HEPHY

Institut für Hochenergiephysik

Silicon Strip Detectors for the Large Prototype TPC Test Setup

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This work is performed within the SiLC R&D collaboration.

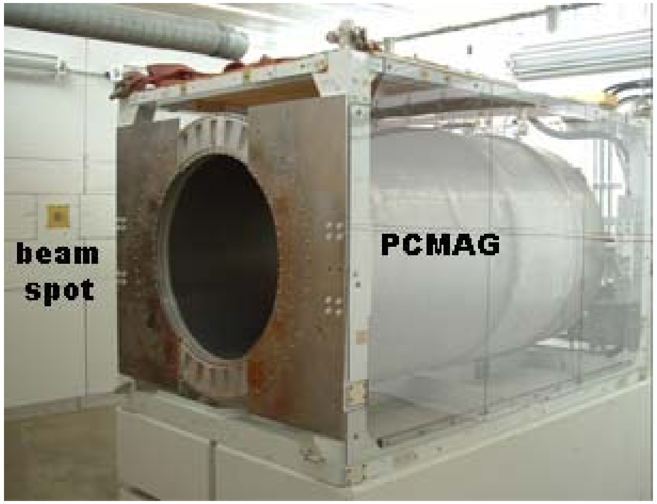
Introduction

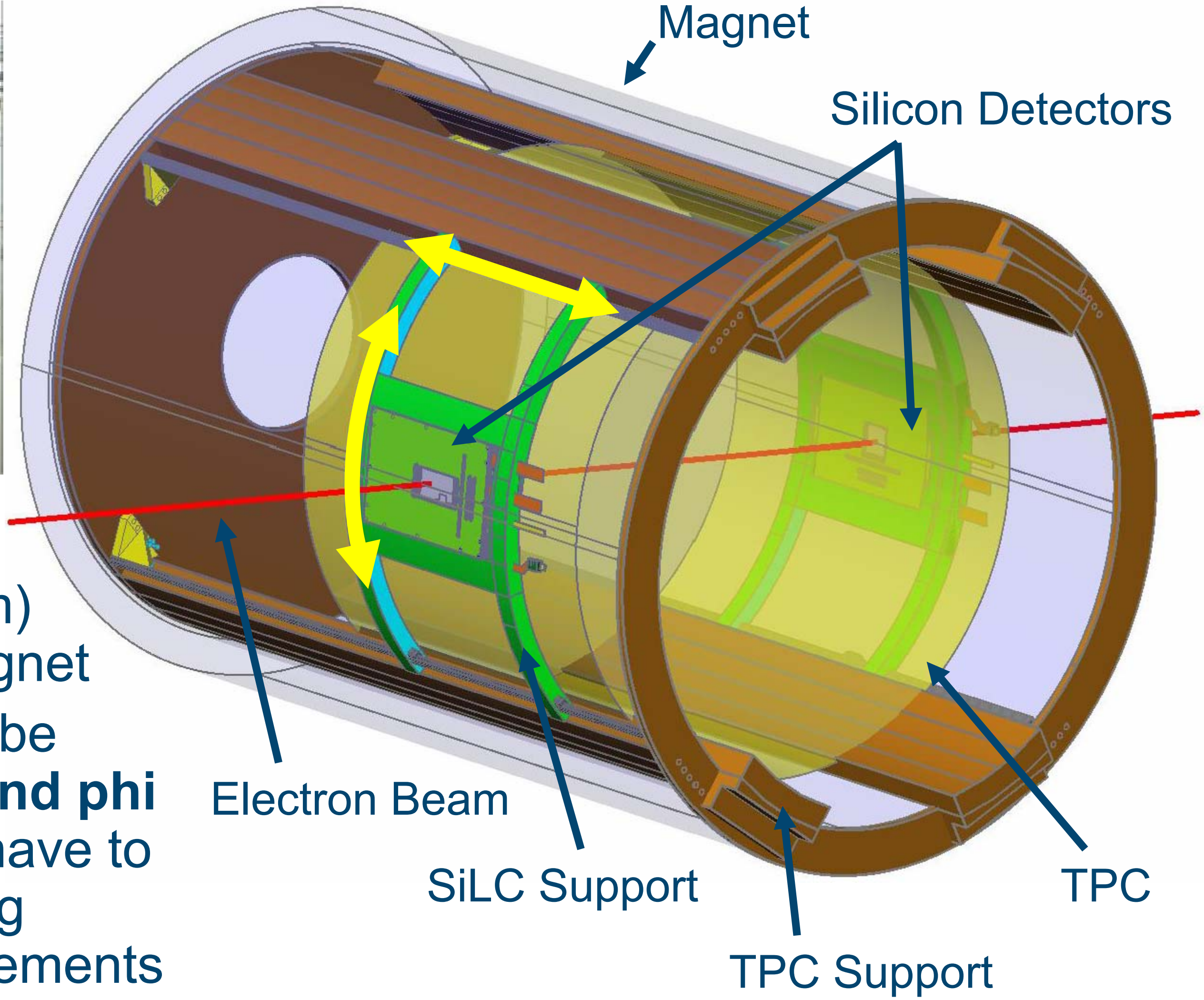
- The SiLC collaboration will participate at the Large Prototype TPC (LPTPC) at the EUDET facility at DESY II.
- SiLC will design, build and install position sensitive detector modules around the LPTPC made of silicon micro strip sensors that can be used as a telescope.
- The design will allow an easily exchange of the modules to enable tests of different sensor- and chip- designs.
- This setup will allow testing a first prototype of a silicon external layer with the TPC prototype.

SiLC Tasks for LPTPC Test Beam

- provide silicon sensors (SiLC)
- design and test silicon sensors (HEPHY)
- build detector modules (HEPHY)
- build mechanical support for modules (IEKP)
- provide data acquisition system
  - short term: adapted CMS readout system (IEKP)
  - long term: new developed silicon tracking DAQ for the International Linear Collider (LPNHE)

LPTPC Setup Overview





challenging task

- **little space** (2 x 35mm) between TPC and magnet
- silicon detectors must be **moveable in both z and phi** because the sensors have to stay in the beam during magnet and TPC movements

Silicon Sensor Design

October 2007: 30 (+5) sensors from HPK, Japan delivered;

6 will be used for the LPTPC setup:

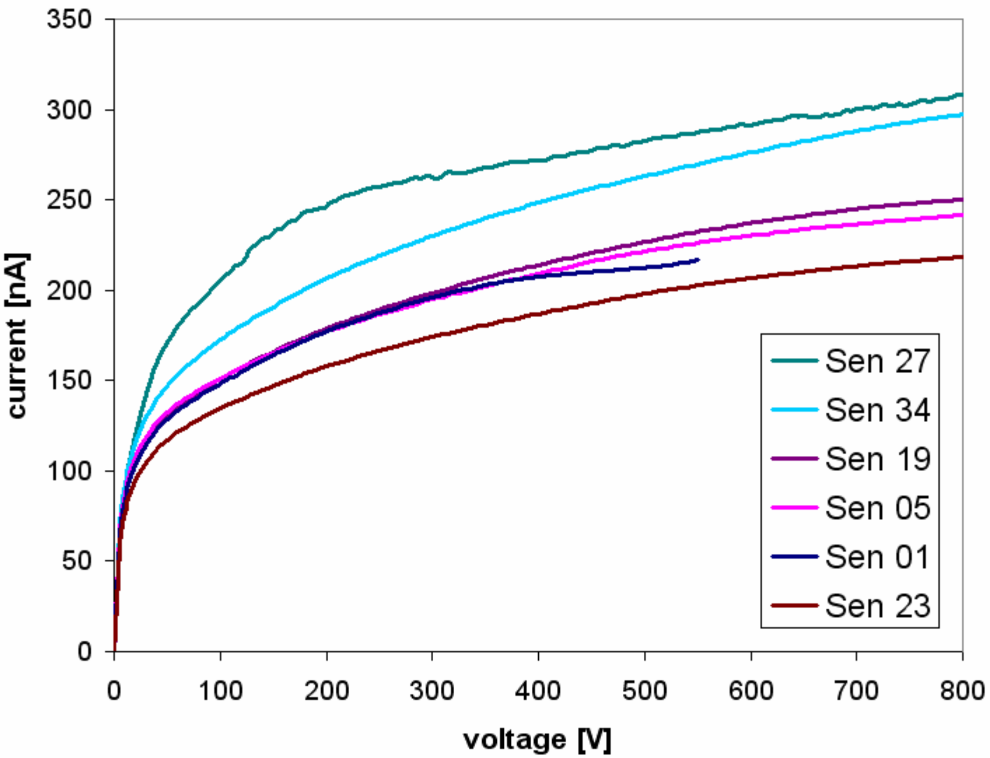
- **single-sided AC coupled silicon strip detectors**
- **sensor size:** 91.5 x 91.5 mm² (± 0.04 mm)
- **wafer thickness:** approx. 320 µm
- **resistivity:** such that depletion voltage: $50\ V < V_{depl} < 100\ V$
- **leakage current:** < 10 µA per sensor
- **number of strips:** 1792 (= 14 x 128)
- **strip geometry:** **pitch = 50 µm** (no intermediate strips)
  strip width = 12.5 µm

> ➢ the SiLC SPS test beam in June 2008 showed that such a sensor has a **spatial resolution of 9 µm**
> (details about the SiLC test beam in talk: “Resolution studies on silicon strip sensors with fine pitch”)

Silicon Sensor Tests*

* here only the 6 sensors used for the LPTPC setup are shown

Sensor	V_{depl} [V]	I_{300V} [nA]	I_{400V} [nA]
27	55	262	277
34	58	230	256
19	50	198	221
05	53	195	216
01	53	196	210
23	50	174	193

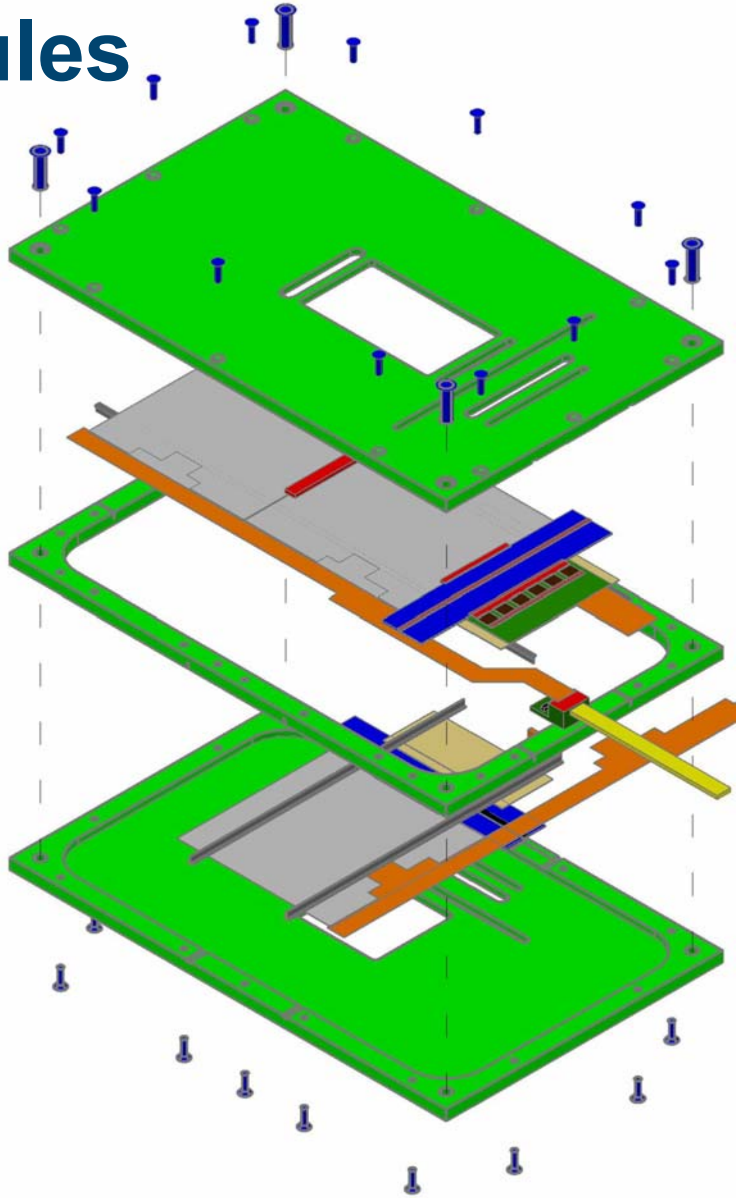


- sensors electrically OK - measurements were approved by IEKP
- sensors can safely be operated by 100V

