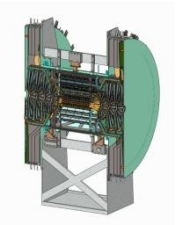


FVTX Wedge Assembly

WBS 1.4.1.3.3 to 1.4.1.3.12

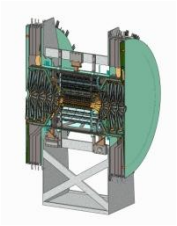
David Winter

Columbia University

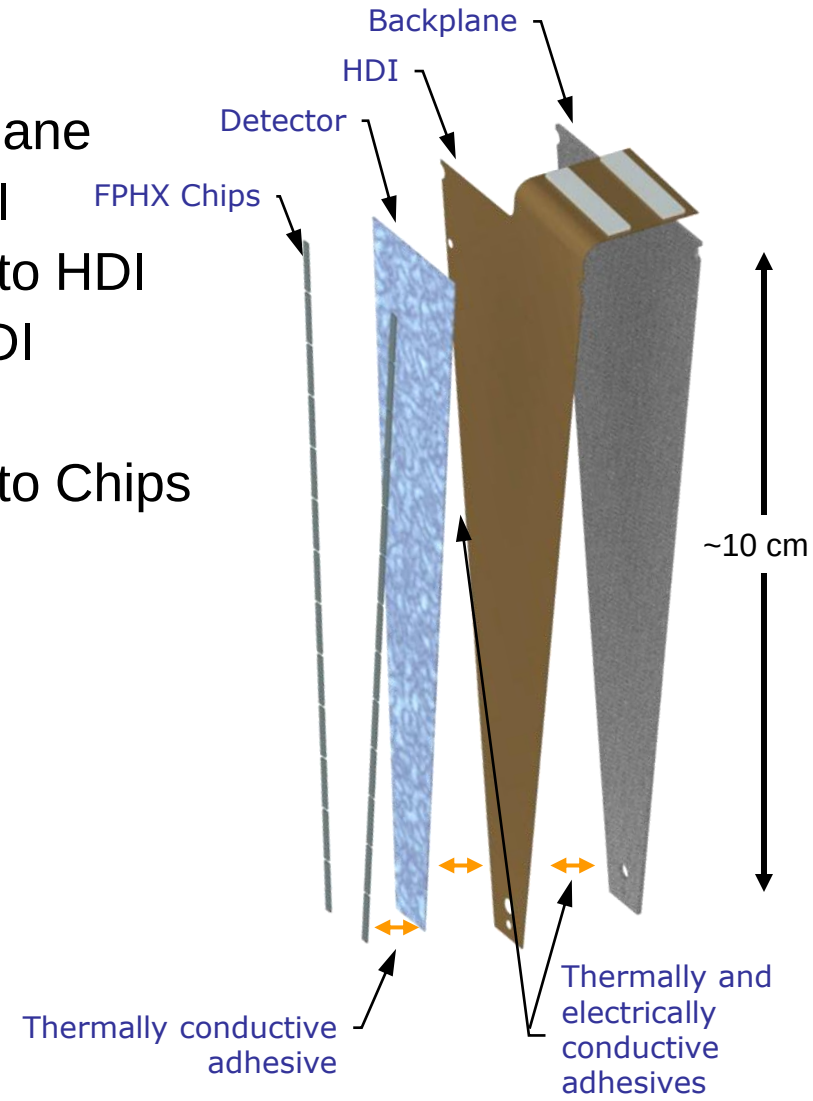
FVTX Wedge Manager

PHENIX

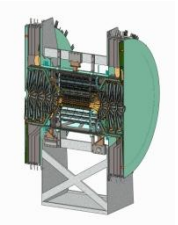
Talk Outline



- Scope
  - WBS 1.4.1.3.3 Attach HDI/Backplane
  - WBS 1.4.1.3.7 Bond Chips to HDI
  - WBS 1.4.1.3.12 Wirebond chips to HDI
  - WBS 1.4.1.3.8 Test Chips and HDI
  - WBS 1.4.1.3.4 Attach Sensor
  - WBS 1.4.1.3.5 Wirebond Sensor to Chips
  - WBS 1.4.1.3.6 Test Assembly
  - WBS 1.4.1.3.9 Encapsulation
- Wedge Schedule
- Procedure and Manpower
- Status of Production
- Summary



Scope

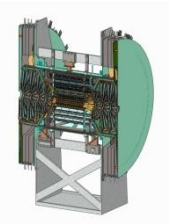


- Work with vendor to:
  - Prepare assembly lab(s)
  - Develop assembly procedure
- Receive backplanes, high-density interconnects (HDIs), sensors
  - All components arrive tested and qualified
  - HDIs populated with passive components
- Assemble received components into wedges
- Execute QA and testing procedures
- Enter QA/Test results into database
- Store assembled units
- Deliver assembled wedges to detector assembly facility at BNL

COMPLETED

IN PROGRESS

Wedge Schedule



Highlights of Dates Important to Wedge Assembly

• 2nd Prototyping/design of components, fixtures:	Completed	
• Procure and Q/A sensors:	Completed	
• Procure HDI:	In progress	
• Fabrication of backplanes:	Completed	
• Procure Wedge Assembly fixtures:	Completed	
• FNAL testing of production run of FPHX:	Completed	
• Wedge assembly:	6/2/10	2/4/11
– WBS 1.4.1.3.3 Attach HDI to Backplane:	6/2/10	11/29/10
– WBS 1.4.1.3.12 Wirebond FPHX to HDI	6/16/10	12/13/10
– WBS 1.4.1.3.5 Wirebond sensor to FPHX	7/7/10	1/6/11
– WBS 1.4.1.3.9 Encapsulation	8/4/10	2/4/11
• Endcap assembly (wedges onto disks):	11/8/10	3/9/11

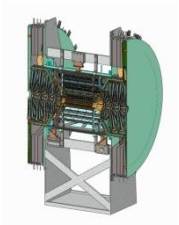
Important dependencies

- Critical path components: (Large) HDI

Main Highlights from Last Review

- Prototyping assembly work complete
  - Several prototype modules
  - Fixtures prototyped and in process of revision
  - Sidet established that assembly is well within their technical expertise
  - Sidet provided production estimate
- Production SOW in place
- Poised to begin wedge production

Wedge Assembly Procedure (1)



Sidet personnel

Bond backplane to HDI
Bond FPHX chips to HDI
Wirebond FPHX chips to HDI

Bond sensor to HDI
Wirebond sensor to FPHX

Encapsulate wirebonds

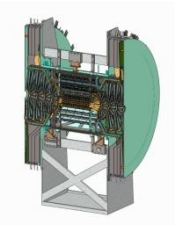
FVTX personnel

Chip readback
Pulser test

Chip readback
Pulser test
Source Test

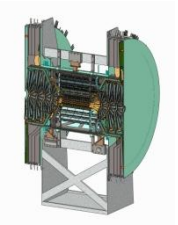
Chip readback
Pulser test
Source Test

Wedge Assembly Procedure (2)



