



ATLAS ITk Upgrade Project

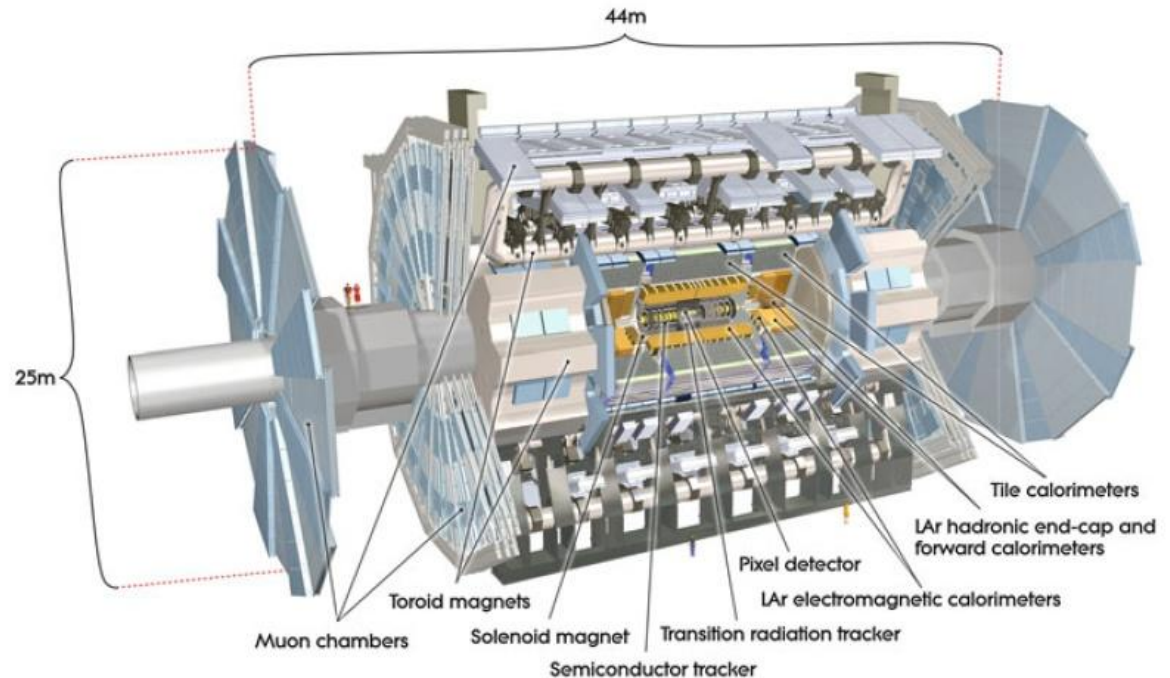
Zdeněk Doležal¹, Peter Kodyš¹, Jiří Kroll², **Martin Sýkora**¹, Ondřej Theiner¹,
Ondřej Kovanda¹, Marek Martaus¹, Lýdia Janitorová¹, Martin Kaplan¹

¹Faculty of Mathematics and Physics, Charles University in Prague

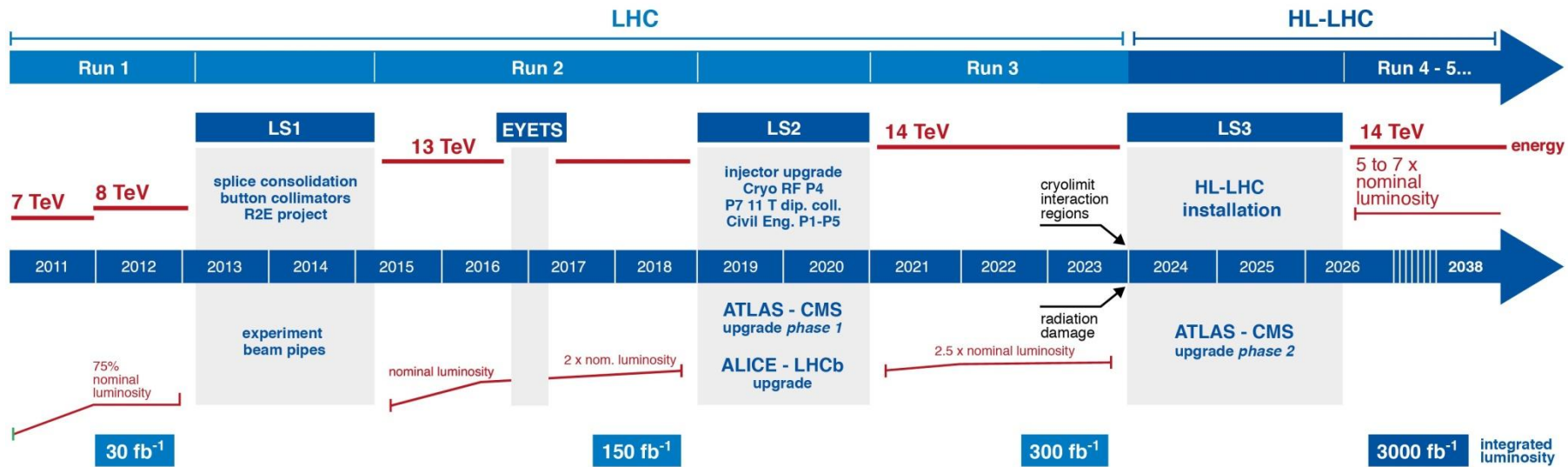
²Institute of Physics, The Czech Academy of Sciences

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)



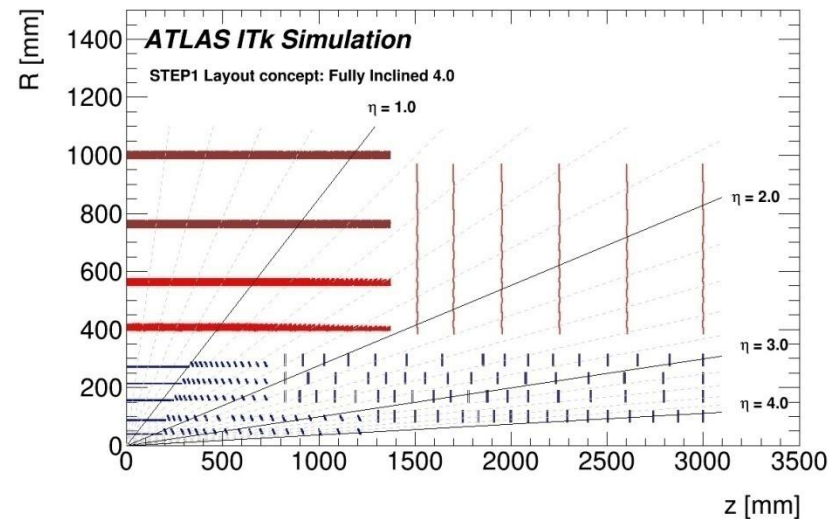
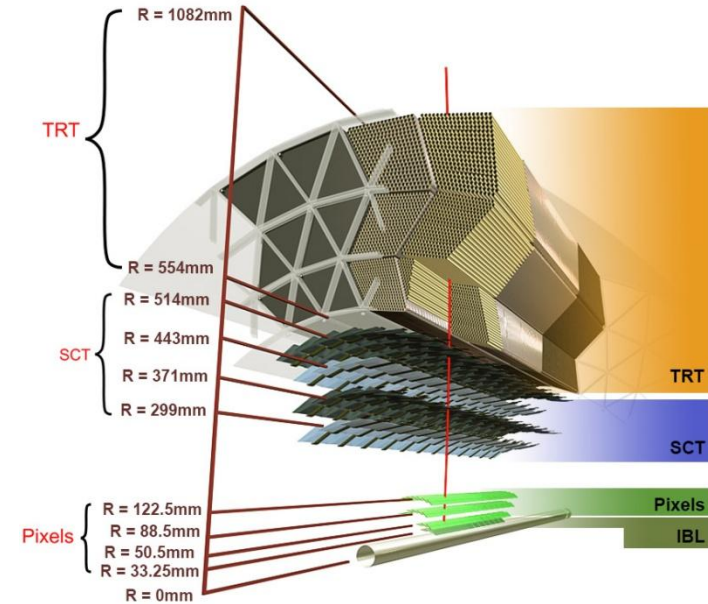
HL-LHC and Upgrades



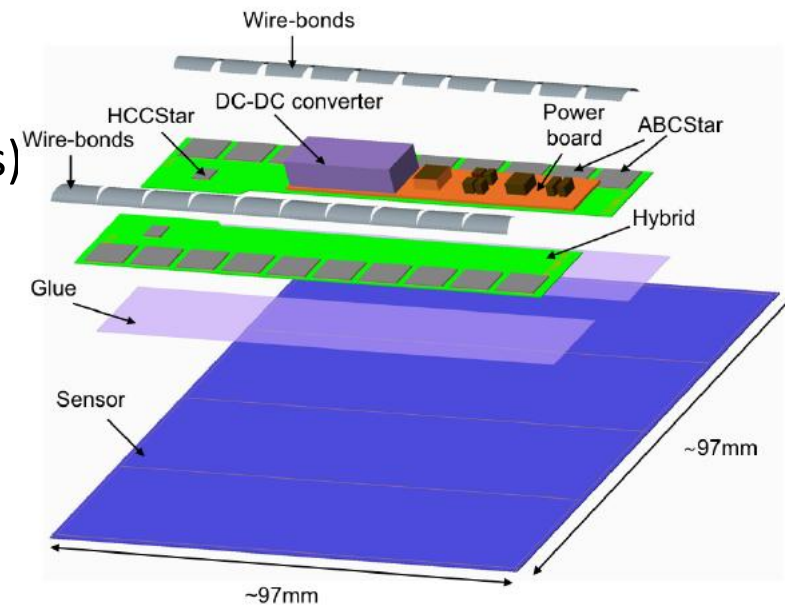
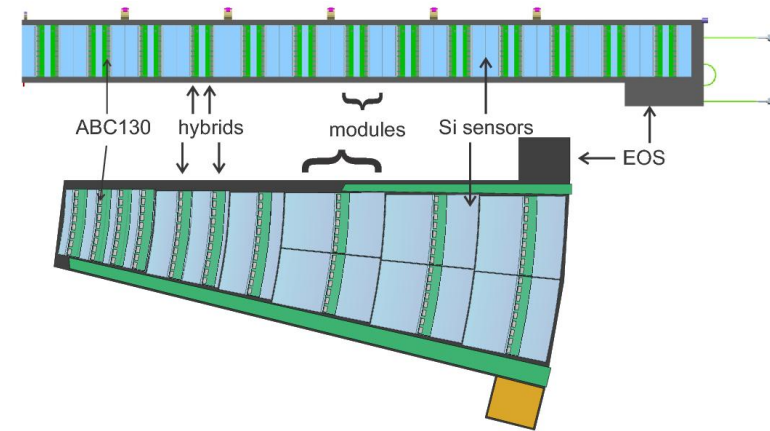
- 2018: last year of Run 2, physics in May, goal 60 fb⁻¹ (50 fb⁻¹ in 2017)
- LS2: injector upgrade Linac 2 -> Linac 4, ATLAS calorimeter trigger systems
- LS3: LIU plans - new SPL and PS2, upgraded SPS

ATLAS ID replacement for Inner Tracker (ITk)

- current ID - coverage $|\eta| = 2.5$
 - 4 barrel layers and 6 endcap discs of pixels
 - 4 barrel layers and 18 endcap discs of strips
 - TRT layer with straw tubes
- future ITk - all-silicon tracker, coverage $|\eta| = 4$
 - 5 barrel layers of pixels in inclined layout
 - 32-38 endcap discs in each of 4 pixel layers
 - 4 barrel layers and 12 endcap discs of strips
- motivation - radiation resistance
 - the most resistant layer IBL up to 850 fb^{-1}

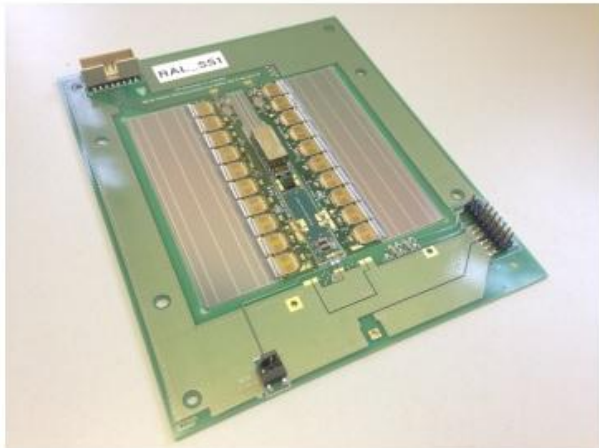
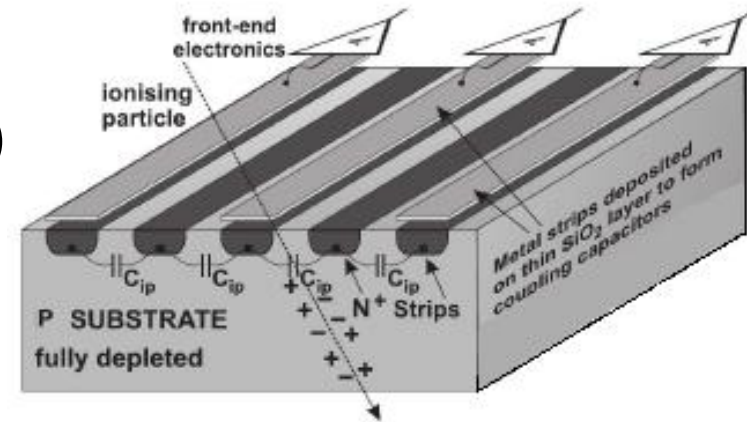