Detector Modules

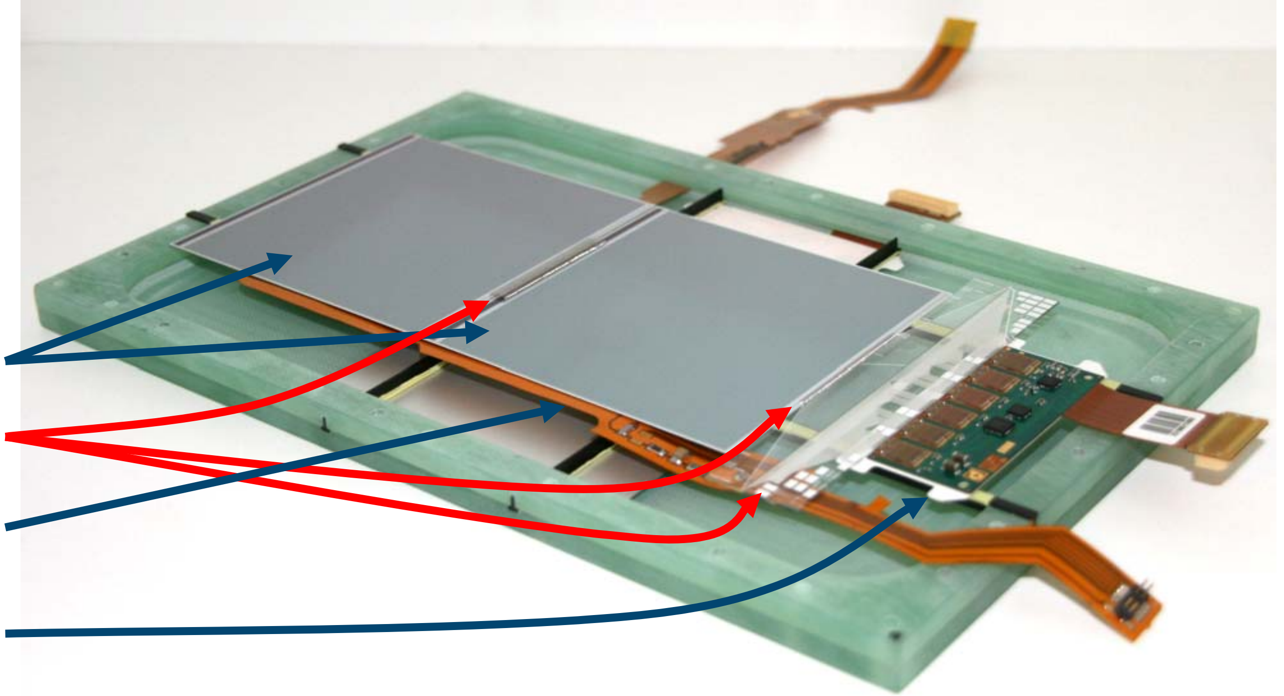
four silicon detectors needed:

- two in front and two behind the TPC, with respect to the beam
  - independent support structures for each side of the TPC are needed
- on each side:
  - one horizontal detector consisting of two daisy-chained sensors (on magnet side)
  - one vertical detector consisting of one sensor (on TPC side)
- angle between sensor strips is 90°



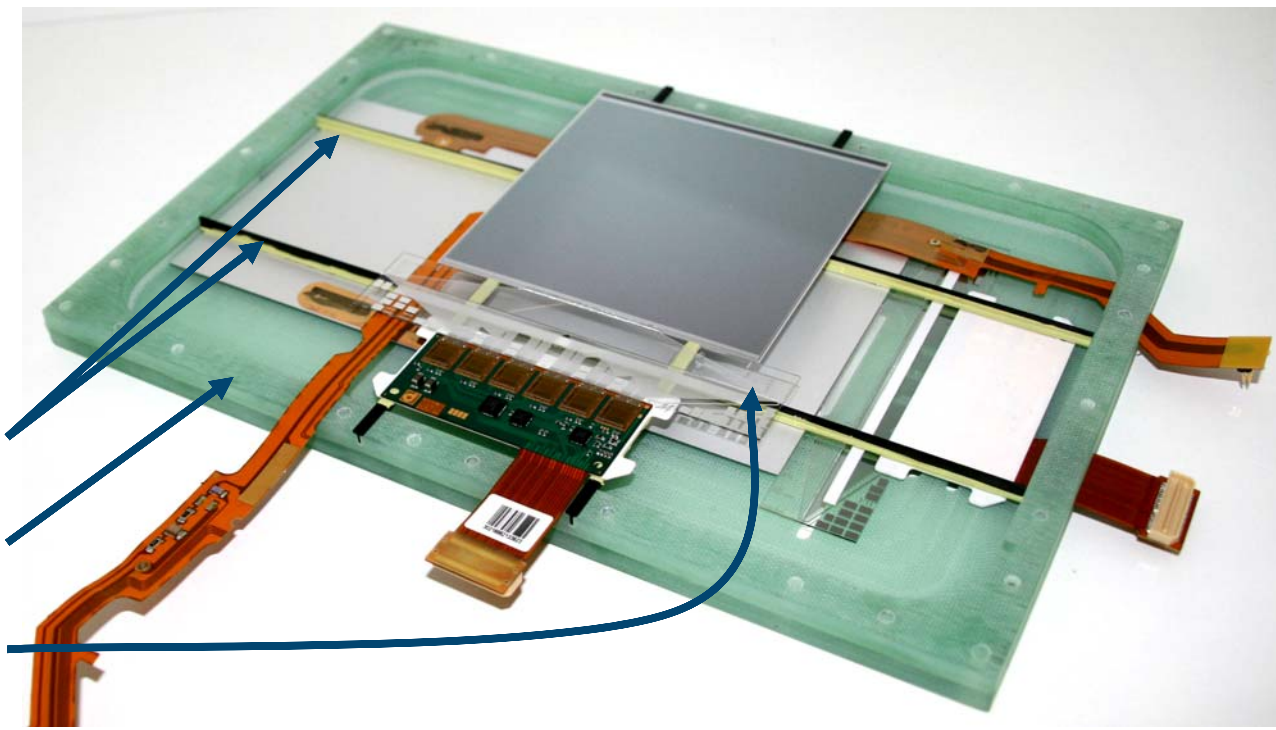
Detector Modules – Components (1)

- **HPK silicon sensors** as described before
- **CMS TEC R2 front-end hybrids** as short term readout – leftovers from the TEC module production – already assembled and bonded
- **CMS TEC R7 Kapton foils** to deliver the HV to the sensor backplane – leftovers from CMS sensor recuperation campaign
- **wire bonds** to connect the different parts with each other



Detector Modules – Components (2)