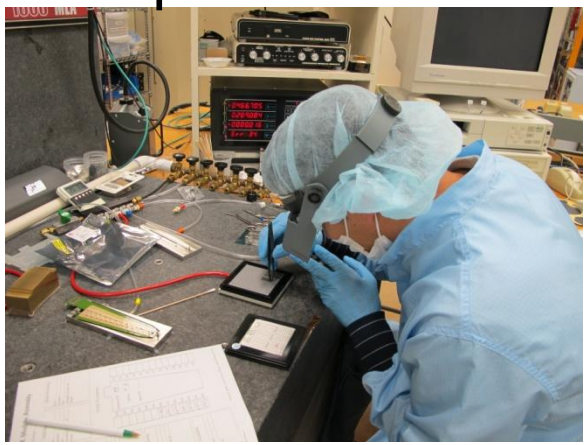
- Additional technical details
  - Arclad 7876 (50 micron thick) to laminate backplane, HDI, sensor and chips
  - Tra-con 2902 Silver Epoxy to provide conductivity between bias plane and sensor
  - Sylgard 186 for encapsulation
- Assembly done in “batches”
  - Small wedges: groups of 5 at a time
  - Large wedges (projected): 3 (or more) at a time
- Each step recorded in a traveler document
  - Originals kept at Sidet until end of project
  - Copy shipped with wedge
  - Traveler data also recorded in database for online search/access
- QA Testing
  - Recorded in paper and electronic log
  - Recorded in database

Wedge Assembly in Action



Assembly station

Chip Placement

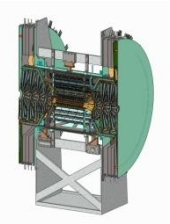


Final Product!

Wirebonding

Encapsulation

QA and Testing of Wedges

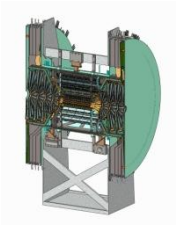


Basic Procedure includes:

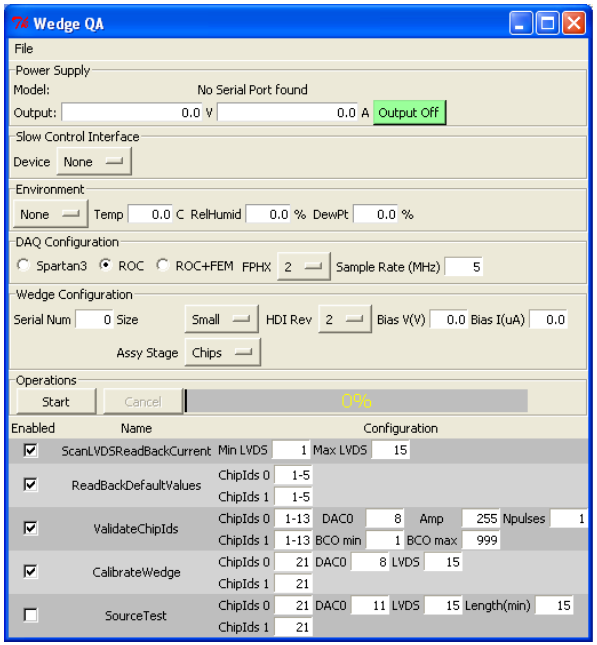
- Power up to verify low voltage and bias channels are operational
- Download/readback of configuration to the FPHX chips
- Threshold and noise measurements of the FPHX chips
- Readout of strips in response to external stimulus (radioactive source)
- Record results in database

- Procedure calls for testing at various stages of assembly
- Test single module at a time (current ROC limited to one wedge at a time)
- Final qualification is performed after assembly completed and before shipping
- In-place for the small production, and has been effective at identifying potential problems as early as possible, allowing us to correct them in a timely manner.
  - Example: Replaced FPHX chips: 3 (small) and 4 (large)

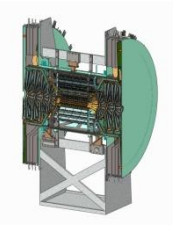
QA Procedure

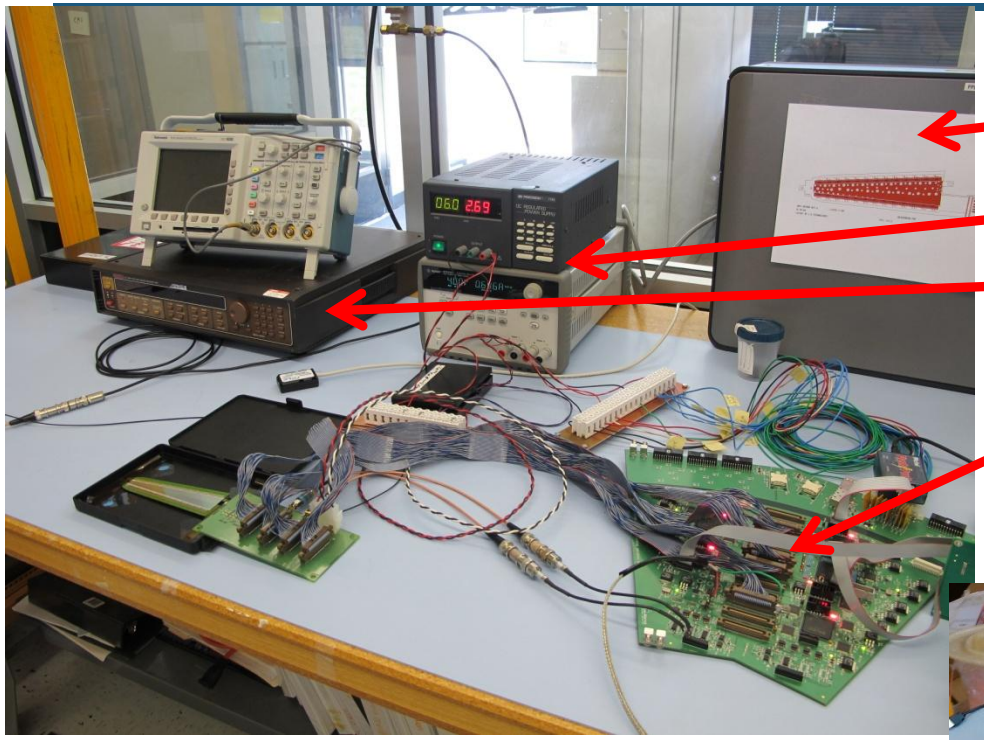


- Five tests performed
  1. Scan output current settings (15 values) and record current draw for wedge at each
  2. Scan Chip Ids and read back (default) values for each register
  3. Scan Chip Ids, enable two channels and pulse once
  4. Perform calibration (pulser) run
  5. Place Sr90 source above wedge, take data for 15 min
- For first iteration (sensor not yet mounted), source test is skipped
- Total test time takes ~20 min (dominated by source time)
- Simple user-friendly GUI

