FNAL Production Experience

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CMS Tracker Week

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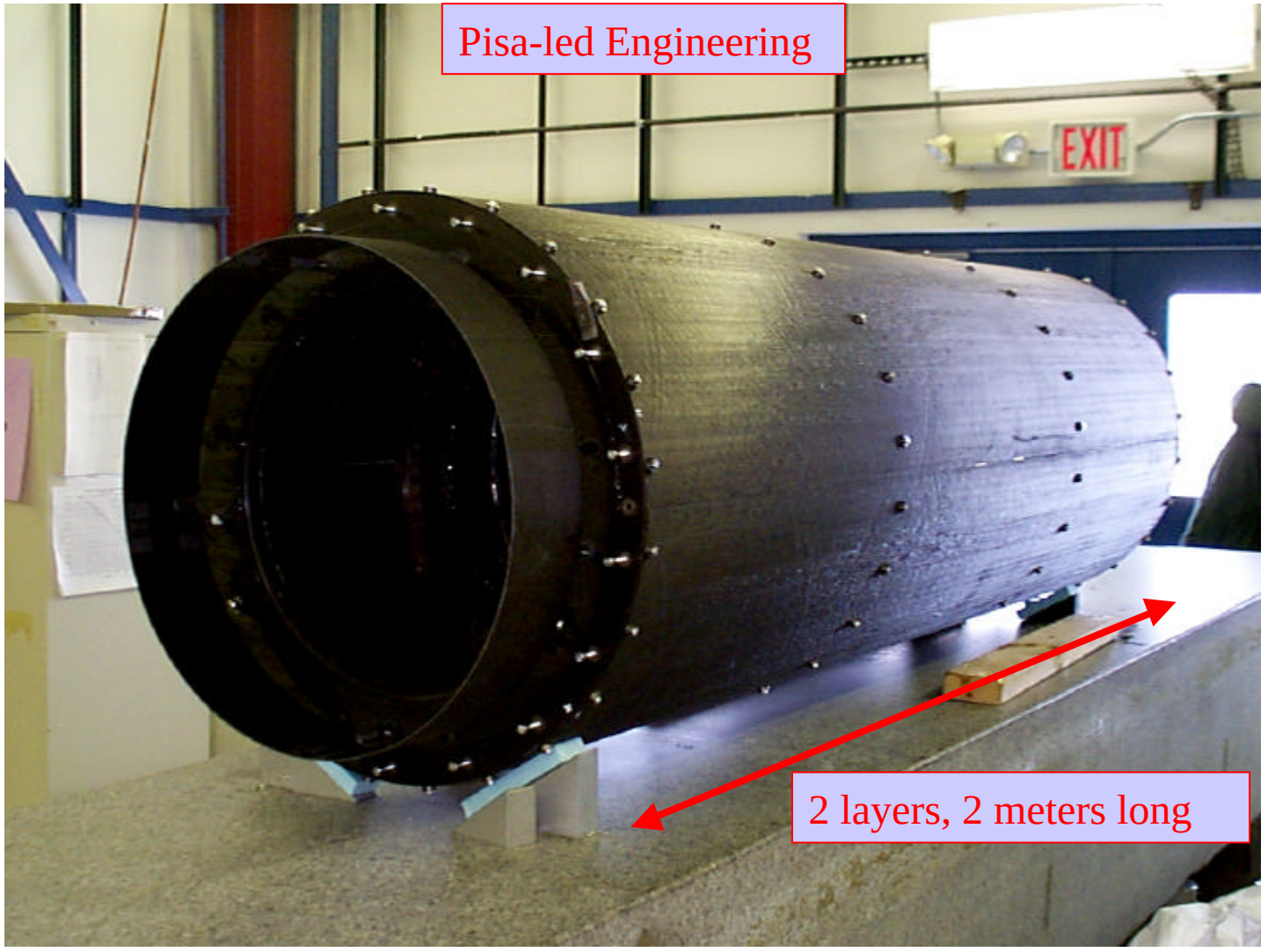
Outline