- aluminium on quartz **Intermediate Pitch Adapter** to connect the CMS R2 pitch of 143 μm to the readout strips of the HPK Sensor with a pitch of 50 μm - Helsinki Institute of Physics (HIP)
- two **carbon fibre T-beams** are the backbone of each silicon detector – 2 rectangular beams from SECAR Technologies glued together
- **Isoval11 frame**: a composite of resin epoxy reinforced with a woven fibreglass mat



carbon fibre T-beams

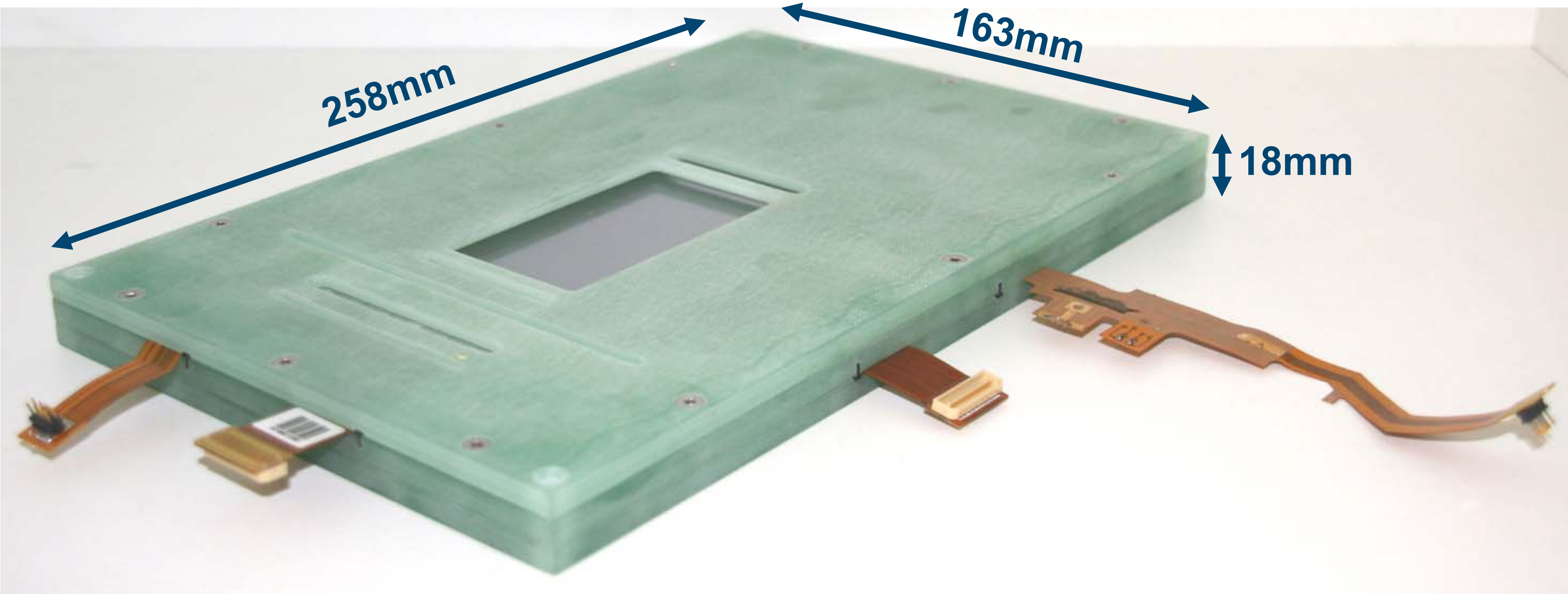
Isoval11 frame

Intermediate PA

Detector Modules

finally the detector modules just have a **thickness** of **18 mm plus** about **2 mm** for a light-tight adhesive foil

- ➢ safety clearance of 4 mm to the TPC and the magnet

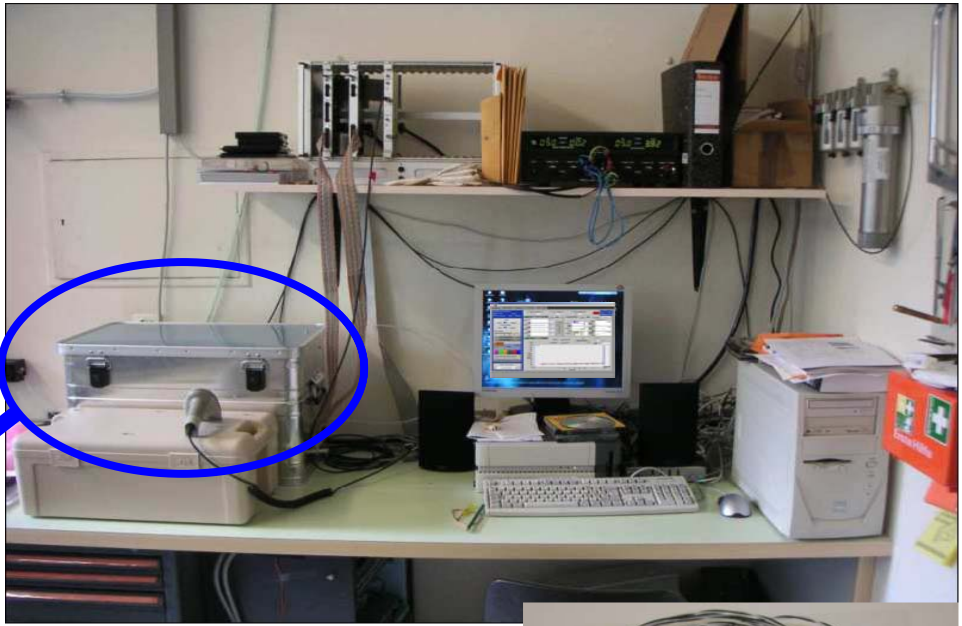


Detector Modules – Electrical Tests (1)

electrical test system:

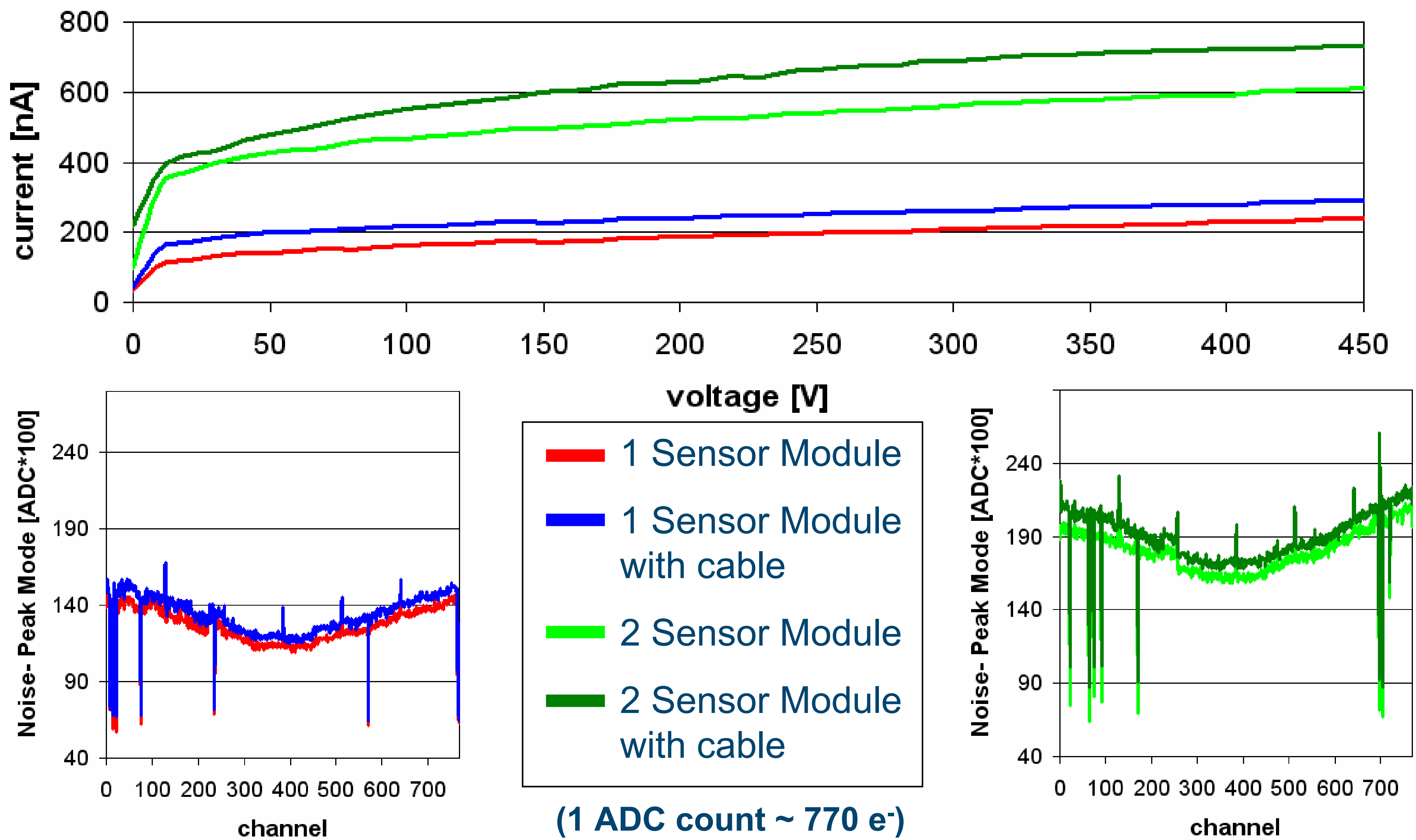
APV **R**eadout **C**ontroller System

(developed by RWTH Aachen for the CMS module production QA)



in the LPTPC setup the signals have to be delivered to the readout electronics via 2 m long twisted pair cables (adapter cards had to be designed)

Detector Modules – Electrical Tests (2)

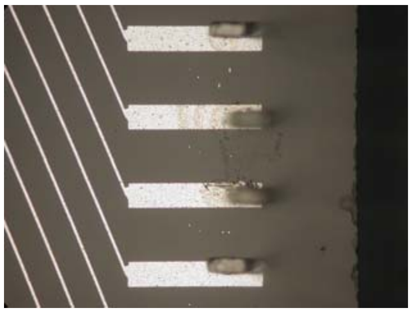
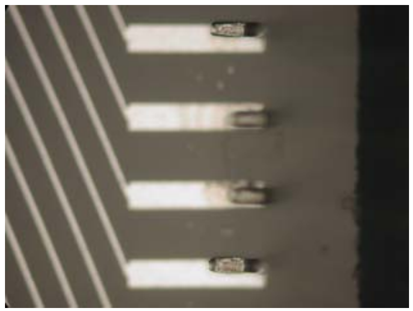


(1 ADC count ~ 770 e$^-$)

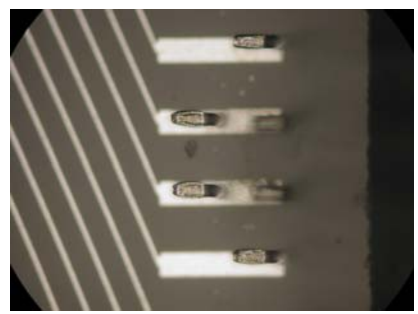
Detector Modules – Electrical Tests (3)

all investigated failures are due to the Intermediate PA

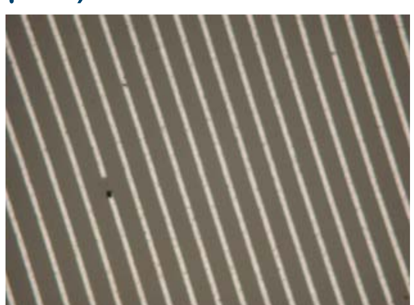
dirt on bond pads -> bonds making no connections (opens)

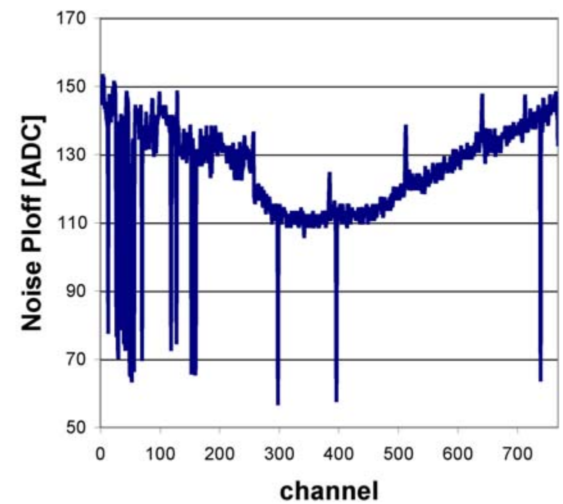

rebonding helps



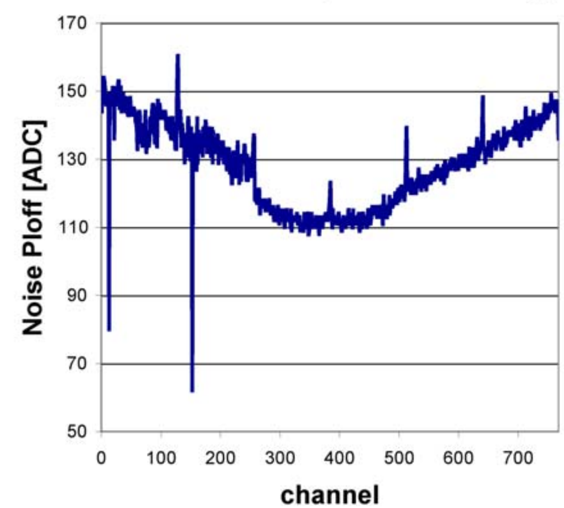
opens on the PA are not repairable (width of Al lines 10 μm)

