A Silicon Strip Recoil Detector for Momentum Measurement and Tracking at HERMES

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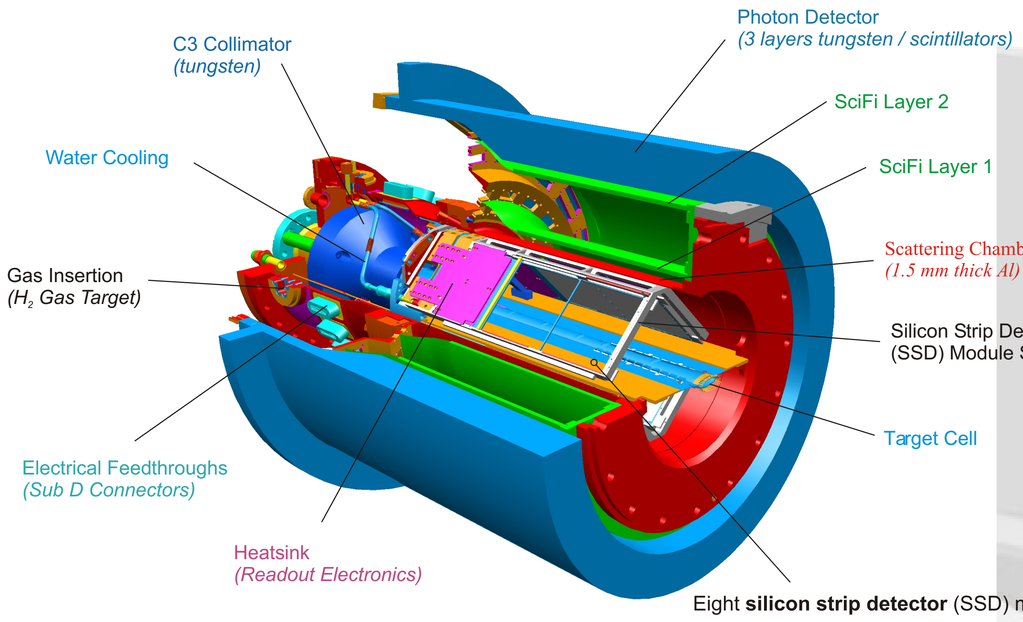
The HERMES Recoil Detector

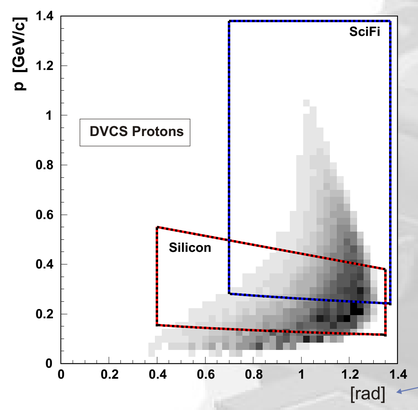
A **recoil detector** will be installed to the HERMES experiment at DESY .
- HERMES : a fixed target experiment with 27.5 GeV electrons/positrons.
- Detection of **protons** from Deeply Virtual Compton Scattering (DVCS).



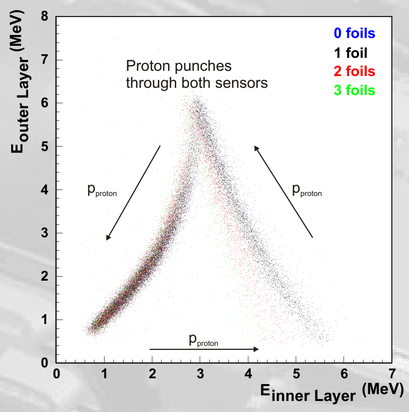
The surrounding magnet (1 Tesla) is not shown.

Eight **silicon strip detector** (SSD) modules in two layers around the elliptical Gas **Target Cell.** Sensors are not shown.

Azimuthal coverage of 76 % and an almost complete polar angular coverage.



Recoil proton momentum versus polar angle (with respect to the beam). The boxes indicate the acceptance of the silicon and SciFi detector.



