IBL Project Overview

9th Trento Workshop

Genova, February 26-28, 2014

D. Ferrère on behalf of the ATLAS Pixel community

Overview

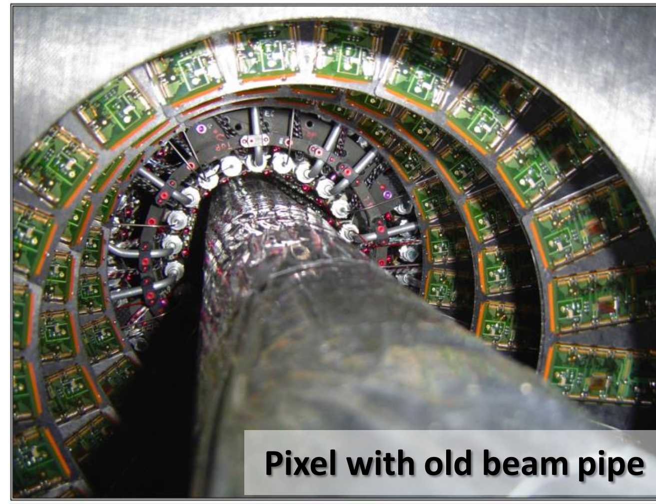
- **IBL project** - Introduction and layout & original challenges
- **Detector** & **FE** design **features**
- **The module and stave** production
- **The module loading & stave QA** overview
- Summary of **issues met**
- **Overview of the produced staves**
- **IBL package** and engineering work
- **The integration & tests**
- **Feedback from the tests -** FBK noise features
- **The IBL insertion tests & CO_2 cooling system**
- **Towards completion** and timelines
- **Conclusions**

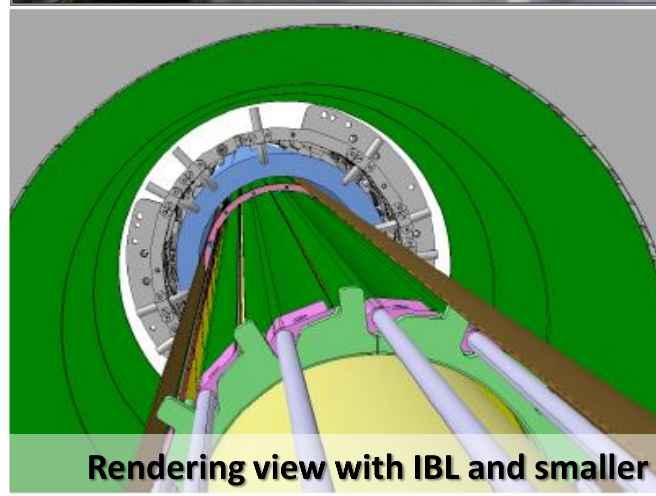
Introduction and Layout

IBL is an additional inner most Pixel layer that will improve our tracking performance

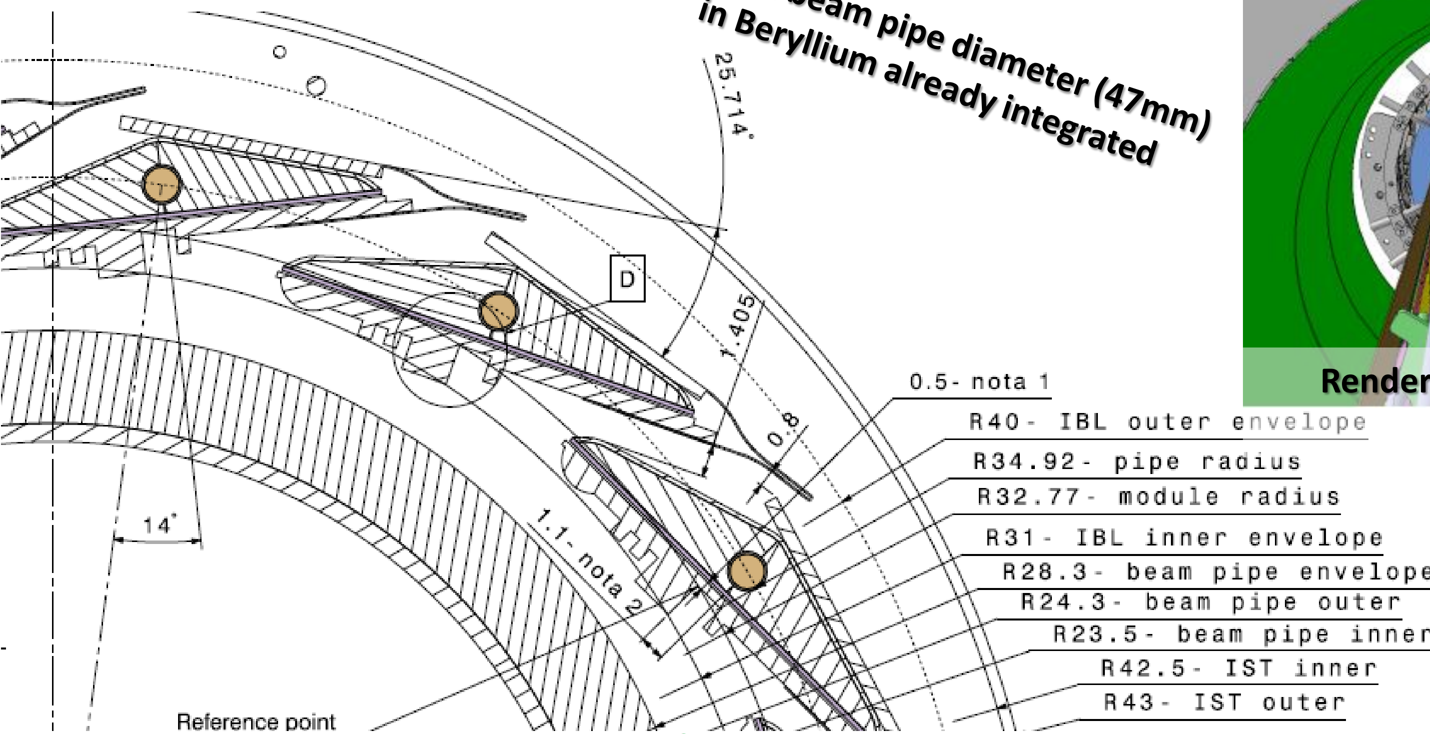
Features:

- ✓ 4^{th} Pixel layer (instead of b-layer replacement)
- ✓ Closer interaction point (5.05 → 3.27cm)
- ✓ Smaller pixels (50 x 250 µm2)
- ✓ Better sensors, better R/O chip
- ✓ More robust tracking
- ✓ Better performance


Pixel with old beam pipe


Rendering view with IBL and smaller beam pipe

Reduce beam pipe diameter (47mm) in Beryllium already integrated



Sensor designs

3D and planar technology are used in combination on the same stave

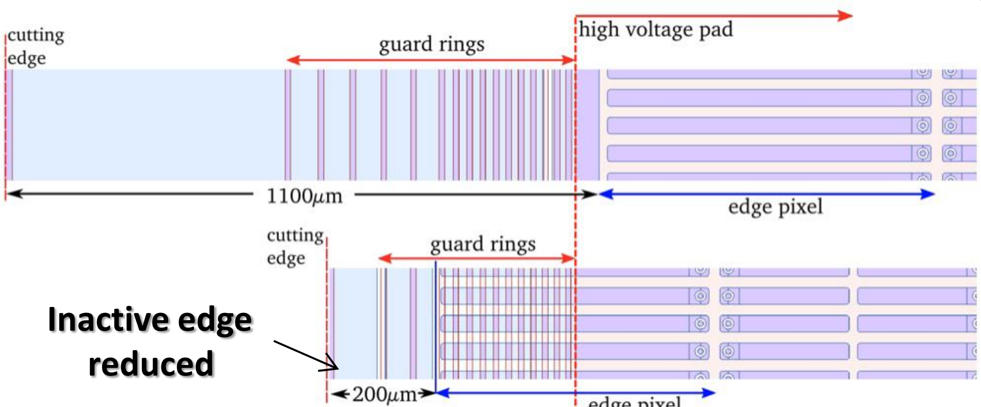
Features	Planar	3D
Thickness (nominal) [μm]	200	230
Depletion voltage [V]	~50	10 - 25
Working voltage after LHC fluence ($5x10^{15}$ 1MeV n_{eq}/cm^2) [V]	~1000	~160
Pixel [FE x Row x Column]	2x336x80	1x336x80
Active size WxL [mm^2]	16.8 x 40.9	16.8 x 20.0

Planar features:

- **n-in-n** technology
- **Lower thickness** than Pixel
- **Inactive edge** minimized to 200 microns

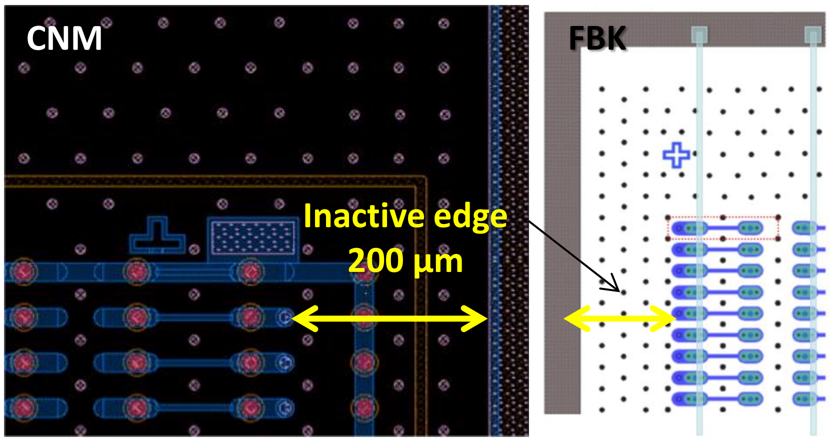
3D features:

- **D**ouble-side **D**ouble **T**ype **C**olumns (DDTC) process
- **Guard ring fence:** 200 microns inactive area
- **CNM:** No full 3D columns (210 μm)
- **FBK:** Full 3D columns (230 μm)



Inactive edge reduced

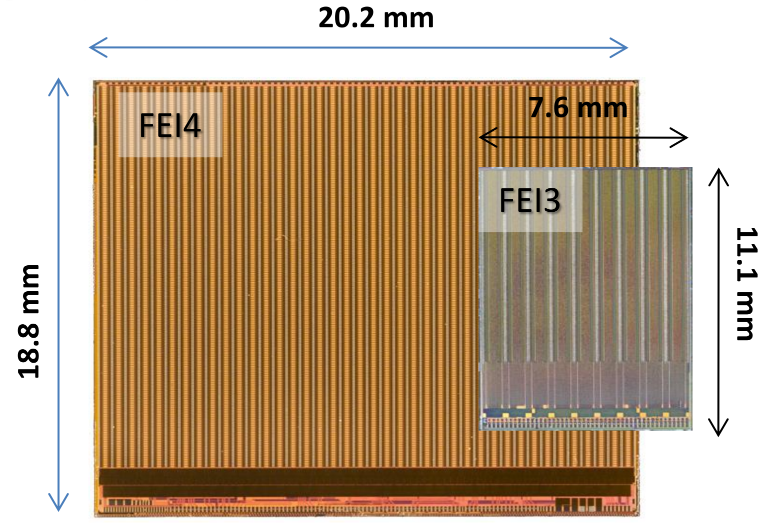
Overlapping of pixels and guard rings



Front-end readout – FEI4

FEI4 main features:

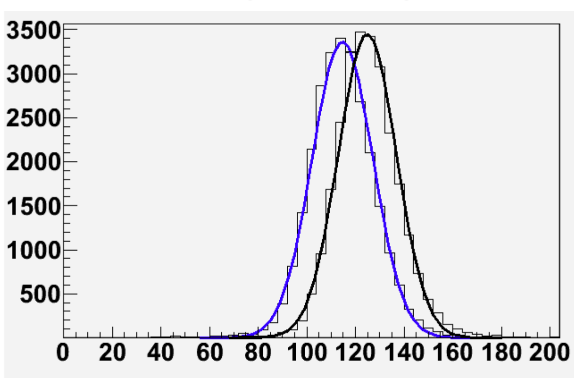
- IBM (130 nm)
- 70 Million transistors
- 26880 pixels (50 x 250 µm2)
- Lower noise than FE-I3 (~150e- with sensor)
- Lower threshold operation
- Higher rate capability
- Radiation hard to >250Mrad
- In use for pixel R&D and towards Upgrade phase2

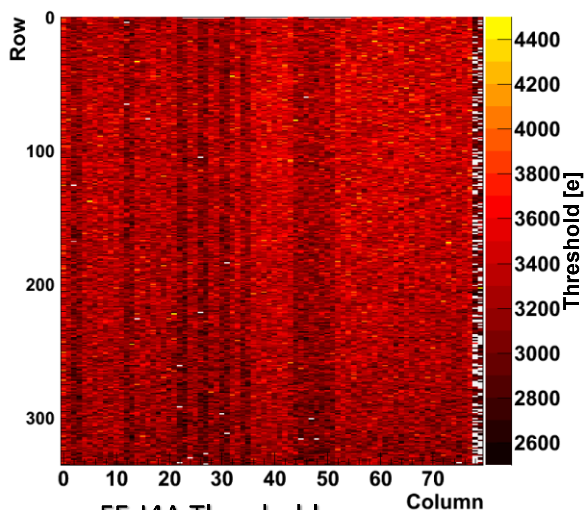


Through the FEI4 history:

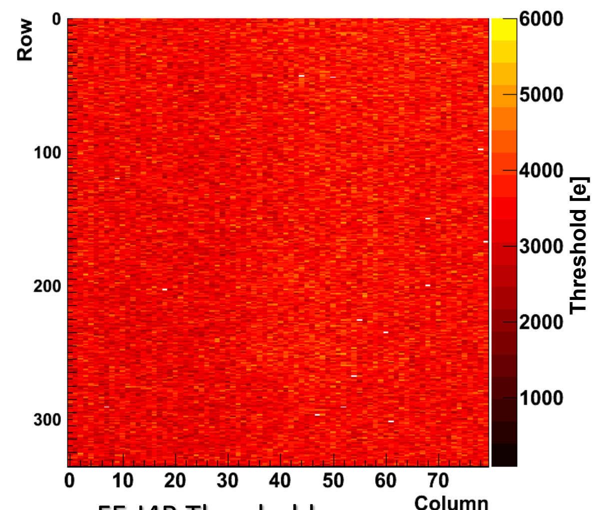
- First version FEI4a for validation and IBL prototypes (32 FE-I4A wafers received in 2010/11)
- FEI4b features: minor fixes + r/o functionalities + uniform pixel matrix + Power functionality
- First FEI4b delivery in Dec. 2011
- FEI4b production (30 wafers) and wafer probing is completed for IBL needs (yield ~60%)

FEI4b noise before and after irradiation (250 Mrad): 114e → 124e (both tuned)





FE-I4A Threshold scan

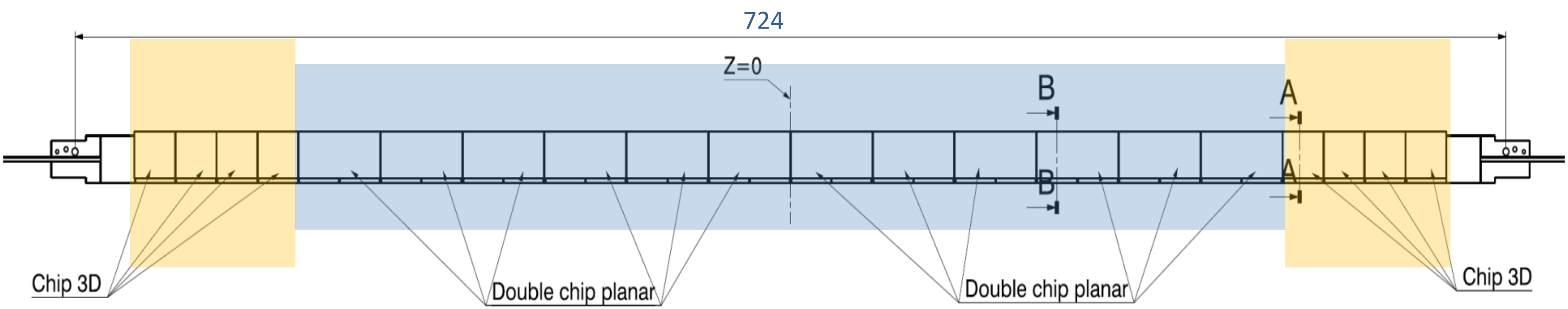


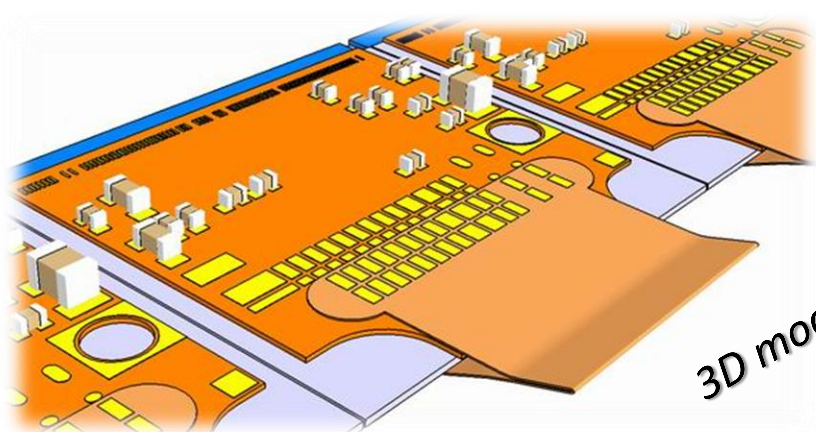
FE-I4B Threshold scan

Stave Layout

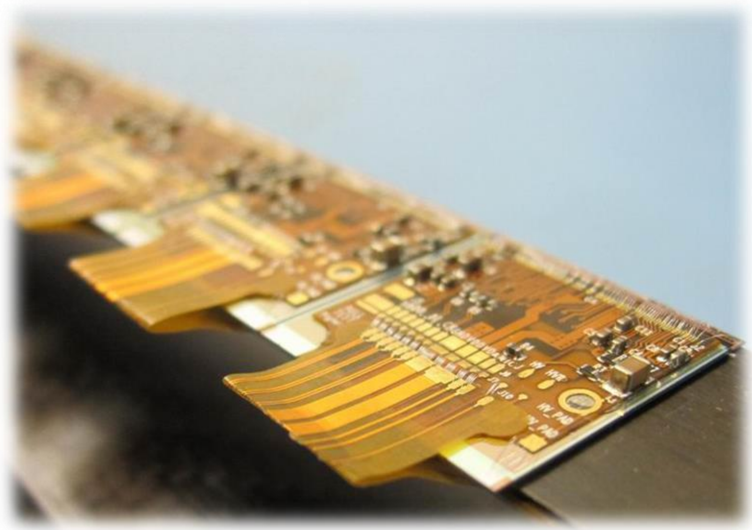
IBL description:

- 14 staves overlapping in Phi and mounted around the beam pipe on the IPT (Inner Positioning Tube)
- All the staves and services will be integrated inside 12mm envelope in radius along ~7m long
- Small clearances between beam pipe – IPT- staves - IST
- Stave to stave gap is only 0.8mm → Integration for the last stave delicate
- An instrumented stave (32 FE chips) consists of **12 planar** and **8 3D** sensor modules along 664mm)





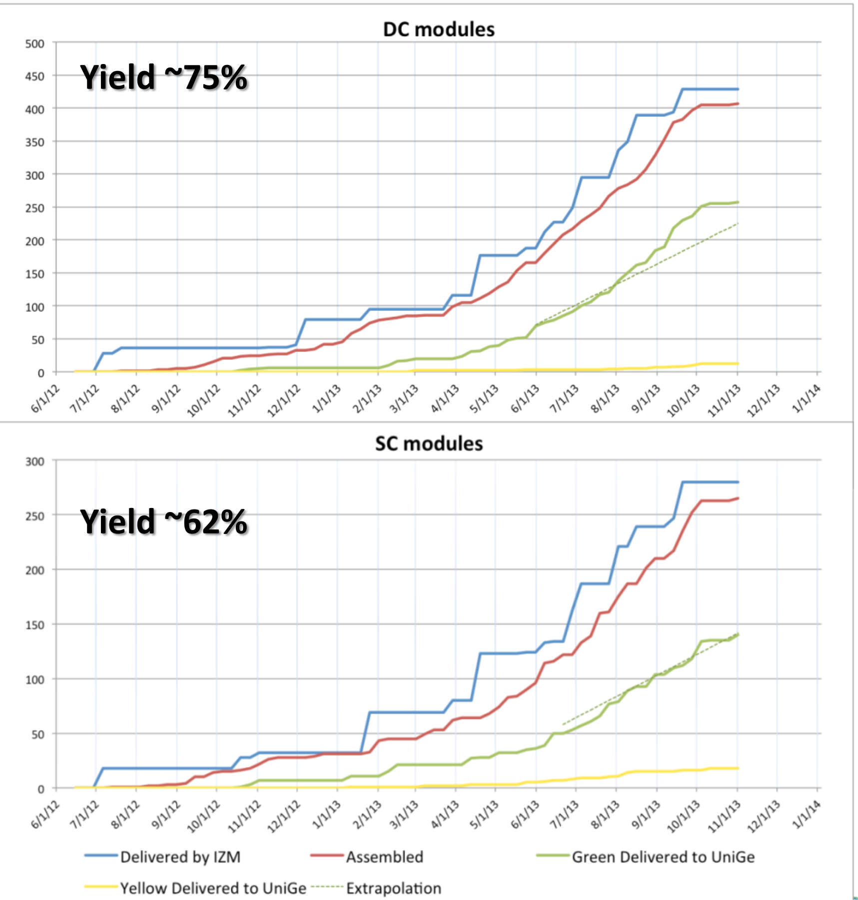
3D modules



Module Production

Thin module process steps:

① FE-I4 wafers thinned (150μm thick FE)
② Glued on glass support wafer
③ Bump deposition
④ Dicing wafer & substrate
⑤ Flip-chip & reflow
⑥ Substrate wafer removal by power laser.

