



ATLAS ITk Upgrade Project

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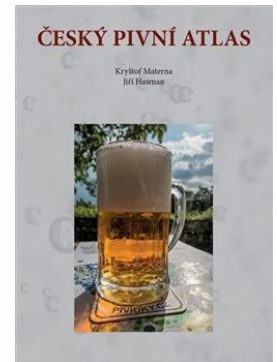
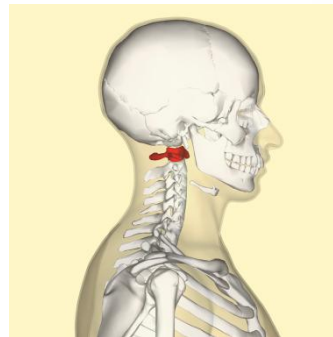
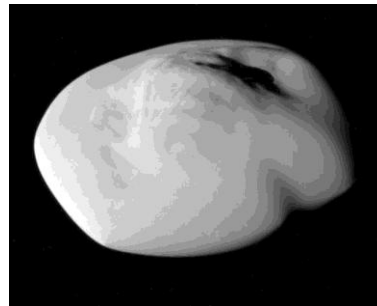
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= the one who dares/suffers

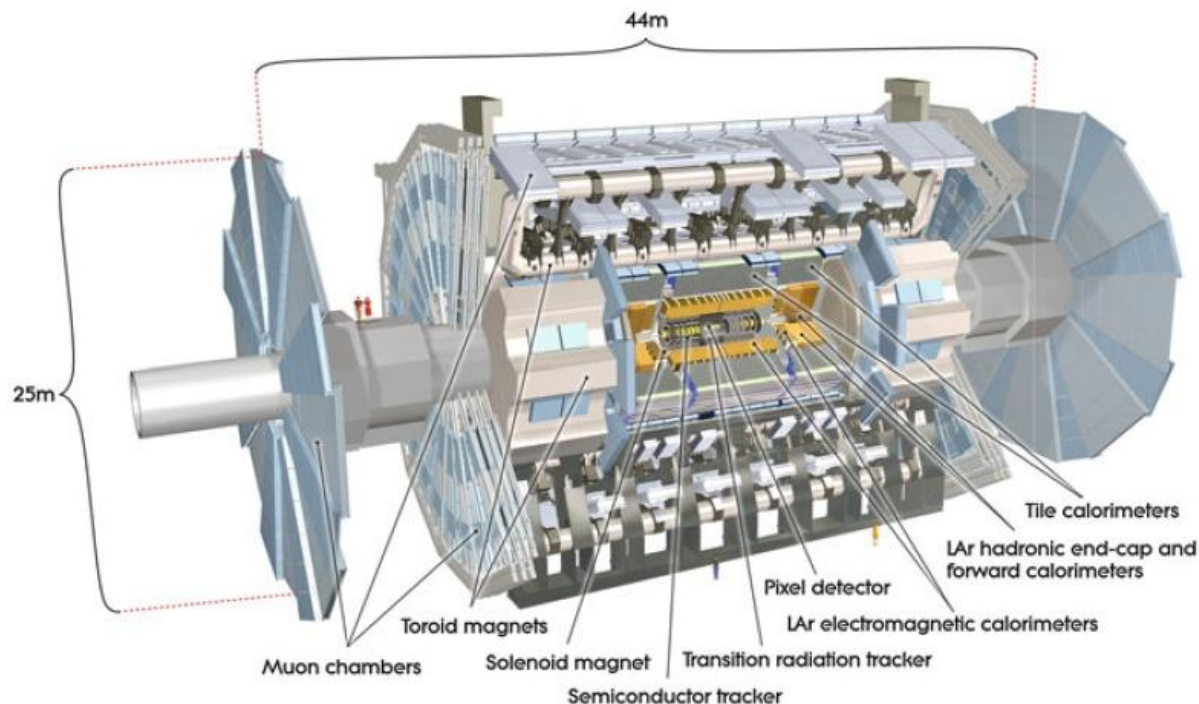


- mythological Titan condemned to hold up the celestial heavens for eternity
- rebellion against the Olympians suppressed, punishment, killed by Perseus on his return journey from Medusa => he was turned to stone (Atlas Mountains)

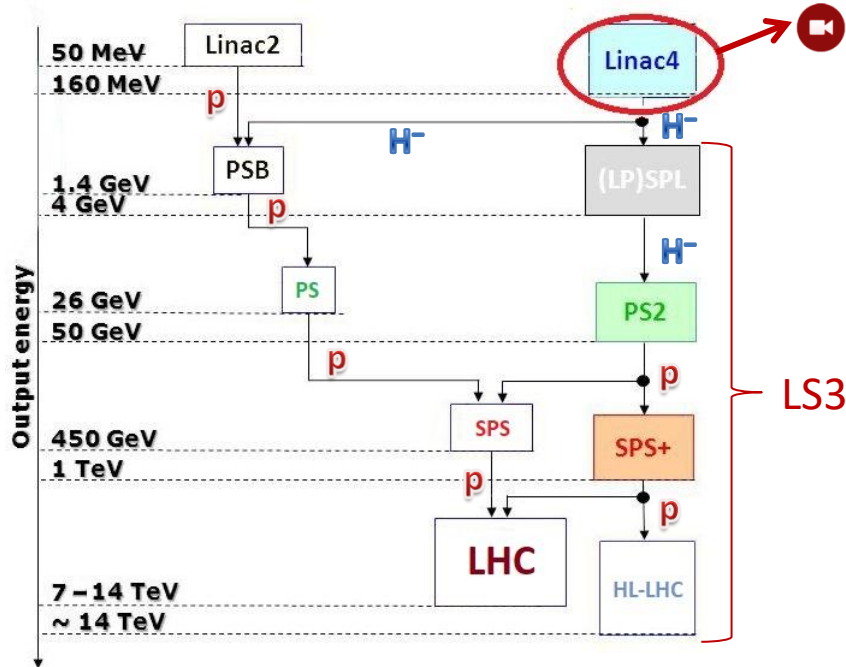


ATLAS Experiment

- general-purpose experiment at the LHC, interaction point
- cylindrical symmetry, several detection subsystems
 - inner detector (ID) - track, vertex, momentum and charge reconstruction
 - calorimeter (LAr, TileCal) - energy reconstruction
 - muon spectrometer (CSC, MDT, RPC, TGC) - muon detection
- magnet system
 - central solenoid (2 T)
 - outer toroid (4 T)

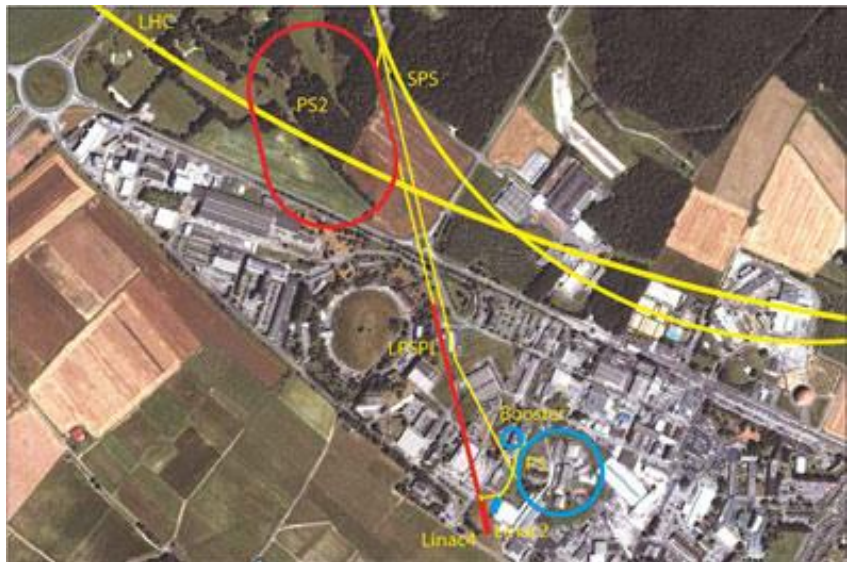


What Will the Future Bring

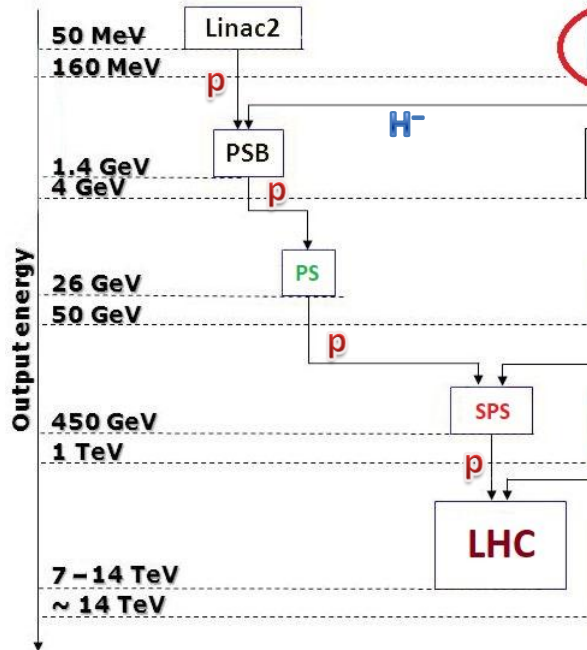


LIVE STREAMING : Installation process

~~3000 fb⁻¹~~
4000 fb⁻¹



What Will the Future Bring

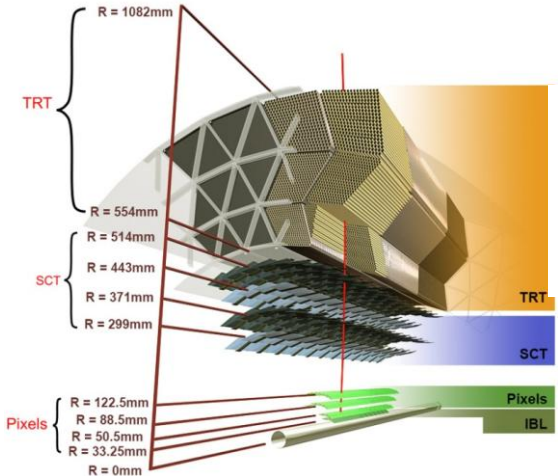


on process

~~3000 fb⁻¹~~
4000 fb⁻¹

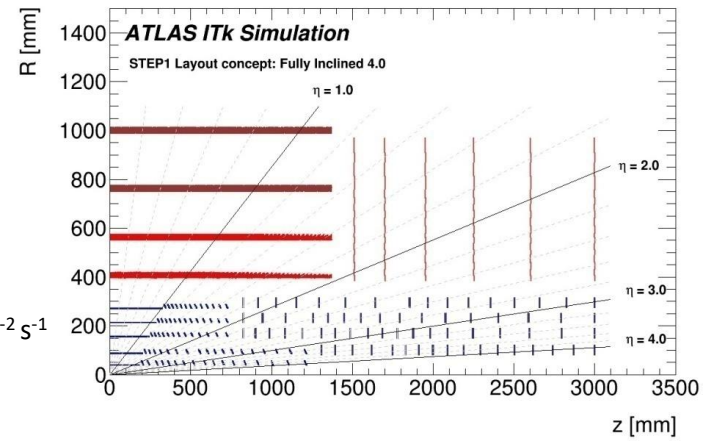


ATLAS ITk Upgrade



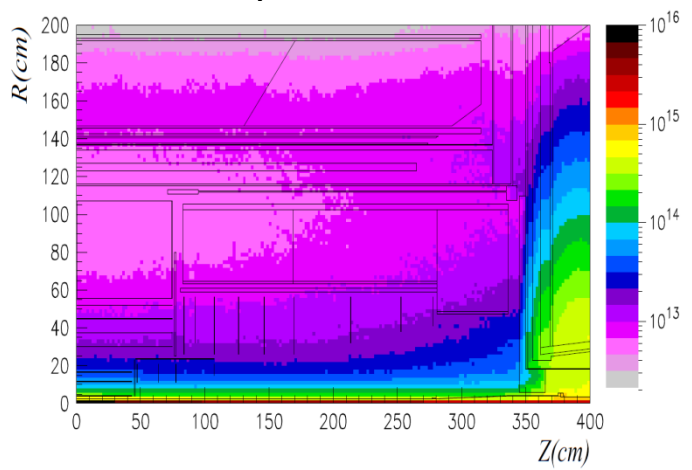
2018:
 $\sqrt{s} = 13 \text{ TeV}$
 $L_{\text{peak}} = 2 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
 $\langle \mu \rangle = 37$

2026:
 $\sqrt{s} = 14 \text{ TeV}$
 $L_{\text{peak}} = 7.5 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
 $\langle \mu \rangle = 200$

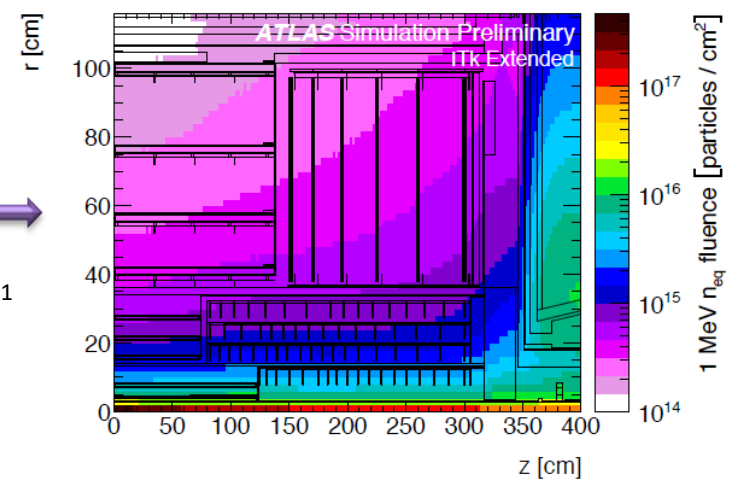


- current ID - coverage $|\eta| = 2.5$
 - 4 Central and 3 Forward Pixel layers
 - 4 Central and 9 Forward Strip layers
 - TRT layer with straw tubes

- new all-silicon tracker - coverage $|\eta| = 4$
 - 5 Central and multiple Forward Pixel layers
 - 4 Central and 6 Forward Strip layers

