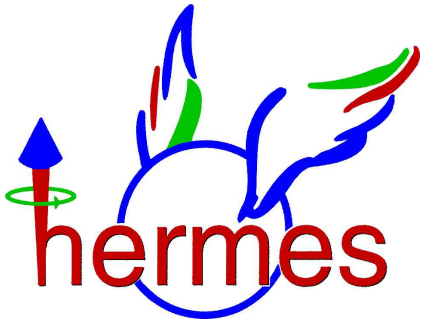
A Silicon Recoil Detector for the HERMES Experiment

A. Vandenbroucke

University Gent



INW inside-out

Outline

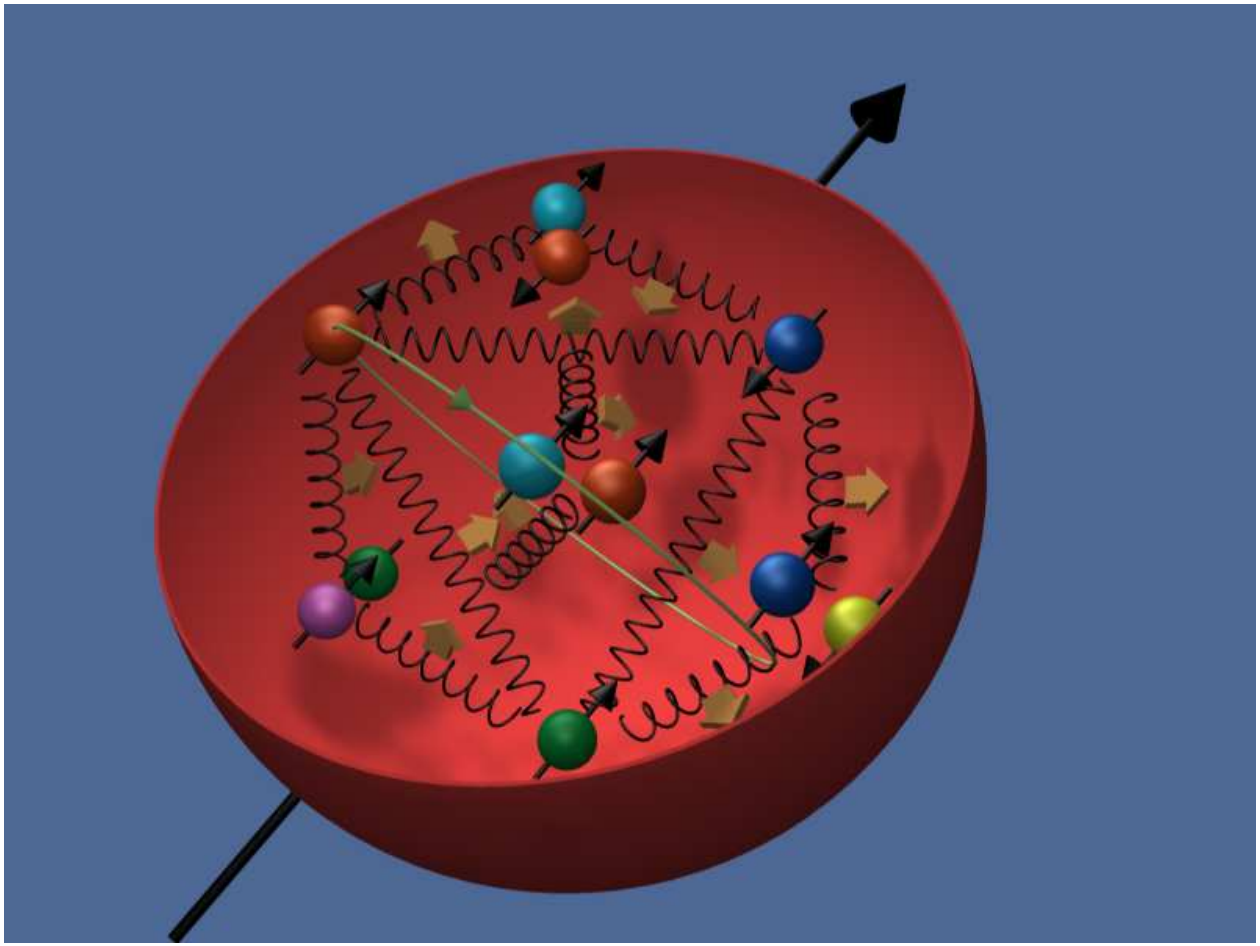
1. The HERMES Experiment
2. A proton's Structure
3. Recoil Detector
4. Silicon Recoil Detector
   - ➡ Sensors, Frame, Hybrid, Foils, Tests
5. Summary

The HERMES Experiment

➜ HERA
ME asurement
of Spin

- ➜ Experiment at DESY Hamburg
- ➜ 27,5 GeV longitudinally polarised $e^{\pm}$ from HERA accelerator
- ➜ Spin like Charge fundamental property

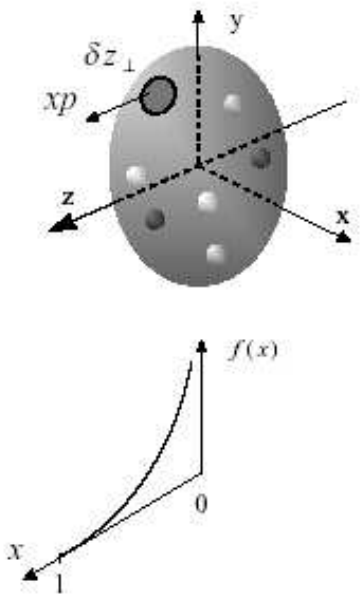
Determining a proton's structure

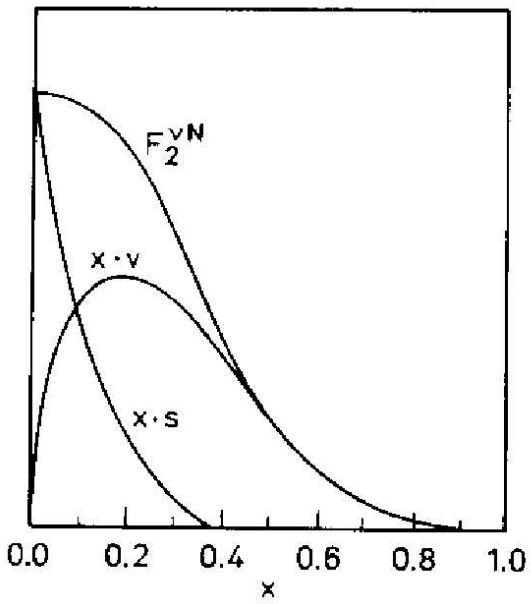


$$\frac{1}{2} = \Delta\Sigma + L_q + J_g$$

Determining a proton's structure

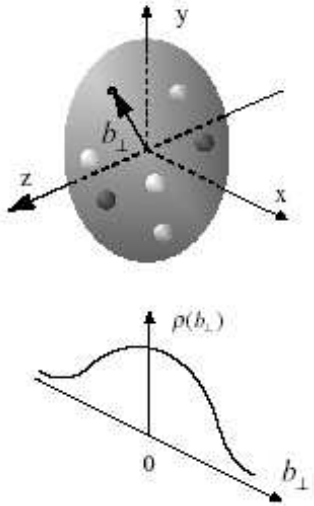
- Deep Inelastic Scattering: $e + p \rightarrow e' + X$
- Leading to Structure function $F_2(x, Q^2)$
- Interpretation: probability to find a quark with momentum fraction x





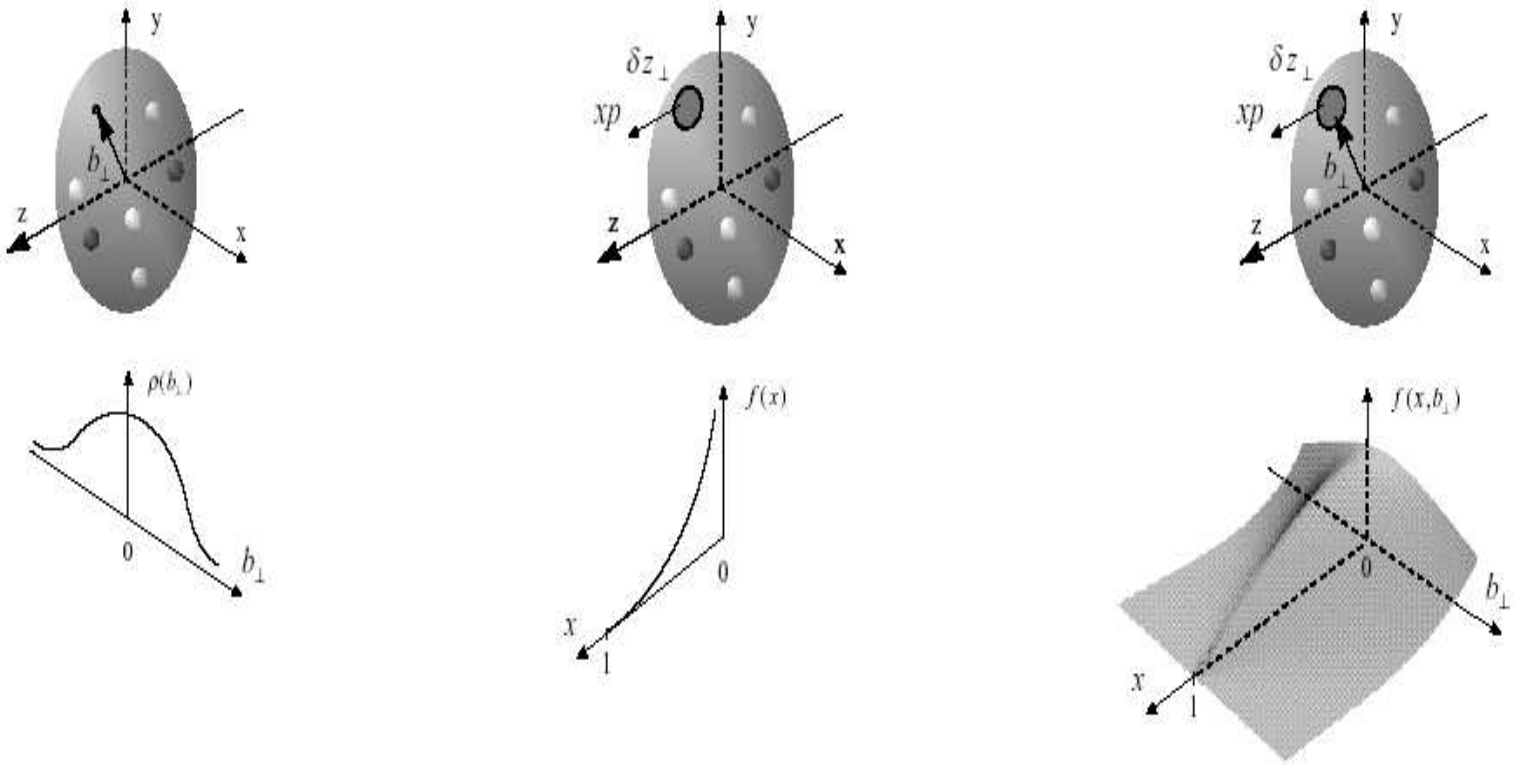
Determining a proton's structure

- Elastic Scattering: $e + N \rightarrow e' + N'$
- Leading to Form Factors (eg Electromagnetic)
- Interpretation: eg Charge Distribution



Towards GPD's

- An *understandable* picture: The Infinite Momentum Frame



Towards GPD's

Exclusive processes give access to Generalised Parton Distribution functions

- 4 for each flavor q: $H, E, \tilde{H}, \tilde{E}$
- Variables $H(x, \xi, t)$:
  - longitudinal momentum fraction x
  - ξ skewedness (2ξ long. mom. transf.)
  - $t = (p_p - p_{p'})^2$ related to transverse momentum transfer

Towards GPD's

- Related to 'classical' distribution functions and form factors:
  - $H^q(x,0,0) = q(x)$
  - $\tilde{H}^q(x,0,0) = \Delta q(x)$
  - $\int_{-1}^{1} dx\,(H^q(x,\xi,t)) = F_1^q(t)$
  - $\int_{-1}^{1} dx\left(E_u(x,\xi,t) - \tilde{E}_d(x,\xi,t)\right) = F_2^q(t)$

Towards GPD's

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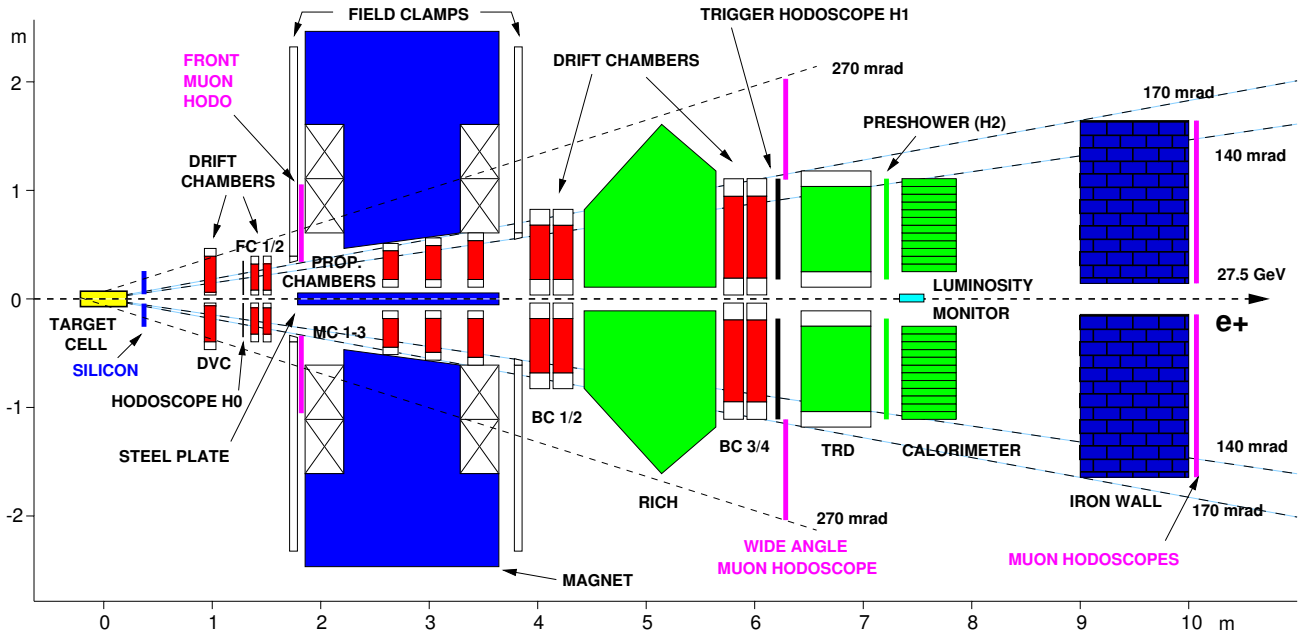
  - $\int_{-1}^{1} dx\left(E_u(x,\xi,t) - \tilde{E}_d(x,\xi,t)\right) = F_2^q(t)$

- Routes to total angular quark momentum

$\mathbf{J^q}(= \frac{1}{2}\Delta\Sigma + L_q) = \lim_{t\to 0} \frac{1}{2}\int (H^q + E^q)x dx$

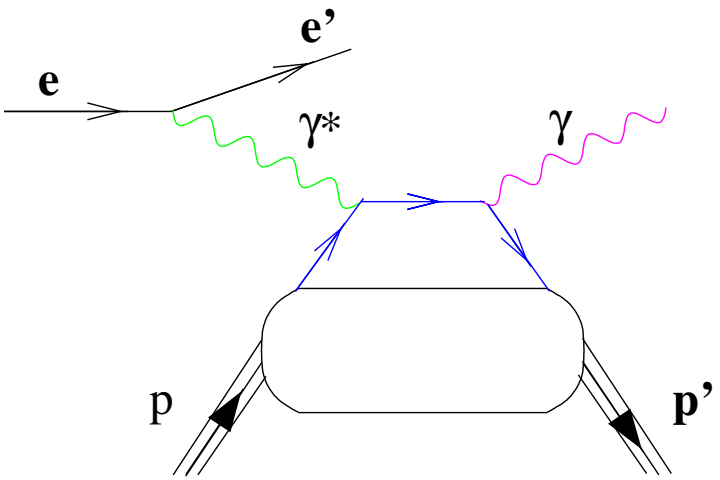
- Access to quark orbital momentum $\mathbf{L}_q$

Detecting Exclusive processes

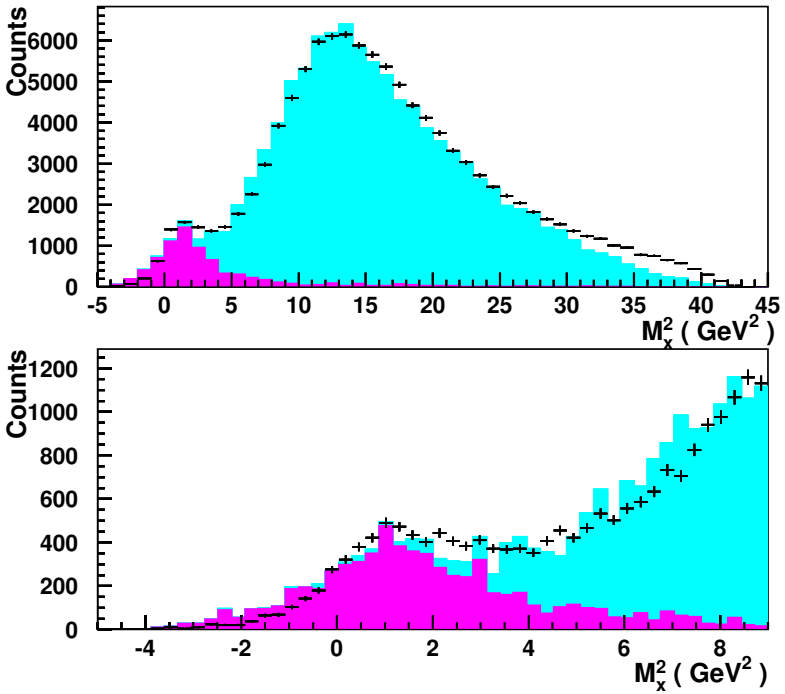


- Internal polarized gas target (H,D ,He,Ne,Kr)
- Tracking: Silicon, Drift Chambers
- PID: RICH, TRD, E/p Calorimeter

Detecting Exclusive processes



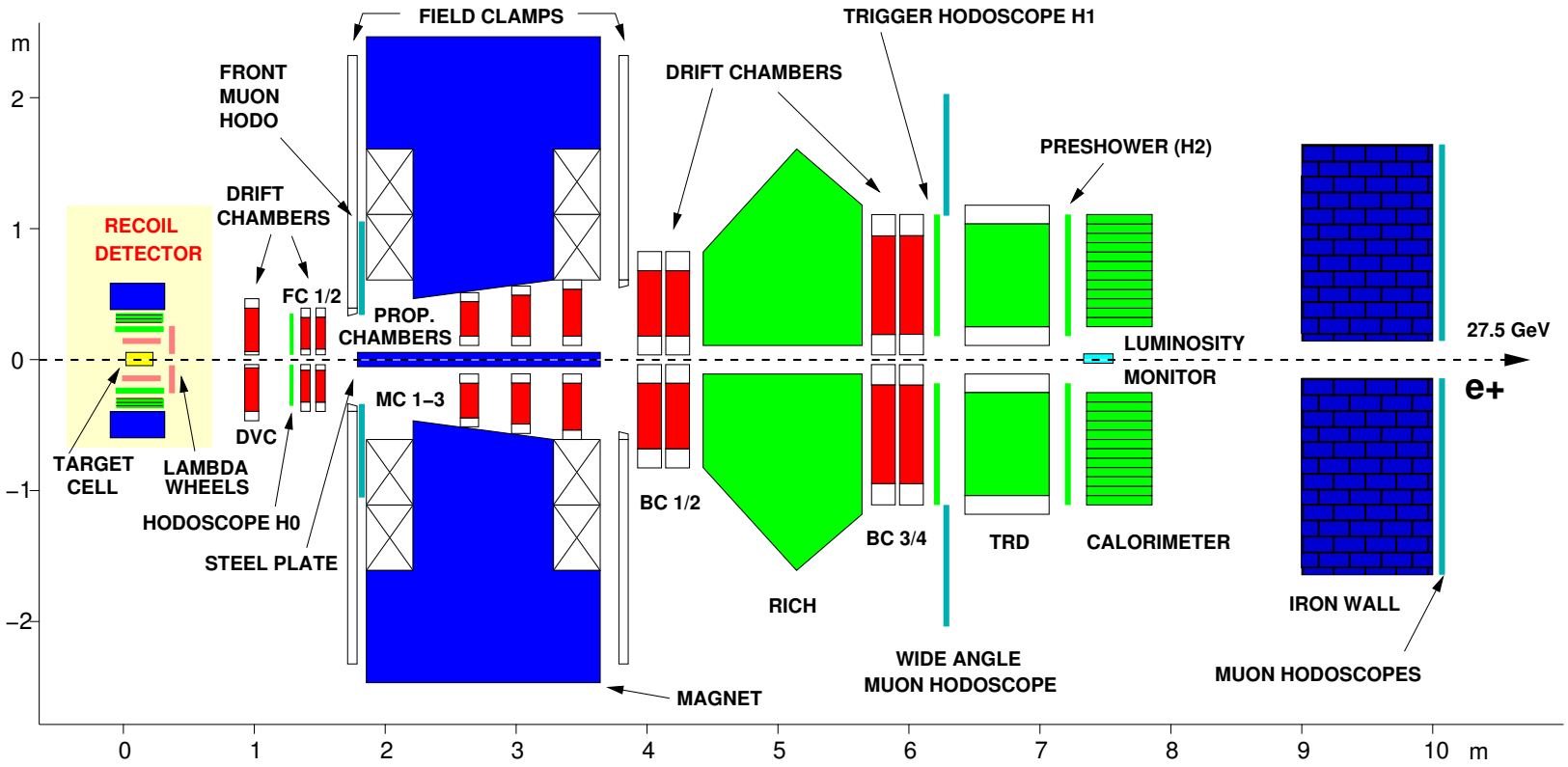
Exclusive Processes:
initial and final state fully known !