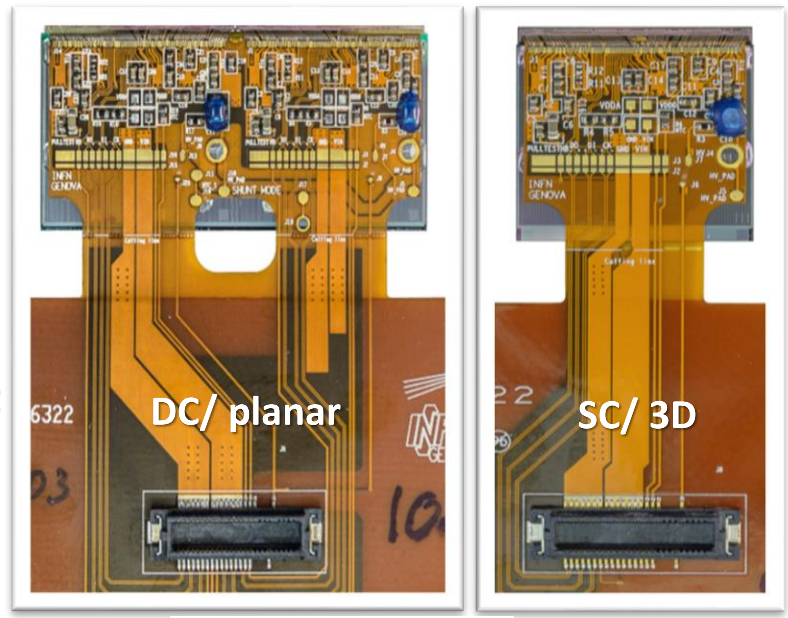


Production completed end of 2013

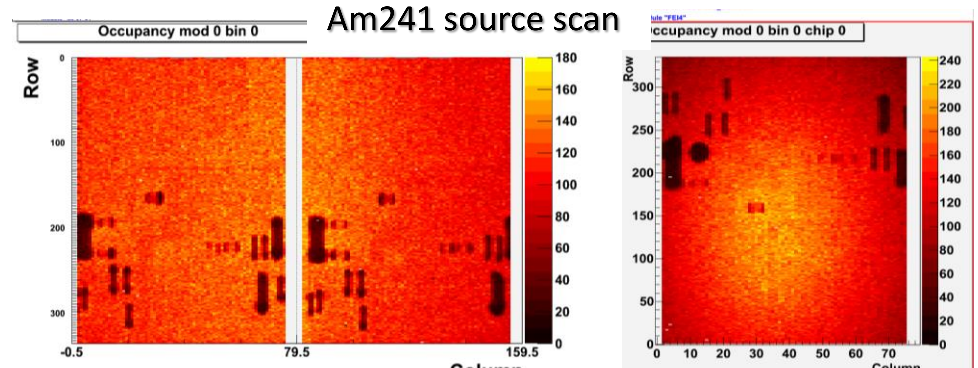
Final module assembly and QA (at Bonn & Genova)

- Module dressing: DC module with flex
- Wire bonding
- Electrical QA and TC (including debug)

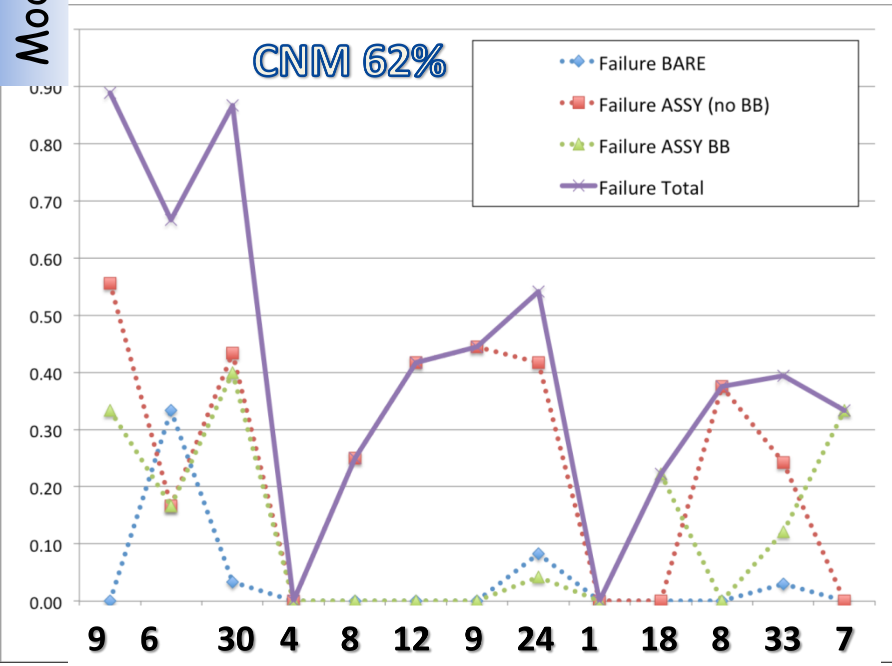
Two types of modules

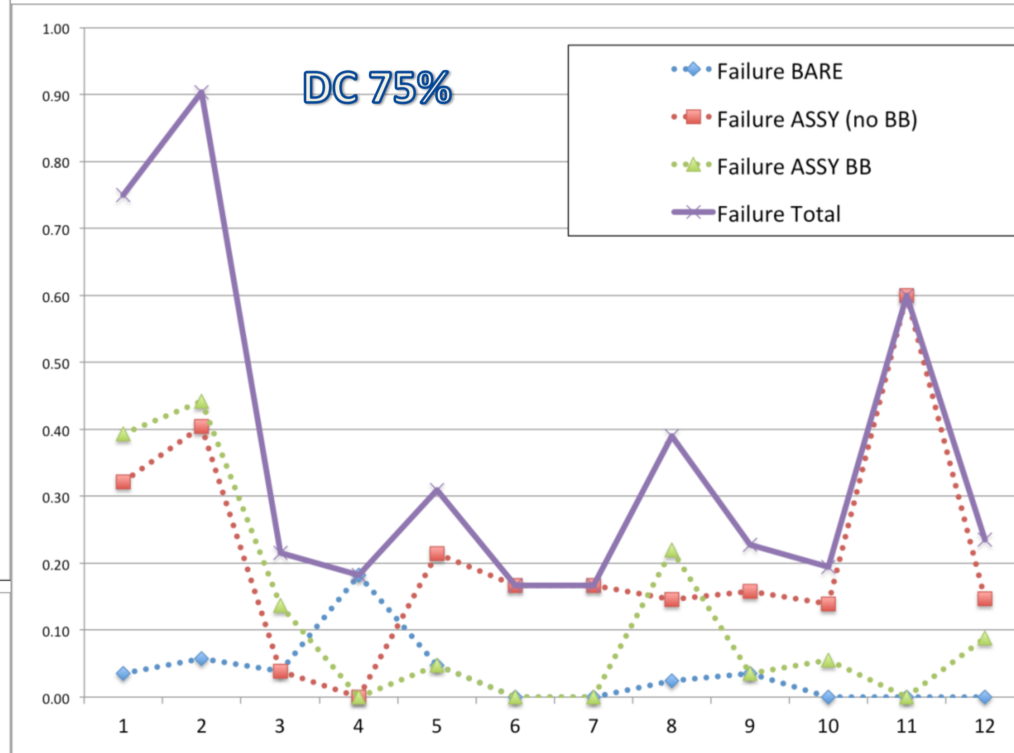


Am241 source scan



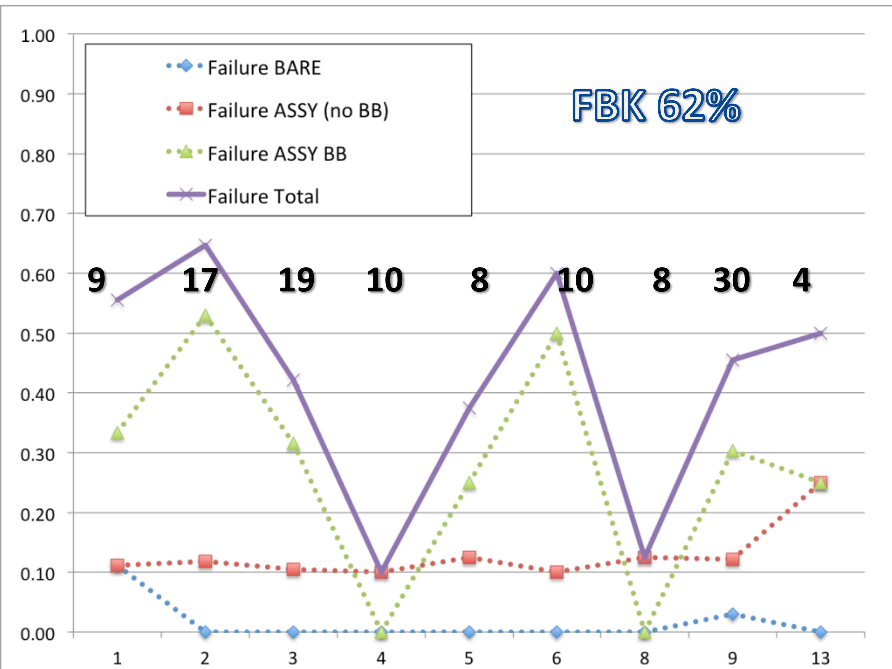
Module Production – Failure along batches





28 52 51 11 42 42 24 41 58 36 5 34

Amount per batch



Bump Bonding (BB) failures were monitored all along the production since this was the major concern during the 1st 3 batches

Module Production – Issues with 1st batches

1st batches started in June 2012

It was observed high failure rate mainly because of two types of defects:

- Open: large fraction of the pixel are not properly connected to the FE pads (seen in the noise map without HV and confirm with the source scan)
- "Shorts": On some region of the FE it was observed coupling between surrounding pixels like shorted pixels or merge bumps (seen on the crosstalk scan)

→ Stopped production in September 2012

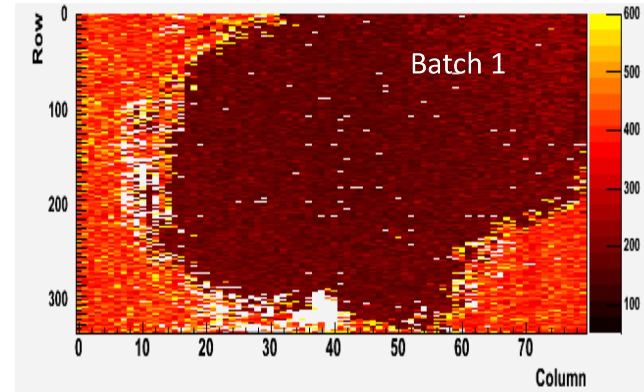
→ Investigations made:

- Open bumps traced back to be excessive flux in Flip Chip process.
- Still lack a convincing explanation of the origin of shorts but problem got vanished with flux-free flip chip.

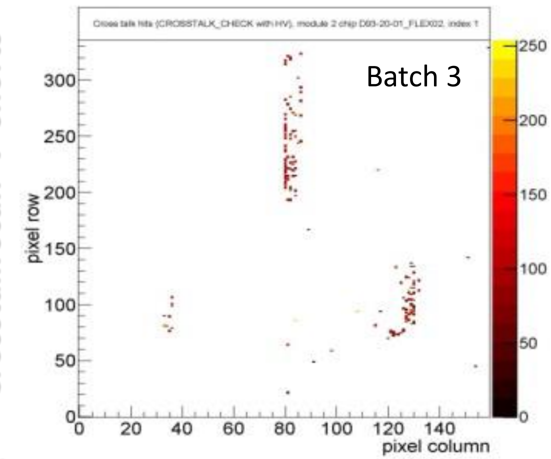
→ Restarted production with flux free Flip Chip after PRR in February 2013

→ The original issue was not observed in later batches (from batch 4ff)

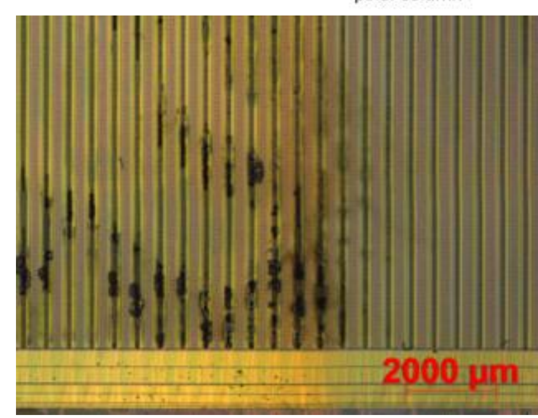
Noise map wo HV → open



Crosstalk scan → shorts



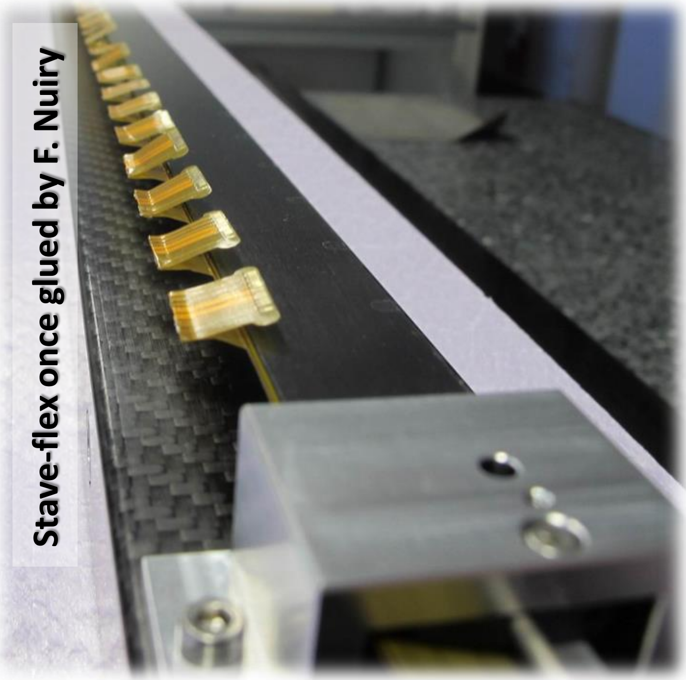
FE chips after desoldering



Stave Flex overview

Stave production and features:

- Production was done at Wuppertal - IVW
- Stave QA and preparation on handling frame followed at CPPM
- Ti pipe of 1.5mm ID and 0.1mm wall thickness
- Face plate (module side) is coated with Parylen for safer electrical break to detector HV
- Tight planarity and envelope tolerance: +/- 0.15mm
- Stave fixations on 3 points: 2 end-blocks + central support



Stave-flex once glued by F. Nuiry

Flex features (made in Rui's workshop at CERN and QA at Genova):

- Mix of 4 Cu-layers and 2 Al-layers for the LV lines. Total thickness ~450μm
- The 2 Al-layers are processed with CVD for Chrome and Copper (vias)
- The wings supply through 1 layer the connectivity for every FE. Wing thickness 70μm
- Wings are folded and glued at 180° for very precise envelope required for the integration

1st AlCu flex ever made for an HEP detector

Production is complete

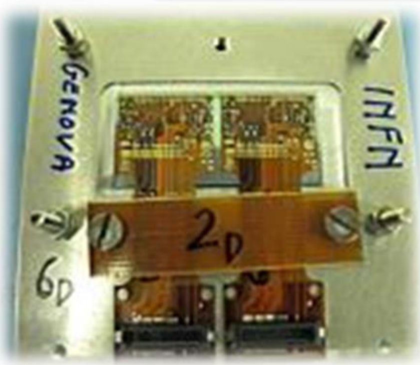
Module Loading

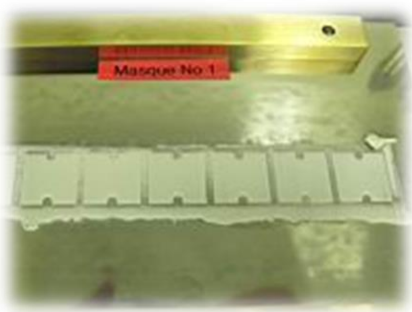
The module loading and QA consisted of 12 working steps

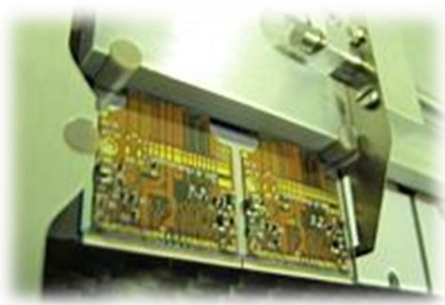
Key features of the loading procedure:

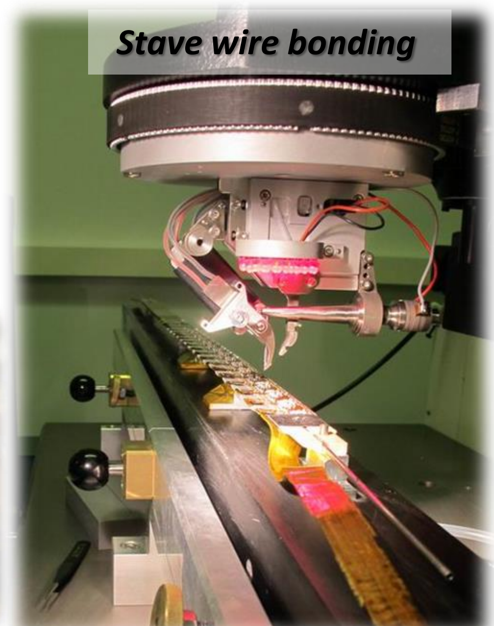
- Modules are mounted with a **thermal grease interface + epoxy glue drops**
- Thermal grease was **qualified for its good thermal performance and for its radiation hardness**
- **Rework and module replacement is possible** but not straight forward → few additional damages observed after this operations
- **11 out of 20 staves were thermal cycled** with loaded modules for QA – Electrical tests and metrology survey were made before and after this operation → 2 FE died after this operation (not explained)
- **Electrical insulation** between HV groups are finally inserted → Thin polyimide layer in module gaps