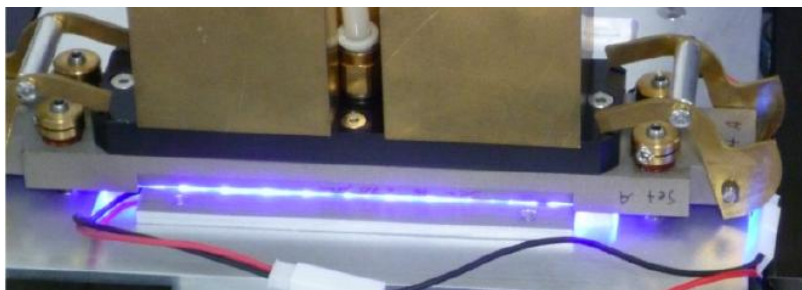


RADIATION HARDNESS
 most resistant IBL
 pixel layer up to 850 fb^{-1}

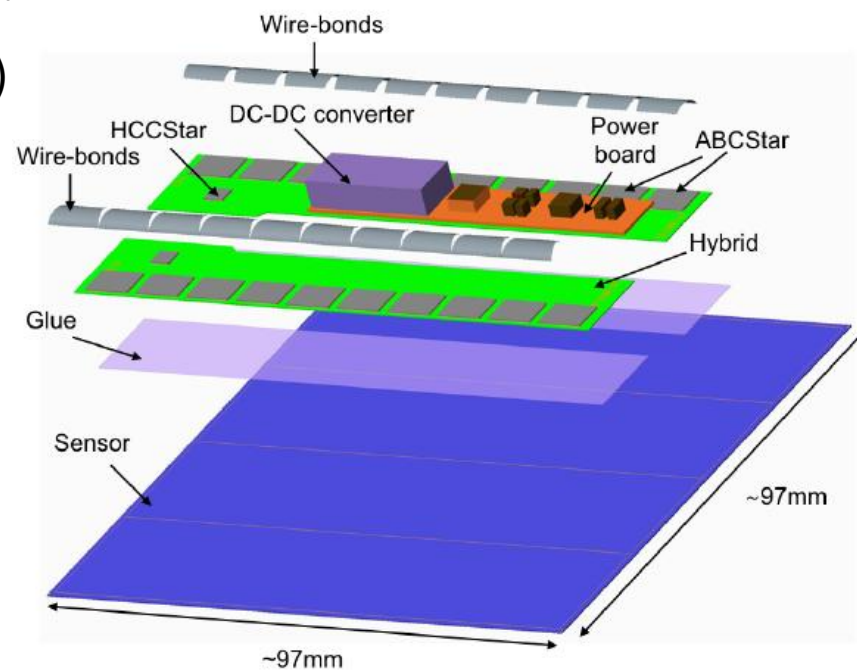


ITk Strip Module

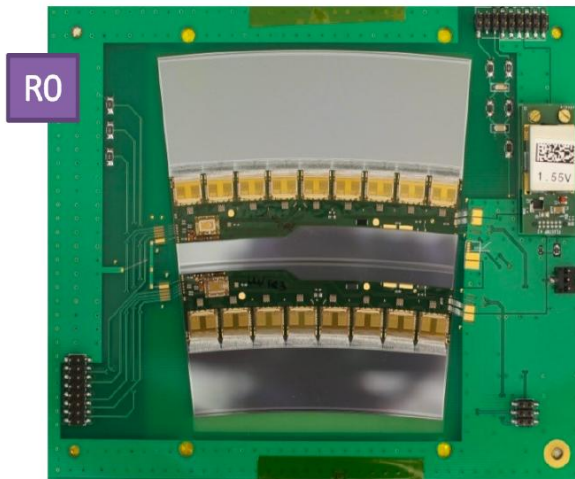
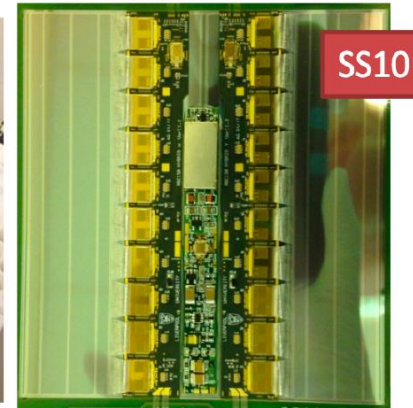
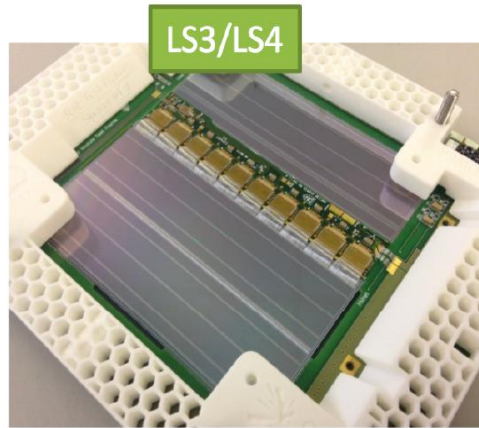
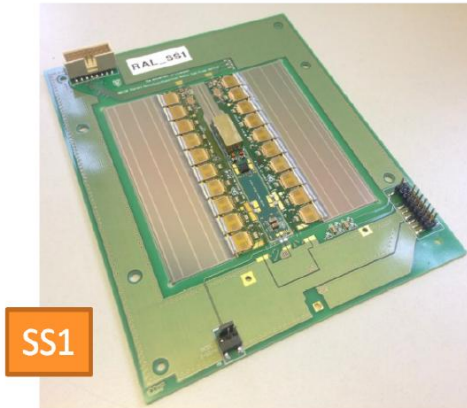
- strip system: **18k** strip modules (SCT 4k), 165 m² of silicon, 60M channels
- 6 end-cap (R0 - R5) + 2 barrel (short-strip, long-strip) design modifications
- module design and assembly procedures:
 - ABCStar/HCCStar readout/control chips UV-glued on kapton PCBs (hybrid)
 - hybrid glued directly on silicon sensor (Epolite)
 - wire-bonding (chips on hybrid, strips on chips)
 - power board (LV/HV power, monitoring)



UV light cures within 6 min / conventional glues > 12hr

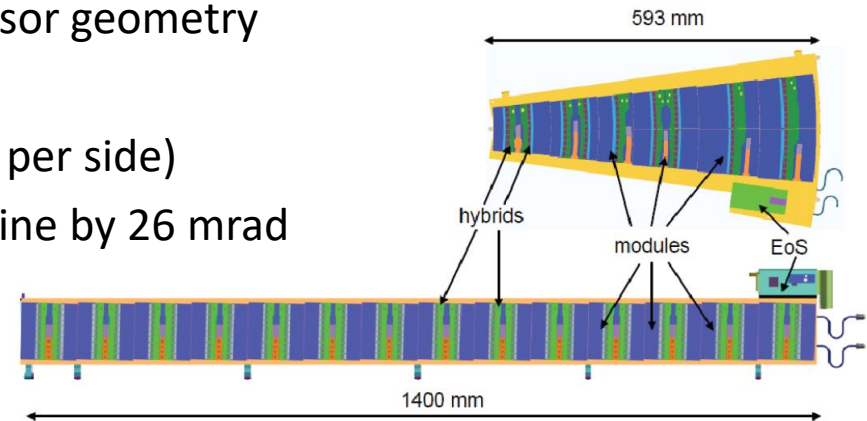


ITk Strip Modules

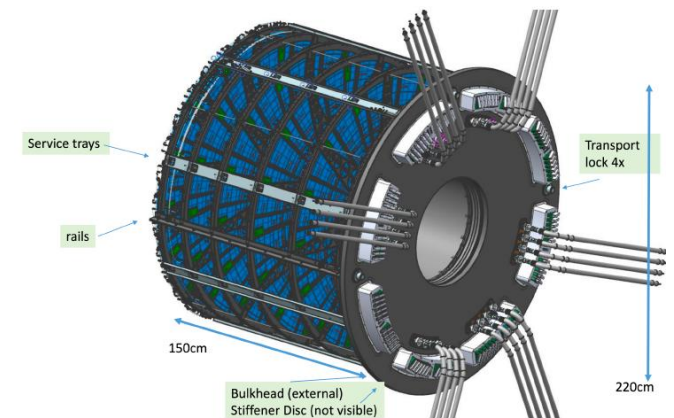
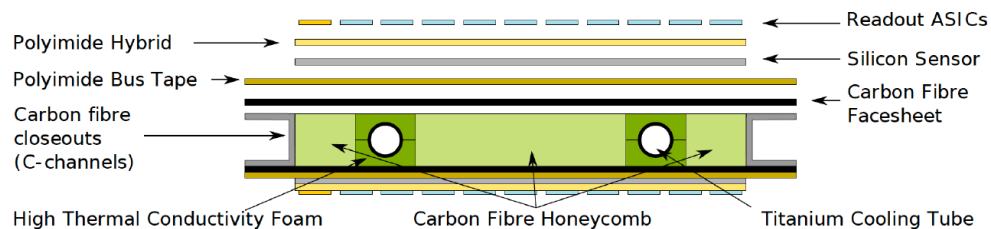


Local and Global Support

- **18** endcap modules on each **petal** (9 modules per side)
 - stereo angle of 20 mrad implemented in sensor geometry
- **28** barrel modules on each **stave** (14 modules per side)
 - each side rotated with respect to the beam line by 26 mrad

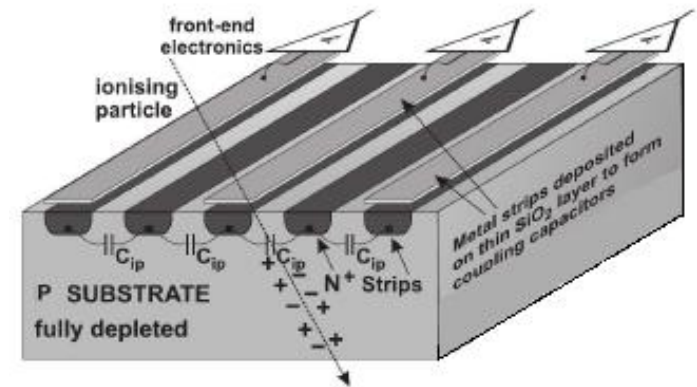


- each local support substructure represents independent unit for data flow and powering
 - DC-DC powering (unlike SCT each module cannot have own voltage cable)
 - stave core - CO₂ cooling system (+20...-40°C), bus tape operated by EoS (LV, HV, TTC, DCS)

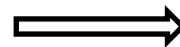


ITk Microstrip Sensors

- n^+ strips in p silicon bulk in case of ITk
 - larger signal after irradiation than p-in-n (SCT)
- sensor width 320 μm , depletion voltage 350 V
- pitch 75.5 μm (barrel) and 70-80 μm (endcap)
- testing of 50% of HPK EC sensors (4500) at the IoP CAS
- new clean room commissioning, sensor testing equipment prepared for operation
- next step: move module testing apparatus for (pre-)production phase



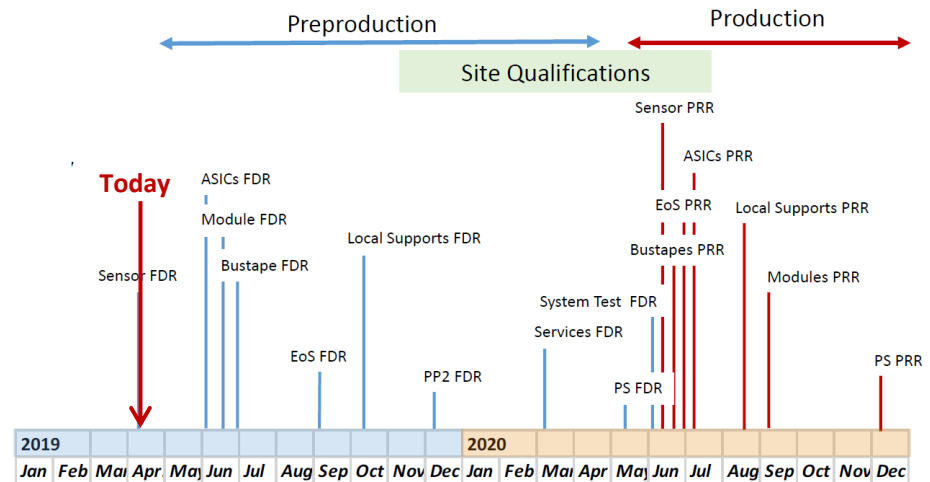
October 2017



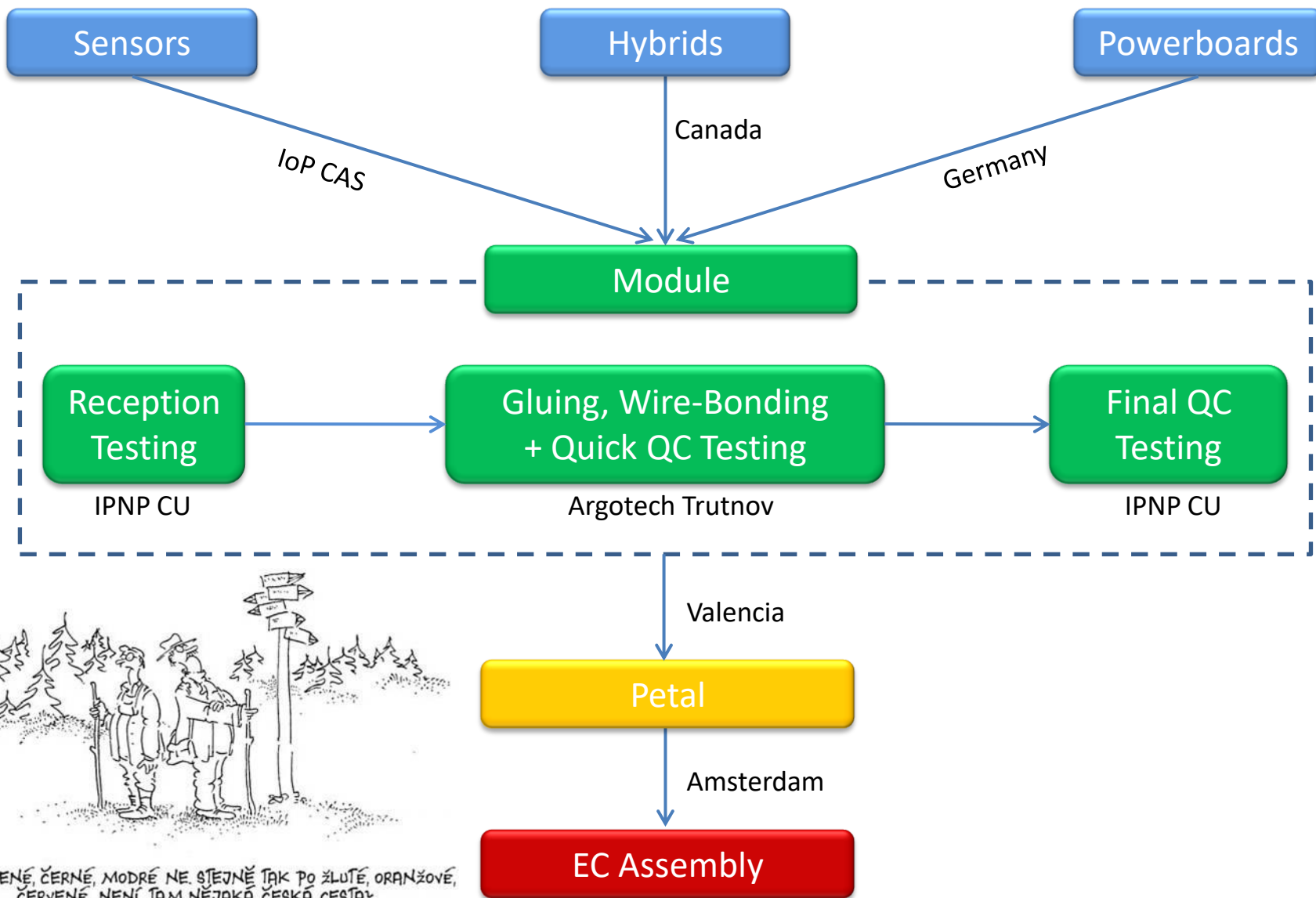
December 2018

Production Schedule

- 101 institutions from 22 countries
(CAS IoP, Charles Uni., Czech Technical Uni., Palacky Uni. Olomouc)
- pre-production (FDRs + module assembly Q4 2019)
- production (PRRs + module assembly Q4 2020, 3 - 4 year period)
- ITk Strips integration (Q3 2021, ready in Q3 2024)
- share of the Czech Republic: tests/assembly of **576 R2/R4 modules** (8.3 % of EC)



Czech Module Production Flow



PO ZELENE, CERNÉ, MODRÉ NE. STEJNĚ TAK PO ŽLUTÉ, ORANŽOVÉ, ČERVENÉ. NENÍ TAM NĚJAKÁ ČESKÁ CESTA!