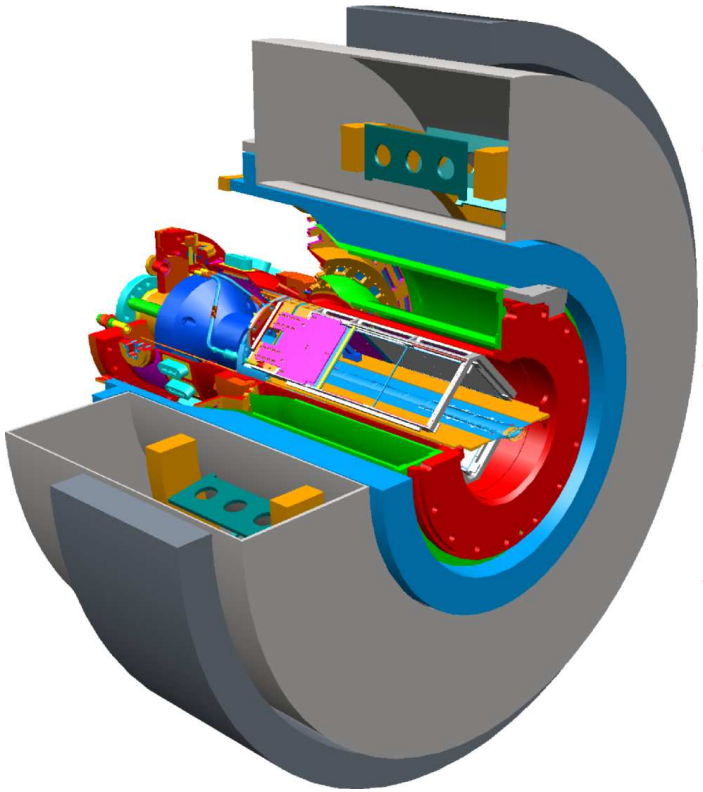
Deeply Virtual
Compton Scattering

A Recoil Detector for HERMES

To improve the measurement of exclusive processes a **Recoil Detector** is presently being built.

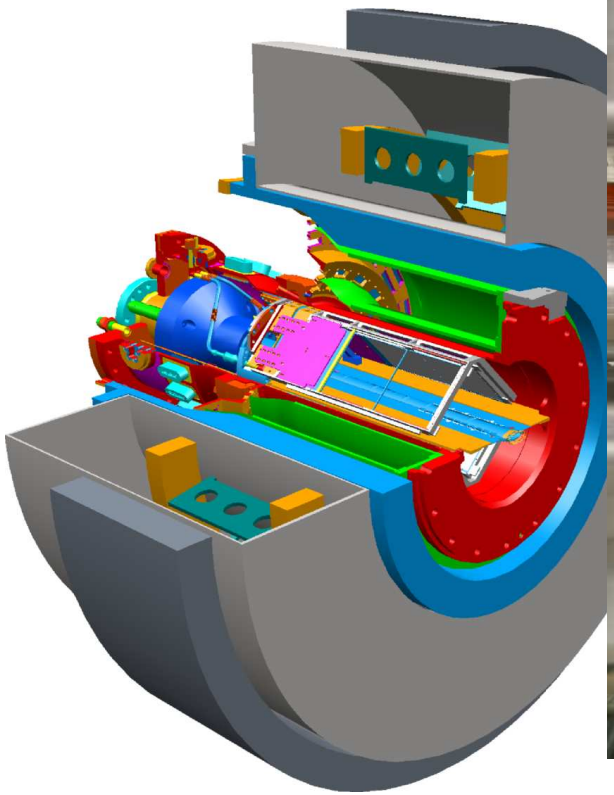


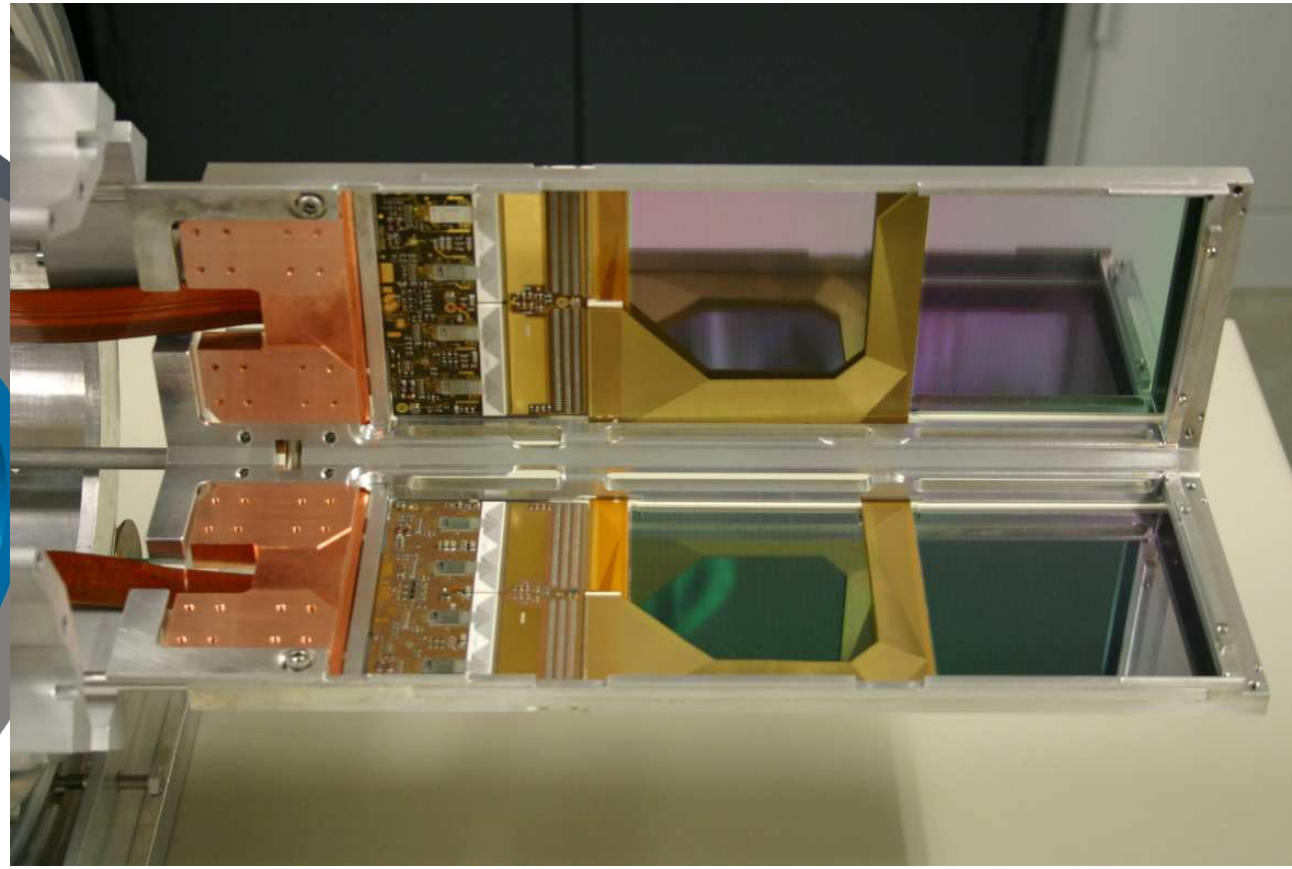
A Recoil Detector for HERMES



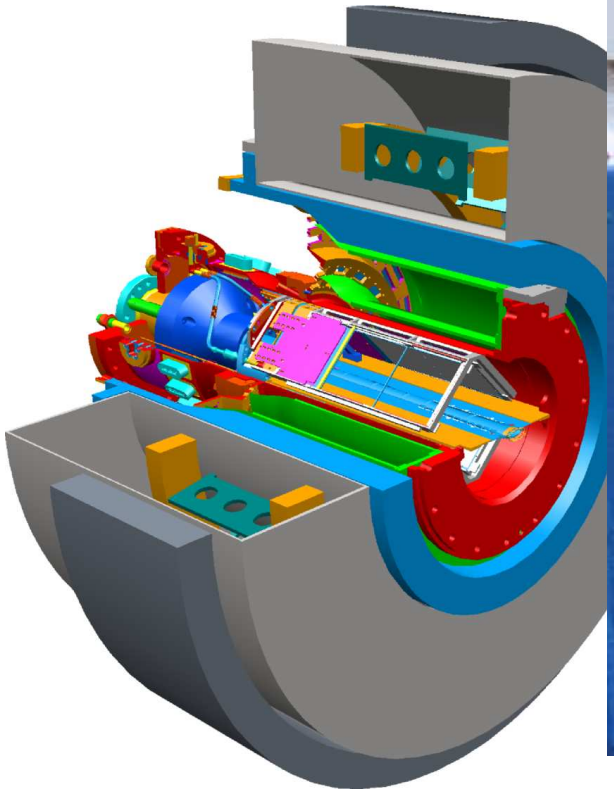
- Silicon measuring low momenta protons
- SciFi for momentum and tracking
- Photon detector to improve exclusivity
- Superconducting Magnet providing field for SciFi
- A new collimator to reduce background hits

A Recoil Detector for HERMES





A Recoil Detector for HERMES



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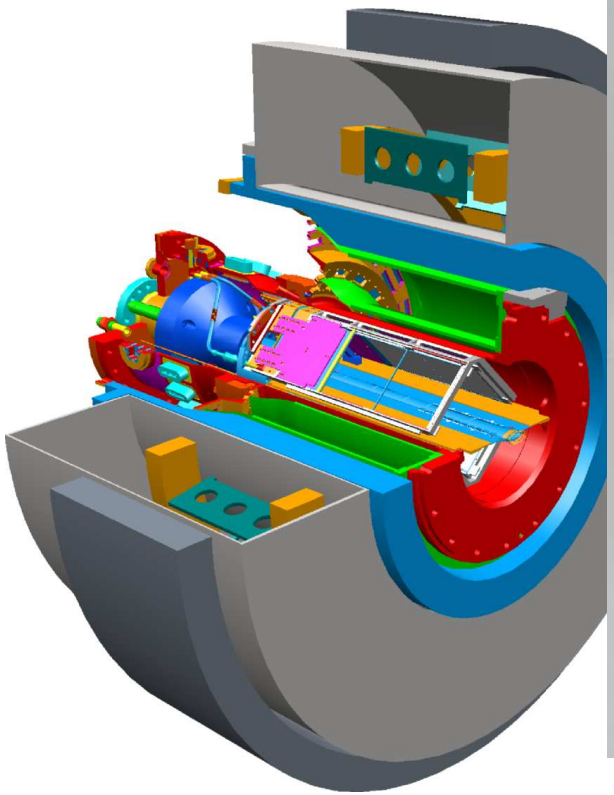
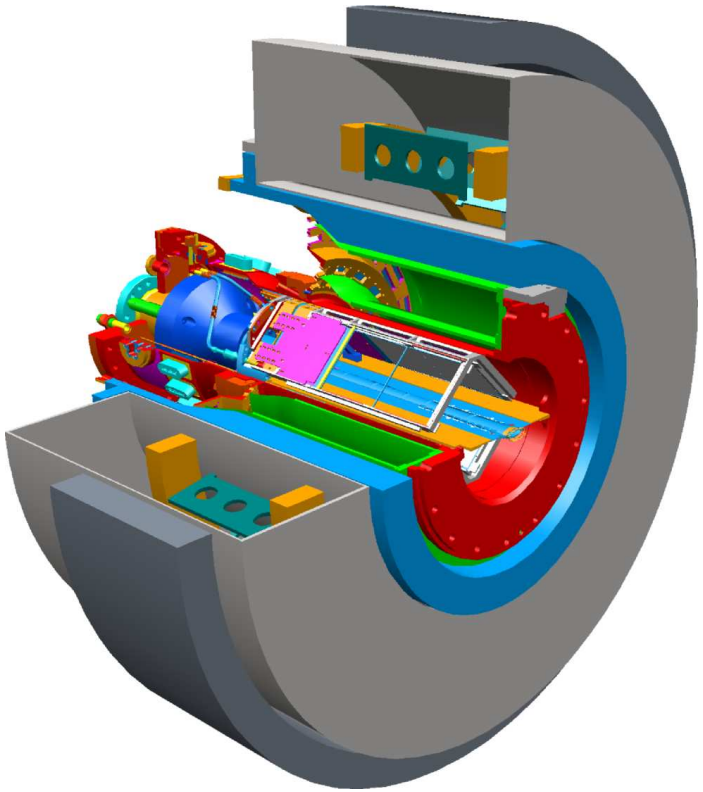
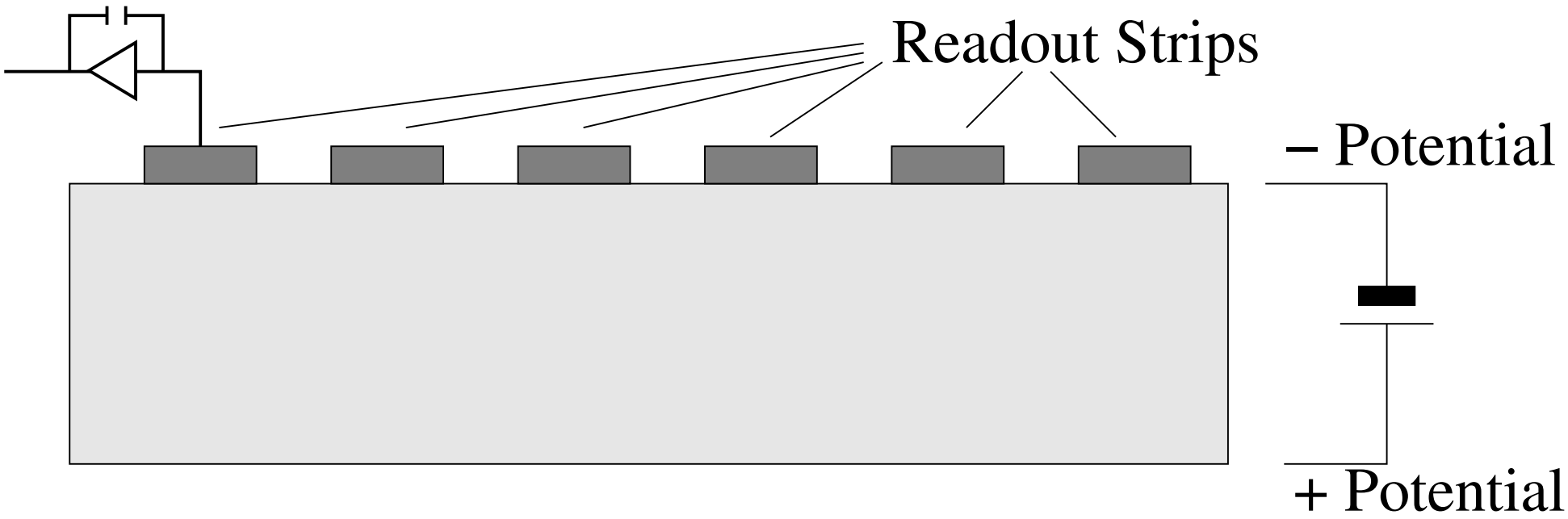