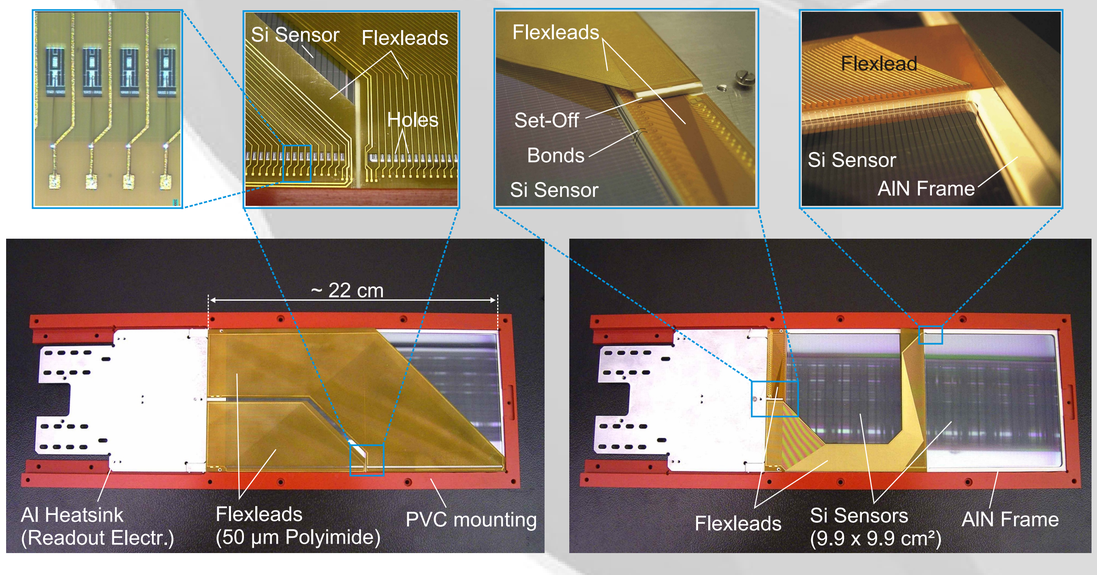
Energy deposition of protons within outer layer of silicon sensors versus the deposition in the inner layer.

Expected recoil proton momenta : from 135 MeV/c up to 1.4 GeV/c.

Deposited energy is a steep function of momentum (**1/ ² area of Bethe Bloch)** ⟶ Momentum measurement !

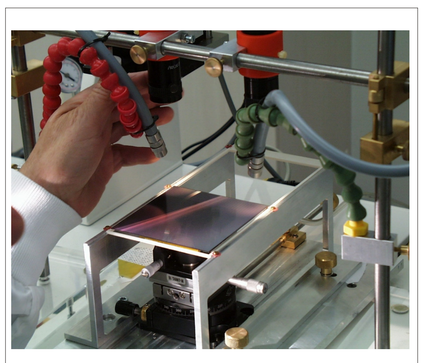
The placement of the silicon detector into the vacuum requires the compatibility of all detector components with a **vacuum of 10^{-9}** mbar.

Silicon Strip Detector (SSD) Module and Assembly



Top Side — Bottom Side

Two silicon strip sensors with the same strip orientation are mounted in an AlN ceramic frame.
The interconnection to the silicon sensors is realised by polyimide flexleads.



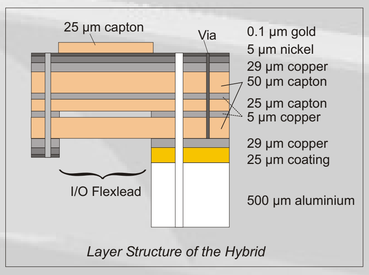
Assembly of the sensors into the ceramic frame

Silicon Sensors :
- **300-µm thick TIGRE** detectors from Micron Semiconductors.
- Size : 9.9 x 9.9 cm².
- 128 strips per side with a **pitch of 758 µm** (perpendicular) for **particle tracking**.
- Measured resolution : 222 µm (excellent agreement to calculations with 219 µm).

