Testing during the assembly of the CDF detector

1st Workshop on QA Issues in Silicon Detectors
17-18 May 2001

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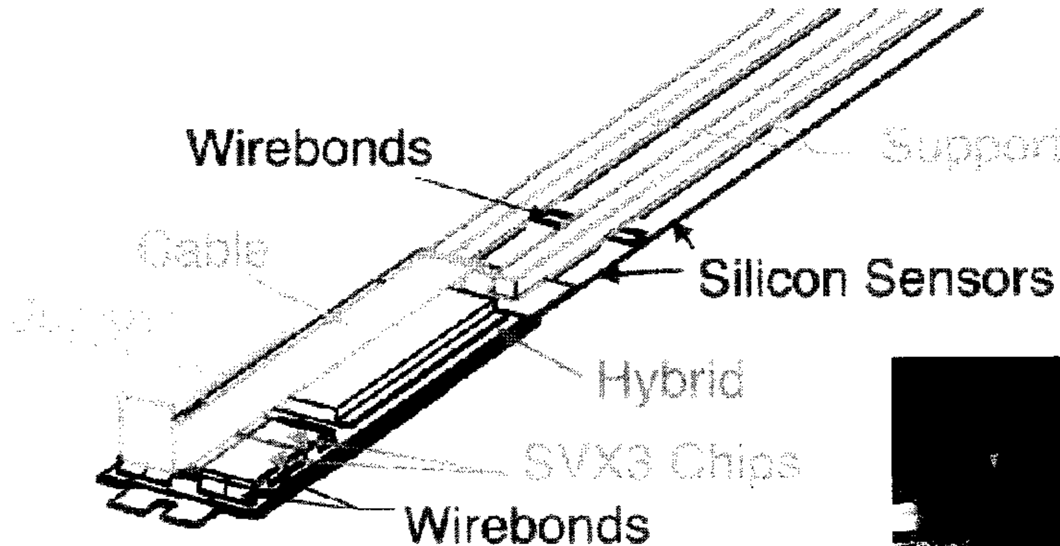
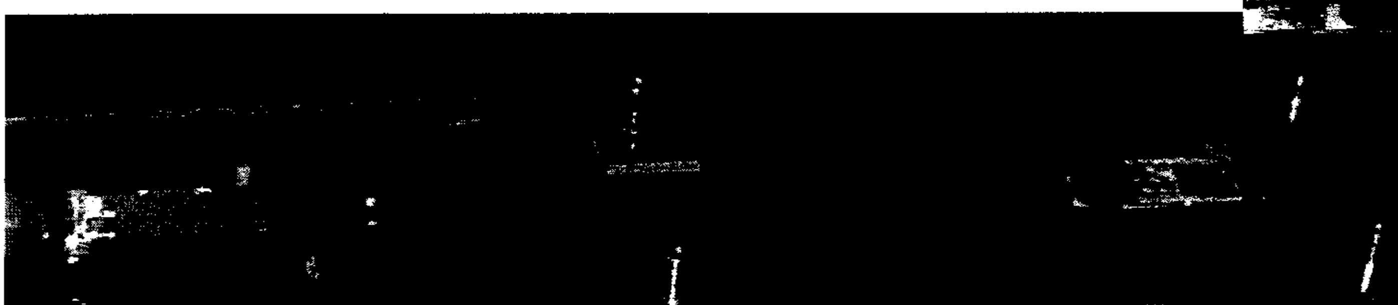
Outline

- The SVXII modules
- Assembly procedures
- Testing procedures
- Systematic problems and associated repairs
- Throughput and limiting factors
- Double sided sensors and Biasing Scheme
- “MOS effect”
- BURNIN procedures and results
- Bad channels distribution
- Database
- Considerations & Conclusions

Ladders Assembly

SVX II half ladder, consisting of two silicon sensors wirebonded with the readout electronics mounted on the first sensor.