A Recoil Detector for HERMES

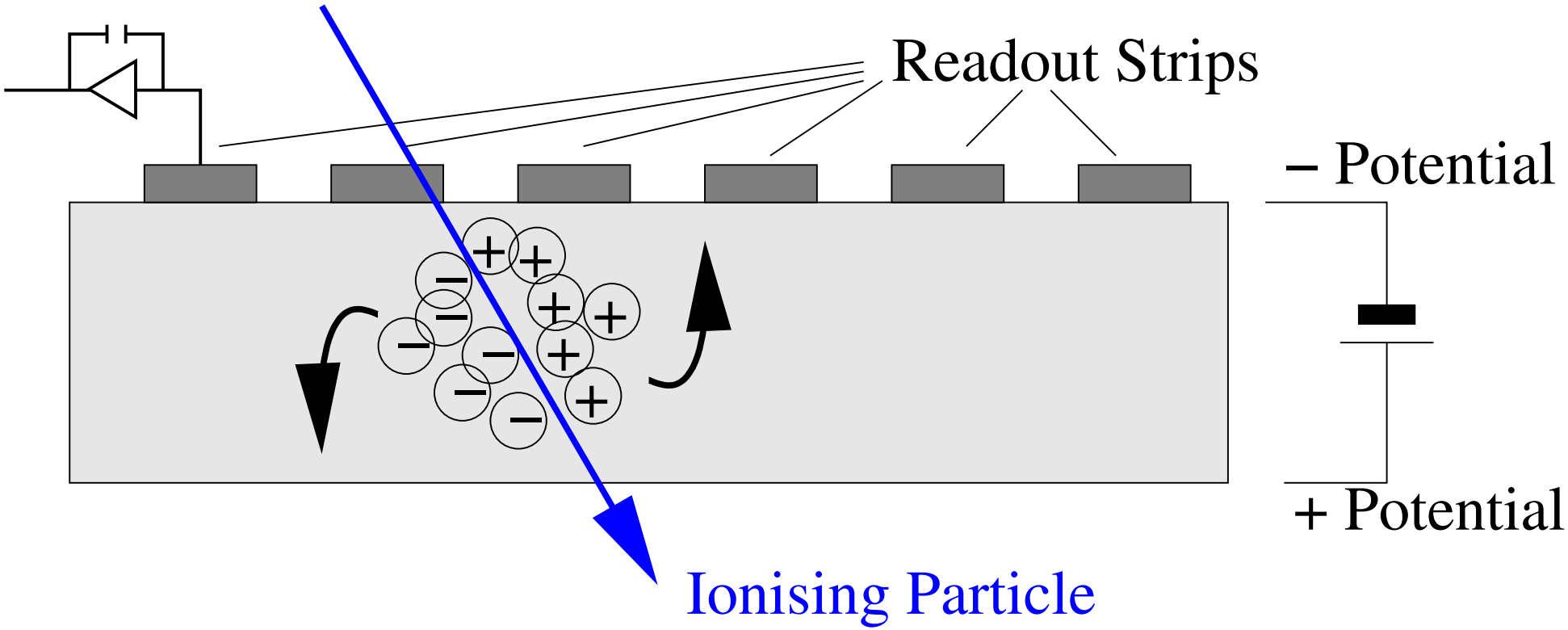


Silicon Detector

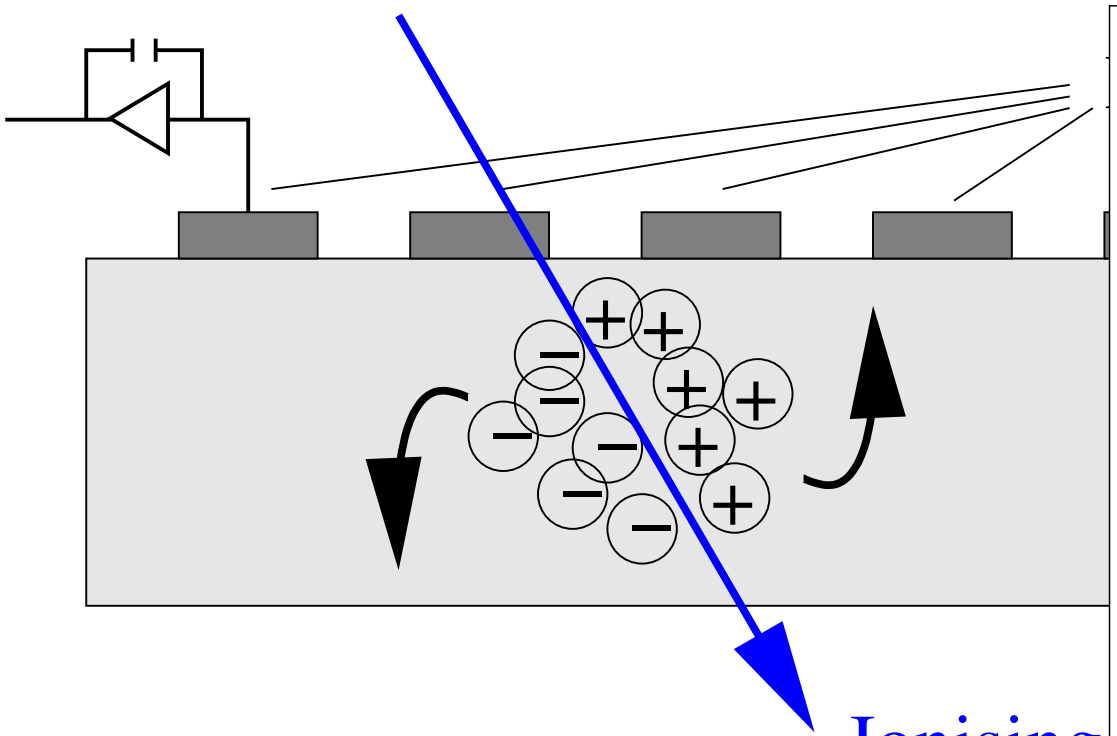
Principle of Operation



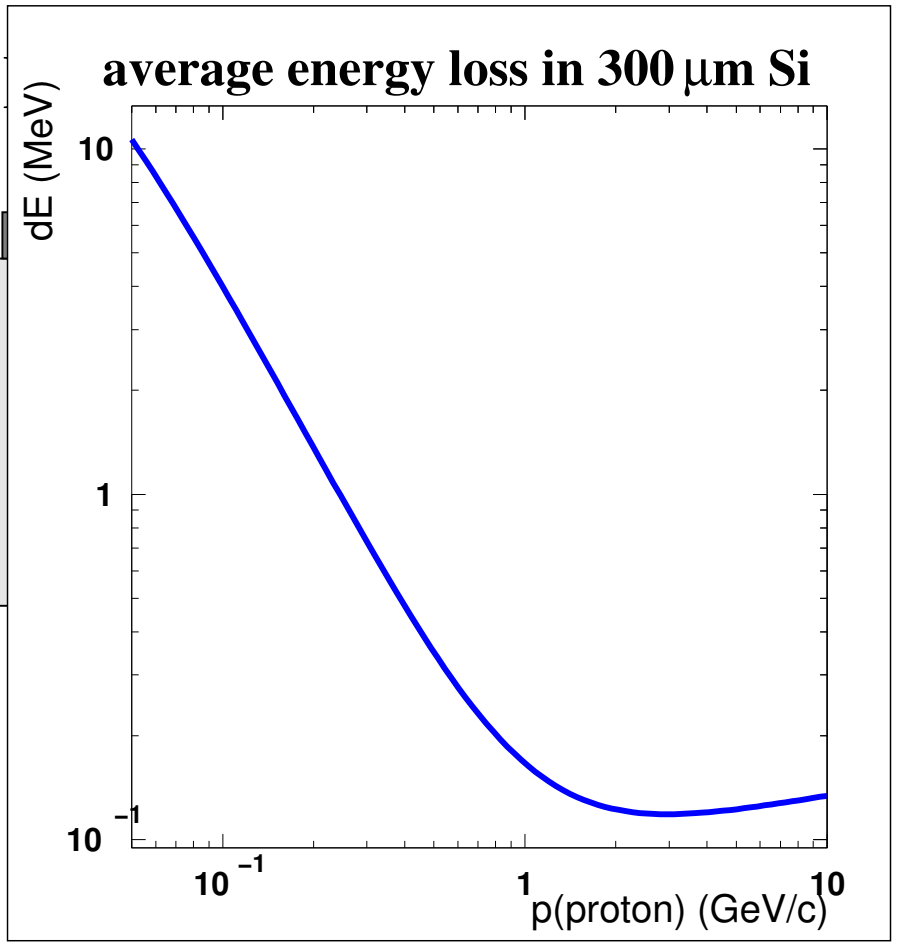
Principle of Operation



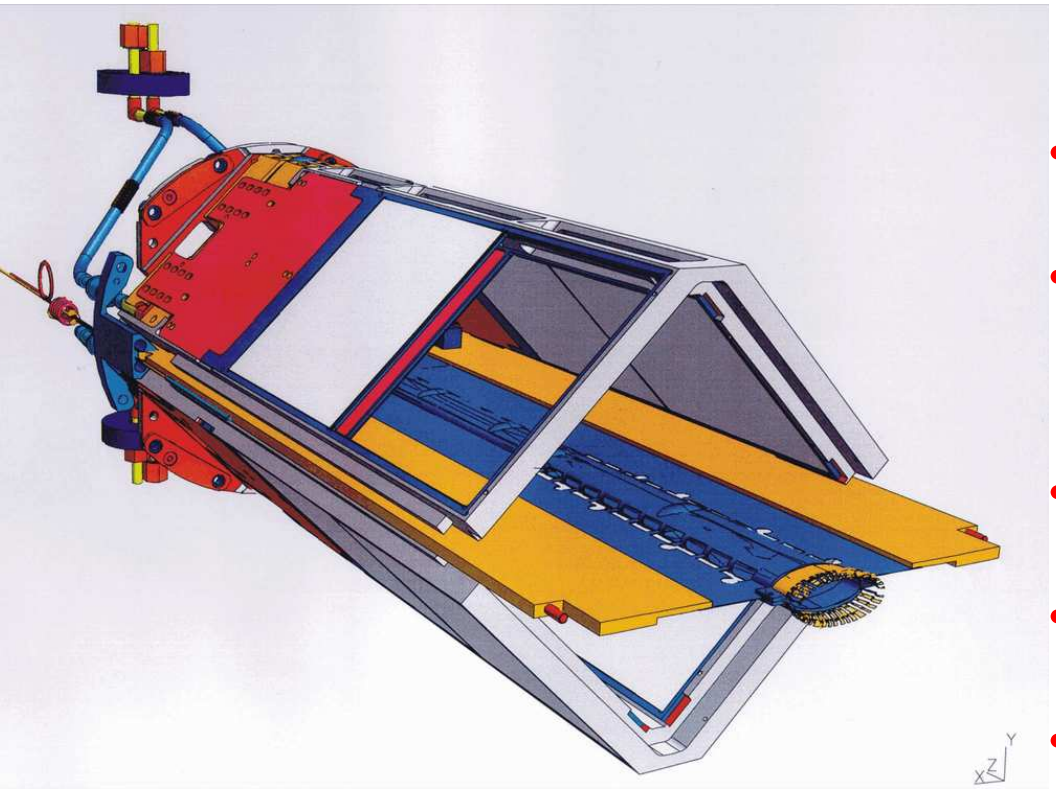
Principle of Operation



Ionising



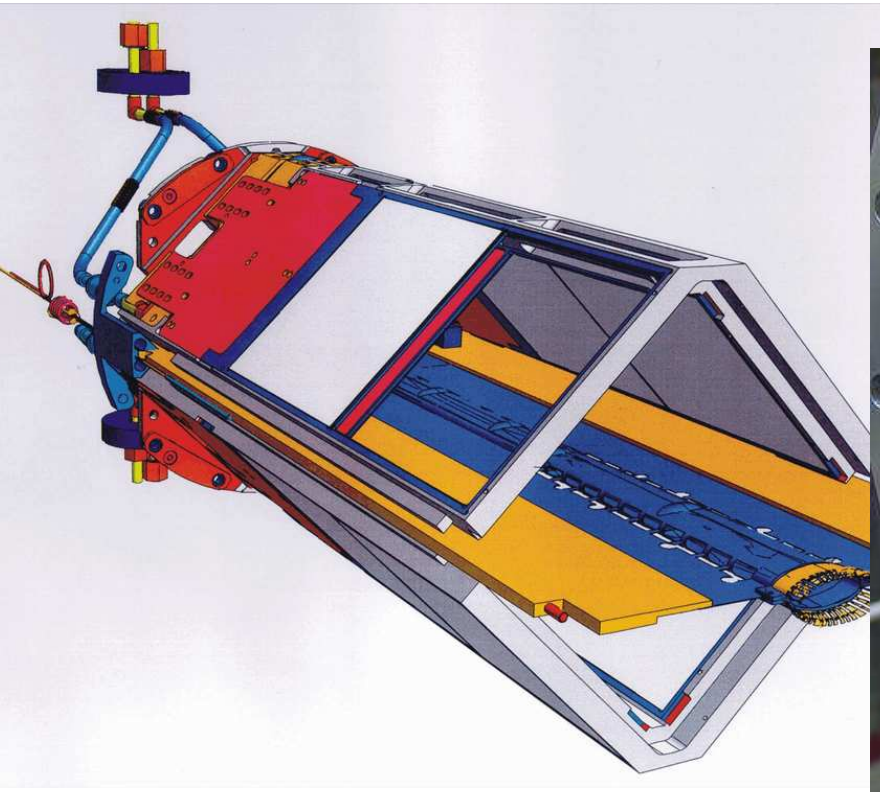
Recoil Silicon Detector

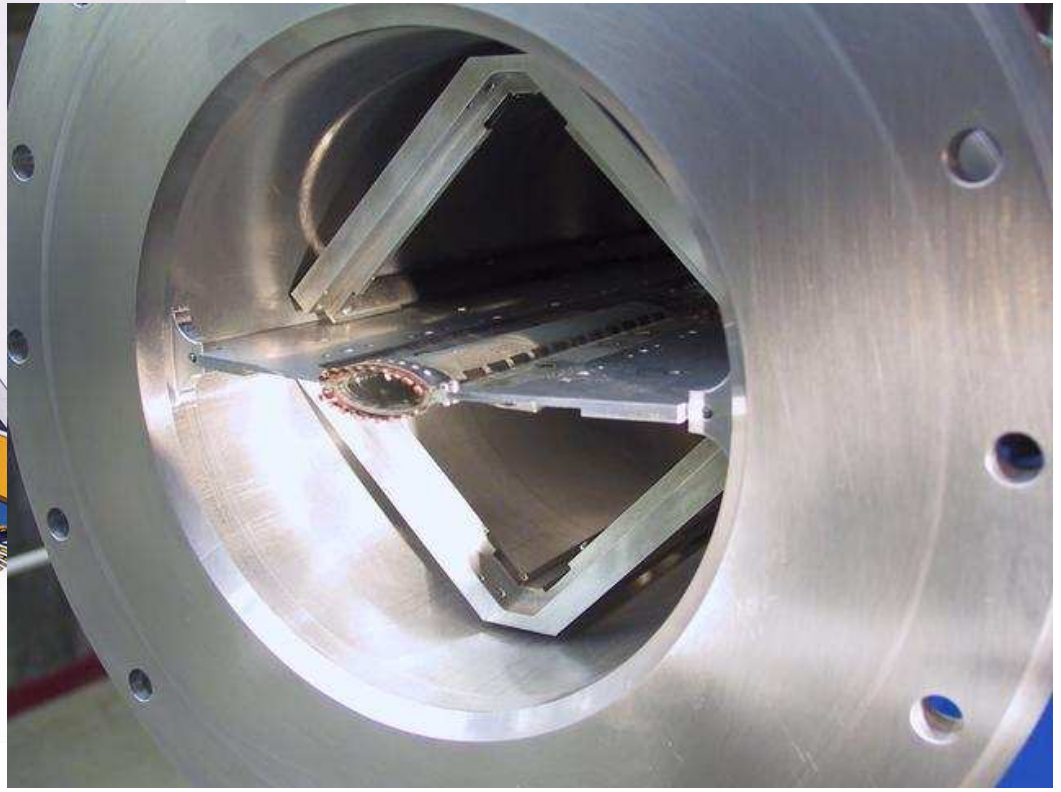


- Inside beam vacuum
- Diamond shape around target cell
- 2 layers of silicon
- 76 % of ϕ
- $23^o < \theta < 80^o$

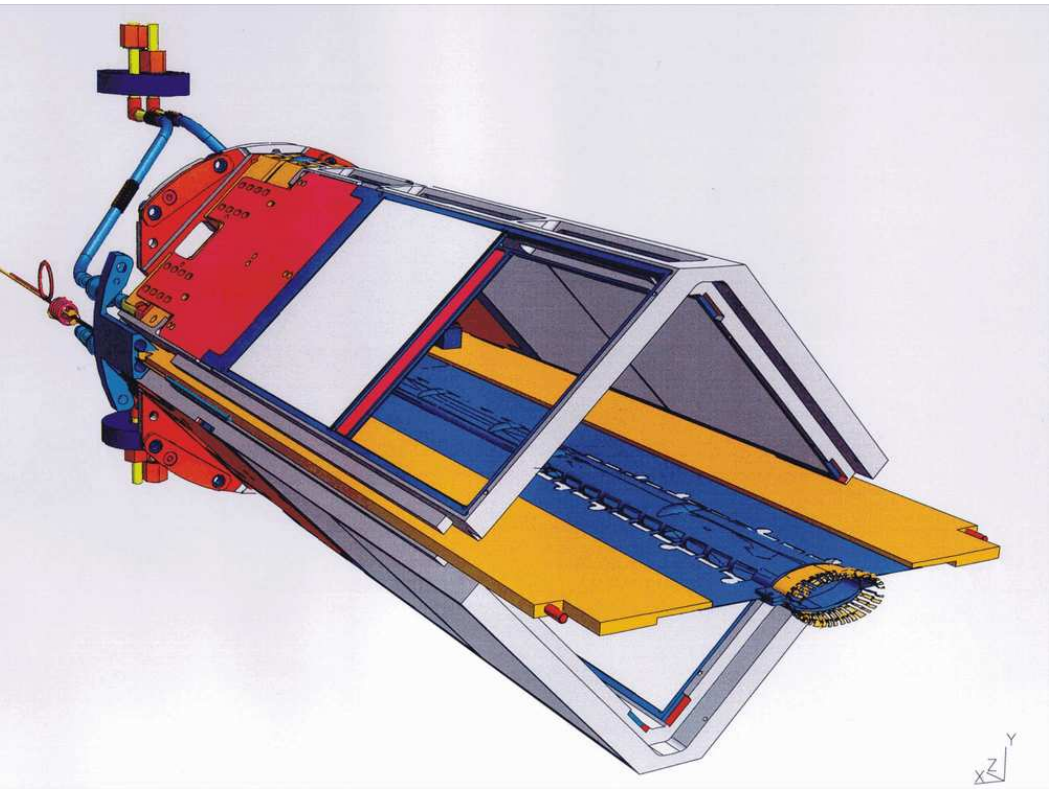
- Project of DESY,Erlangen,Gent,Glasgow

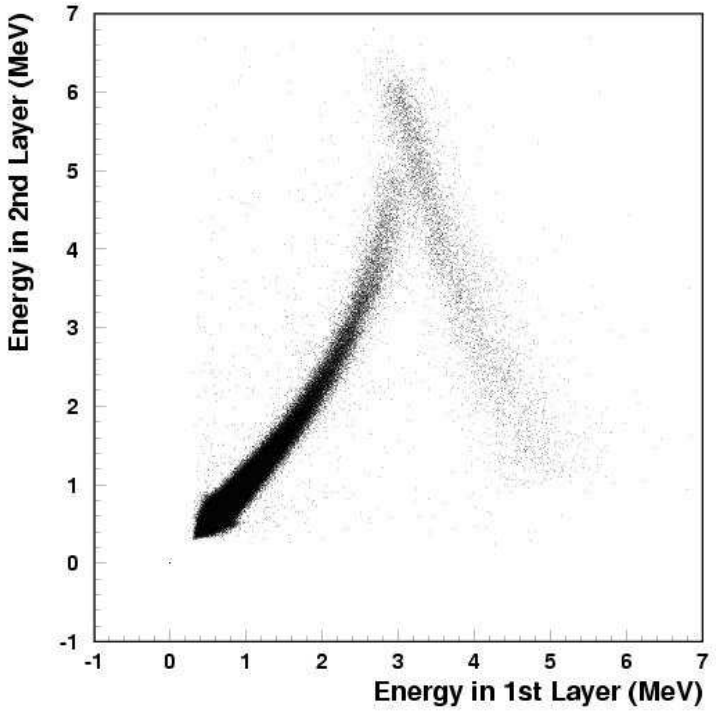
Recoil Silicon Detector





Recoil Silicon Detector





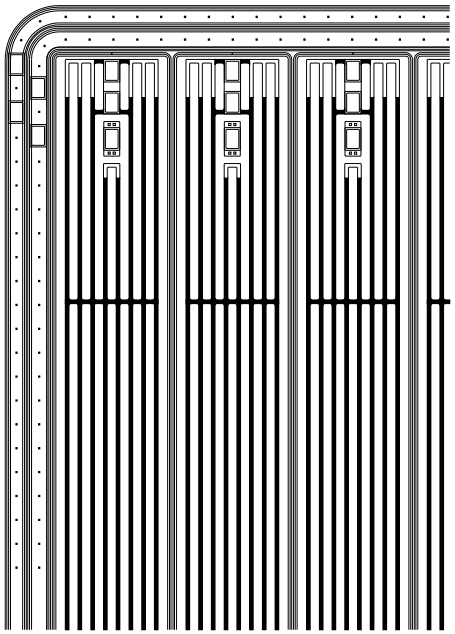
Recoil Silicon Detector

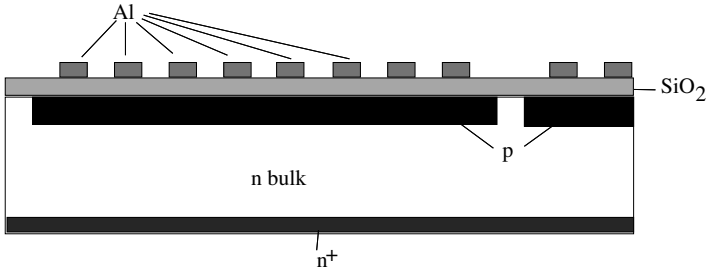
Most important Requirements:

- ➜ Large Dynamic Range required
- ➜ Vacuum compatible components
- ➜ Response linear with particle momentum

Silicon Sensors

TIGRE sensors





- Largest commercially available silicon sensor
- Double sided
- 99 $\times$ 99 mm^2, 300 μm thick
- 758 μm pitch
- Strip width: 702 μm
- Si0$_2$ layer ensures AC-coupling

TIGRE sensors

All TIGREs have been tested by means of a probe station

- Bias resistors
- Overall I/V–C/V characteristics: diode functionality, depletion voltage
- Long Term Test
- . . .