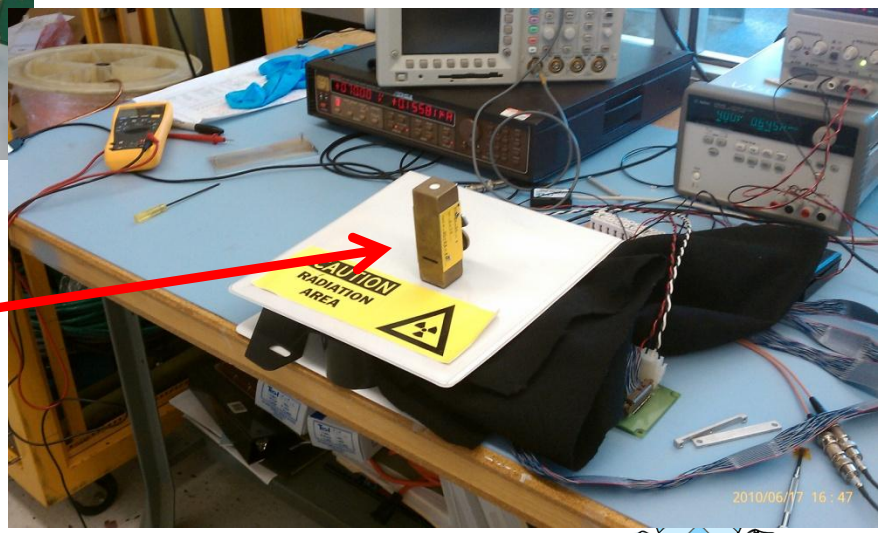


QA Setup



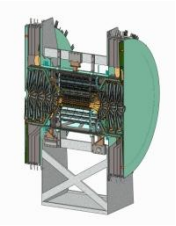


PC
LV supply
HV Supply
ROC

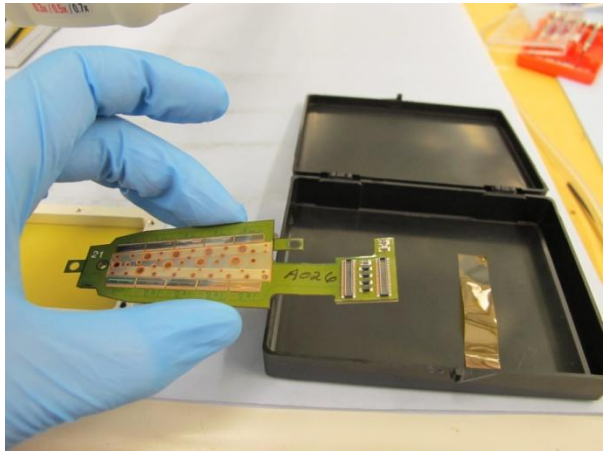


Sr90 source held ~3in above wedge

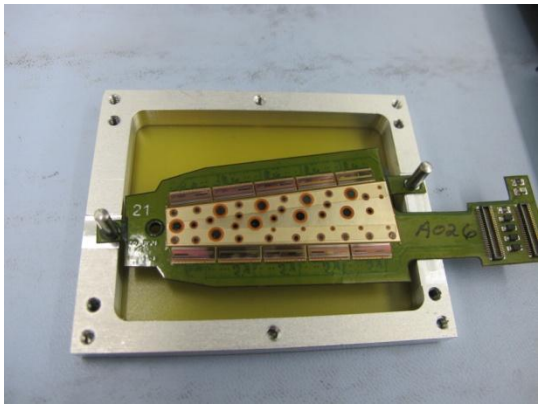
QA Testing in Action



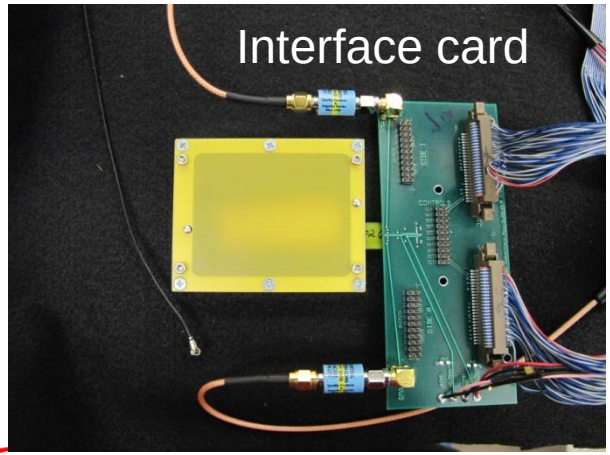
Pass-through from clean room to test area

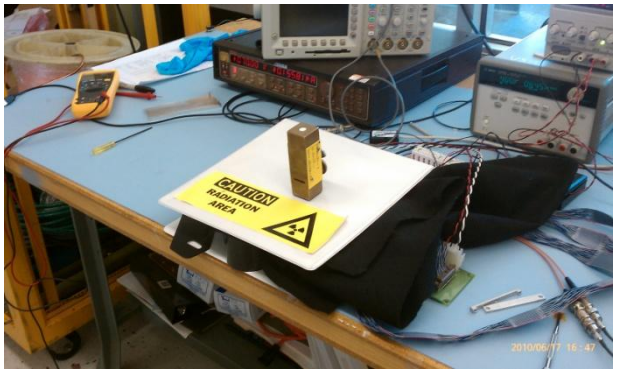


Wedges transferred in ESD boxes



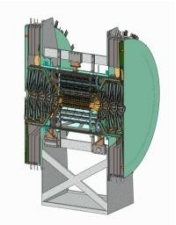
Wedges mounted in rigid enclosure for testing

