Quality Control in BaBar SVT module assembly

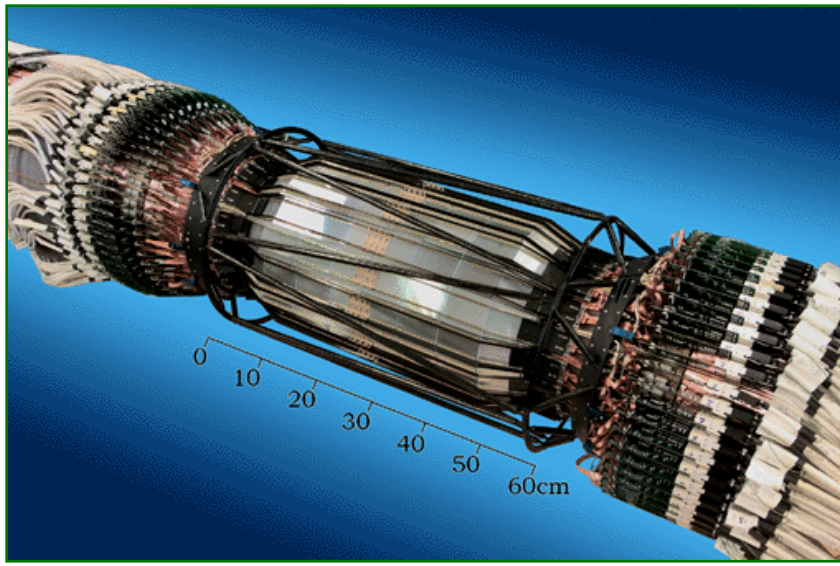
Meeting with Belle2 HEPHY Group
Wien- April 25-26 2013

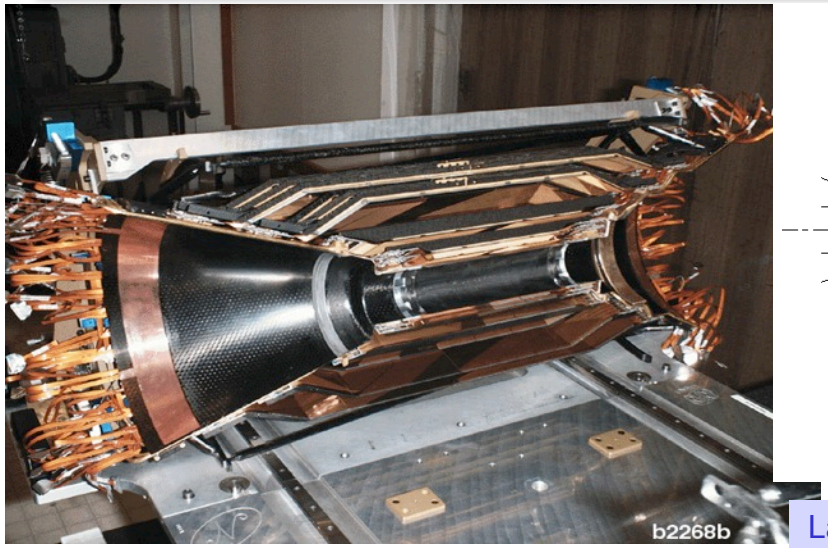
Giuliana Rizzo
Universita' & INFN Pisa

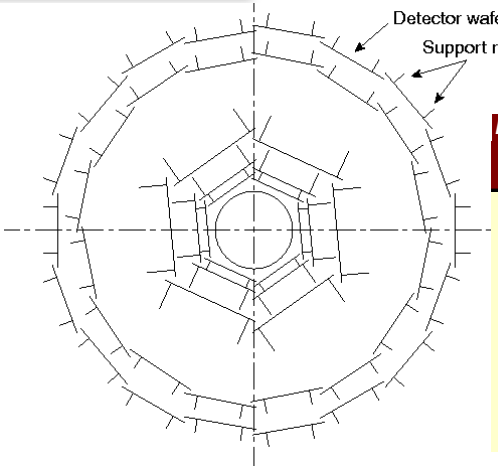
BaBar SVT

BaBar SVT

- 5 Layers of double-sided Si strip sensor
- Low-mass design: ~ 0.5% X_0 /layer (Pt < 2.7 GeV/c^2 for B daughters)
- Stand-alone tracking for slow particles.
- 97% reconstruction efficiency
- Hit resolution ~15μm at normal incidence







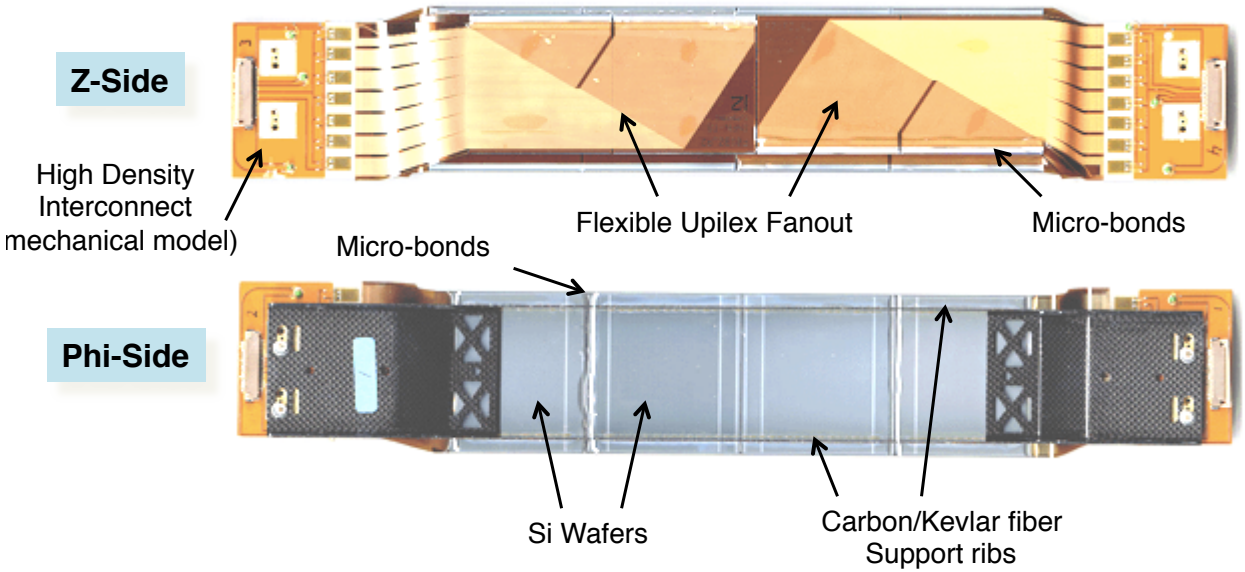
Layer	Radius (mm)	Modules/ Layer	Wafers/ Module	F Pitch (μm)	Z Pitch (μm)
1	32	6	4	50 or 100	100
2	40	6	4	55 or 110	100
3	54	6	6	55 or 110	100
4a	124	8	7	100	210
4b	127	8	7	100	210
5a	140	9	8	100	210
5b	144	9	8	100	210

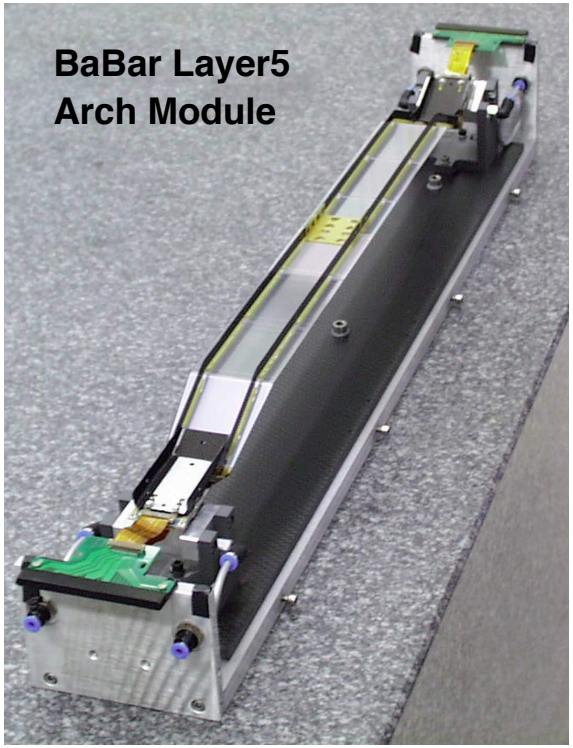
Layer 1-2-3: barrel modules
Layer 4-5: arch modules

BaBar Modules

Each Module (52) has 2 independent electrical units HalfModules (104 - HM) build with several sensors + 2 fanout (phi-z), HDI with FE chips

BaBar Layer1 Module





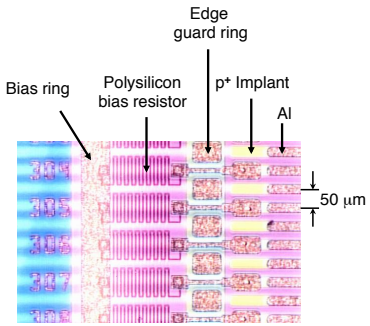
Glossary of SVT terms

- DFA (Detector Fanout Assembly):
  Two or more wafers glued end-to-end with fanouts glued on both ϕ and z sides
- Half Module (also HDFA):
  - A DFA bonded to a hybrid (HDI)
  - 1/2 coverage in z
- Module:
  - Two HDFAs mechanically connected by ribs
  - full z coverage
- Sextant:
  - Layer 1 + Layer 2 modules (one mechanical unit)