- Similarity of CDF ISL to CMS tracker
- Recent CDF ISL Production Experience at FNAL

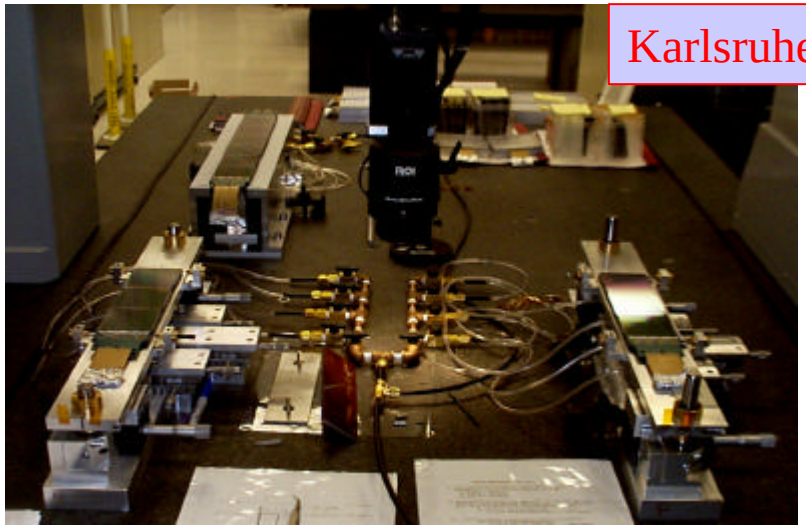
  (A. Affolder, S. Baroiant, J. Goldstein, C.Hill, and D. Stuart)

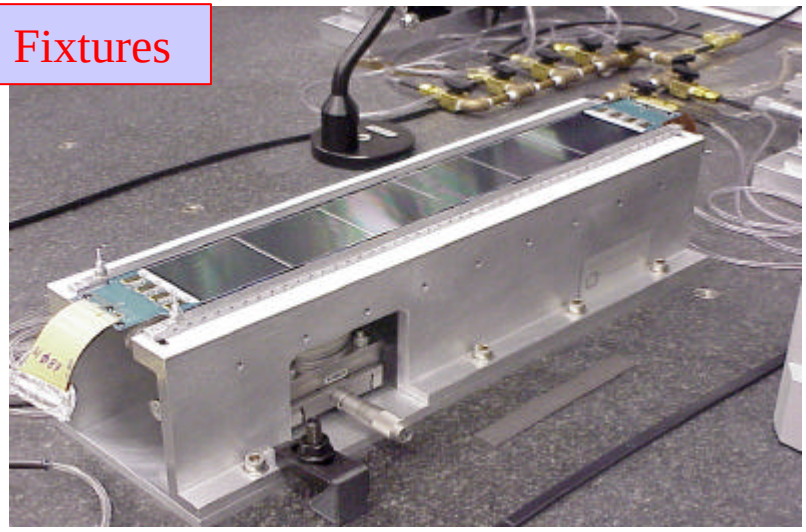
  – Production rates
  – Testing results
  – Mechanical quality
  – Damage
- Expectation for CMS