Stave handling frame

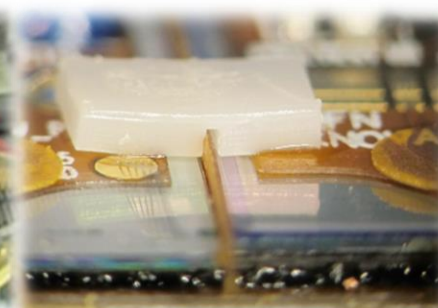








Stave wire bonding



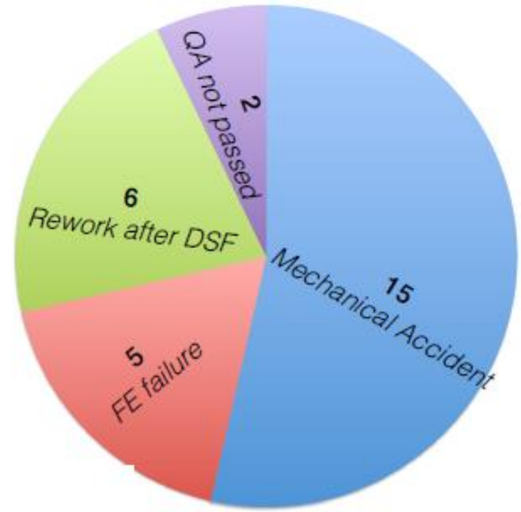
Module Loading - Rework

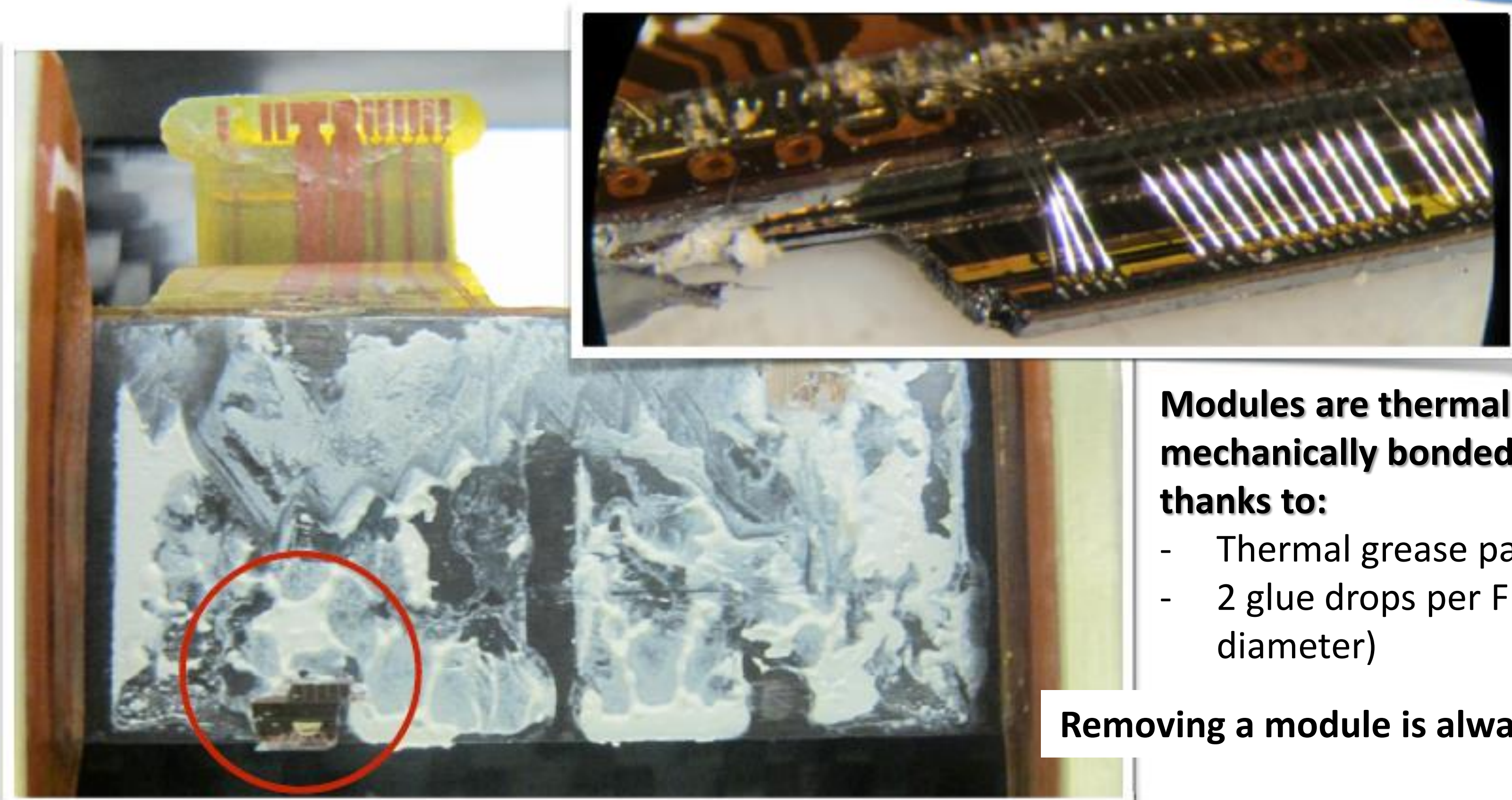
Out of 20 production staves made 14 got 1 and up to 4 module replacements

- 54% is due to damage during one of the loading or rework step
- 21% are identified after corrosion rework at DSF
- 18% are linked to FE issues not identified at an early stage
- 7% are seen at the very last step of the QA

Level of exposure to damage risk is height → To be investigated

Module replacement





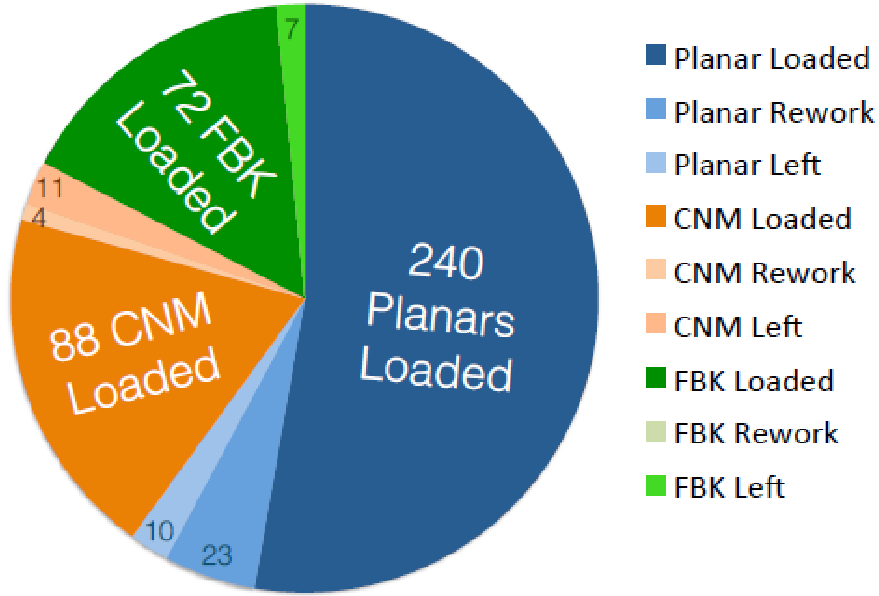
Modules are thermally and mechanically bonded to a stave thanks to:

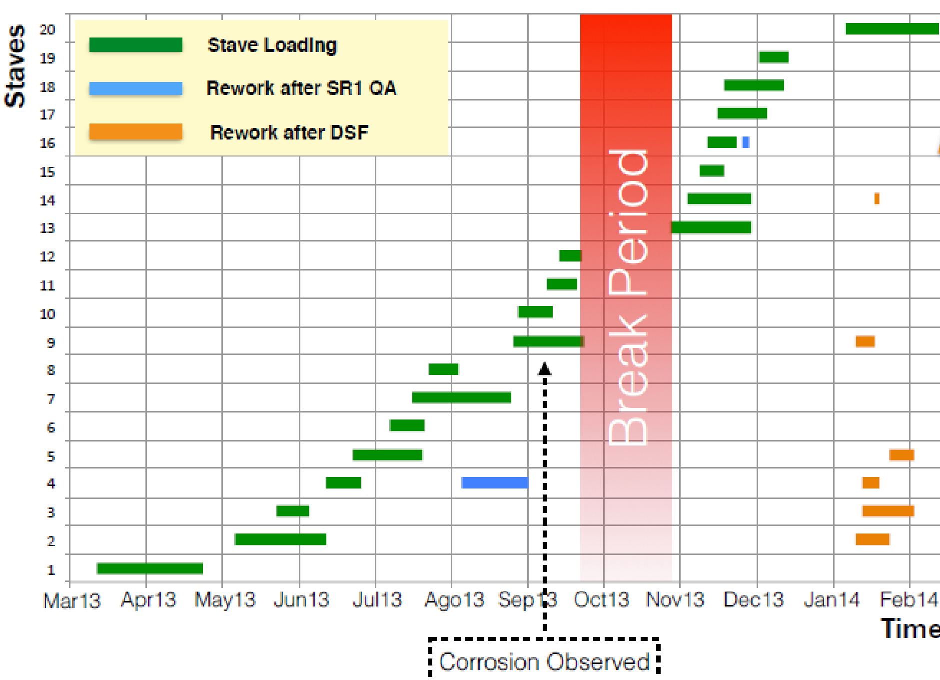
- Thermal grease pad
- 2 glue drops per FE (size of 2mm diameter)

Removing a module is always destructive

Module Loading - Overview

- **273 DC Modules Received**
  - 240 Modules Loaded on production staves
  - 23 used for reworking
- **103 CNM Modules Received**
  - 88 Loaded on staves
  - 4 used for reworking
- **79 FBK Modules Received**
  - 72 Loaded on staves





Almost 1 year of production for 20 staves
→ **Considered as a big success** with a lot of lessons learned

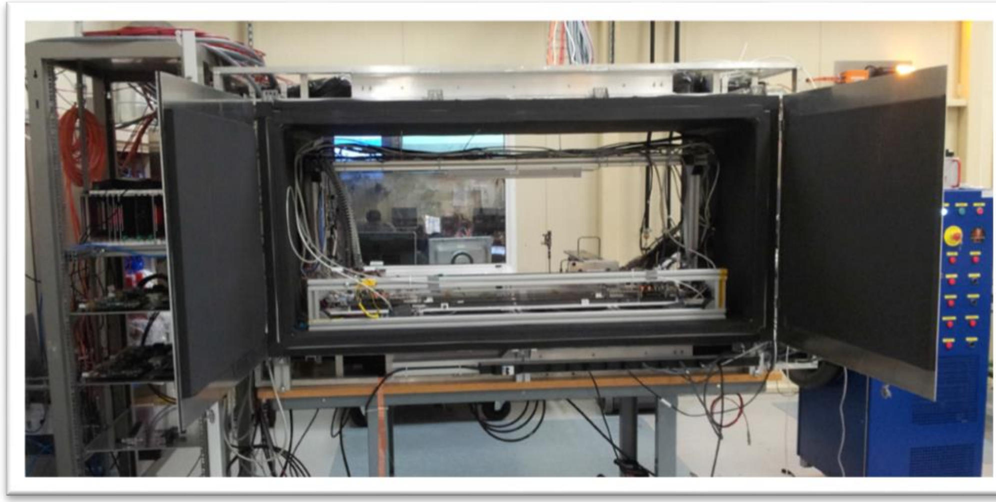
- Work parallelization could allow having 1 stave production rate per week
- Average time spent on a stave is 16 wd while it is 10 wd if there is no rework

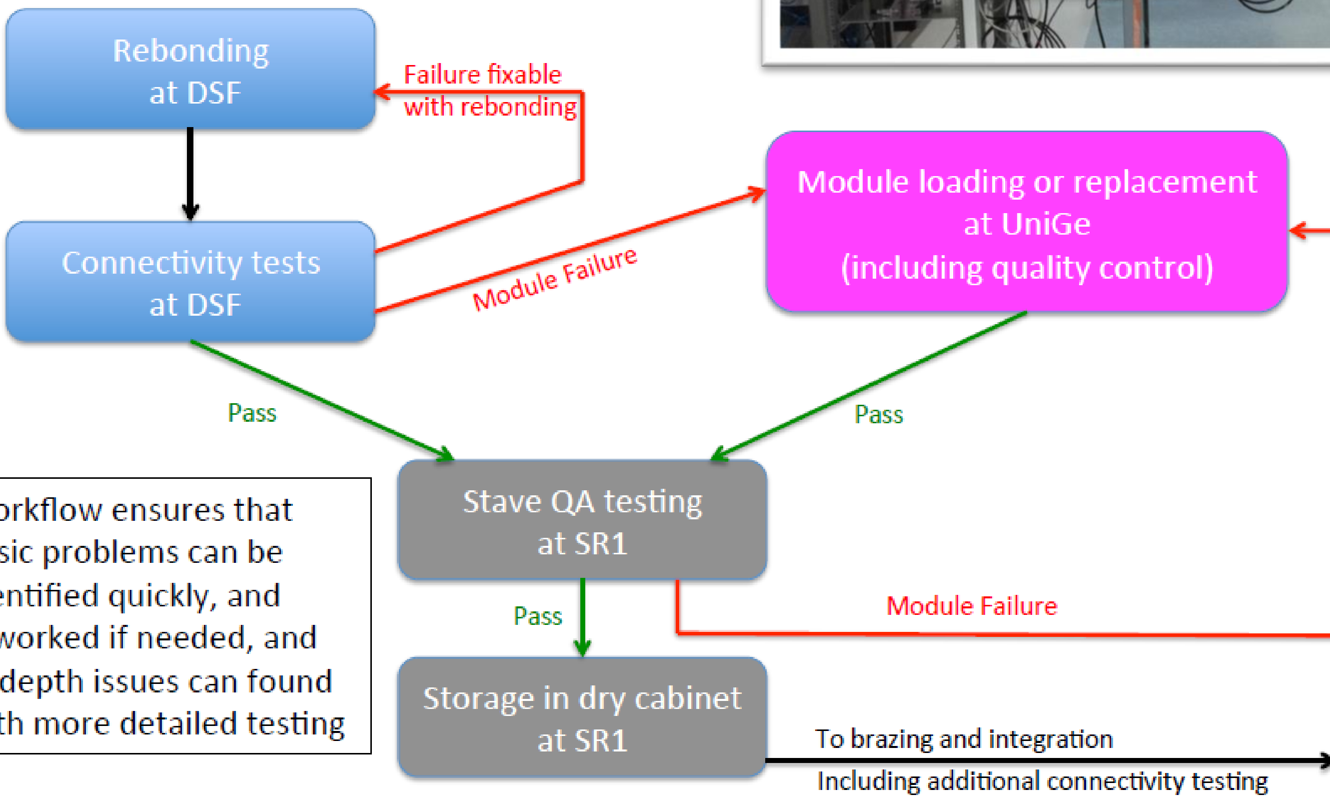
Stave Quality Assurance

Target: Final test and inspections which will define the acceptance for integration

Working steps:

- **Visual inspection** + high resolution pictures
- **Power test and IV scans**
- **Basic digital and analog functionalities**
- Tuning 1st at warm temperature
- **Tuning at cold temperature at -15°C to -20°C**
- **3 thermal cycles** from warm to cold in operation
- **Source scan Sr90** (for disconnected pixels)

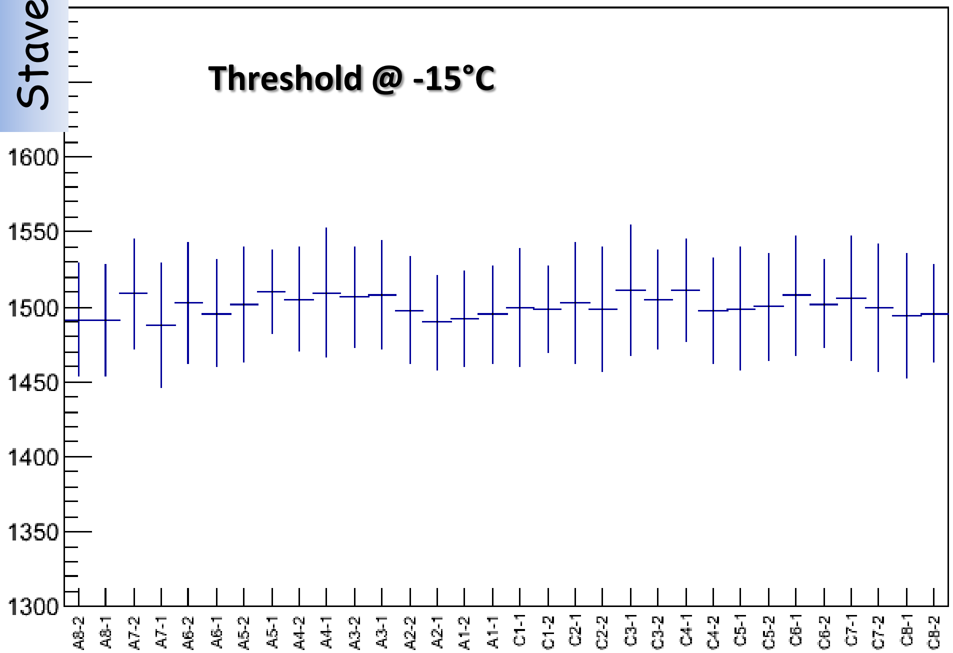


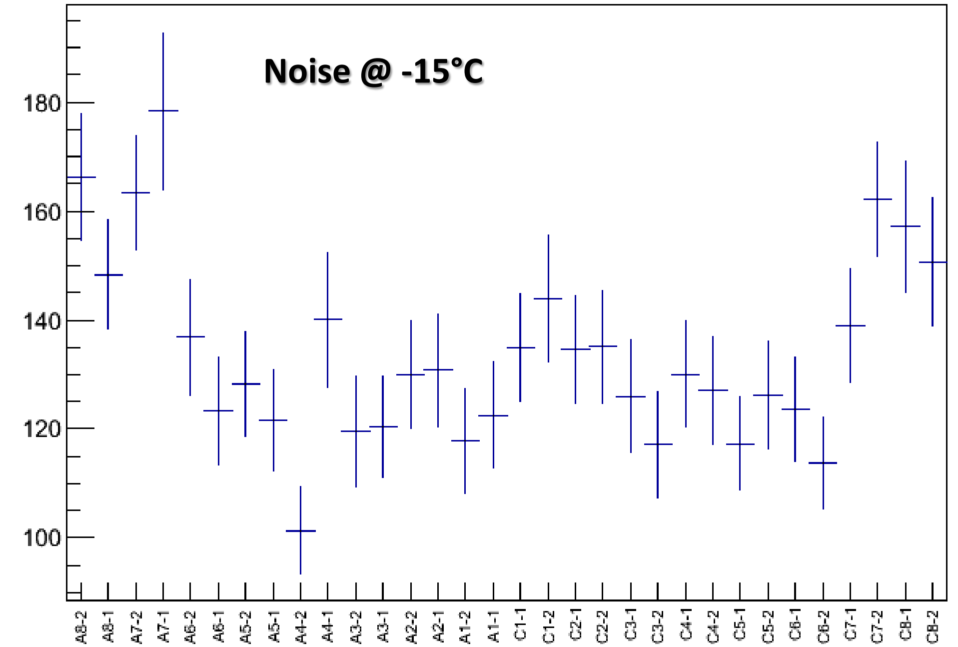


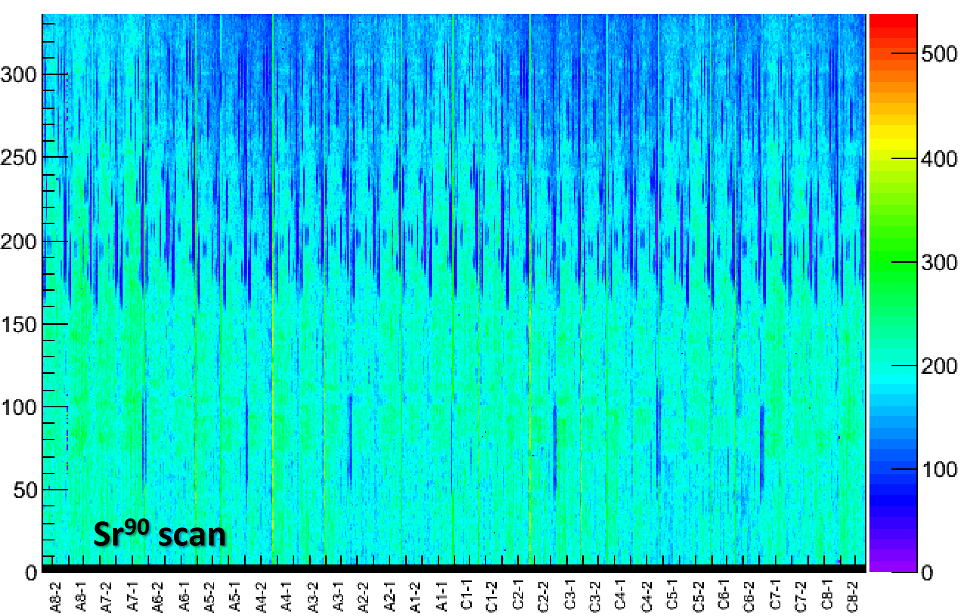
Workflow ensures that basic problems can be identified quickly, and reworked if needed, and in-depth issues can found with more detailed testing

