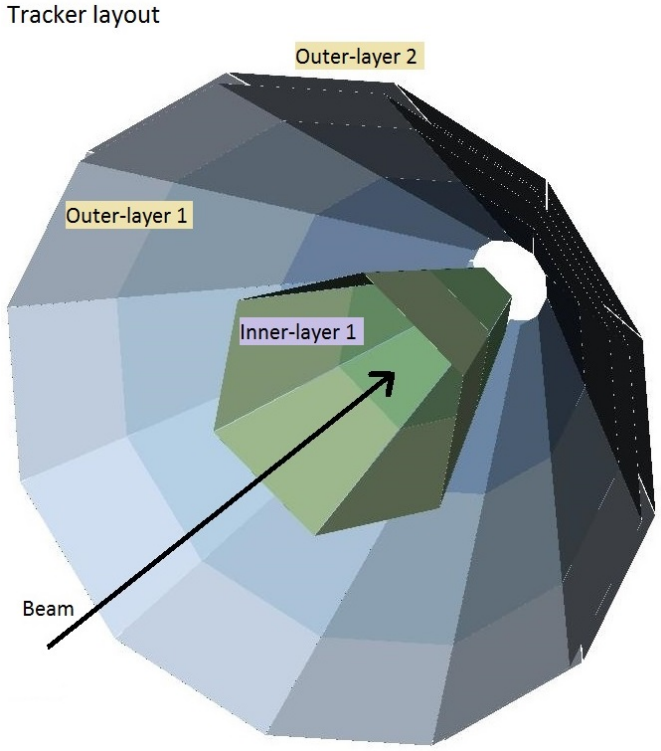
In-beam and lab tests

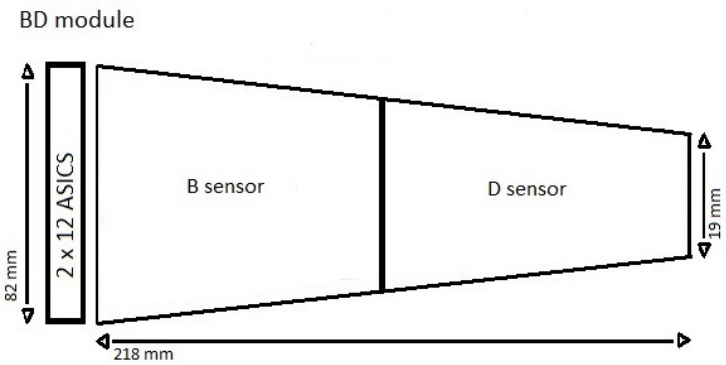
M.Borri (STFC)
on behalf of the teams at Daresbury, Edinburgh, Liverpool

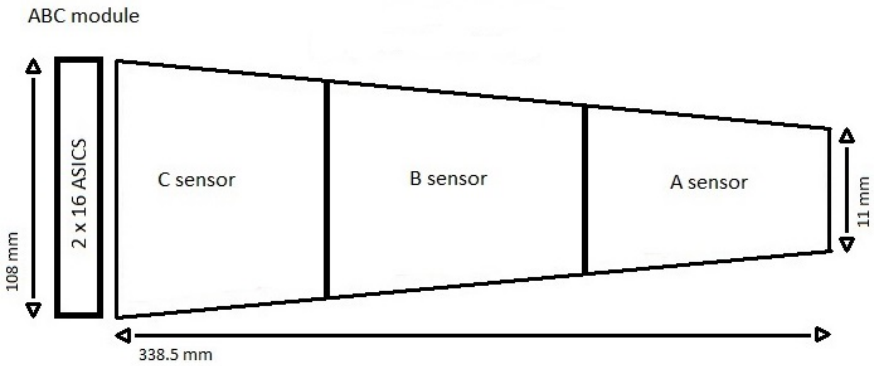
- Overview of silicon tracker.
- Devices under test.
- Tests prior in-beam period.
- In-beam test.
- Tests after in-beam period.
- Conclusion.

R3B Si-tracker.

- It is a micro-vertex detector.
- Total of 116,736 readout channels.
- It is shaped like a lamp-shade.
- Three layers: one inner; two outer.
- 2x12 ABC-detectors for outer layers.
- 6 BD-detectors for inner layer.
- ASICs are wire bonded to sensors making a detector.
- Sensors are Double Sided Silicon Micro-Strips.

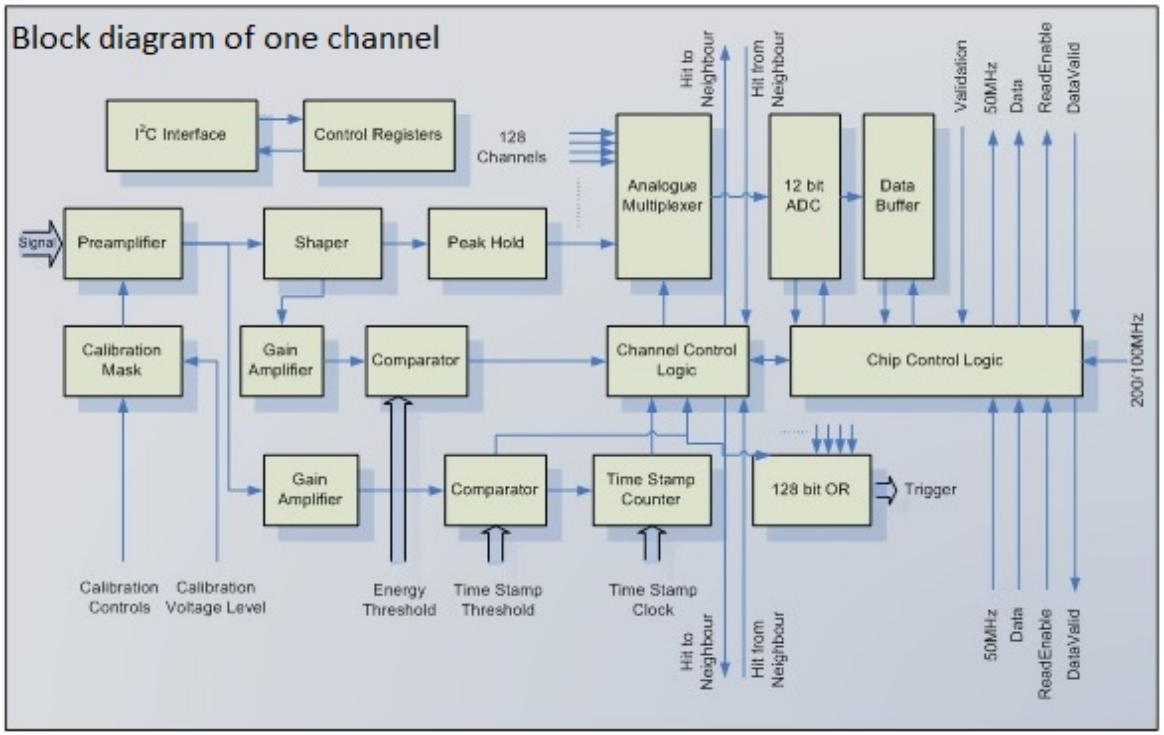






Sensor specifications	
Type	double sided
Bulk doping	n-type
Bulk thickness	300 μm [ABC] 100 μm [BD]
Strip pitch	50 μm
Strip width	38 μm
Strip length	variable
Strip stereo angle	16.2^o
Guard rings	9 floating
I-leak per strip	3.25 nA/cm [<100 nA]
Strip capacitance	2.3 pF/cm [<80 pF]

The ASIC.