- 28 barrel modules create stave and 18 endcap modules create petal
- 6 rings (R0-R5) in petal with different design
- module design:
 - ABC readout chips and HCC control chip UV-glued on kapton PCBs (hybrid)
 - hybrid glued directly on silicon sensor
 - wire bonding (chips on hybrid, strips on chips)
 - power board, end of structure

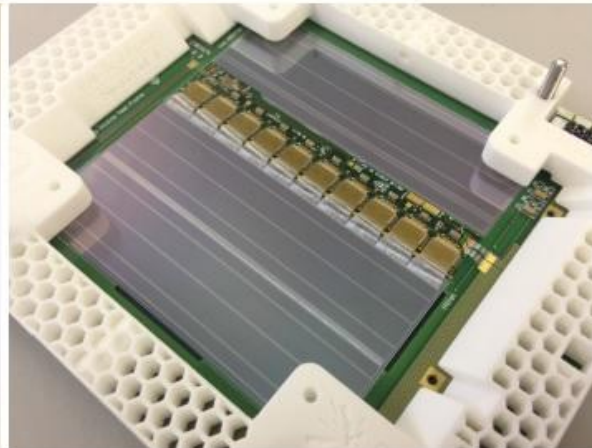


Microstrip Sensors

- n^+ strips in p silicon bulk in case of ITk
 - larger signal after irradiation than p-in-n (SCT)
- depletion zone width $W = \sqrt{\frac{2\epsilon}{e} \left(\frac{N_A + N_D}{N_A N_D} \right) V_{bi}} \cong \sqrt{\frac{2\epsilon V_{bi}}{e N_D}}$
- sensor width 320 μm , depletion voltage 350 V
- strip pitch 75.5 μm (barrel) and 70-80 μm (endcap discs)
- testing prototypes



Short-Strip Barrel Module



Long-Strip Barrel Module



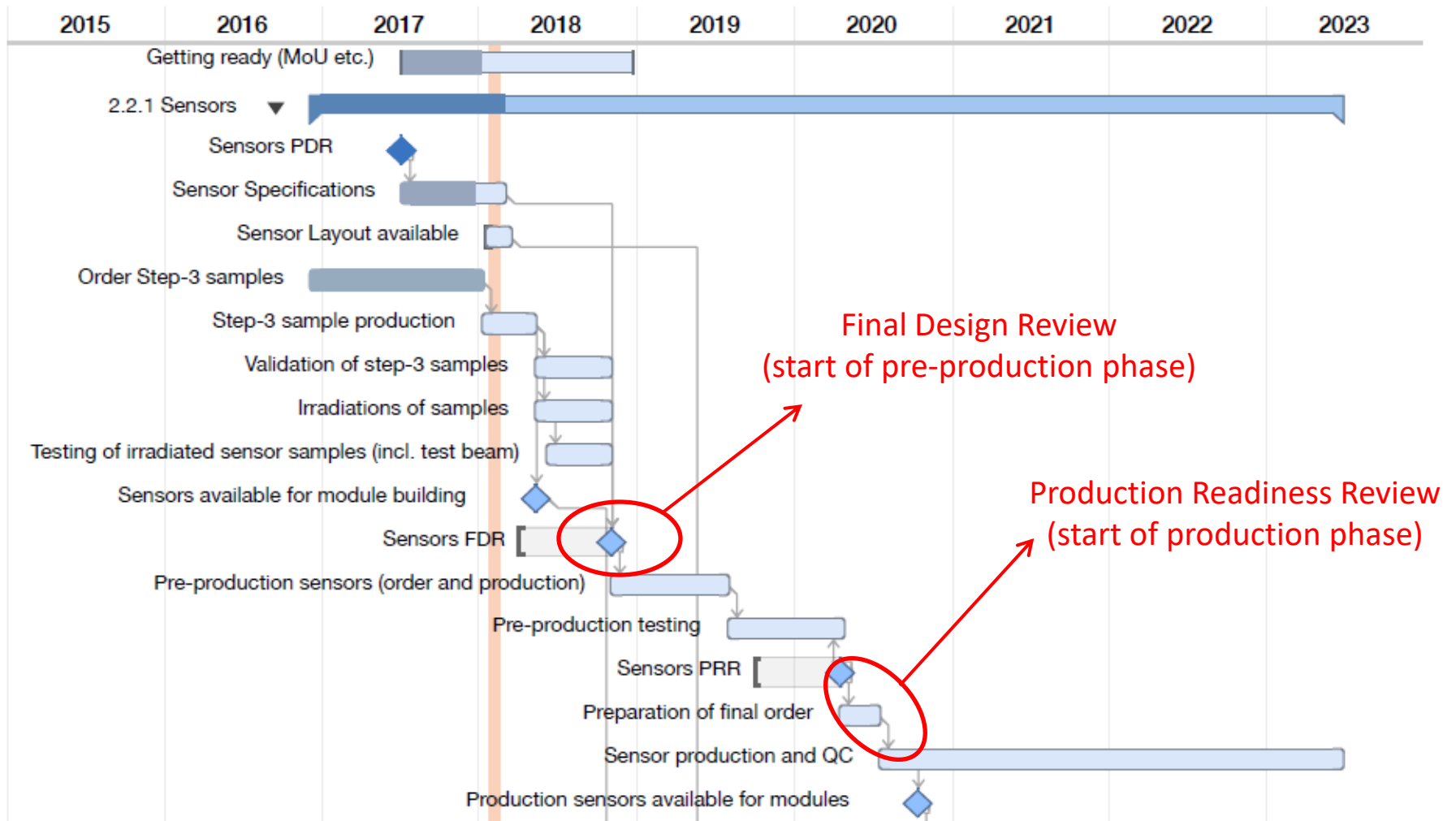
Endcap DAQload

Overview of Strip (ITk) Community Activities

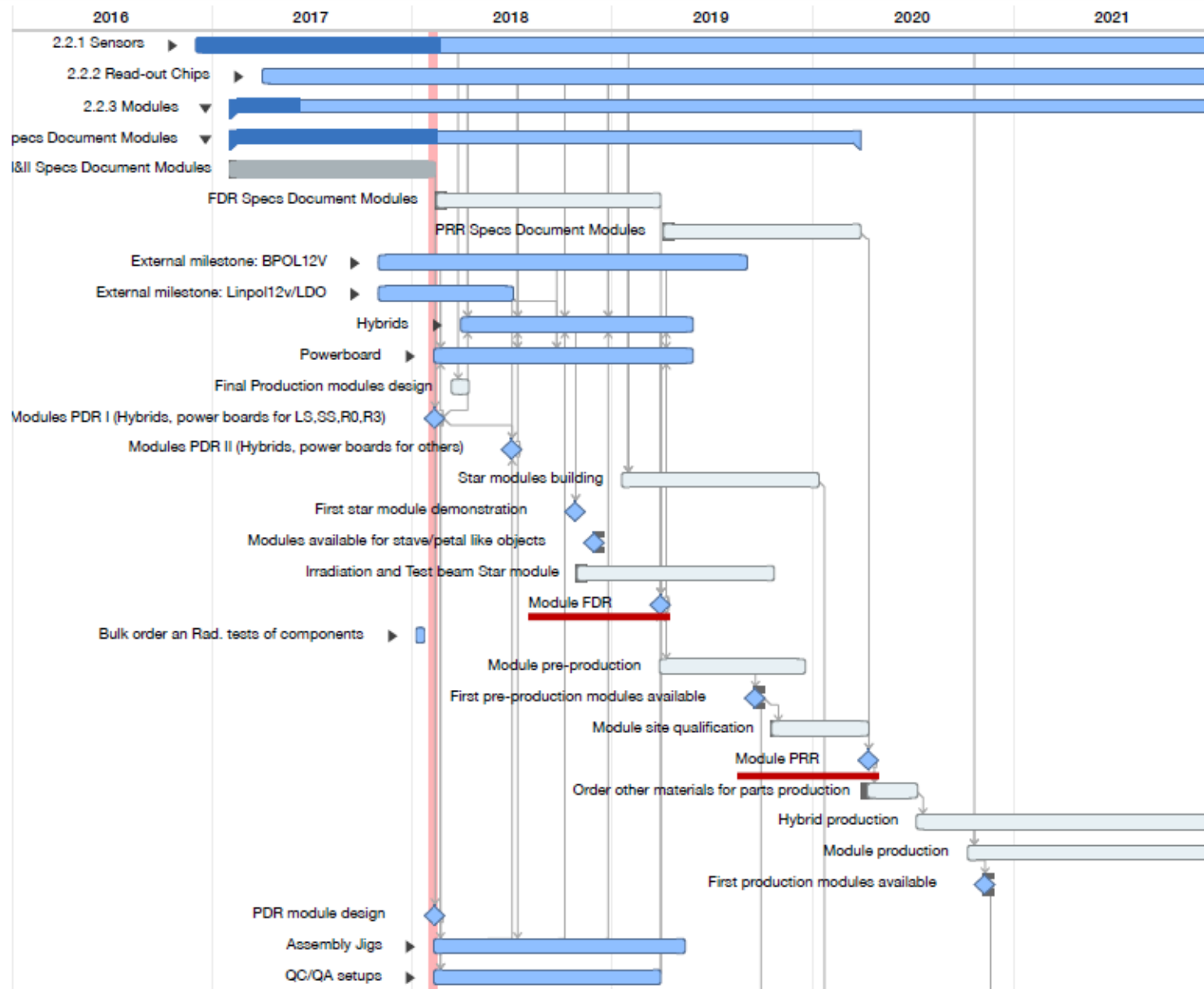
- **Sensors/Hybrids/Modules** – assembly, testing
- ASICs – development of chips
- On-detector control/readout electronics – EoS development, monitoring systems
- Local support – electrical and mechanical concept of staves/petals
- Global support – carrying of local substructures such as staves/petals

- **Database**
- Powering/cables/off-detector electronics
- Common mechanics/electronics
- Cooling

Working Schedule and Milestones - Sensors



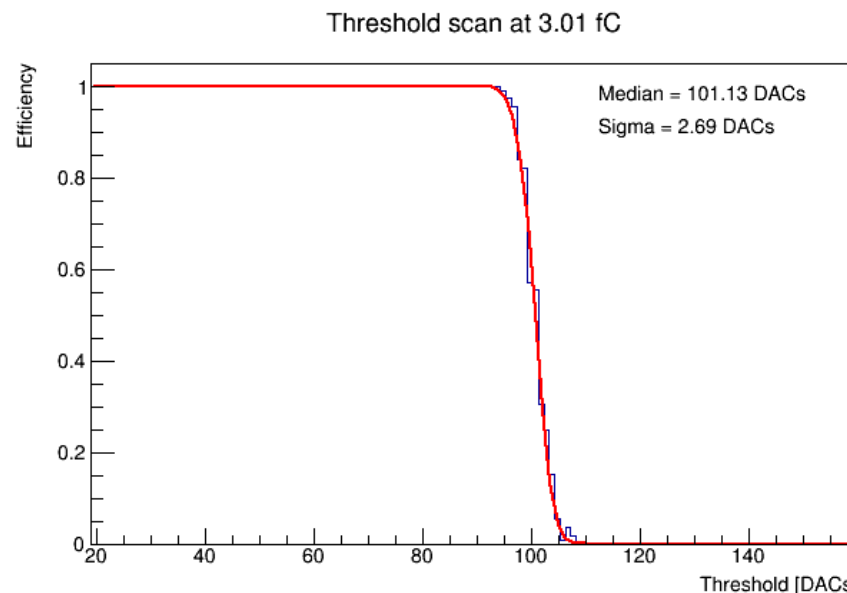
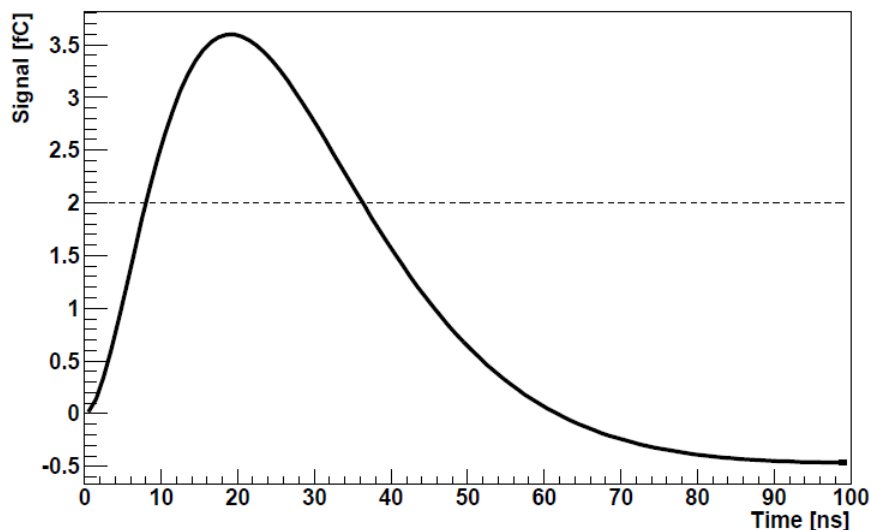
Working Schedule and Milestones - Hybrids/Modules