CDF ISL



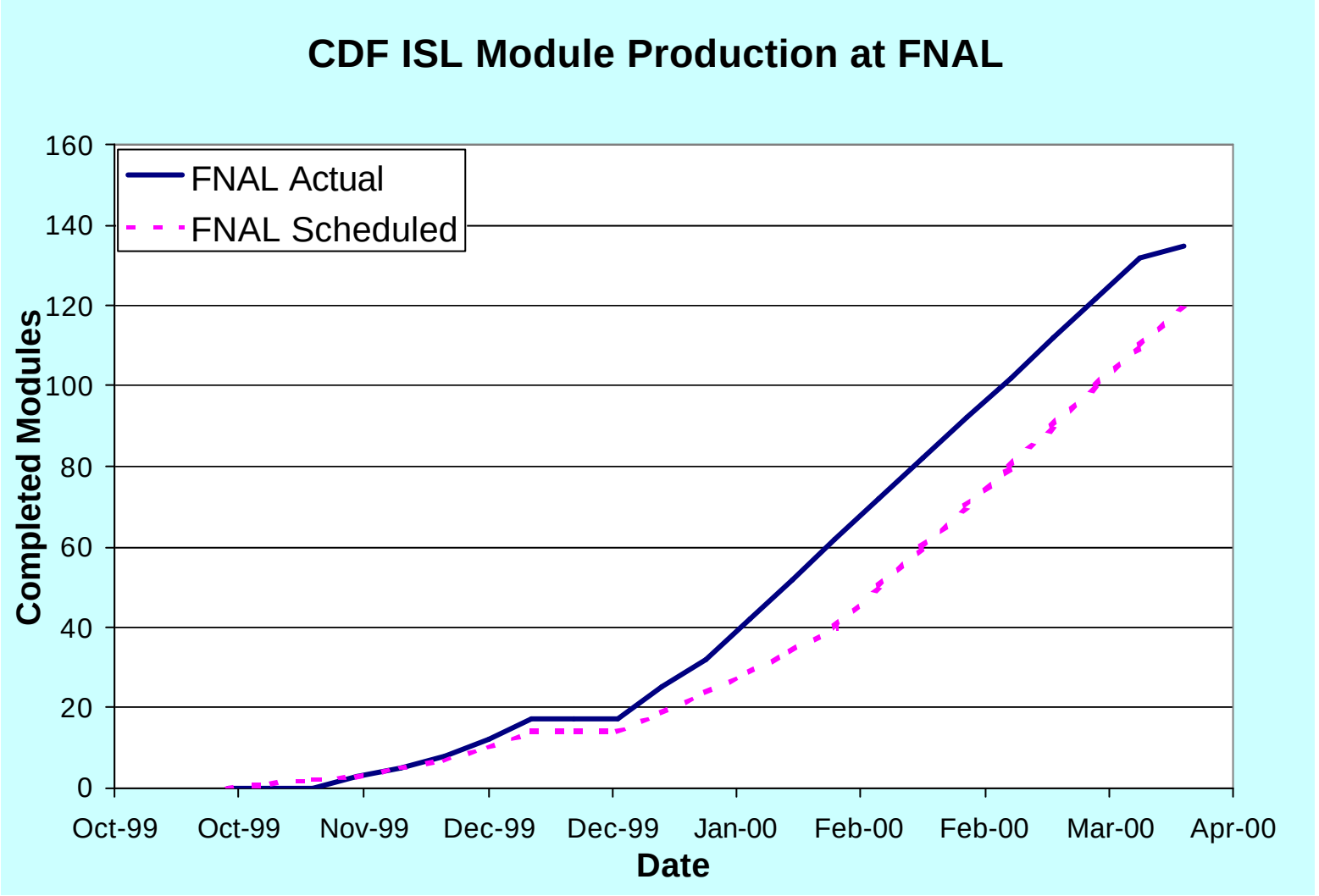
ISL Module Assembly at FNAL



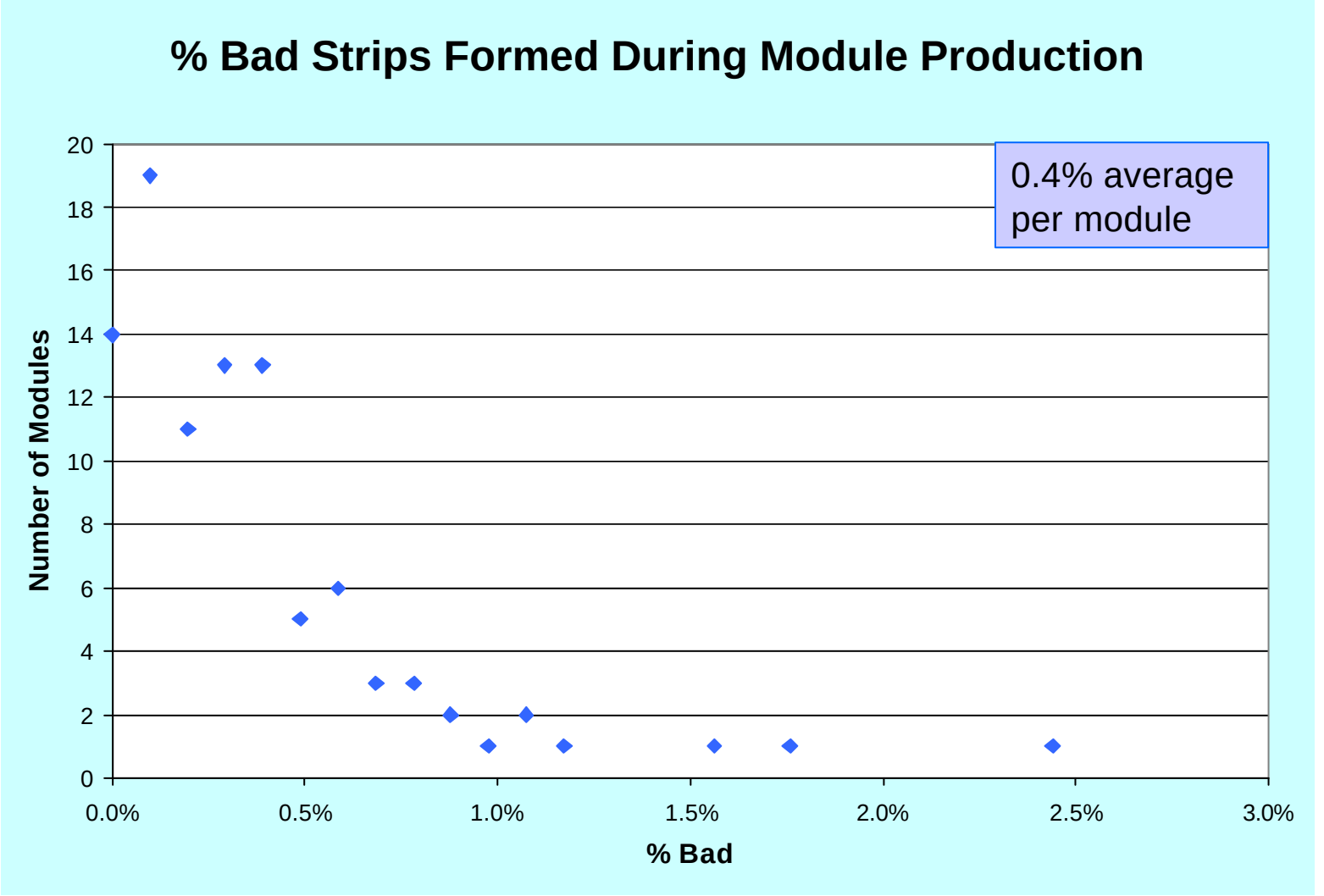


- ISL half modules
  - 3 double-sided sensors
  - 1 double-sided hybrid w/pitch adapters
    - 512 channels/side
    - 4096 total wirebonds