- Visual inspection
 - check of packaging and each following assembly step
- Metrology
 - glue height, hybrid/powerboard positioning, module bow



- IV test
 - sensor electrical test at reception



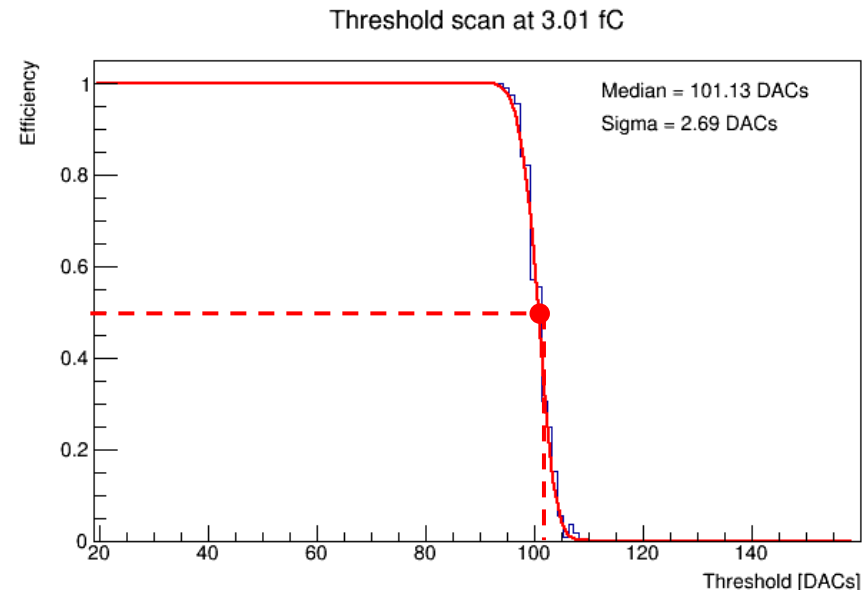
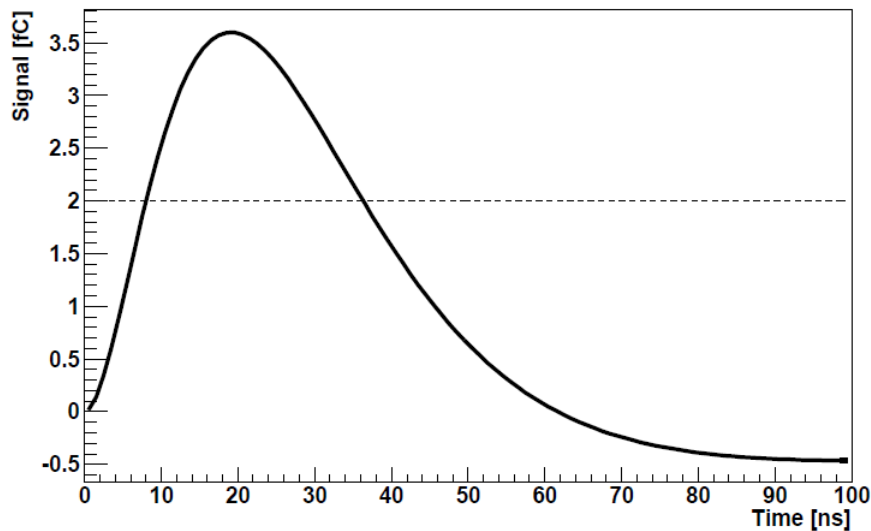
- Thermal cycling
 - final tests of electrical performance with cycling $-35...+40^{\circ}\text{C}$
 - 10 cycles in 12 hours while powered + 2 hours for HV stability test



- Electrical characterization tests
 - during wire-bonding to find failed bonds, final DAQ tests in running conditions (cold box)

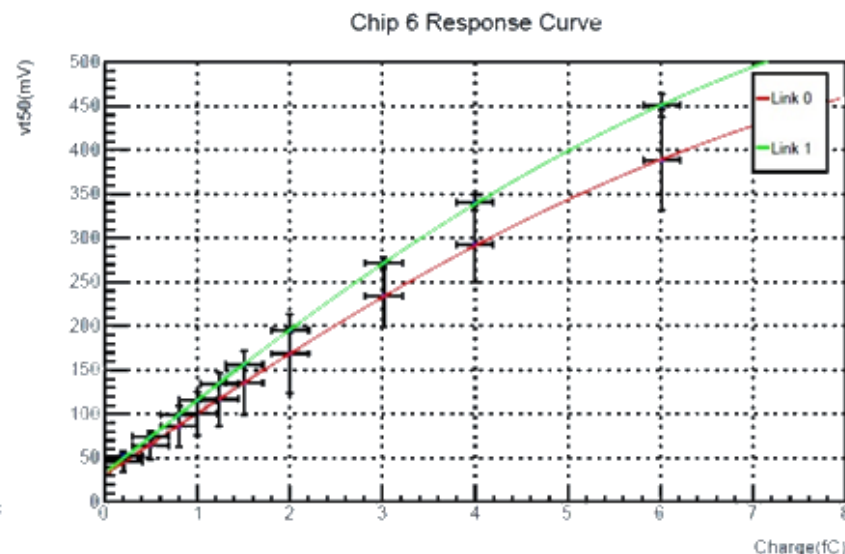
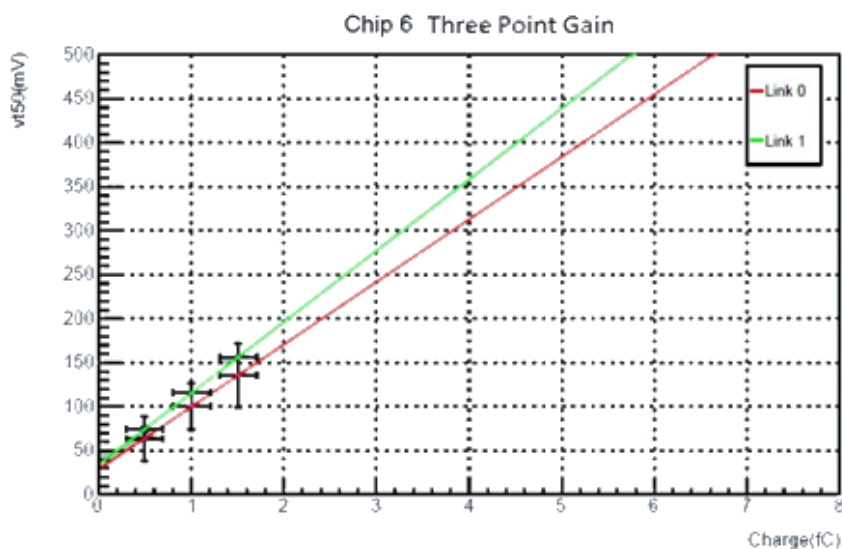
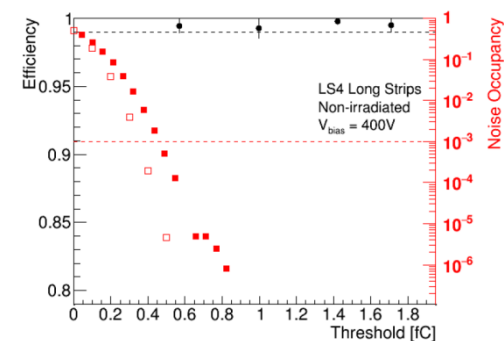
Electrical QC Testing - Threshold Scan

- testing = charge injection into sensor/chip channels + (triggered) readout
- basic ITSDAQ scan, amplitude reconstruction using **binary readout**
- gradual threshold increase at FE discriminators of individual chip channels
- integral form of convolution of noise and signal distribution
- critical parameters: collected charge, noise (ENC), hit efficiency, gain, noise occupancy, S/N



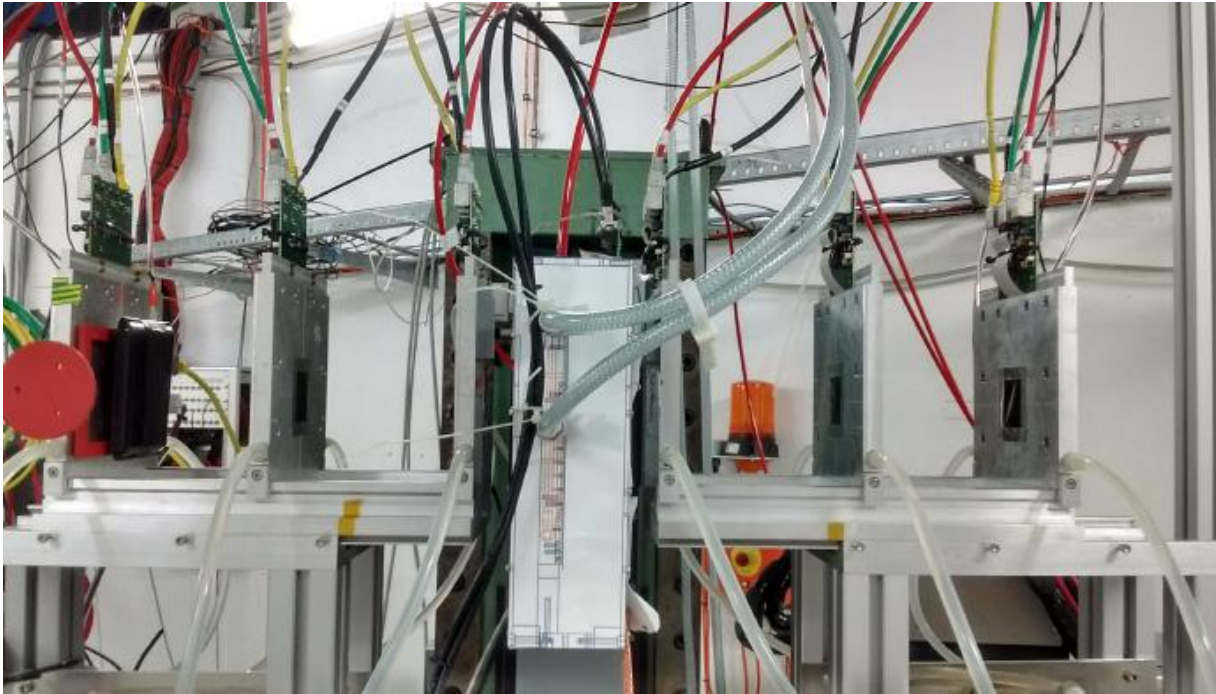
Electrical QC Testing – Characterization

- internal ITSDAQ units DACs, conversion to fC required
- DACs-to-mV conversion using ABC130 chip simulation
- mV-to-fC conversion using **set of threshold scans**
- Strobe Delay Scan (timing setting), Noise Occupancy Scan (no injected charge)
- Three Point Gain (linear, gain + offset), Response Curve (non-linear, 3 parameters)