Testing of Strip Modules - Threshold Scan

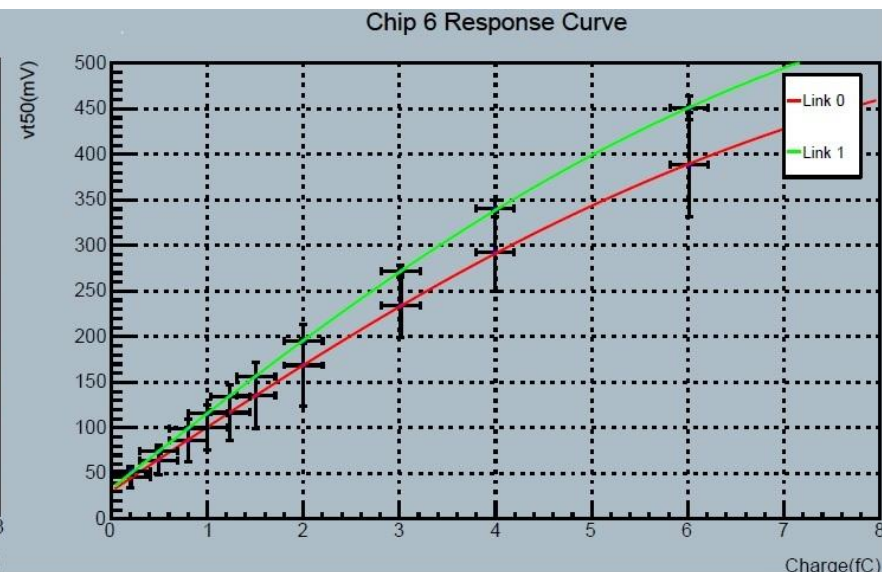
- testing = charge injection into sensor/chip channels + (triggered) readout
- basic ITSDAQ scan, amplitude reconstruction using binary readout
- integral form of convolution of noise and signal distribution
- critical parameters:
 - collected charge, noise, hit efficiency, gain, S/N

$$f(x) = \epsilon_{max} \operatorname{Erfc} \left[x \left(1 + 0.6 \frac{e^{-\xi x} - e^{\xi x}}{e^{-\xi x} + e^{\xi x}} \right) \right]$$



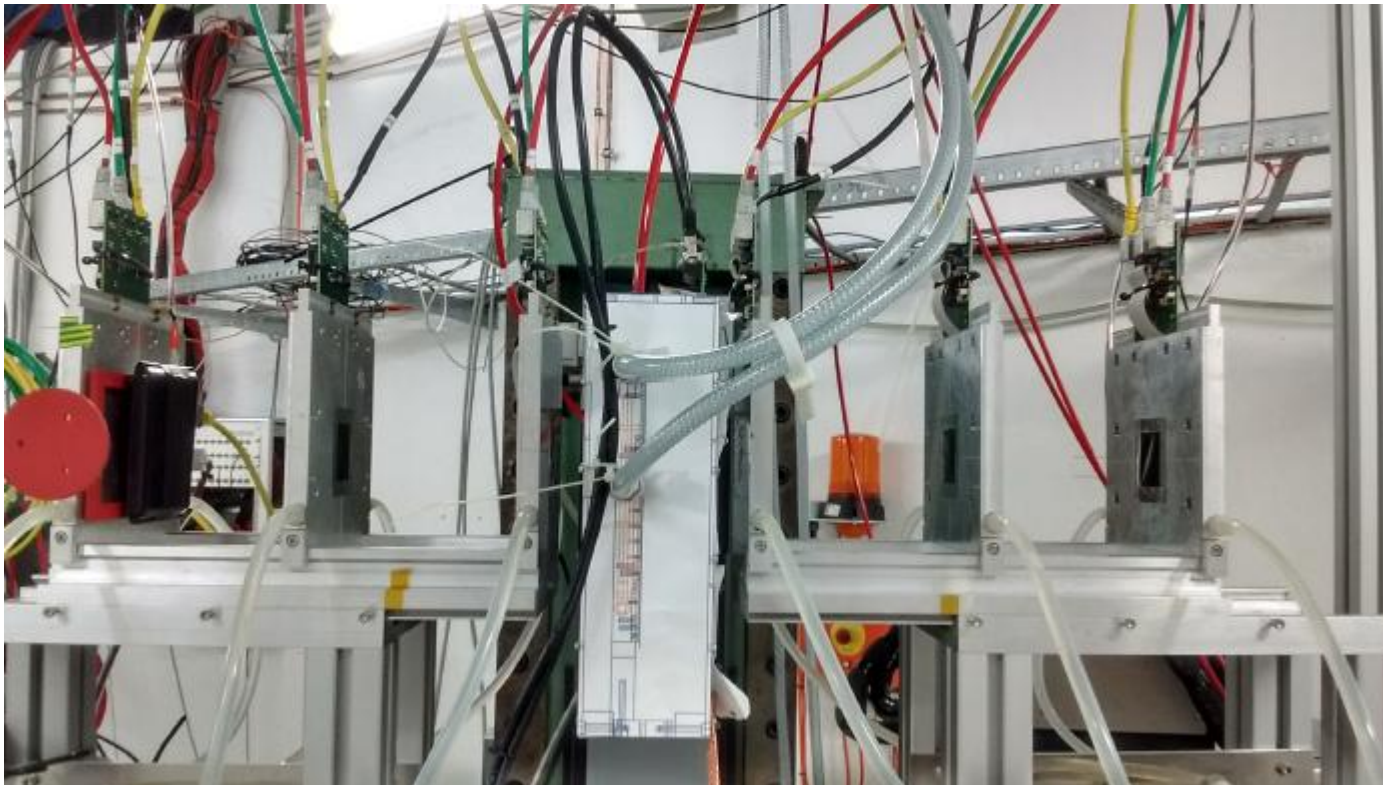
Testing of Strip Modules - Calibration

- internal ITSDAQ units DACs, conversion to fC required
- DACs-to-mV conversion using ABC130 chip simulation
- mV-to-fC conversion using injected charge through calibration circuit
- Three Point Gain (linear, gain + offset), Response Curve (non-linear, 3 parameters)



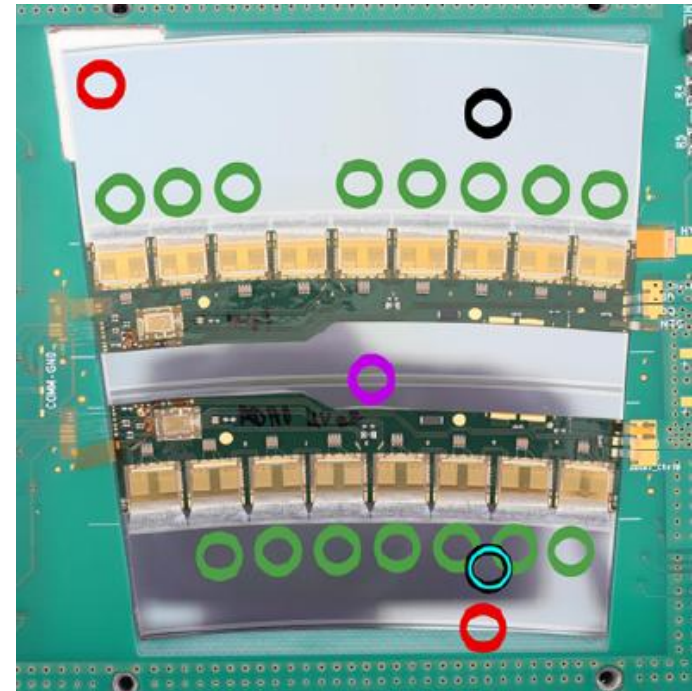
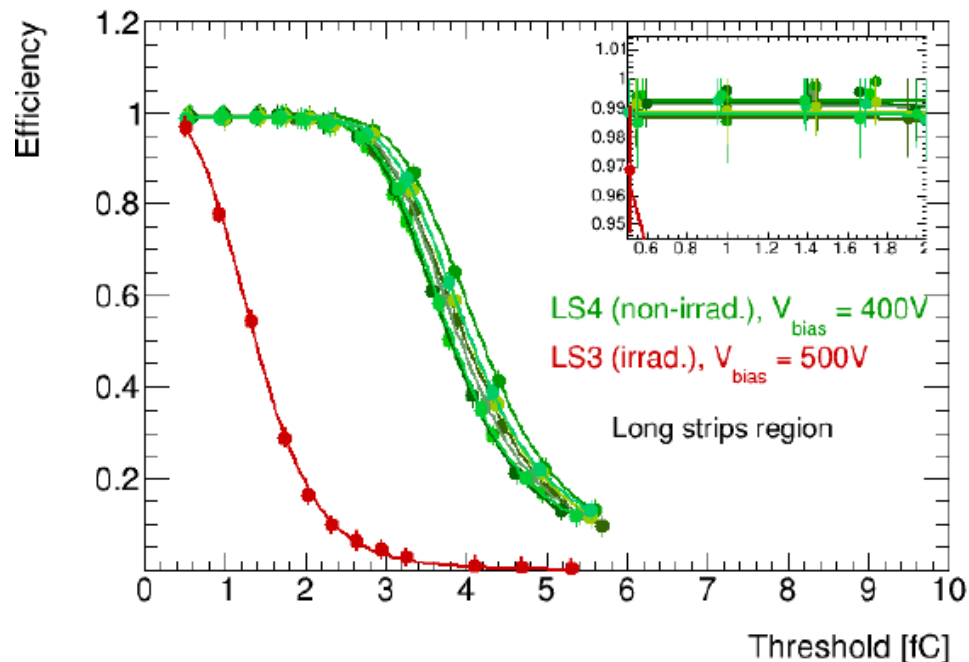
Testing of Strip Modules - Test Beam