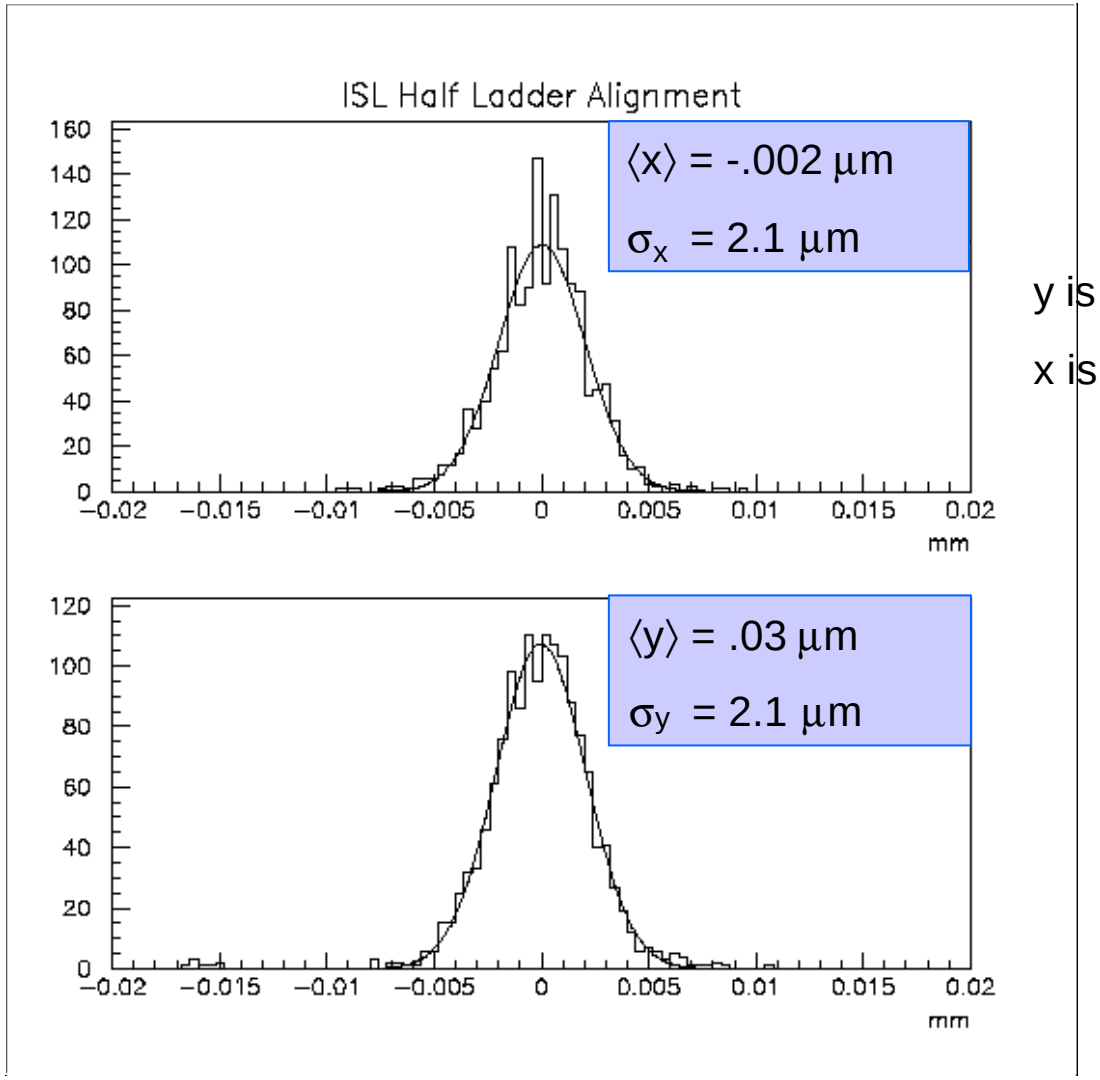
CDF ISL Production



Low Production Damage



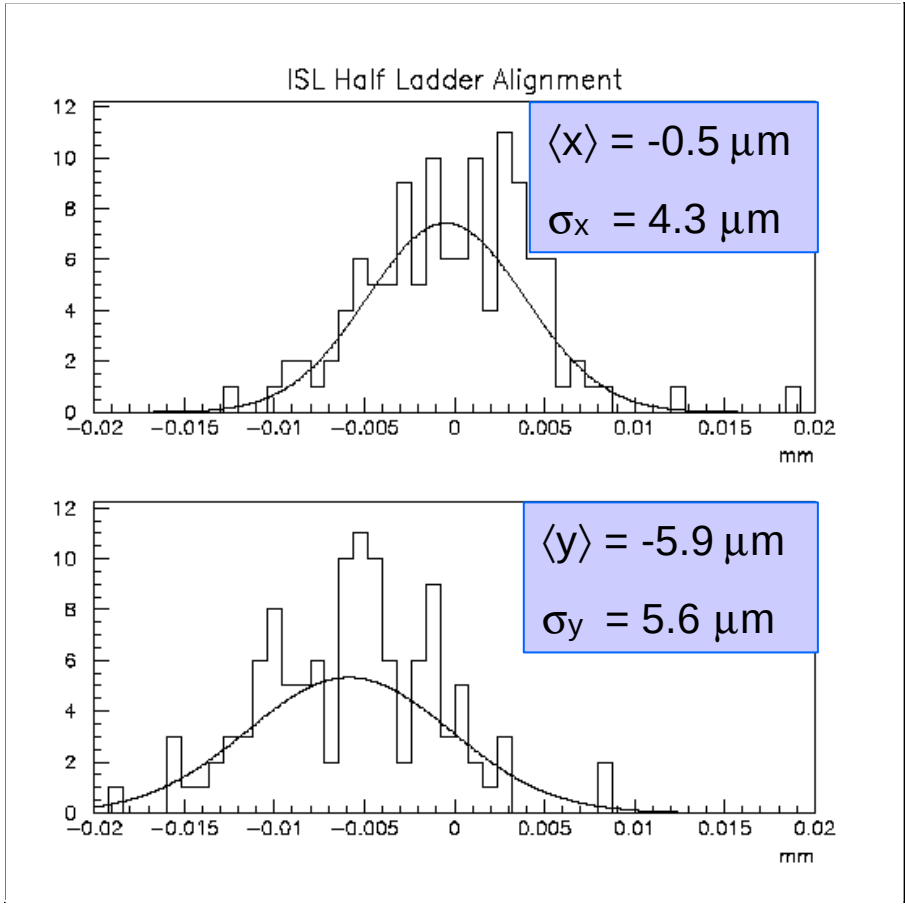
Silicon Alignments



y is orthogonal to strips

x is parallel to strips

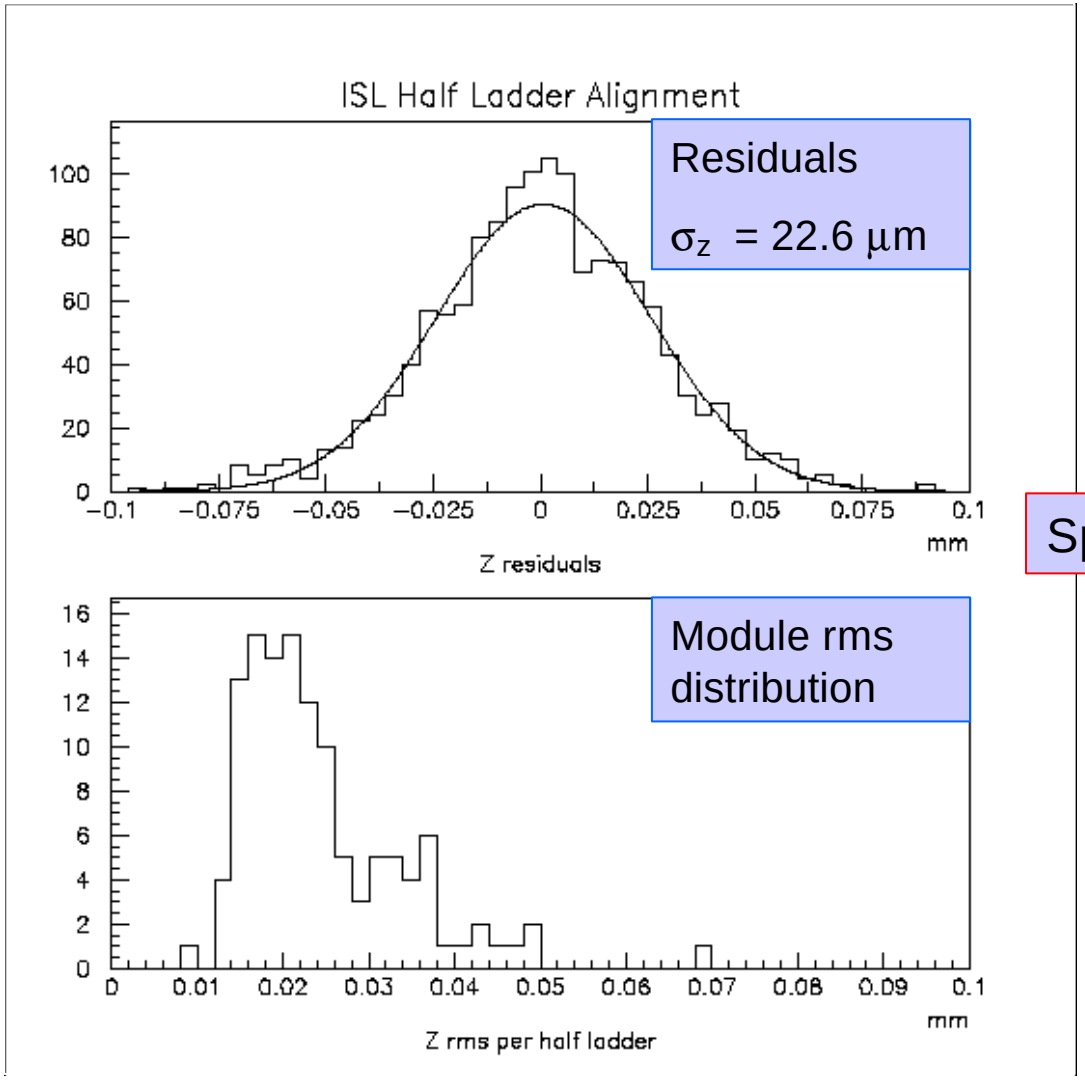
Si-to-Mounting Hole



Mounting Hole Alignment

- Factors into alignment in the final assembly.
- Use one machine to build module (B&S CMM) and another to check it (OGP)
  - y-offset indicates the systematic uncertainty.
    - different lighting (non-uniform)
    - inherently difficult to measure a hole location.
  - Spec. is ±25 μm

Flatness



Spec. 100 μm

Damage Rates

- Silicon Loss rates (~420 HPK DS sensors used)
  - 1 damaged during probing
  - 6 lost in module construction (see below)
- Module Loss rates (~140 manufactured modules)
  - Two modules irretrievably damaged by wirebonder
    - new machine had an unexpected referencing feature
      - no longer an issue
    - no other damage
  - None lost in testing or burn-in