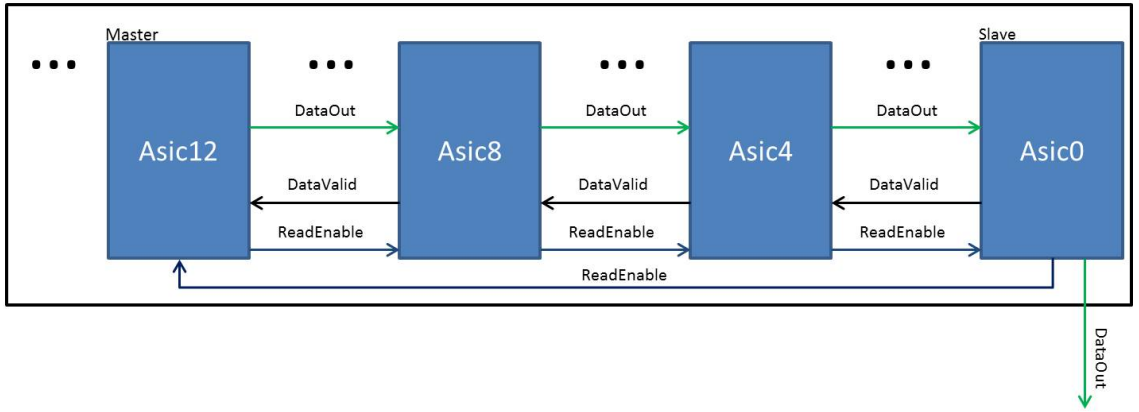


- Designed at STFC Rutherford Appleton Lab.
- The R3B ASIC is intended for reading out signals from the N and P strips.
- The chip provides three informations:

1. space coordinate.
2. energy deposit.
3. time of the hit.

ASIC specifications	
Size	13x6 mm^2
CMOS process	AMS 0.35 μm
Power consumption	$<$ 1.5 W/ASIC
Channels per chip	128
Data rate	$<$ 5 kHz/channel
Energy range	0-50 MeV
Time stamp	100 MHz

Daisy chain



- Readout based on a daisy chain sequence.
- Four ASICs are connected in a chain.
- They are not adjacent to each other.
- Rate in each ASIC proportional to the associated strip length.

Detectors and lab tests.

- Only ABC detectors.
- Problem in building them.
- Sensor IVs are systematically worse after detector production.
- Limited amount of time available to debug and test before test-beam.

Det	Built	Broken ASICs	Went to GSI	Lab.Test before GSI	Lab.Test after GSI
101	End of Jul	1,5,9,13 (N-side)	Yes	Yes	Yes
102	End of Aug	N/A	No	No	Yes
103	Beginning of Sept	1,5,9,13 (P-side)	Yes	No	Yes
104	Beginning of Sept	15 (N and P-side)	Yes	No	No

Lab tests before GSI test run

- Initial set of electrical tests (ETs) identified and implemented in MIDAS-DAQ.
- ETs performed on bare ASICs [not presented].
- Testing Det101 since August.
- Focus on:

1. IVs.
2. Channel response.
3. Noise.
4. Charge collection.

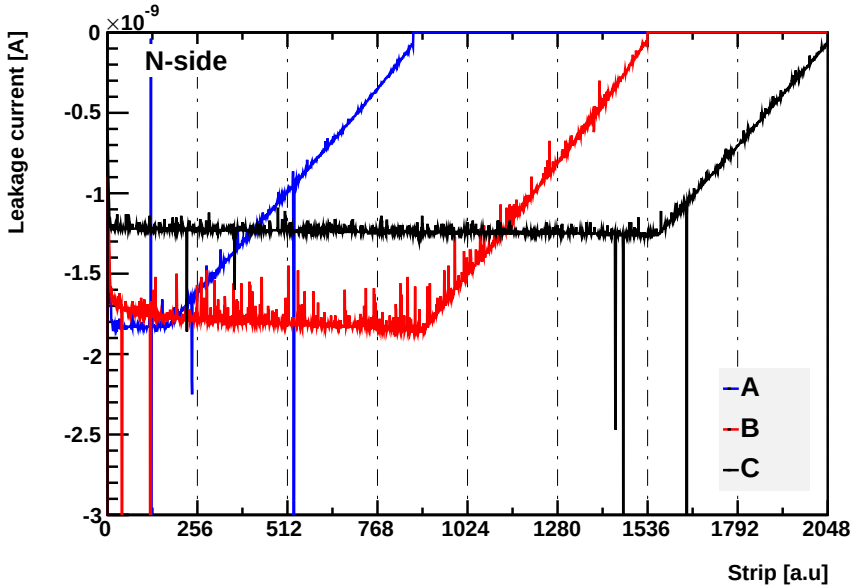
- Test performed with:

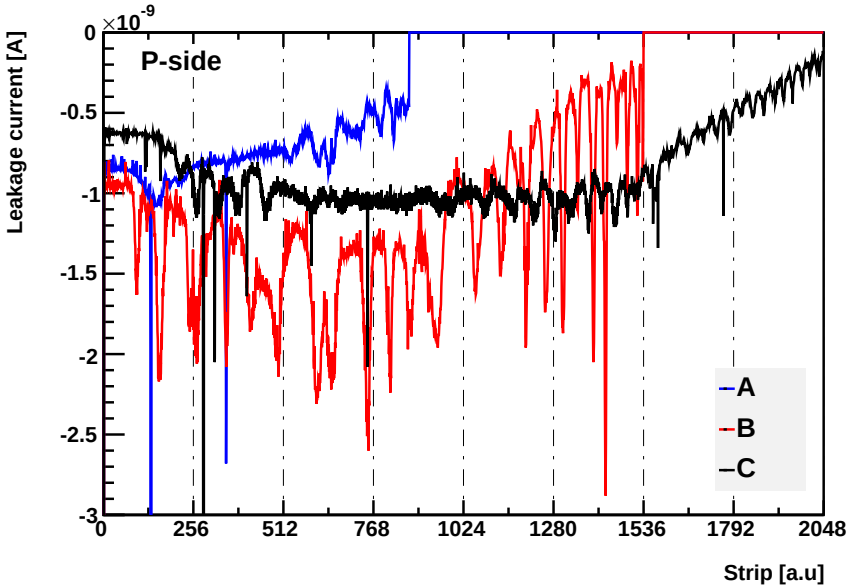
  100MHz input-clock.

  energy threshold@2.4MeV.