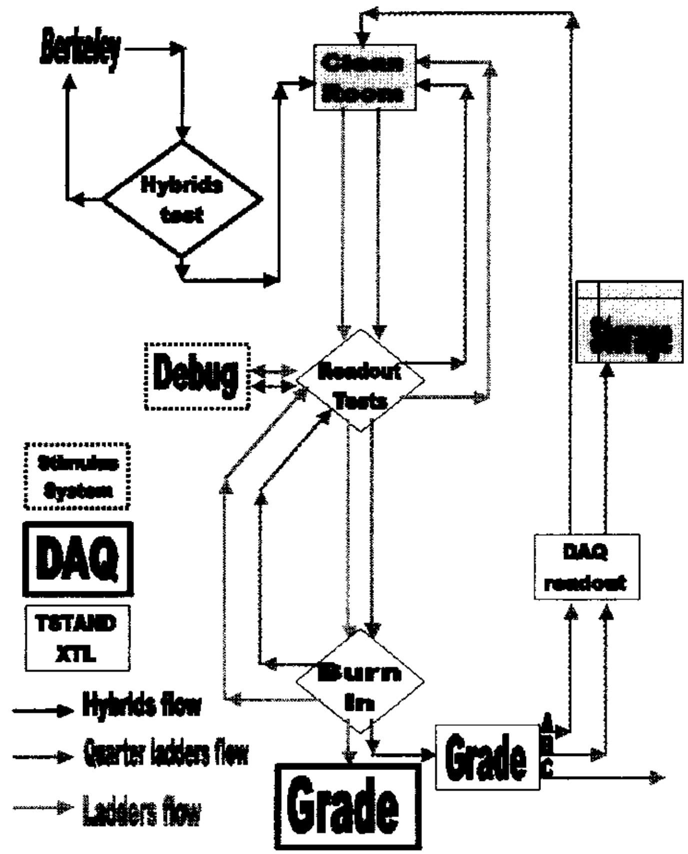


Ladders Assembly

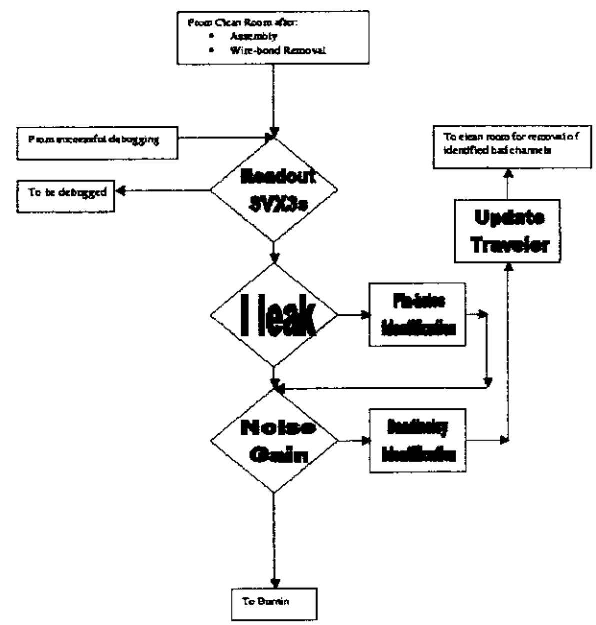
- **In house painting of sensor scratches**
- **Quarter Ladders (QLS):**
  - **Jumper, split Z, Z hybrid and thermal bridge glued on Silicon.**
  - **Bonding of the Z side (silicon and jumper)**
  - **Phi hybrid glued on Silicon**
  - **Bonding of the Phi side**
  - **Verification of alignment**
- **Full Ladders (FLs)**
  - **Alignment (2 QLs 2 middle sensors) with Phi side up**
  - **Bonding of Phi side**
  - **Carbon fibers rails glued**
  - **Bonding of Z side**

Ladders Testing

Testing Flowchart



Read-out Tests



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Ladders construction

- **30 % of the ladders had to go through the repair loop**
- **100 % had to go through "maintenance"**
- **2 changes had to be implemented on each device during production:**
  - HV line through the jumper had to be bypassed with an external wire
    - **Procedure implemented after completing the full assembly of each ladder**
  - Capacitors for Digital voltage had to be replaced
    - **After 15 % of the production in order to have outer layers (mainly layer 4) working reliably**

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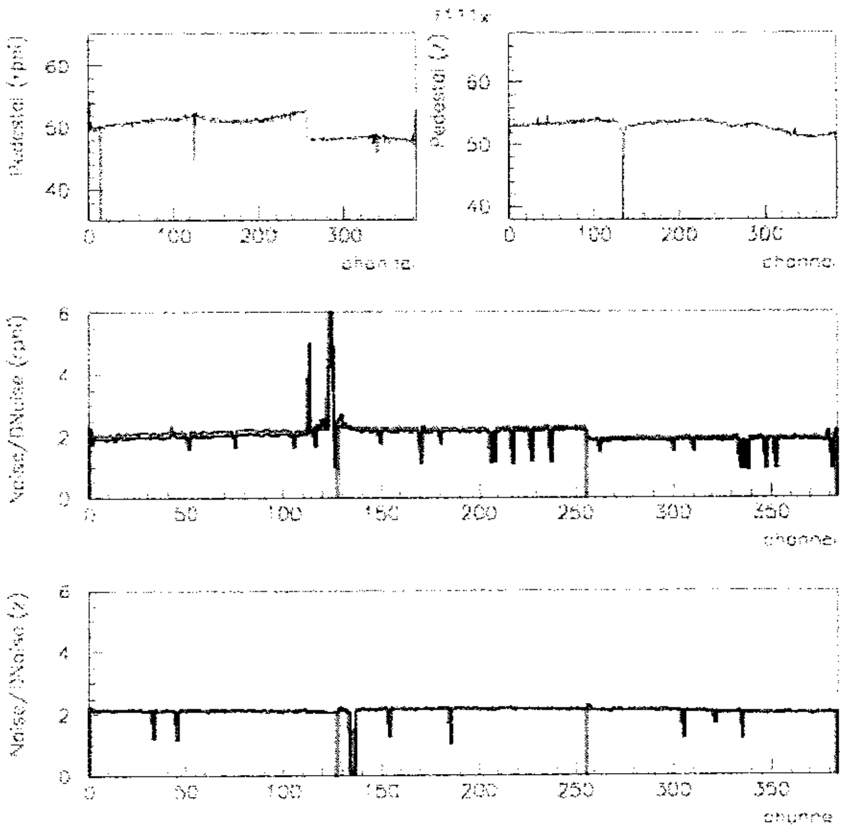
Ladders construction

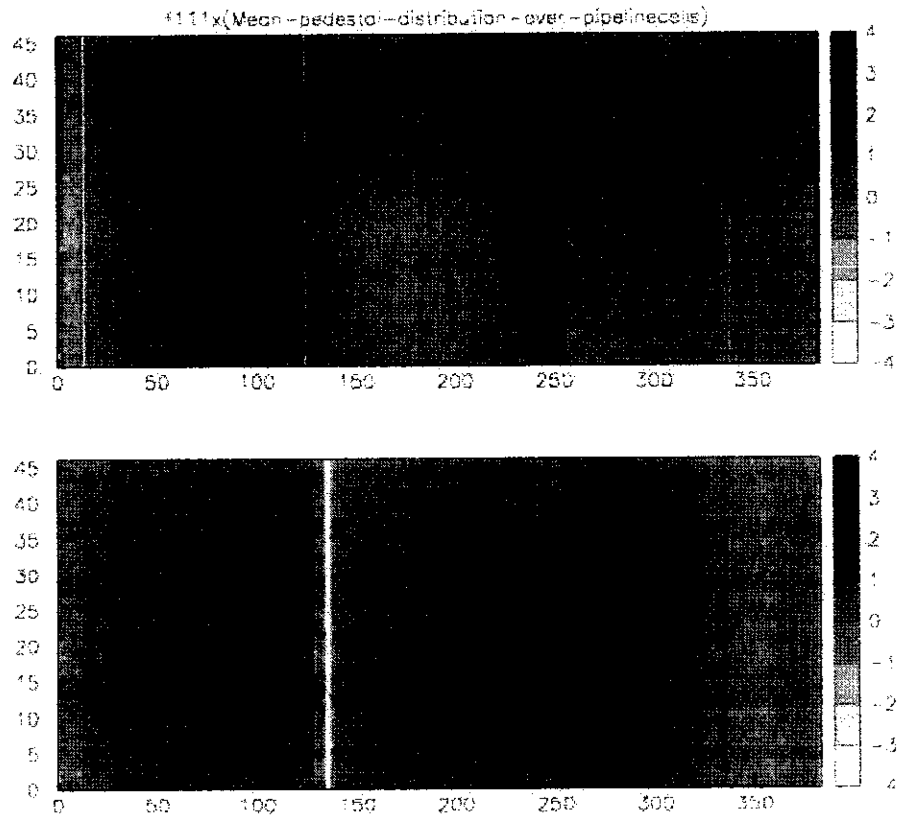
- **Finished on end of July 2000:**
- **Total of 224 ladders built in 8 Months**
  - 45 Layer 0 (36 +2 needed)
  - 47 Layer 1 (36 +2 needed)
  - 44 Layer 2 (36 +2 needed)
  - 43 Layer 3 (36 +2 needed)
  - 45 Layer 4 (36 +2 needed)
    - **Production Capability of 15 Ladders/week but an average of 7, a sustained flat rate of 10-12 with peaks of 16**
    - **Limited by availability and quality of parts (hybrids, jumpers and sensors)**