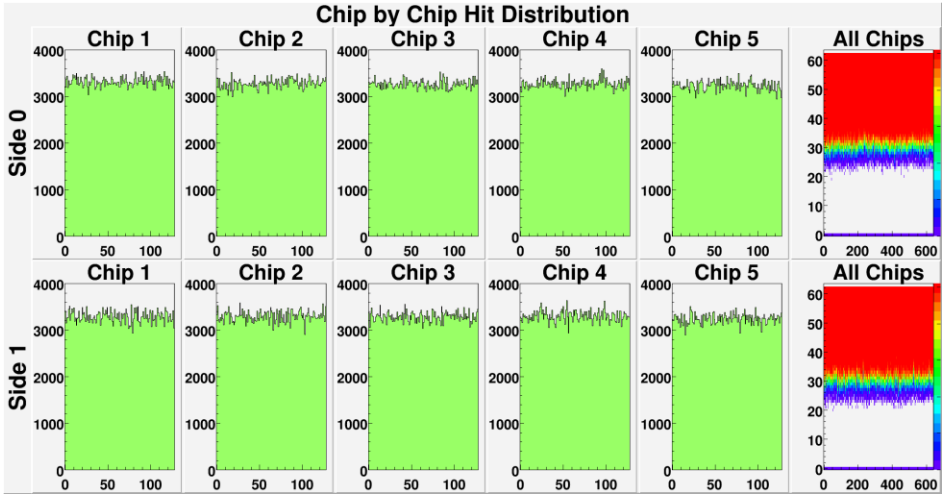


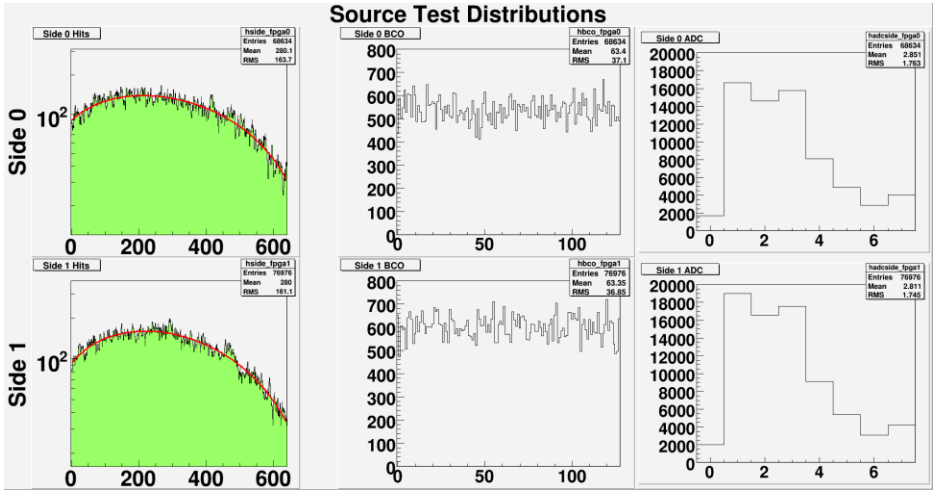


Taking data

QA Results (Typical)







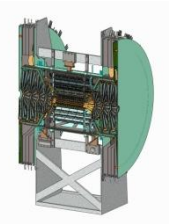
Calibration test with pulser:

- Enable one channel at a time (on each chip at same time)
- Scan through 63 pulser amplitudes
- Pulse 100 times
- Test duration = 30 secs

Source test:

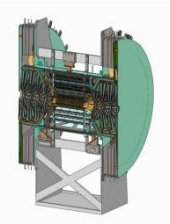
- Sr90 source @ ~3in
- All channels enabled
- Test duration = 15 min

Manpower Requirements



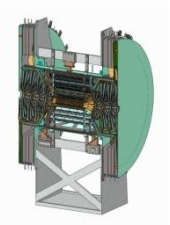
- Assembly calls for Sidet technicians
  - Manpower- and time-intensive tasks require technical skill
  - Originally to be handled by senior techs, then load taken by junior techs as experience is gained
    - Assembly: Tech Supervisor, Sr/Jr Technician
    - Wirebonding: Tech Specialist, Sr/Jr Technician
    - Encapsulation: Technician
  - [Small wedges] In the end Tech Supervisor (Bert Gonzalez) did all micro-assembly
- FVTX personnel in charge of testing
  - Requires 1-2 people for span of production time
    - AAron Veicht (Columbia Grad Student) on-site full-time
    - Dave Winter (Wedge Manager) on-site on rotating basis
    - Additional students and postdocs available from other institutions
  - Testing rate
    - Chips only: very rapid (typically 4-6 per hour), more than keeps up with production
    - With sensor: slower (typically 1-3 per hour), longer setup and running time

Status of Production Cost

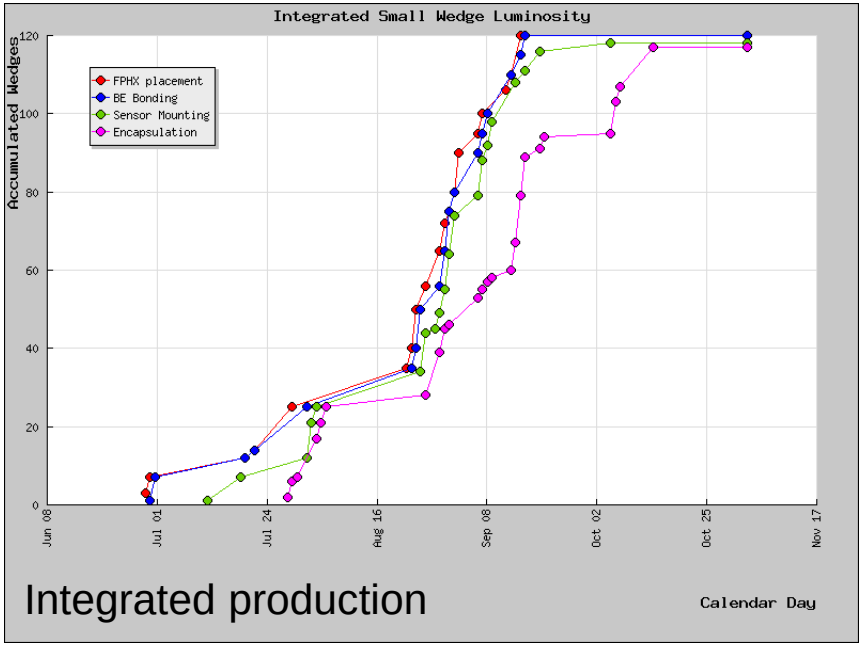


- In current estimate, production spans ~40 weeks
  - Primary bottleneck is wirebonding (31.5 weeks)
  - Testing takes place in parallel
  - Does not include attaching of pedestals or HDI bending
- Quoted cost was $248k. Includes:
  - Labor
  - Materials and Services
  - Indirect
- $65.5k spent (charged) to date
  - Represents ~25% of cost, produced 2/8 FVTX planes so far
  - On target with original estimate