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



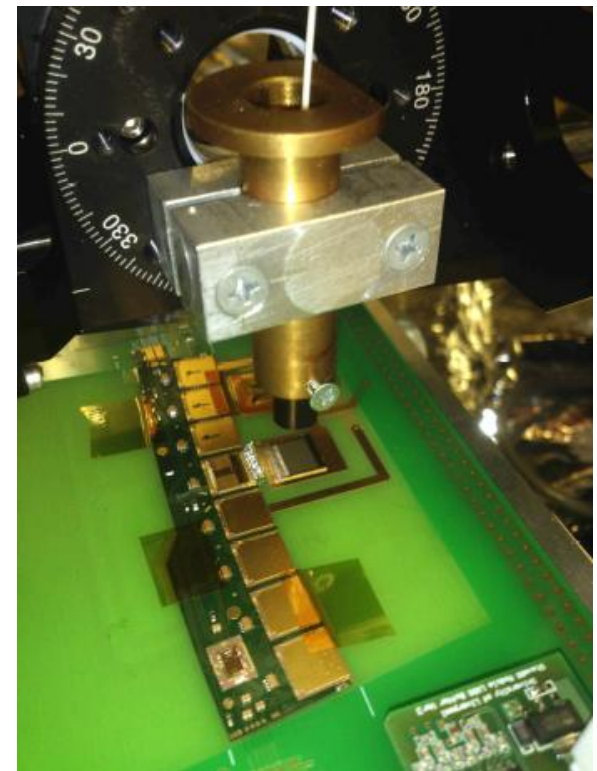
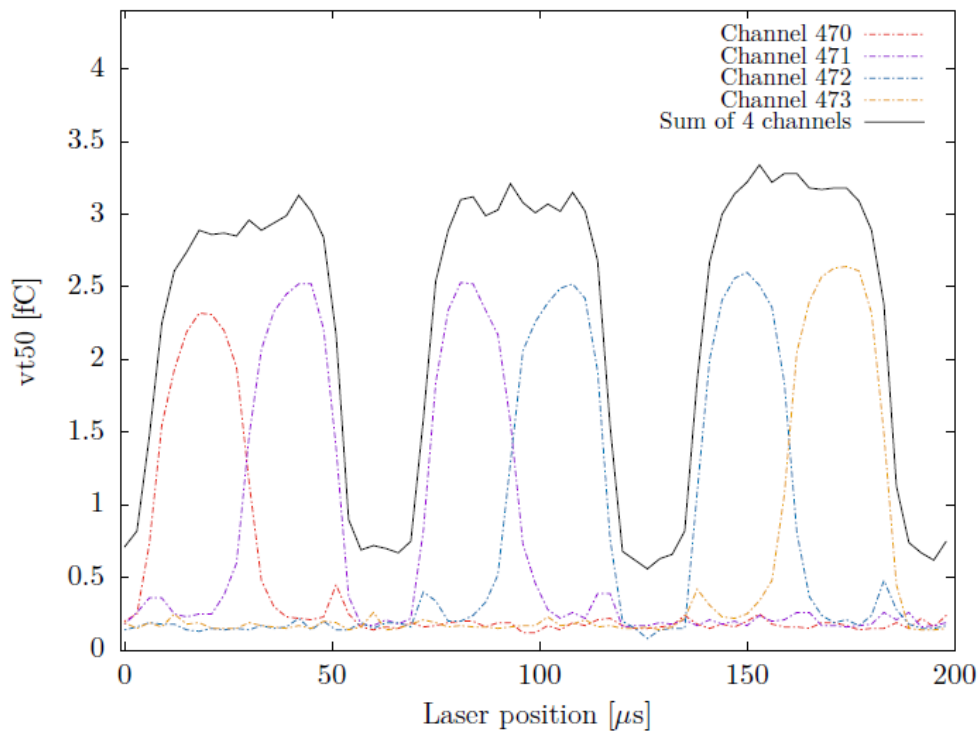
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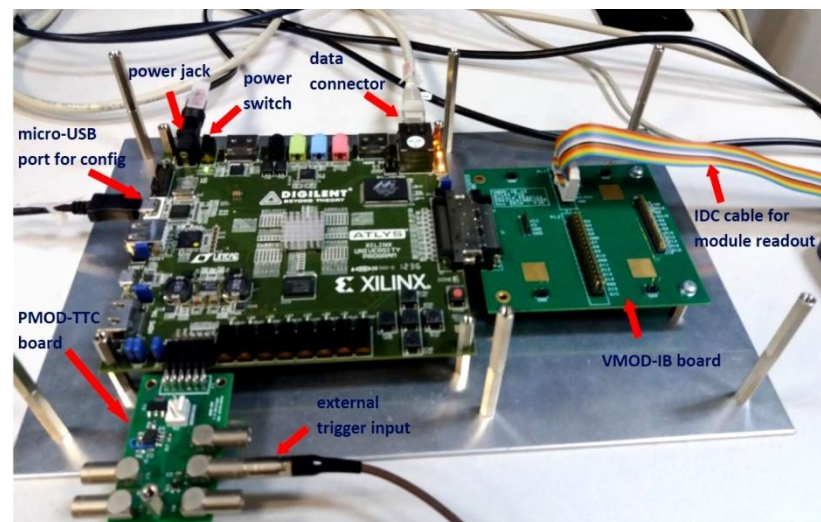
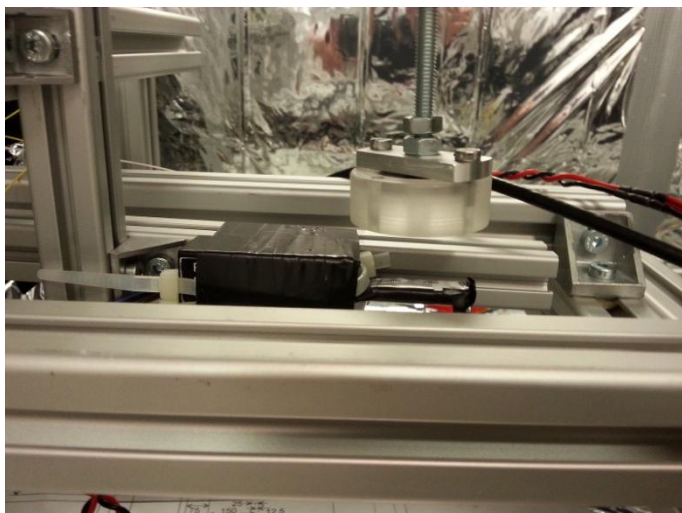
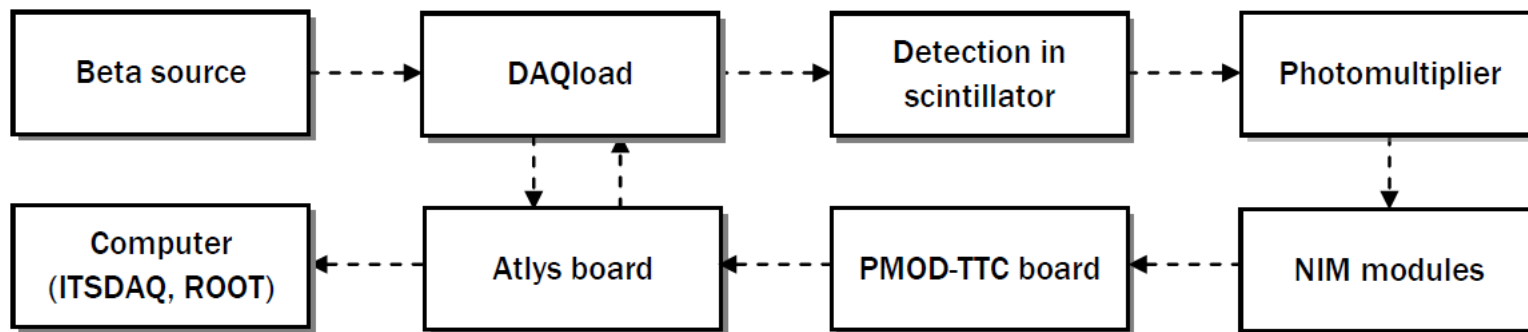
Testing of Strip Modules - Laser Tests

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



Testing of Strip Modules - Beta Source Tests

- beta source ^{90}Sr , e^- collimated, mini sensor $1 \times 1 \text{ cm}^2$ (M. Sýkora, O. Kovanda)
- scintillator as an external trigger, Atlys board for readout, software ITSDAQ, ROOT

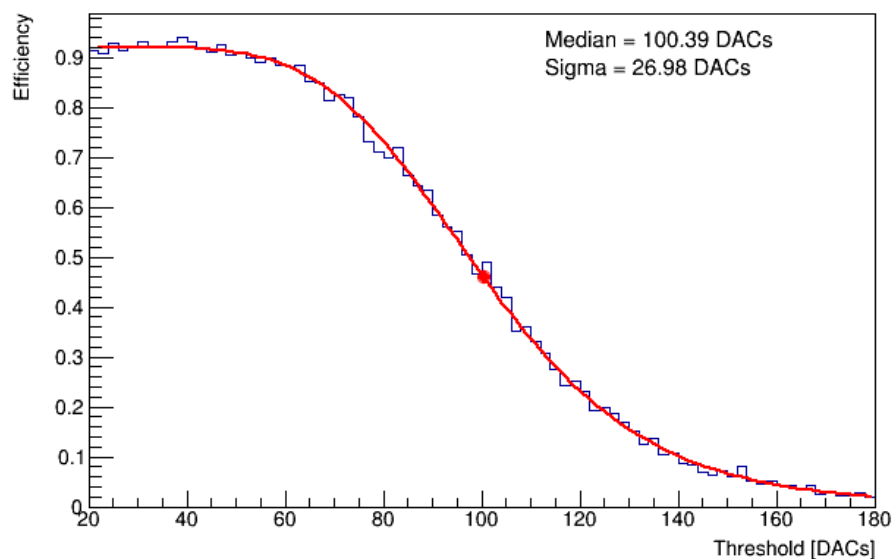


Testing of Strip Modules - Beta Source Tests

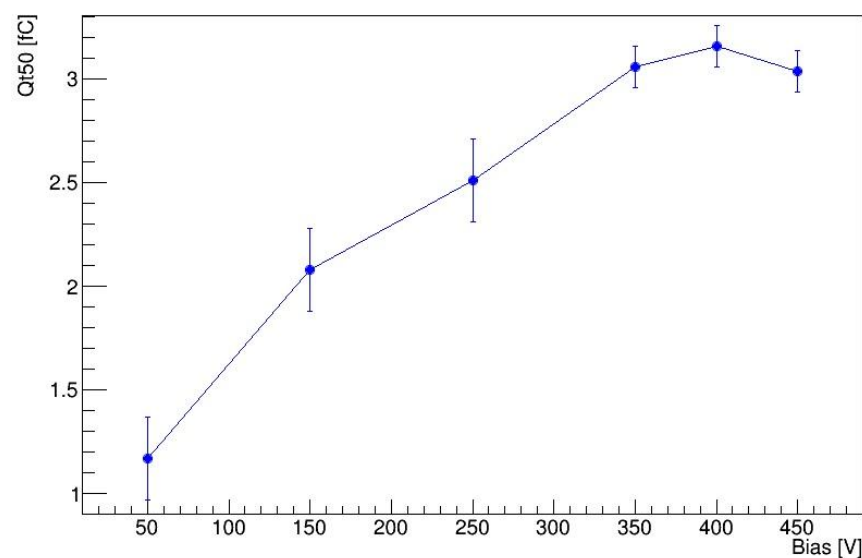
- bias scan, angular scan, temperature scan, FE parameters scan, latency scan
- collected charge **3.1 fC** , noise (ENC) **550 e⁻** , S/N **35**
- sensor fully depleted above 350 V