The Holding Frame

A Holding Frame

Requirements for the holding frame:

- Sufficient stability
- Suitable for vacuum applications
- Thermal expansion coefficient close to that of silicon

A Holding Frame

	Silicon	Aluminium	Graphite	Shapal-M	Unit
Resistance	$10^{-4} - 10^{4}$	$5 \cdot 10^{-6}$	0.02	10^{12}	$\Omega \cdot cm$
Thermal Expansivity	2.6	23	7.4	4.4	$\frac{10^{-6}}{K}$
Modulus of Elasticity	170	70	15	160	GPa
Thermal Conductivity	150	130	65	100	$\frac{W}{m \cdot K}$
Outgassing Rate	n.a.	10^{-10}	$8 \cdot 10^{-11}$	$2.3 \cdot 10^{-11}$	$\frac{\text{mbar} \cdot l}{s \cdot \text{cm}^2}$
Costs per frame	n.a.	30	110	1200	€

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Costs per frame	n.a.	30	110	1200	€

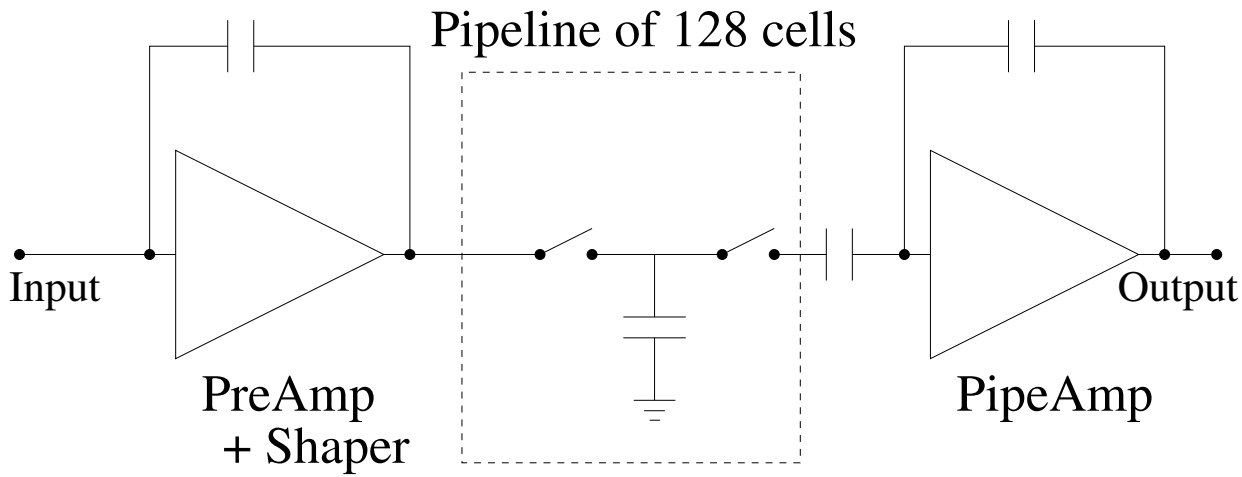
Go for Shapal-M

➠ Sensors are glued with two component epoxy glue at 150^{o}

Readout Hybrid

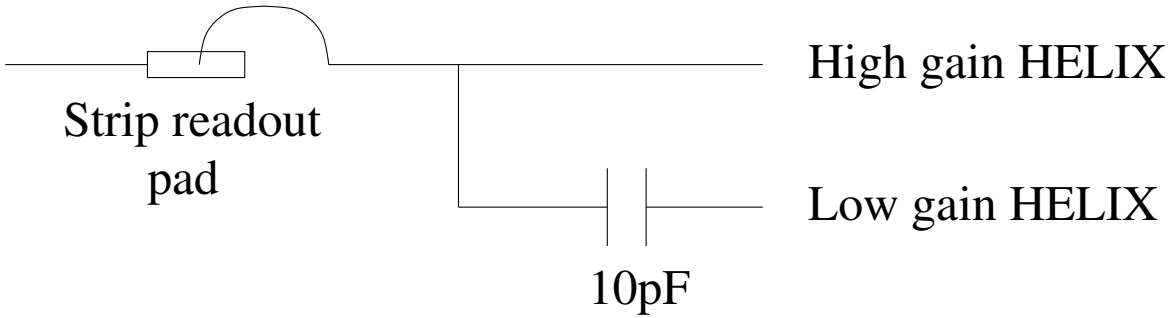
Readout Hybrid

Two readout chip candidates were tested: APC and HELIX128-3.0



Readout Hybrid

Extend Dynamic range with Charge division method:



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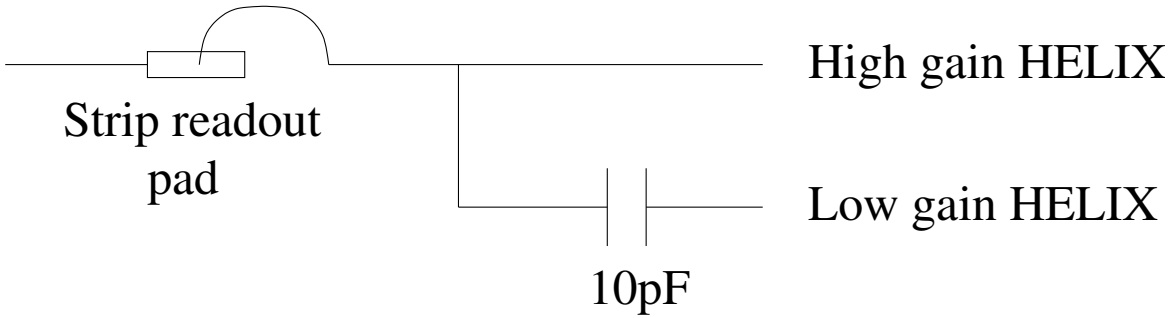
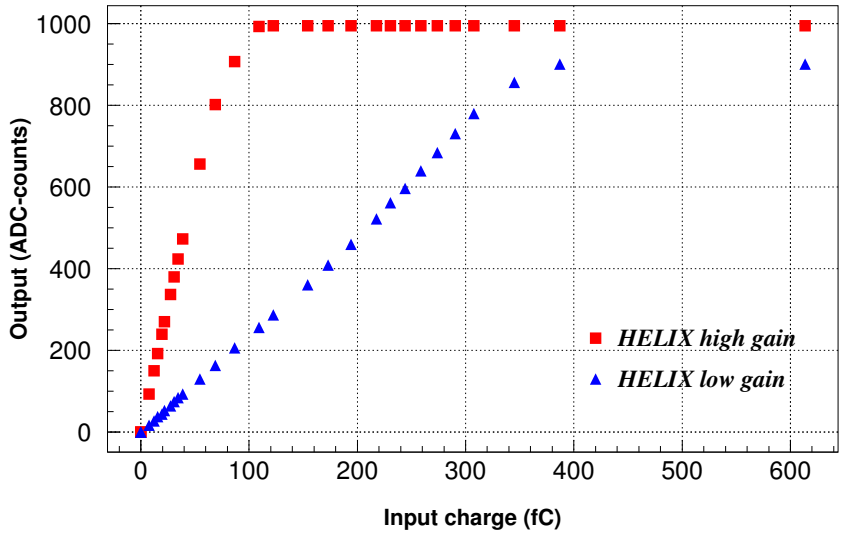
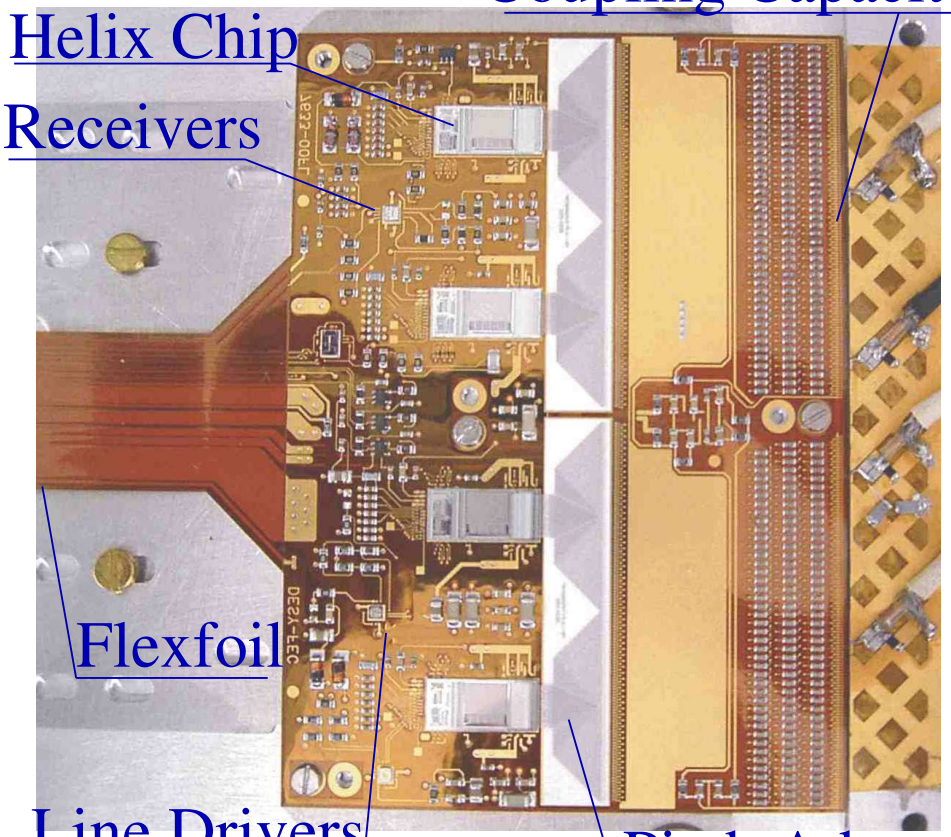


- Sufficient Dynamic Range
- HELIX already used in HERMES

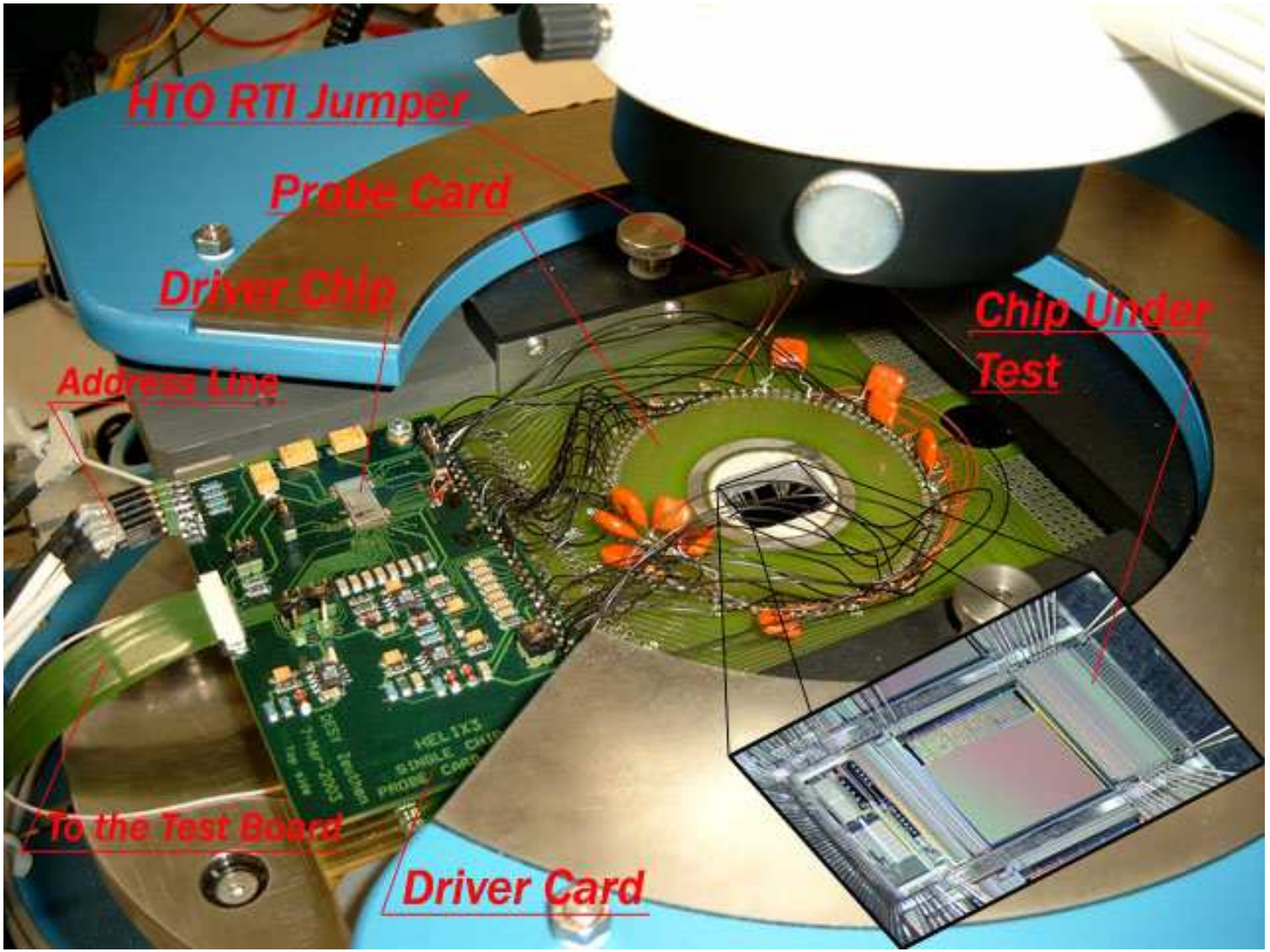


Readout Hybrid



- 4 layers, with kapton cores
- Glued to aluminum heatsink

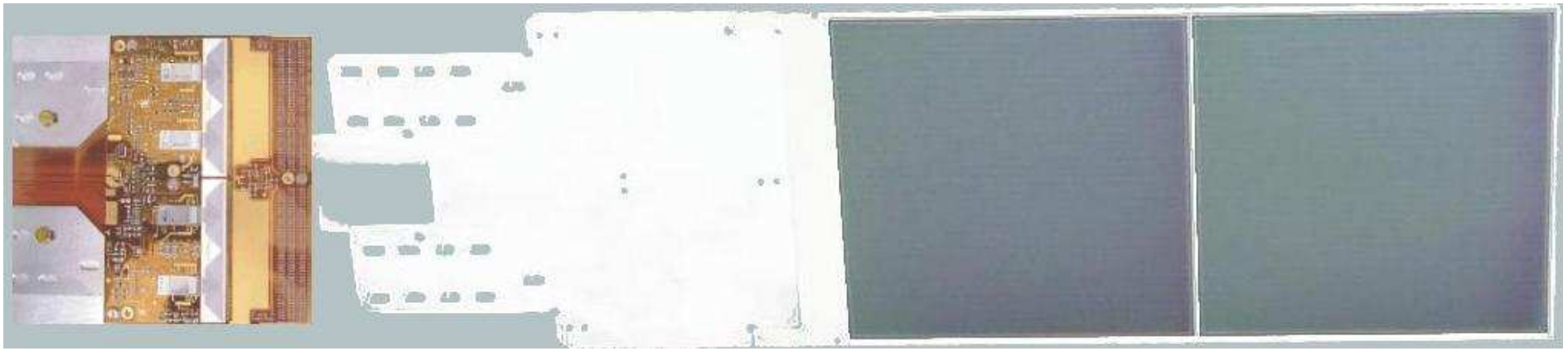
Chip Tests


HTO RTI Jumper
Probe Card
Driver Chip
Address Line
Chip Under Test
To the Test Board
Driver Card

Chip Tests

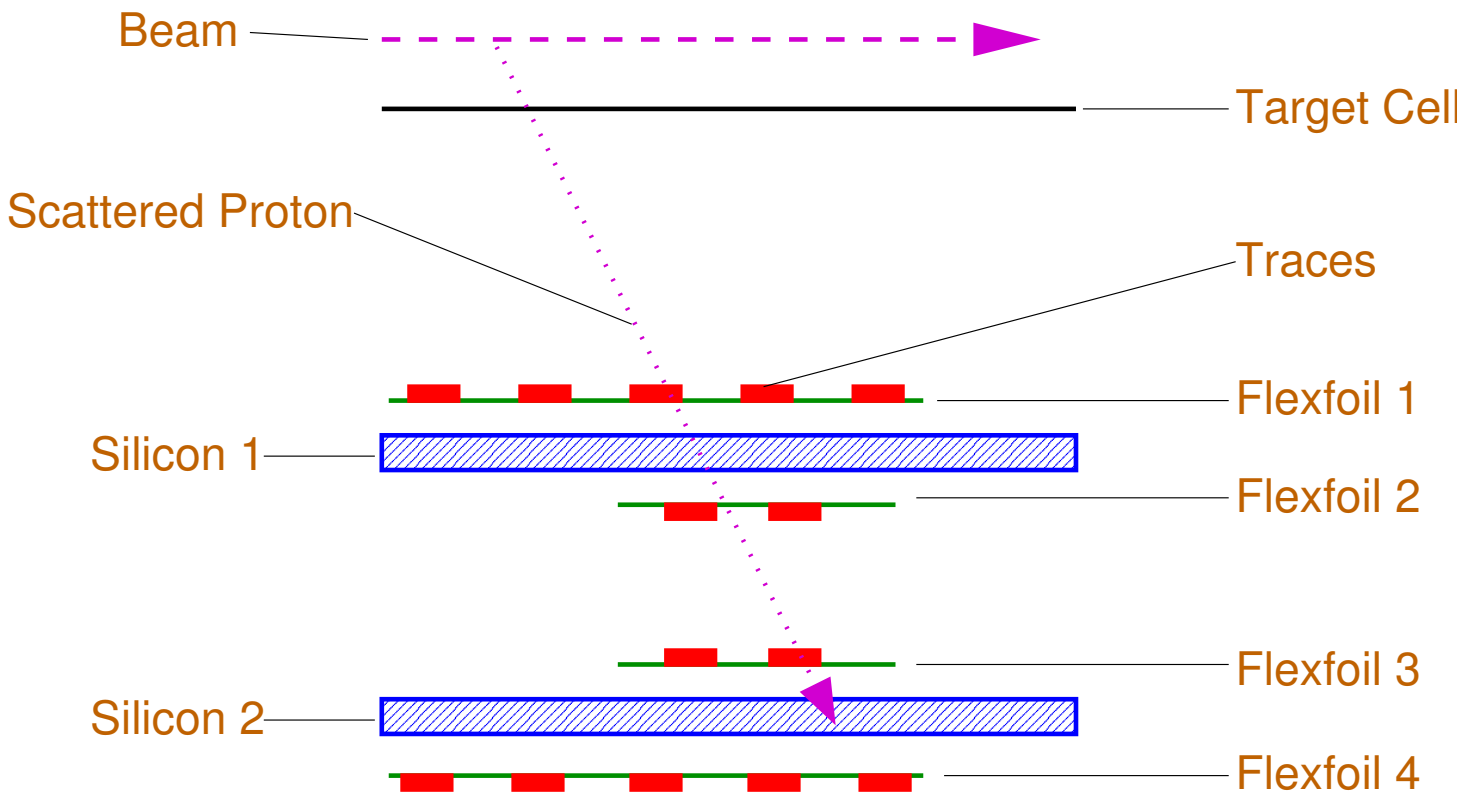
- Basic functionality (addressing, programming)
- Uniformity checked with internal testpulse
- 372 chips tested
  - 64 chips needed
  - 153 Class A chips
  - 100 Class A1

Kapton Readout foils



➵ Readout Foils needed !