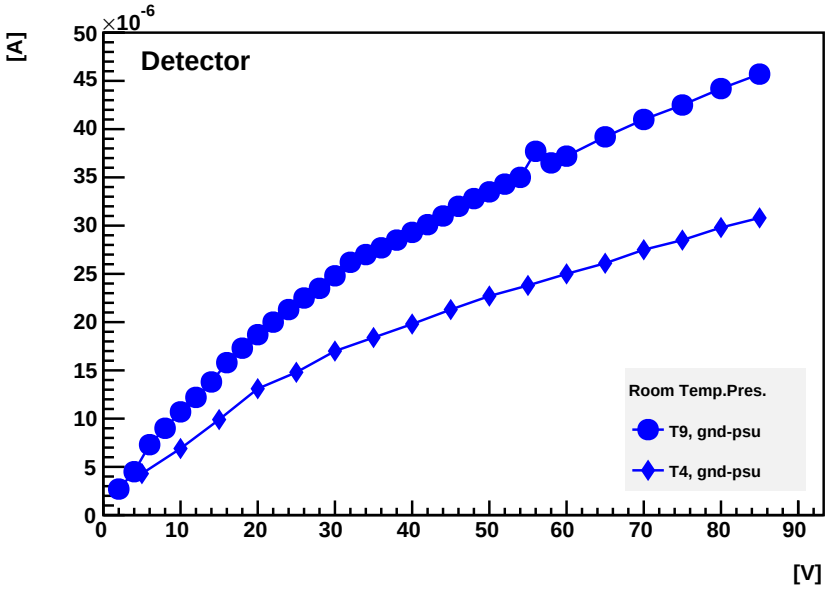
Sensor electrical test	I-V measurement	100%
Front-end operation	Energy threshold	90%
	Time-stamp threshold	50%
	Peak time	100%
	Noisy channels	50%
	ADCtoEnergy calibration	70%
	Cross-talk	50%
	Timewalk and jitter	0%
Detector performance	Charge collection efficiency	20%
	Signal-over-noise	20%

Det101: IV characteristics.

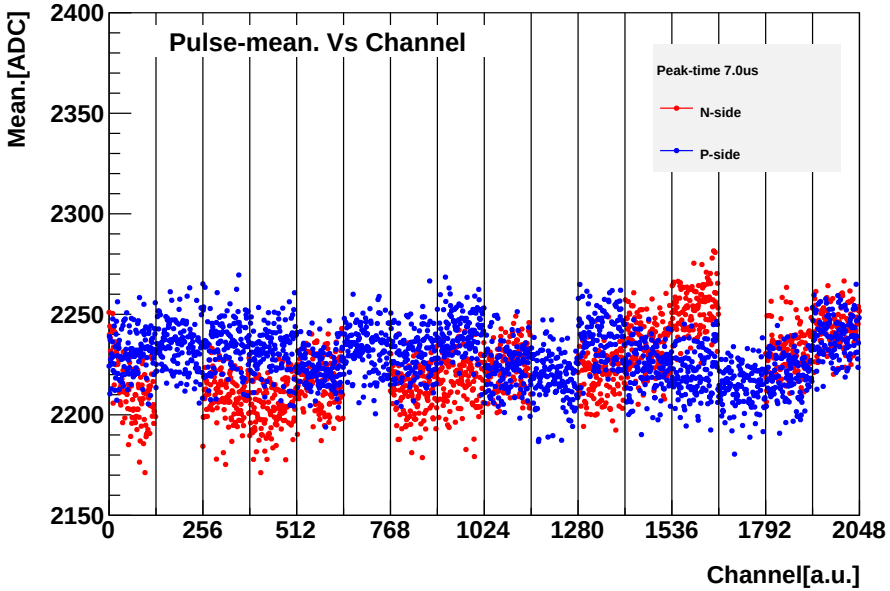


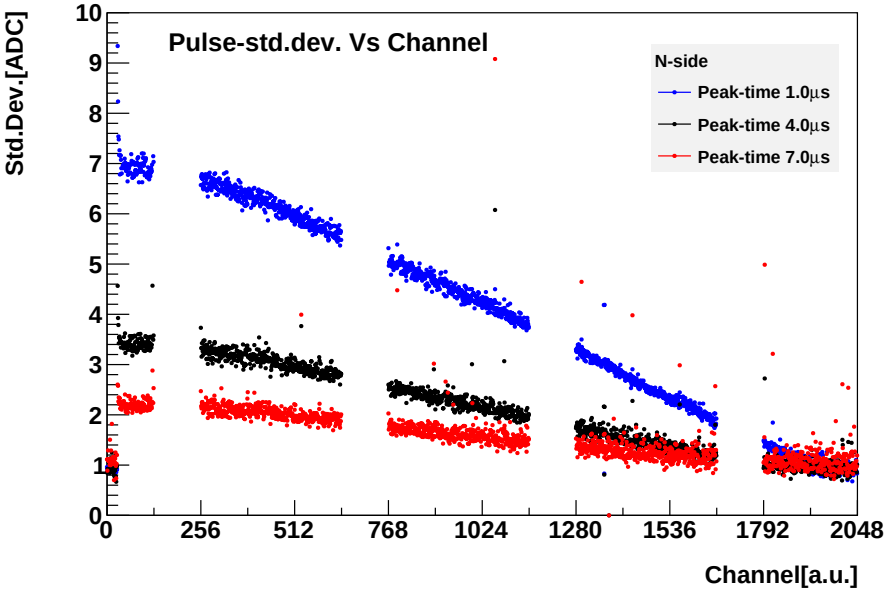


- Det101 was built with sub-standard sensors.
- I-leak was $\sim$8 μA@65V after A,B and C sensors were wire bonded together.
- I-leak was $\sim$40 μA@65V after ASICs were wire-bonded to C sensor.
- I-leak partially-recovered for unknown reasons when detector was relocated in another lab.

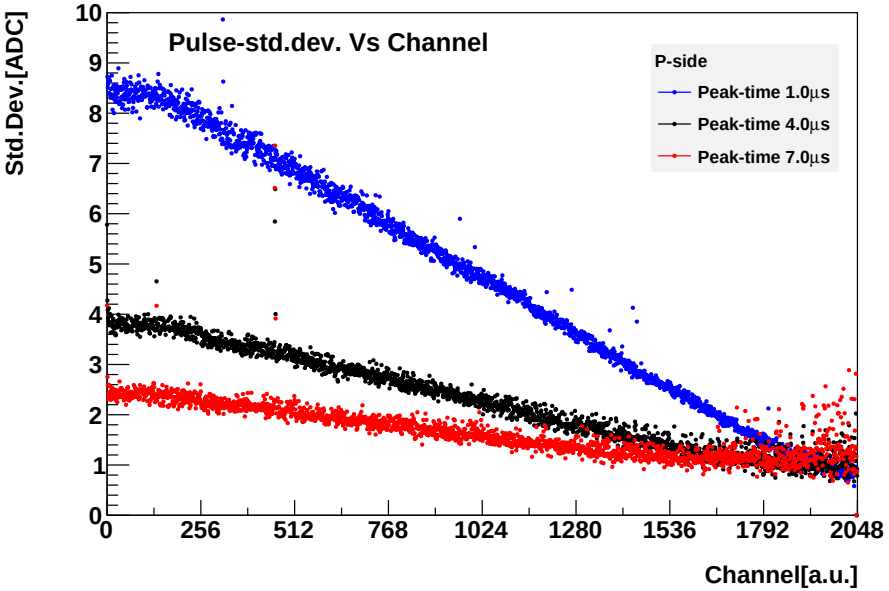


Det101: pulse-injection tests.