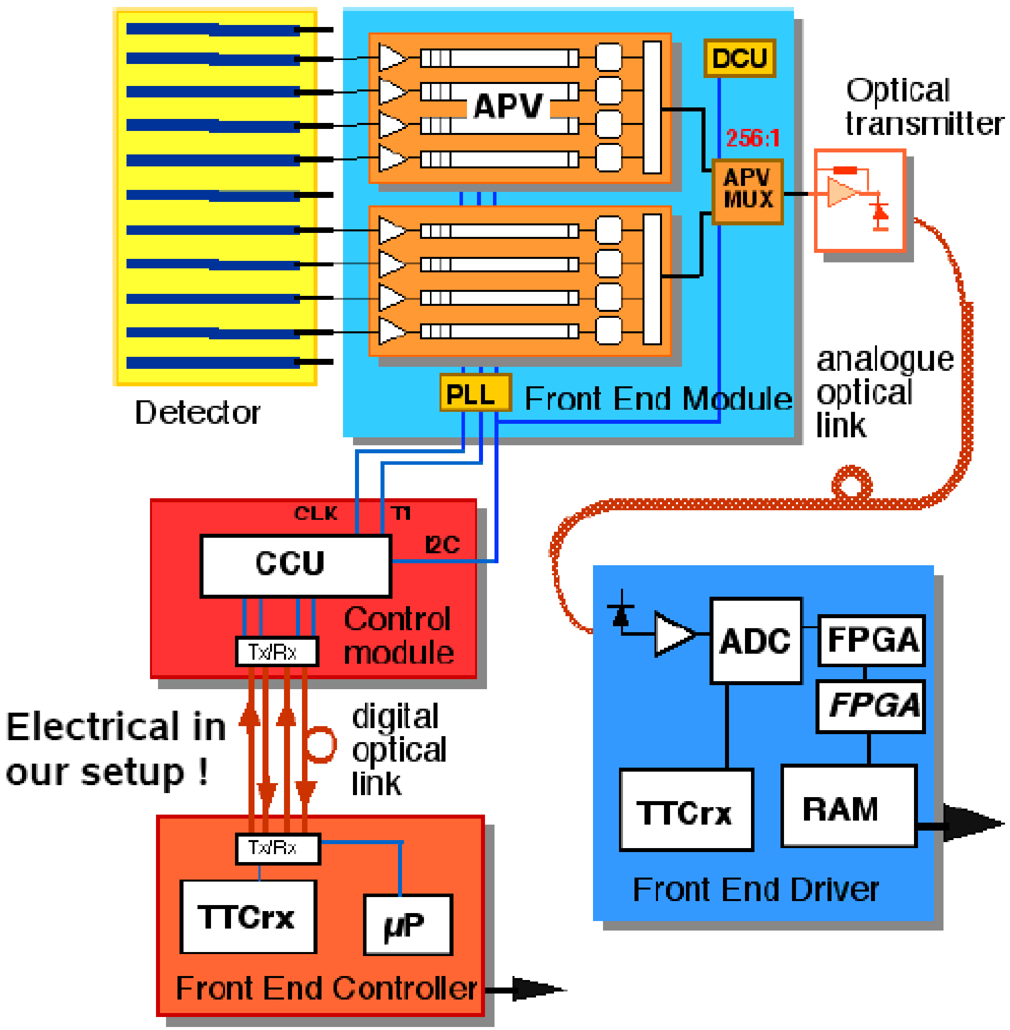
2nd 1-Sen Detector (before rebonding)



2nd 1-Sen Detector (after rebonding)

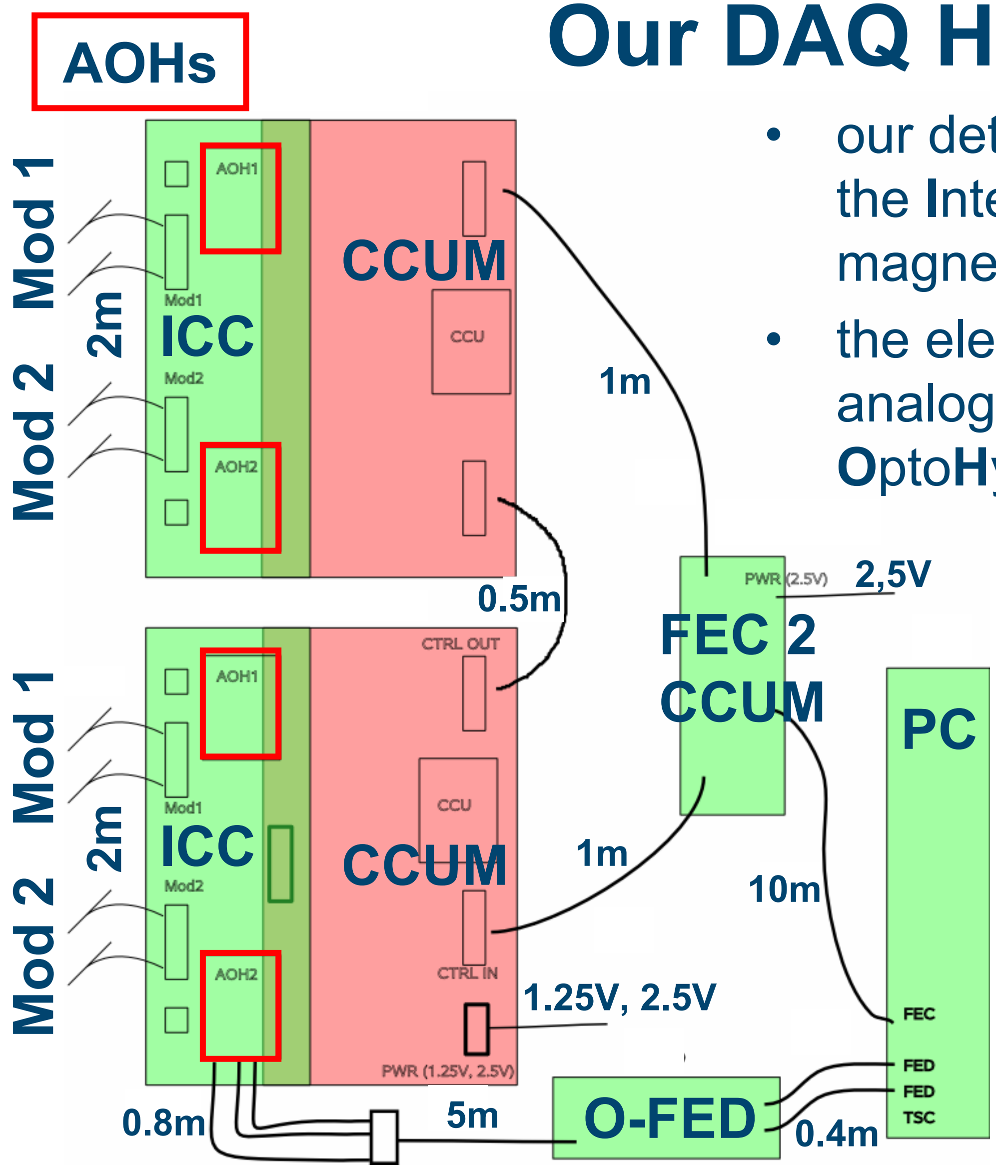


Schematic of CMS Tracker DAQ



- the CMS Readout System is build on the **xdaq framework**
- the **Front End Controller** (FEC) steers the **Central Control Units** (CCU) which provide I²C control sequence and clock for the APV readout and controls
- the electrical signals from the **APVs** get multiplexed and transferred to the **Front End Driver** (FED) via analogue optical links