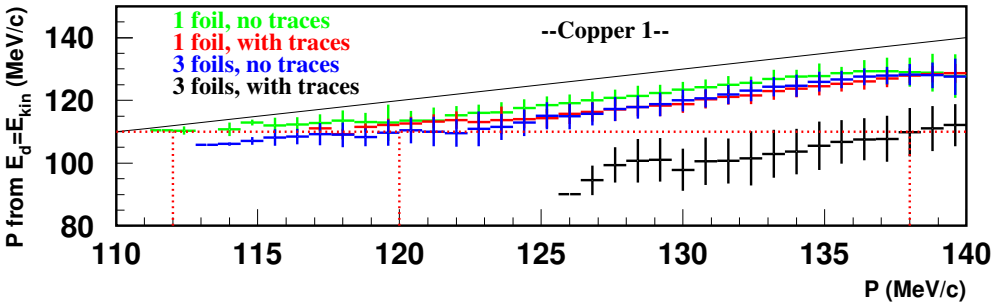
Kapton Readout foils

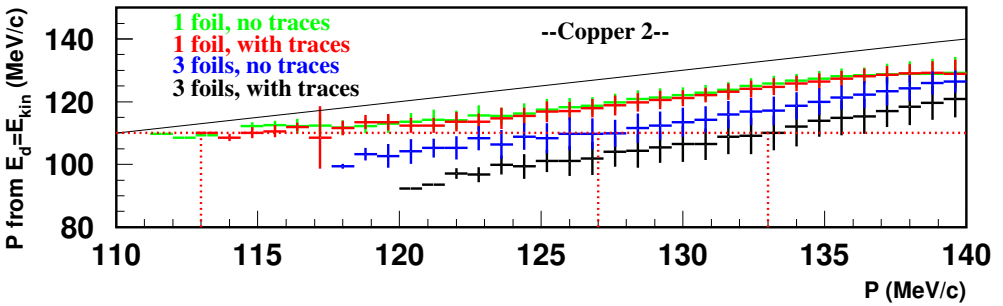


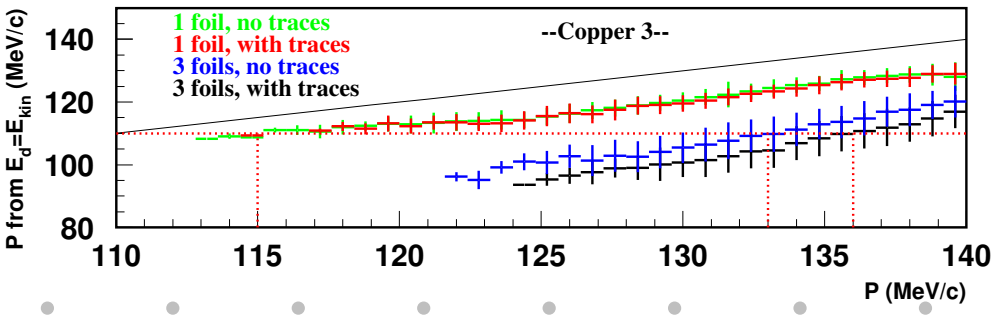
Kapton Readout foils

➟ Different designs: (μm)

	C1	C2	C3
Kapton	25	50	50
Copper	17	5	5
Nickel	5	5	–
Gold	0.1	0.1	–
Kapton2	–	–	25

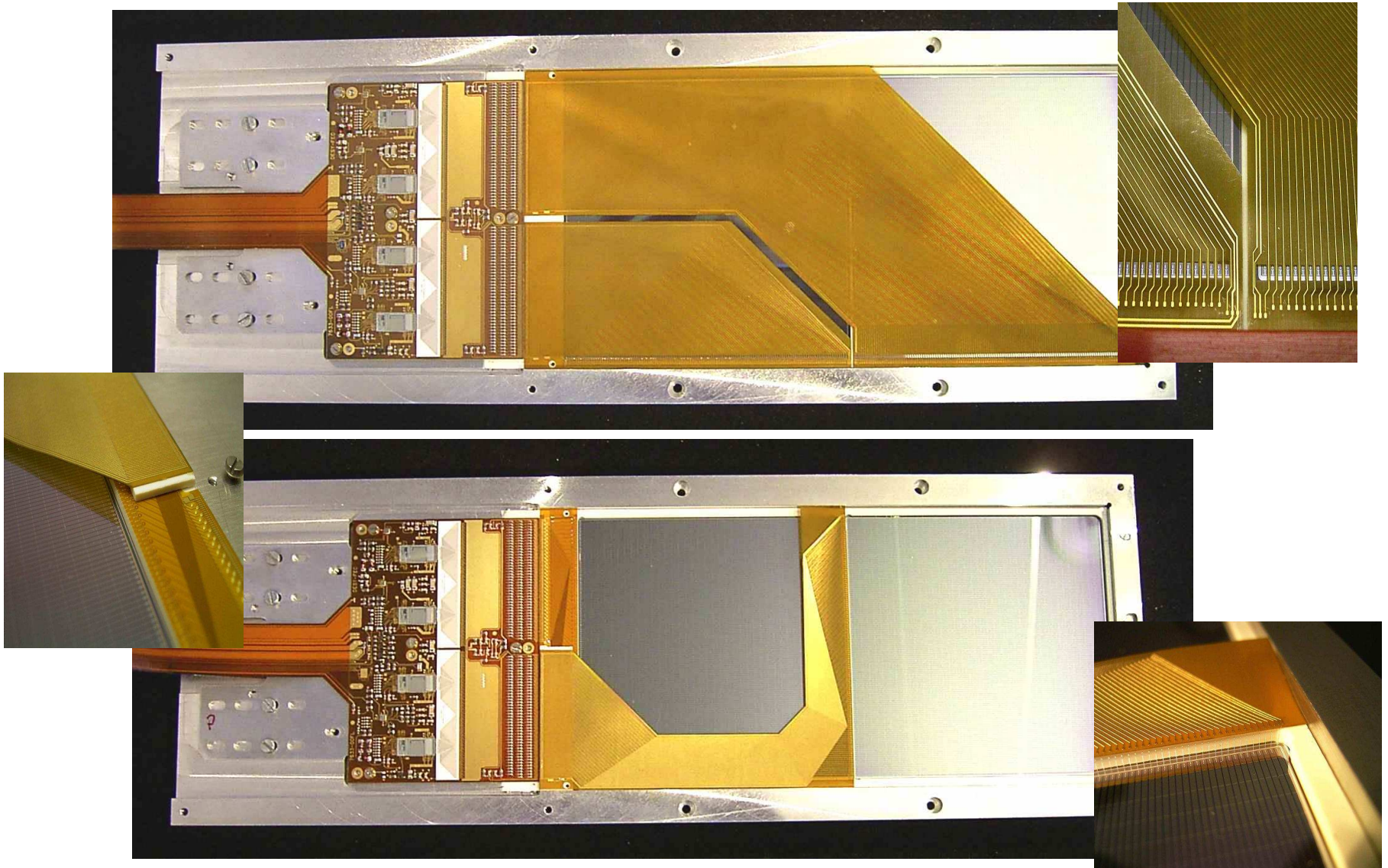




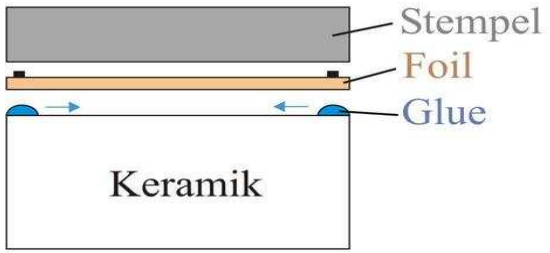


A Module

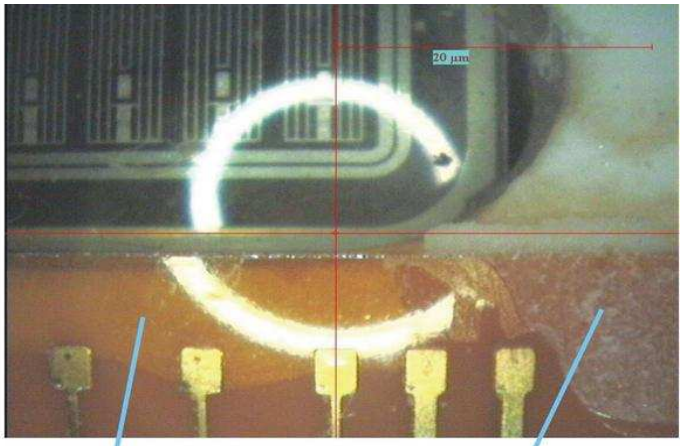
An SRD Module



Assembly-Glueing

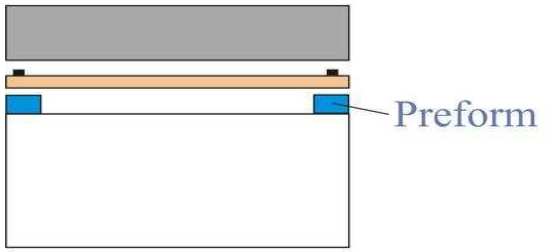


Glue : 2-Component Epoxy
Epotek H77 (Polytec)