Production Progress

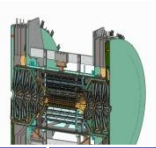


- **Overall production has been extremely smooth and successful**
  - Sidet is highly skilled & professional
  - Assembly & QA well-designed
  - Wealth of remote expertise
- Small and Large HDIs began to arrive at Sidet in June 2010
- Large wedge production (of first articles) completed in June 2010
  - 20 modules fully assembled and tested
- Small wedge production completed Oct 2010
  - 117 modules fully assembled and tested



Integrated production

Production Statistics

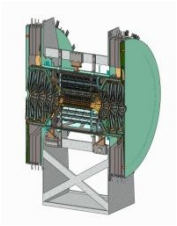


Stage	Avg (min)	Std Dev (min)
HDI to Backplane	10	1.5
Chips on HDI	30	3.4
Backend WB	8	1.4
Sensor to HDI	15	2.2
Frontend WB	21	12

Week #		# Started
26	6/28	7
29	7/19	18
33	8/16	7
34	8/23	24
35	8/30	34
36	9/6	15
37	9/13	15

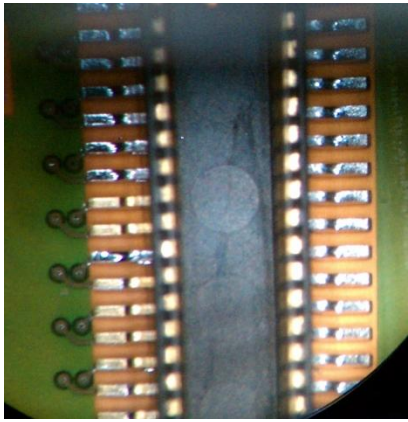
- Wedges were started and moved through assembly in batches (5 for small wedges)
- Average number per week = 17 (21.2 excluding two worst weeks)
- Peak per-week throughput = 34
- Bottlenecks
  - Wirebonding
  - Testing with sensor (setup is longer, source exposure is 15min)

Yields – Large Wedges



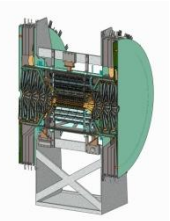
- 25 HDIs delivered to UNM in May
  - 24 “passed” all tests
  - 23 shipped to Sidet
- 23 wedges started
- 20 wedges completely assembled and tested
  - 2 needed rework and are ready for encapsulation

    Paused due to readout card issues and start of small production
  - 1 has a bad HDI that slipped thru QA
- Total of 299 FPHX chips placed!



20 fully working large wedges produced

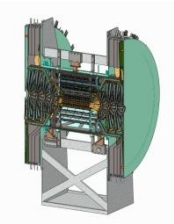
Yields – Small Wedges

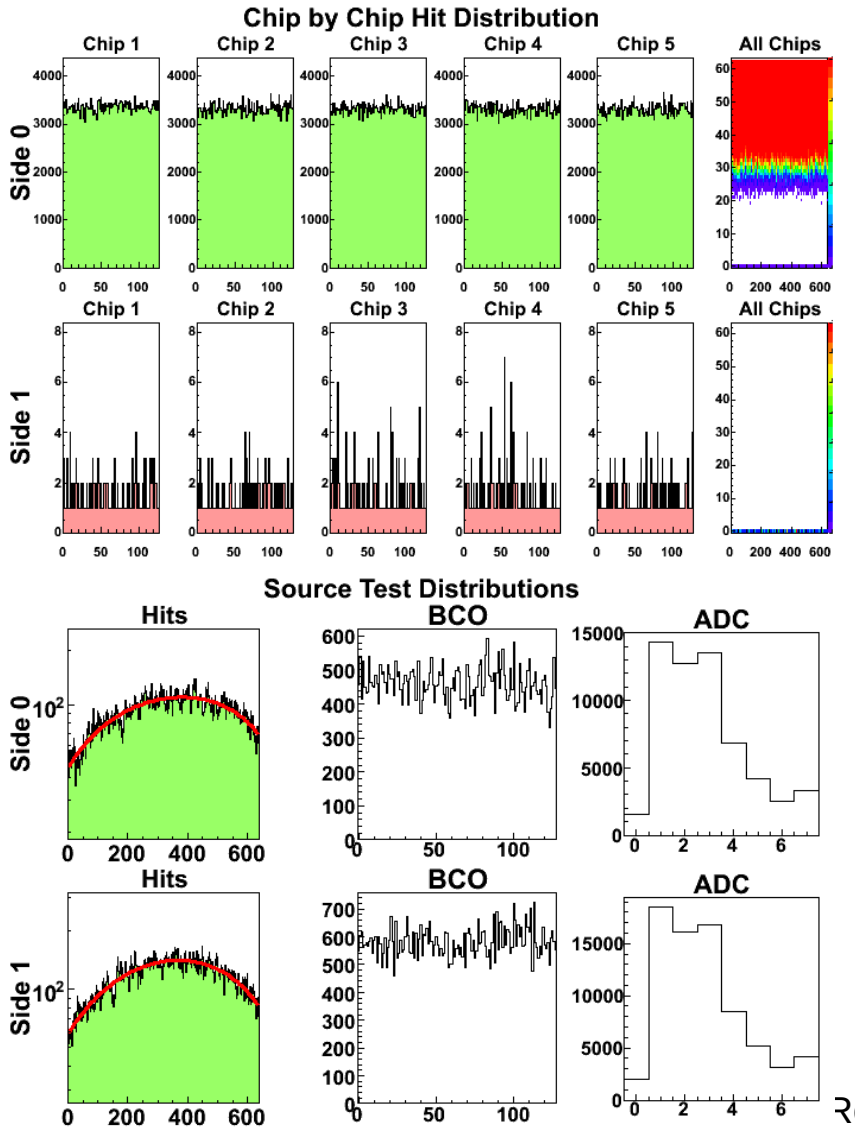


- 120 sensors delivered to UMN
  - 118 passed all QA test and were delivered to Sidet
- 120+ Small HDIs delivered to UNM in June
- 120 wedge assemblies started (we thought we had 120 sensors)
- 117 wedges fully assembled and tested
- 1 wedge has sensor which draws too much current
  - Defies both fixes and explanation
- Total of 1200 FPHX chips placed!
  - Including large wedges, grand total is 1499
  - Only a handful of chips (< 8) had to be replaced

117 fully working small wedges produced

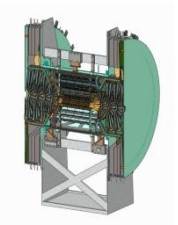
Production Problems (Injection Line1)