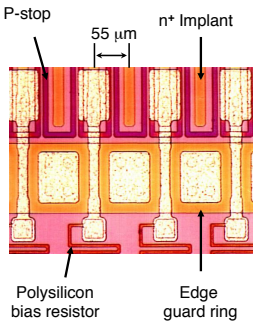
Half Module parts

Si sensors double sided

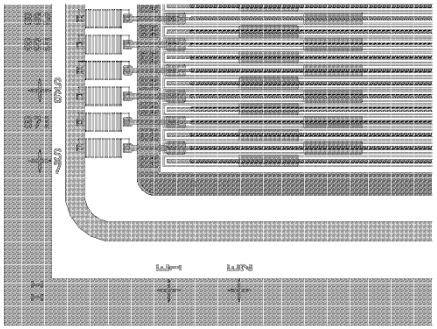
6 different types ->340 sensors



p+ strip side

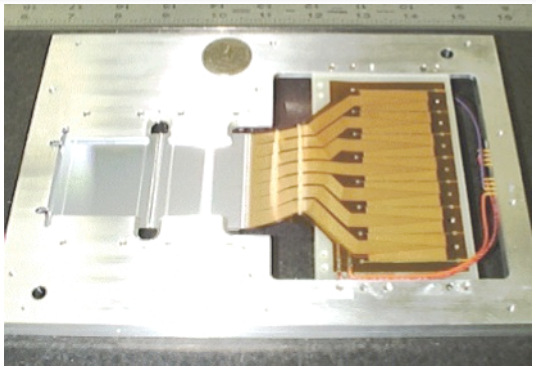


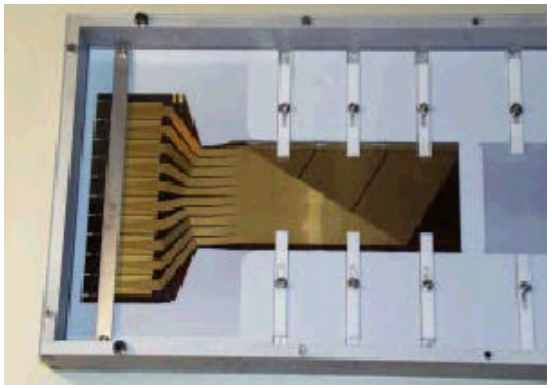
n+ strip side



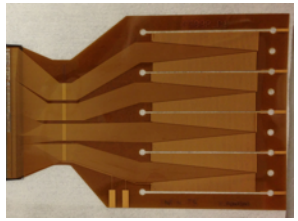
DFA: Detector Fanout Assembly

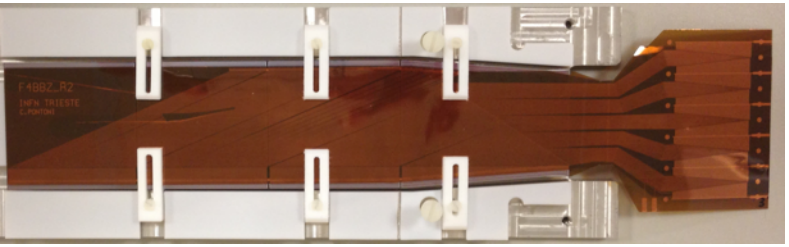
7FW + 7BW different types → 104 DFA's





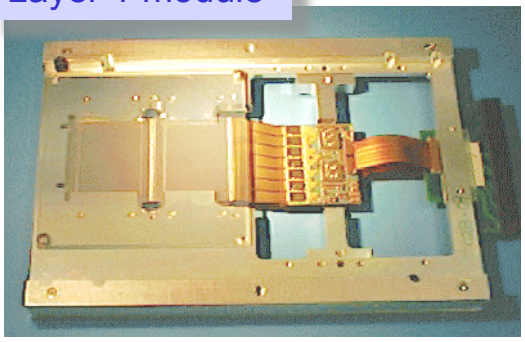
Fanout: 14phi+14z different types → 208 units





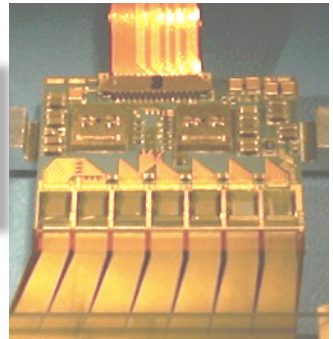
Test Tree extension very useful for DFA test, before connection to HDI (cut before connection to HDI).