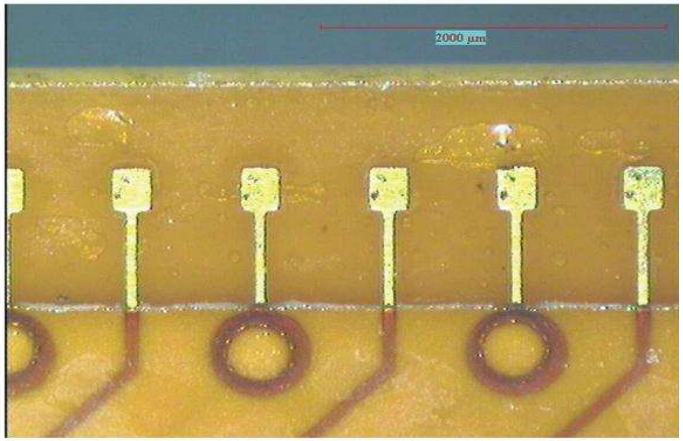


Air bubbles below bondpads

Glue on foil

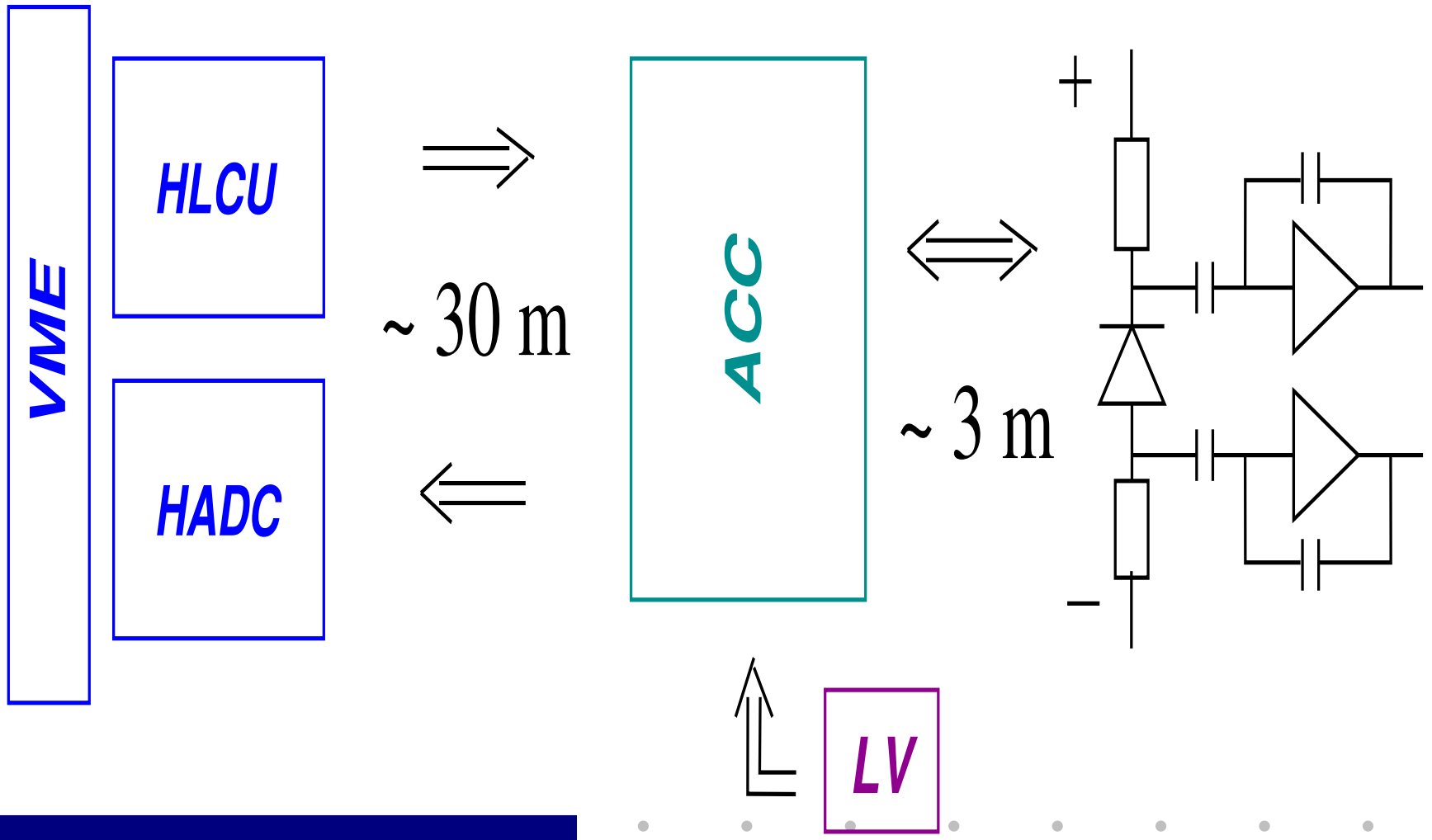


Preform : Woven material filled
with Epoxy Glue.
Polytec TFT D18-1 SP4



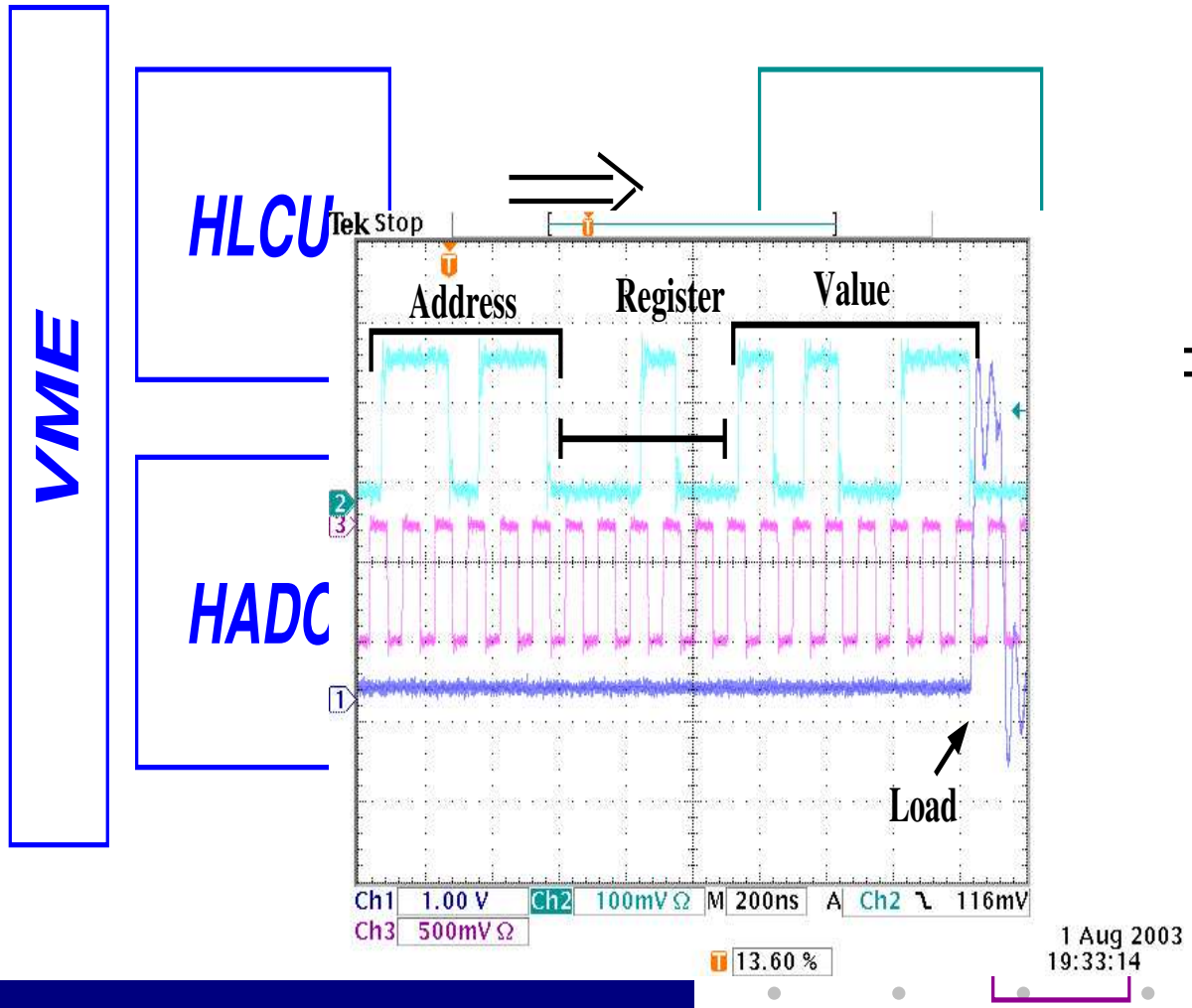
Readout Scheme

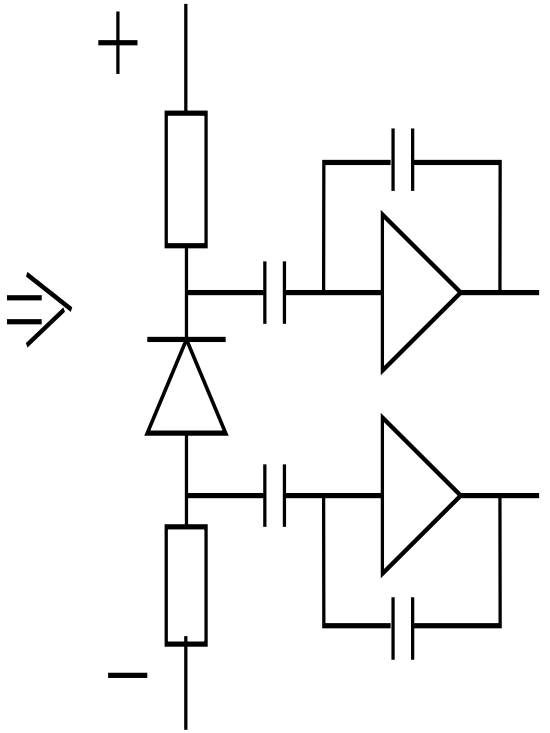
Readout Scheme



Readout Scheme

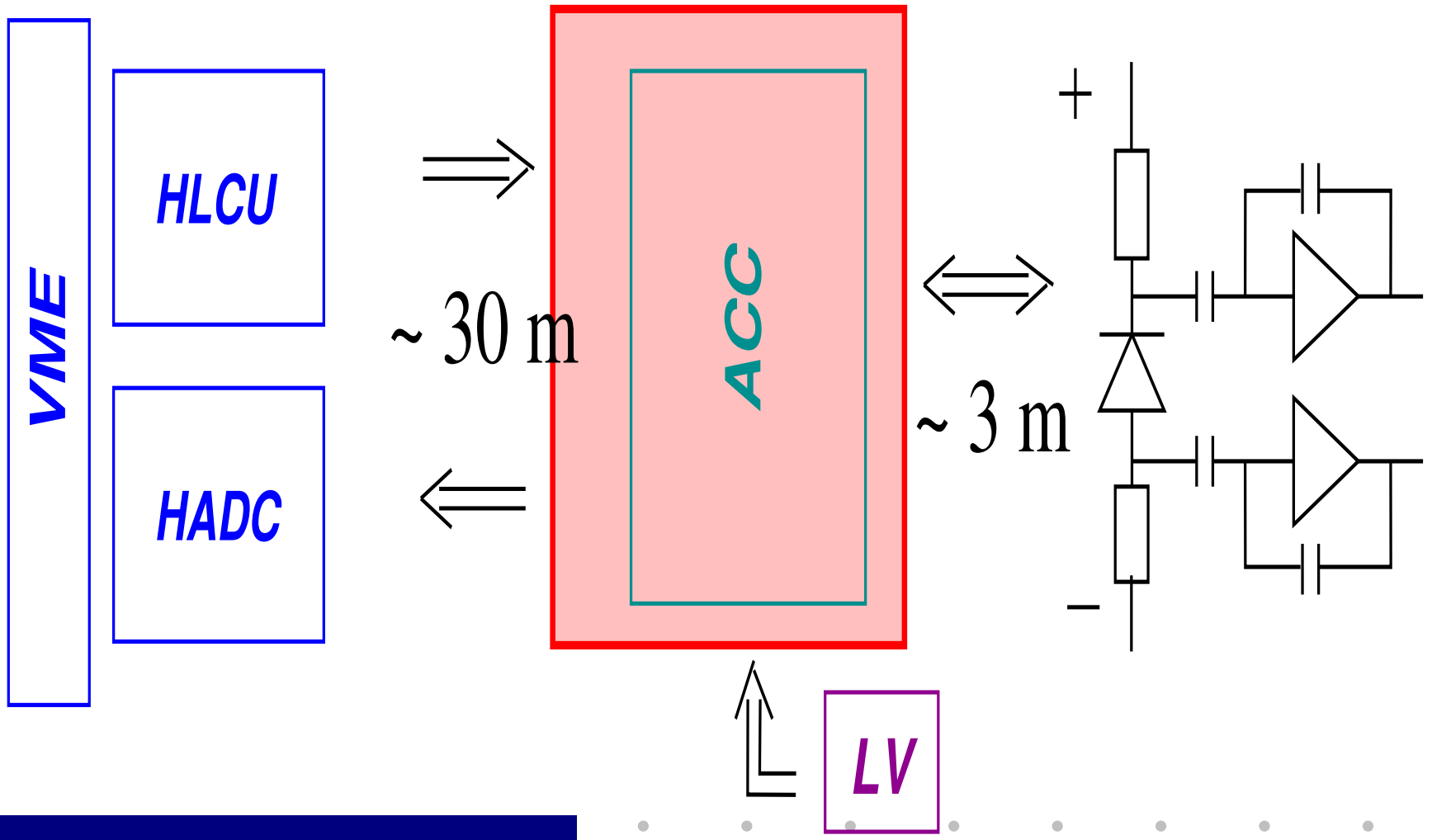
HLCU: Programming,Clock,Triggering



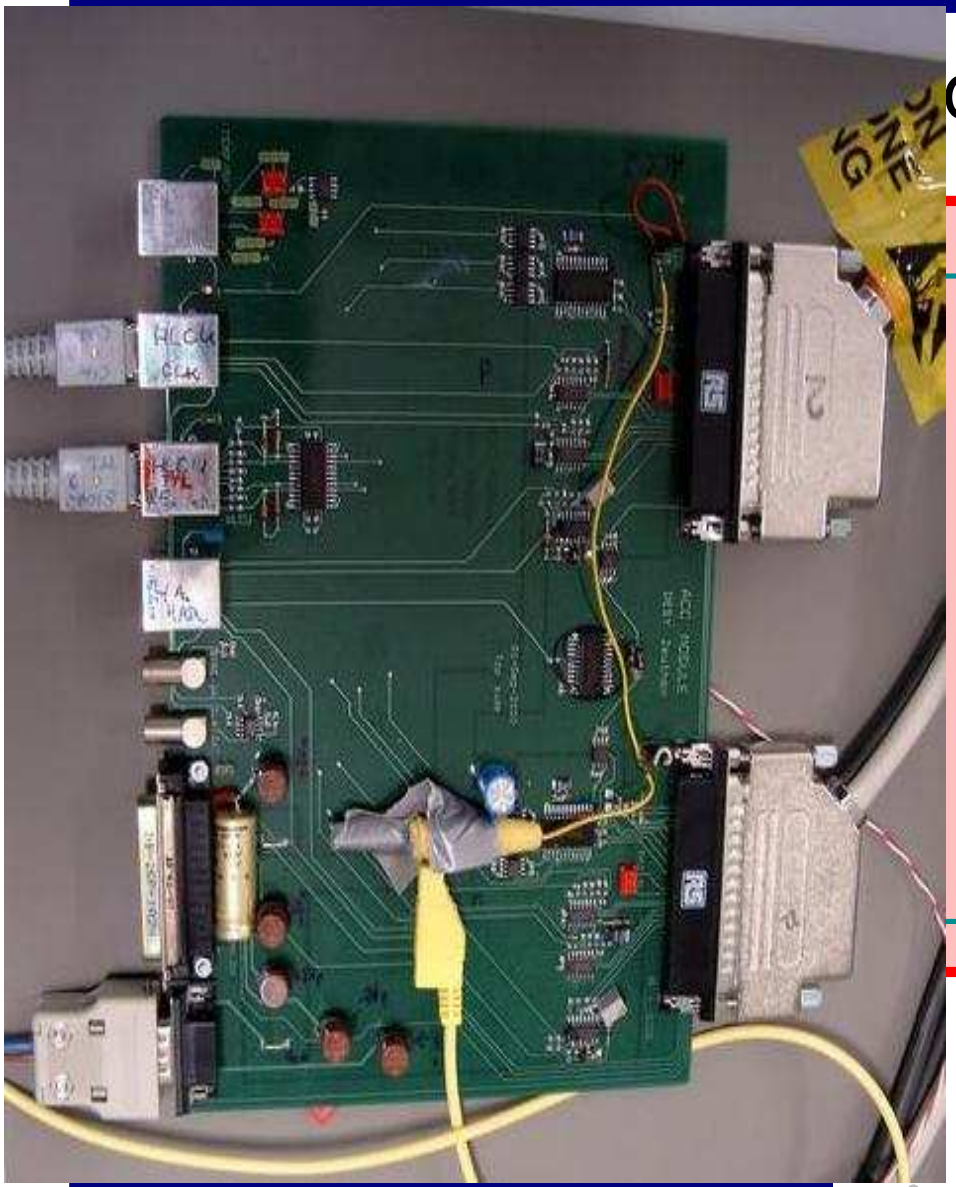


Readout Scheme

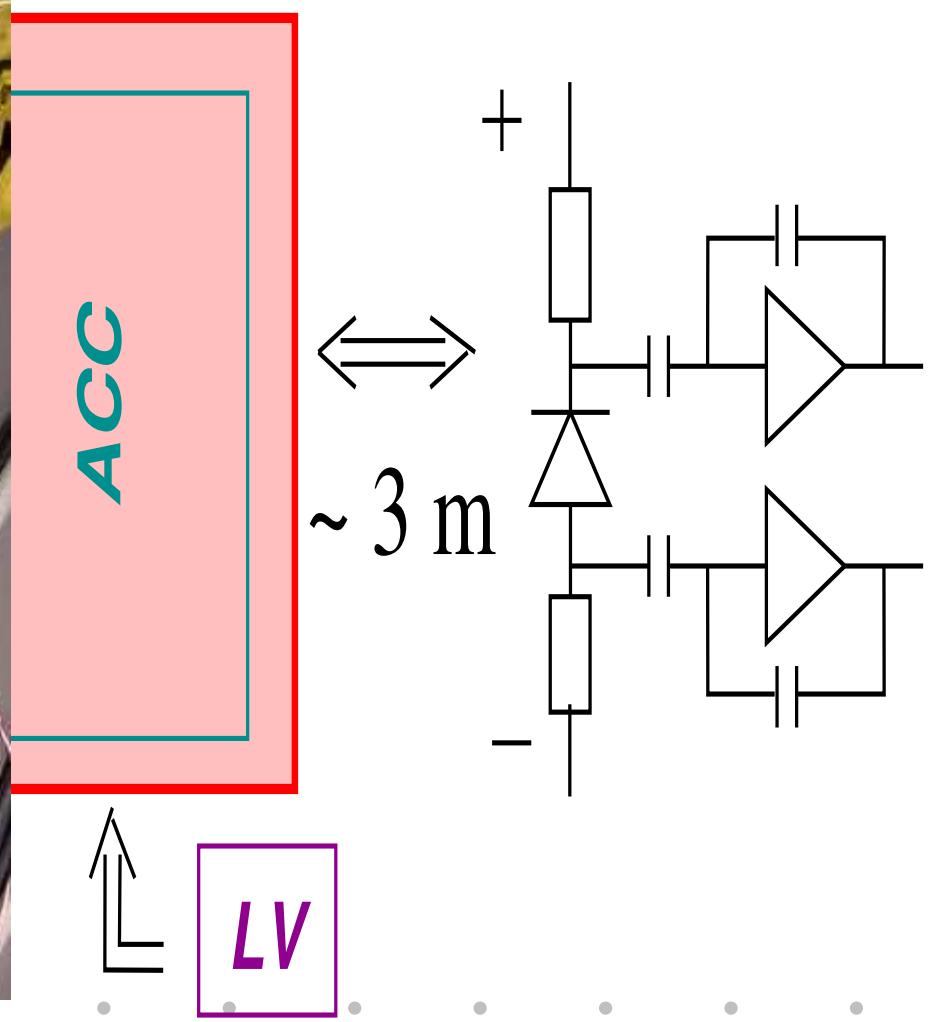
ACC: Repeater board, drivers/receivers



Readout Scheme

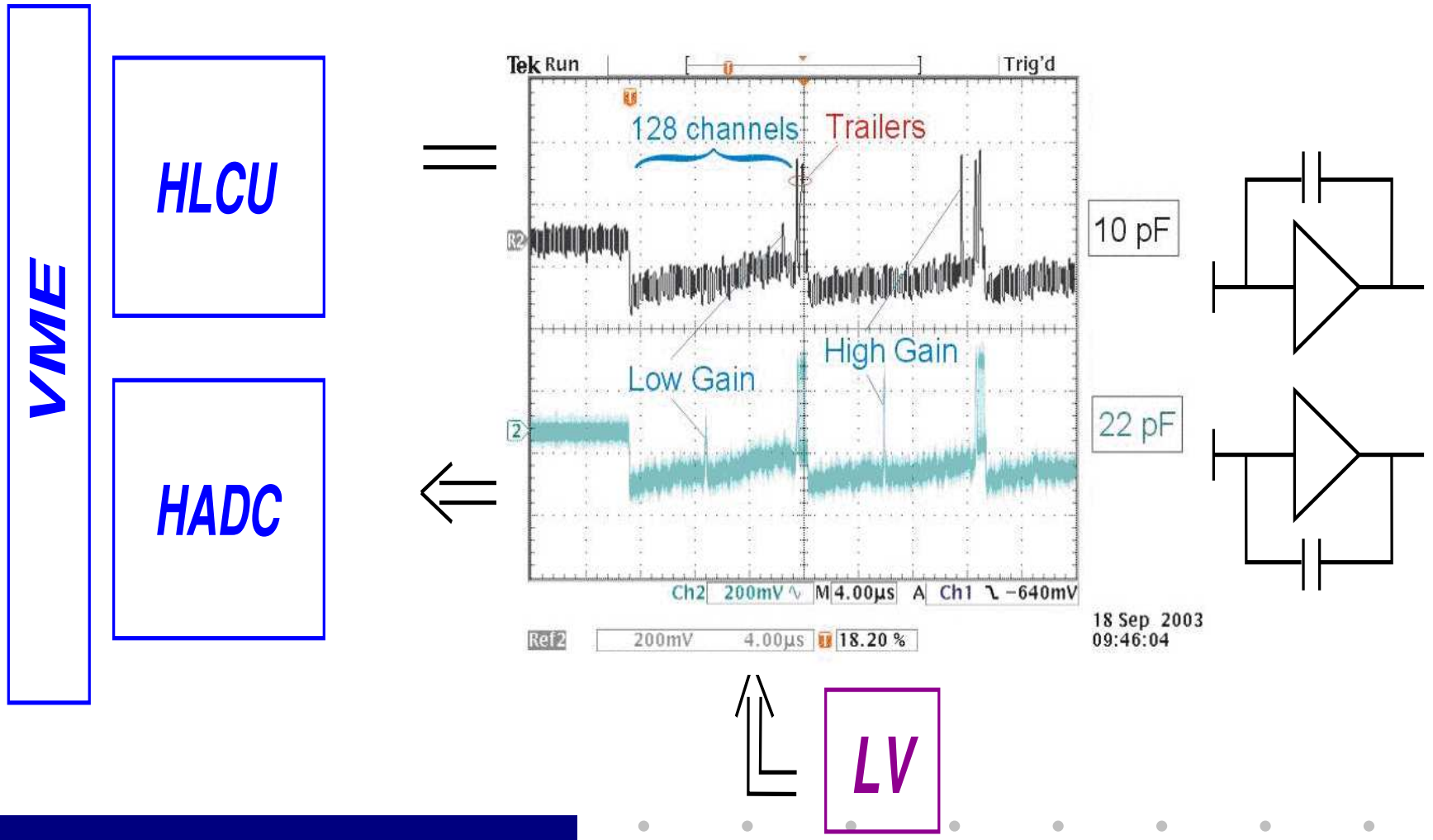


drivers/receivers



Readout Scheme

HADC: ADC, CMC, Zero Suppression



Testing

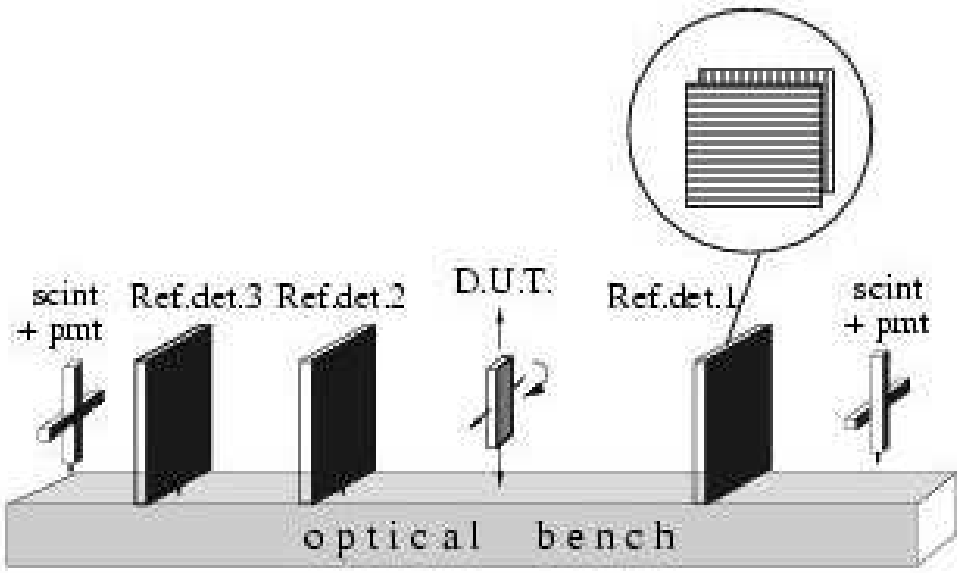
Prototype Testing

- Testbeams
  - DESY: MIP
  - Erlangen: Low Energy protons
- Laser Test Stand
- Detailed noise optimisation
- Parameter tests
- Bench Test