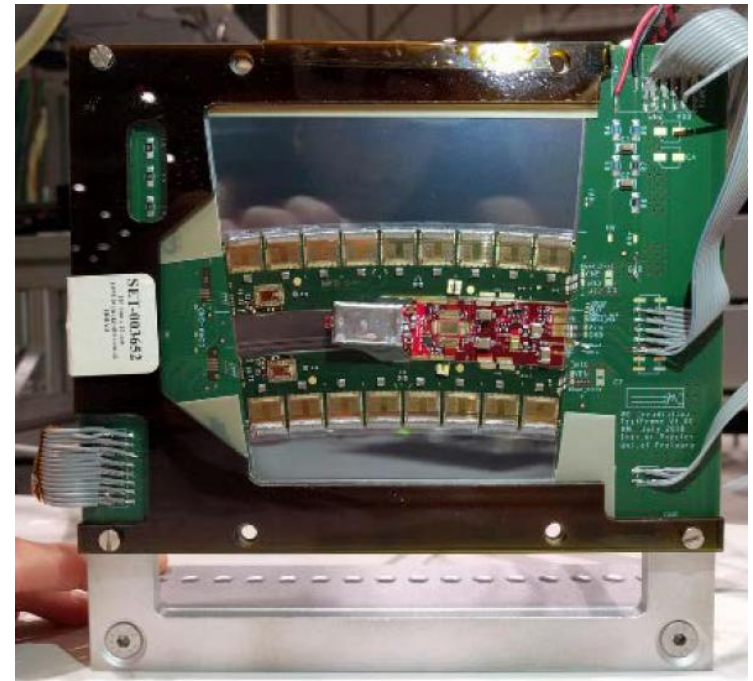
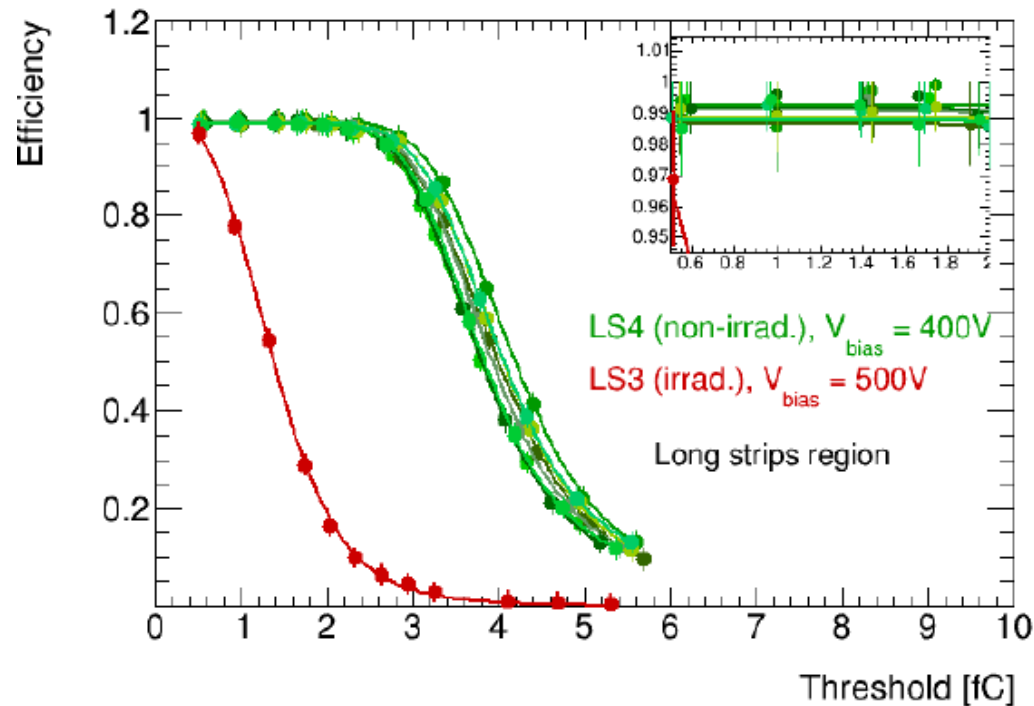
Additional Testing Methods - Test Beam

- accelerated particle beam, expensive, less available, including tracking
 - ~~CERN (120 GeV pions), DESY (4 - 4.8 GeV electrons)~~^{LS2}
- DAQloads, SS, LS, R0 modules so far (J. Kroll - Test beam coordinator)



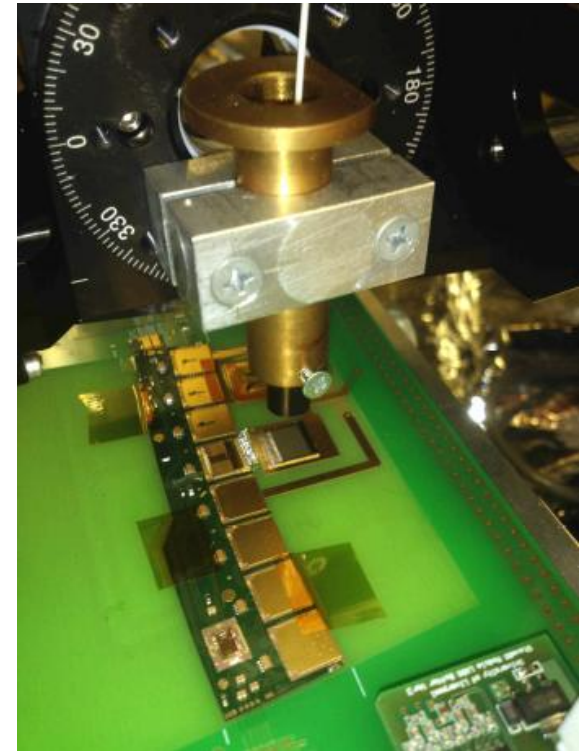
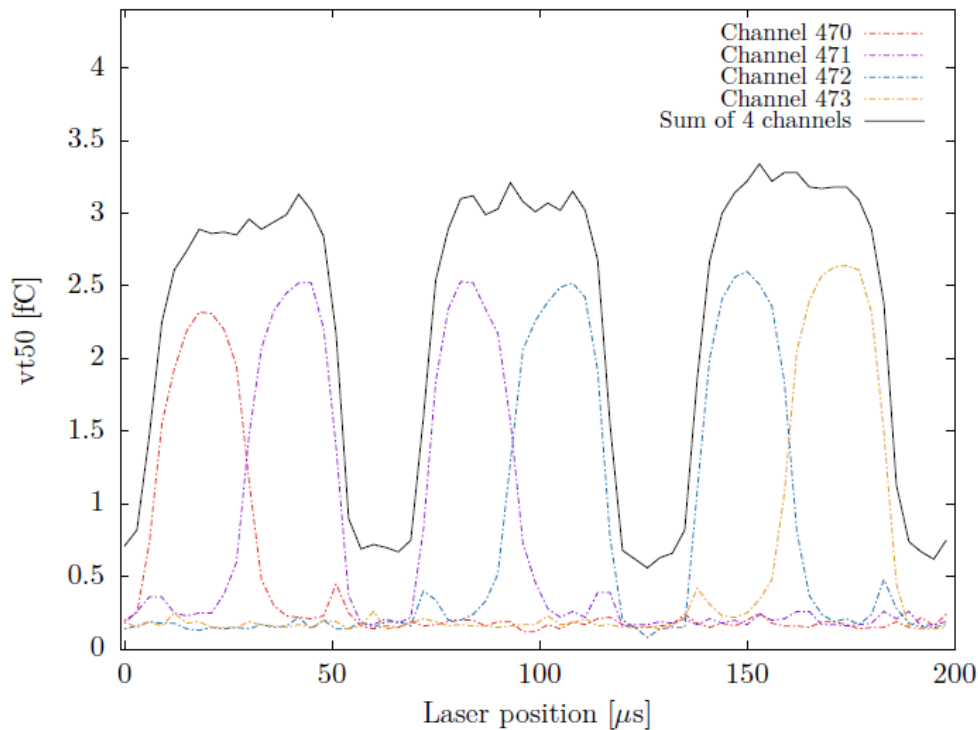
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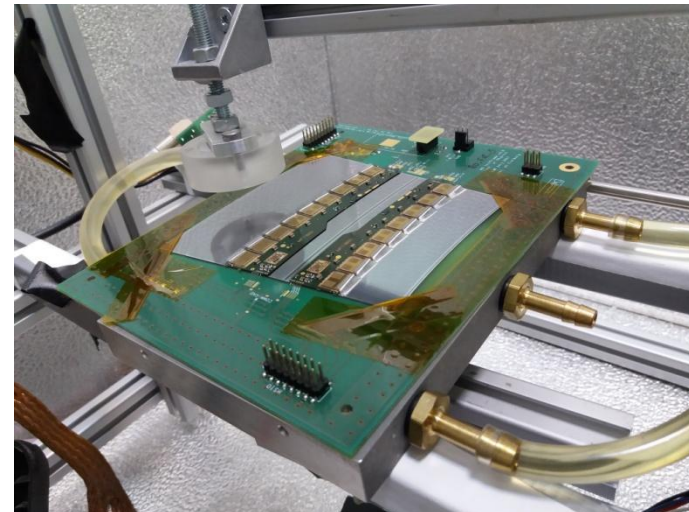
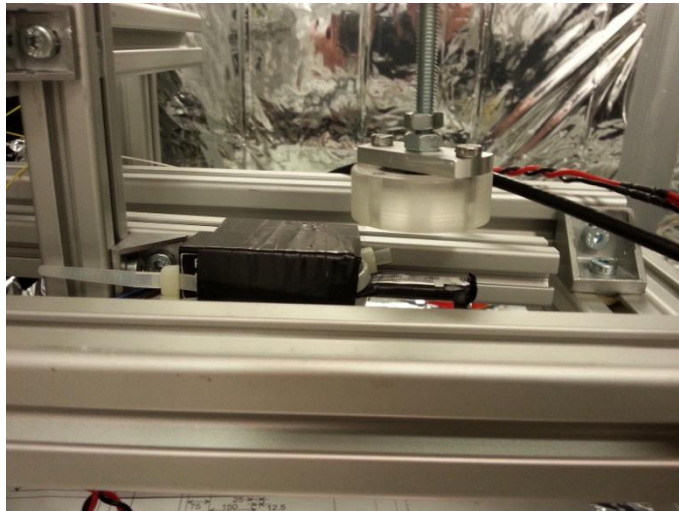
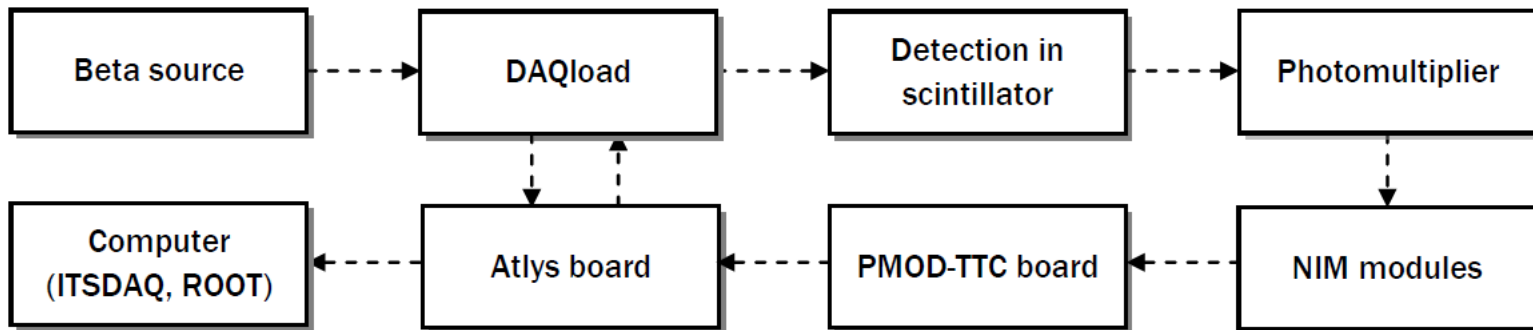
Additional Testing Methods - Laser

- available, cheap, good spatial resolution, adjustable intensity
- in operation at IPNP
- 3-axis motorised translation stages, red/infra-red laser, pulse generator
- strip-by-strip scan + interstrip charge collection



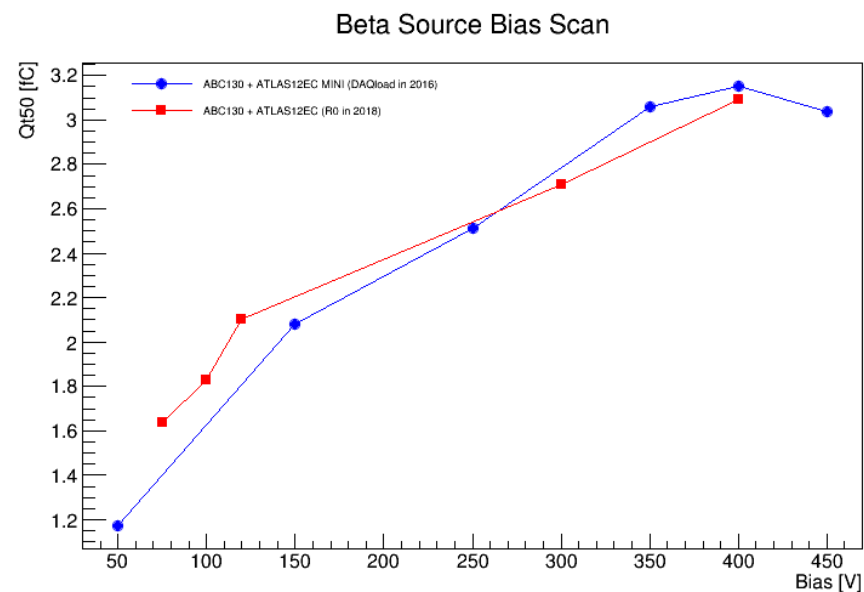
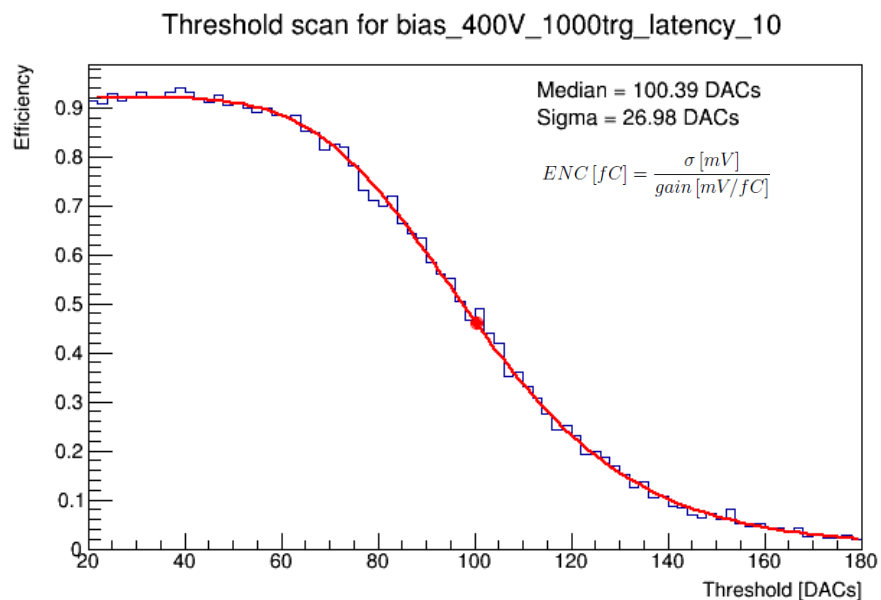
Additional Testing Methods - Beta Source

- beta source ^{90}Sr , e^- collimated, first Prague R0 module (talk by O. Kovanda)
- scintillator as an external trigger, Atlys/Nexys board for readout, software ITSDAQ, ROOT