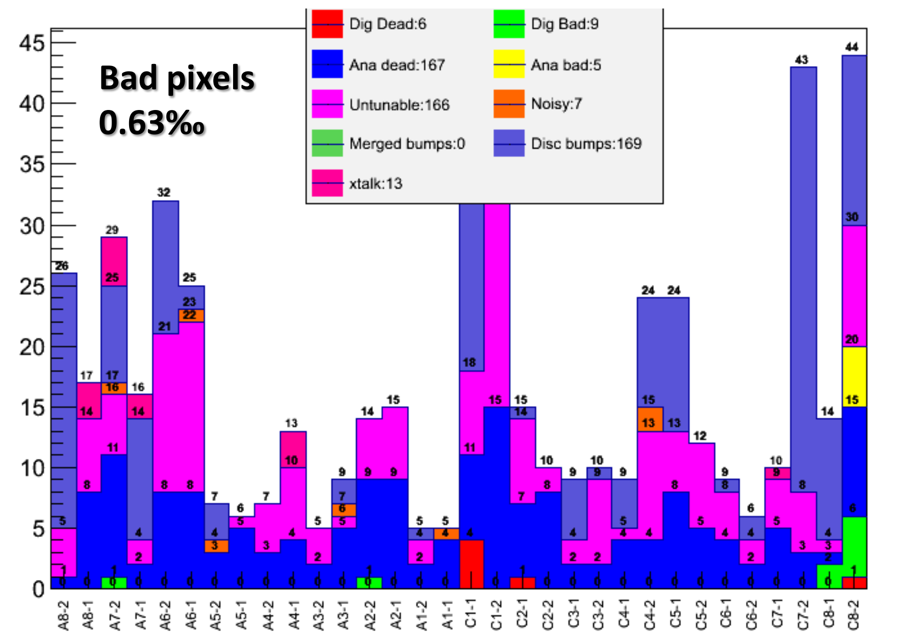
All data, plots, pictures and comments are stored into a DB and accessible on a web server

Typical results from stave QA









IBL issues

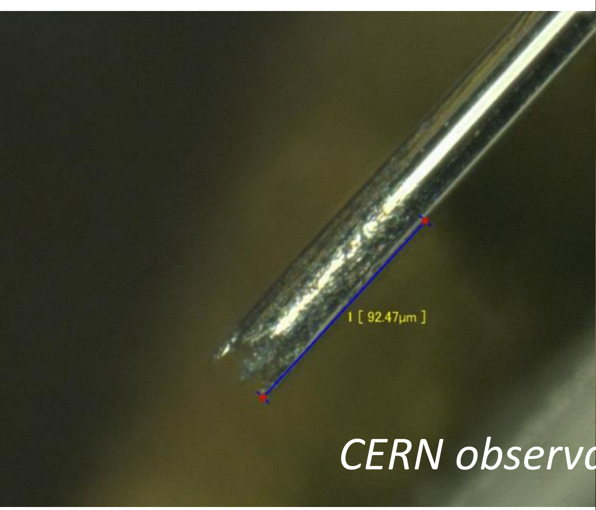
History of big crisis:

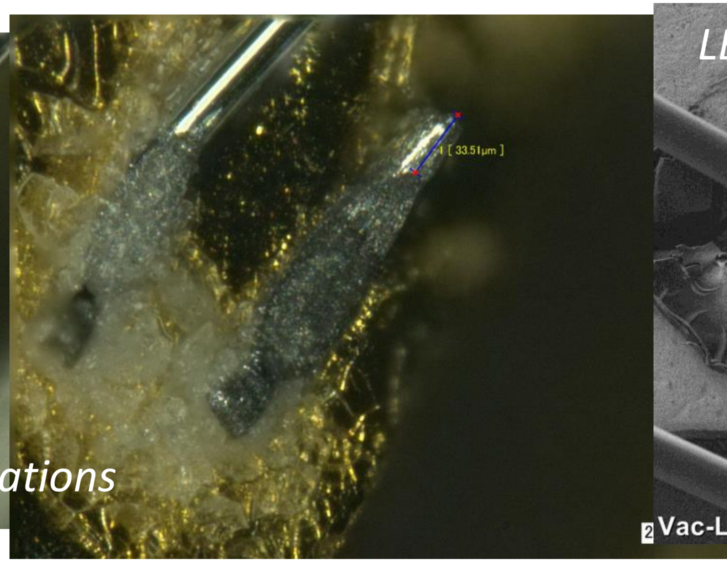
- 1st one in September 2012: **Bump bonding defects** (short and open) after FC - **Resolved**
- 2nd one in September 2013**: Corrosion issue** found accidentally after stave07 and 08 got frozen – **Rework completed**

→ Both impacted the schedule by several months

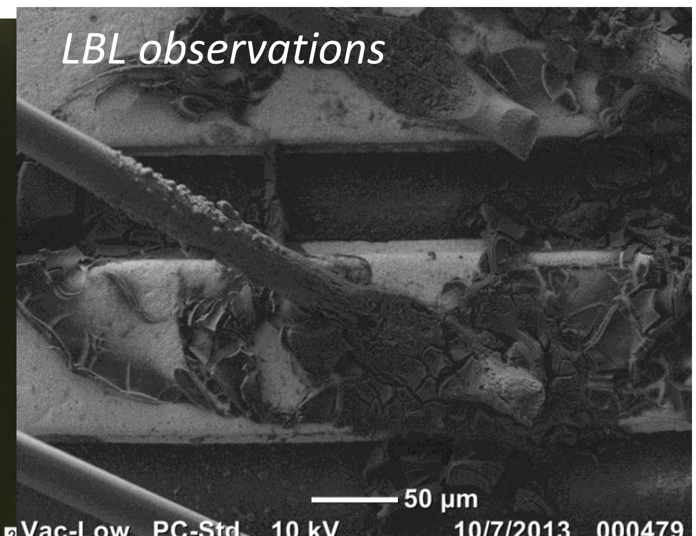
Origin:

1. **Bump bonding defects: L**ikely to be due to the FC machine together with the tacking method for reflow. When both were changed the problem disappeared!
2. **Corrosion issue:** DI water tests allowed to observe an extreme sensitivity of wet flex surface which with the galvanic coupling and the presence halogen explained the chemical attack of the Al-wire.
   - White persistent residue Al(OH)3
   - Detected halogen in samples taken from production staves after corrosion spotted





CERN observations

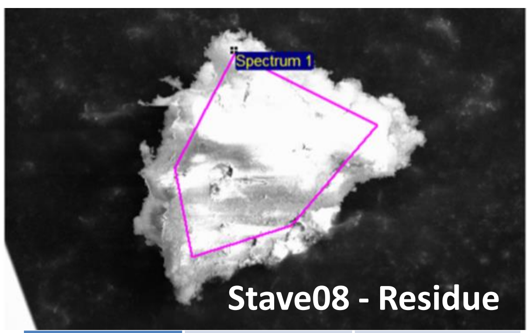


Corrosion study

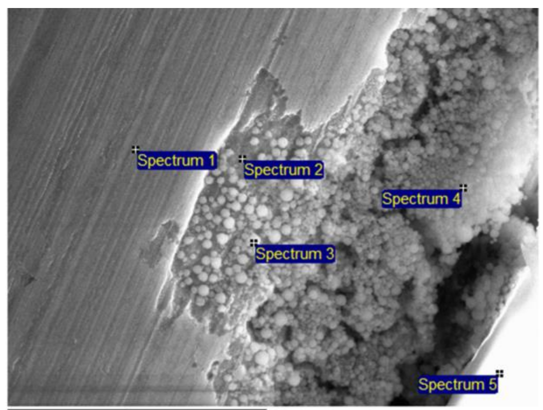
Understanding and questions:

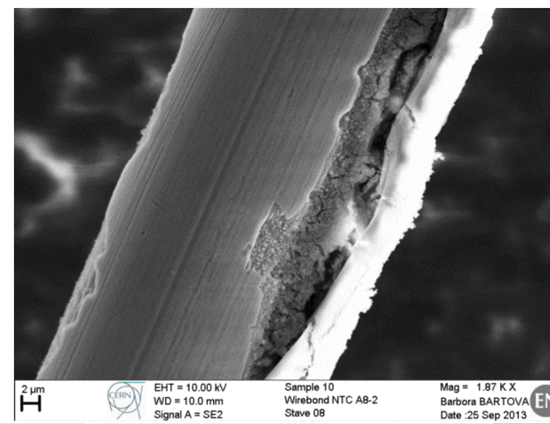
- The corrosion can be reproduced even on bare cleaned flex with the drop of DI water
- Also seen on most of the flex producers while not systematically not on all pads
- The most aggressive cleaning seems to help but also weaken the gold metallization
- Coating the surface like with Urethan compounds show very good protection
- EDS/XPS/FBI analysis showed:
  - Halogen (Cl or F) associated with the corrosion product (residue)
  - No surface halogen contamination measured on cleaned samples
  - One over two techniques showed significant Fluorine into the gold layer (~7nm)

→ Where the Cl and F could come from? Surface migration, Coverlay, gold metallization?



Element	Weight%	Atomic%
Sp1		
C K	14.37	20.70
O K	53.17	57.48
F K	4.05	3.69
Al K	26.91	17.25
Si K	0.98	0.60
P K	0.51	0.28





Spectrum		C	O	F	Al	Si	P	S	Cl
Spectrum 1		6.2	2.3		90.8	0.7			
Spectrum 2		9.2	4.1		86.0	0.8			
Spectrum 3		16.0	34.6		48.5	0.6			0.3
Spectrum 4		17.3	47.7	1.1	32.0	0.4	0.8	0.4	0.4
Spectrum 5		25.6	54.0	1.7	17.4	0.3	0.5	0.2	0.2

Stave Rework

Corrosion issue: Right after the observed problem on 11 of the 12 produced staves a TF was set-up to investigate the cleaning, the understanding of the origin of the pollution, the stave rework and, the potential risk wrt the B-field and the LV current fluctuations

What is known:

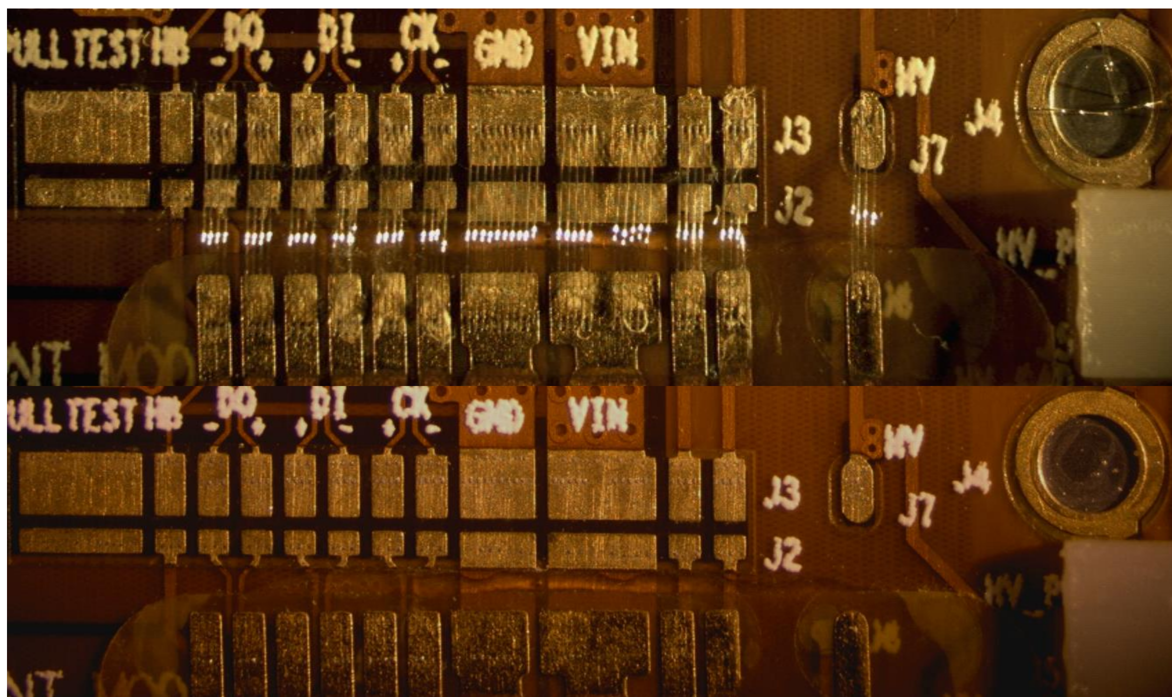
- The origin of the pollution is on the flex (same issue on many manufacturers) but it is not clear where the Cl/F is located (metal layer/kapton)?
- No efficient cleaning works without degrading the metallization layer
- Potting was qualified on real module wrt to electrical functionalities before/after TC and Irradiations. → Not adopted change due to long term operation uncertainties

Rework consists of: Cleaning after wire removal, and re-bonding all the FE and wing pads

Corroded wing region
Before wire removal and cleaning

After wet cleaning

Cleaned in term of corrosion residue but not free of halogen



Overview of the produced staves

Target is to get the best 14 staves out of the 20produced

Stave #	Corroded and reworked?	Passed QA	# defective channels ‰
1	Yes	Yes	1.18
2	Yes	Yes	0.67
3	Yes	Not yet	-
4	Yes	Yes	0.93
5	Yes	Yes	0.70
6	Yes	Yes	0.85
7	**Yes**	**No**	**1.08**
8	**Yes**	**No**	**3.30**
9	Yes	Yes	1.29
10	Yes	Yes	0.75

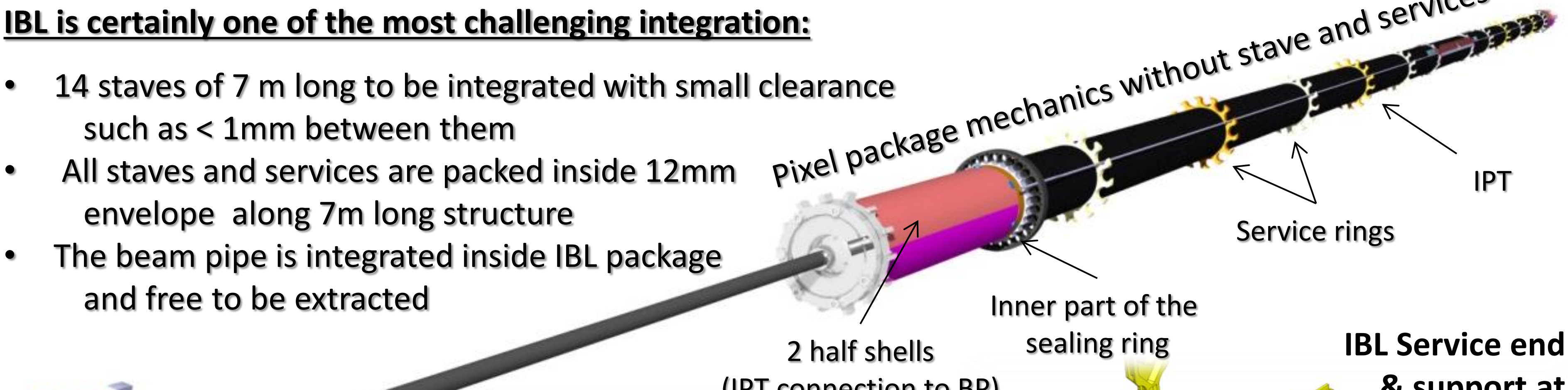
Stave #	Corroded and reworked?	Passed QA	# defective channels ‰
11	No	Yes	0.68
12	Yes	Yes	0.63
13	No	Yes	0.83
14	No	Yes	2.18
15	No	Yes	1.00
16	No	Yes	1.02
17	No	Yes	1.22
18	No	Yes	1.47
19	No	Yes	1.13
20	No	Not yet	-

- *Stave 7 and 8 were classified as failing after the condensation incident (used for practicing for the next integration steps)*
- *FE module criteria was based on ranking less than 1% defects per FE (including additional penalties identified during the production) but stave defects is at ‰ level*

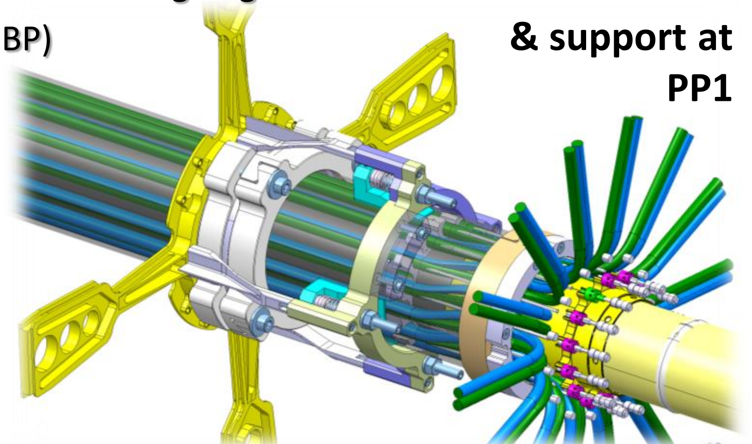
IBL Package overview

IBL is certainly one of the most challenging integration:

- 14 staves of 7 m long to be integrated with small clearance such as < 1mm between them
- All staves and services are packed inside 12mm envelope along 7m long structure
- The beam pipe is integrated inside IBL package and free to be extracted

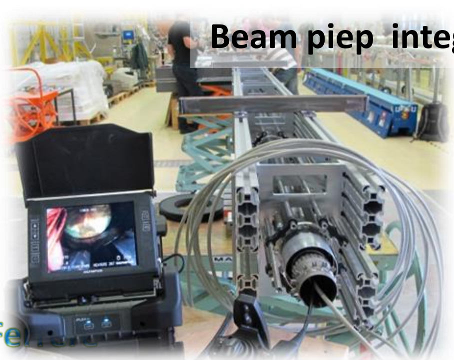


IBL Service end & support at PP1

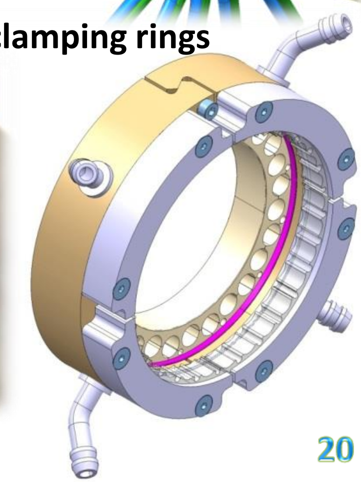


IPT is integrated on the MPC (Multi Purpose Container)

