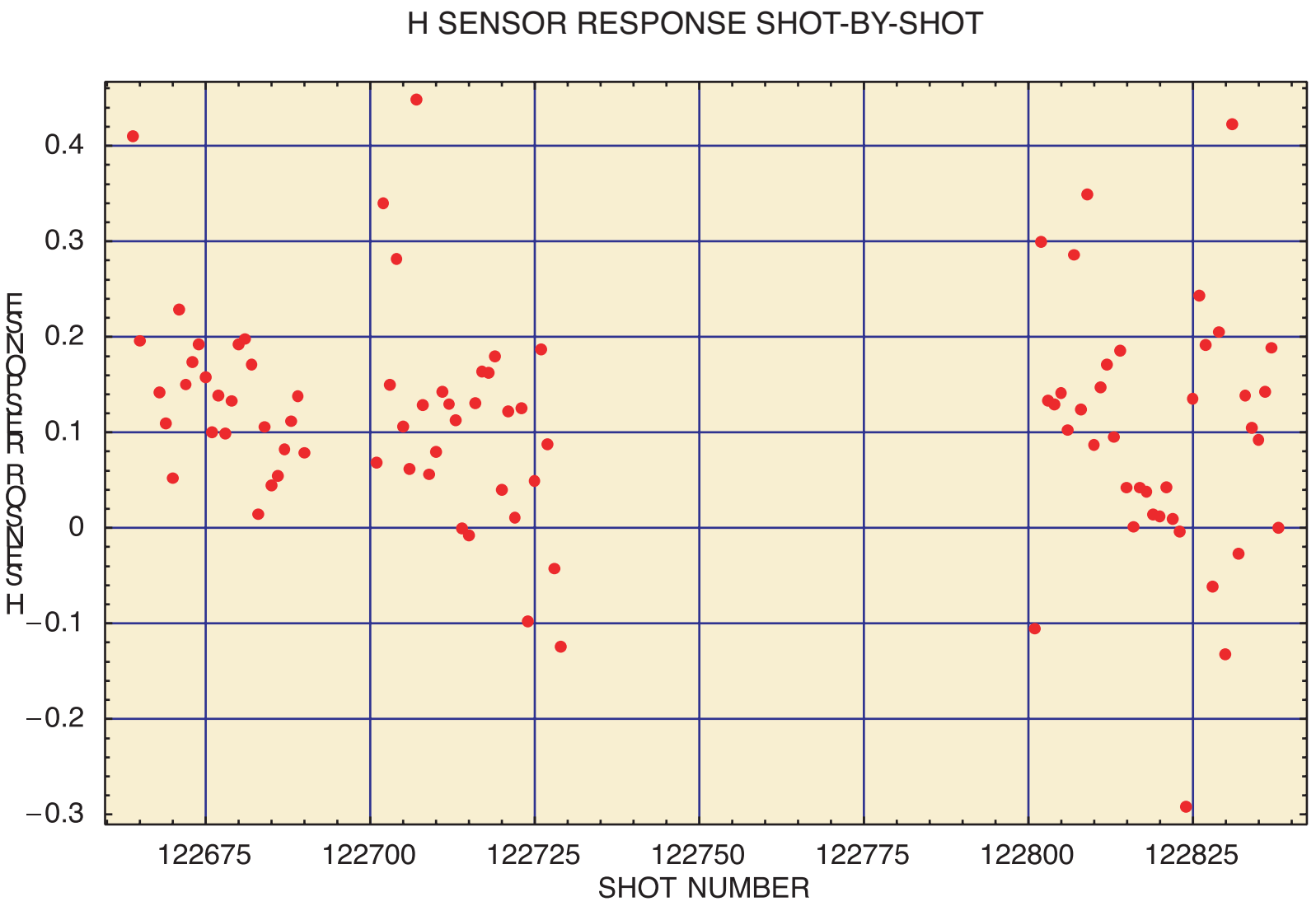
Example of data: evaluation of flat band voltage