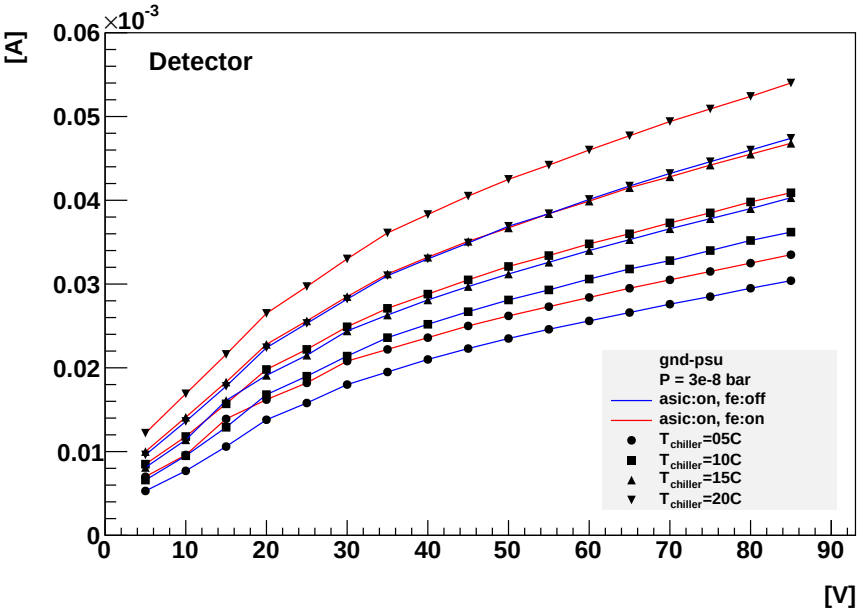


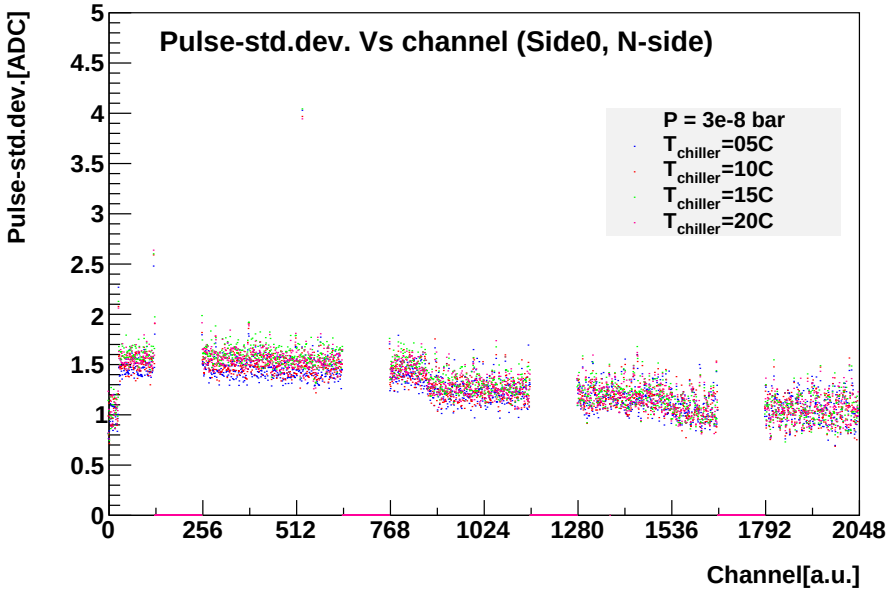
- Measured in lab.T9.
- Test-pulse injected in each individual channel.
- Mean and std.dev. retrieved for each channel.
- ASIC to ASIC variations of pulse mean.
- Input capacitance $\propto$ strip length.
- I_leak $\propto$ strip length.
- Higher noise for longer strips.
- More uniform and lower noise with high shaping time.
- No obvious dependency to leakage pattern on P-side.
- Possible to use sub-standard sensors ?



N.B. chain 1 (n side) is not working.

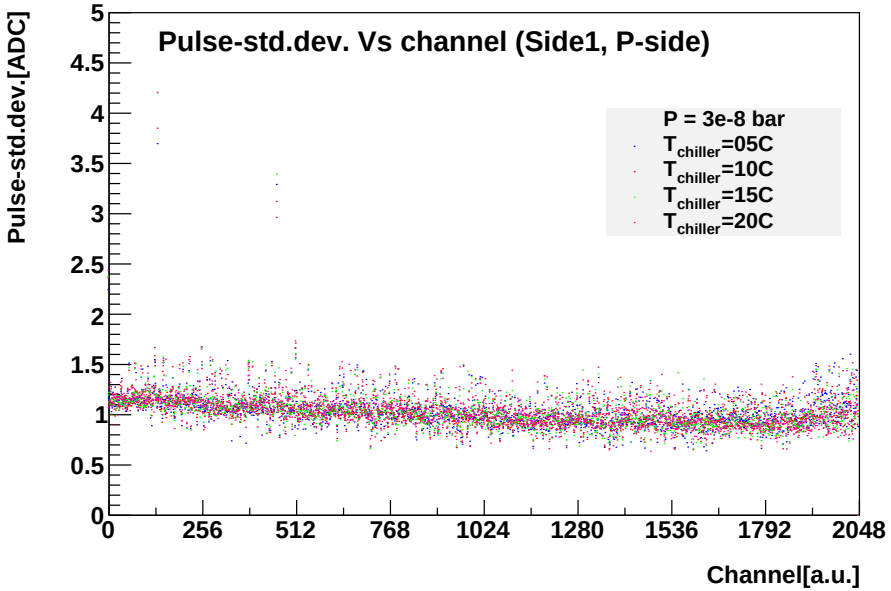
Det101: noise vs leakage current.