Repairs Considerations

- **The SVXII ladder design is really aggressive:**
  - Very compact
  - Fine pitch (~60 um)
  - A lot of handling involved (Double sided Si)
- **“Non Optimal” quality control on the parts to be assembled:**
  - Jumper opens and shorts (very difficult to probe)
  - Open and shorts on hybrids (compatible with the hybrid working by itself but not with the ladder)
- **Two changes had to be implemented on each device during production**
- **Very tight schedule**

Quality Control





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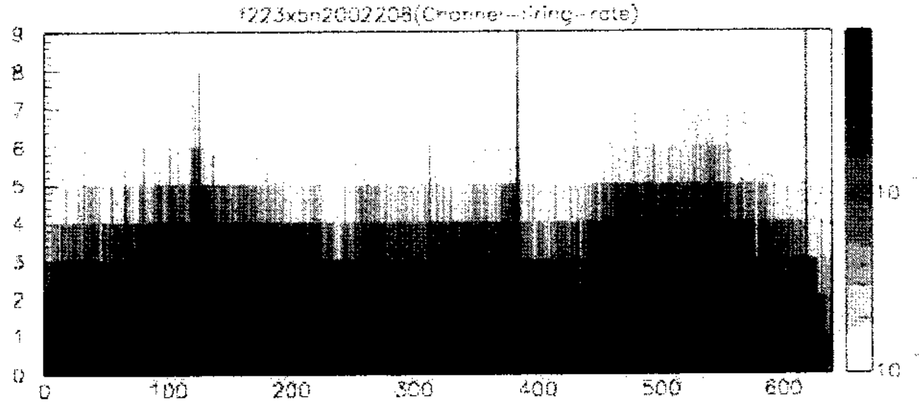
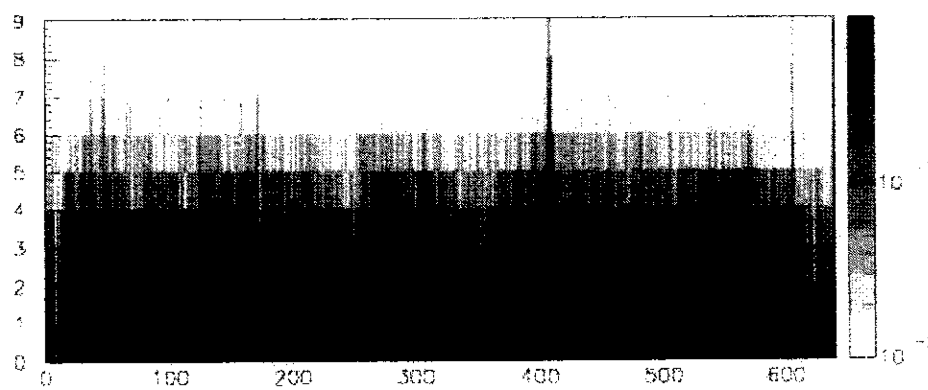
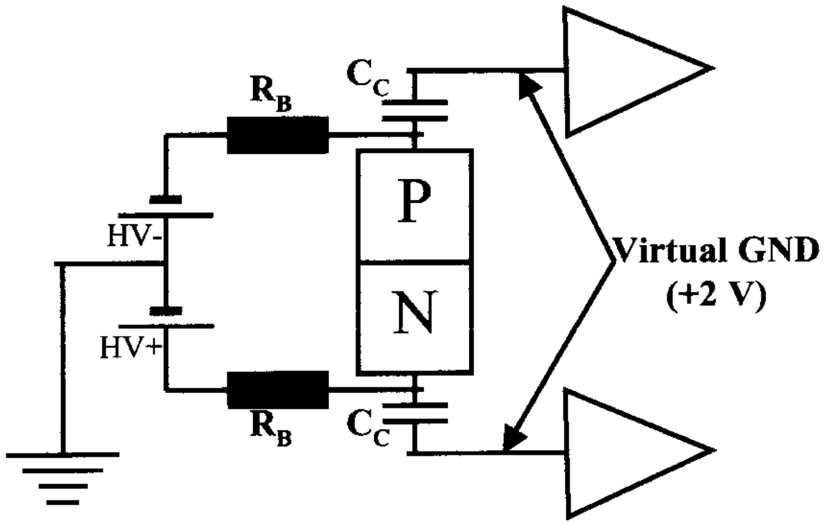
Quality Control

- Pedestal, Noise are monitored for each pipeline cell
- Fake occupancy rate has a cut at 1% with a threshold of ~ 1/5 of a mip signal

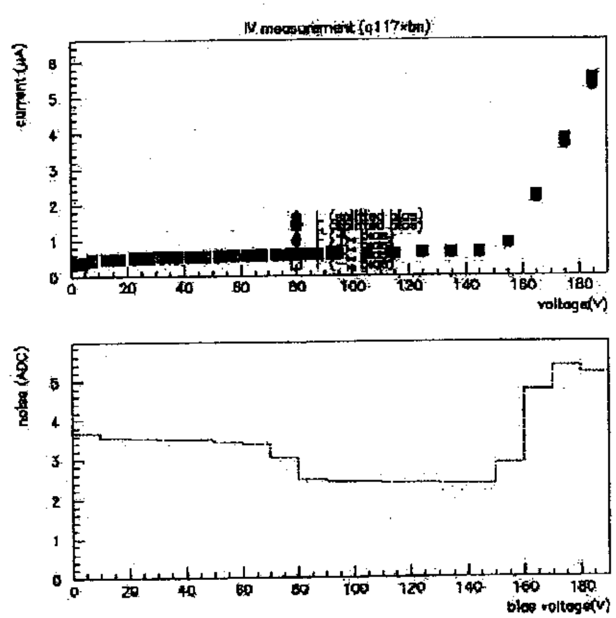




Double sided sensor biasing scheme



- Electric Field across coupling capacitor (C_C).
- ~200 nm SiO2
- Rated 100 V (measured at 120 V)



- No more than 200 V can be applied to the P-N junction without the risk of breakdown across the dielectric.
- In reality around 160 V some devices show micro-discharge.