Our DAQ Hardware



- our detector modules will be connected to the **I**nter **C**onnect **C**ards (outside the magnet) via 2 m long twisted pair cables
- the electrical signals get converted to analogue optical signals in the **A**nalogue **O**pto**H**ybrids and transferred to the **F**ront **E**nd **D**river via 5 m long optical links
- the **F**ront **E**nd **C**ontroller steers the **C**entral **C**ontrol **U**nits on the **C**entral **C**ontrol **U**nit **M**odules via a 10 m long electrical cable
- the CCUs control the APV-chips on the front end hybrids

(by Alexander Dierlamm)

Our Data Output

- two kind of root data files can be produced:
  - data associated to modules
  - data associated to FED channels
- these root data files will hold the trigger number in their headers (the trigger number is produced by the Trigger Logic Unit (TLU) and provided to all LPTPC subsystems by the so-called Distributor Box)
- the raw data contain ADC counts for each strip
- need pedestal subtraction and common mode correction
- then cluster search, which gives hit strip positions
- together with positioning information one can obtain tracks
- then the file must be converted to LCIO format and written to a common LCIO file

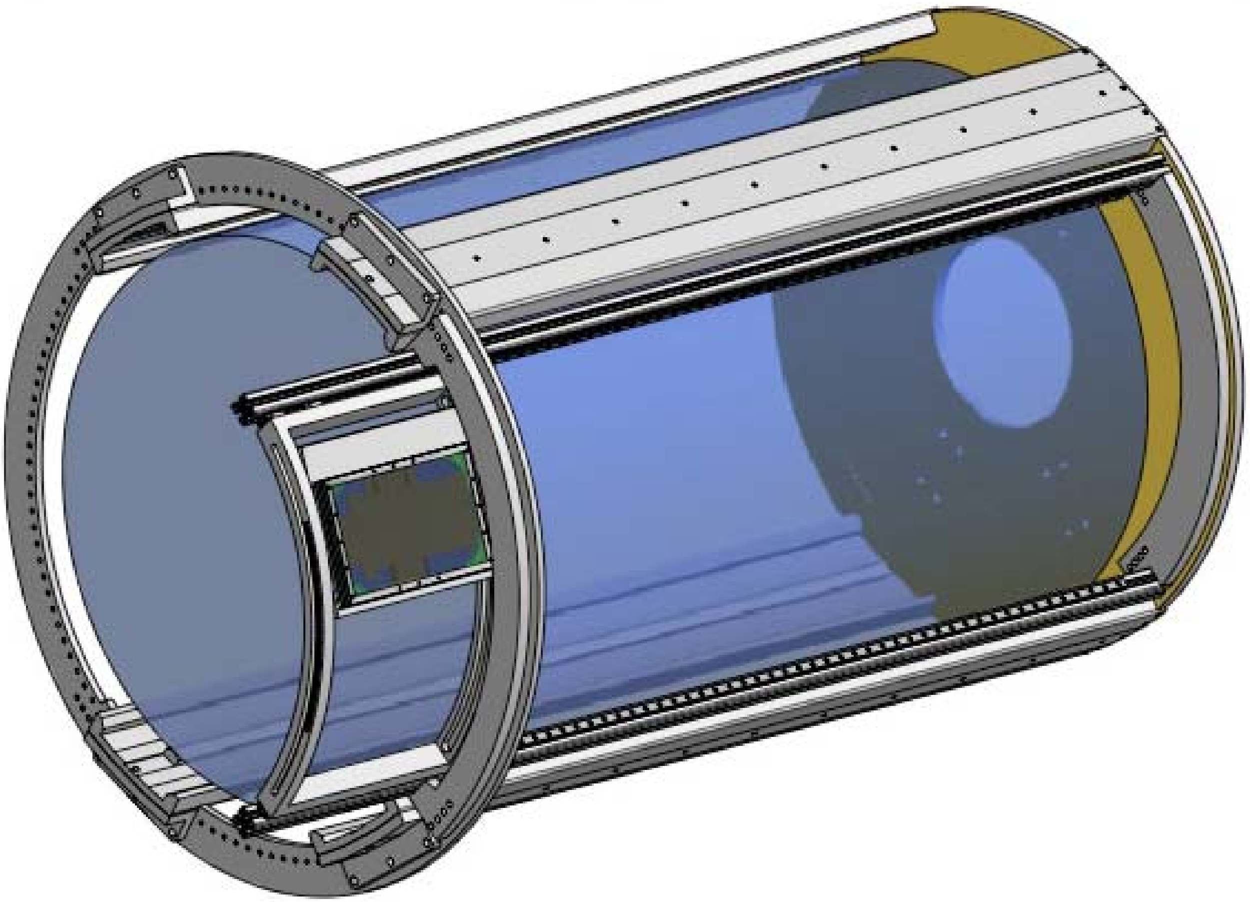
ALL THIS WILL BE OFFLINE!!!

(by Alexander Dierlamm)

Mechanical Support

- TPC support structure is already installed in PCMAG (threaded holes for the SiLC support are already foreseen)
- IEKP has started with designing and building the moveable support structures for both sides:

  a sledge containing the SiLC module can be moved on two rails screwed on the TPC support (everything made of nonmagnetic material)



Next Steps

Mechanical Support:

- Finalise the design and build the moveable support structure.

Detector Modules:

- Investigate all faulty channels and repair everything possible.
- Ship the detector modules to IEKP for electrical tests in the final DAQ system.

Data Acquisition:

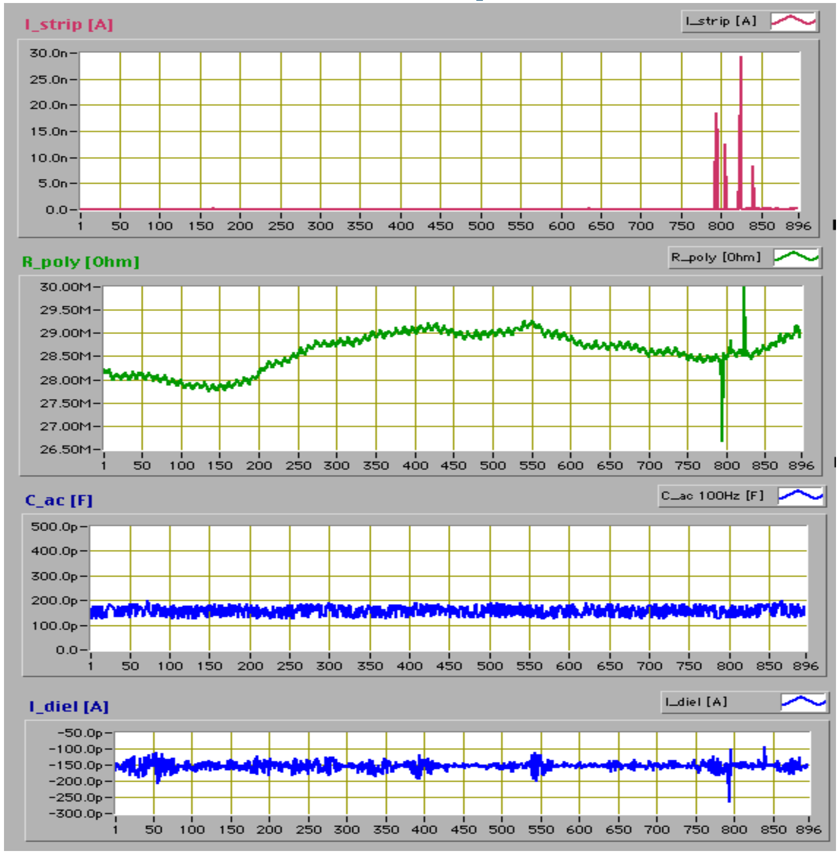
- Finalise the adapted DAQ system.
- Find a way of integrating the Trigger information from the Distributor Box (TLU) into the root header.
- Develop a possibility to merge our data with the data from the other LPTPC subsystems (LCIO based)?