$$ENC [fC] = \frac{\sigma [mV]}{gain [mV/fC]}$$

Threshold scan for bias_400V_1000trg_latency_10



Bias_scan_distance23mm



Testing of Strip Modules - Beta Source Tests

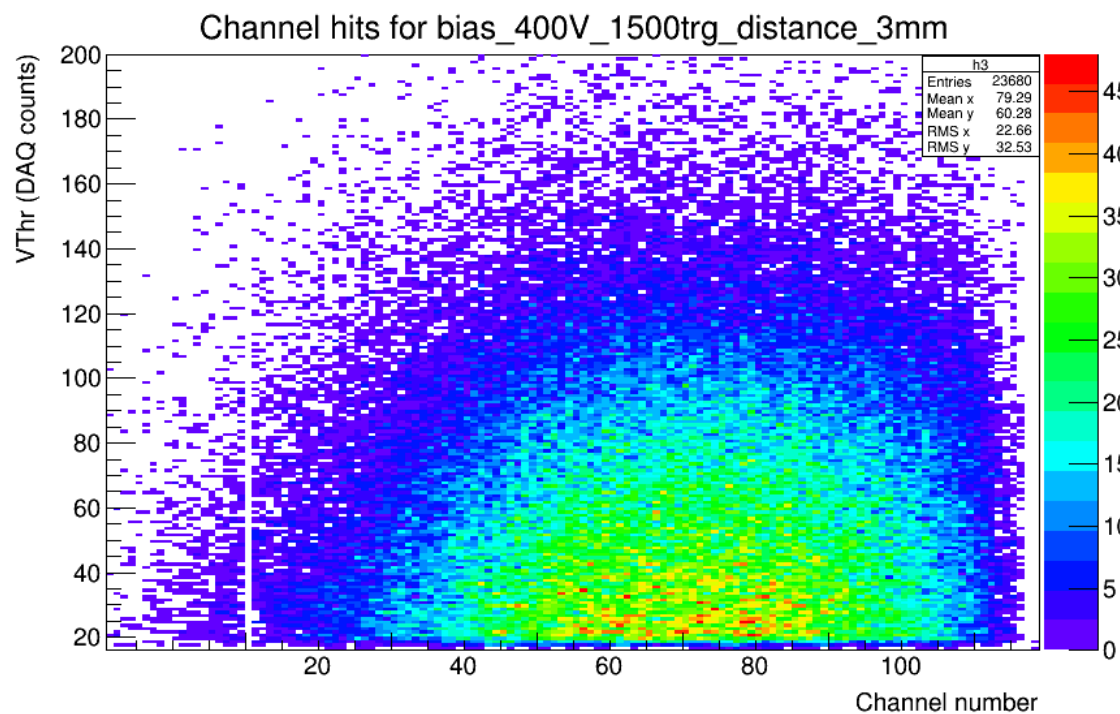
- collected charge **3.1 fC**

- noise (ENC) **550 e⁻**

- S/N **35**

=> non-irrad. R0 mini sensor

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



- hit map for 128 channels

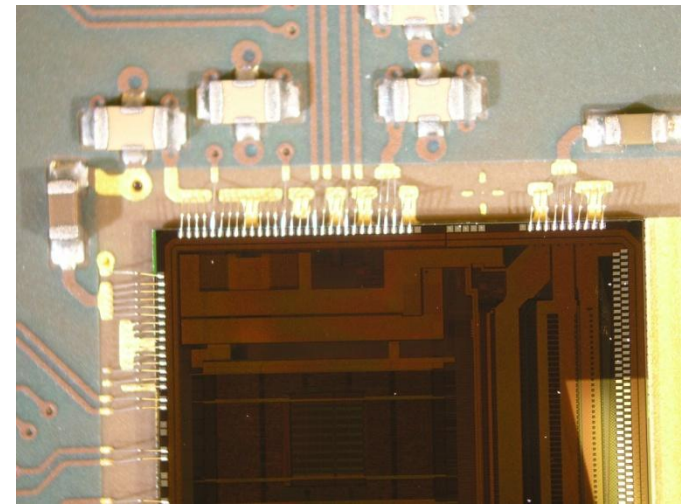
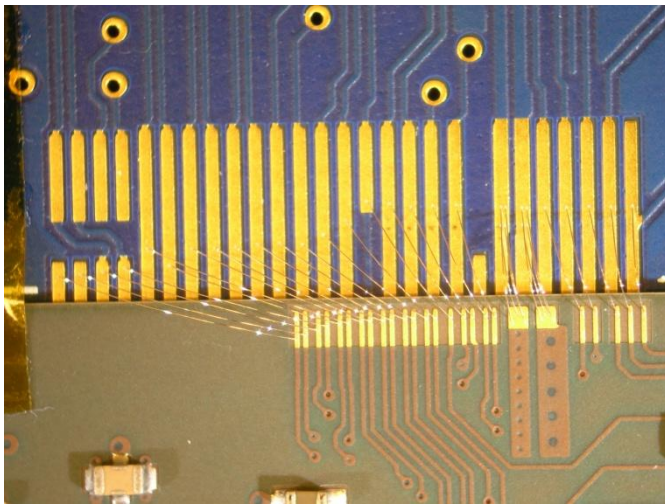
- cut-off rules for analysis:

- 1 cluster/event

- cluster size < 6

Preparations for Production

- share of Czechia for production approx. 650 EC R2/R4 modules (9 - 10 %)
- including partial assembly:
 - completed electrical hybrids should be glued on sensor and wire-bonded
 - => cooperation with the czech private company Argotech based in Trutnov
 - => now being tested, plan to built fully functional R0 module together



- thermal cycling, metrology (L. Janitorová), continuous QC testing, database entry

- to record details of used components, their assembly, shipments, test results
- being designed by the Unicorn College, just 1 DB for the whole ITk
- should stay accessible during ITk operation for better understanding of defects
- SCT DB ~ 350 000 registered items ; ITk DB ~ 10^6 - 10^7 numbered items
- current status:
 - basic testing version of PD is already running
 - UC gradually adds new types of components/tests according to our specification
 - still more and more ITk collaboration people are getting in touch with PD

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
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16
Institutions 

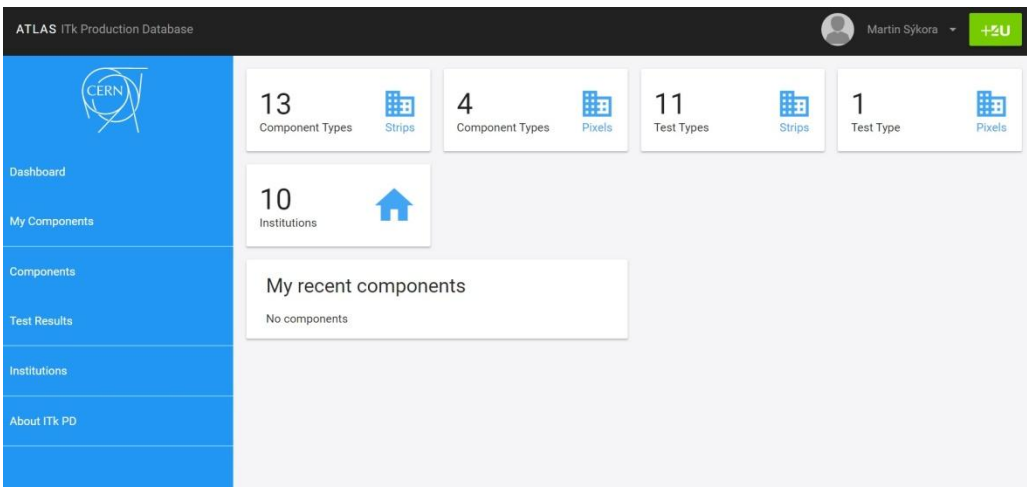
My recent components

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)



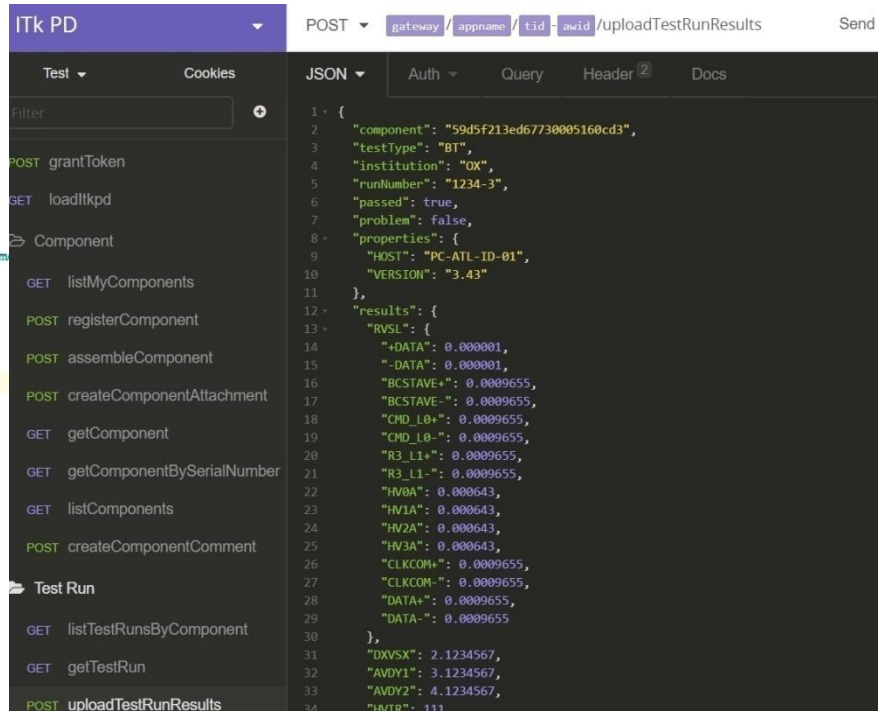
API Client
(same principle as UI,
but more sophisticated)



```

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",

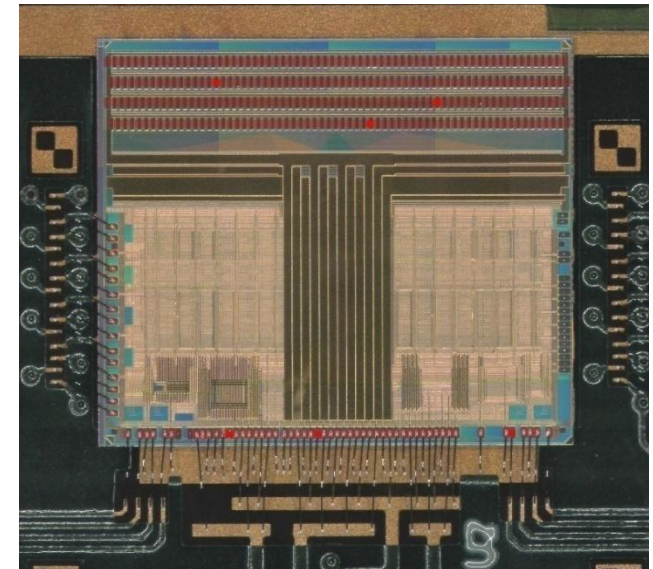
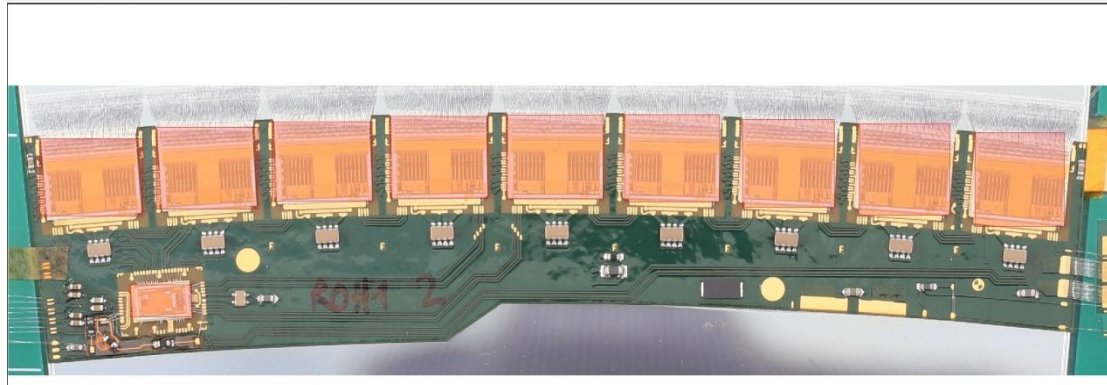
```



Production Database - API Scripts

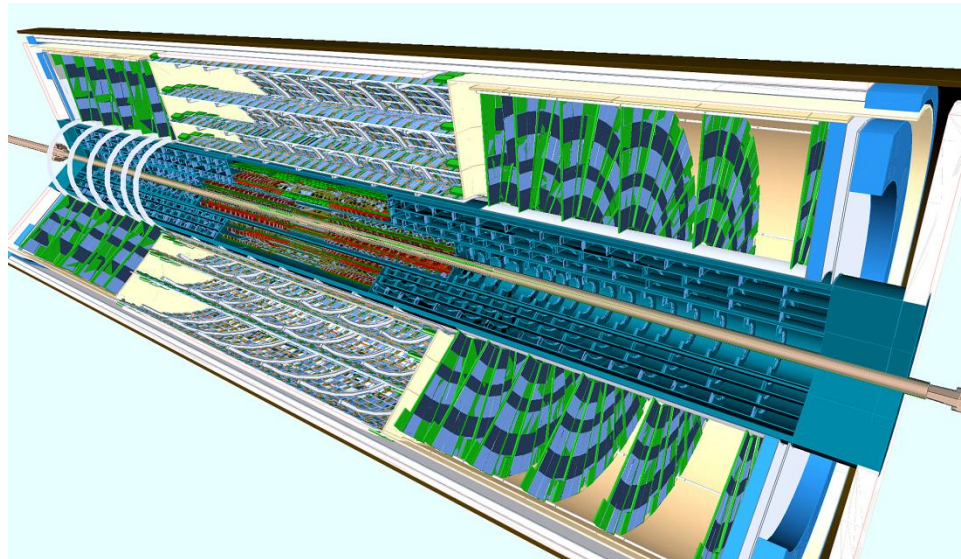
- to develop API scripts for various purposes of PD focusing on ITSDAQ integration
=> respond to changes in new DB releases (commands definition slightly differs)
- registration/update/deleting/assembly of components, comments, attachments
- starting to add definition of test types and their parameters
=> script for Visual Inspection data upload to the DB for purposes of tracking GUI