MOS Effect

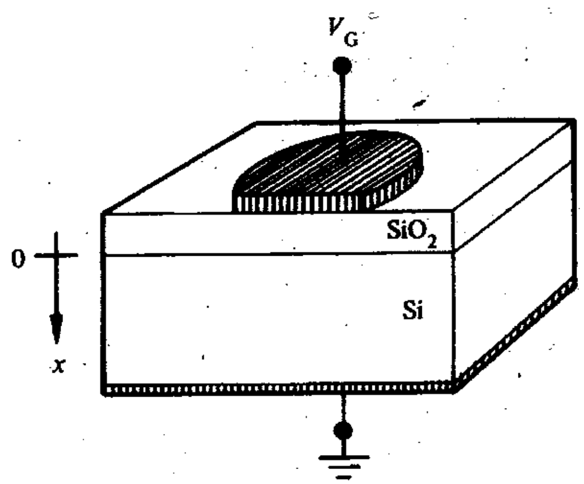


Fig. 2.1 The metal–oxide–semiconductor capacitor.

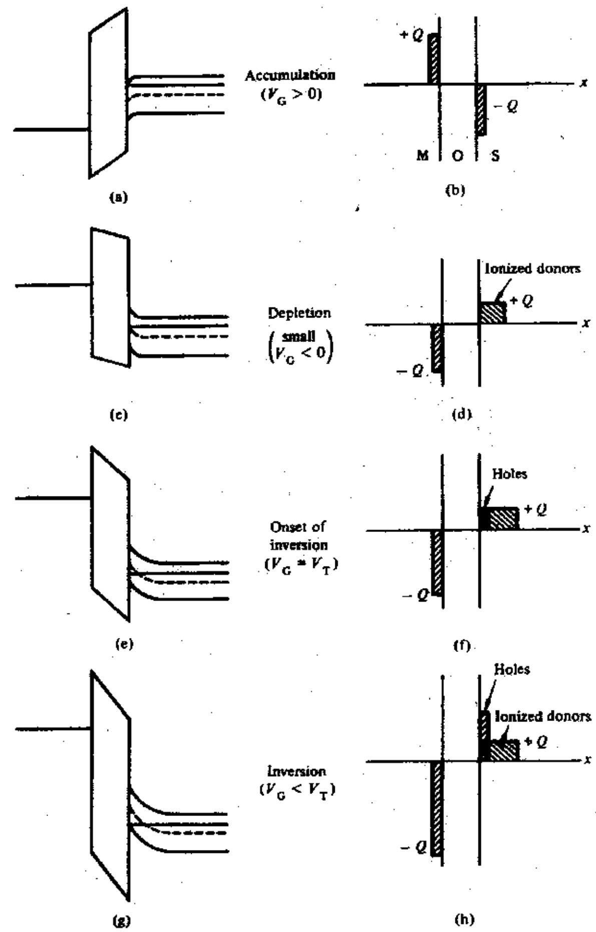
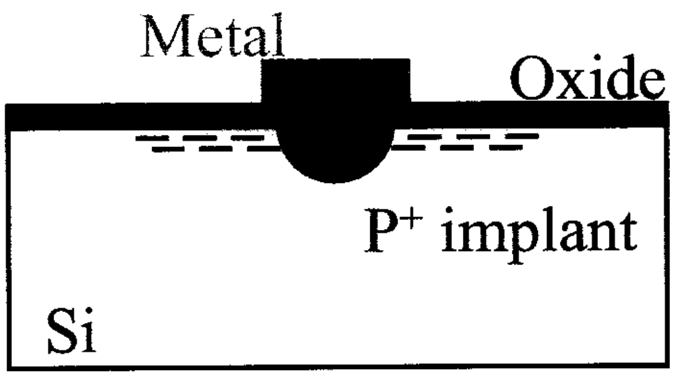
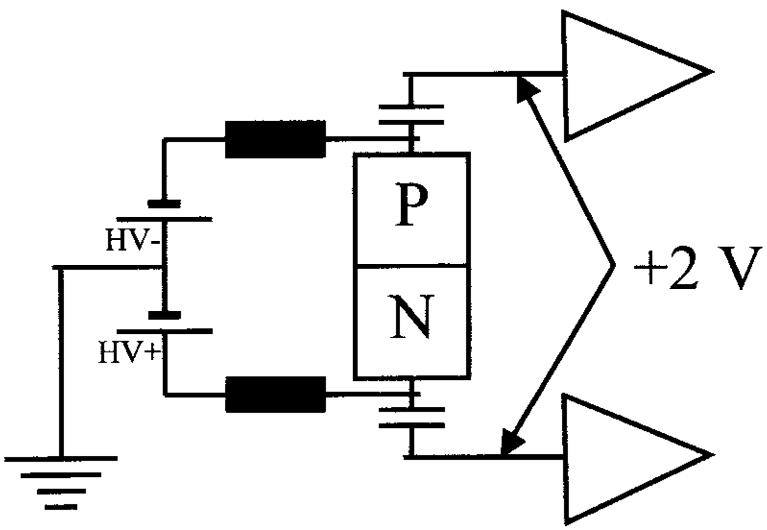


Fig. 2.5 Energy band diagrams and corresponding block charge diagrams describing the static state in an ideal *n*-type MOS-capacitor.