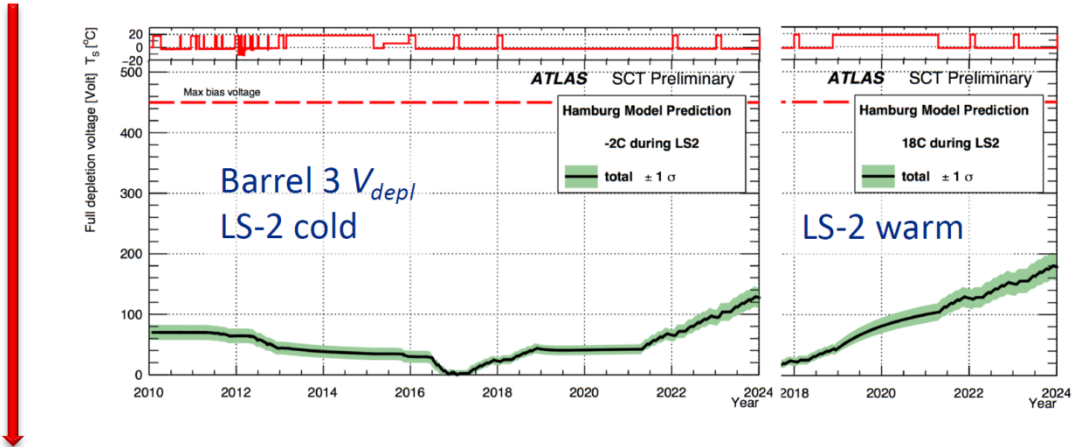
Additional Testing Methods - Beta Source

- bias scan, angular scan, temperature scan, FE parameters scan, latency scan
 - non-irradiated R0 module: collected charge **3 fC** , noise (ENC) **900 e⁻** , S/N **20**
 - worse multiple scattering effect + larger cluster size wrt test beam (**4 fC**)
- > AllPix² simulations (O. Theiner) to explain/confirm these effects



End-of-lifetime Requirements

- 1) Channel noise occupancy **less than 10^{-3}** ...
- 2)...at a threshold resulting in efficiency **greater than 99%**



- SCT designed to 8:1
- max. $V_{depl} = 450\text{ V}$
- current operation: $V_{depl} = 200\text{ V}$

- 3) S/N greater than **10:1**, depletion voltage **500 V**

Module Type	Fluence $10^{14} n_{eq} cm^{-2}$	Charge ke^- 500 V	Charge ke^- 700 V	Noise e^-	S/N 500 V	S/N 700 V
SS	8.1	13.7	16.1	630	21.8	25.6
LS	4.1	17.3	19.5	750	23.1	26.0
R0	12.3	11.5	14.0	650	17.7	21.5
R1	10.1	12.5	15.0	640	19.6	23.4
R2	8.7	13.3	15.7	660	20.3	23.9
R3	8.0	13.8	16.2	640	21.4	25.1
R4	6.8	14.6	17.0	800	18.4	21.3
R5	6.0	15.3	17.6	840	18.3	21.1


TDR educated estimate

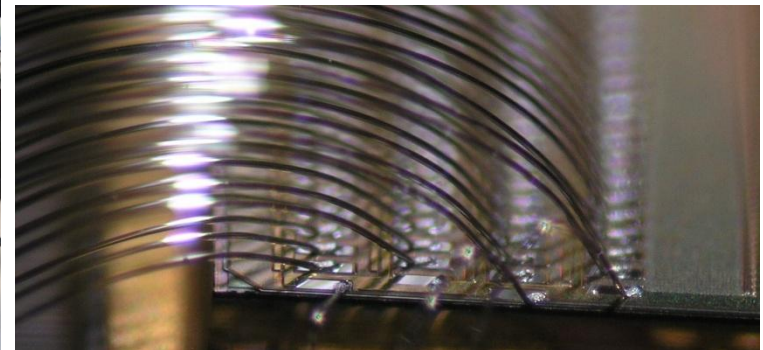
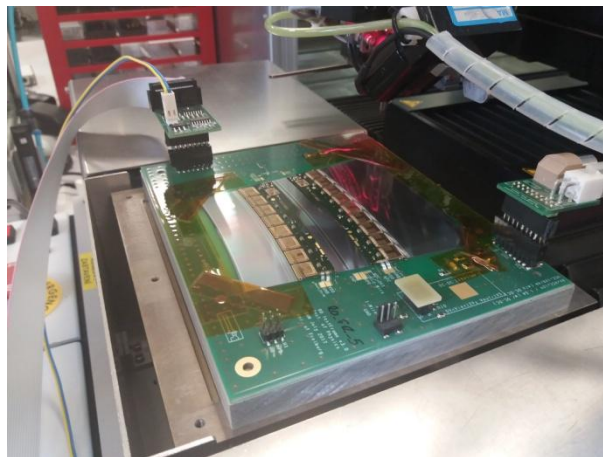
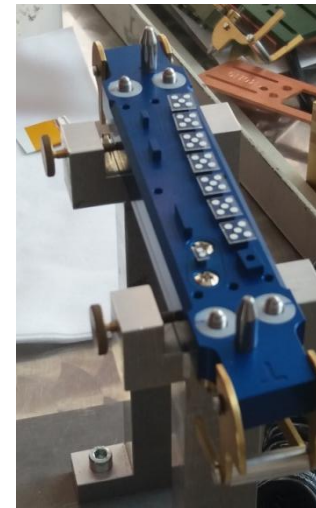
ABCStar chips

Layer/Ring	Barrel	Disk 0	Disk 1	Disk 2	Disk 3	Disk 4	Disk 5
0	16.4	15.7	15.4	15.0	14.5	13.7	11.8
1		17.9	17.5	17.0	16.4	15.4	13.7
2	15.3	18.1	17.9	17.2	16.6	15.6	14.0
3		19.4	19.2	18.4	17.7	16.6	15.1
4		14.4	14.2	13.6	13.2	12.4	11.5
5		13.9	13.7	13.1	12.7	12.0	11.1

New S/N estimate for 500 V

Module Assembly at IPNP CU

- prototype of hybrid populated with ABCN250 chips (Q1 2018) ✓
- full-sized R0 module construction (Q2 – Q3 2018) ✓
 - cooperation with IoP CAS (sensor), Freiburg Uni. (gluing, chips-to-hybrid wire-bonding)
 - sensor-to-hybrid wire-bonding done in Argotech Trutnov
 - QC testing performed by institute person from IPNP
- in progress in Q1 2019 
 - 1 or 2 R0 modules to be assembled with Freiburg omission



- to record details of used components, assembly, shipments, QA/QC test results
- being designed by the Unicorn College, just one DB for the whole ITk
- should stay accessible during ITk operation for better understanding of defects
- SCT DB ~ 350 000 registered items **Vs** ITk DB ~ 10^6 - 10^7 numbered items
- development of API scripts focusing on ITSDAQ routines

The screenshot shows the ATLAS ITk Production Database Test interface. The top navigation bar includes the CERN logo, the text 'ATLAS ITk Production Database Test', and a user profile for Martin Šýkora. The main dashboard area is divided into several sections:

- Component Types:** 32
- Strips:** 8
- Component Types:** 8
- Pixels:** 65
- Test Types:** 65
- Strips:** 65
- Test Types:** 30
- Pixels:** 30
- Institutions:** 34

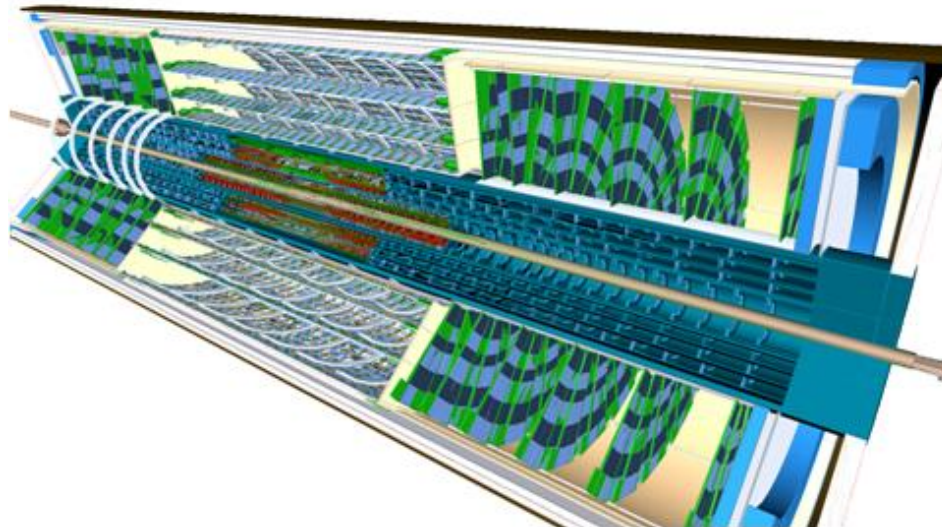
Below the dashboard, there are two tables:

My recent components	
Sensor - R0	20USE000000057
Sensor - R0	20USE000000056
Sensor - R0	20USE000000055
Sensor - R0	20USE000000054
Sensor - R0	20USE000000053

My recent test results	
IV Characteristics	1
Manufacturing	1
IV Characteristics	1
Manufacturing	1
IV Characteristics	1

Summary and Outlook

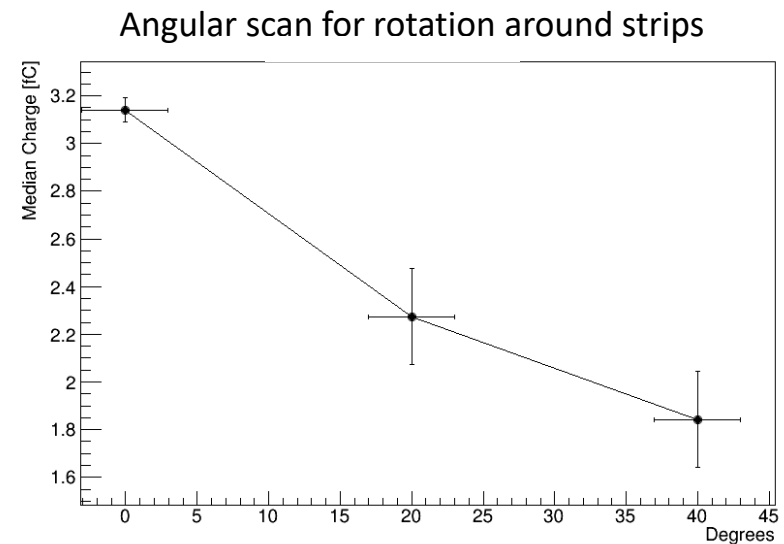
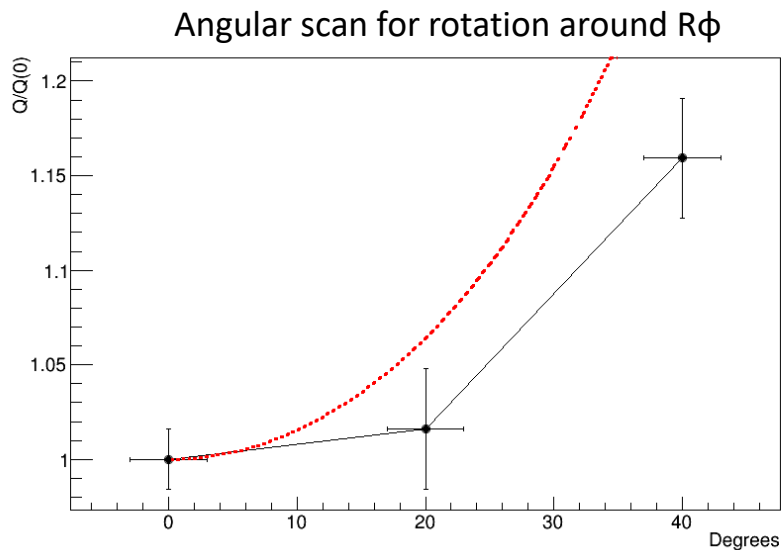
- all-silicon ITk will replace current ID in 2025, 8 designs of modules
- production is comming (Q4 2020), ITk final settlement (2024 -2026)
- Prague groups involved in sensor/hybrid/module testing, module assembly, database
- successful laser, beta source and QC tests of DAQloads + assembled R0
- near future: R0 assemblies and its testing, pre-production starts this year
- functional team of supervisors (3) and students (countless), newcomers welcome



BACKUPS

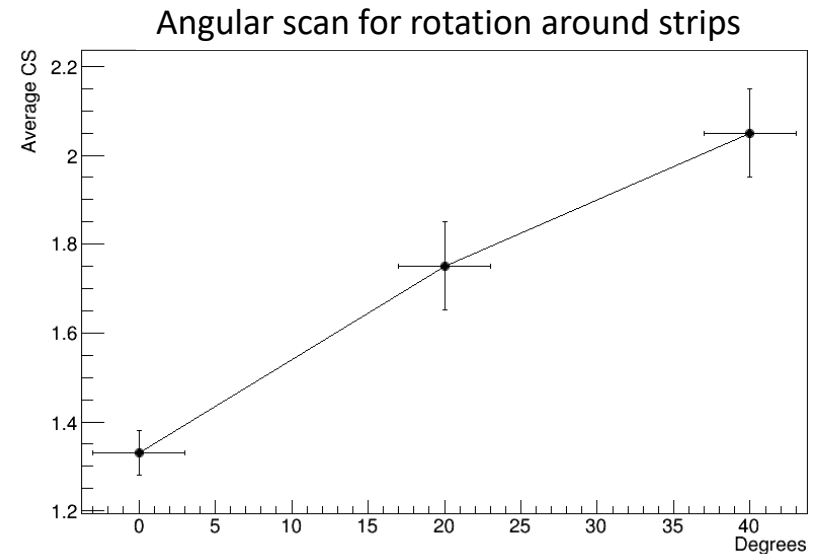
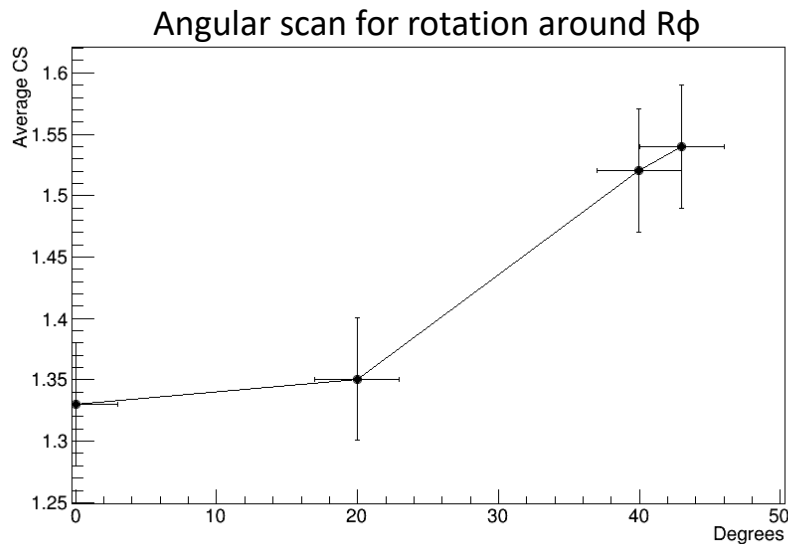
Angular Scan