ITk Issue Tracking GUI



Summary and Outlook

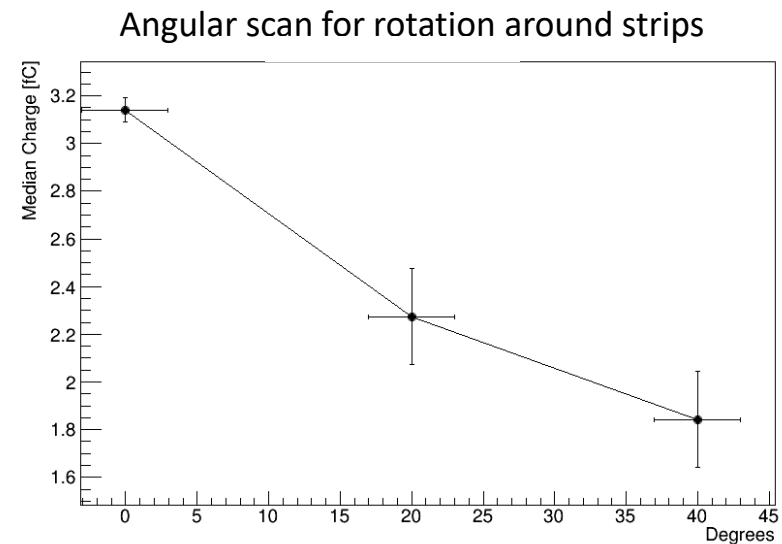
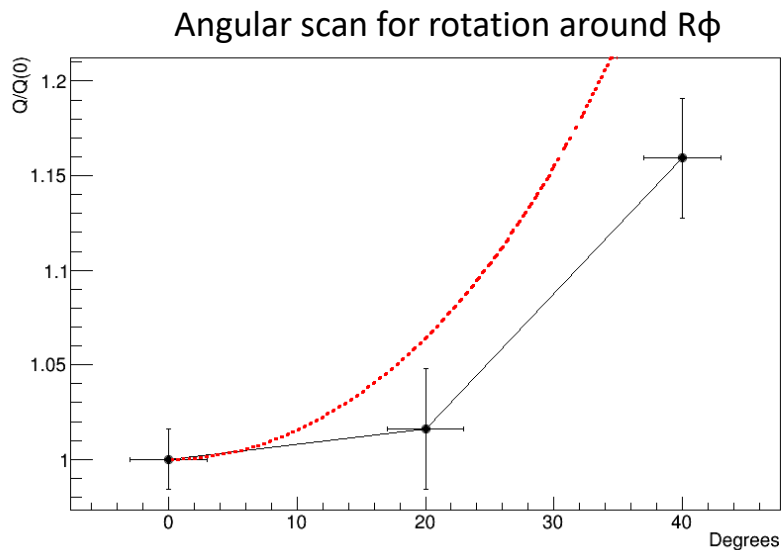
- all-silicon ITk will replace current ID in 2025, 8 types/designs of modules
- production is comming (Q2 2020), ITk final settlement (2024 -2026)
- Prague group involved in sensor/hybrid/mod. testing, module assembly, database
- at IPNP successful tests of DAQloads (laser, beta source) + QC testing
- near future - R0 assembly and its testing, CERN/DESY test beams
- functional working team of supervisors (3) and students (6), newcomers welcome



BACKUPS

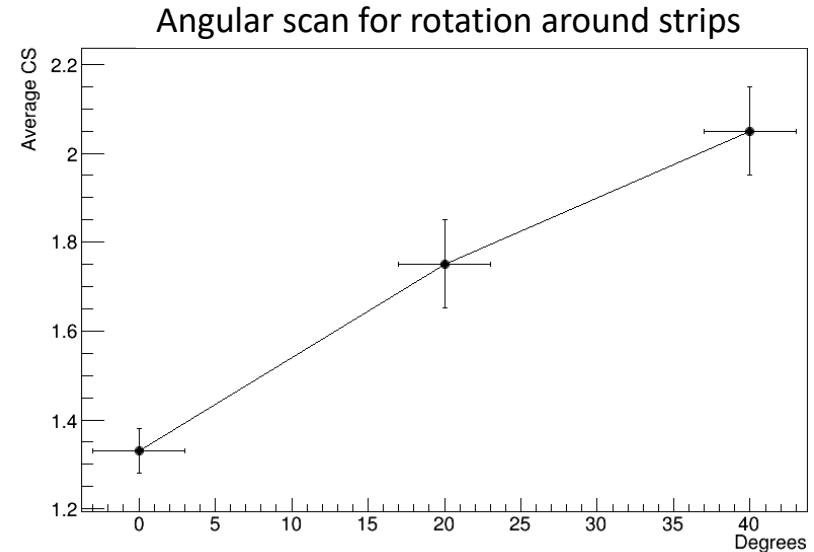
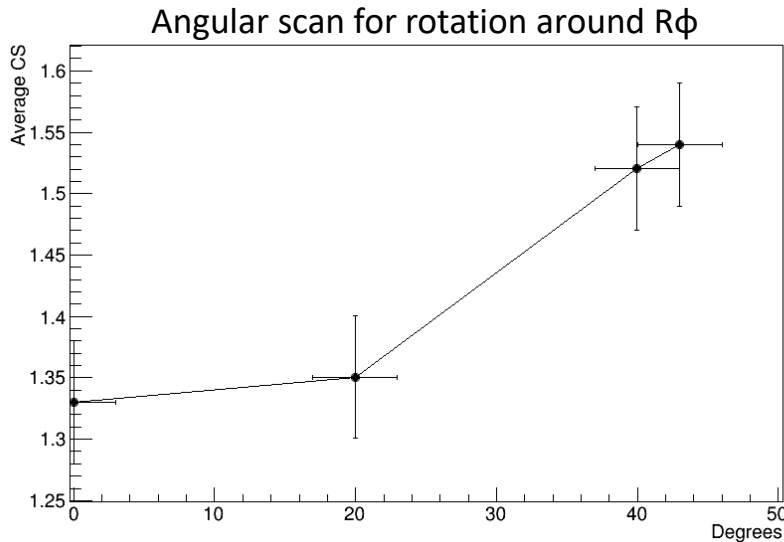
Angular Scan

- 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



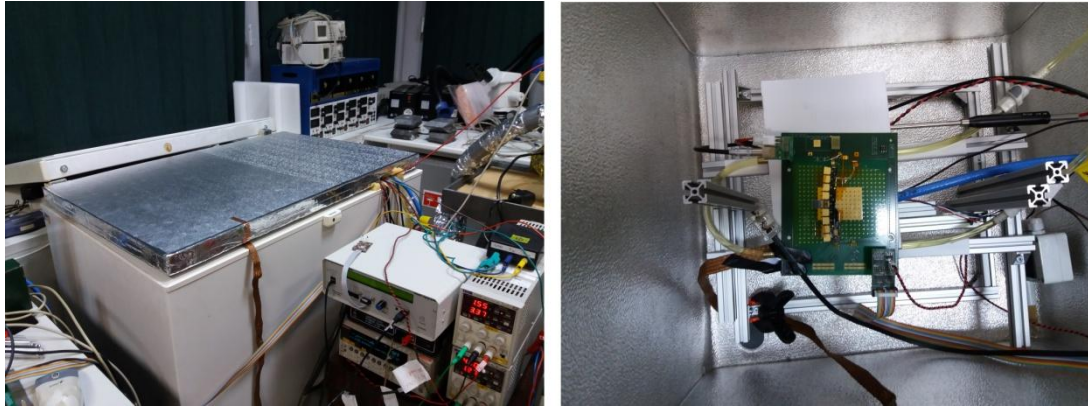
Angular Scan

- 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

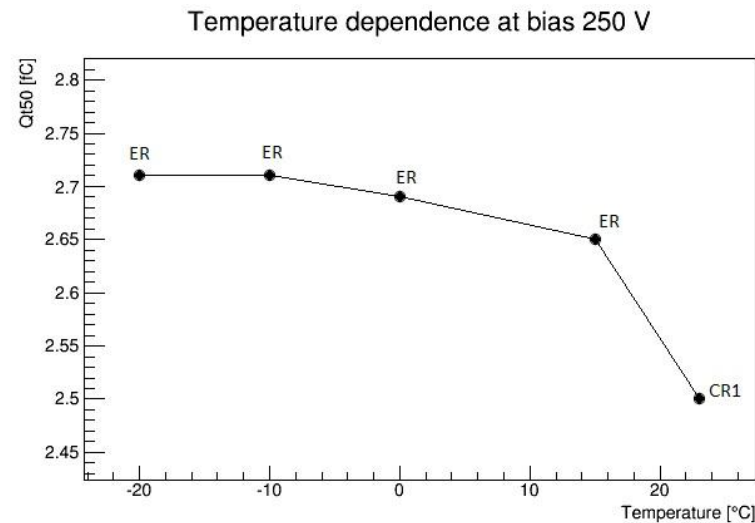


Temperature Scan

- 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



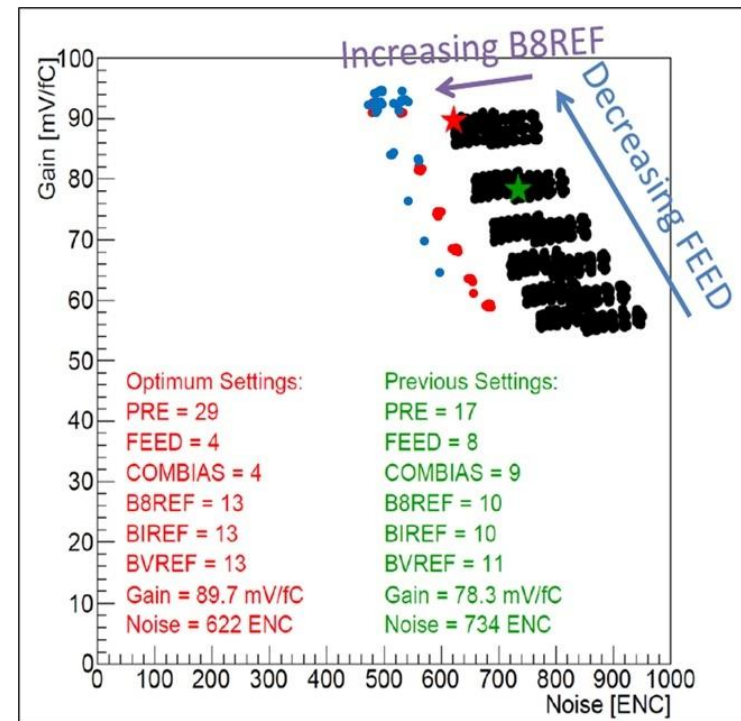
- possible explanation: shorter cabling in CR1
=> larger delay between external trigger signal and readout signal
- integer ITSDAQ variable latency (step 25 ns), finer latency scan with delay unit
- Atlys firmware version problem, preset latency value 10 changed to 11



FE Parameters Scan

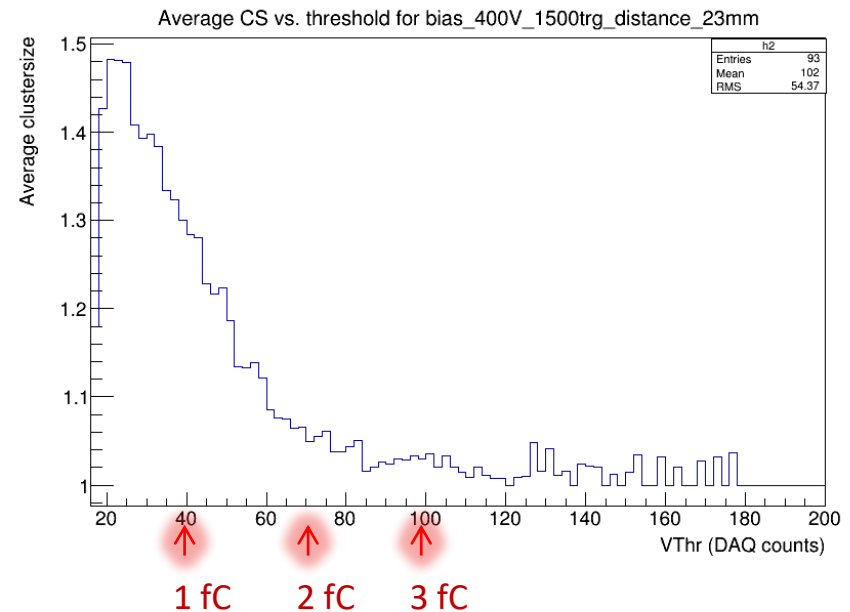
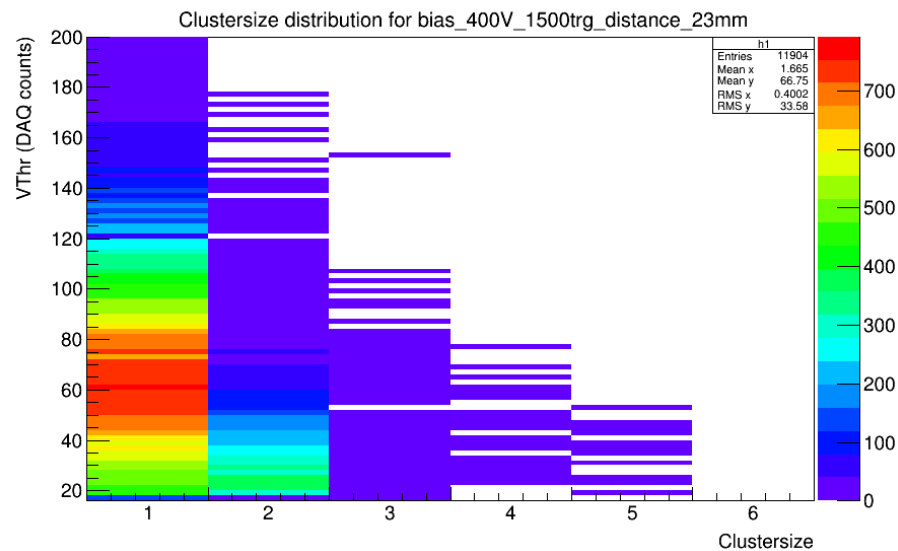
- 6 internal parameters of front-end electronics of ABC130 chip
- to adjust control currents and voltages, possible change of pulse shape
- search for best setting (high gain, low noise)