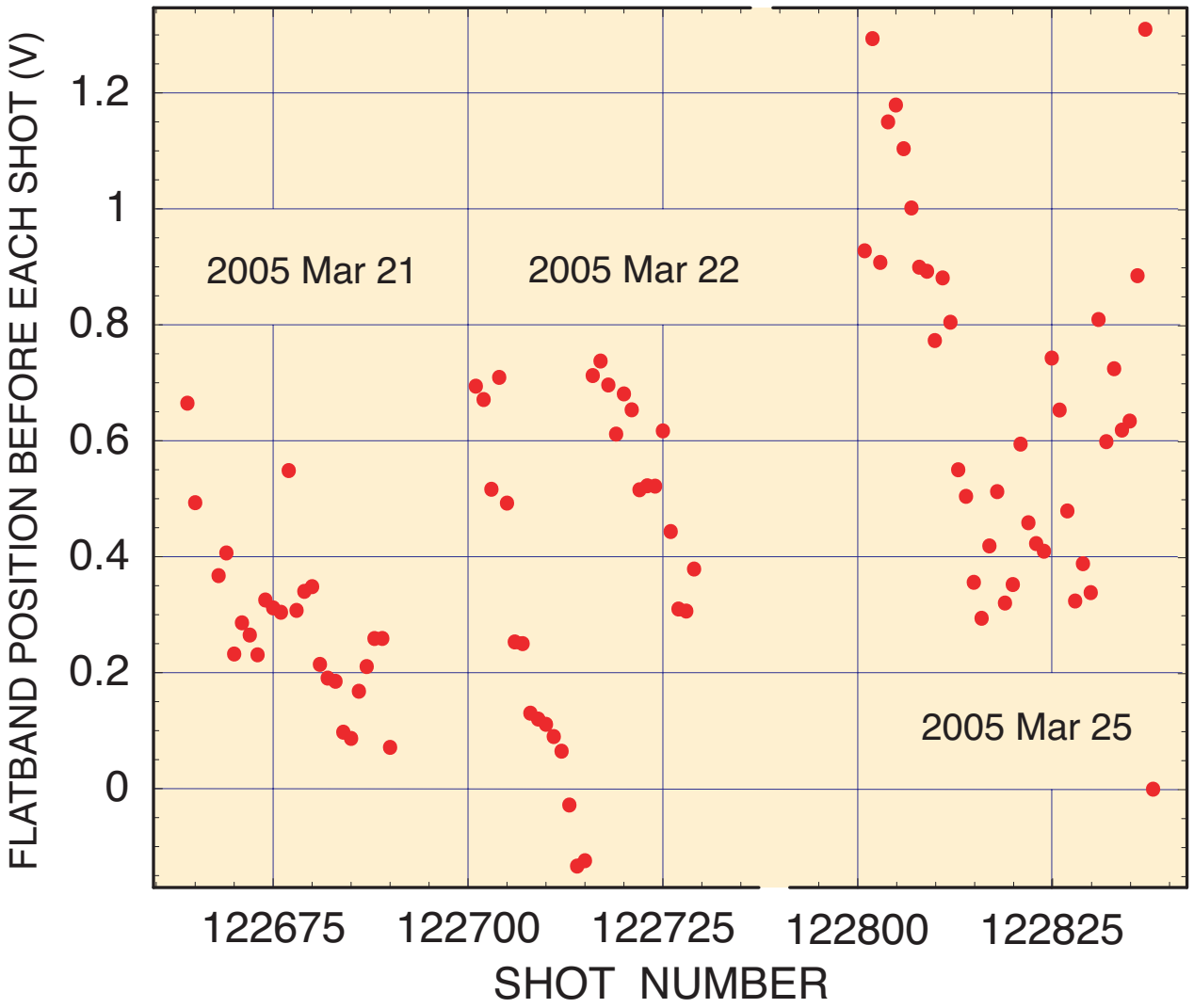
Example of data: evaluation of sensor response