Beam piep integration into the IPT structure



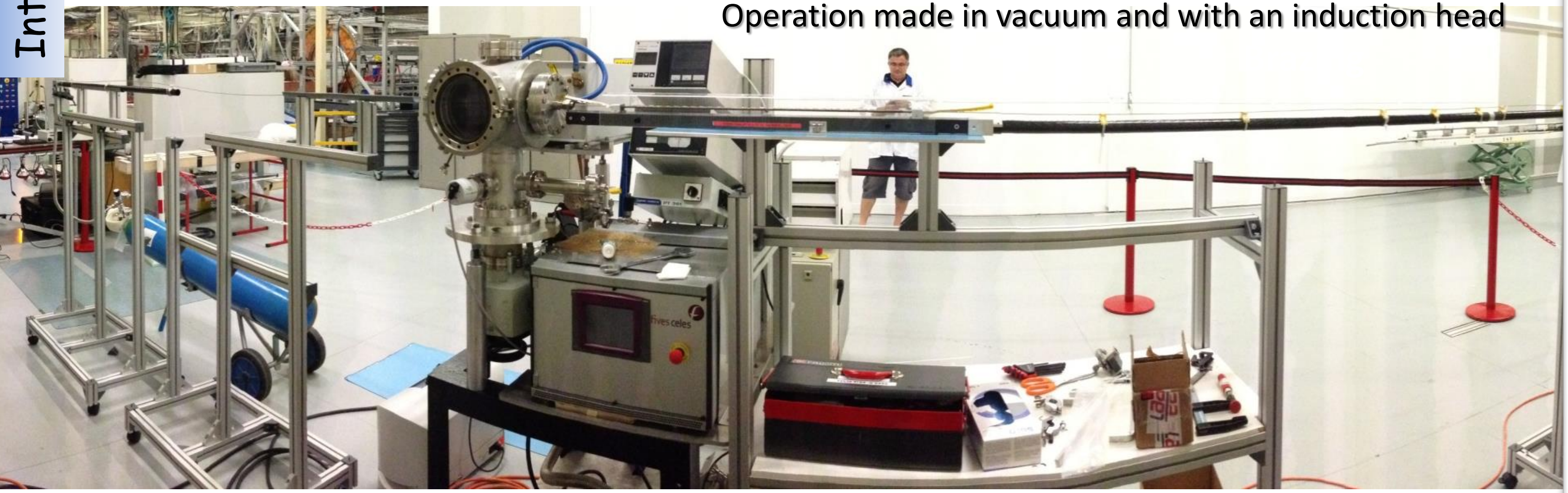
Sealing and clamping rings

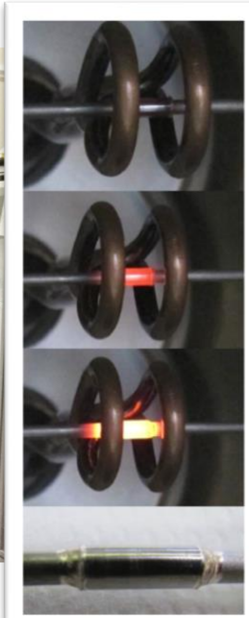


IBL integration

Next step before integration is the cooling pipe extension for each stave to 7m long by brazing

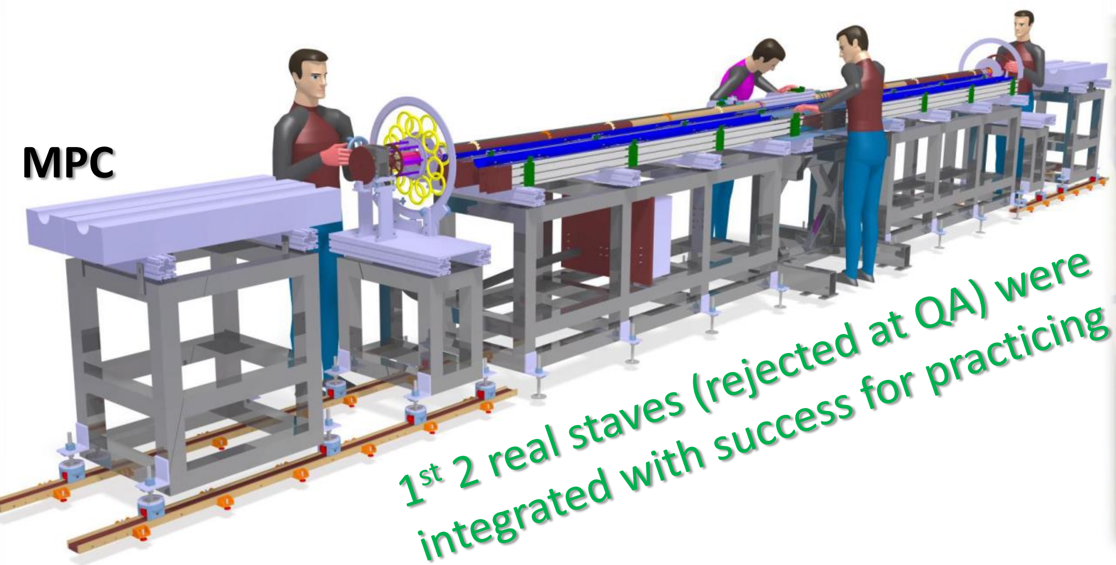
Operation made in vacuum and with an induction head





Integration is done on the MPC with the integration tool allowing fine tuning

MPC



1st 2 real staves (rejected at QA) were integrated with success for practicing

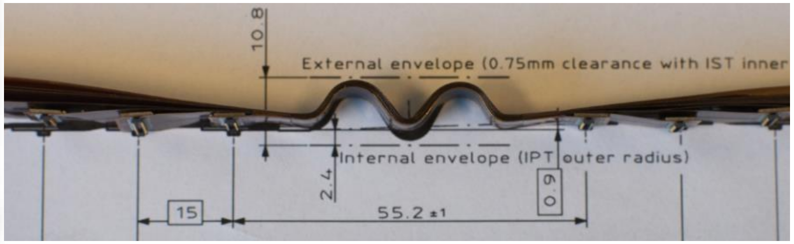
Stave integration

IBL service integration

Practice of service assembly and integration with all the strain relief along the IPT structure

- CTE mismatch of the copper type-1 bundles will be absorbed by the controlled waves
- Intermediate flex joining the stave to the Type-1 is corrugated and allows to compensate for small inaccuracy and CTE

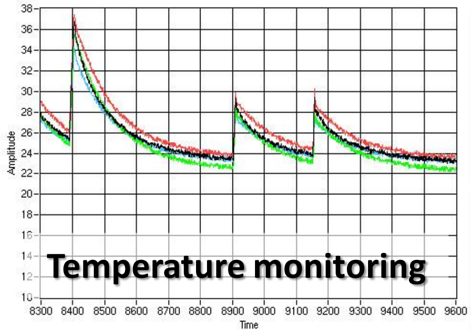
Corrugated intermediate flex



Qualification of the stave and service integration thanks to the connectivity set-up

Features:

- Can test that all the FE functionalities is working
- No cooling required & test is performed in less than 5s
- Interlock is always active based on temperature survey
- Setup is mobile and can be also used in the pit
- Two set-ups built to work in // on the two sides

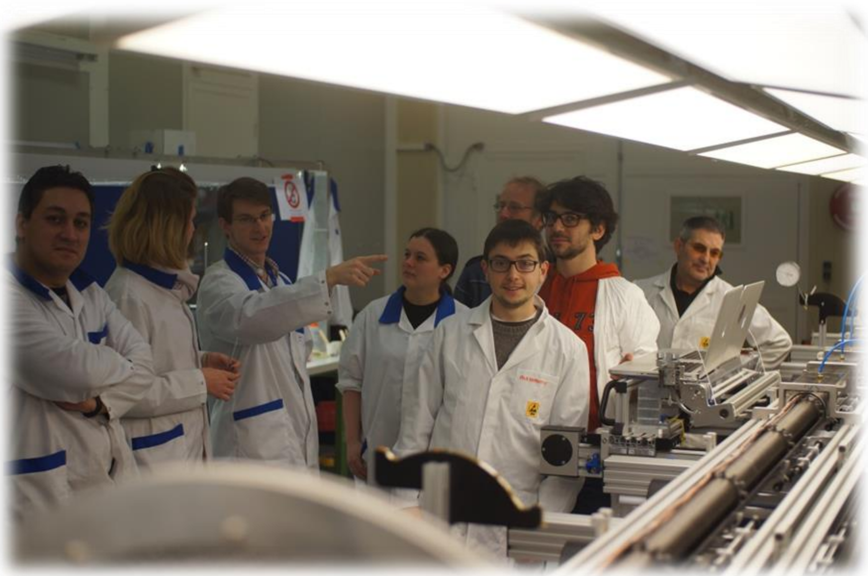


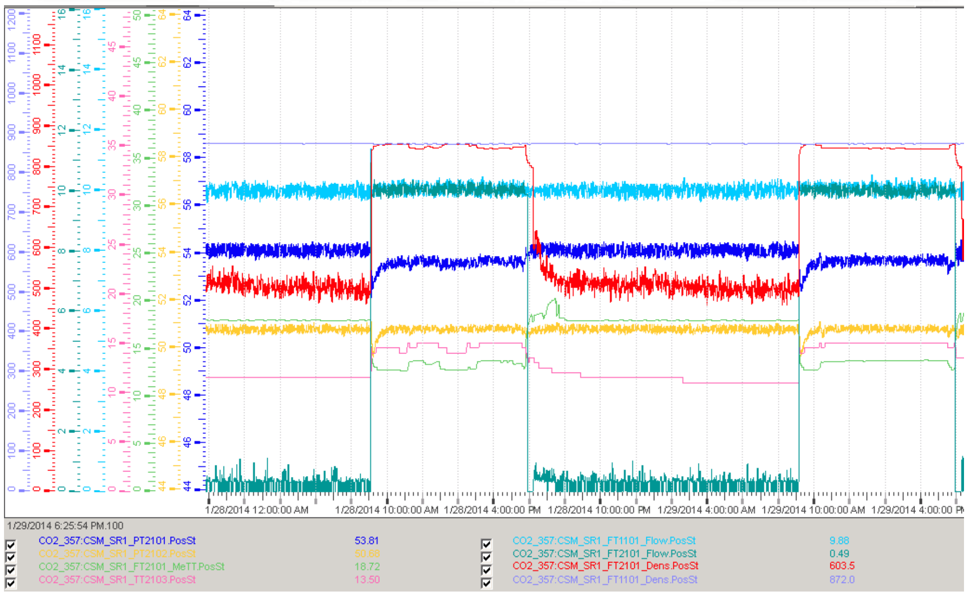
System was extremely useful for the stave rework and for the validation of the stave07 and 08 integration practicing

Tests of staves on the IPT

After integration of stave07, 08 and service for practicing the two staves could be characterized with C02 cooling and using the final hardware components including services.

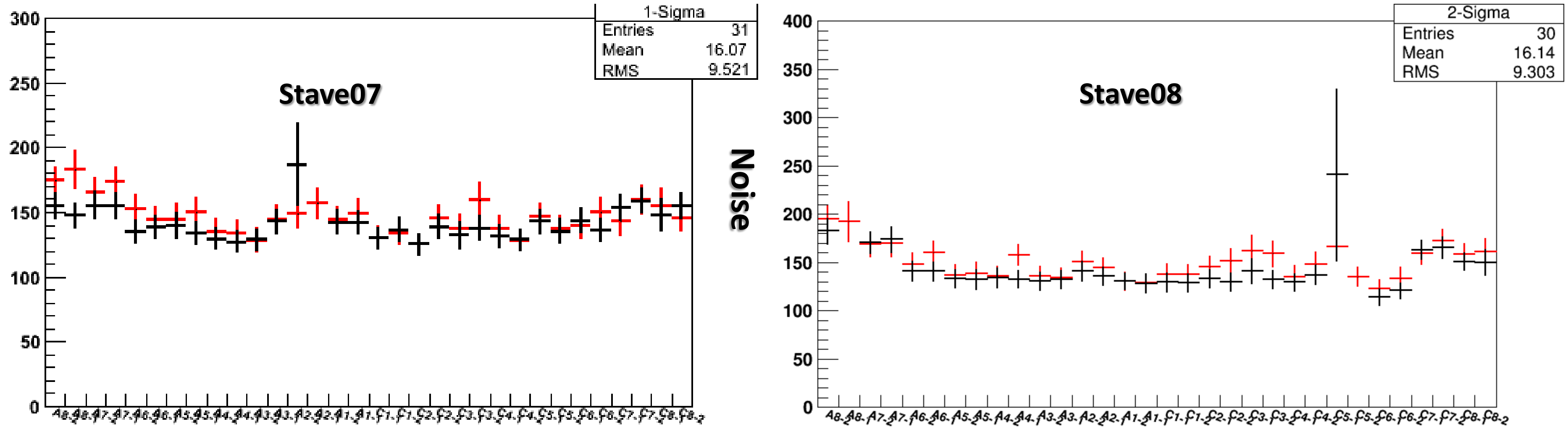
- Operating conditions +15°C on the cooling line
- Very stable condition in term of cooling and operation
- Dryness of the volume was about 2-3% RH
- Readout system based on RCE
- DAQ with the production ROD/BOC was also tested successfully (limited tests)
- Efficient team for work preparation and tests

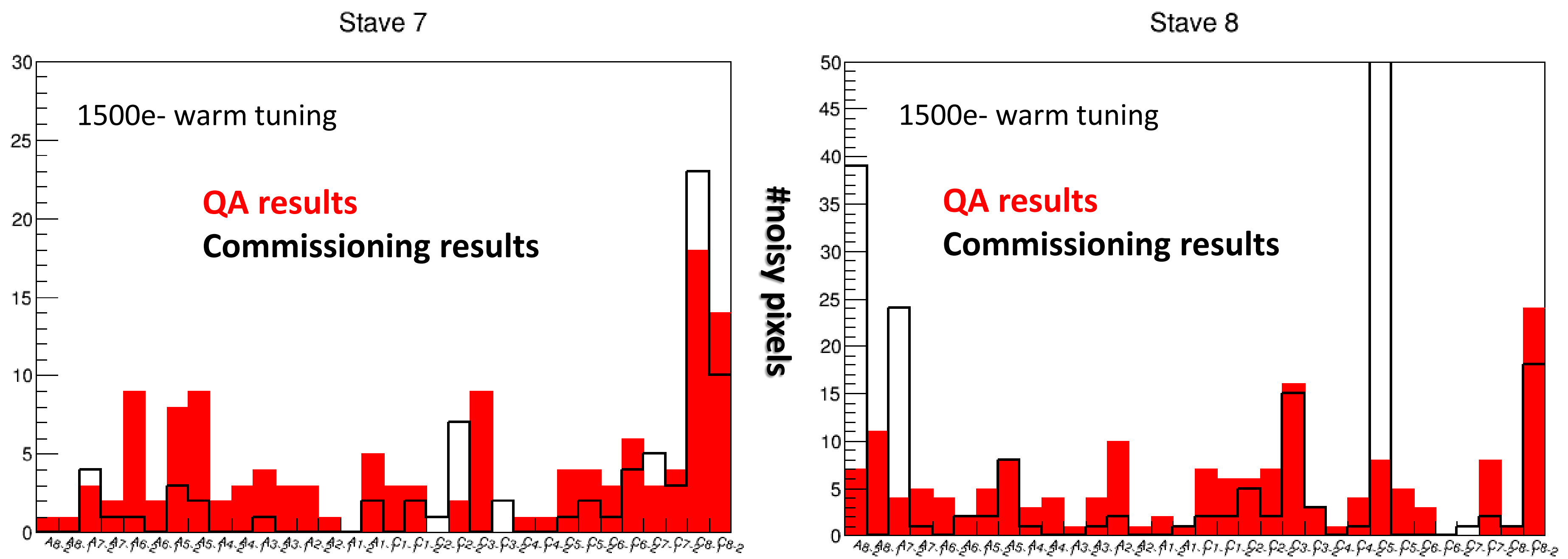




"Commissioning" on the IPT

Excellent results were obtained & compatible with QA results or slightly better





"Commissioning" on the IPT – Con't

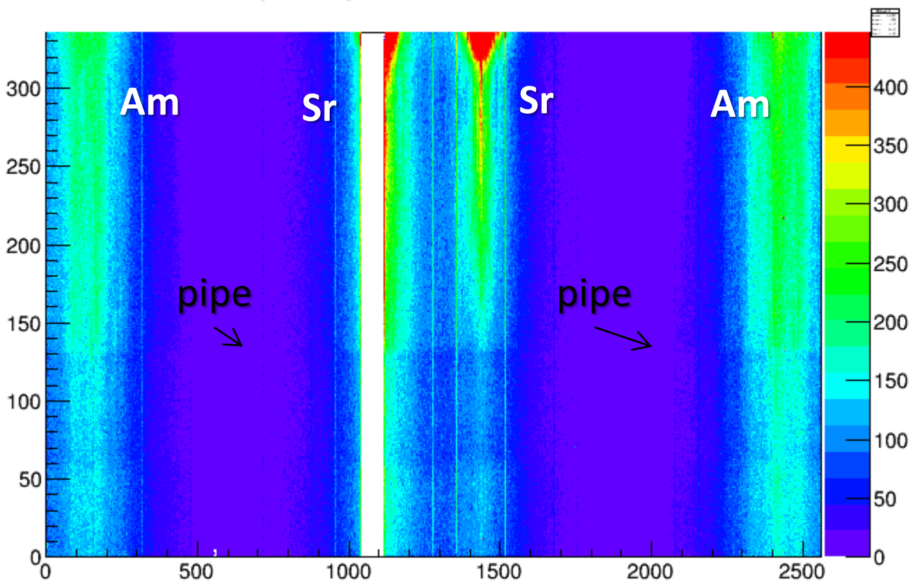
Surface commissioning happened with two staves with the full off-detector chain

All the tests performed were completed with success:

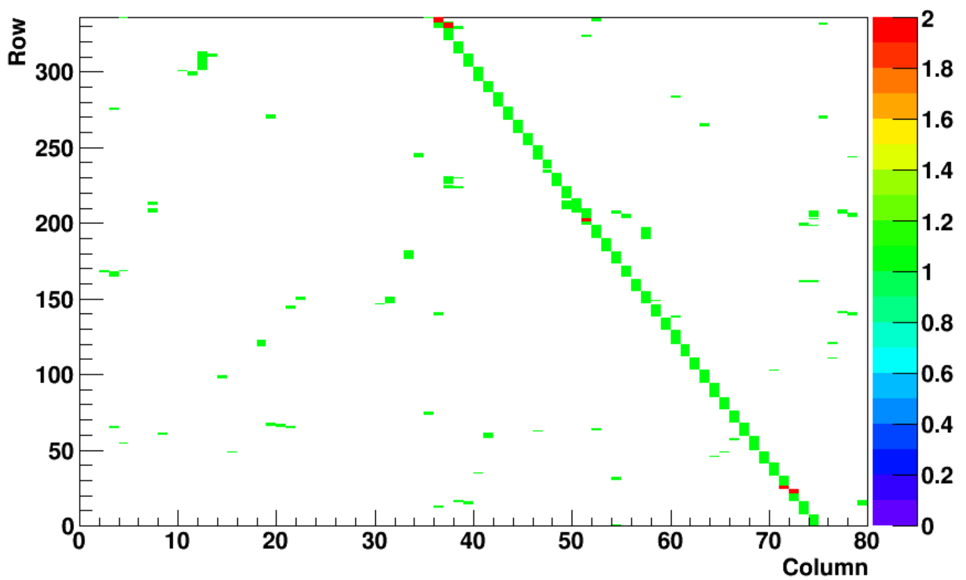
- Connectivity finally understood and corrected on many levels
- Excellent performance with noise performance and tuning level
- Low noise occupancies and no increased occupancy with synchronous external triggering at 5kHz of the two stave
- No increased noise occupancy on one stave/half-stave when threshold scans are running on the neighbor stave/half-stave
- Beautiful cosmic tracks along the entire FE
- Nice source data with Am241 and Sr90 source