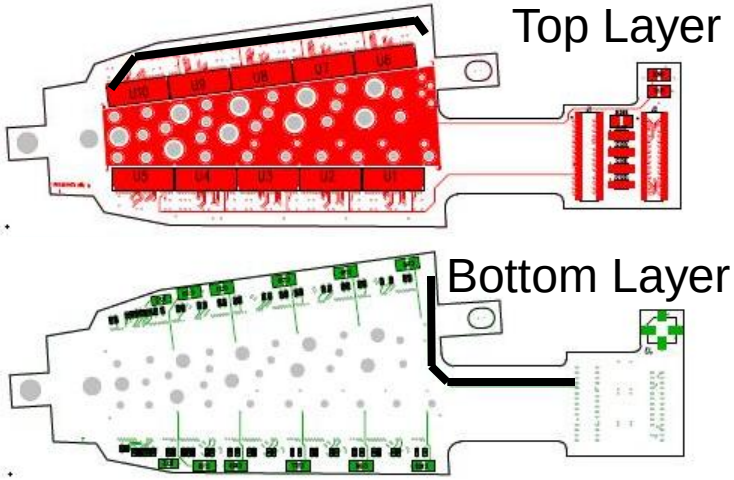


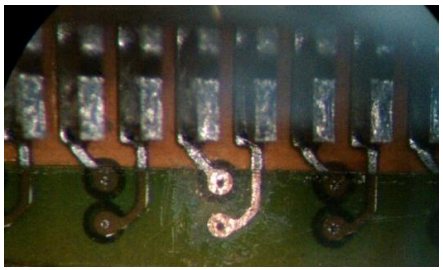
- Some wedges developed a problem with the Side 1 pulse inject line
- They produce no response to pulses on Side 1
- They work fine in response to a source
- Develops over time (ie. all HDIs passed their tests at UNM)
- Currently affects 39/118 small wedges

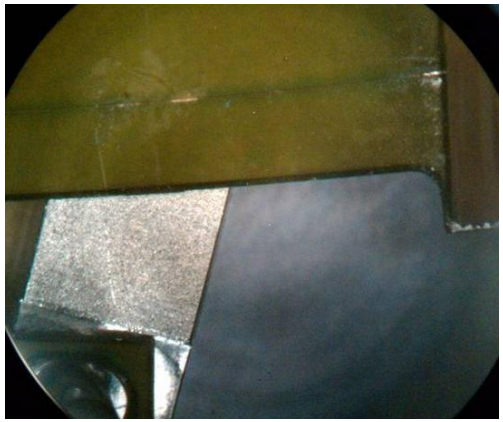
Inject 1 Investigation



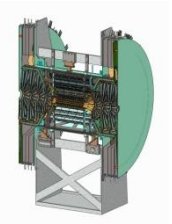
- Side 1 inject is the only trace to run along bottom layer
  - This means it connects to the input pin by way of via thru all 7 layers
- Systematically probed points along trace to find source of break
- Concluded the break was at/near via on bottom surface
- Not seen so far in large wedges, but steps have been taken by Dynconnex to minimize this happening in the current run.
- Solution is to hand-solder a wire from input pin to the trace, bypassing weak area.





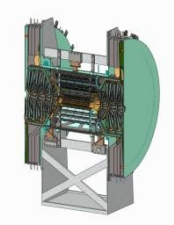


Production Plans

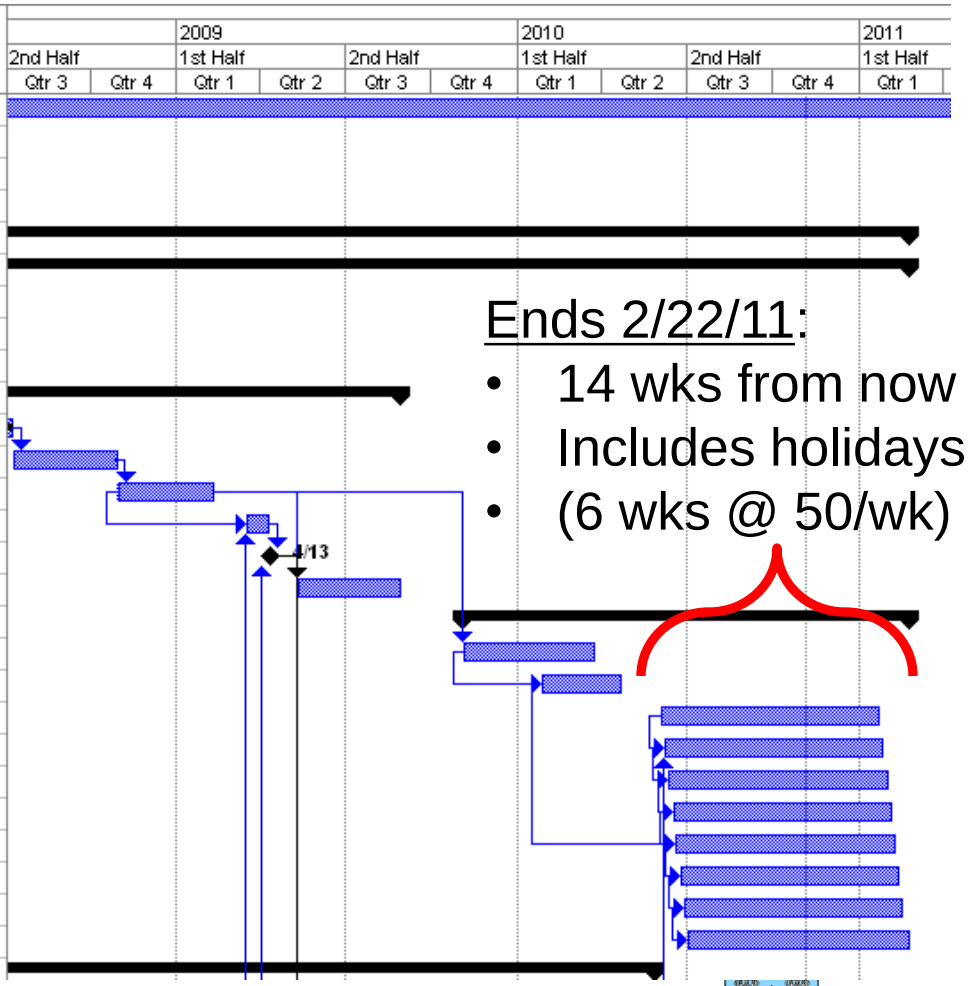


- Impact of large HDI delay
  - Directly delays production
  - Current estimate has HDIs arriving at Sidet ~ mid-Dec.
- Potential schedule compression drives need to economize in two places:
  - Sidet through-put: Increase personnel
    - Train a “Second Bert” for chip placement
    - DES project has completed at Sidet, giving us two full-time wirebonders
  - Testing through-put: Improvements in order of preference/ease:
    - More active Sr90 source to reduce exposure time
    - Adopt testing shifts (obviously requires second person)
    - Add second test station
- Nominally should allow a doubling of throughput (originally 5 per day, double that to 10 per day)