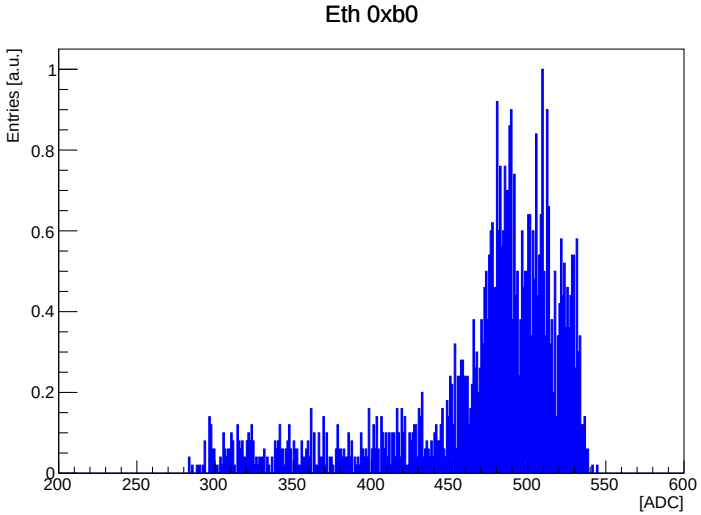


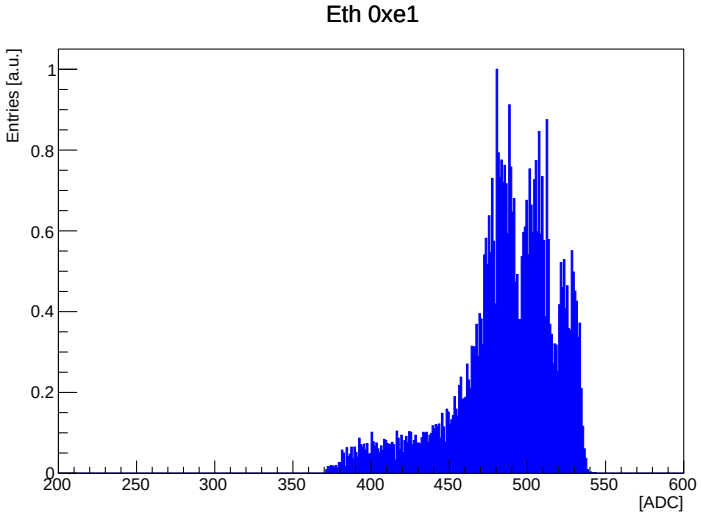
- Measured in lab.T4.
- Noise also decreased when detector was relocated in another lab.
- Effect of I-leak on noise was investigated.
- ASICs ware used as heaters.
- Det101 was placed in vacuum.
- Chiller temperature was scanned from 5C to 20C, steps of 5C.
- Peak-time 7.0 μs.
- No obvious dependency of noise from I-leak.

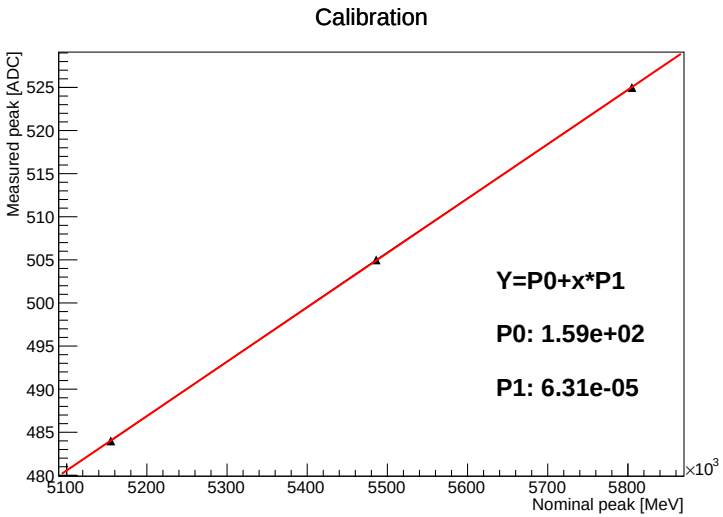
N.B. chain 1 (n side) is not working.



Det101: charge collection.







- Mixed alpha source: Pu-239 (5.155MeV,1kBq); Am-241 (5.486MeV,1kBq); Cm-244 (5.805MeV,1kBq).
- Single channel spectra, no clustering.
- Gain measured with source is biased by charge sharing effects.
- Threshold step measured with source uses a rough method.
- Values are encouraging.

Comparison

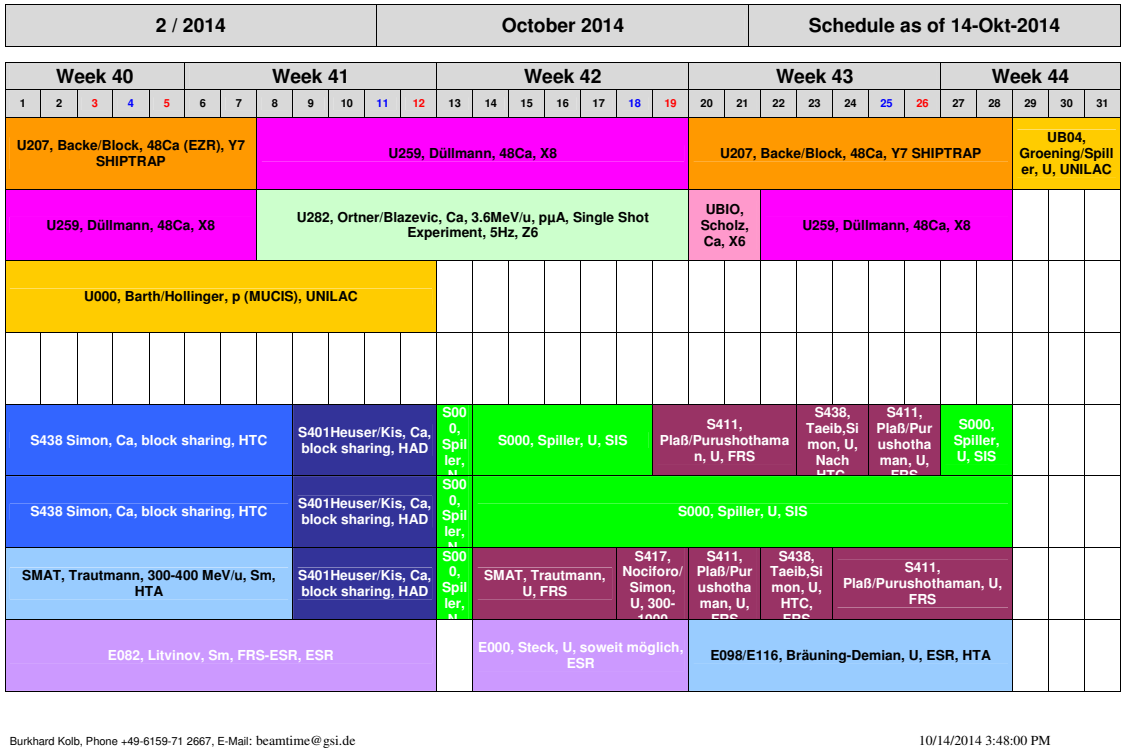
		theoretical	internal pulse	α-source
Gain	[ADC/eV]	6.45e-5	6.2e-5	6.31e-5
Eth-step	[keV/DN]	24.7	23.7	29.1

N.B. internal-pulse values quoted for bare asics.

In-beam test @ GSI.