Tests performed in Jan 14

Occupancy run with source- Stave 7



Cosmic track on the entire FE



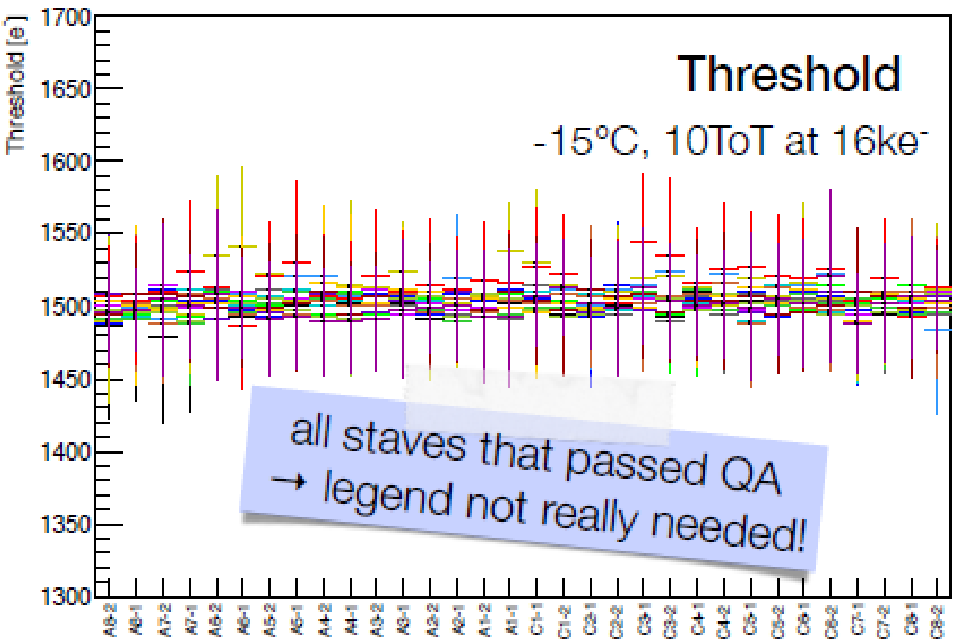
Feedback - Noise on FBK modules

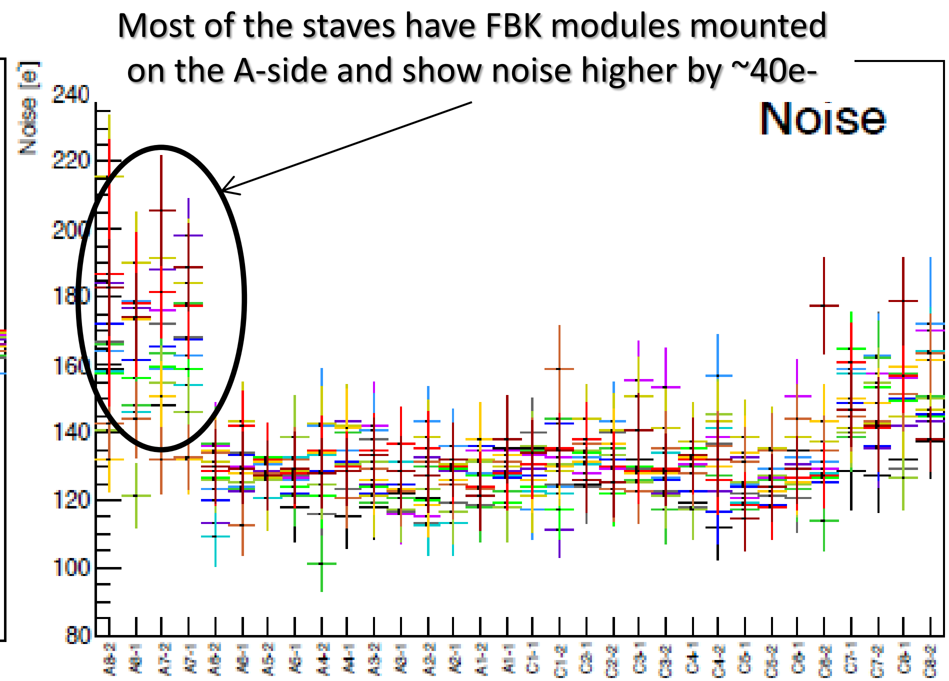
Higher noise on FBK modules are regularly observed:

- During Threshold scan → 1st four FEs on A-side are often FBK module
- Noise sensitivity seen when HitBus is enable and wire bond connected on the flex
- Noise sensitivity seen underneath the NTC when they are powered
- Double trigger noise tests exhibit some noise on FBK module into some BC ID

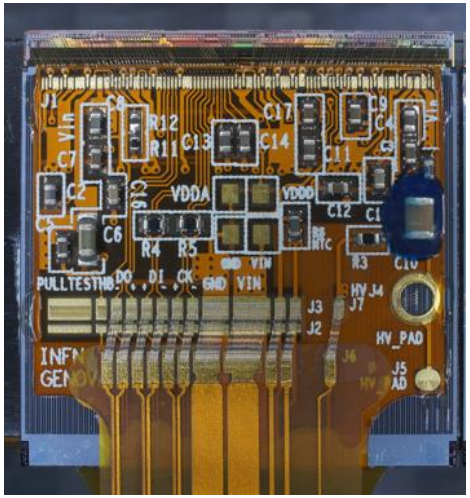
NB:

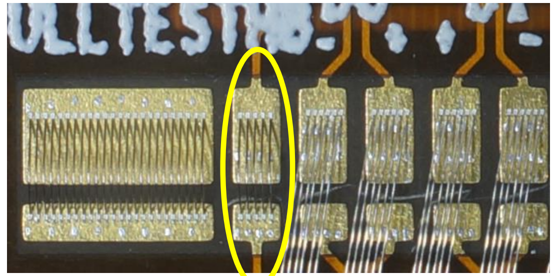
- It seems that the sensor backplane has a sensitive coupling to the module flex design features
- All of this should have only little impact during operation (Threshold can be adjusted, and HB is not used)





Feedback - Noise on FBK modules (Con't)

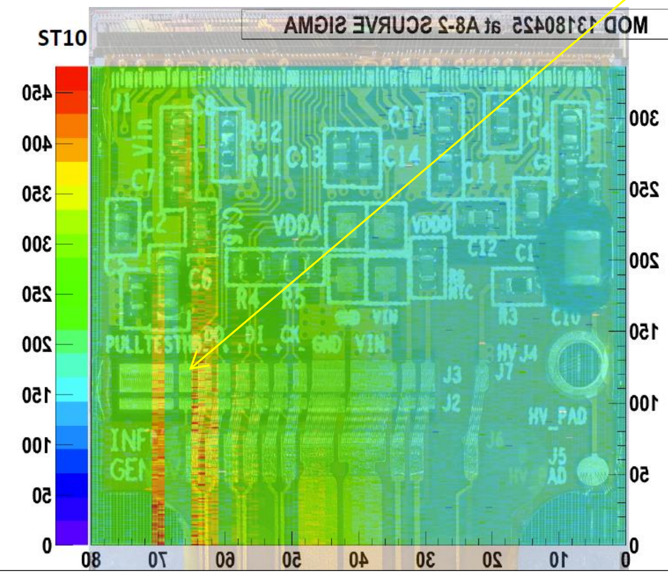


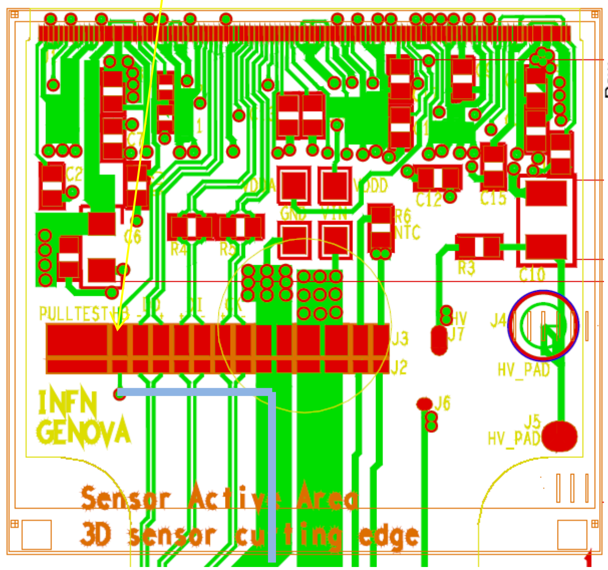


HitBus wire bonds:

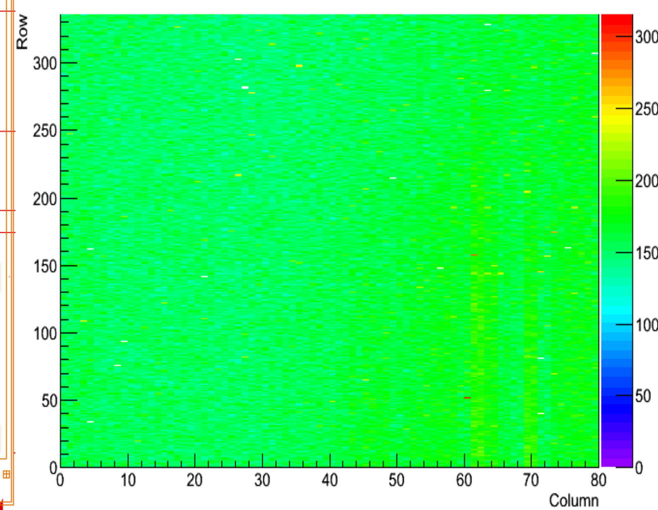
- Connected on all modules between FE and flex
- Connected on reworked staves on wing side
- Register that can be disabled and not needed in operation

Stave10 and 'HitBus' enable – A8-2 (FBK)





'HitBus' disable – A8-2 (FBK)



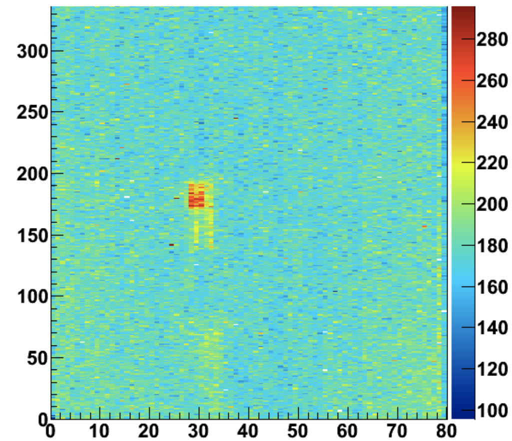
HitBus: FE feature that allows self-triggered operation mode

This line is active when the chip have digital activities and the 'HitBus' register is enable

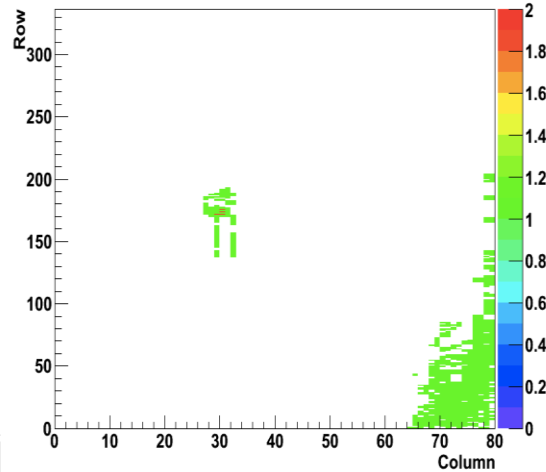
Feedback - Noise on FBK modules (Con't)

- Observed noise spot which fit with the NTC location
- Measurement from UniGe with NTC power at 5V but also seen at CERN when supplying at 2.5V
- Modules are always FBK when NTC is powered. Not seen on planar and CNM modules

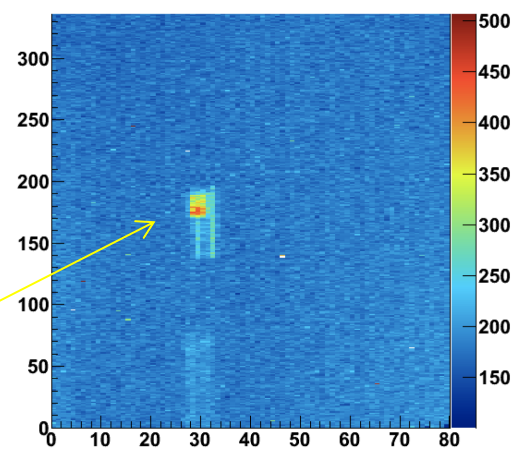
Stave 6 A8-2
Noise from Threshold scan

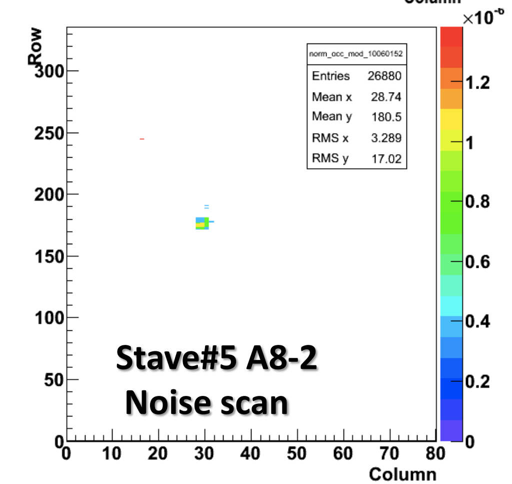


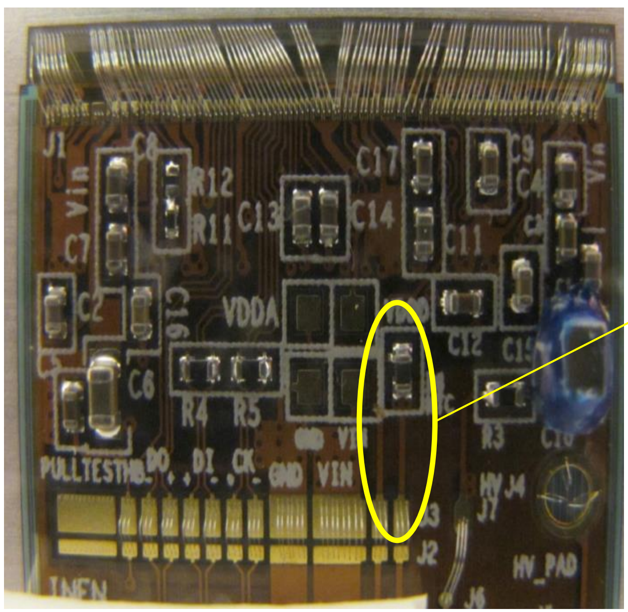
Stave#3 A8-2- Noise scan



Stave#5 A8-2





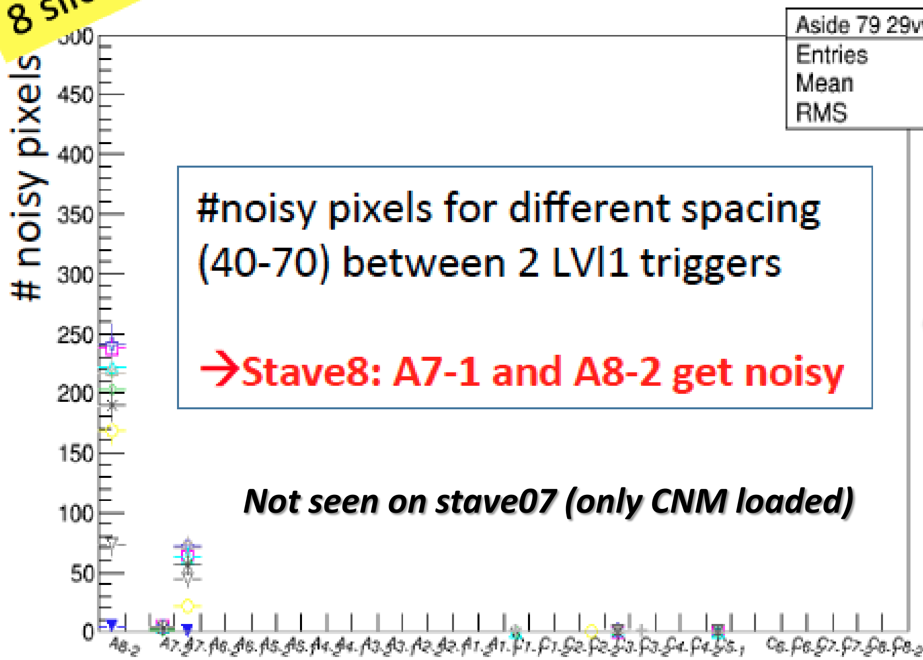


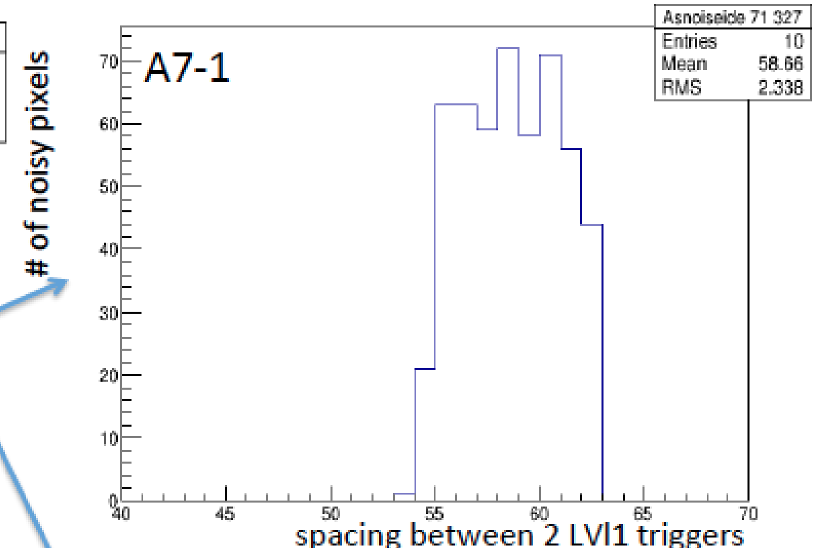
Feedback - Noise on FBK modules (Con't)

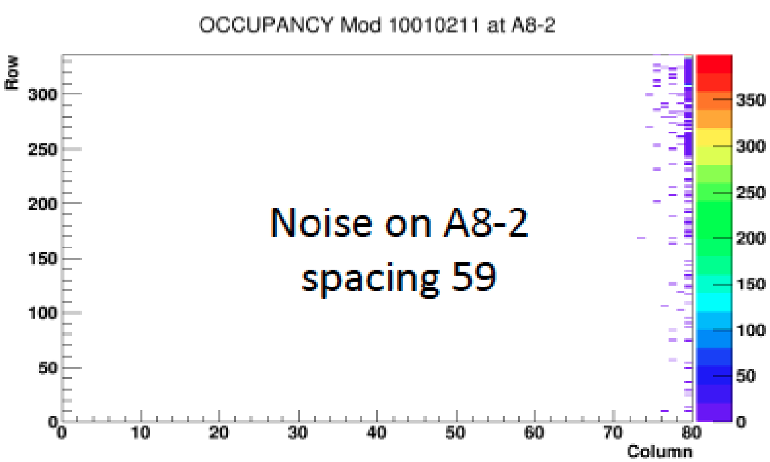
Latency 210
8 slices read

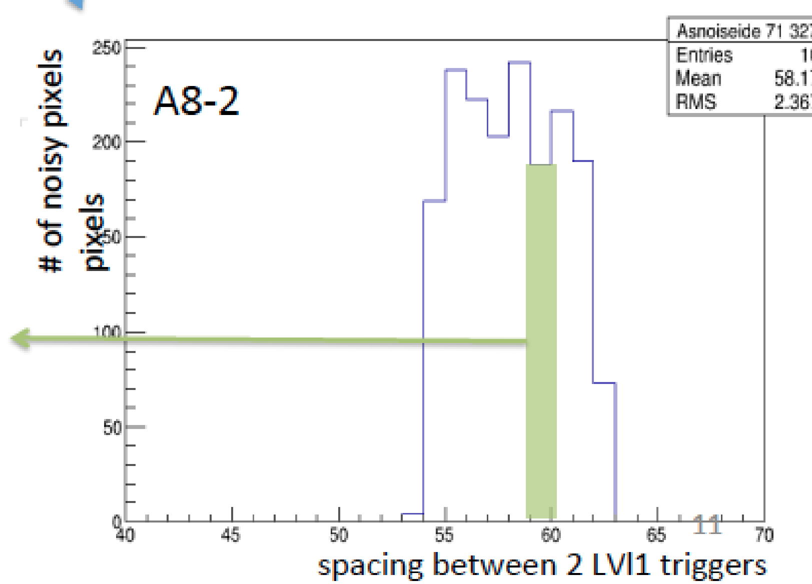
Stave08 Double trigger noise tests

Noise found on FBK modules







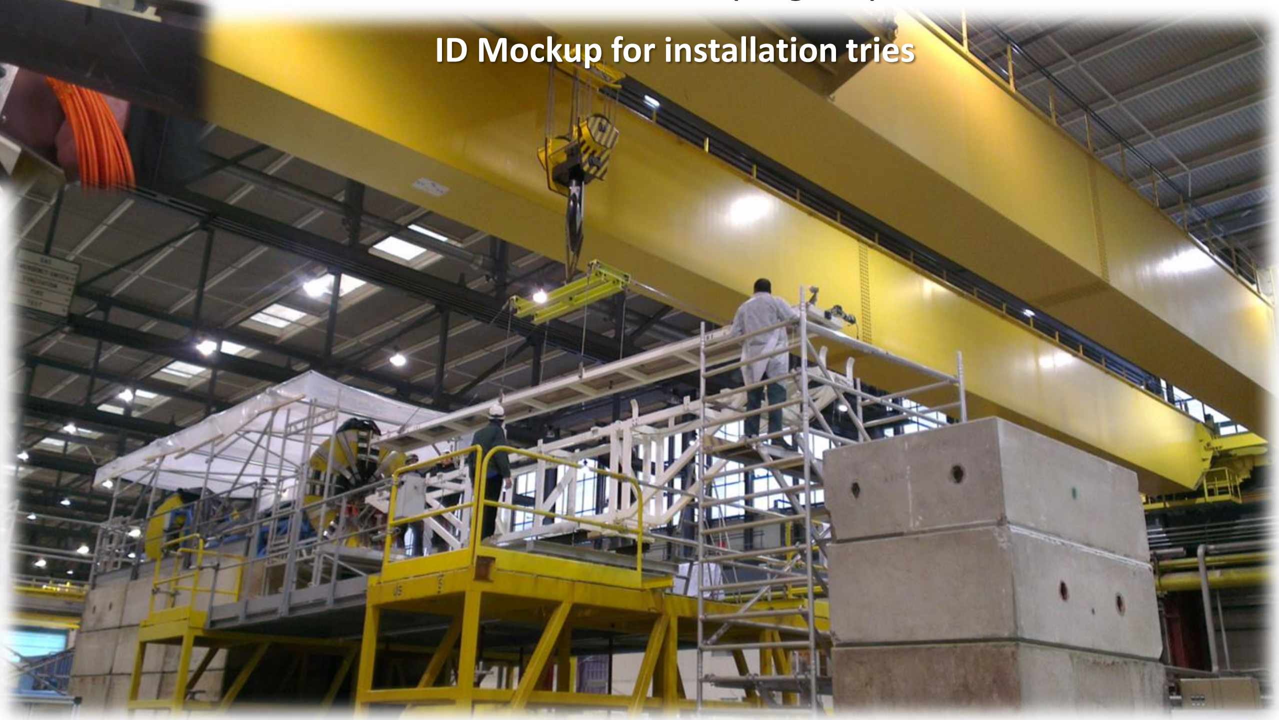


IBL insertion tests on the mock-up

Extremely delicate part for the IBL installation is the insertion

A mock-up exists in bldg 180 to practice (originally to minimize the time of intervention in the cavern and review the procedures)