Schedule (with higher throughput)



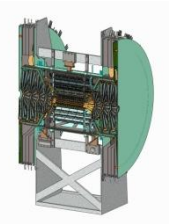
WBS	Task Name	Start	Finish
1	**FVTX Project**	**Fri 10/21/05**	**Tue 9/27/11**
1.1	**Start Construction**	Tue 4/1/08	Tue 4/1/08
1.2	**Start R&D BNL**	Mon 1/2/06	Mon 1/2/06
1.3	**Start R&D LANL**	Mon 1/2/06	Mon 1/2/06
1.4	**Wedge Components**	**Thu 3/15/07**	**Tue 2/22/11**
1.4.1	**Wedge sensors**	**Fri 2/15/08**	**Tue 2/22/11**
1.4.1.1	**Vendor selection**	**Fri 2/15/08**	**Thu 4/10/08**
1.4.1.1.1	develop criteria	Fri 2/15/08	Thu 2/28/08
1.4.1.1.2	Vendor quotes	Fri 2/29/08	Thu 4/10/08
1.4.1.2	**procure prototype sensor**	**Wed 6/11/08**	**Fri 8/28/09**
1.4.1.2.1	mask set	Wed 6/11/08	Tue 7/8/08
1.4.1.2.2	sensor manufacture	Wed 7/9/08	Tue 10/28/08
1.4.1.2.3	test prototype sensor	Wed 10/29/08	Tue 2/10/09
1.4.1.2.4	wire bond FPHX	Mon 3/16/09	Fri 4/10/09
1.4.1.2.5	1st prototype wedge assembly	Mon 4/13/09	Fri 5/8/09
1.4.1.2.6	test wedge assembly(system test)	Mon 5/11/09	Fri 8/28/09
1.4.1.3	**procure sensors**	**Wed 11/4/09**	**Tue 2/22/11**
1.4.1.3.1	procure sensor(fully tested)	Wed 11/4/09	Tue 3/23/10
1.4.1.3.2	Sensor Q/A	Wed 1/27/10	Tue 4/20/10
1.4.1.3.3	Attach HDI to Backplane	Wed 6/2/10	Fri 1/21/11
1.4.1.3.7	Glue chips to HDI	Mon 6/7/10	Wed 1/26/11
1.4.1.3.12	Wire bond chips to HDI	Thu 6/10/10	Mon 1/31/11
1.4.1.3.8	Test chips and HDI	Tue 6/15/10	Thu 2/3/11
1.4.1.3.4	Attach sensor	Fri 6/18/10	Tue 2/8/11
1.4.1.3.5	Wire bond sensor to chips + HDI	Wed 6/23/10	Fri 2/11/11
1.4.1.3.6	Test chip,sensor + cable assemblies	Mon 6/28/10	Wed 2/16/11
1.4.1.3.9	Wire bond encapsulation	Thu 7/1/10	Tue 2/22/11
1.4.2	**FPHX Chip**	**Thu 3/15/07**	**Thu 5/27/10**



Ends 2/22/11:

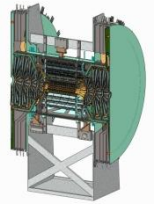
- 14 wks from now
- Includes holidays
- (6 wks @ 50/wk)

Summary

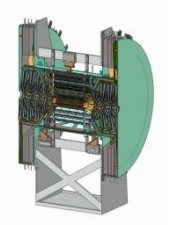


- Wedge assembly comprises WBS items 1.4.1.3.3 – 1.4.1.3.12
- Small wedge production **completed**
  - Very smooth, no major issues
  - Spanned June – Oct 2010
  - 117 working wedges (needed 96+8)
  - High yield due to both well-designed assembly and QA procedures
- Large wedge production **to restart in mid-Dec**
  - Dependent on HDIs – projecting week of 20th Dec
  - Duration should be 6 weeks
- Doubling throughput will ensure assembly can maintain schedule

Backup slides



Example Traveler Document



PHENIX FVTX Module Assembly

Module Number: 005

HDI Mounting
Date: 6/14/10
Operator: Bert
Site: FNAL
Assembly Fixture #: 1
Notes:

FPHX Mounting
Date: 6/15/10
Operator: Bert
Site: FNAL
Assembly Fixture #: 1
Notes: Chip placement Fixture # 2

Backend Wirebonding
Date: 6/15/10
Operator: T. Hemke
Site: Fnal
Assembly Fixture #:
Notes: 417 one pad very dirty three times to get Bond to stick U6 - 3 Re Bonds - OK 30 mins - Bonding & QA

Sensor Mounting
Date: 6/16/10
Operator: Bert
Site: FNAL
Assembly Fixture #: 1
Notes:

Frontend Wirebonding
Date: 6/16/10
Operator: T. Hemke
Site: FNAL
Assembly Fixture #:
Notes: Bonding went well no problems.

Encapsulation
Date: 06/21/2010
Operator: MWH
Site: FNAL
Notes:

FPHX Placement

R3#0	U14	Backplane ID: 046	U1	R2#7
R3#7	U15		U2	R2#8
R3#8	U16	HDI ID: 01	U3	R2#9
R3#9	U17	Sensor ID: 24	U4	R2#10
R3#10	U18	S/10938-942/(x)	U5	R2#11
R3#11	U19		U6	R2#12
R3#12	U20		U7	R2#13
R3#13	U21		U8	R3#6
R4#6	U22		U9	R3#5
R4#5	U23		U10	R3#4
R4#4	U34		U11	R3#3
R4#3	U25		U12	R3#2
R4#2	U26		U13	R3#1

Revision 1

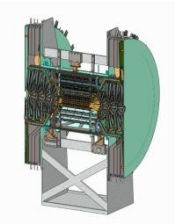
If found, please contact David Winter, winter@alum.mit.edu

Testing Notes *HDI + FPHX*:
JLW 6/15/10: Initially looks good. Calibration seems to be very noisy e DAC0=9. Needs investigation
HDI draws < 0.002 nA @ 5V Rins
Calibration has a few channels that are "dead", but they move around so we think this is a software prob.