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

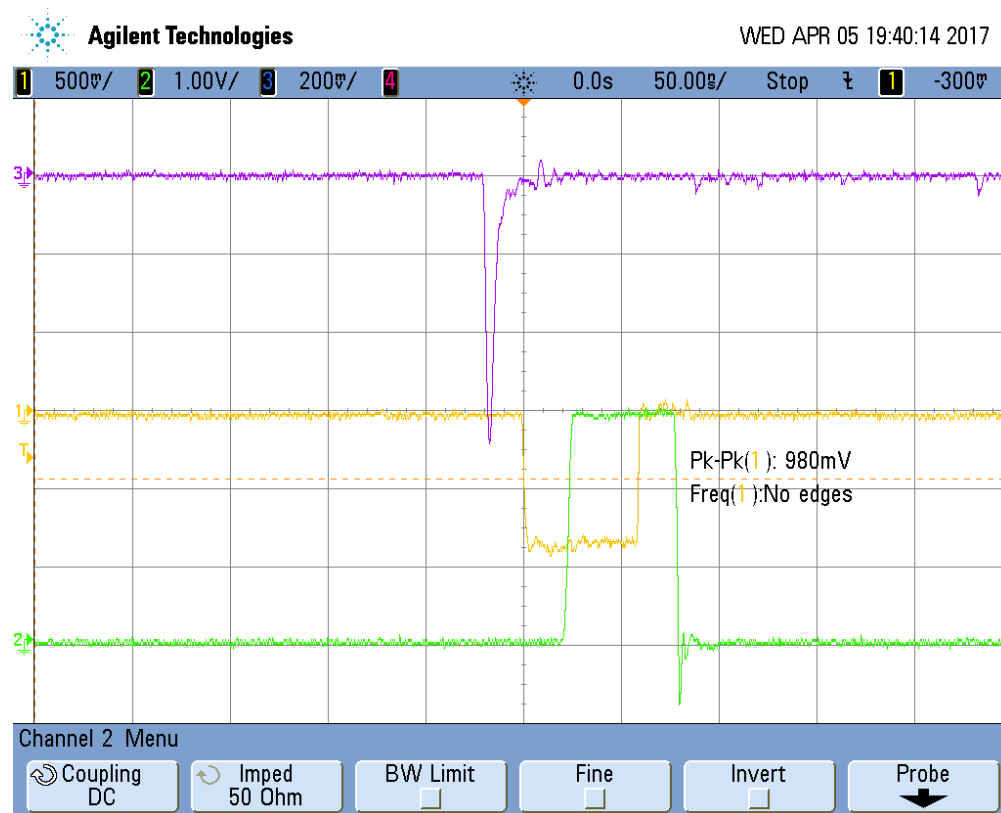


Cluster Analysis

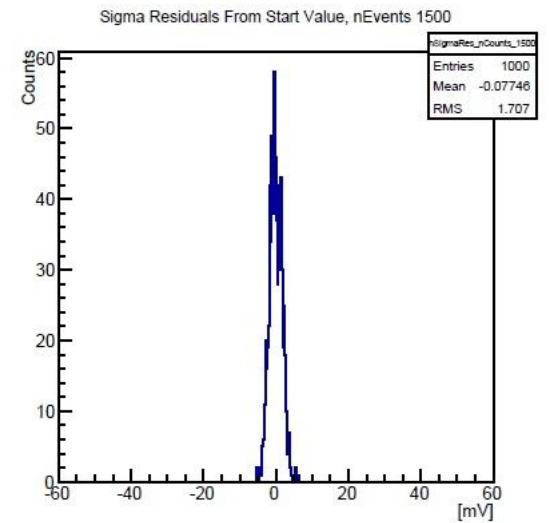
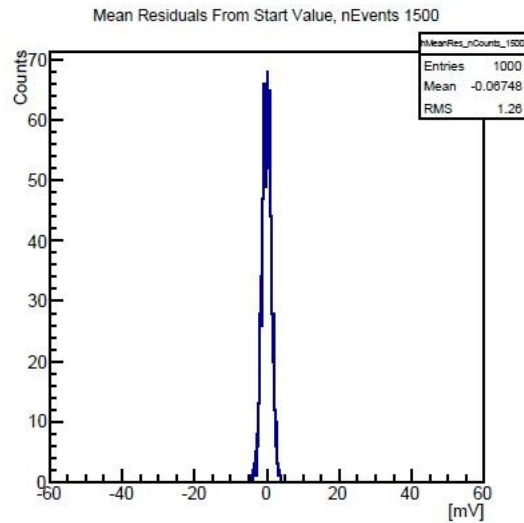
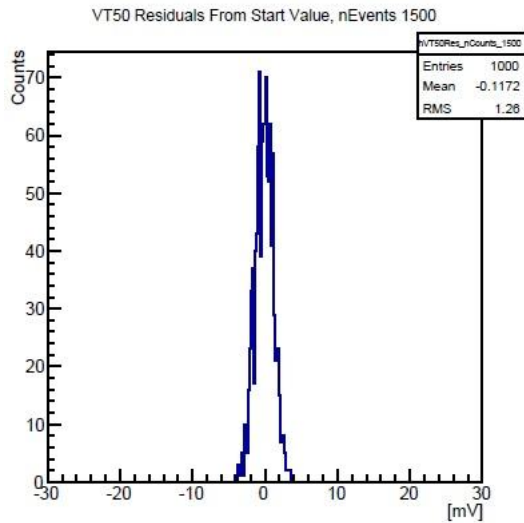
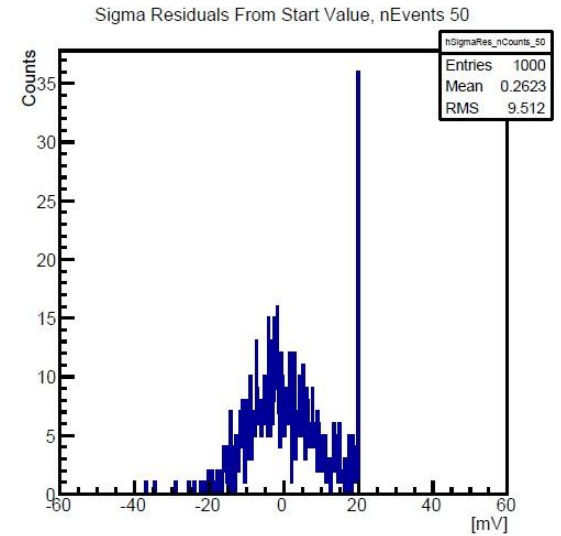
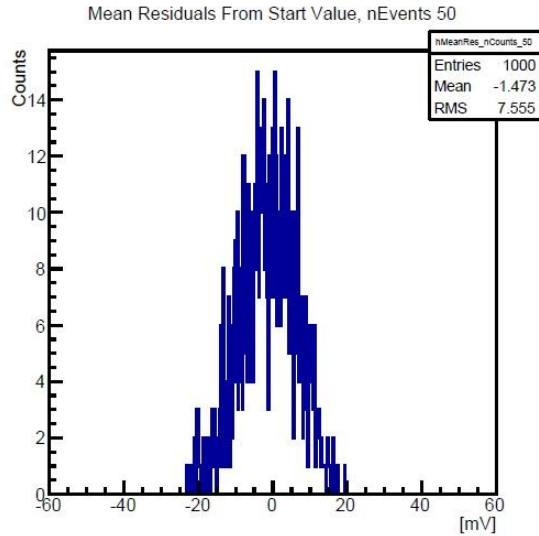
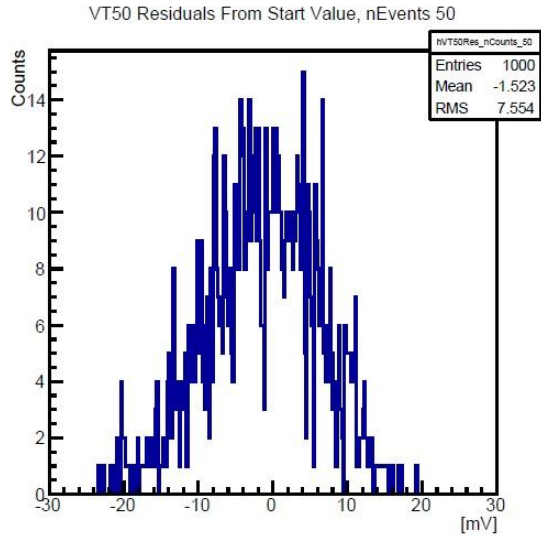
- cluster reconstruction from event lists
- sum of clusters for every cluster size gives S-curve
- average CS at 1 fC: 1.33 (fully depleted, perpendicular scan)



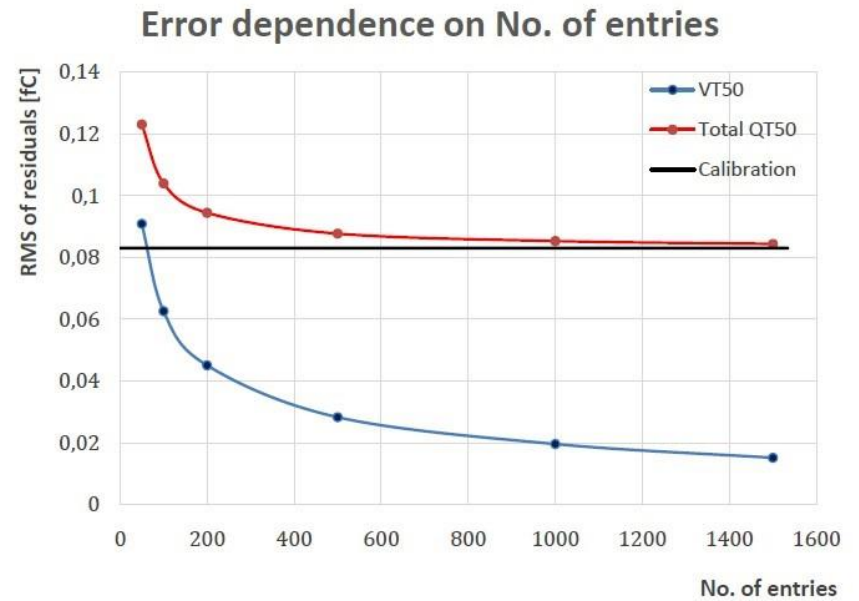
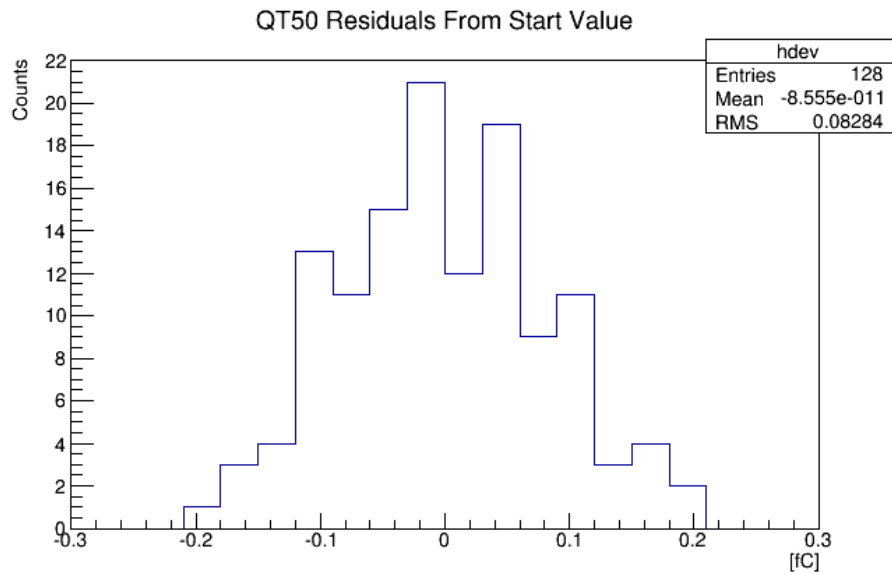
- negative analogue signal from scintillator does not meet Atlys requirements
=> signal modulation using NIM crate (Discriminator, Level Adapter modules)