MOS Effect



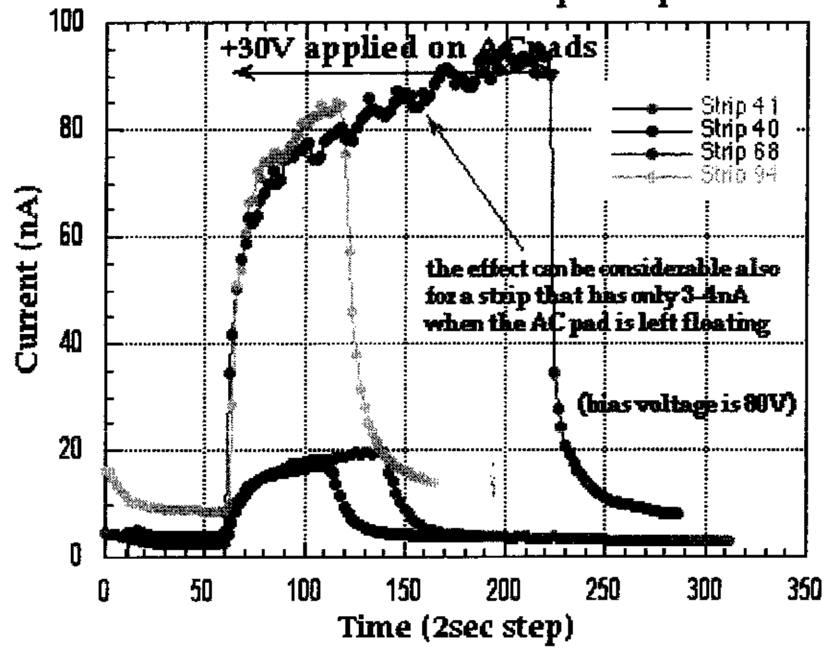


- Each strip is a MOS device.
- While probing the metal is floating
- When wire-bonded to the preamplifiers the MOS is driven by the bias voltage.
- If in accumulation the risk of breakdown increases.
- Defects can show up only after the module is built.
- Instability of surface charges could imply instability of performances.

MOS effect and leakage current

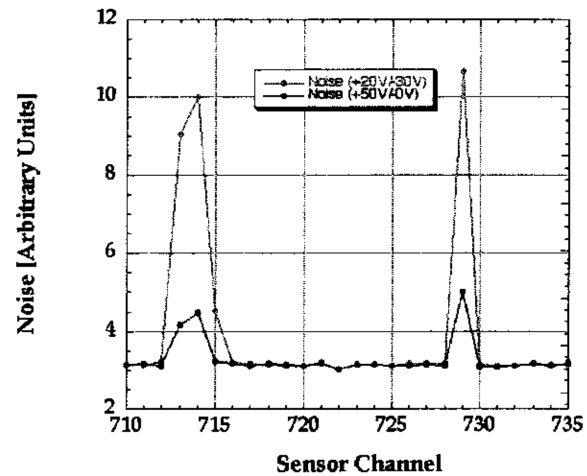
- At the probe station the single strip leakage current has been measured with different voltages on the aluminum readout strip.
- Some strips are more sensitive than others to this effect.
- Probably due to:
  - Imperfection on
    - Metal profile
    - Implant profile
  - Local differences on the interface quality
- Difficult measurement unless the strips are wire-bonded

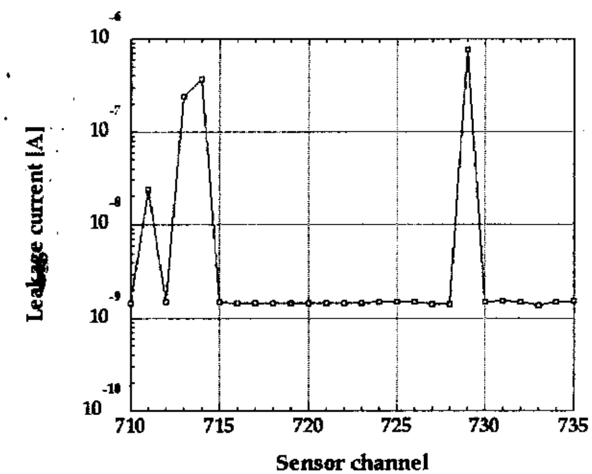
Enhancing defects on Micron sensors' p-strip



MOS effect and Noise

- Leaky strips on sensors are correlated with Noisy channels on modules.
  - The noisy is much bigger than the expected shot noise
- The effect can be modulated by the potential at the surfaces.
- Due to this effect CDF lost the freedom to split the bias on some layers.
- We still do not how to detect faulty sensors before wire-bonding them to the FE electronic.