Testing Notes *HDI + FPHX + Sensor*:
DW: Ran source test (run #1477) looks great

Testing Notes *HDI + FPHX + Sensor + Encapsulation*:
source (1808) DAC0=8 so a few hot channels OK
OK

Traveler Web Interface



https://www.phenix.bnl.gov/WWW/p/draft/fvtx/WedgeAssembly/Database/traveler_form.php

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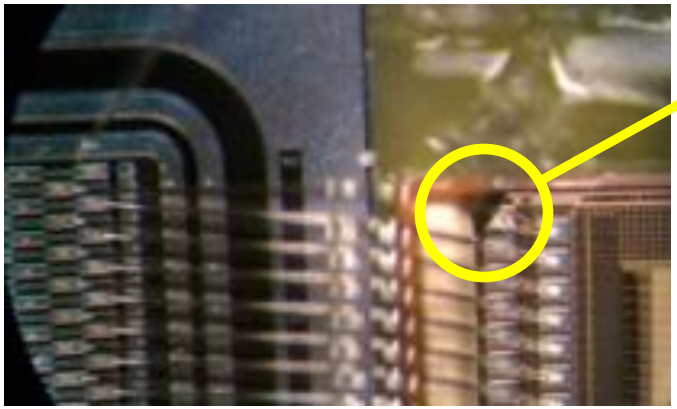
Module ID	Size	Archive	Assembly Stages					Assembly Tests			Inject1 Prob	Det Assembly (TBD)			
			Backpl ID	HDI ID	# chips placed	Sensor ID	Encap	Chips	Sensor	Encap		Station	E/W	plane	Pos.
1	large	front/back (pdf)	2	8	26	25	✓								
2	large	front/back (pdf)	8	9	26	21	✓								
3	large	front/back (pdf)	4	4	26	22	✓								
4	large	front/back (pdf)	7	12	26	27	✓								
5	large	front/back (pdf)	46	1	26	24	✓								
6	large	front/back (pdf)	47	3	26	23	✓								
7	large	front/back (pdf)	48	13	26	26	✓								
8	large	front/back (pdf)	49	14	26	28	✓								
9	large	front/back (pdf)	150	15	26	29	✓								
10	large	front/back (pdf)	151	16	26	30	✓								
11	large	front/back (pdf)	152	18	26	31	✓								
12	large	front/back (pdf)	153	19	26	32	✓								
13	large	front/back (pdf)	154	20	26	33	✓								
14	large	front/back (pdf)	155	21	26	35	✓								
15	large	front/back (pdf)	156	22	26	36	✓								
16	large	front/back (pdf)	158	23	26	37	✓								
17	large	front/back (pdf)	159	24	26	38	✓								
18	large	front/back (pdf)	70	25	26	39	✓								
19	large	front/back (pdf)	71	26	26		✗								
20	large	front/back (pdf)	72	27	26	40	✓								
21	large	front/back (pdf)	73	28	26	41	✗								

Traveler_Large_005_r....jpg | Traveler_Large_005_fr....jpg | gifsicle-1.60.tar.gz | Show all downloads...

Production Problems (Minor examples)



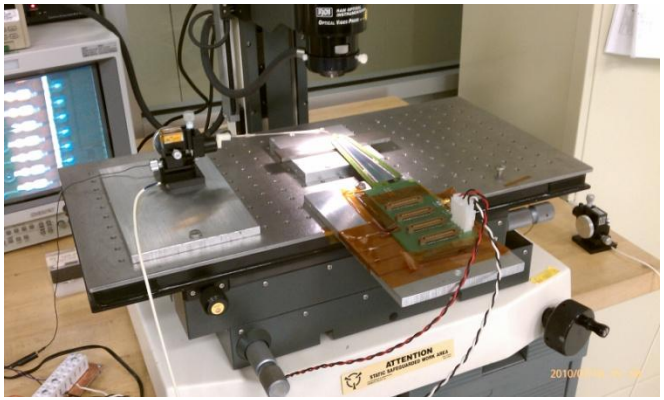
Occasionally FPHXs do chip during wirebonding

Procedure exists to replace damaged chips

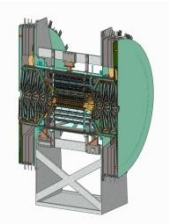
In one case, HDI “lost” a chip id pad

Confirmed with probe station

Wirebonded to good pad



Managing the Schedule

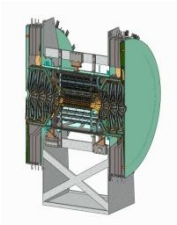


- Input constraints
  - Wedges are started in batches, and more or less move thru system that way
  - Between chip placement and wirebonding, arclad needs about 2 hours to "harden"
  - Testing keeps pace with production (latency problems with source testing are solved)
  - Ag epoxy needs at least 4 hours curing to be effective
- Assume 2 batches of 5 at a time

Task	M	T	W	Th	F	Total
HDI+FPHX	10	10	10	10	10	50
BEWB	10	10	10	10	10	50
Sensor	10	10	10	10	10	50
FEWB	10	10	10	10	10	50
Encap	10	10	10	10	10	50

Note:
- Chip placement, wirebonding and encapsulation scale with size (various amounts)
- Other tasks do not
- 5/batch considered average – will be slower at start, and faster later

Silicon Detector Center @ FNAL



- Primier facility for building and testing vertex detectors for HEP experiments
- Five large-scale clean rooms for assembly and testing
- Several wirebonding stations
- Wide expertise with Silicon and CCD technology
  - CDF, D0, CMS, SNAP among others

Example of managed process flow

	week 1	week 2	week 3	week 4	running total	week 5	week 6	week 7	week 8	running total	
Bert											
HDI	104 HDI BP				104	104 HDI BP				208	Bert
Chips		40 chip HDI	24 chip HDI	40 chip HDI	104		16 chip HDI	40 chip HDI	40 chip HDI	208	
Sensors			40 sensors		40		64 sensors			104	
Tammy											
Chips		40 chip HDI			40	64 chip HDI			80 chip HDI	184	Tammy
Sensors			16 sensors	20 sensors	36	4 sensors	20 sensors	20 sensors		80	
	week 9	**week 10**	**week 11**	**week 12**		**week 13**	**week 14**	**week 15**	**week 16**		
Bert											
HDI	104 HDI BP				312	104 HDI BP				416	Bert
Chips		16 chip HDI	40 chip HDI	32 chip HDI	296			40 chip HDI	40 chip HDI	376	
Sensors		80 sensors		24 sensors	208		80 sensors			288	
Tammy											
Chips			24 chip HDI		208	80 chip HDI				288	Tammy
Sensors	20 sensors	20 sensors	14 sensors	20 sensors	154		20 sensors	20 sensors	20 sensors	214	
	week 17	**week 18**	**week 19**	**week 20**		**week 21**	**week 22**	**week 23**	**week 24**		
Bert											
HDI					420						
Chips	40 chip HDI	4 chip HDI			420						
Sensors		80 sensors		52 sensors	420						
Tammy											
Chips	80 chip HDI		52 chip HDI		420						Tammy
Sensors		20 sensors		20 sensors	254	20 sensors	20 sensors	20 sensors	20 sensors	334	
	week 25	**week 26**	**week 27**	**week 28**							
Tammy											
Sensors	20 sensors	20 sensors	20 sensors	20 sensors	420						Tammy