Layer 1 module

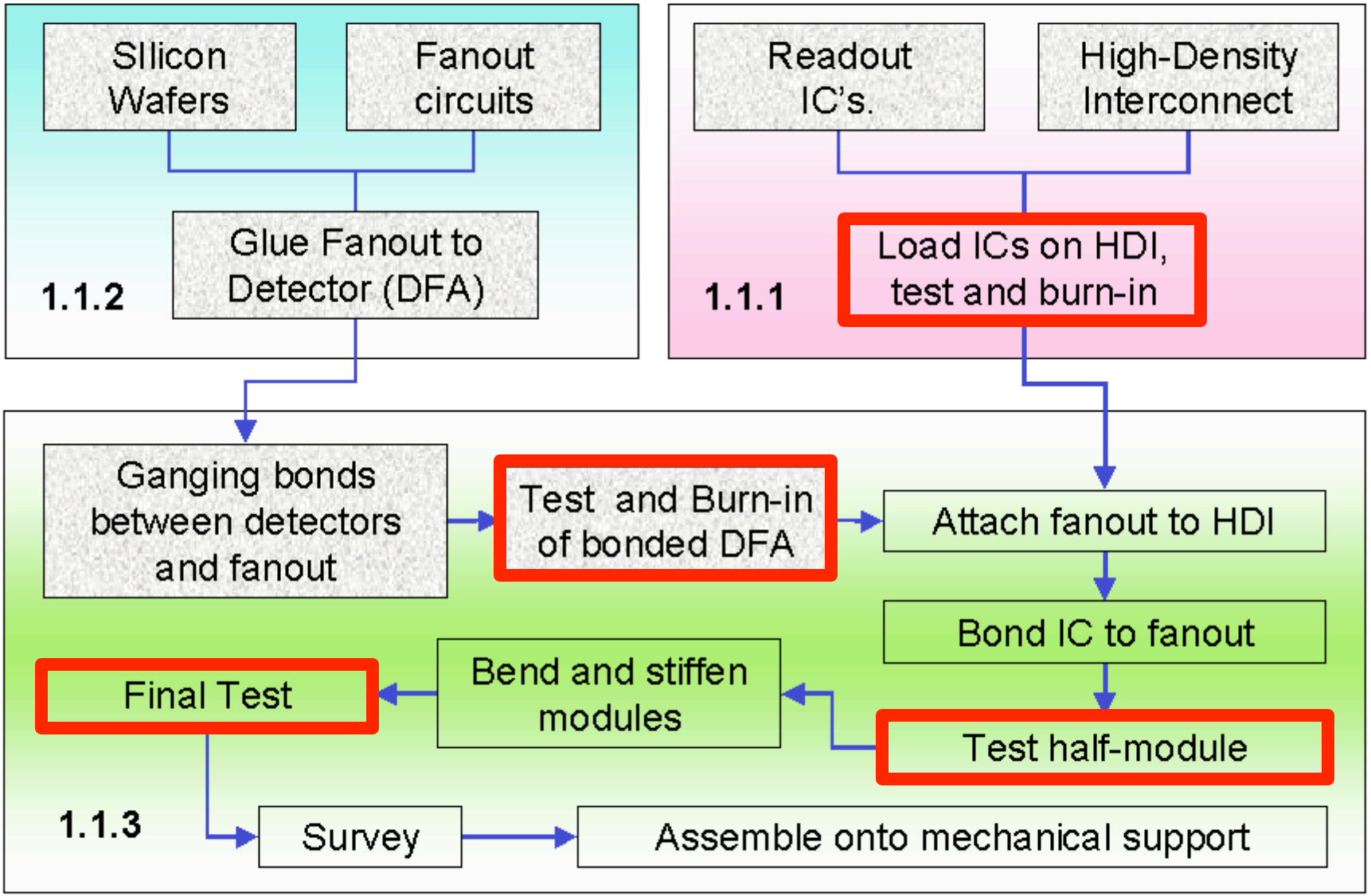


Double sided AlNi HDI loaded with AToM chips

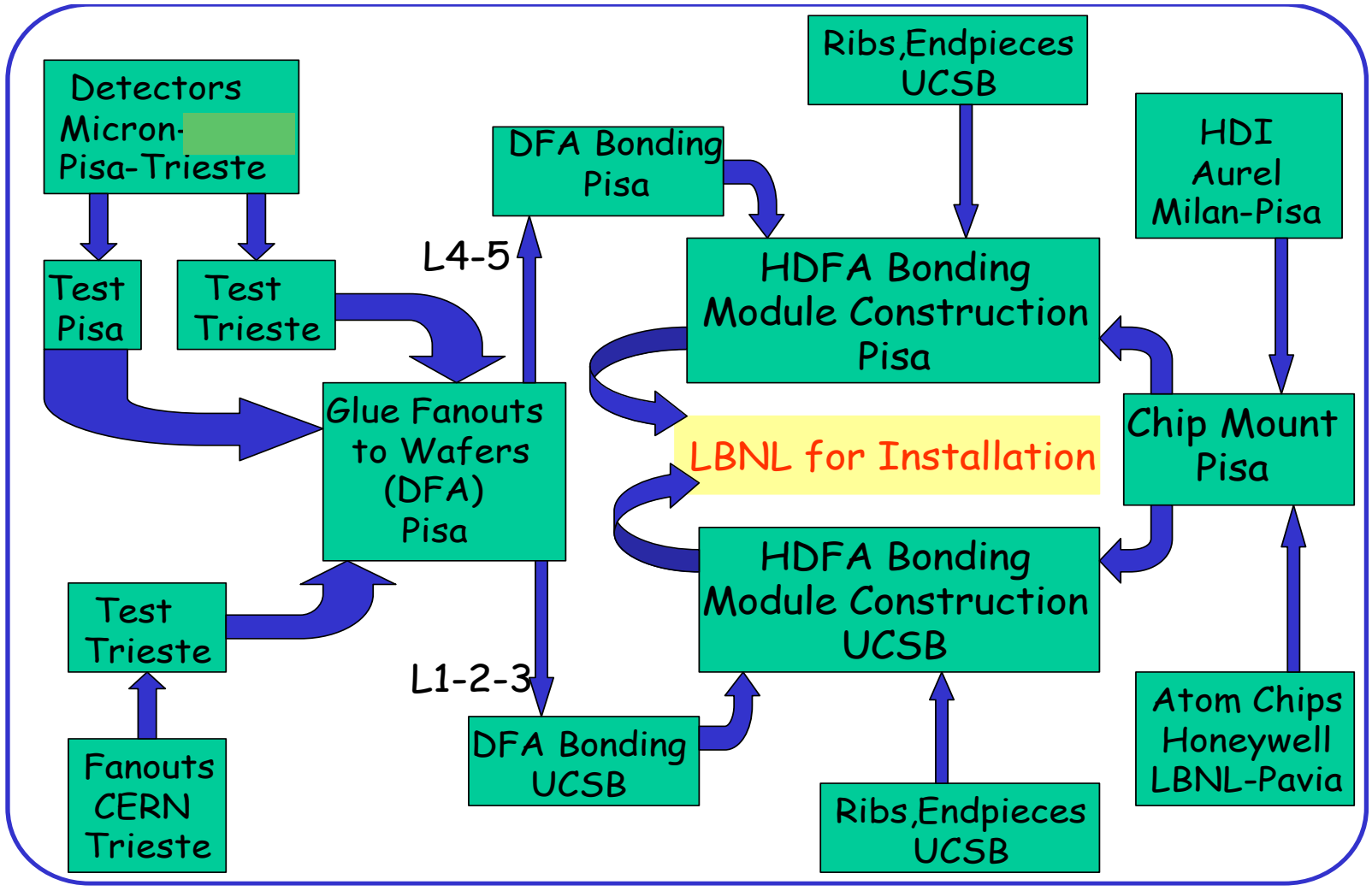
3 different types → 104 HDI's



SVT Assembly Procedure +TEST



SVT Construction in many sites



Some dates

- Module Assembly Feb. 97-Dec. 98
- Module Mounting/Commissioning @ LBL Jan 99-April 99
- Installation in BaBar May 99
- Data taking started in June 99

QC: general approach (I)

- For all parts (sensor, fanout, FE chips, HDI, HDI loaded with chips) electrical tests, mechanical survey & optically inspections were performed before module assembly in various sites.
  - Pretest by vendor+additional electrical tests in construction sites (some details in next slides)
  - Long term stability tests done on sensor (hours) and HDI (days) to spot for infant mortality BEFORE assembly.
  - **1 week** long term stability on DFA's (sensor+fanout assembled) after bonding BEFORE connection to HDI. ~5% of DFA's showed a drift of current after a few days.

QC: general approach (II)

- All data (mechanical survey & electrical test) were logged to a Construction DB, very useful during module assembly but also after installation in BaBar to retrieve infos for pathological behaviour.
  - http://www.pi.infn.it/bfactory/SvtConstruction/index.html
  - http://www.pi.infn.it/bfactory/SvtConstruction/SVTModAss/index.html
  - Simple structure based on text files + perl script & web access
  - Very useful to:
    - Match parts for module assembly
    - Log phases, keep track of parts available for next phase
    - Generate bonding maps, updates with new defects, final list of defects/bonding errors
- Very important to keep track of all the operations and the operator name in the Construction DB

QC: general approach (III)

- Data from initial tests used to classify parts:
  - Class A: OK, defects < given threshold (i.e. 3% for sensors, ~ 1% average)
  - Class B: working parts with defects > threshold
  - Class C: degraded to mechanical samples.
- Qualified parts where then shipped to assembly site and optically inspected before module assembly.
- Matching of parts for module assembly (sensors, fanout, HDI) was done in order to keep average number of defects below a given threshold.
- During module assembly (next slide) electrical tests were repeated several times:
  - Search for new defects & possible rework in early phase
  - Qualify the parts before following phase
  - Update and keep track of evolution (currents, noise, ….)
  - Stop the part in case of failure (avoid to waste more parts).

Pisa SVT Construction Page

Welcome to the Pisa SVT construction page. Below there are links to the collection of files that constitute our local construction Database. The interfaces to these files are at different levels, as indicated in the list.

- **Arch module assemby area. We have Daily Briefings.**

- **DFA Construction** (full html). From here you access an html interface that gives you the list of DFAs, along with parts that make them, ie fanouts and detectors. In the bottom frame you will get by point and click the data sheets.

D01	D02	D03	D4A	D4B	D5A	D5B

- **Silicon Detectors** (full html). From here you access an html interface that gives you the list of Detectors, how good they are and the DFAs they are mounted on. In the bottom frame you will get by point and click the data sheets.

BB1	BB2	BB3	BB4	BB5	BB6

- **Fanouts** (full html). You get an html interface with the list of received fanouts. Selecting the fanout will bring up the datasheet. Electrical data is transferred from the Trieste server to this area when the fanouts are received in Pisa.

F01	F02	F03	F4A	F4B	F5A	F5B

Status

Back Home Next

- Instructions for carrying modules to the US.
- Module status information and data logging:
  - Viewed by layer:
    - Layer 4A
    - Layer 4B
    - Layer 5A
    - Layer 5B
  - Viewed by phase.
  - Module Summary.
  - Viewed by date.
- shift assignment for the Team members.
- For information about scheduled events and project milestones, see our Schedule page.
- October 23: Daily briefing introduced at 14:00 in the lab. Minutes available.

SVT Arch Module Assembly Area

For problems or questions regarding this web contact Francesco.Forti@pi.infn.it.
Last updated: January 06, 1999.

Update Construction DB at each operation

D5AB.10

DFA Scan and burn in information

DFA	CLASS	P-dead(%)	N-dead(%)	P-newdef	N-newdef	Burn-in	Comments
D5AB.10	A	3.6	3.1	1ph+3sh	1psh	COUPLED 44V 3uA	

Teststand information for D5AB.10 [History file] [Data directory] [No DFA specific page]

Construction information for D5AB.10

DFA	Class	FOP	FOZ	Det1	Det2	Det3	Det4	HDI	OthDFA	Module
D5AB.10	A	F5ABP.14	F5ABZ.16	BB6-1574.12	BB4-1524.13	BB4-1543.4	BB4-1540.2	H3.17	D5AF.6	M5A.4

Bond map page for D5AB.10

D5AB.10: Completed operations

Operation	Date	Operator	Info	Comment
Fanout Extension cut	10/22/1998	grassano		cut ok
Schedule HDI	11/12/1998	gbx	H3.17	
Schedule Other HM	11/12/1998	gbx	D5AF.6	
Zed gluing	11/16/1998	grassano		gled ok
Phi gluing	11/16/1998	grassano		Glue OK
Schedule Module Name	11/17/1998	forti	M5A.4	
Chip Bonding map	11/13/1998	bettarin		
HDI to Fanout Bonding	11/19/1998	profeti		
Start Testing HM Flat	11/20/1998	rizzo		
Finish Testing HM Flat	11/27/1998	rizzo		n=1.3%, p=5.2%
Alignment and Bending	12/9/1998	Sandrelli		
Rib and endpiece gluing	12/10/1998	rama		
Start Testing HM Bent	12/11/1998	folegani		
Finish Testing HM Bent	12/15/1998	rizzo		n=2.0%, p=5.3%
Survey	1/4/1999	Folegani, Piemontese		
Final Gluing of Connecting Piece	12/30/1998	bosi		
Final Testing	1/11/1999	calderin		
Ship	1/20/1999	calderin		travel III