- source rotation around axis perpendicular to strips in the sensor plane
 - decrease of V_{t50} and increase of cluster size
 - comparison with geometric relation $1/\cos(\alpha)$ (red dotted line)
- source rotation around axis parallel to strips
 - increase of V_{t50} and cluster size



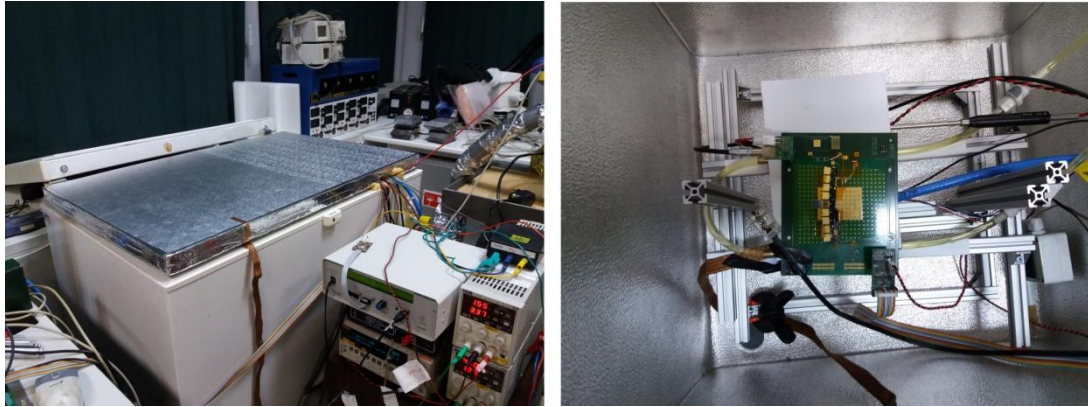
Angular Scan

- source rotation around axis perpendicular to strips in the sensor plane
 - decrease of $Vt50$ and increase of cluster size
- source rotation around axis parallel to strips
 - increase of $Vt50$ and cluster size
- cluster size = number of neighboring strips with hit

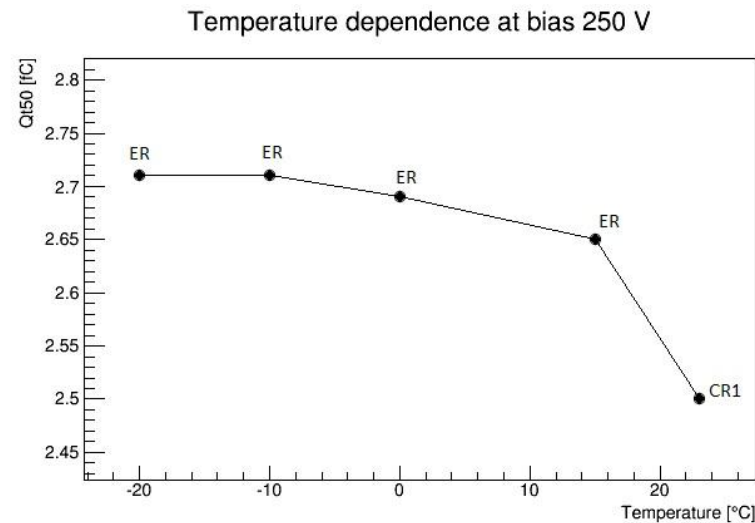


Temperature Scan

- measurement at 250 V, setup moved to the freezer in Electronic Room (ER)

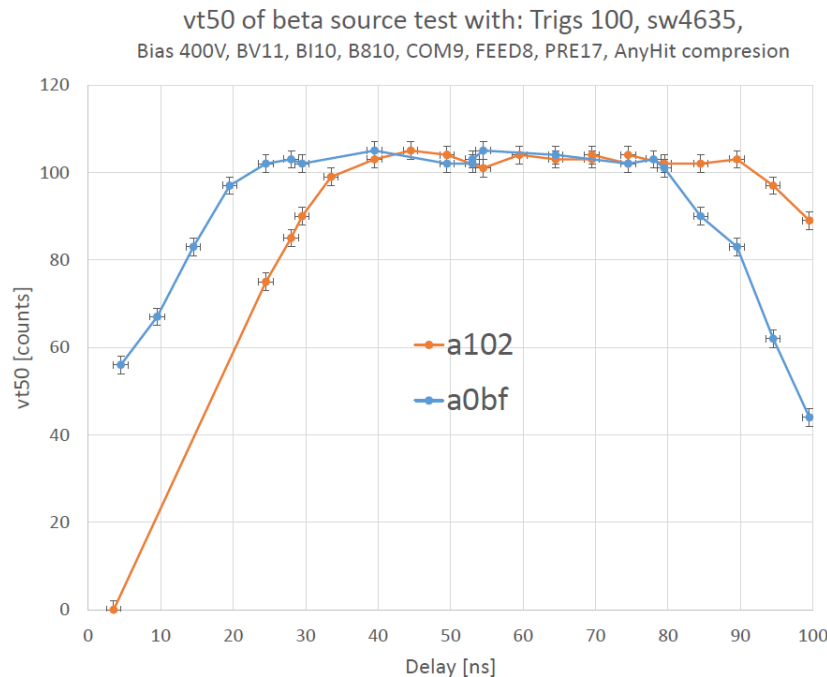


- up to -20°C , small discrepancy between ER and CR1 in collected charge



Latency Scan

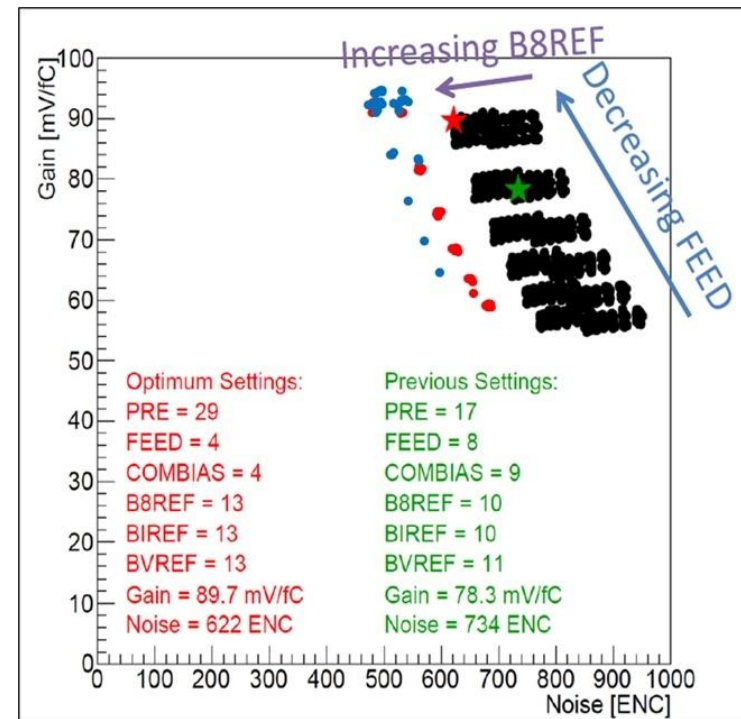
- possible explanation: shorter cabling in CR1
=> larger delay between external trigger signal and readout signal
- integer ITSDAQ variable latency (step 25 ns), finer latency scan with delay unit
- Atlys firmware version problem, preset latency value 10 changed to 11



FE Parameters Scan

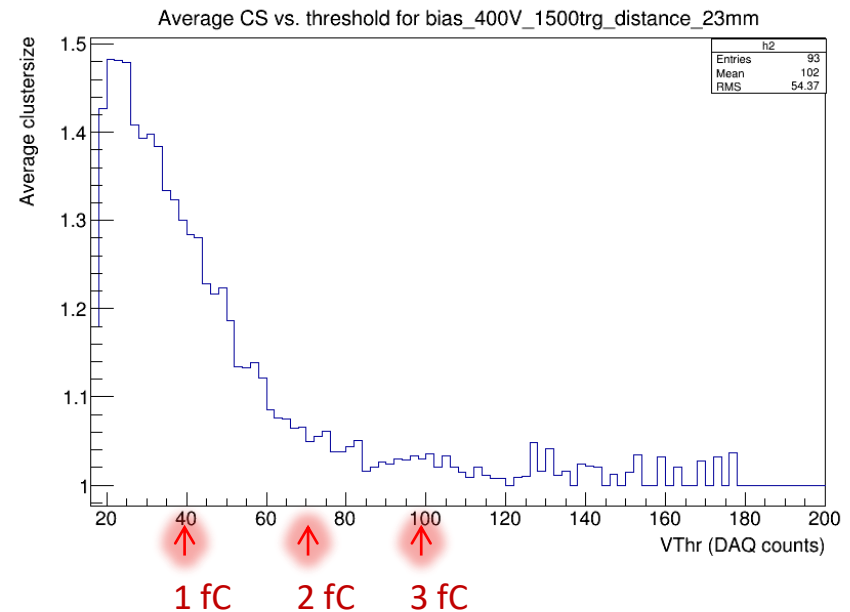
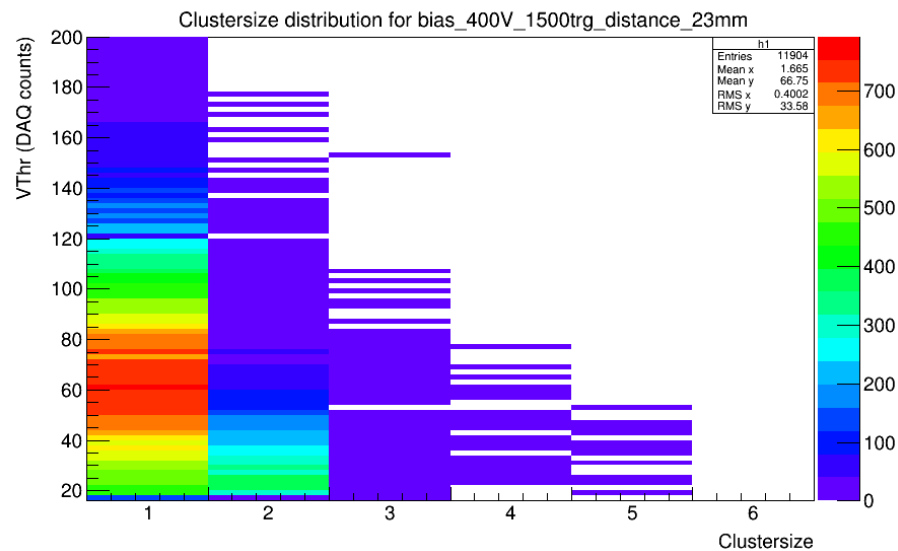
- 6 internal parameters of front-end electronics of ABC130 chip
- to adjust control currents and voltages, possible change of pulse shape
- search for best setting (high gain, low noise)

- new recommended setting
- collected charge 3.1 fC \rightarrow 2.8 fC
- noise 550 e^- \rightarrow 500 e^-

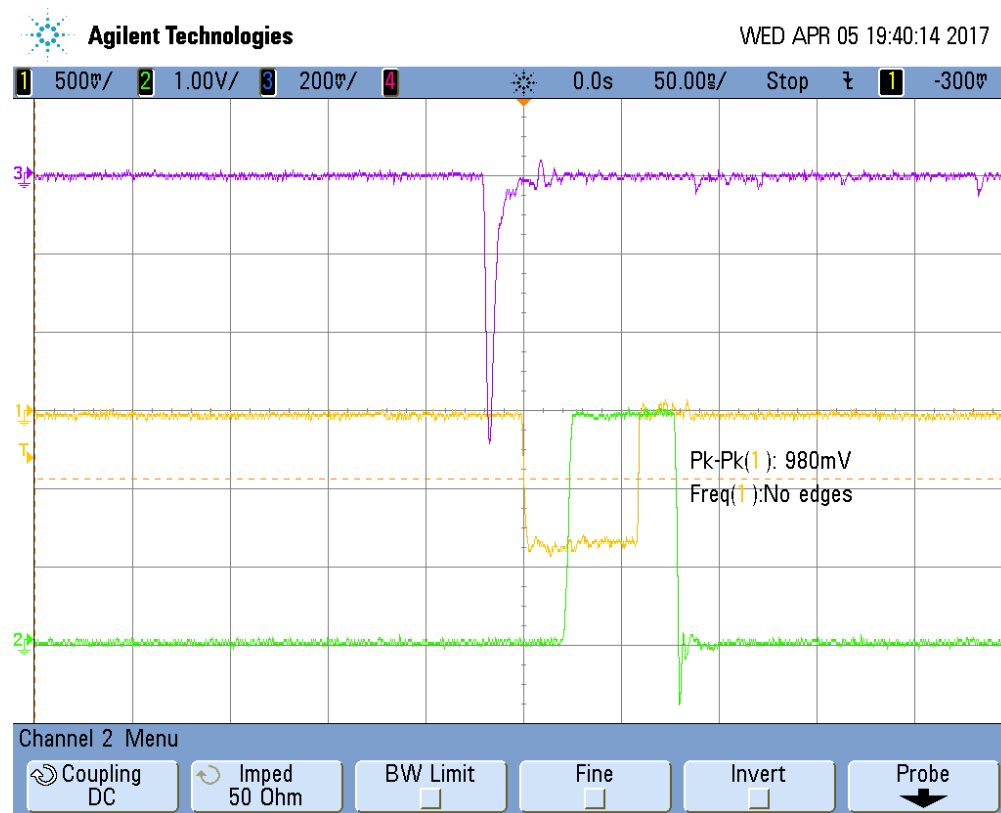


Cluster Analysis

- cluster reconstruction from event lists
- sum of clusters for every cluster size gives S-curve
- average CS at 1 fC: 1.33 (fully depleted, perpendicular scan)



- negative analogue signal from scintillator does not meet Atlys requirements
=> signal modulation using NIM crate (Discriminator, Level Adapter modules)



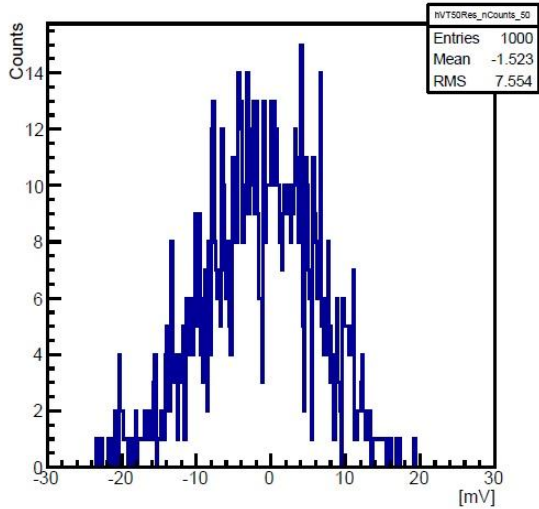
ARE YOU SERIOUS??? **ARE YOU REALLY**
READING BACKUPS SO DEEPLY???