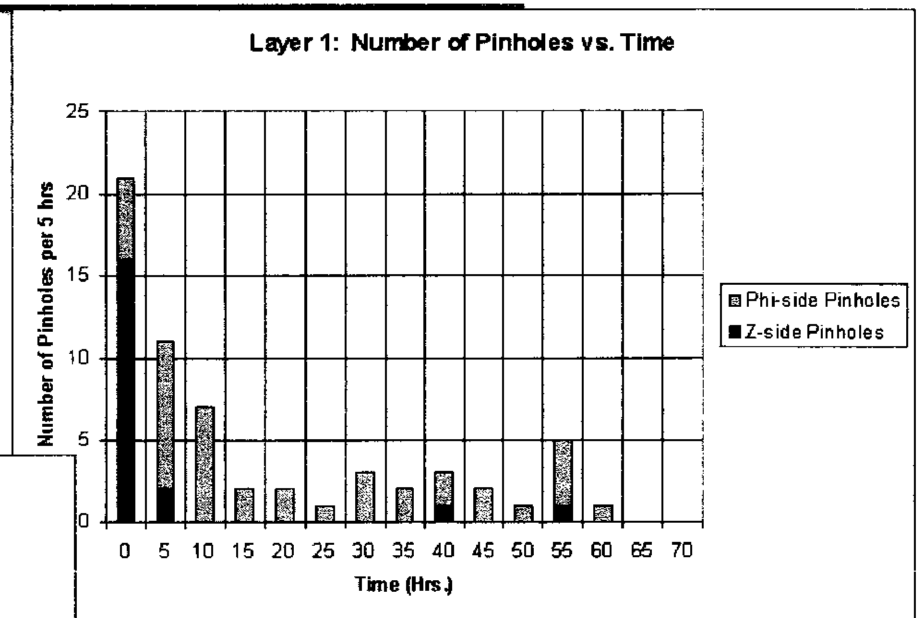


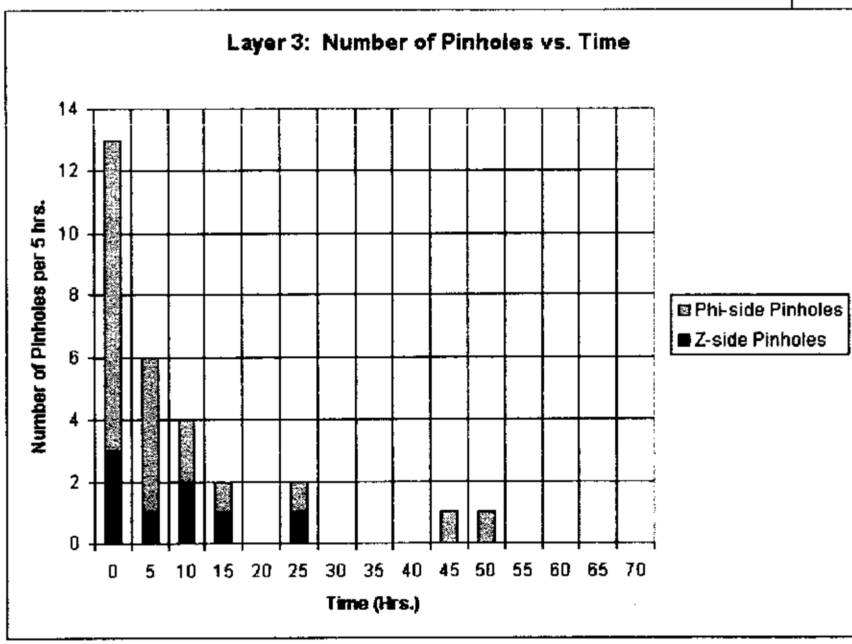
Burnin Results

- **Both QLs and FLs have been burned in for 72 Hours with**
  - Layer dependent Bias voltage conditions
  - Exercising continuously the electronic
  - Recording pedestal every 5 minutes
- **The overall result can be summarized as:**
  - Stable electronic (chips)
  - A non negligible infant mortality rate of coupling capacitors (basically creation of pin-holes)
  - "**Failures**" of the HV lines on both hybrid and jumper
    - **Leaky path generation on hybrids**
    - **Sparks on jumpers**

Hamamatsu Burnin Results

- L0 & L1 were burned in with 180 V symmetrically split on the 2 sides
- A non negligible PH introduction rate is visible even for time longer than 2 days.





- L3 were burned in with 140 V symmetrically split on the 2 sides
- Here we can clearly talk about infant mortality.

- **<u>For the innermost layers the maximum bias voltage applicable is a limiting factor for the lifetime</u>**.

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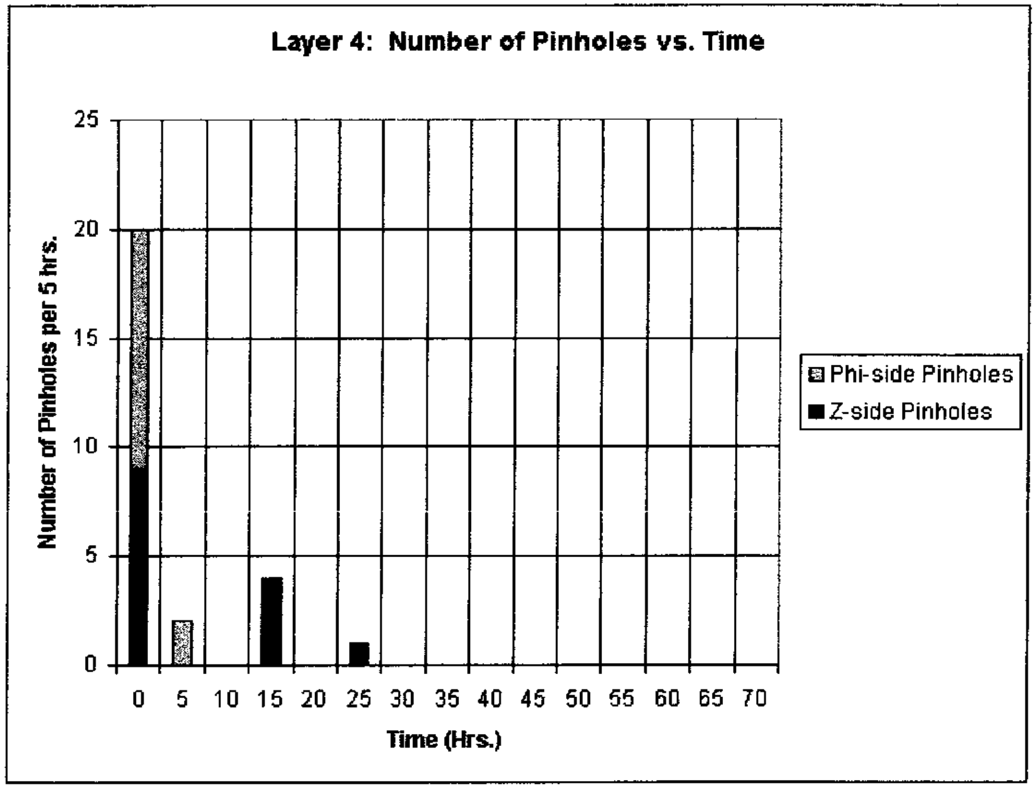
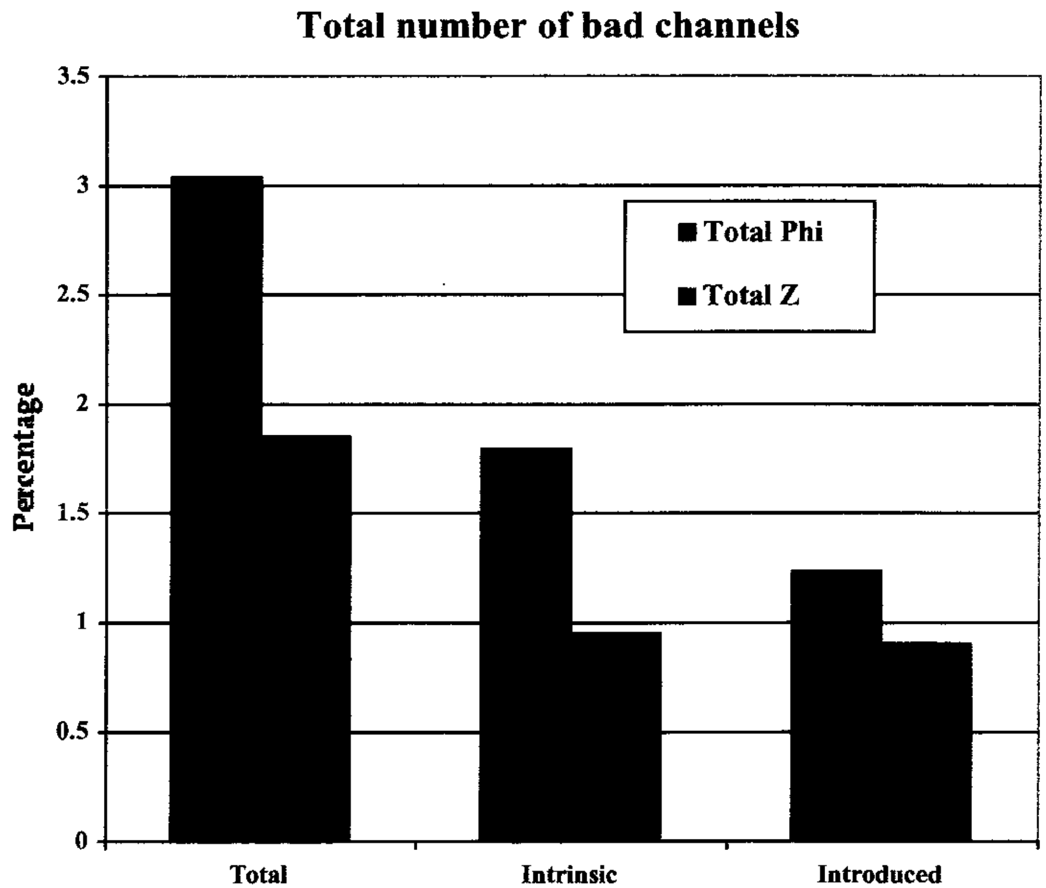
Micron Burnin Results