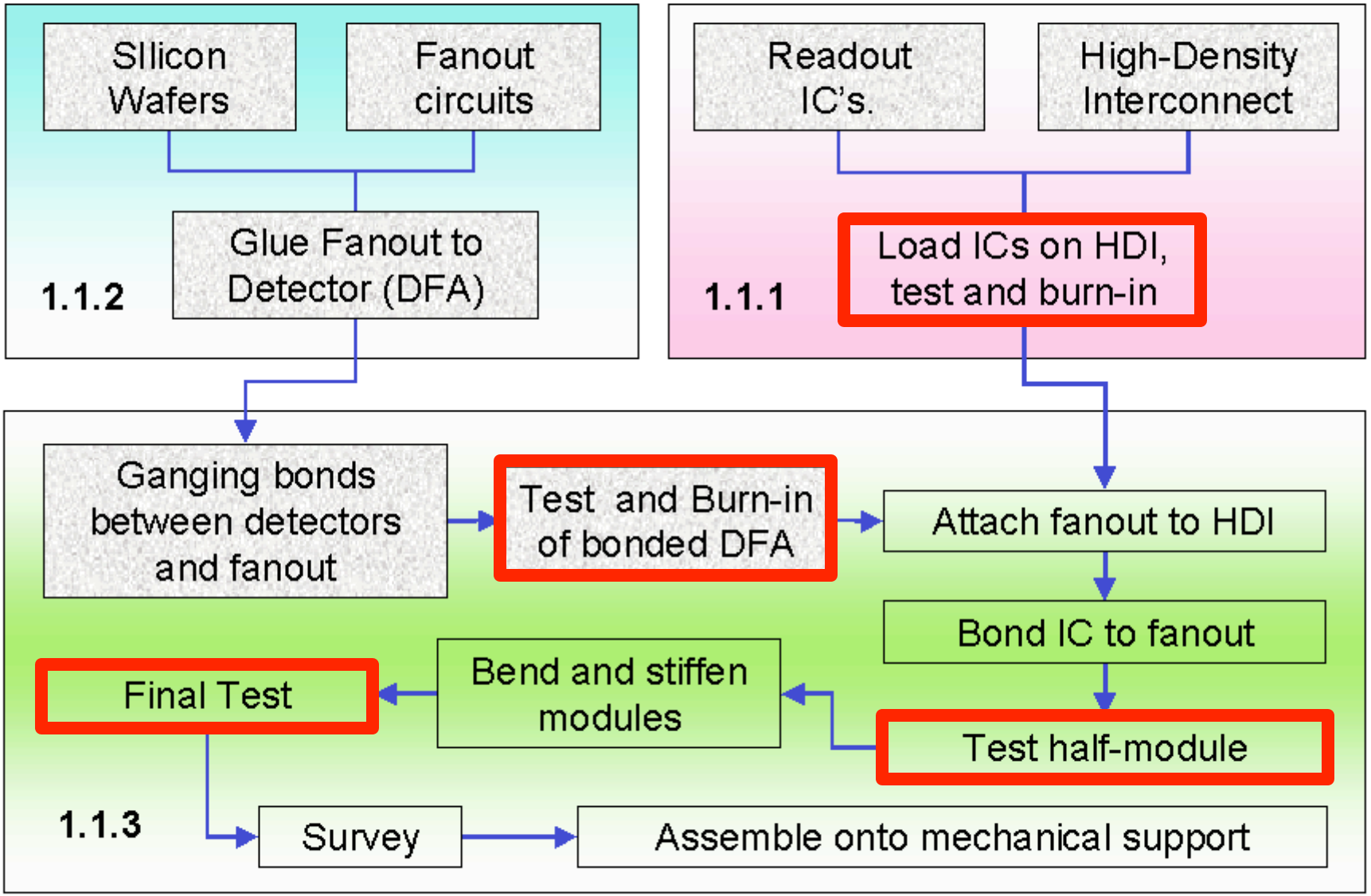
Insert new operation.

Username: Password:

Operator(if different from Username):