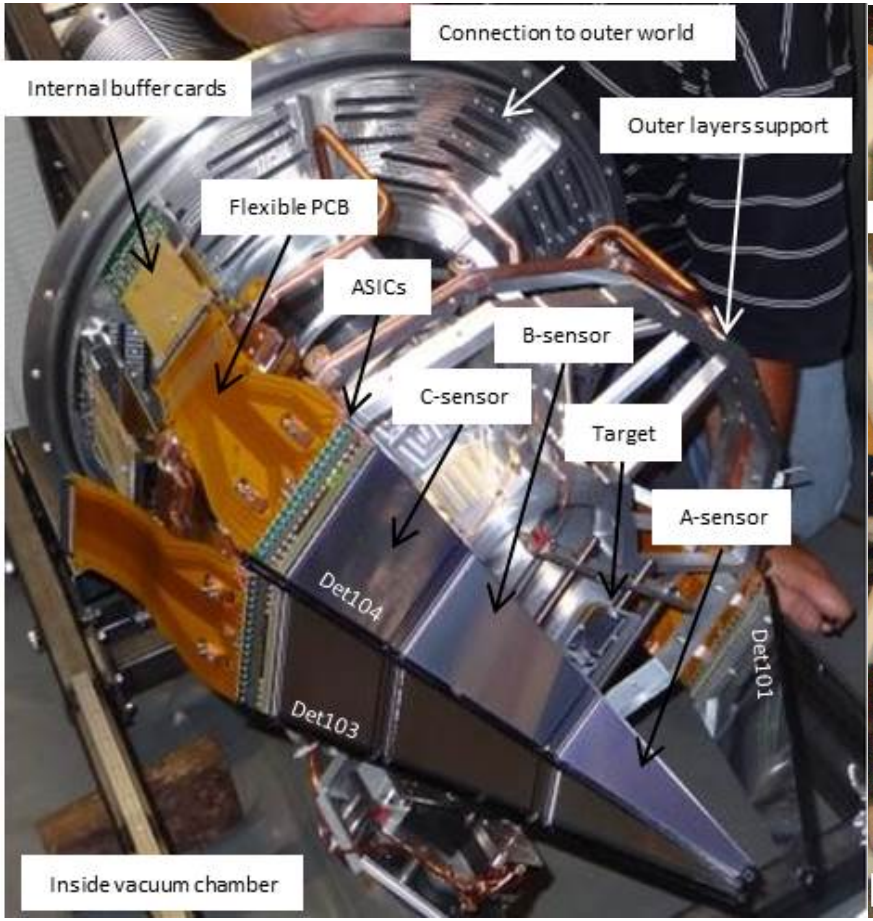
- GOAL: study reactions produced by a Ca48 beam hitting a CH2 target.
- MEAN: detect correlations of signals produced by particles in CALIFA and Si-tracker.
- OUTCOME: we acquired two data sets which could enable finding correlations.
- BUT: To achieve this goal we had to adopt several work around to overcome several difficulties.
- The scientific goal allowed us to test our detector system in terms of:

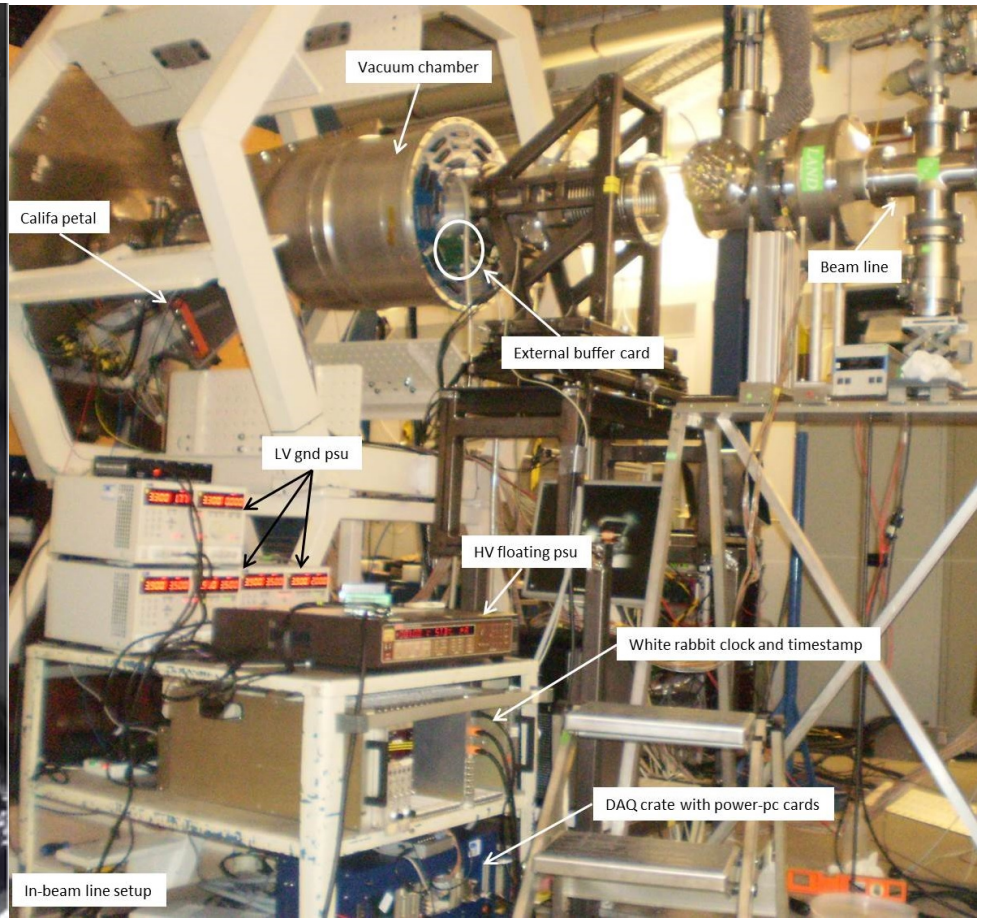
1. building.
2. mounting*.
3. operating.
4. taking data.
5. analysing data.



* See A.Grant's talk in Infrastructure session (08/12/2014).

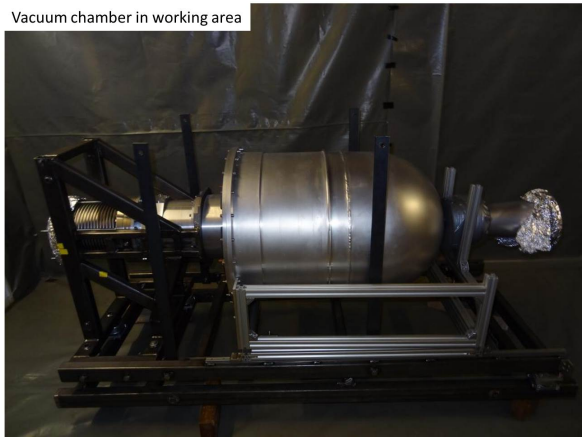
Setup.

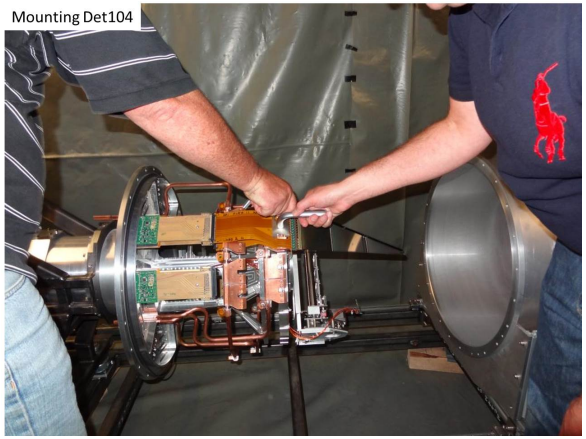




- We took 3 detectors to GSI.
- Det101 and Det104 are in front of CALIFA petals.
- Det103 does not have a CALIFA petal behind it.