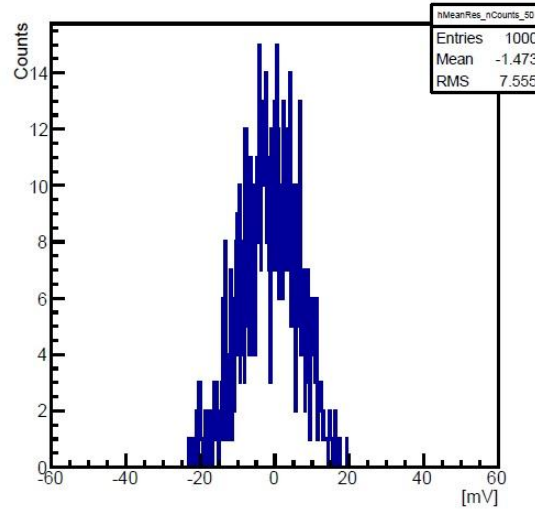
IT'S HIGH TIME TO STOP WORKING AND GET
AS MANY BEERS AS (IM)POSSIBLE, PLEASE!

Error Estimation

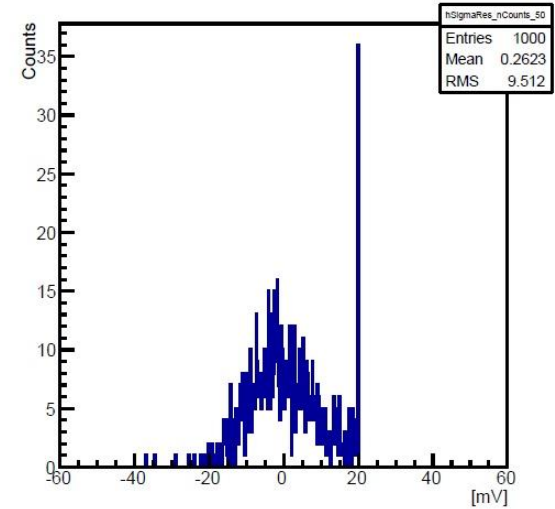
VT50 Residuals From Start Value, nEvents 50



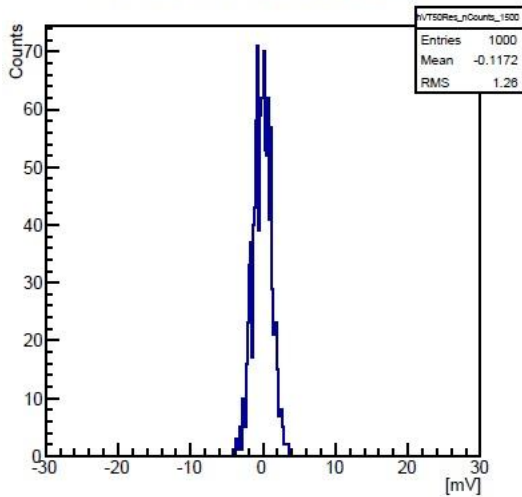
Mean Residuals From Start Value, nEvents 50



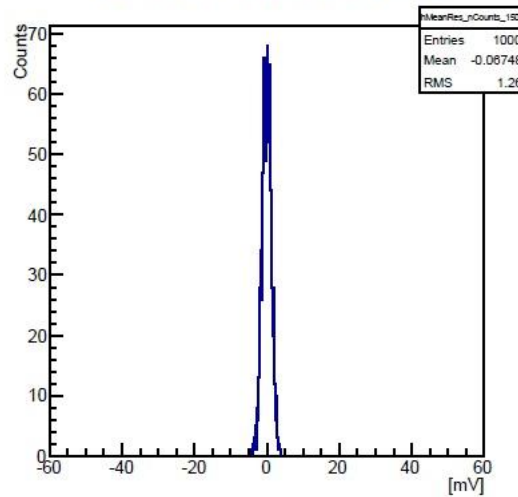
Sigma Residuals From Start Value, nEvents 50



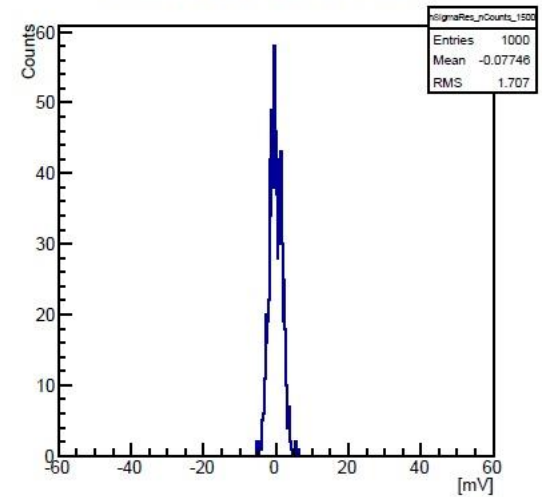
VT50 Residuals From Start Value, nEvents 1500



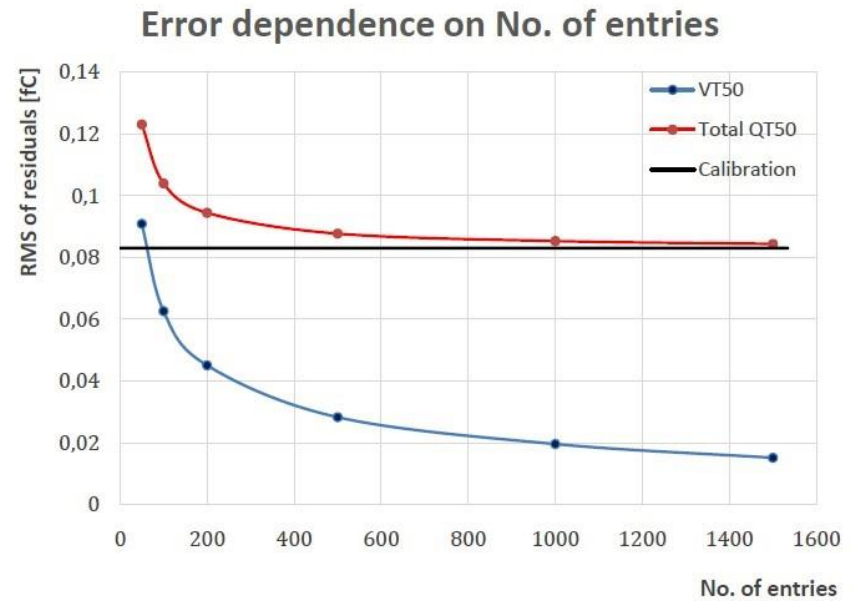
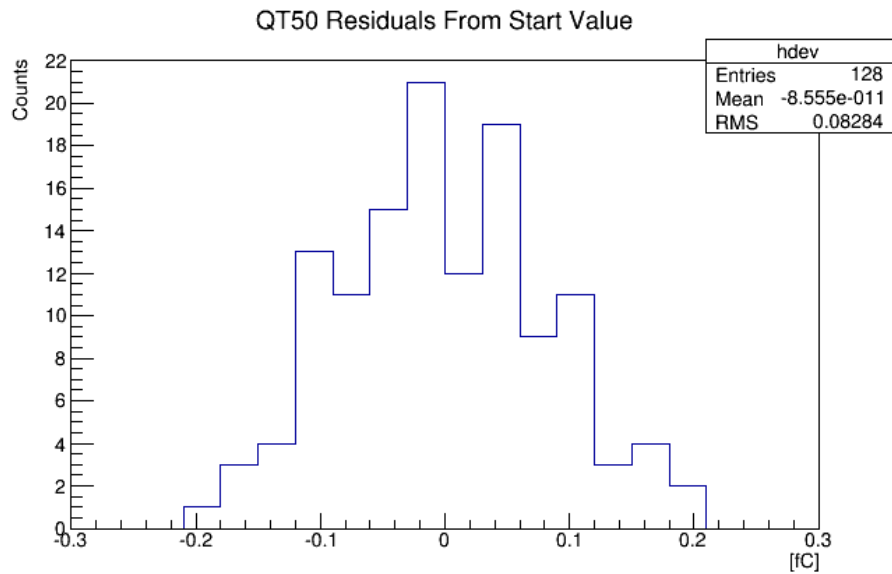
Mean Residuals From Start Value, nEvents 1500



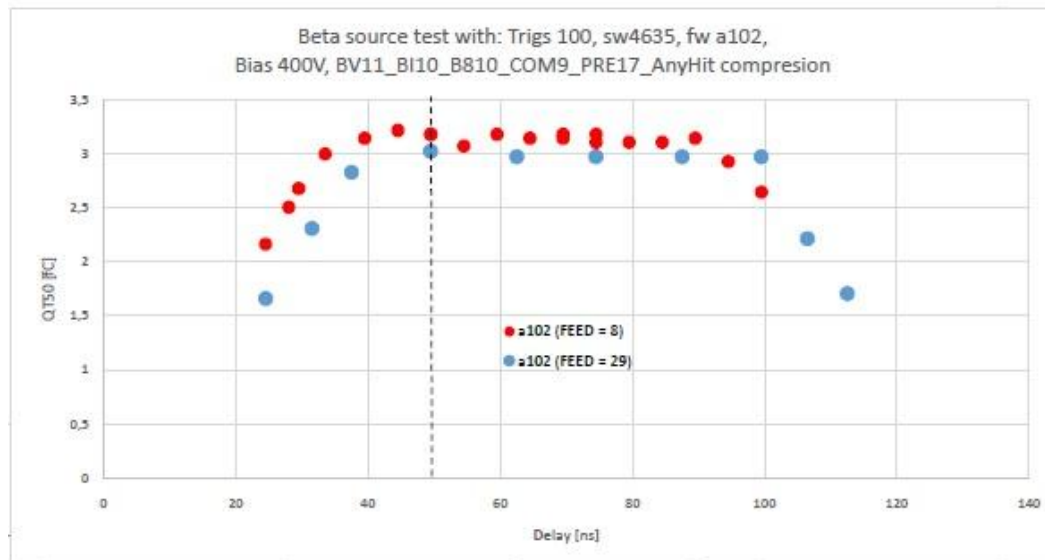
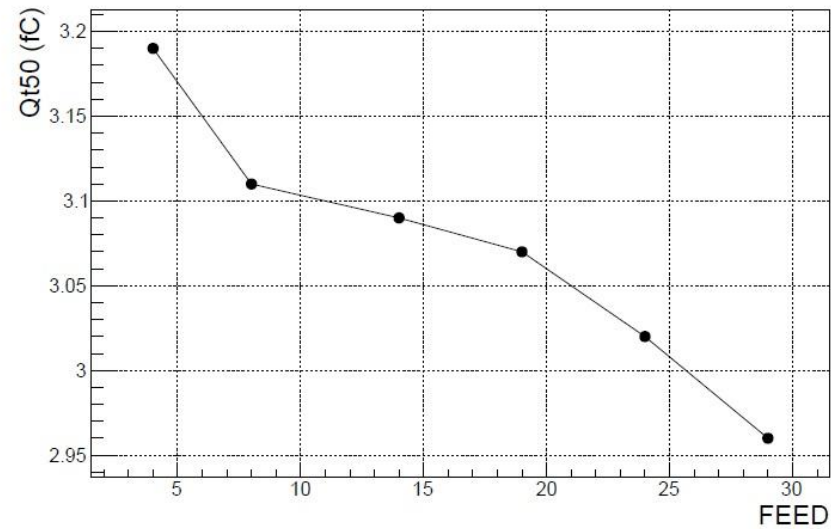
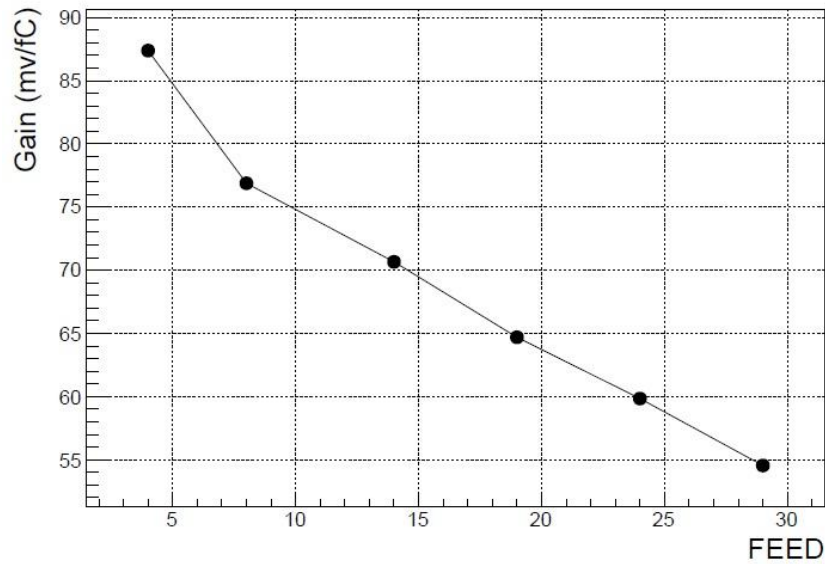
Sigma Residuals From Start Value, nEvents 1500



Error Estimation



FE Parameters



Module Type	Fluence $10^{14} n_{eq} cm^{-2}$	Charge ke^{-}		Noise e^{-}	S/N	
		500 V	700 V		500 V	700 V
SS	8.1	13.7	16.1	630	21.8	25.6
LS	4.1	17.3	19.5	750	23.1	26.0
R0	12.3	11.5	14.0	650	17.7	21.5
R1	10.1	12.5	15.0	640	19.6	23.4
R2	8.7	13.3	15.7	660	20.3	23.9
R3	8.0	13.8	16.2	640	21.4	25.1
R4	6.8	14.6	17.0	800	18.4	21.3
R5	6.0	15.3	17.6	840	18.3	21.1