- Tests made first by insertion by hands ✓
- Second stage of test with linear motor and torque limit ✓
- Repeat the above operations with services loaded into the sealing rings and test also the leak rate
- Practice the Z positioning pin insertion (IPT wrt IST)
- Practice the insertion with wrapped services at IPT extremities
- Practice the service unwraping → procedure



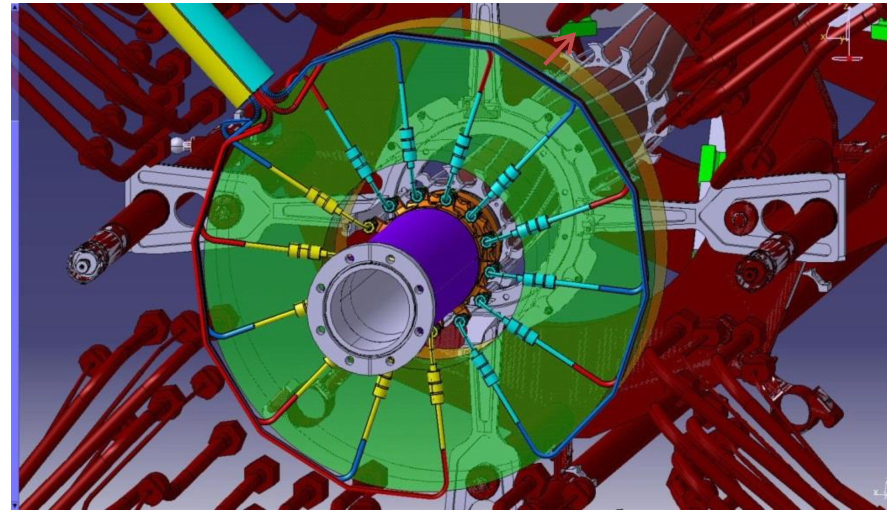
CO_2 cooling system

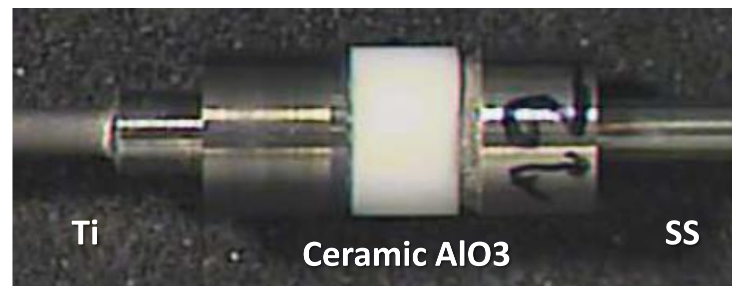
IBL cooling features:

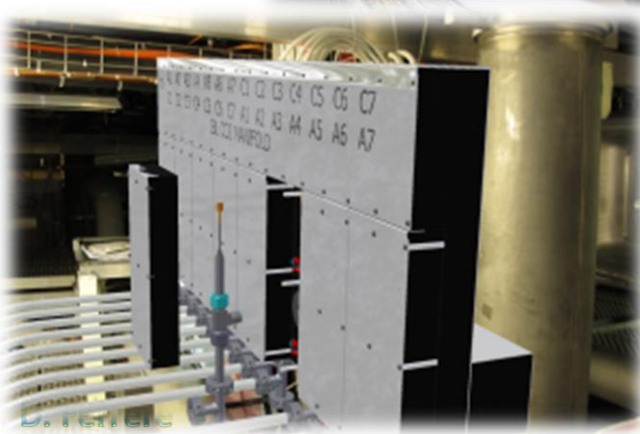
- CO2 cooling is new for ATLAS
- Cooling capacity is for 3kW
- Two cooling plants running in parallel

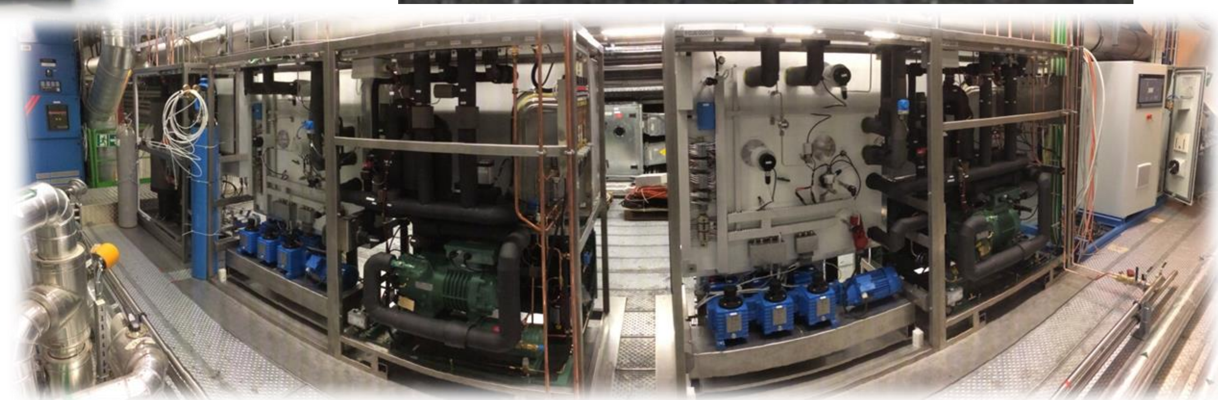
→ Increase the safety during bake-out in addition to the blow-off system

- Plant & 100m vacuum transfer lines already installed with distribution system close the detector
- Commissioning and 1st circulation of liquid CO2 started last week success fully
- Electrical break at the junction of the Ti and SS pipe was a technological challenge









IBL towards the completion

Work steps	Time line
Completion of the last staves which required module replacement	mid of February
Completion of stave rework	Beginning of February
Completion of stave QA	mid-end of February
Completion of readout of stave 07 & 08 around IPT	Beginning of February
IPT engineering work – Ti-extremity to IPT electrical connection + sealing ring installation	Mid of February
Start of brazing of the 1st 3 staves and integration of the 1st stave	Mid of February (started)
Completion of stave and service integration (including functional electrical tests)	Mid of April
Completion of service wrapping and **IBL packing for pit**	End of April
IBL transport to cavern and installation/alignment inside the Pixel	From May 5th to 14th
Electrical and cooling service **connection and final tests**	Mid May to end of June

Conclusions

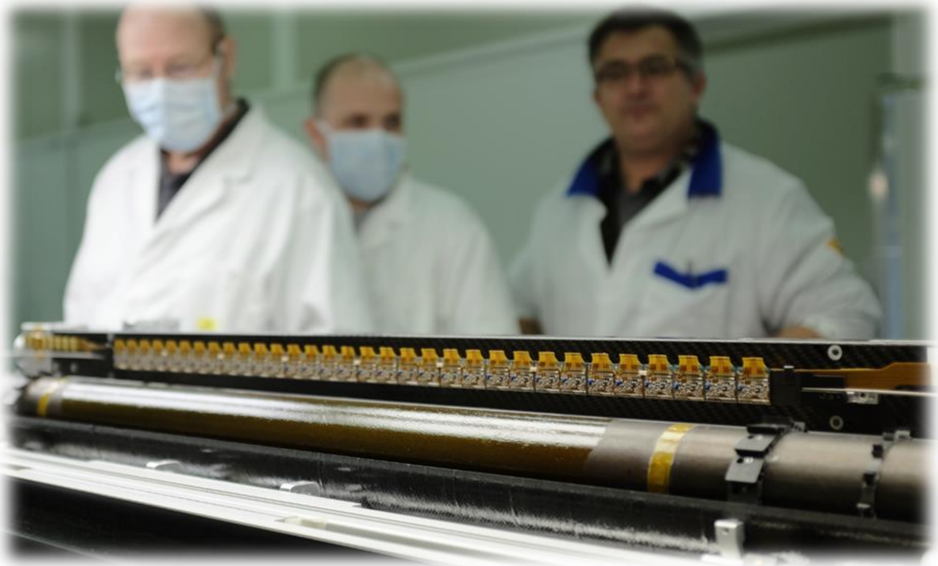
IBL is a detector with many interesting challenges such as:

- **New detector technology:** 1st time 3D detector produced for a detector
- **Thinner sensor and FE**: impact on the flip-chipping
- **New FE in 130nm:** after FEI4A, the B version is working as expected with set of improvement
- **Stave Al-Cu flex** to save material budget: 1st time ever tried this technology
- **Light stave structure**: Light, long and stiff object including the thin Ti-pipe
- **Stave extension to 7m long** for cooling: Brazing technique required a lot of investigations
- **Integration with tight clearances:** thanks to very precise and very well engineered tools
- **Overall engineering structures** with new composite material

Two major crisis allowed to gain more experience about what we are building but also good to remind us that building even a small scale Pixel detector is not a straight forward project

The integration and commissioning tests results are extremely positive
→ Allowing to complete the IBL with a higher level of confidence

1st stave integrated last week



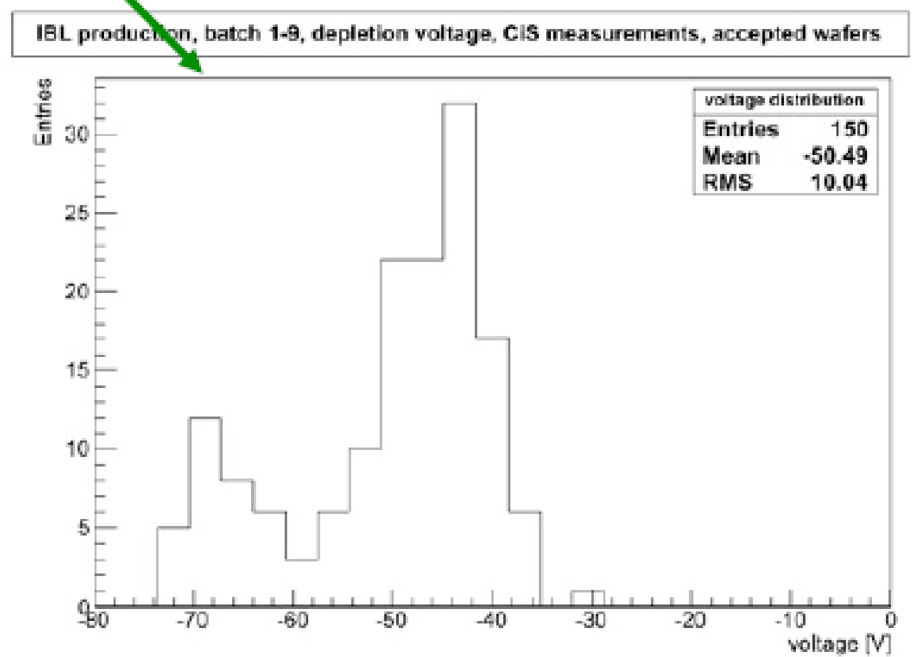
BACK-UP SLIDES

Quality and yield of received wafers (depletion voltage)

latest numbers

- we received measurement results performed at CiS
- these include IV measurements and depletion voltage
- distribution of 150 depletion voltages

Depletion voltage 46±6 V mpv



CiS measurements of some wafers show higher values

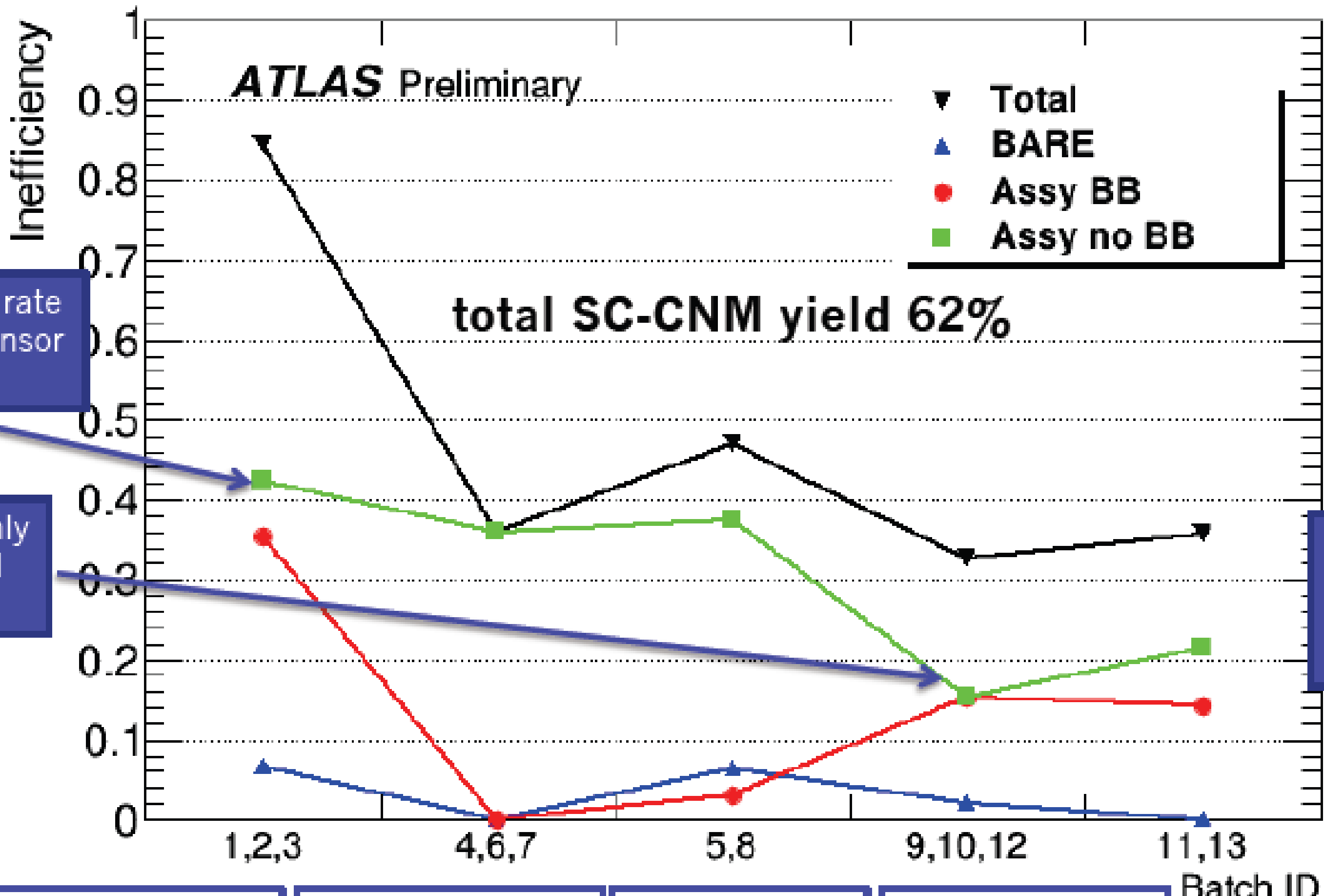
still to be re-checked with independent measurements