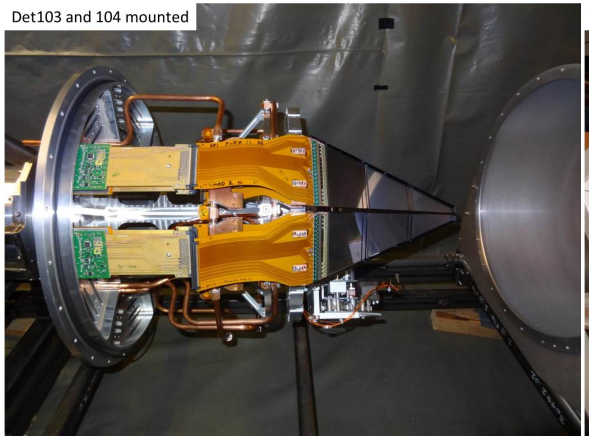
Time line.

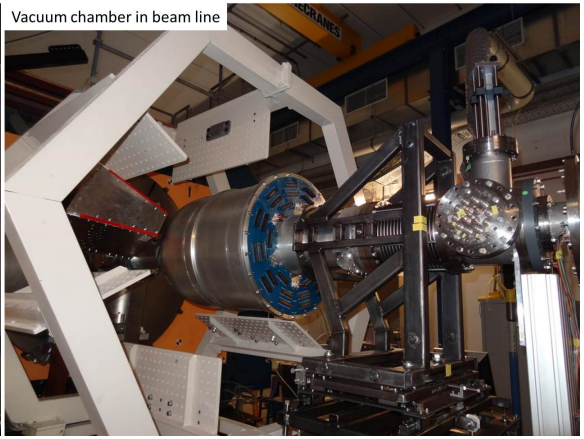

Vacuum chamber in working area


Mounting Det104

20/09	Equipment dispatched to GSI
21/09	3/3 detectors installed in vacuum chamber
	Corrupted data coming from detectors
	Repeated data coming from detectors
22/09	Chamber goes in beam line
25/09	DAQ successfully transfers data to MBS
27/09	Operating successfully 0.5/3 detectors
	Keep searching cause of data corruption
01/10	First day of beam
	No solution to data corruption
	Operating ∼(0.5-0.25)/3 detectors
03/10	Lowered energy threshold, higher data rate (noise)
	Time ordering issues with MBS
05/10	Work around to time ordering
06/10	Acquire data in best possible operating condition
09/10	Last day of beam
14/10	Equipment returned to the UK

More info at:
https://docs.google.com/spreadsheets/d/1H9xHbSwvJV9QKgueFMPMrP5YESBHoB9va2
_0tWnDqs/edit?pli=1#gid=0


Det103 and 104 mounted


Vacuum chamber in beam line

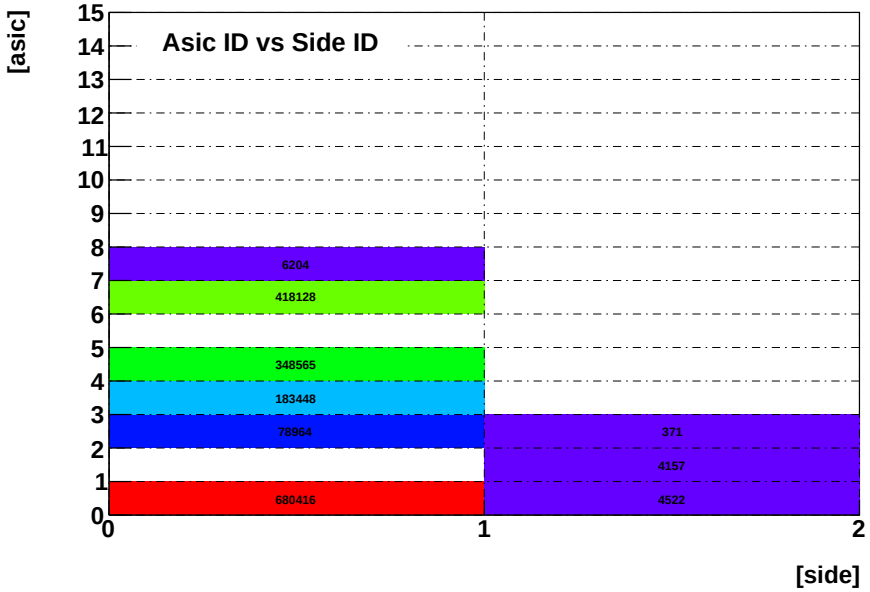

Vacuum chamber back @ DL

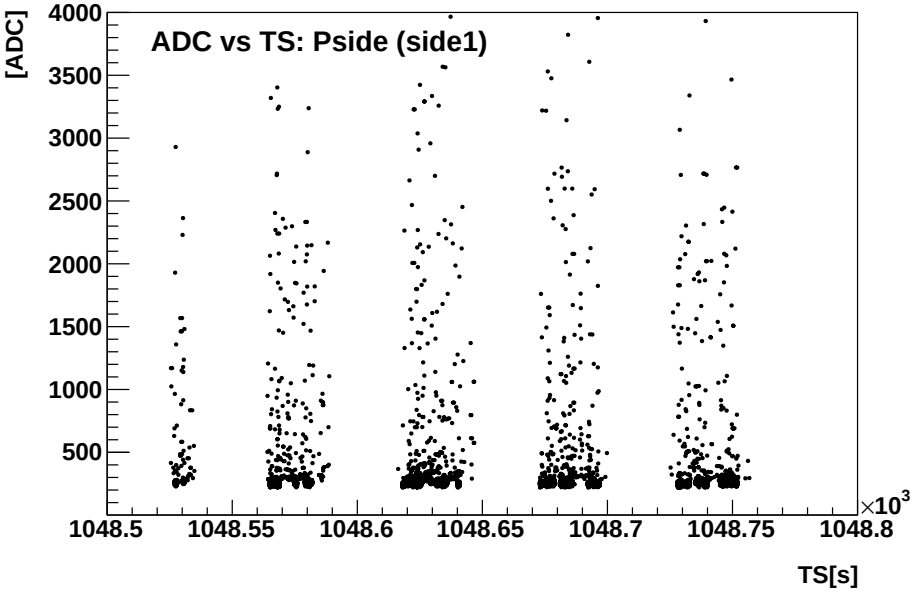
Data taking and analysis.

Taget threshold settings		
	N-side	P-side
Noise floor	∼395 keV	∼790.4 keV
En-threshold	∼100 keV	∼790.4 keV
	E-kin	Edep in 300μm of Si
α	∼100 MeV	∼4.7 MeV
proton	∼250 MeV	∼250 keV

Run290_3777		
Target	Beam type	Beam energy
CH2	Ca48	550MeV

- Used only Det101.
- Enabled (50-25)% of channels.
- Enabled long-strip channels for wide area.
- It has high noise floor.
- P-side noisier that N-side in cave C.
- 250 MeV protons will give only 1D coordinate in position.
- Analysis started in R3B-root (A.Estrade, M.Labiche, W.Powell).
- Delayed by problem with inversion in time stamp: was bug in firmware.





In the lab after in-beam period.

- We investigated our main problems:
  - Data corruption: main cause of limited success in-beam.
  - Data repetition.
  - IV problem.
- We want to address the following questions:
  - Are there any risks for the third iteration of the ASIC ?
  - Why can we not build optimal detectors ?
  - What do we need to improve in our detector system ?

Data corruption.