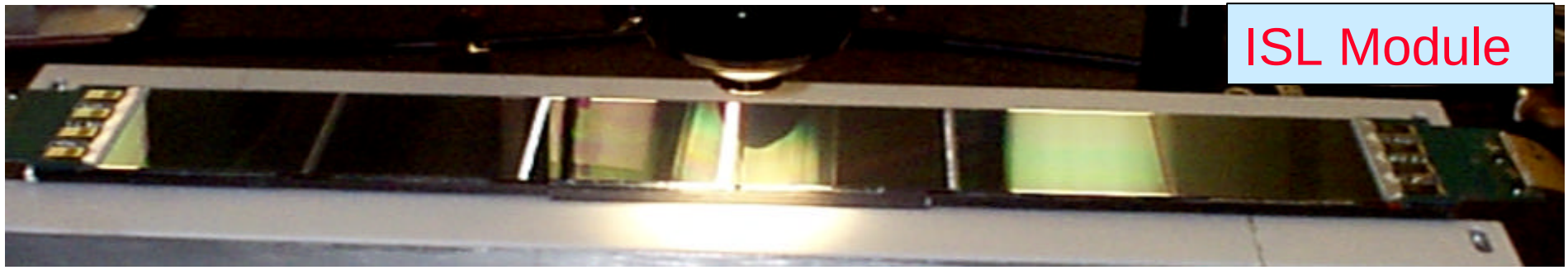
Test Procedures

- Test parts at each stage of module construction
  - Ensure no loss of functionality of SVX3D chips
  - Identify damage due to construction
    - (e.g. pinholes created in fabrication/wire-bonding)
  - Characterize performance
- “Burn in” parts to test long-term reliability
  - Hybrids are burned in for 72 hours continuous operation
  - Half-ladders are burned in for 48 hours
    - Bias Voltage cycled every 6 hours from 0V to 50% over depletion
    - Thermally cycled every 6 hours over 20 degrees
- Testing should be fast, efficient, and accurate
  - Testing is procedural, presentation of results is automated

Procedure

- Hybrids burned in at LBL, then shipped to FNAL
- Tested upon arrival at FNAL
- Pitch-adaptor is bonded and the hybrid is re-tested
- Silicon is bonded, pinholes identified, removed from readout
- Half-ladder is tested
  - Operating voltage determined
  - Occupancy and efficiency estimated from measured quantities
  - Ladder graded (grade A is > 94% efficiency, < 2% occupancy)
- Half-ladders burned in then mated to make modules
  - mates are selected to match in occupancy and efficiency
- Modules tested, put into storage until installed on space frame

Re-testing



- Re-test rate is quite low since number of repairs needed is quite low
  - hybrid re-test rate: 4.7%
  - ladder re-test rate: 3.2%
- We would expect these rates to be significantly lower for CMS

Burn-in

- Hybrids operated 72 h before installed in half-ladders.
- Burn-in includes temp. and voltage cycling.
  - Every 6 hours we simply turn off the chillers. Once things warm up, the power is automatically tripped off by the interlocks. Temperature swing is ~ 20 C.
  - This is abrupt and a bit violent but not uncommon in actual operation.
- Up to now, the only failures observed in burn-in have been pinholes being formed.
  - 8 in the first 15 minutes
  - 1 at 4.5 h
  - 1 at 16.5 h
- ISL Burn-in time was therefore reduced to 48 hours.

Expectations for CMS

Rad-tolerant Layer 00 Silicon (HPK)

Specications	wide	narrow
# channels	256	128
active area (cm^2)	9.7	4.8
implant pitch	25μm	
readout pitch	50μm	
implant width	8μm	
Test Results		
bad strips (@100 V)	0.10 %	0.047 %
depletion voltage	$\simeq$65 V	$\simeq$65 V
current @ 500V (nA/strip)	0.5-1.0 typ.	0.5-0.8 typ.

single-sided p-in-n silicon

- CMS modules simpler and more robust.
  - 2 single-sided sensors and single-sided hybrid
    - less likely to damage backside
    - silicon itself more robust with fewer bad channels
      - HPK single-sided sensors received for CDF L00 project were nearly perfect
  - CMS construction times and loss rates should be lower than CDF ISL.
    - Minimal damage possible
    - Repair effort could be very small

Summary

- ISL is going really well
  - Easy to pace and schedule reliably (assuming hybrid supply is not interrupted)
  - Very low losses from damage
- CMS is simpler
  - With proper care we should have very low losses, and not a lot of repair required.
  - Assuming electronics is robust and on-time, production schedule can be met.