Expect to see lower values

Backup

universitätbonn

SC-CNM yields smoothed



electrical failure rate dominated by sensor failures

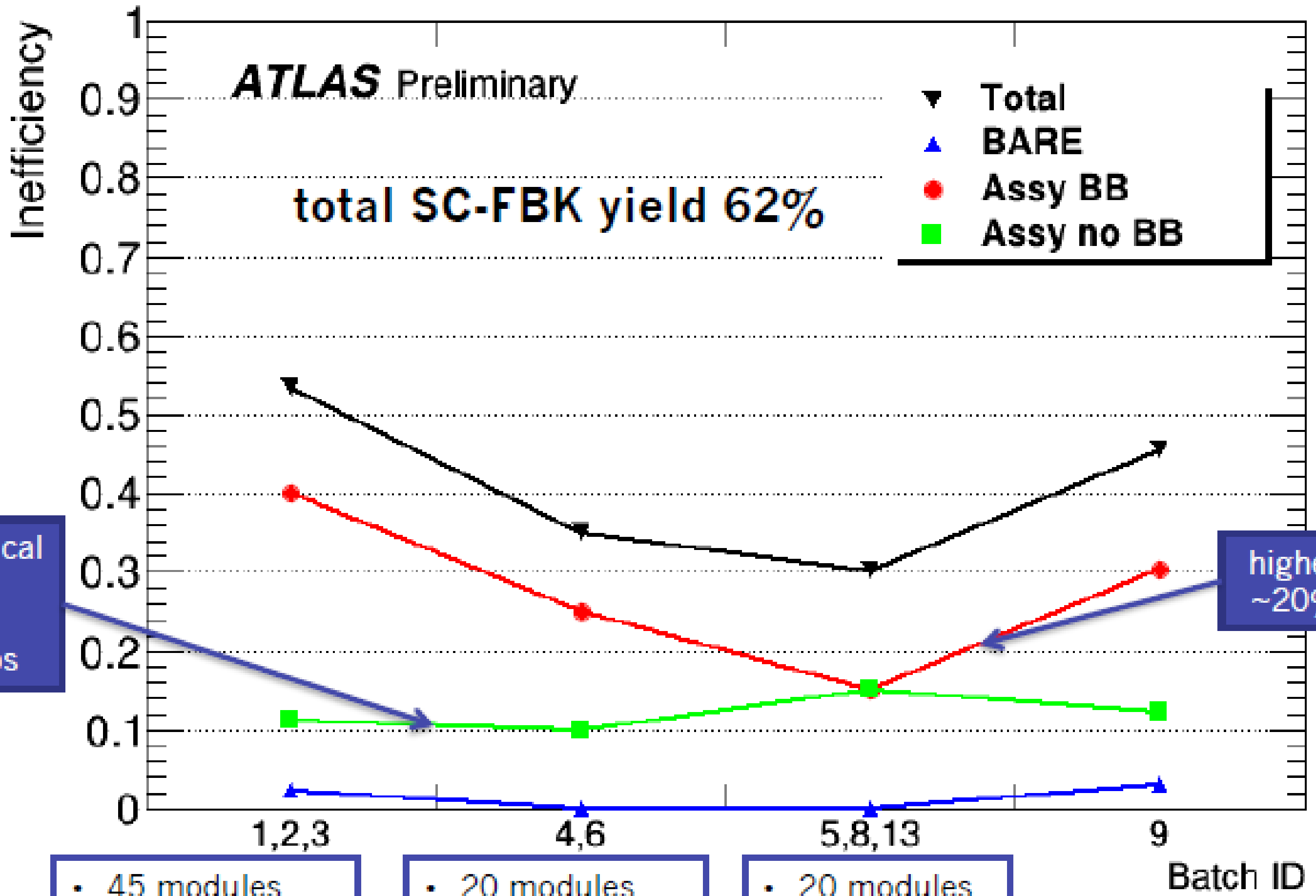
from here on only re-tested CNM sensors

BB failure rate better than for FBK ~10% on average

1,2,3	4,6,7	5,8	9,10,12	11,13
• 45 modules • Tamarack laser • Flux FC method	• 25 modules • Tamarack laser • Flux-free FC	• 32 modules • Gö. laser • Flux-free FC	• 52 modules • Ta. laser • Flux-free FC • retested sens.	• 14 modules • Gö. laser • Flux-free FC • retested sensors

universitätbonn

SC-FBK yields smoothed



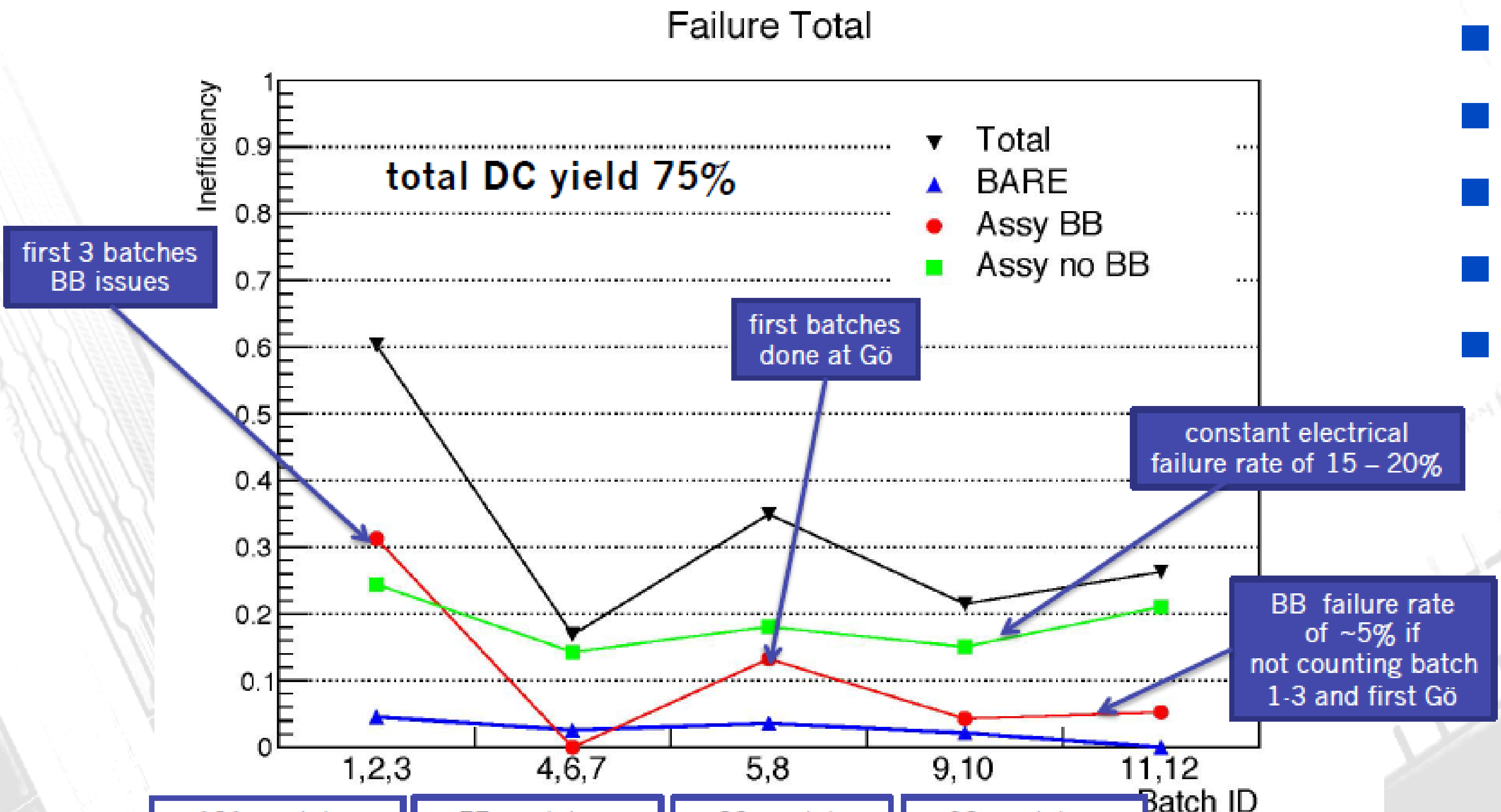
reduced electrical failure rate ~10% → single chips

higher BB failure rate ~20% for all batches

1,2,3	4,6	5,8,13	9
45 modules	20 modules	20 modules	33 modules
Tamarack laser	Tamarack laser	Gött. laser	Tamarack laser
Flux FC method	Flux-free FC	Flux-free FC	Flux-free FC

Note: reworked modules not included here universitätbonn

DC yields smoothed



- 131 modules
- Tamarack laser
- Flux FC method

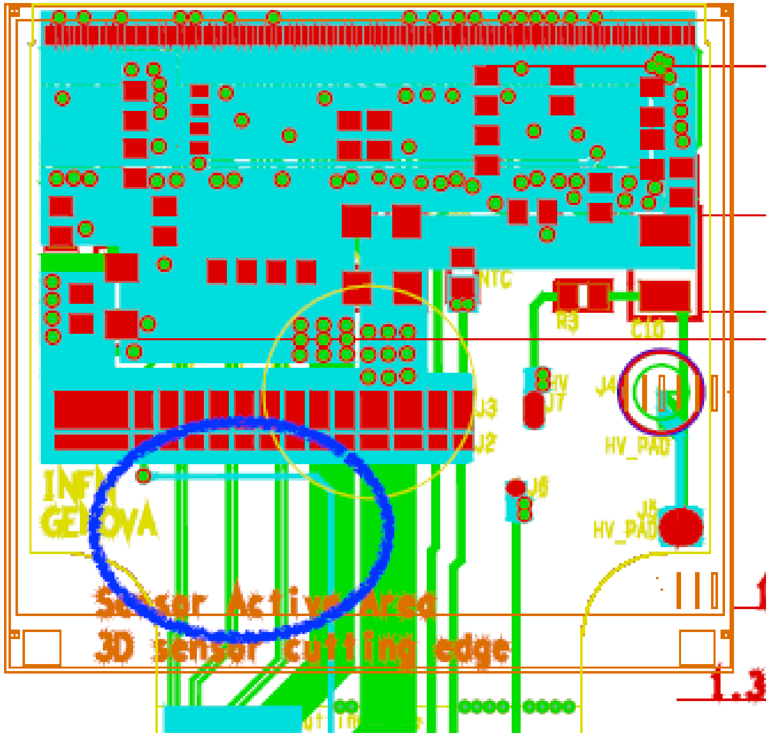
- 77 modules
- Tamarack laser
- Flux-free FC

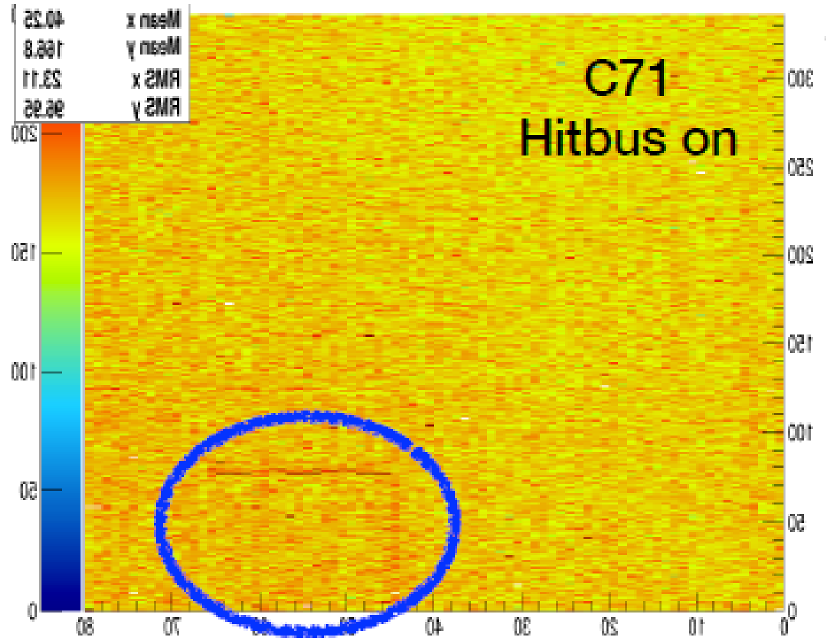
- 83 modules
- Gött. laser
- Flux-free FC

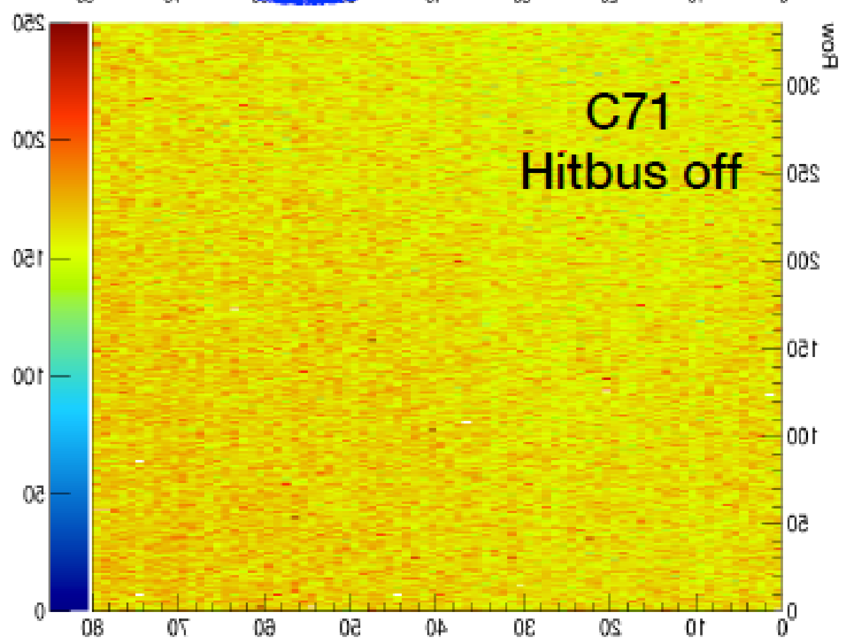
- 93 modules
- Ta. & Gö. laser
- Flux-free FC

- 39 modules
- Gött. laser
- Flux-free FC

Feedback - Noise on FBK modules – Con't







- were able to make **noise disappear** by **disabling hitbus output** of each pixel
- only seen on FBK so far (but not always)

Stave Score

Stave	#BadPix	BadPix Ratio (‰)	▼ Score
ST02	579	0.67	0.44
ST13	718	0.83	0.56
ST11	585	0.68	0.58
ST12	542	0.63	0.62
ST10	646	0.75	0.62
ST05	601	0.70	0.68
ST04	799	0.93	0.69
ST06	734	0.85	0.79
ST16	879	1.02	0.83
ST15	864	1.00	0.84
ST18	1266	1.47	0.94
ST09	1110	1.29	1.00
ST17	1052	1.22	1.01
ST01	1011	1.18	1.04
ST14	1877	2.18	1.11

Better score

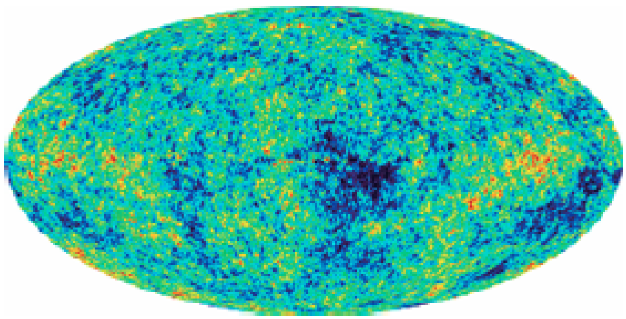
Worse score

$$\text{score} \equiv \left(\frac{\sum_{i \in \text{BadPixel}} w_i}{\sum_{i \in \text{AllPixel}} w_i} \right) \times 10^3$$

weight on each pixel

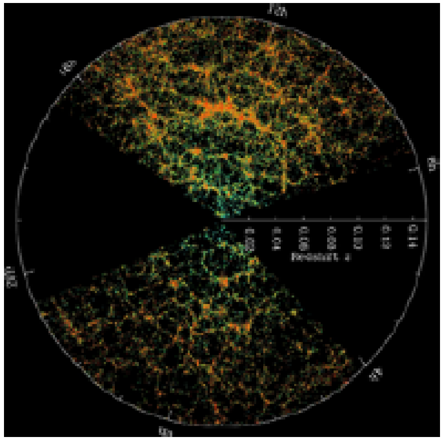
Mapping algorithm – Two points correlation function

It is commonly used in cosmology to describe distribution of observables in the sky using two-point correlation function for studying the structure of the space.

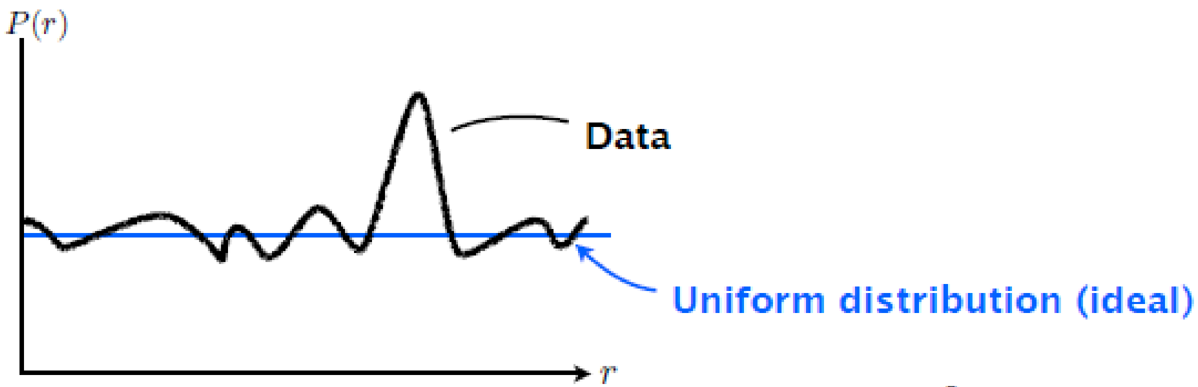


$$P(r) = \int d^3x \int d^3x' A(x) A(x') \delta^3(|x - x'| - r)$$

A(x): some amplitude as a fund of position



We don't like IBL stave bad pixels localized to some area which creates holes, therefore bad pixels are better to be distributed as uniform as possible.



$$X^2 = \int dr \, |P(r) - P_{\text{base}}(r)|^2$$

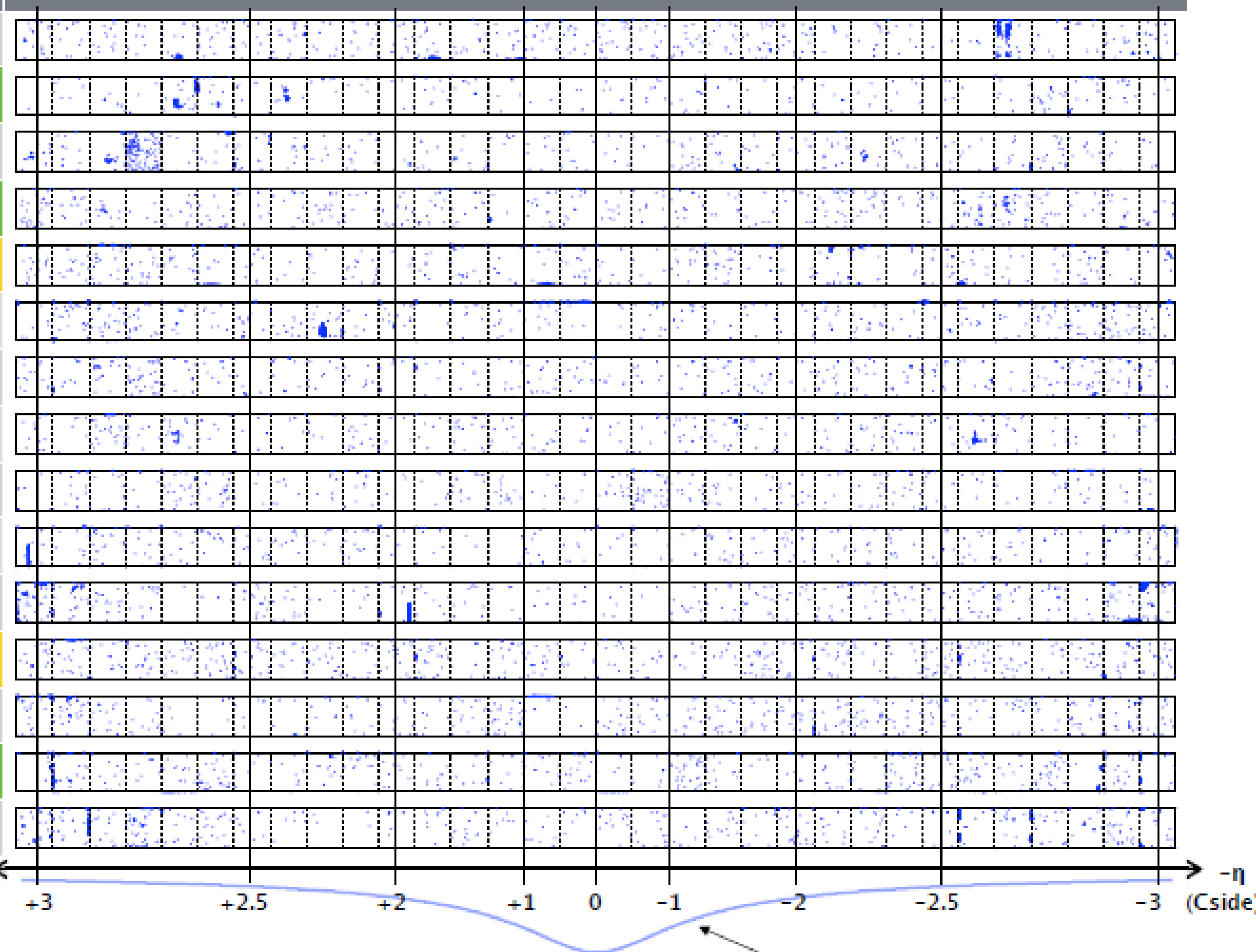
The basic concept:
Compare the correlation function with uniform distribution ("baseline"), and the deviation of the data from the baseline can be a measure of anisotropy.

Backup

Layout summary table – Stave integration order

Stave	DSF Rework	#Bad	Score	Planarity	Map
ST01	YES	1011	1.04	224	
ST02	YES	579	0.44	205	#2
ST04	YES	799	0.69	235	
ST05	YES	601	0.68	189	#14
ST06	YES	734	0.79	290	#12
ST09	YES	1110	1.00	229	
ST10	NO	646	0.62	243	
ST11	NO	585	0.58	298	
ST12	YES	542	0.62	314	
ST13	NO	718	0.56	224	
ST14	NO	1877	1.11	218	
ST15	NO	864	0.84	325	#13
ST16	NO	879	0.83	329	
ST17	NO	1052	1.01	114	#1
ST18	NO	1266	0.94	336	

BadPix Distribution



Weight on each pixel by eta-acceptance

$$w_i = \frac{1}{\cosh(\eta)} = \frac{1}{\cosh(\mathrm{asinh}(z/r_0))}$$

$$(z = r_0 \sinh(\eta))$$