Integration of the silicon modules into the LPTPC setup for combined data taking in February 2009.

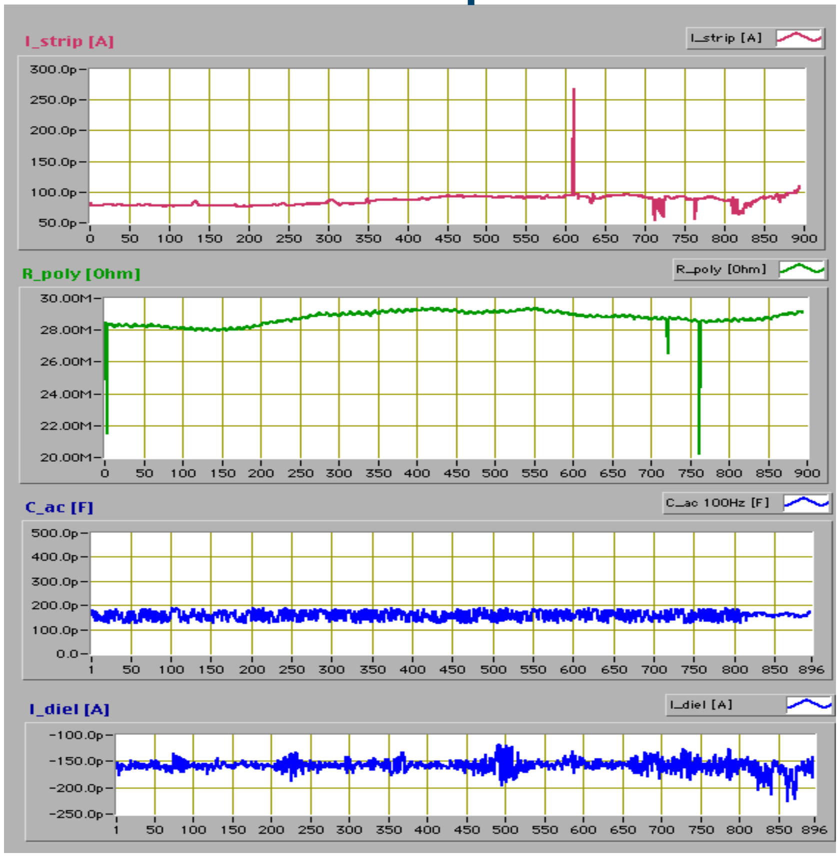
Thank you very much!

HPK Sensors: Strip Scan Results

Even strips



Odd strips



I_strip

R_poly

C_ac

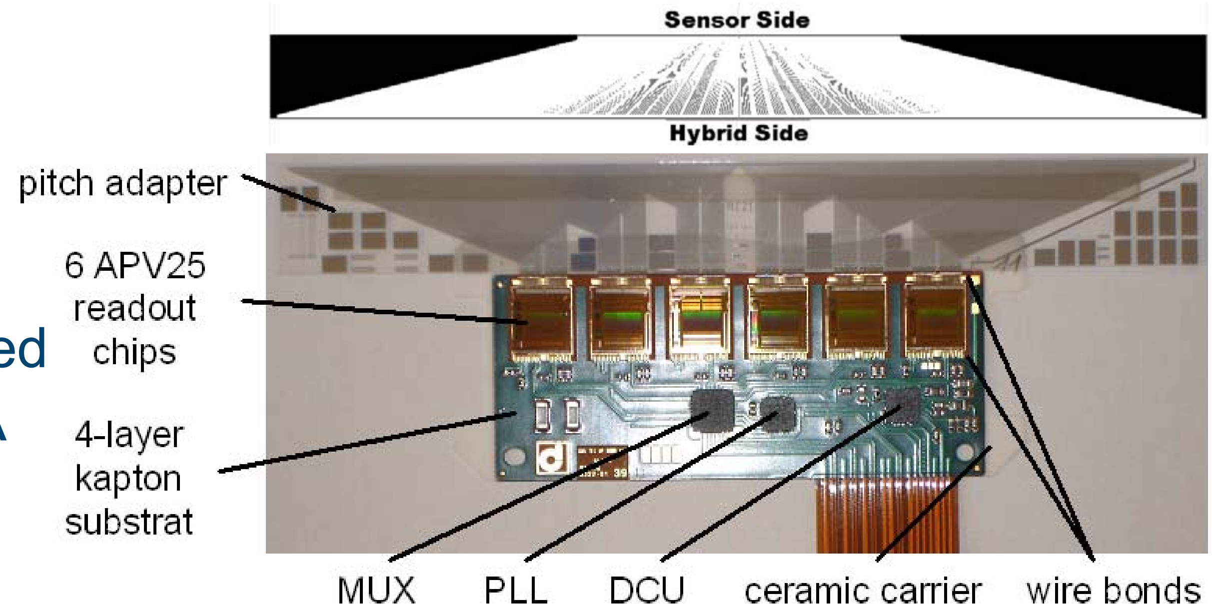
I_diel

Single Strip Current: I_strip = 137 pA	Poly Si-Resistor: R_poly = 28.65 MOhm
Coupling Capacitance: C_ac = 156 pF	Dielectric Current: I_diel < 160 pA

Detector Modules – Components (3)

CMS TEC R2 Front End Hybrid is already glued and bonded to Pitch Adapter

-> Intermediate PA required (aluminium on glass PA produced by HIP)



Wire Bonding:

- standardised ultrasonic wire bonding with a Delvotec 6400 automatic bonding machine
- aluminium wires: 25 µm diameter including 1% silicon bonded with a 17 µm bonding jig