Operation: (none) Date: 21 April 2002

SVT Assembly Procedure +TEST

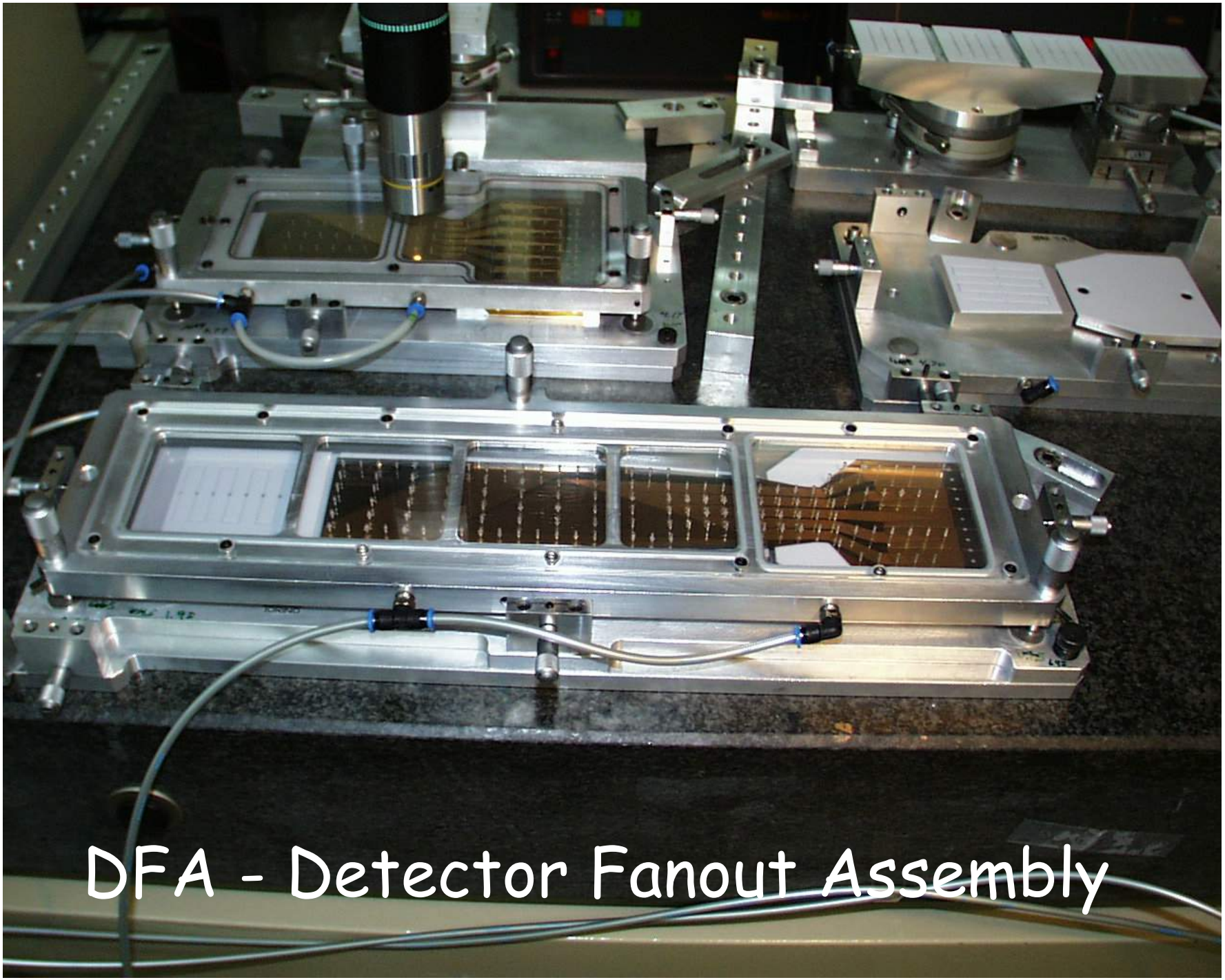


Some documents on BaBar SVT Module Assembly & QC

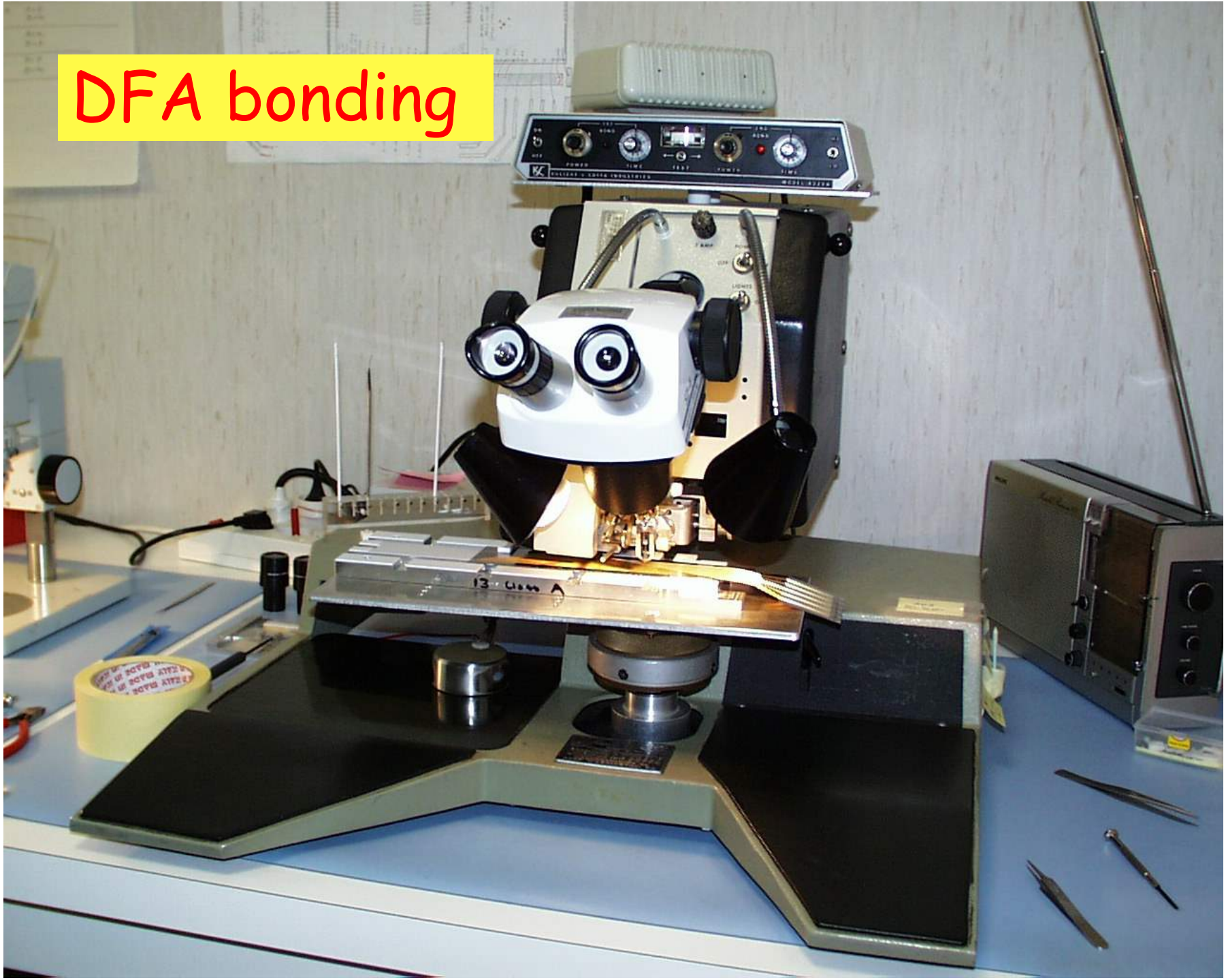
- Silicon sensor

Specifications and Quality Control Procedures of Silicon Detectors for SVT (BaBar Note 312)-July 1996

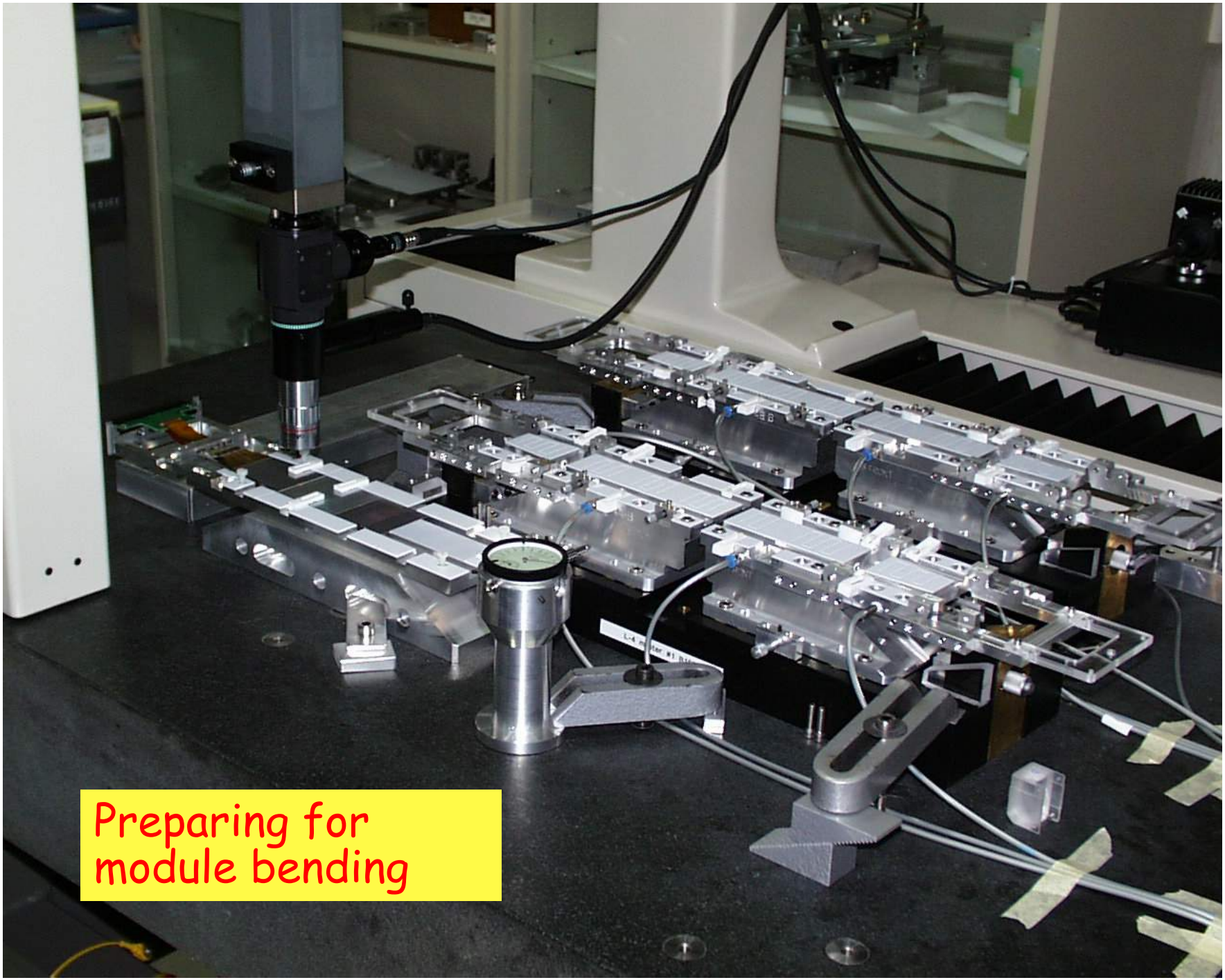
- Fanout: Specifications of the BaBar SVT FanOuts (BaBar Note 376) – August 1997
- Mechanical QC:
  BaBar SVT Mechanical Systems Design, Assembly, Procedures, and QC Description (BaBar Note 307) -April 1996
- Construction paper:
  The design and construction of the BaBar silicon vertex tracker NIM A 447, 15-25 (2000)