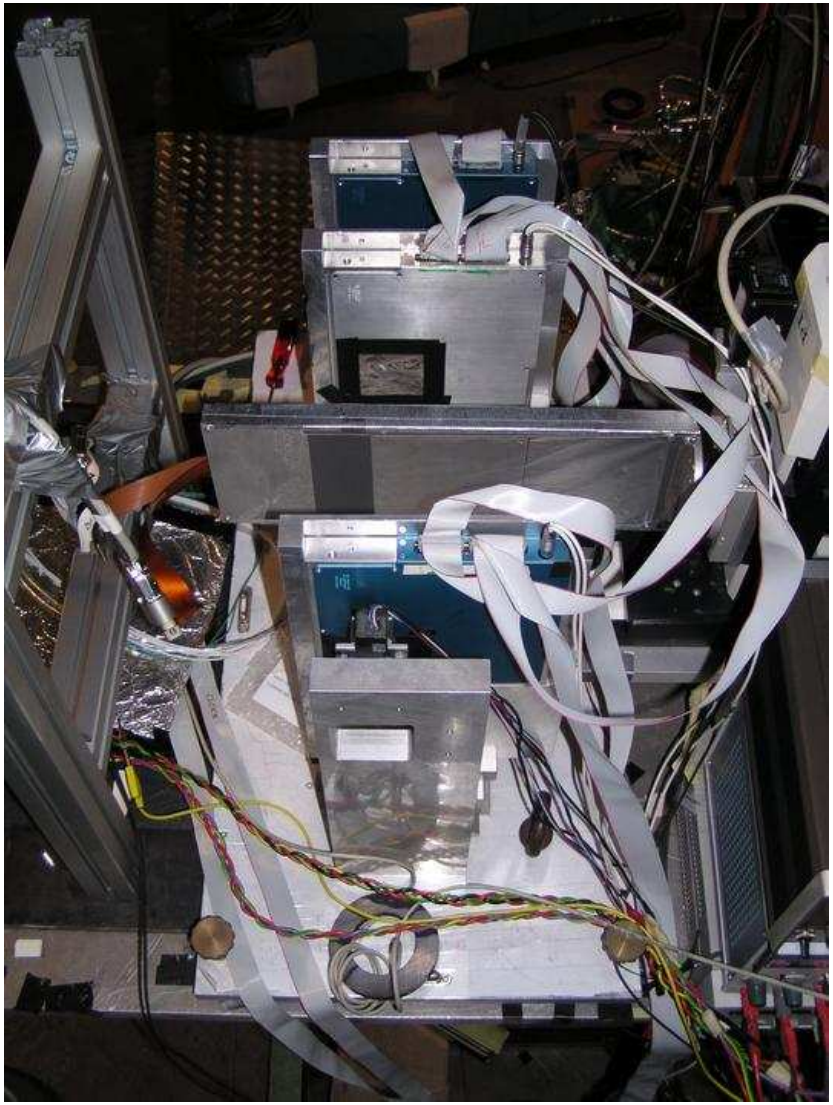
Zeuthen Lab

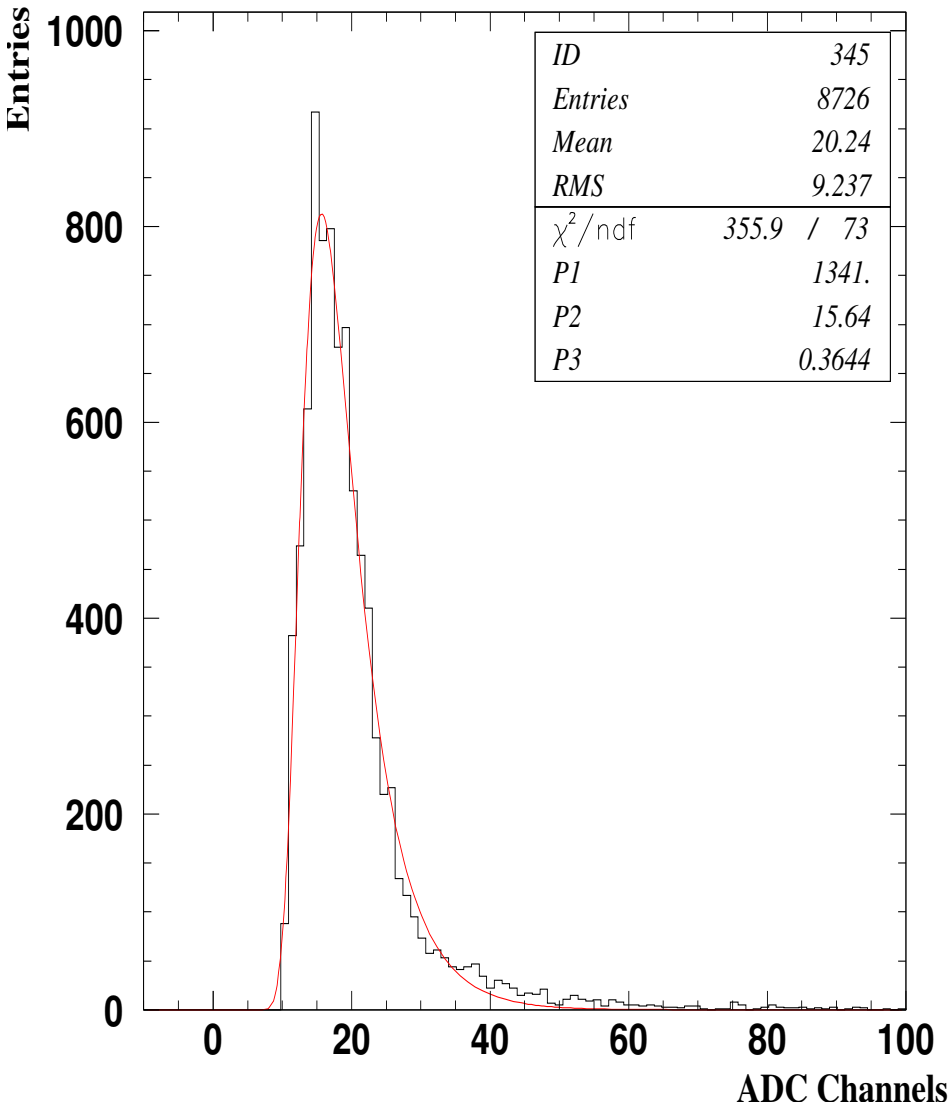
Testbeam at DESY

- Electrons from pre-accelerator DESYII (1-6 GeV)
- Use Zeus Telescope
  - 6 Reference detectors
  - $\frac{S}{N} > 60$
  - pitch 25 (50) μm

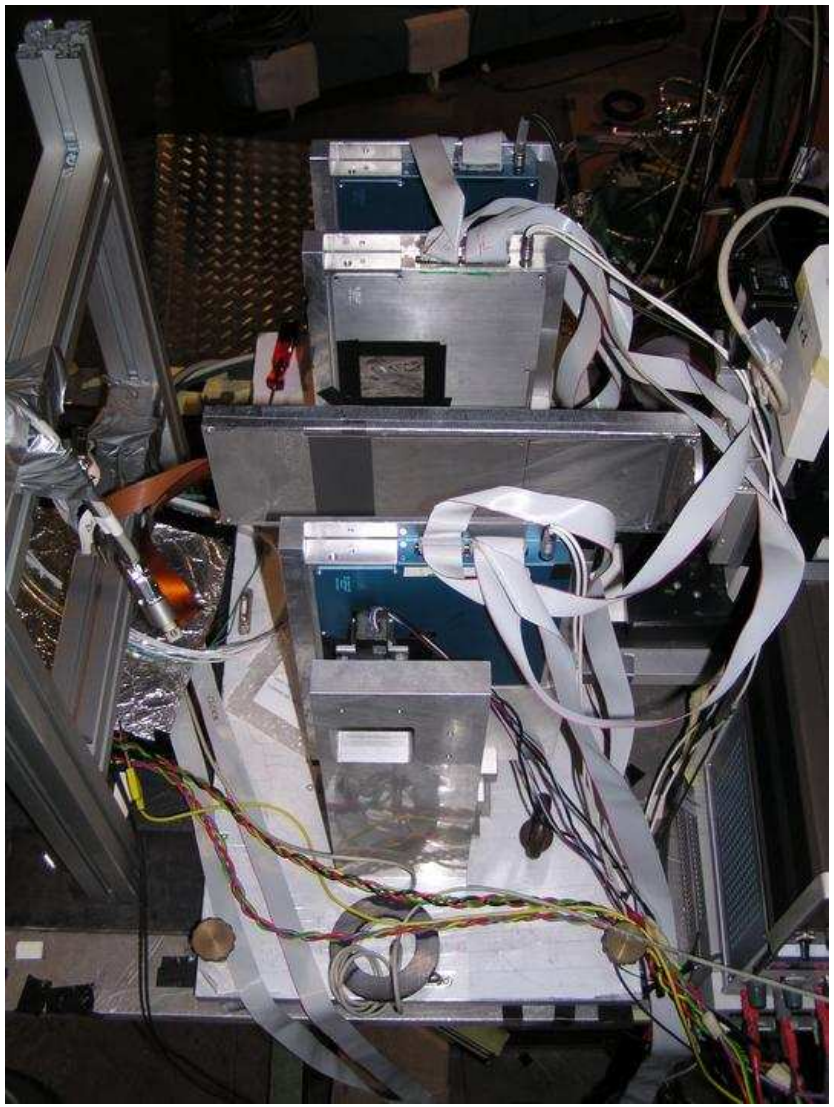


Testbeam at DESY





Testbeam at DESY



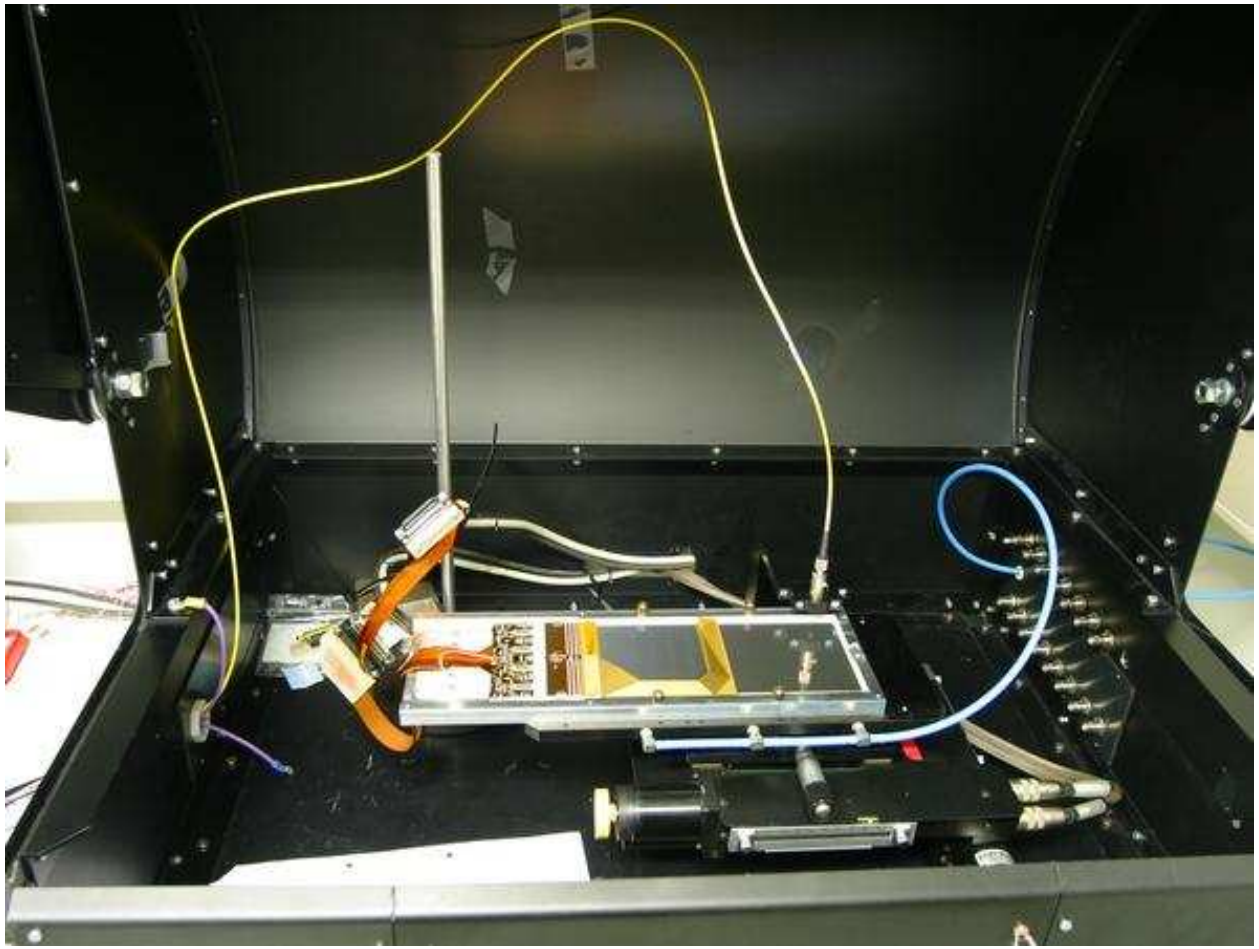
'*Pre*' Prototype:

- ➜ $\frac{S}{N} = 7.5$
- ➜ $\epsilon = 99.73 \pm 0.04\%$

'*Final*' Prototype:

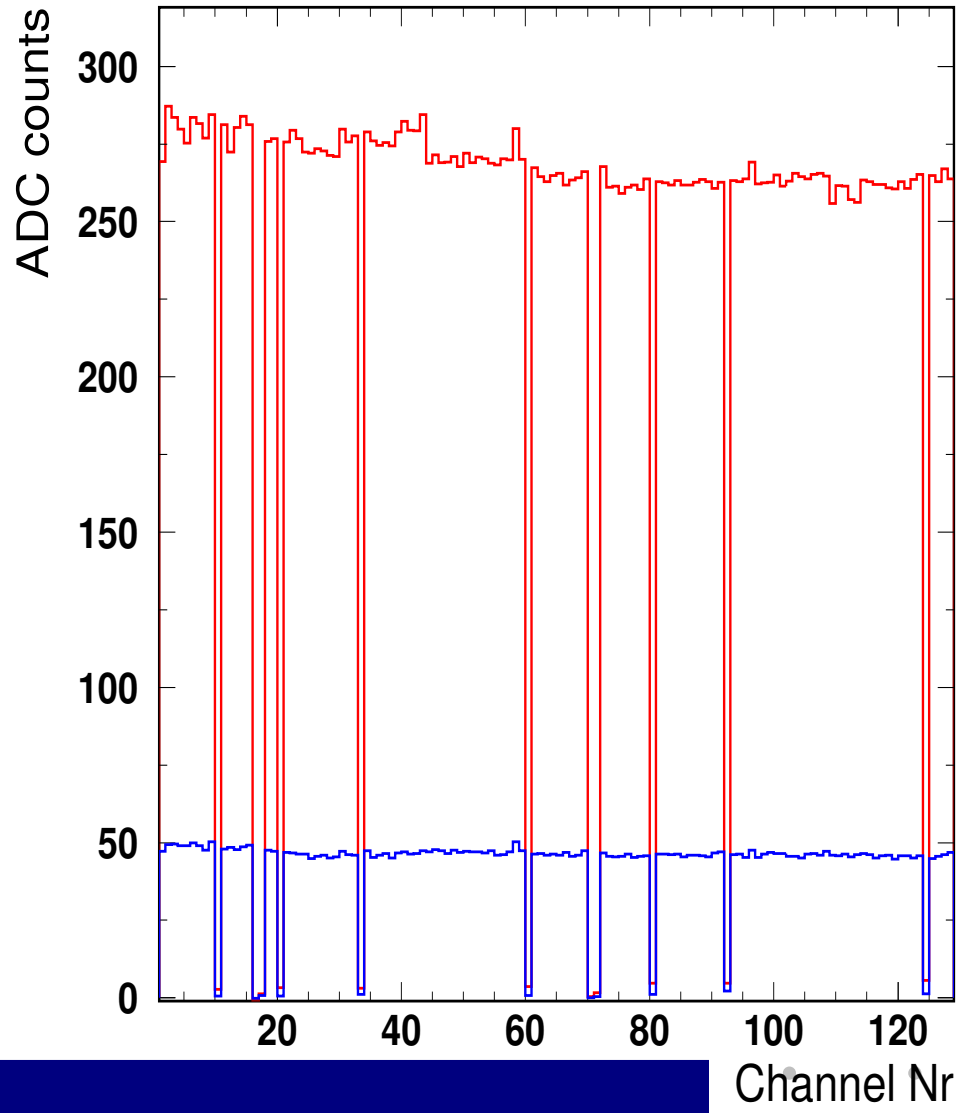
- ➜ $\frac{S}{N} \sim 6.2$

Laser Test



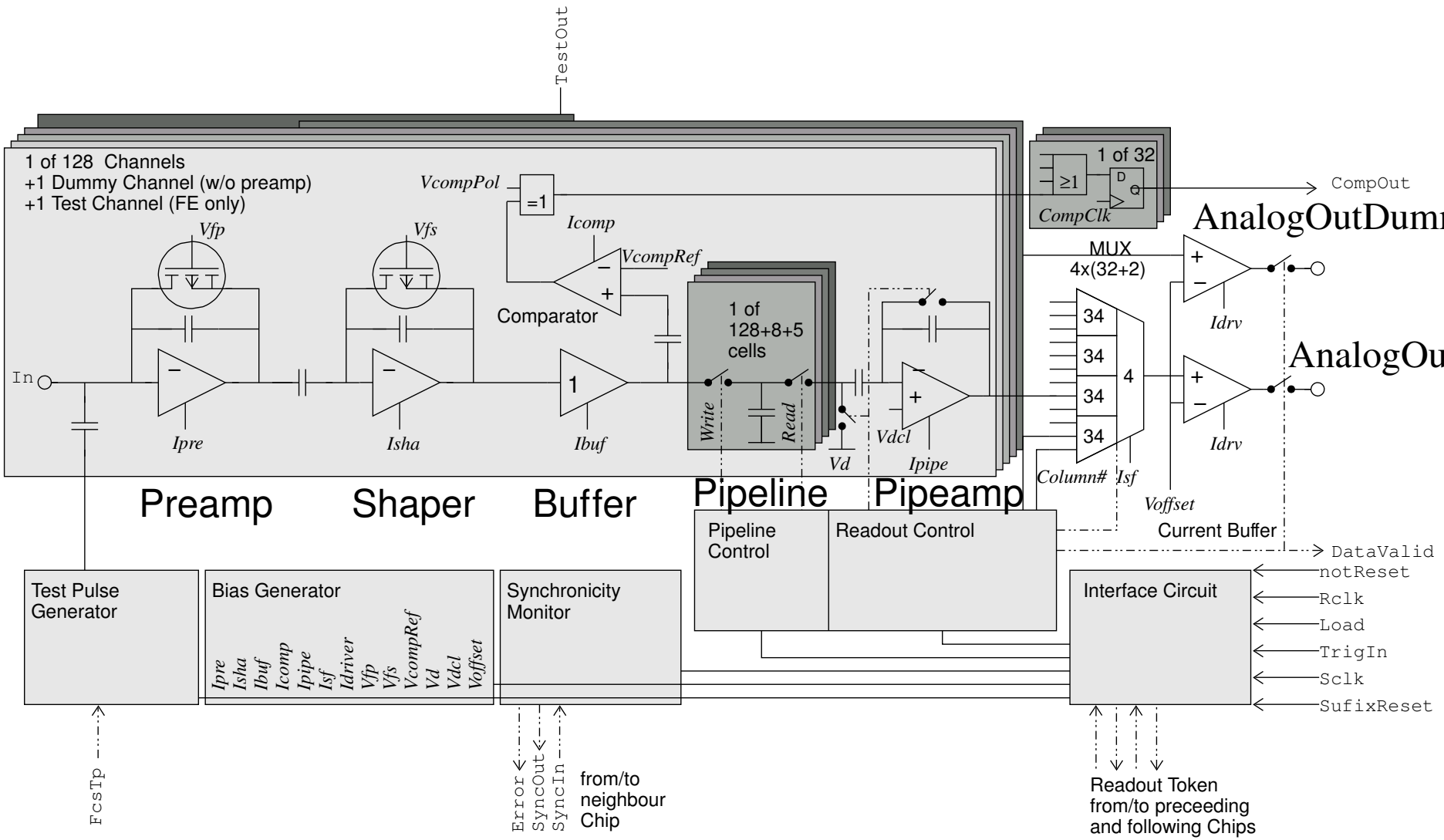
- Black Box
- Red Laser
- X-Y Table
- Spot $\sim 20\mu m$