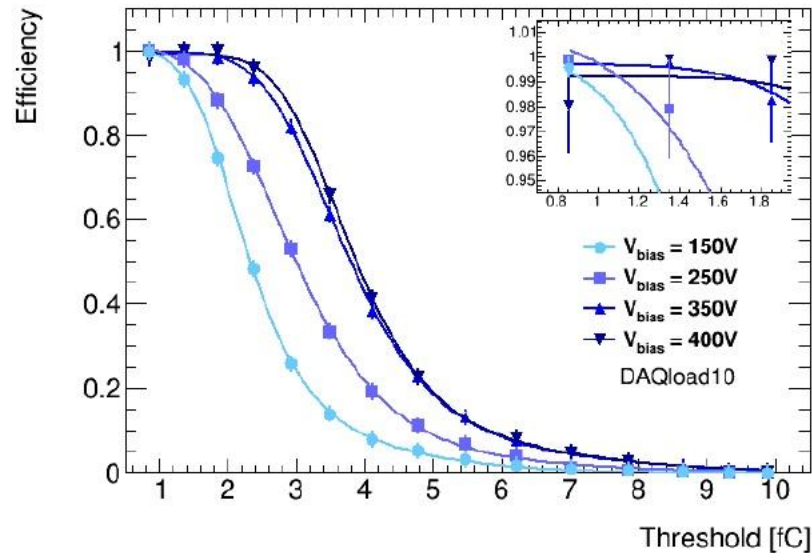
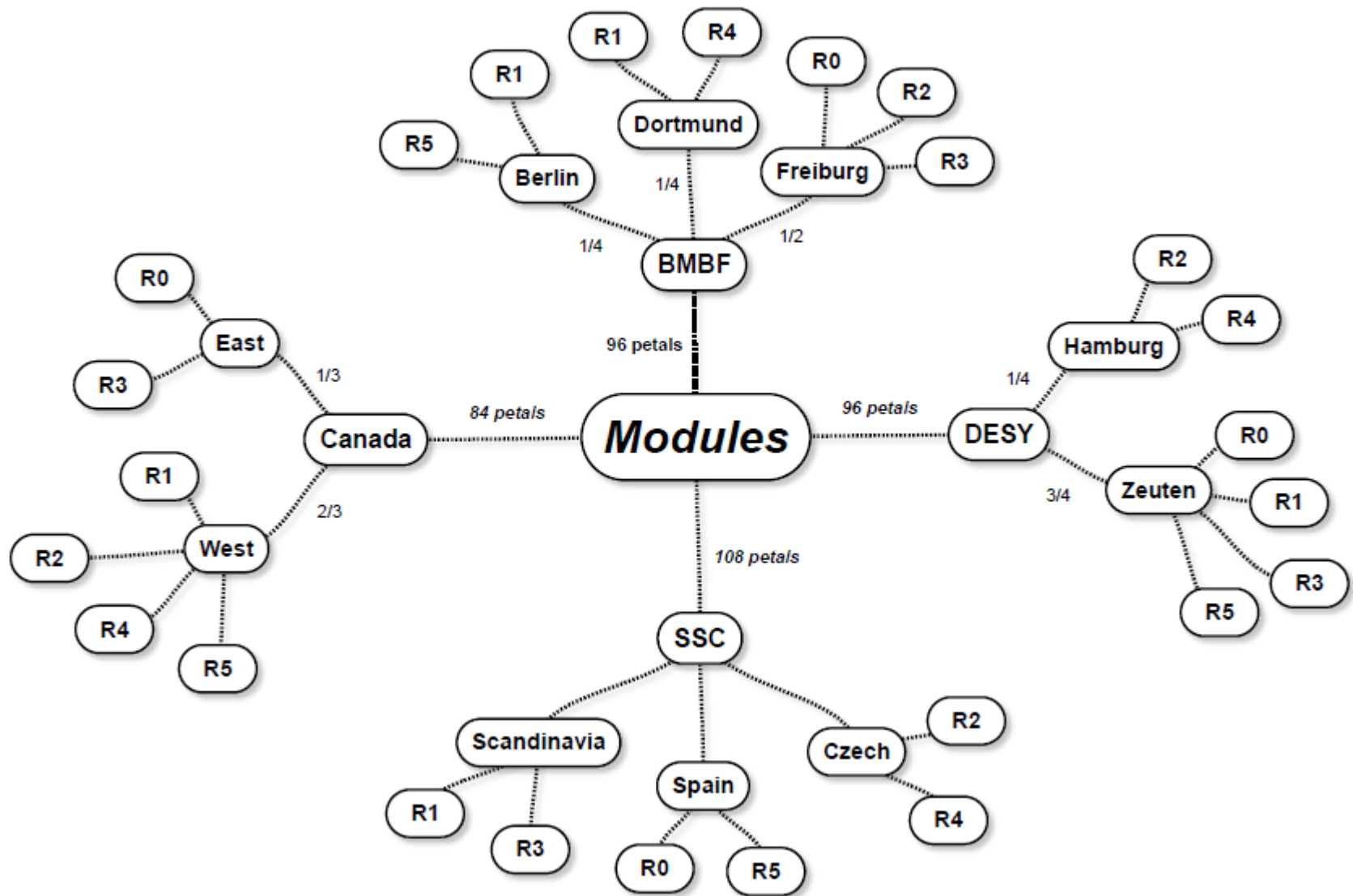
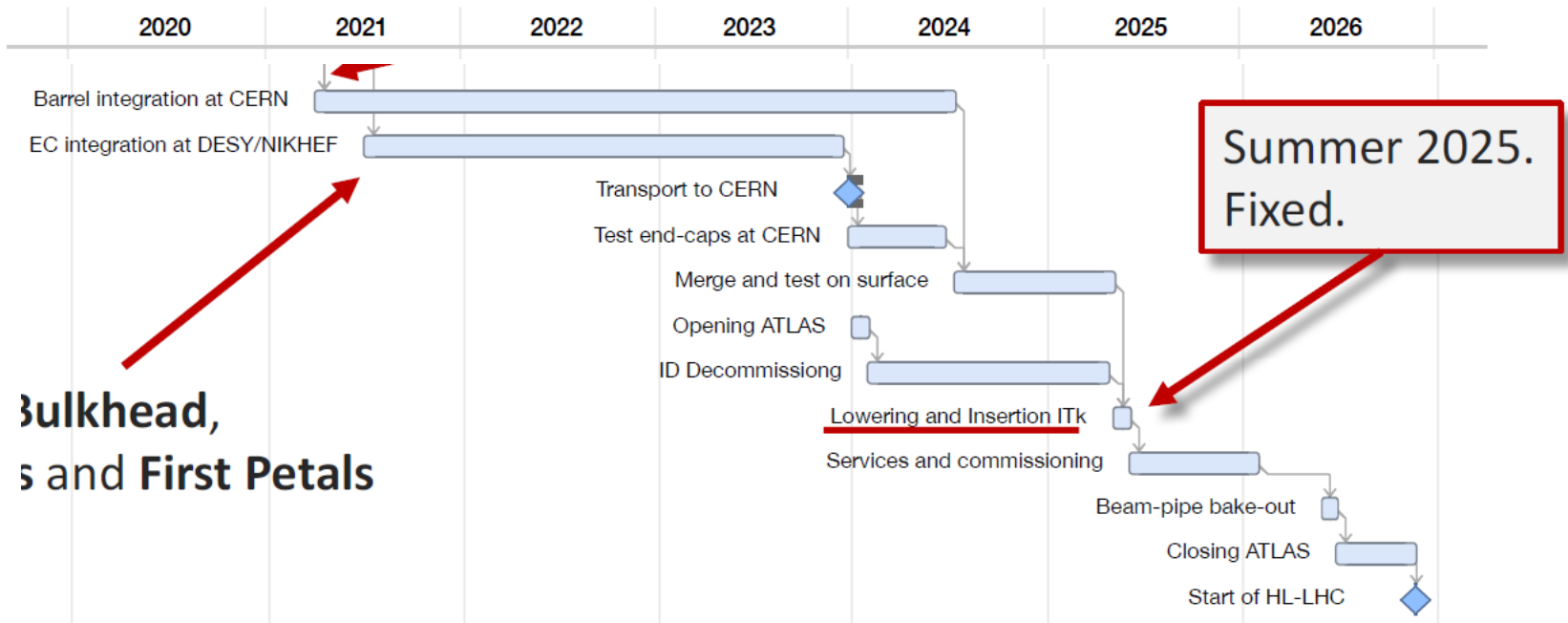


Figure 8.12: Efficiency versus threshold for one sensor on DAQload10, at four different bias voltages.

Production of Petals





Production Database - User Interface

SCT database WEB access modules

SCT users accesses:

- Read Write
- Read only
- Administration
- Mails


Manufacturers accesses:

- Read Write
- User guide

Other links :

- Tutorials
- Last news
- Other links


Welcome to the WEB interface ATLAS-SCT **PRODUCTION DATABASE**



The Web SCT DB is available !

Since February 1999 :

Version 5.12 : July 2003

running on  database.



[Read the News](#)


Important note:

15 years




ATLAS ITk Production Database

Martin Sýkora  



- Dashboard
- My Components
- My Test Results
- Components
- Test Results
- Institutions

15 Component Types Strips	7 Component Types Pixels	14 Test Types Strips	1 Test Type Pixels
---------------------------------	--------------------------------	----------------------------	--------------------------

16
Institutions 

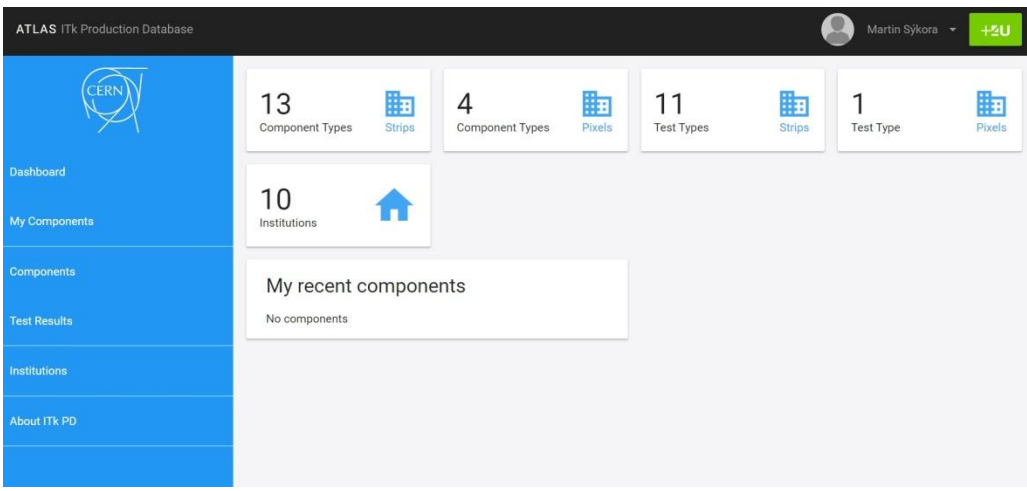
My recent components

ABC CMOS Chip - ABC130	
ABC CMOS Chip - ABC130	
Hybrid - R0_H0	20USEH00000017
ABC CMOS Chip - ABC130	

My recent test results

No test results

Production Database - Communication Methods



← User Interface (very user friendly)

Own API script (preferred for automatization)



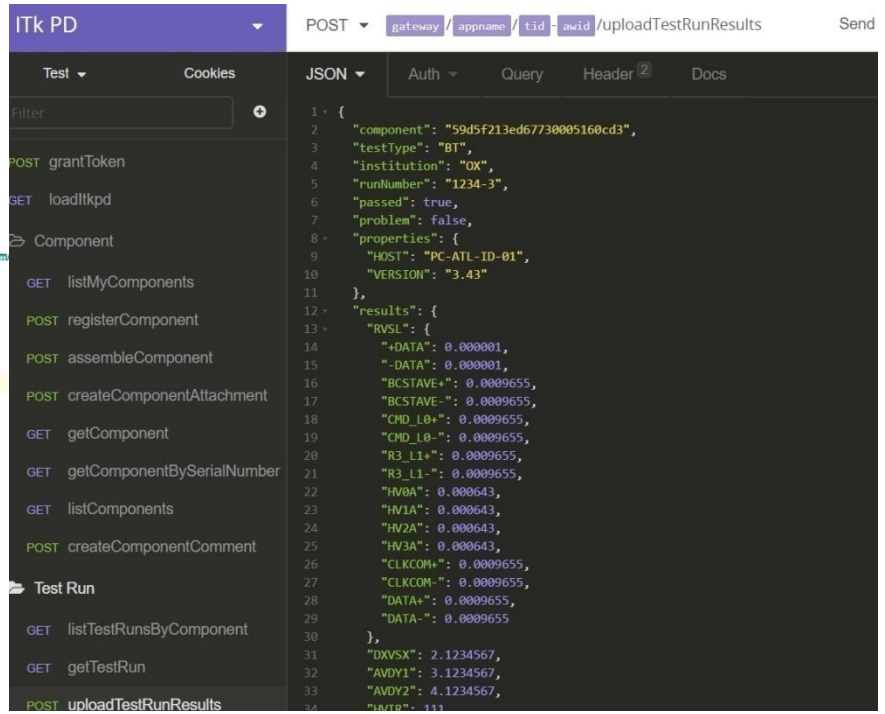
API Client (same principle as UI, but more sophisticated)



```

1  #!/usr/bin/python
2  import ...
11
12  UU_OIDC_GATEWAY = "https://oidc.plus4u.net"
13  UU_OIDC_TOKEN_URI = "/uu-oidcg01-main/0-0/grantToken"
14
15  CMD_GATEWAY = "https://uos9.plus4u.net"
16  TID = "98234766872260181"
17  AWID = "dcb3f6d1f130482581bale7bbe34413c"
18  CMD_UPLOAD_TESTRUN_RESULTS = '/cern-itkpd-test/' + TID + '-' + AWID + '/uploadTestRunResults'
19  CMD_CREATE_TESTRUN_ATTACHMENT = '/cern-itkpd-test/' + TID + '-' + AWID + '/createTestRunAttachment'
20
21  INPUT_FLD = "./input_TestResults"
22  PROCESSED_FLD = "./processed"
23
24  http = httpLib2.Http()
25
26  class CommandError(Exception):
27      """Error thrown when some problem occurs in communication with uuOIDC server. """
28      def __init__(self, status, code, message):
29          super(CommandError, self).__init__(message)
30          self.status = status
31          self.code = code
32          self.message = message
33
34      def __str__(self):
35          return str(self.status) + "," + self.code + "," + self.message
36
37  def oidc_grant_token(access_code_1, access_code_2):
38      post_data = {"grant_type": "password",

```



=> respond to changes in new DB releases (commands definition slightly differs)

- registration/update/deleting/assembly of components, comments, attachments
- starting to add definition of test types and their parameters

=> script for Visual Inspection data upload to the DB for purposes of tracking GUI

ITk Issue Tracking GUI