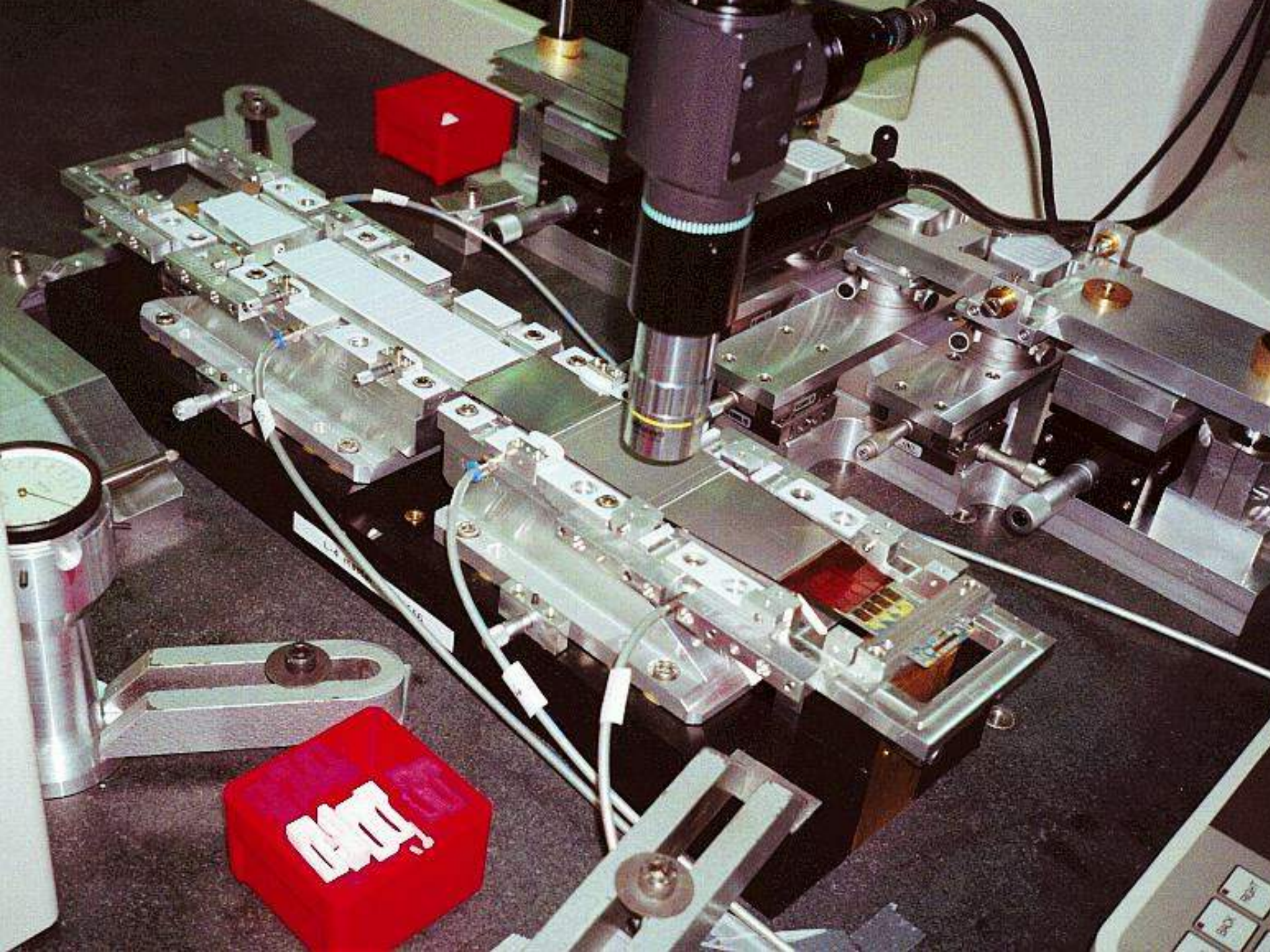

DFA - Detector Fanout Assembly

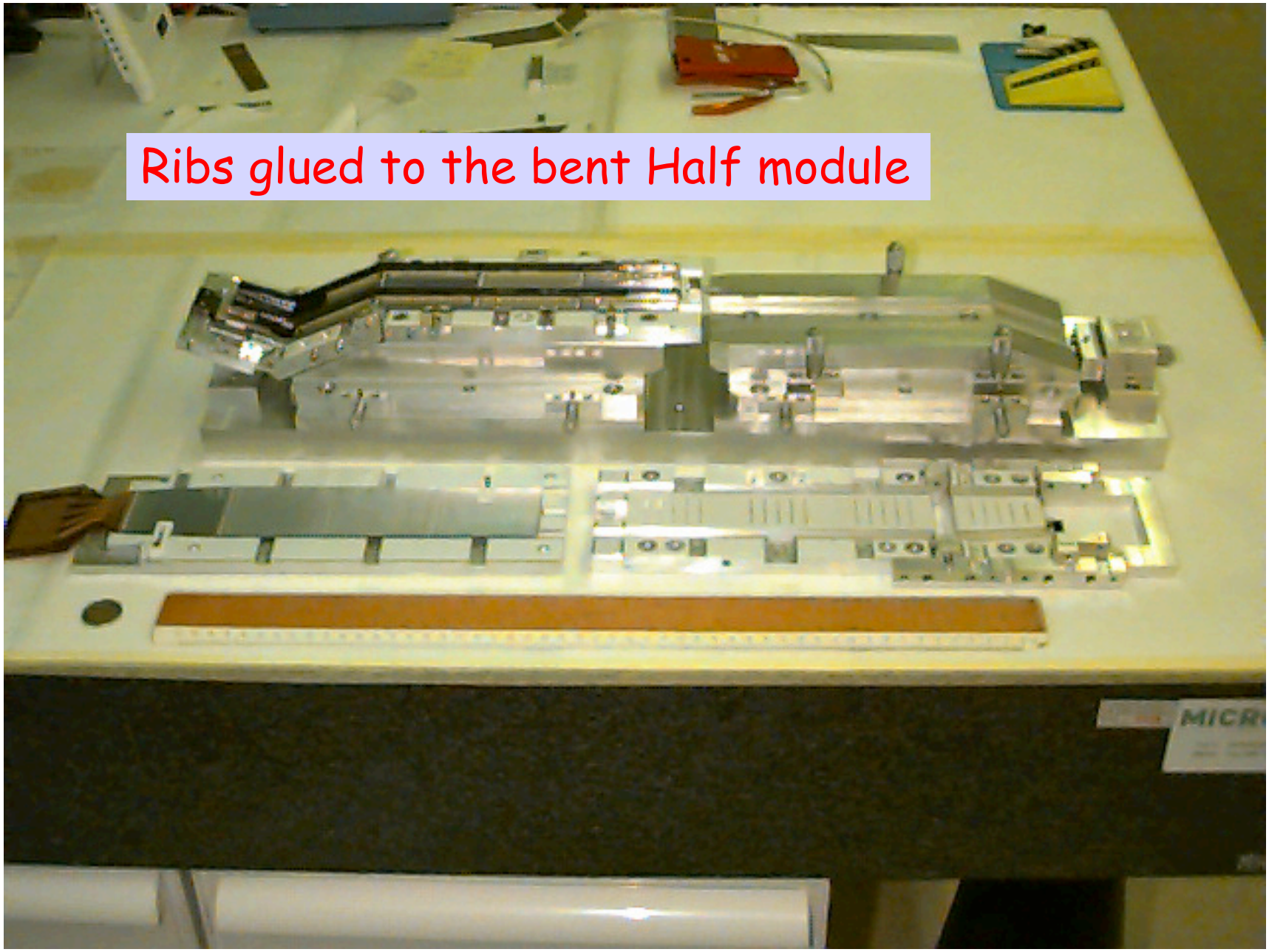
DFA bonding



DFA to HDI bonding


Preparing for
module bending




Ribs glued to the bent Half module

Sensor Test (I)

- Many details in BaBar Note 312- July 1996: "Specification and Quality Control Procedures of Silicon Detectors for SVT"
- Pretest @ Micron on wafer, before cut
  - total leakage current of all strips,
  - guard ring current,
  - scan of AC capacitors at 20V,
  - depletion voltage, oxide thicknesses, capacitor breakdown voltage and sheet resistances on test structures.
- Test in Trieste and Pisa, after cut, for final classification
- Optical inspection

a1) Total strip current after cut ($I_{DET} < 100$ nA/cm^2).

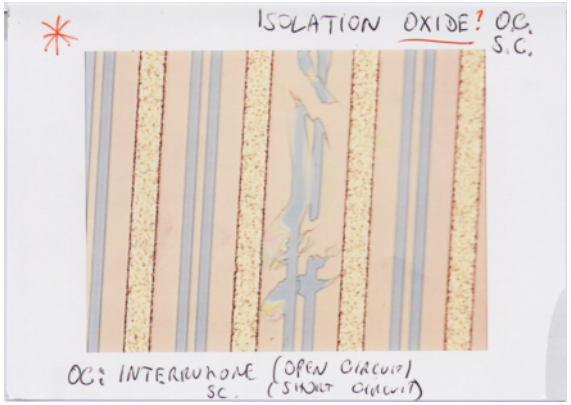
a2) Guard ring current after cut ($I_{GR} < 15$ μA).

a3) Isolation voltage sampled on a few strips, typically one in the middle and two on the edges ($V_{OP} < 60$ V).

b1) Interstrip capacitance (C_{IS}), sampled on both sides.

b2) Decoupling capacitance (C_{AC}), sampled on both sides.

b3) Series resistance of metal plate (R_S), sampled on both sides.



Sensor Test (2)

Additional tests to find defective strips

- AC scan on all readout strips:
  - Metal shorts,
  - AC broken capacitor (pinhole): short between metal and strip implant,
  - AC pad shorted to the p+ blocking strip on n-side (p-stop short)
- DC scan on all readout strips:
  - Leakage current
  - Interstrip resistance
  - Bias resistance
- Long term stability tests (a few hours) logging total current.
- Class A sensors must have < 3% defective strips, average quality ~ 1%
- Defective strips are NOT connected to fanout/FE chip

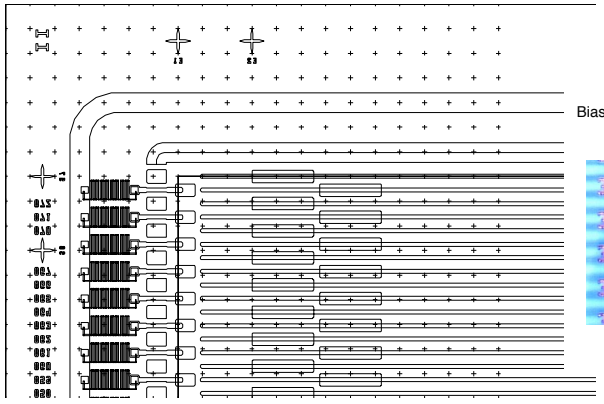
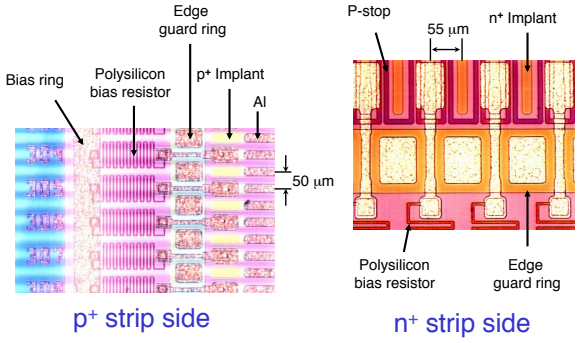


Figure 8: Pad rows on phi side of model II. Grid is 100 μm.