Laser Test

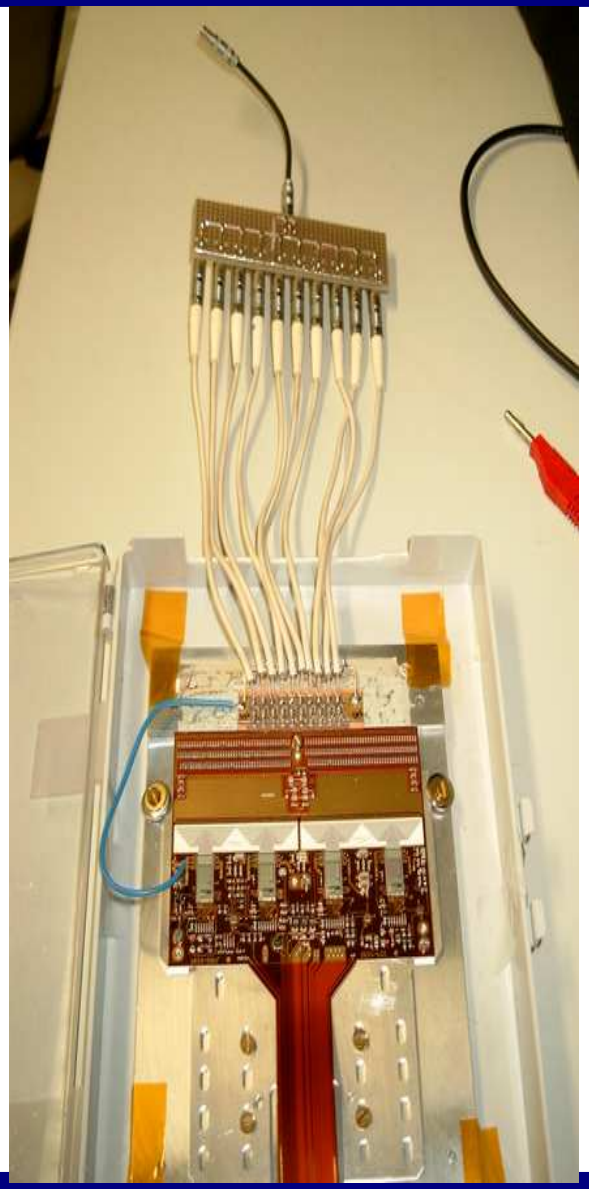


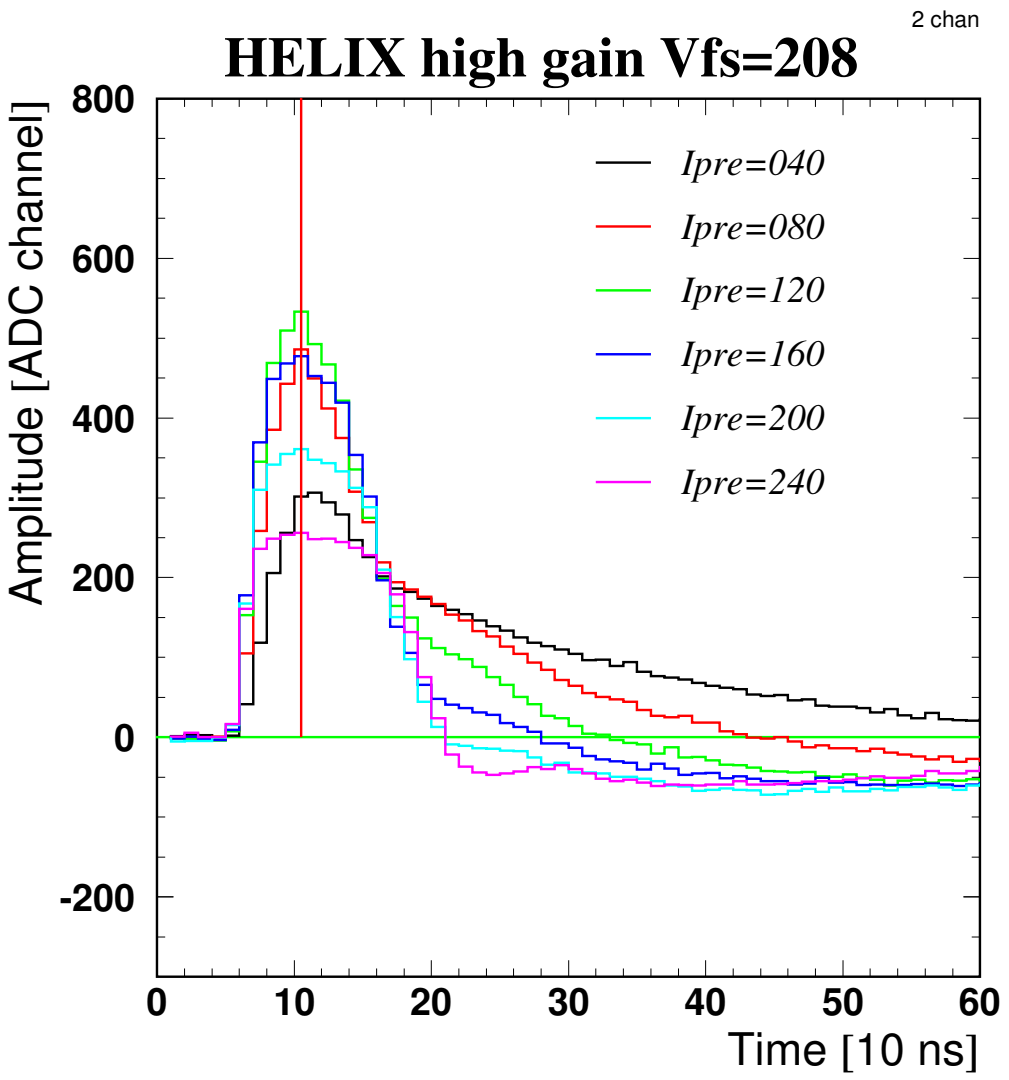
- Uniformity
- Linearity
- Pipe Spread

Parameter Tests



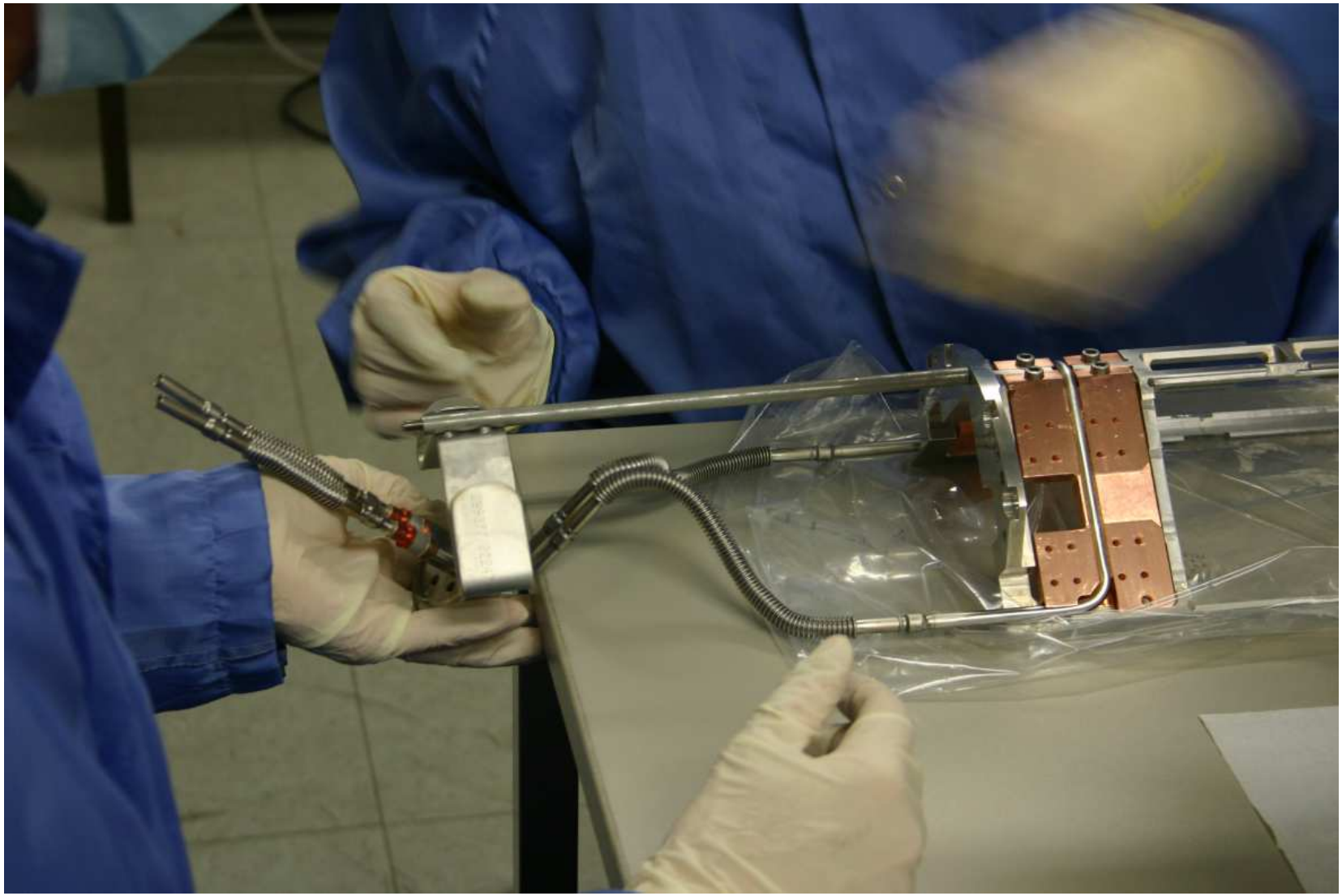
Parameter Tests





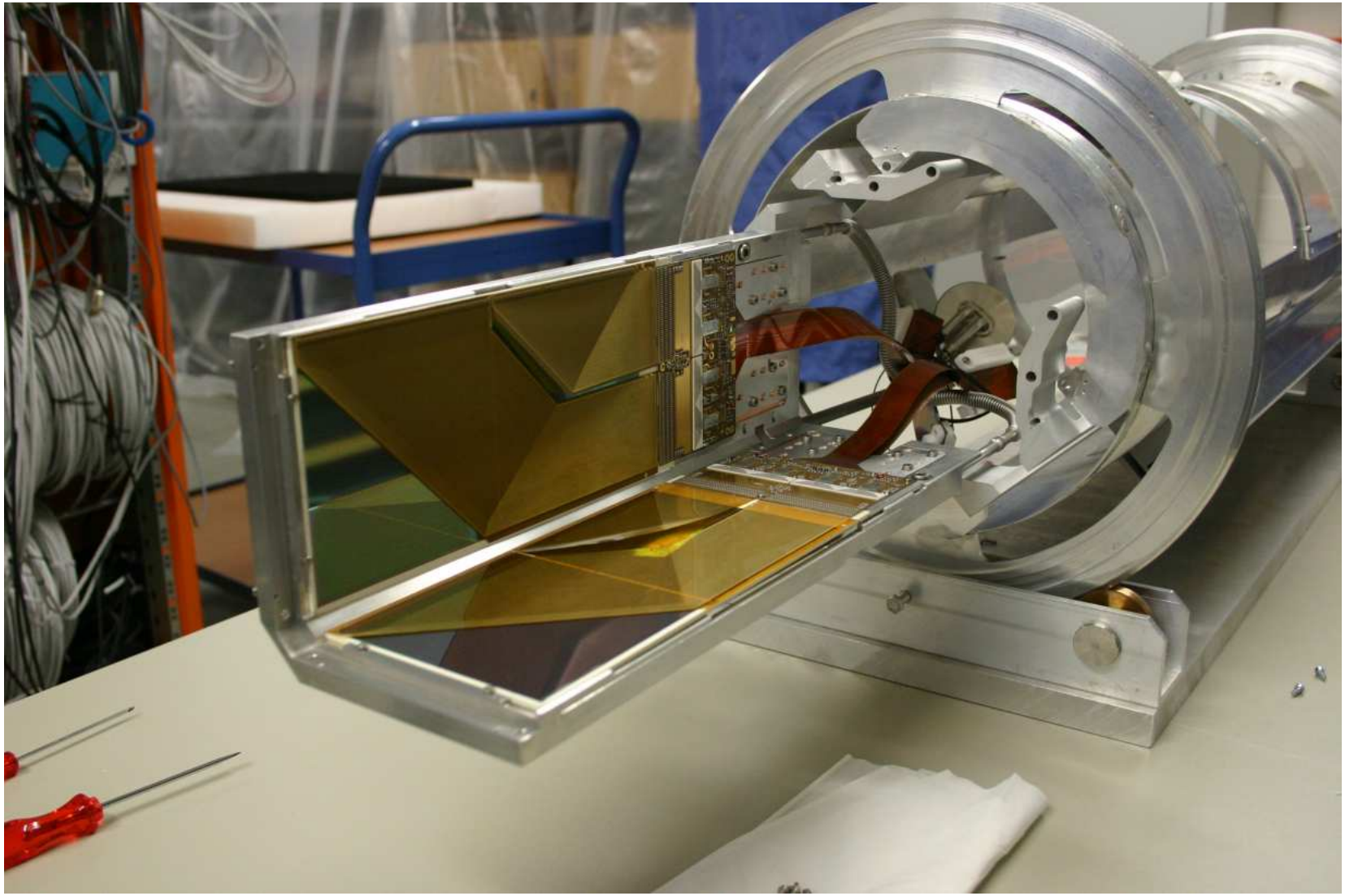
Bench Test

Installation Pictures

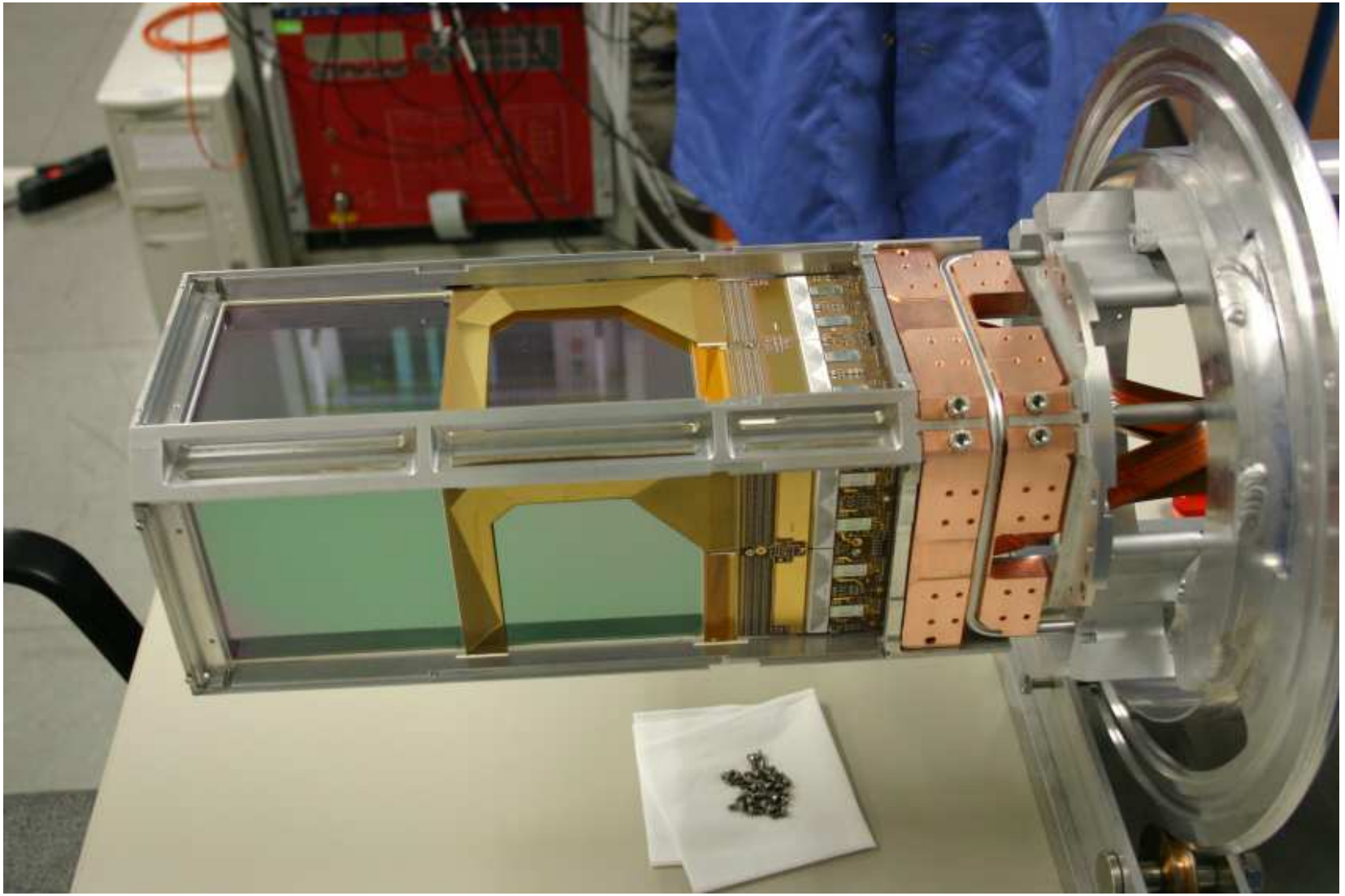


Installation Pictures

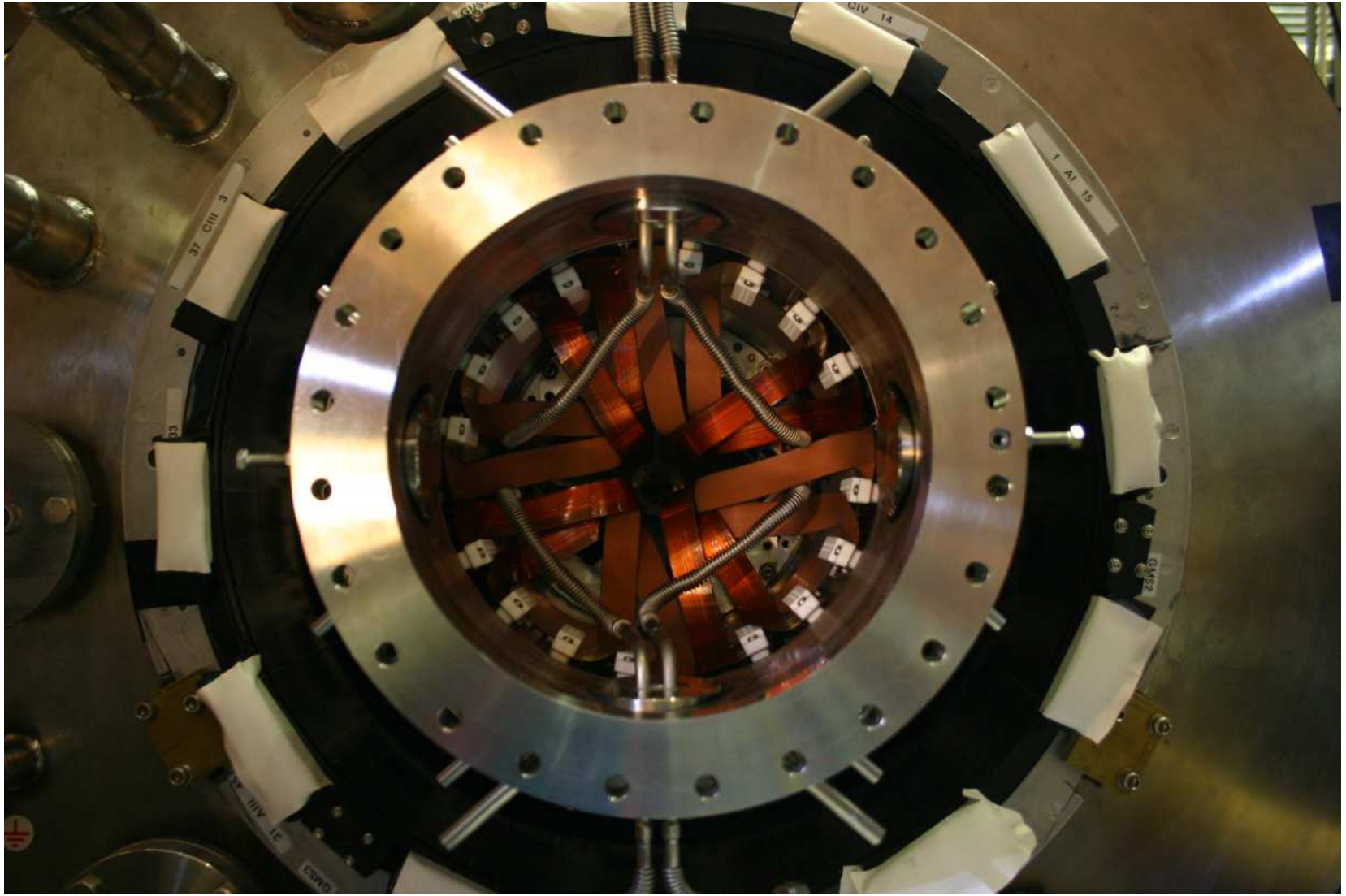
Installation Pictures



Installation Pictures



Installation Pictures



Summary

- Interest in Exclusive Physics
- Development of a Silicon Recoil Detector for HERMES
- Mechanical construction fixed and working
- Test installation running, take cosmics data