- L2 & L4 were burned in with 120 V symmetrically split on the 2 sides
- The PH introduction rate is null after 1 day.
- But large current and many noisy channels if bias is split
- Radiation environment will allow single side biasing scheme through the full lifetime of SVXII



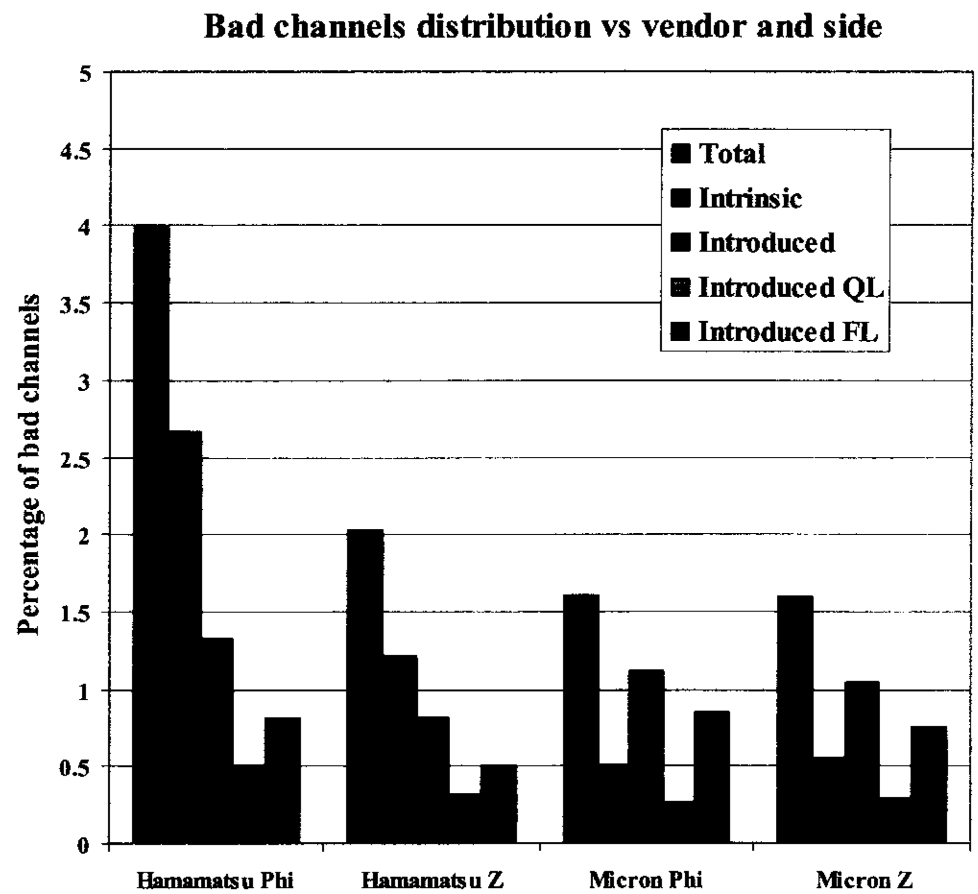
Bad Channels count

- Final percentage (average) of bad channels is around 3 % for the Phi side and 2 % for the Z
- The introduction rate of bad channels is comparable with the initial quality of the parts (chips and sensors).