Findings:

- Corrupted data are received from the detector (e.g. random side ID).
- Corruption is produced when the ASICs are not properly biased.
- Corruption is also produced by external sources of noise.
- Corruption seems not to be produced by high data rate.

Consequences:

- Sufficient to use existing sense-line ?
- Grounding needs to be optimized.

Det101		
Condition	1st trial	2nd trial
All FE on; Scroll pump off	No data corr. (14h)	No data corr. (9h)
All FE on; Scroll pump on	No data corr. (14h)	-
All FE on; Scroll pump off; Plug switching	Yes data corr.	Yes data corr.
All FE on; Scroll pump on; Plug switching	Yes data corr.	Yes data corr.
FE on chain 0,2,4,6; Scroll pump off	Yes data corr.	Yes data corr.

Data repetition.

Findings:

- Identical data words were received during data taking.
- Most of repeated data words were produced by a bug in the firmware. This is fixed.
- After the fix, it is still possible to observe data repetition.

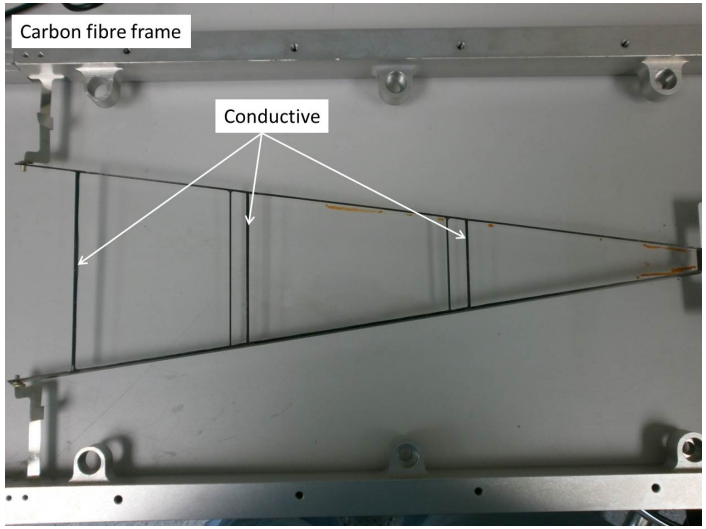
Consequences:

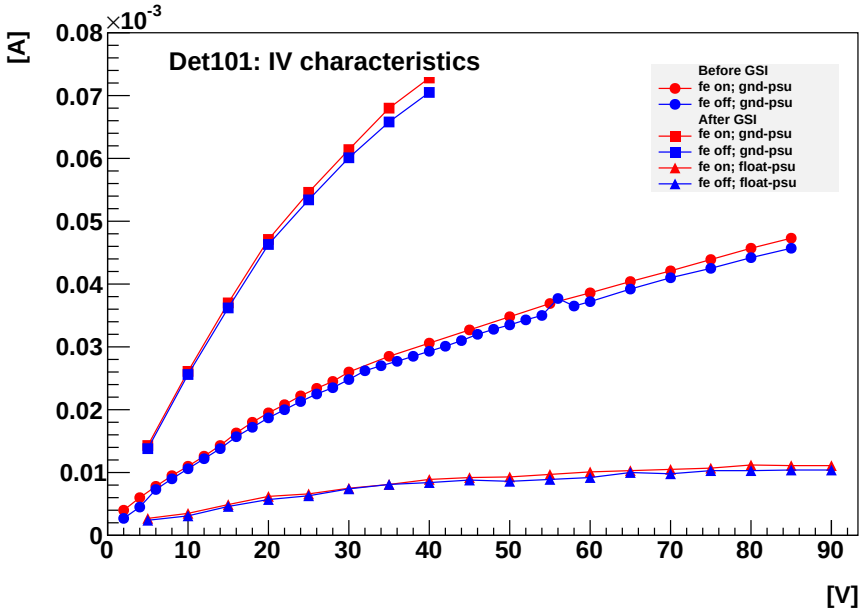
- Simulate the chain response before ASIC submission.

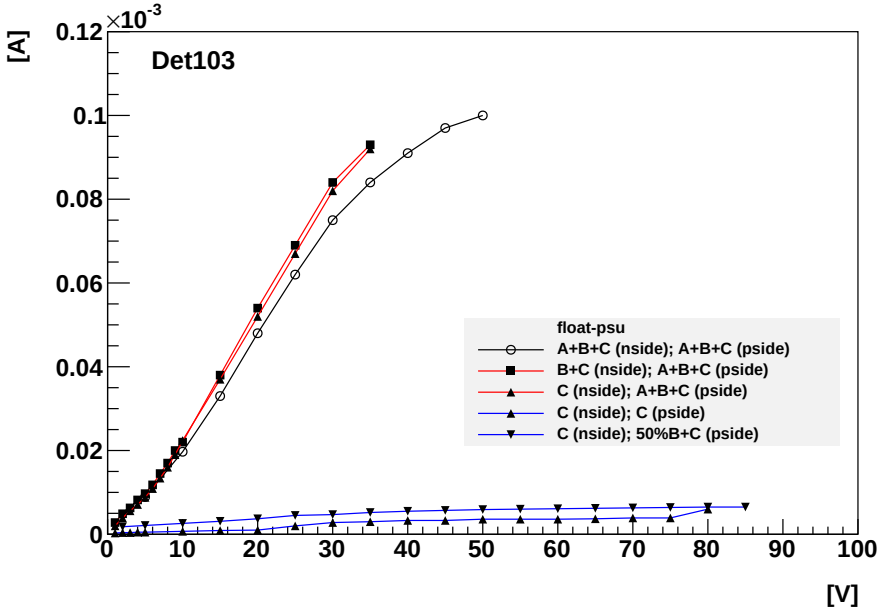
Rate set to 900kHz/chain (design limit at 1MHz/chain)						
			Det101	Bare ASICS		
PulseInjection	PulseWidth	PulseDelay		1st trial	2nd trial	3rd trial
8 channels/ASIC	555*10ns	3000*10ns	Yes rep.	No rep.(1h)	No rep.(1h)	No.rep(9h)
32 channels/ASIC	4222*10ns	10000*10ns	Yes rep.	Yes rep.	Yes rep.	No rep.(4h)
128 channels/ASIC	6888*10ns	50000*10ns	Yes rep.	No rep.(1h)	No rep.(1h)	No rep.(15h)
128 channels only in ManEnc	4222*10ns	10000*10ns	No rep.	No rep.(1h)	-	-

IV characteristics.

- Det101 can only be biased with floating psu.
- Det103 was systematically taken apart.
- Wire bonds were removed from different sensor pieces.
- IV recovered when only the C piece was connected.
- IV is the same with grounding/floating power supply.
- Cross-piece in carbon fibre (CF) frame is conductive.
- High risk of shorts between the silicon sensor and the CF frame.







Conclusion.

- Four ABC detectors were built.
- Systematic increase in leakage current after building.
- Preliminary lab characterization of detectors.
- We acquired data which could enable finding correlations between CALIFA and Si-tracker (our goal!).
- We completed the whole cycle of building, mounting, operating, data taking and data analysis.
- The system weaknesses were exposed.
- Debugging/improvement was carried out and is still ongoing.