Sensor burn-in station (Pisa)

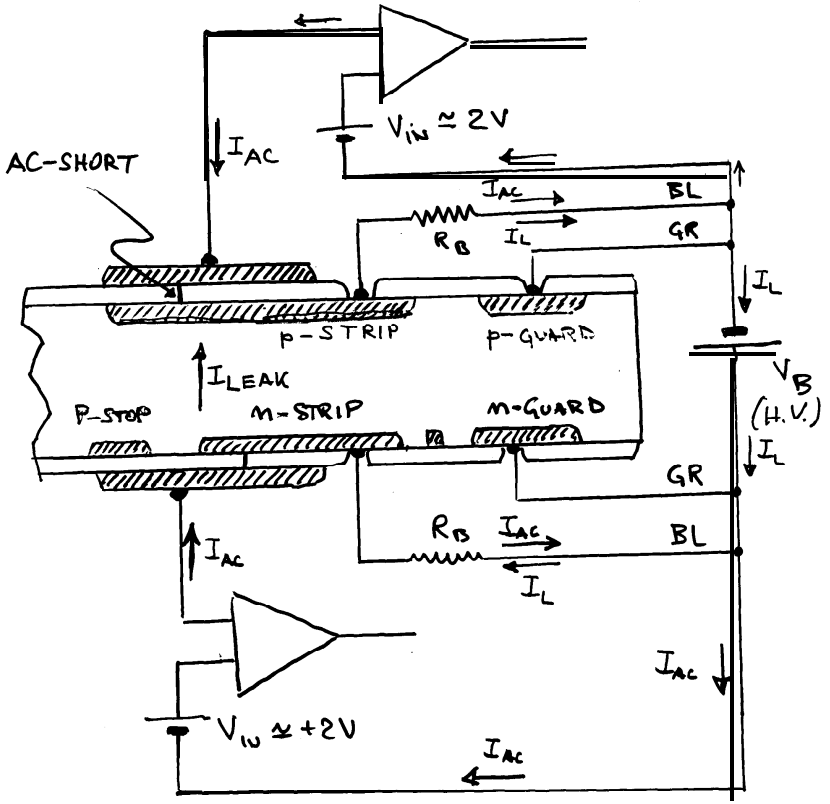
Details on P-stop short

L. BOSISIO
29-10-98
BABAR COLL. METING

1

- P-stop short on n-side could arise for small pitch detector, 50 um, where p+ is very close to n+ strip and AC pad is above both implants. Can cause large current when AC pad is connected to FE chip due to hole injection from p-stop.
- Power Supply setting modification foreseen in BaBar to avoid such a large current in case of pstop short connected to the FE chip

DETECTOR BIASING SCHEME



I_{LEAK} = STRIP LEAKAGE CURRENT
(GUARD RING CURRENT OMITTED FOR SIMPLICITY)

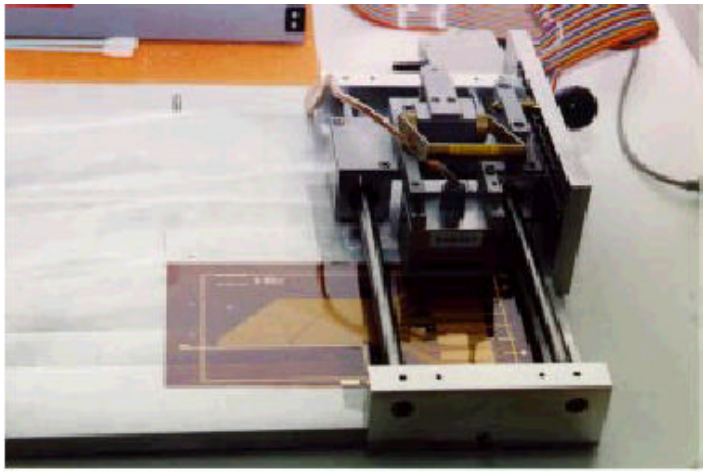
I_{AC} = ADDITIONAL CURRENT DUE TO AC SHORTS

Fanout Test

- @ Cern visual inspection: checks for open and remove shorts

Trieste:

- electrical test for shorts & open
- Rework
- Cut of extension used for testing & retest
- Mechanical survey



Fanout under test (Trieste)

HDI test

http://www.pi.infn.it/bfactory/HDIPages/

- Infos from chip loaded on HDI, and all the operations stored in the DB.

Operation	Side	Date	Operator
Load passive comps	A	12/9/98	R.Rava
Optical Inspection	A	12/9/98	R.Rava
Check shorts	A	12/9/98	R.Rava
Connector mech test	A	12/9/98	R.Rava
Check IC position	A	12/16/9	M.Ceccanti
Wirebond	A	12/17/9	P.Mammini
Load passive comps	B	12/10/9	Rosalba
Optical Inspection	B	12/10/9	R.Rava
Check shorts	B	12/10/9	R.Rava
Connector mech test	B	12/10/9	R.Rava
Check IC position	B	12/16/9	M.Ceccanti
Wirebond	B	12/17/9	P.Mammini
Thermal cycles	N/A	12/10/9	R.Rava
Connect A-B Sides	N/A	12/10/9	R.Rava
Label	N/A	12/10/9	Rosalba

Tuesday, December 29, 1998

H3.100 *Direction:* Any *Class:* A

DateReceived 12/12/98 *DateShipped:* 12/21/98 *I*

Notes:

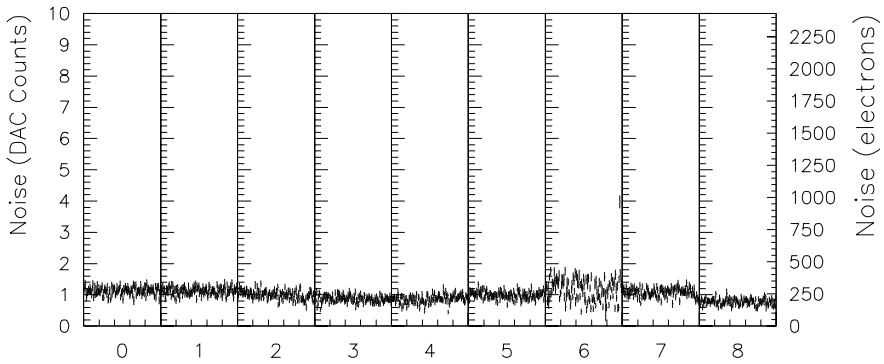
APlane: *AP1:* *AP2:* *BPlane:*

Side **A** *Polarity:* **P**

Pos	AtomID	Glued	Removed	Who	C
0	424306	12/16/98		MC	
1	424307	12/16/98		MC	
2	424308	12/16/98		MC	
3	424309	12/16/98		MC	

Side **B** *Polarity:* **N**

Pos	AtomID	Glued	Removed	Who	C
0	424406	12/16/98		MC	
1	424408	12/16/98		MC	
2	424409	12/16/98		MC	
3	424410	12/16/98		MC	
4	424411	12/16/98		MC	



- Electrical test to qualify parts & eventual rework
- Burn-in done with several HDI in parallel.

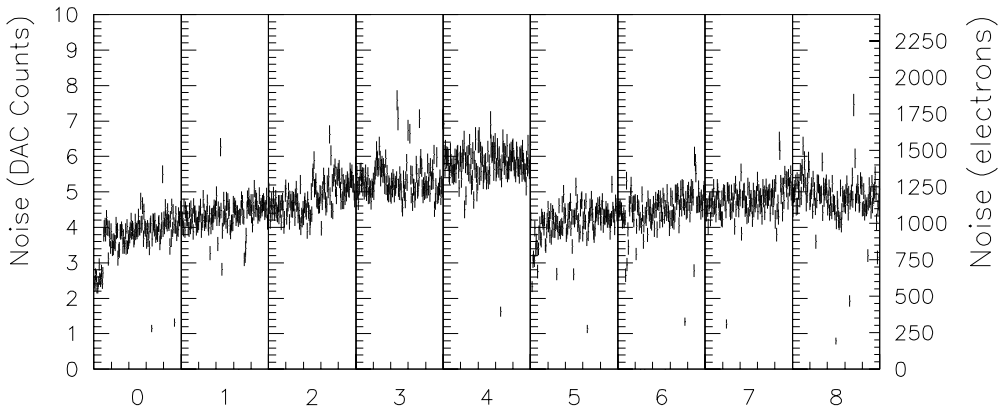
DFA test

- After DFA assembly and bonding new electrical test performed to look for new defects (sensor/fanout defects were not connected)
- Pinholes/pstop short: can occur during bonding if too much power is used in the wirebonding or if insufficient electrostatic protection is employed. Pinholes ~ 1-2% in DFA's, p-stop-short . 0.3% of channels in the 3 inner layers, almost absent in outer layers due to larger strip pitch;
- shorts: any mechanical damage due to improper handling may cause scratching of the detectors and fanout;
- un-bondable channels: a pad on the detector or on the fanout that has been damaged or obstructed such that wirebonding is no longer possible.
- Rework done in this phase if possible.
- On a DFA the sum of the manufacturing defects and defects that occur during assembly is 2-4%.
- Long term stability test (1 week): a few modules were stopped at this phase since Bias current started to drift after few days.