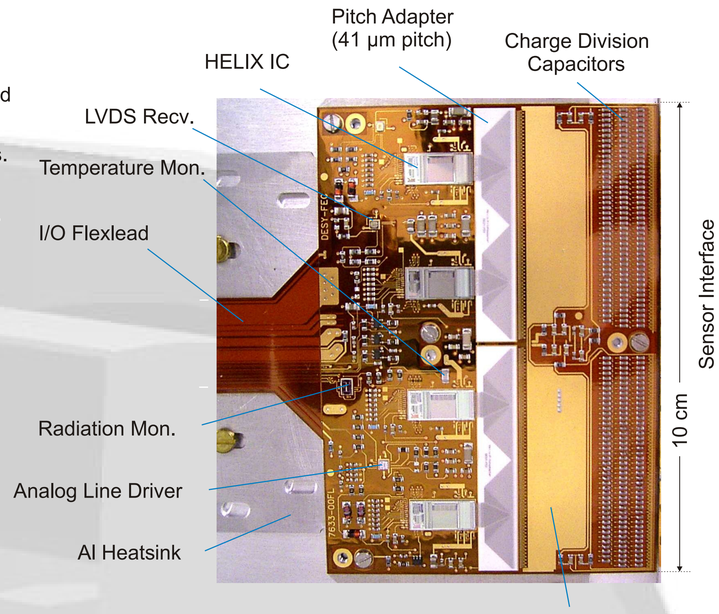
Sensor's Frame :
- Aluminium nitride ceramic Shapal M
- Excellent machinability
- Thermal expansion coeff. very close to that of silicon

Flexleads :
- 50 µm polyimide with 5 µm copper traces.
- 390 x 990 µm² large holes (laser cut) for bonding
- Gluing onto the frame with **supported preforms** :

The readout electronics (Hybrid) :
- Hosts the analog signal processing and digital control circuitry.
- Four layer design with polyimide cores.
- The flexible part (I/O Flexlead) forms the interface to the outer electronics.

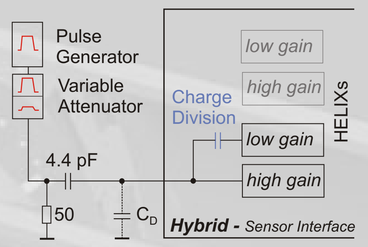


Layer Structure of the Hybrid



The analog readout IC HELIX 3.0 with 128 channels is used.
Sampling and readout rate of 10.4 MHz is applied.
The **power dissipation** per hybrid amounts to 2200 mW (8.6 mW/channel).
A special **charge division setup** enables an **input dynamic range** from 8 fC (S/N ratio of 13) up to 270 fC.

Charge Injection Test of Hybrid



For the **charge division** between 'high gain' and 'low gain' HELIX the capacitor values **4.7 pF, 10 pF and 22 pF** are used.

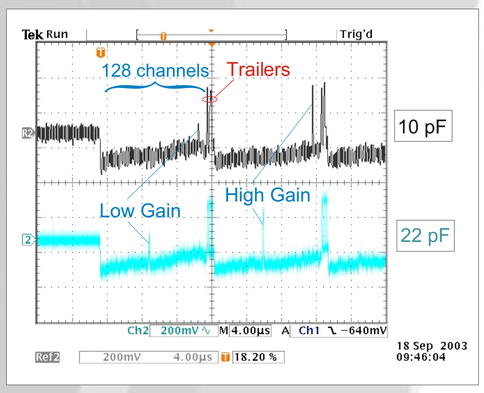
A pulse generator is connected via a variable attenuator and a 4.4 pF capacitor to the hybrid (Sensor Interface).