H sensor shot-by-shot response



Cumulative response over 3 days of operation



Further data analysis

(1) Correlate data with strike-point position

(2) Correlate data with edge-plasma parameters

(3) Compare data with other diagnostics

(4) Apply H loading factor to response

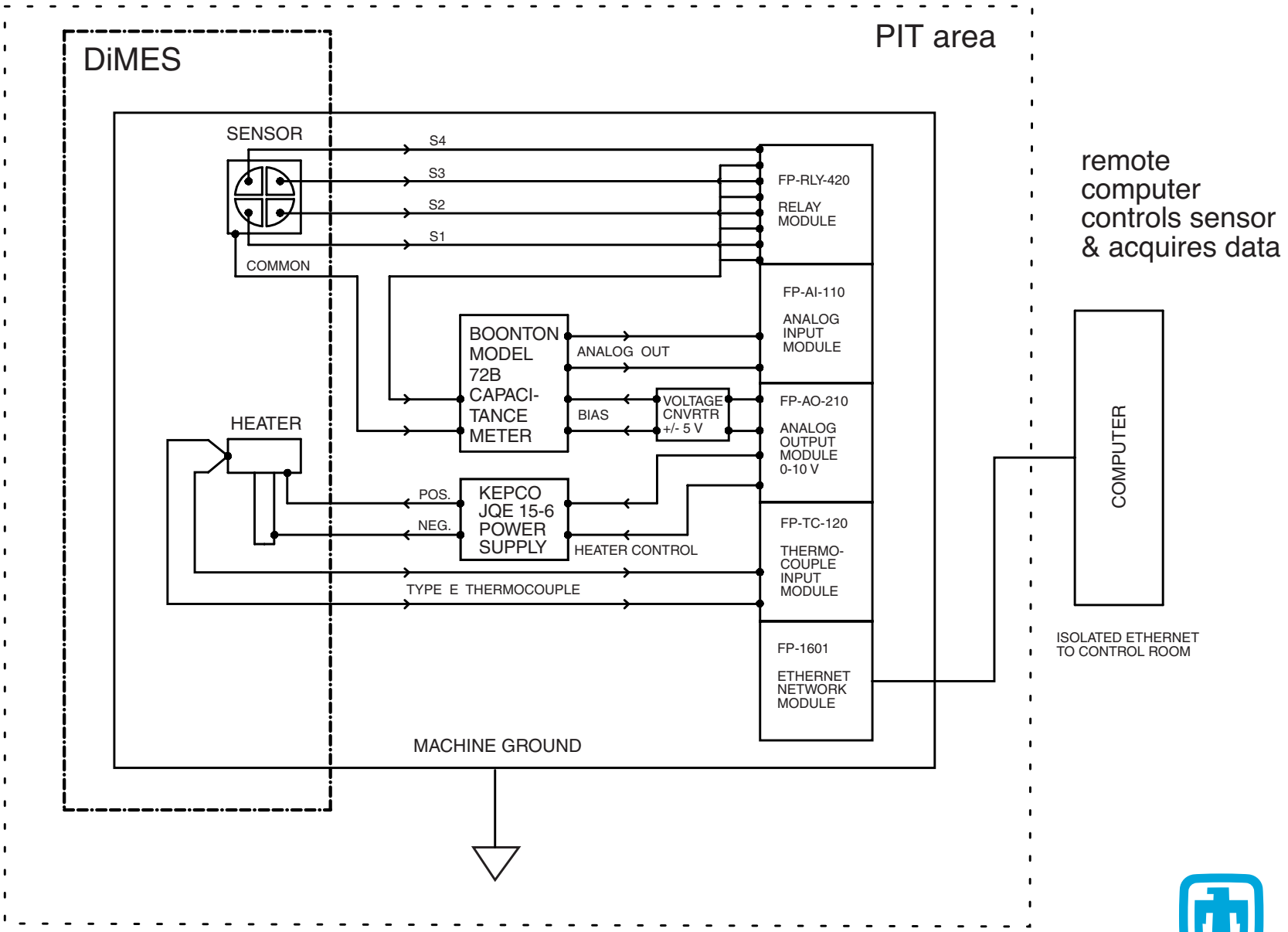
(5) Correct for temperature variations

(6) Calibrate sensors using a known flux H^+ beam

Summary

- A compact diagnostic was built and tested using DiMES on DIII–D to monitor the energetic hydrogen CX flux to the divertor.
- The diagnostic successfully recorded 3 days of plasma shots in DIII–D.
- Data are being analyzed and studied.
- More operation in DIII–D is planned, including adding a sensor to the new mid-plane DiMES (MiMES).
- The possibility of installing the diagnostic on NSTX, LHD, or other devices is being considered.
- The potential use of solid-state hydrogen sensors in distributed PMI diagnostics for ITER is being explored.

DiMES H sensor connection diagram



No direct correlation with neutron output.