Bad channels distribution

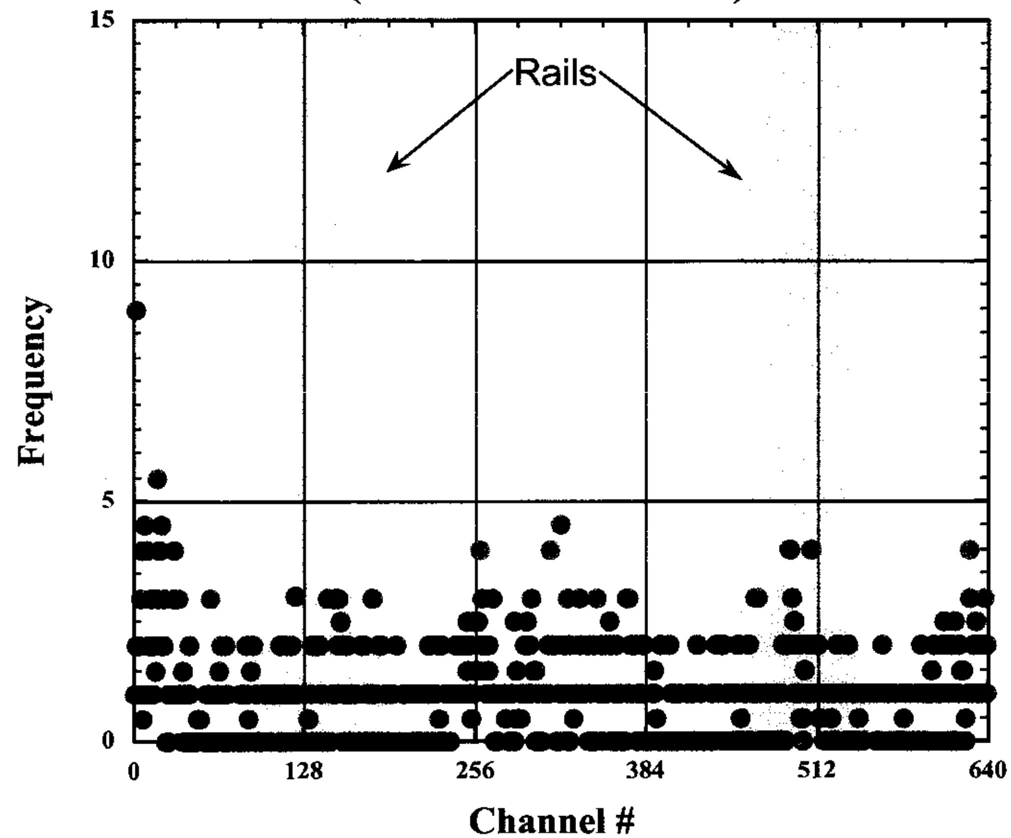
- Clear difference between vendors
- On Hamamatsu ladders almost a factor of 2 between Phi and Z side. (process sequence???)
- An almost flat introduction rate of 1 %, (small differences associated with oxide thickness?)
- Bad channels introduced during FL assembly is twice that for QL. Pretty good correlation with the number of bond's feet on sensor.



Spatial distribution of introduced bad channels

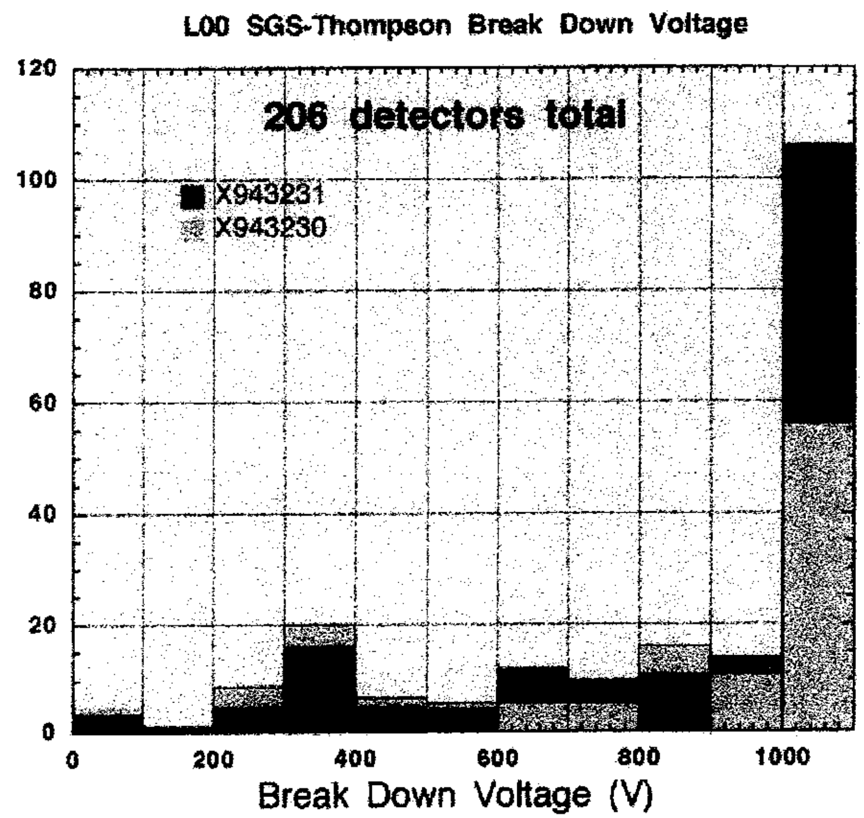
Spatial distribution of introduced bad channels is pretty homogenous and does not show any correlation with glued objects

Layer 2 Phi side introduced bad channels
(total of 84 half ladders)



Hopes for the future: "L00" like projects

- Solid single-side process
- 3 vendors (Micron, Hamamatsu and ST) with similar results
- Quality control reduced to minimum.
- Young project can take advantage of the lesson previously learned.



Documentation and database

- **QA has to be associated with an EFFICIENT Database in order to:**
  - Keep track of components
  - Mate components to each other
  - Be able to spot short-term and long-term quality trends
- **In case of problems it is crucial to access the history of each component.**
  - Time/environment
  - Personnel/location
- **A good database prevents from doing the same job twice (or more)**
- **Information useless today could be very valuable tomorrow.**
- **The power of the database is NOT on the AMOUNT OF INFORMATION you can store but on the capability to GET THEM OUT.**

Considerations & conclusions

- **QA procedures must be developed with the final product in mind.**
  - A "PERFECT" part could be responsible for a BAD module.
  - SOLID pre-production phase with final components is mandatory.
    - **Interaction between components:**
      - Chemical
      - Mechanical
      - Electrical
    - **Long term reliability**
  - Finalize testing procedures only at this time
  - Finalize specifications only at this time
- **Move QA to manufacturer but still "spot-check" quality.**
- **QA is meaningful only if:**
  - There are spare parts
  - Project can afford to reject parts
    - **Schedule**
    - **Money**
- **QA should not have an impact on assembly/construction schedule**