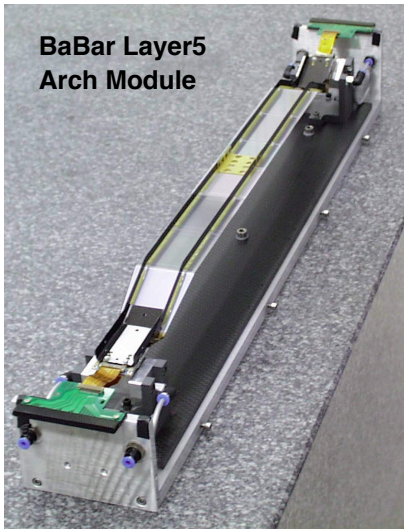
Final Assembly phases

- DFA to HDI gluing and bonding
- "Flat module" test: threshold scan, noise, gain

Internal charge injection used for
- Measuring **Gain**, **Noise**, and **Threshold Offsets**
- Identifying shorts and bad channels
- Examining Time Over Threshold (TOT) response
- Testing digital functionality



- Module alignment & bending (L 4,5) and rib (e-c piece) gluing
- "Bent module" test threshold scan, noise, gain
  Compare results before/after bending, Update bonding map → final grade
- Final central piece gluing & survey → final test
- Arch shipping



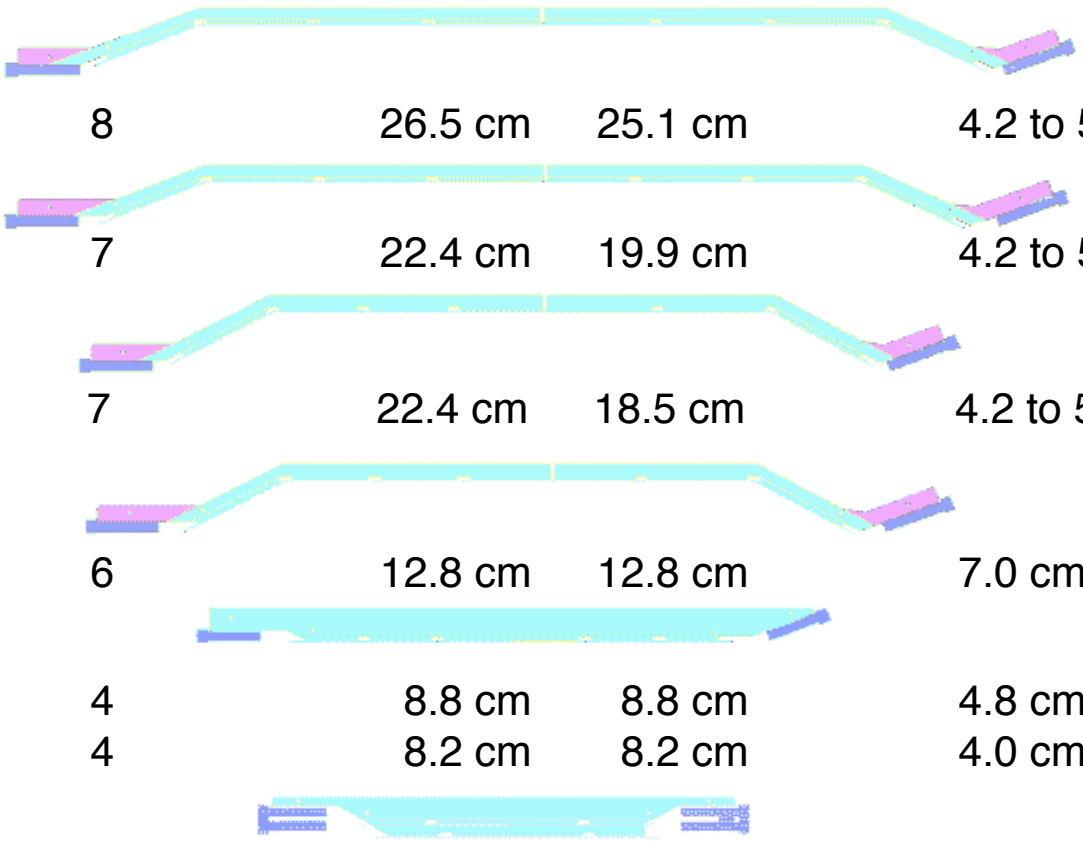
Questions for Belle2 SVD ladder assembly

- Sensor test: AC, DC scan info available?
- Pitch Adapter test: defect list ?
- Defective channels (sensor to PA) bonded?
- Long term stability after PA connection to sensor?
- What is the effect of defective sensor channels bonded to APV25?
  - AC short? Metal short? Other? Are they connected to chips?
- Which electrical test foreseen during assembly phases?
- Rework ?
- What level of test is performed on HDI? Long term stability?
- Details on APV25 Teststand for module test during assembly
- Cooling?
- Spare philosophy?
- HDI assembly/test ?

Backup

SVT Modules

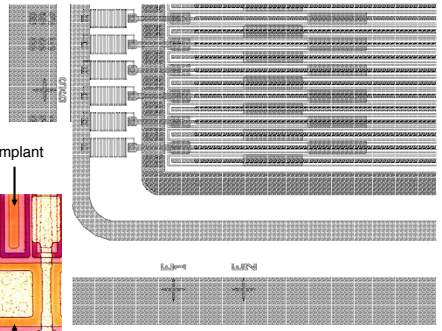
Layer	Number of Wafers	Total **Phi-Strip** Length Backward	Forward	**Z-Strip** Length
5b	8	26.5 cm	26.5 cm	4.1 to 5.1 cm
5a	8	26.5 cm	25.1 cm	4.2 to 5.1 cm
4b	7	22.4 cm	19.9 cm	4.2 to 5.1 cm
4a	7	22.4 cm	18.5 cm	4.2 to 5.1 cm
3	6	12.8 cm	12.8 cm	7.0 cm
2	4	8.8 cm	8.8 cm	4.8 cm
1	4	8.2 cm	8.2 cm	4.0 cm

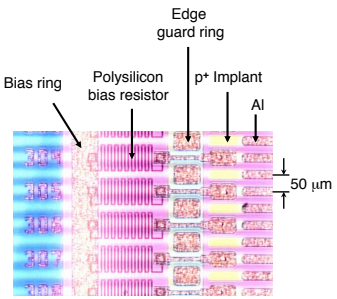


Half Module parts

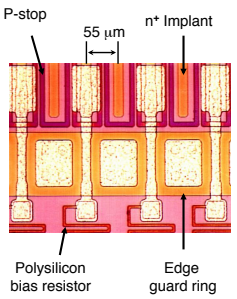
Si sensors double sided

6 different types ->340 sensors





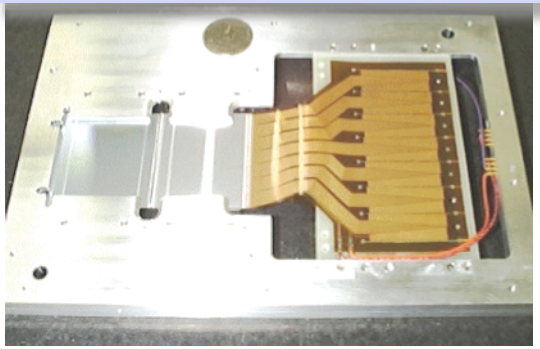
p+ strip side

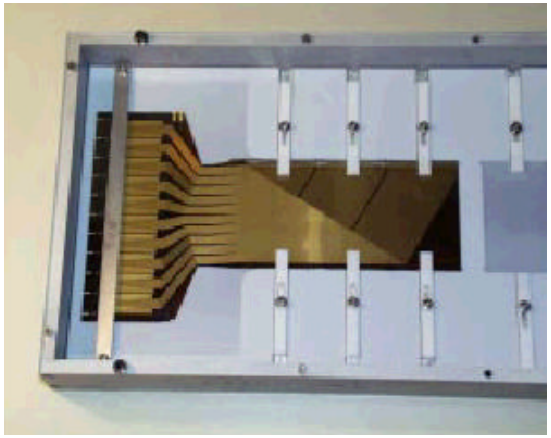


n+ strip side

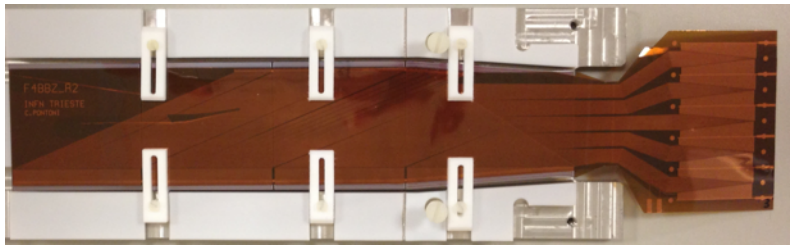
DFA: Detector Fanout Assembly

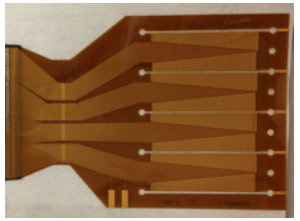
7FW + 7BW different types → 104 DFA's





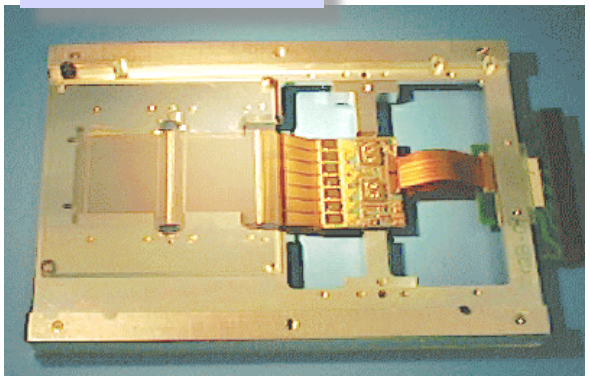
Fanout: 14phi+14z different types → 208 units





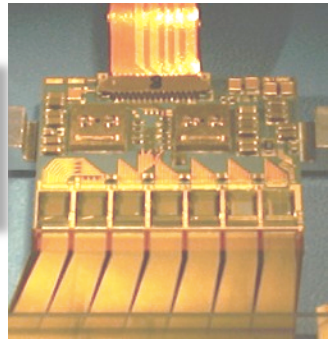
Test Tree extension very useful for DFA test, before connection to HDI (cut before connection to HDI).

Layer 1 module



Double sided AlNi HDI loaded with AToM chips

3 different types → 104 HDI's



G. Rizzo