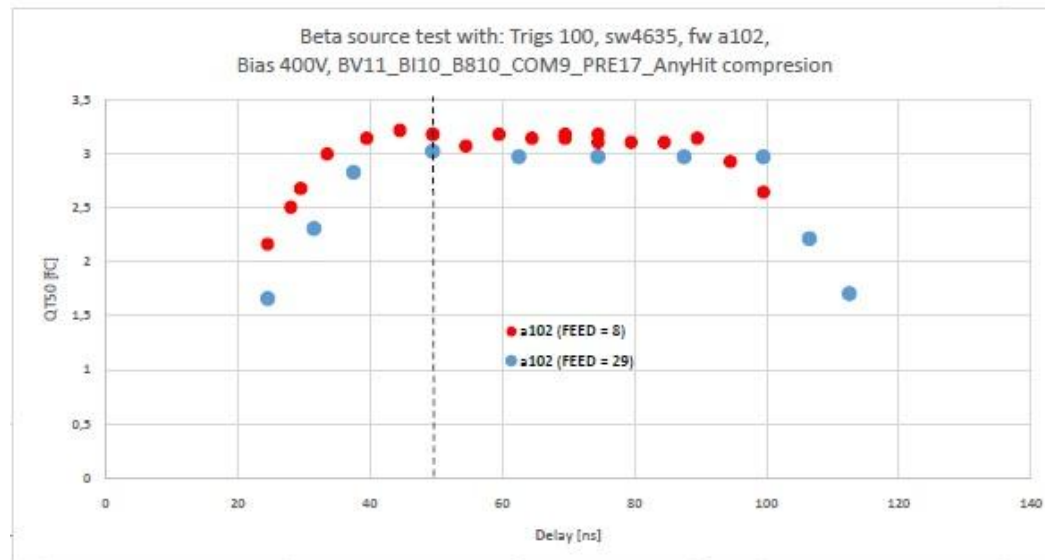
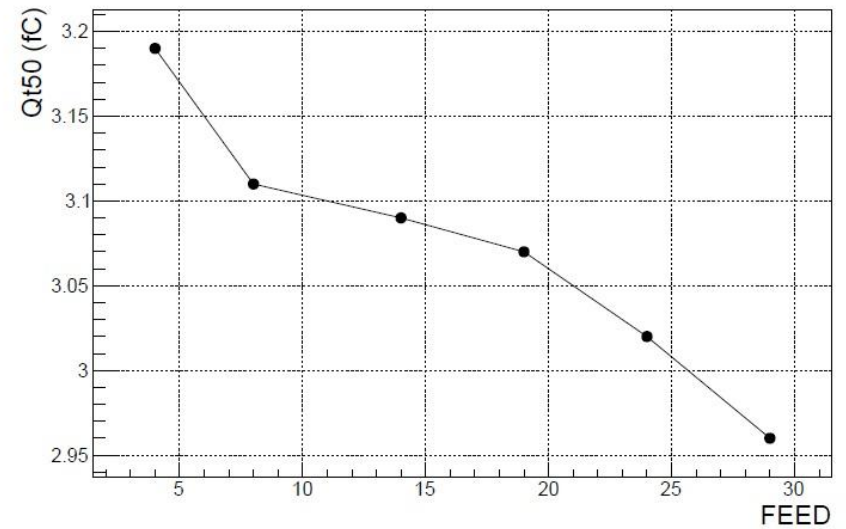
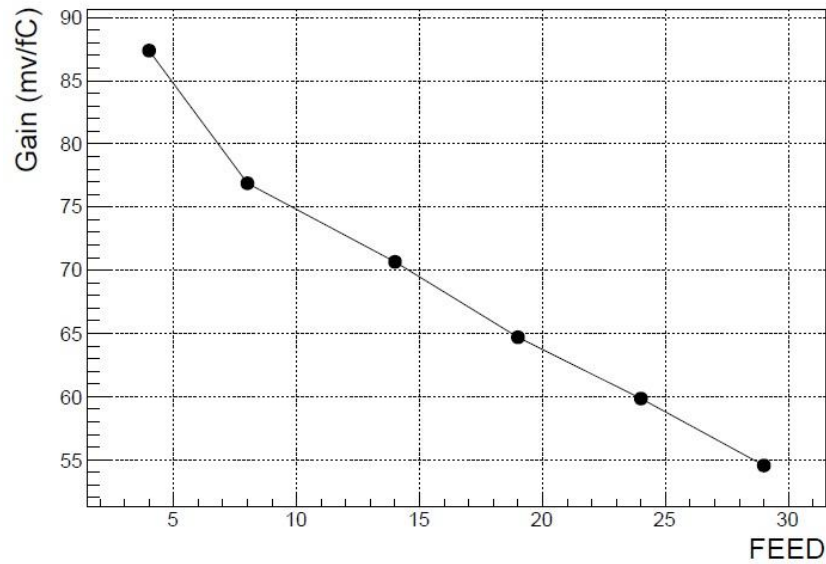
Error Estimation



Error Estimation



FE Parameters



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

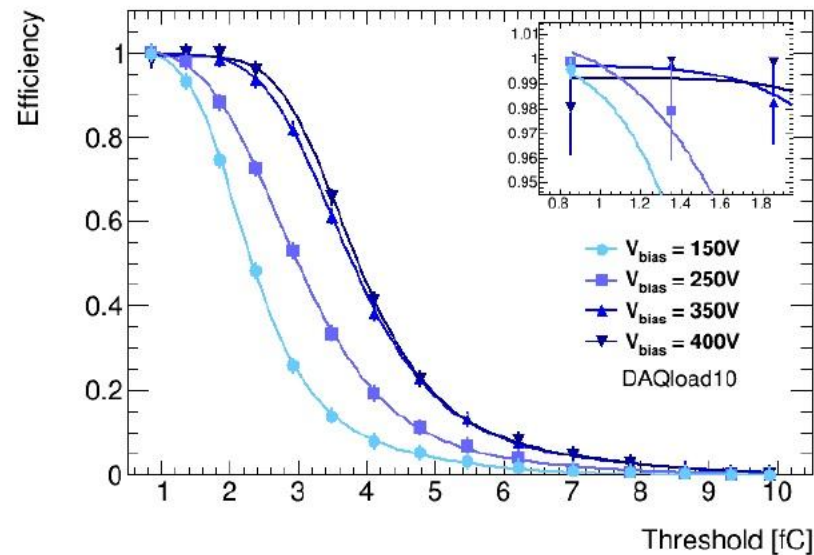
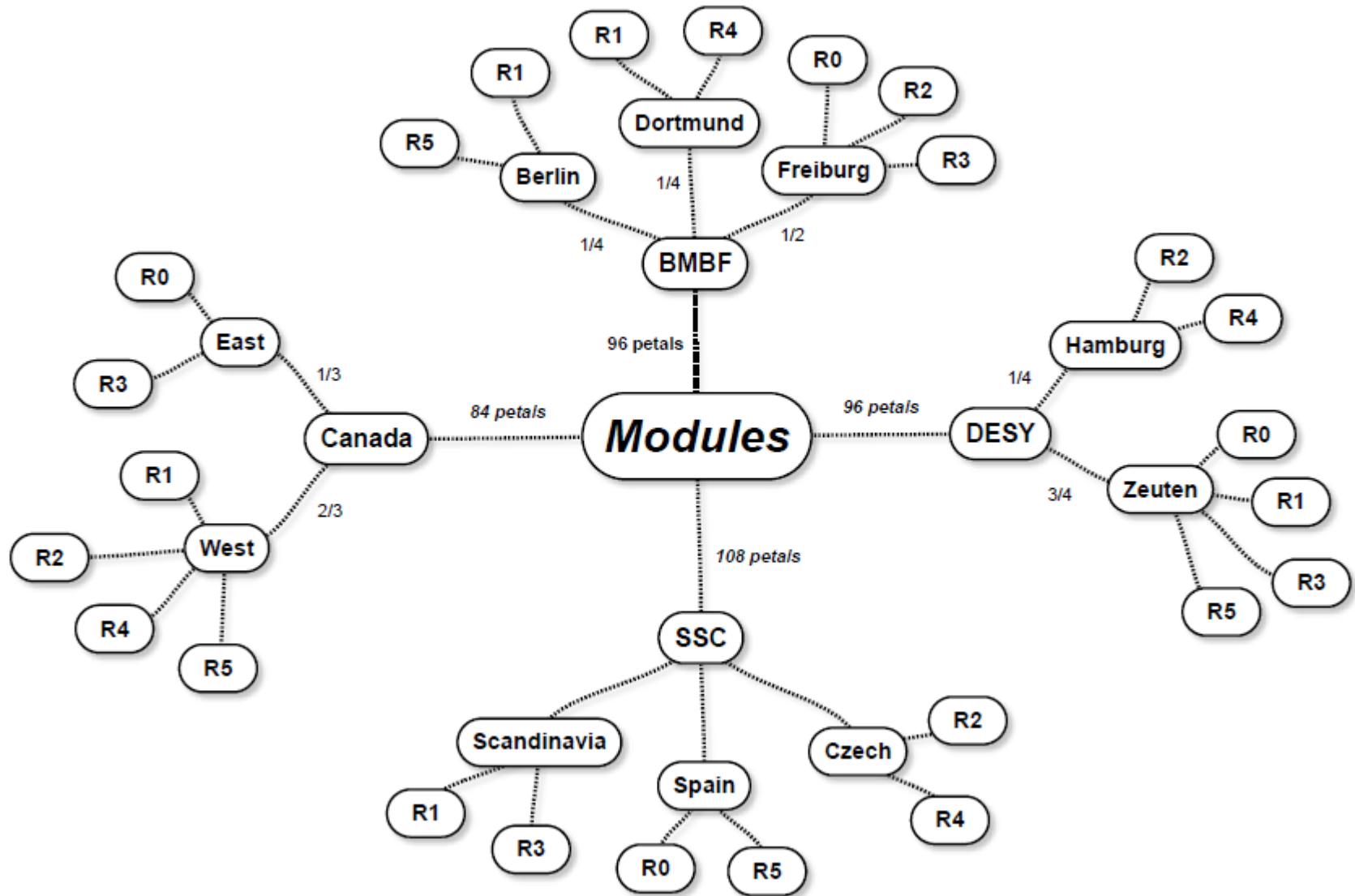
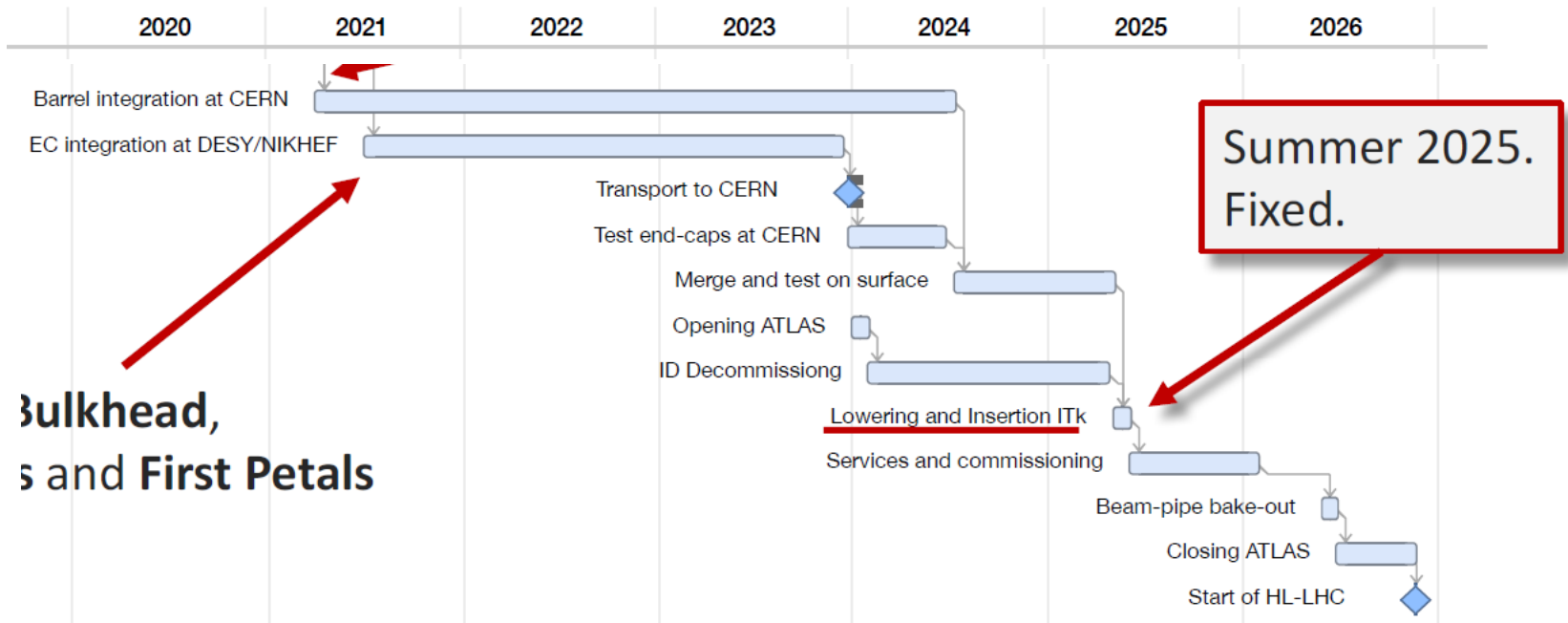


Figure 8.12: Efficiency versus threshold for one sensor on DAQload10, at four different bias voltages.

Production of Petals





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**Summer 2025.
Fixed.**