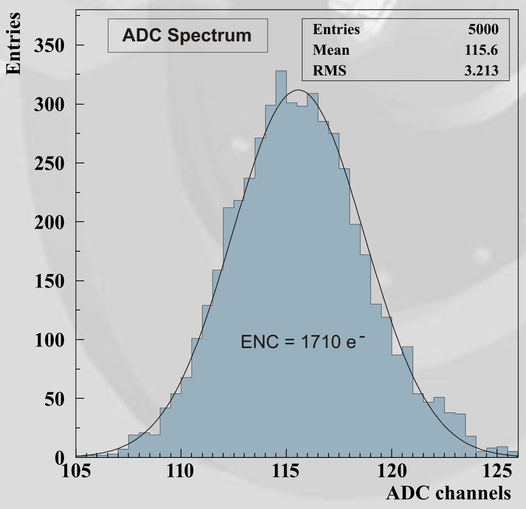
Measurement of **dynamic input range**, **crosstalk** and the **equivalent noise charge (ENC)**.

The hybrid's analog output :
- Sequential readout of 128 analog channels, followed by :
- 8 bit trailer (event number information).
- Trailer height : 96,000 electrons (15.4 fC).

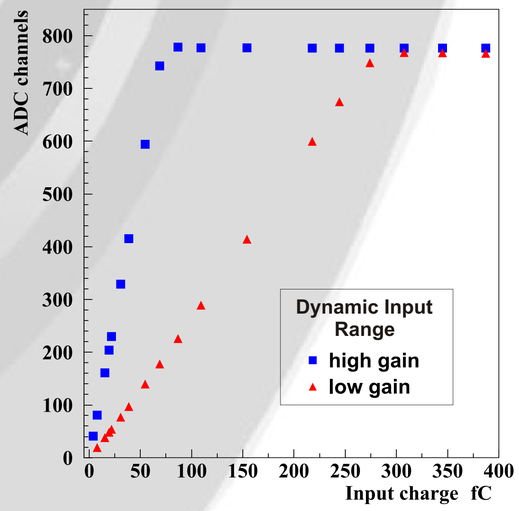
The injected **signal charge** of 22 fC divides up between high- and low-gain HELIX :
- for 4.7 pF in the ratio 7.4 : 1
- for 10 pF in the ratio **4 : 1**,
- for 22 pF in the ratio **2.4 : 1.**

The **signal-to-noise ratio** is **6.8** for **3.84 fC** input charge.





Measured output spectrum of the hybrid (A/D resolution 10 bit). The ENC (root-mean-square value of the spectrum) results in 1710 electrons (average value).



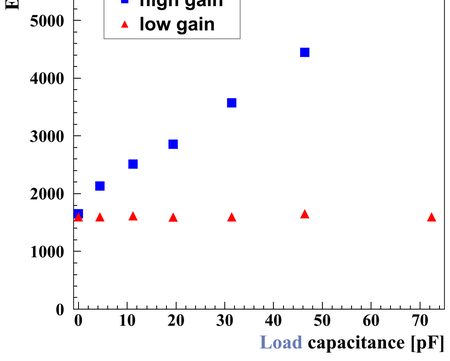
Measured **total dynamic input range** for a coupling capacitor of 10 pF. The dynamic range is improved by a factor of five to 270 fC.

The **Noise (ENC)** of only the HELIX : **460 (e^-) + 47 (e^-) * C_D/pF**
with C_D : detector **(load)** capacitance
(e^-) : number of electrons.

HELIX on hybrid :
The **noise of the low-gain HELIX** is independent of the connected capacitance value.
Reason : Charge division capacitor in series to the load.

The **noise of the high-gain HELIX** increases linearly with **56 electrons per pF** (good agreement to the theoretical value of 47 (e^-)/pF).

The **lower ENC limit** is determined by the charge division **setup**.



Conclusion

- The developed assembly procedure (sensors) is feasible.
- The hybrid fulfils all electrical requirements concerning dynamic input range and noise.
- The production of the **complete HERMES silicon recoil detector starts now.**

Future Plans :
- **Laser test stand** : Crosstalk, check of all channels.
- 10 MeV **Proton test beam** : exact energy calibration.

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