Development of a Beam Profile Monitor based on Silicon Strip Sensors for Low-Charge Electron Beams at ARES.

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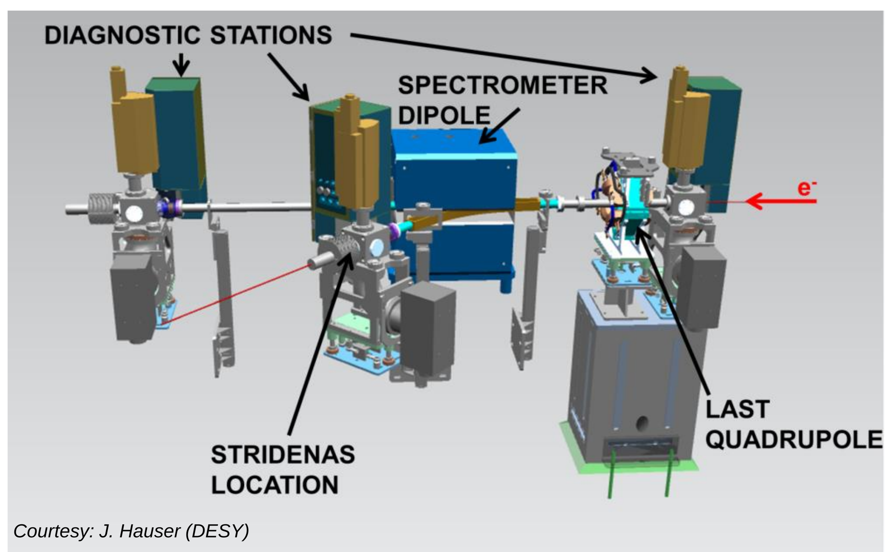
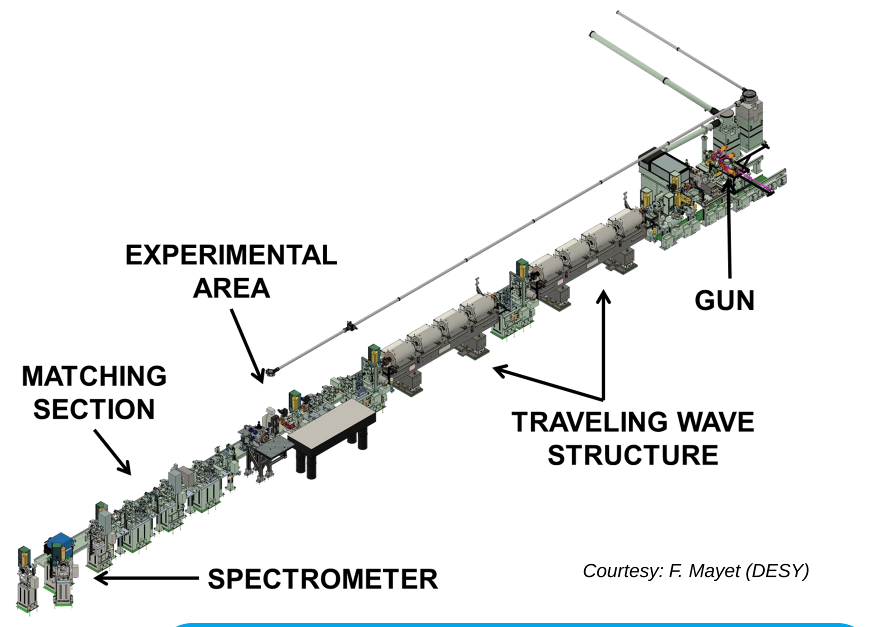
INTRODUCTION

- Tests of **novel acceleration techniques** such as dielectric laser acceleration (DLA).
- Using the **ARES linac** at the SINBAD facility (DESY, Hamburg).
- Measure beam energy and determine performance of the novel accelerator under test with a **spectrometer setup**.
- Consists of a **dipole** and a **beam profile monitor** downstream.



Courtesy: J. Hauser (DESY)



Courtesy: F. Mayet (DESY)

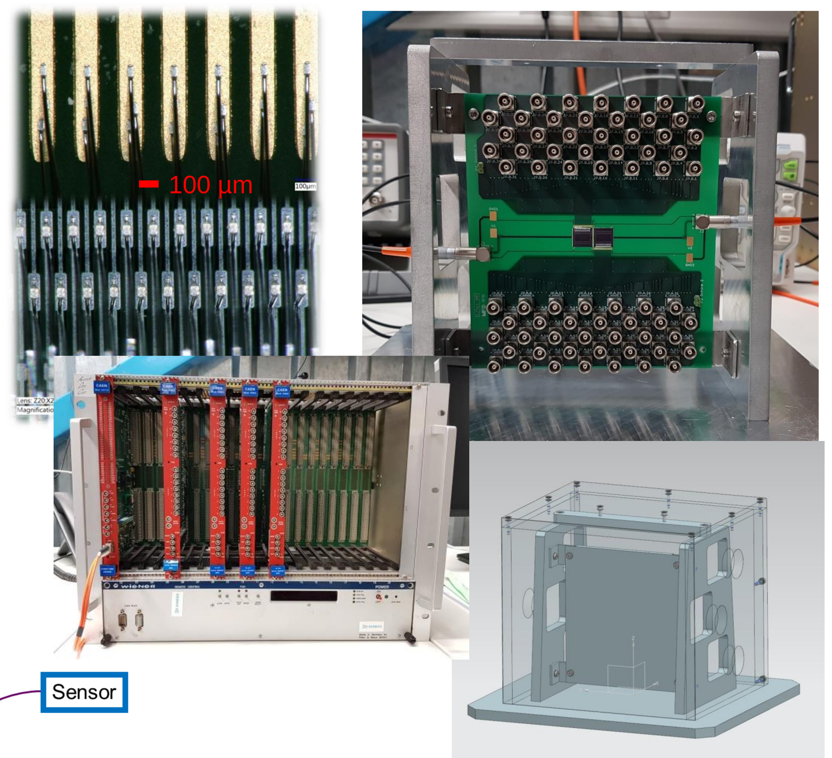
Novel acceleration techniques with **small volumes**. → Beams with **charge densities below 7 electrons per µm²**. → **Challenging to measure with conventional diagnostics.** → SOLUTION → **STRIDENAS** Dedicated beam profile monitor based on **silicon strip sensors** for low-charge beams.

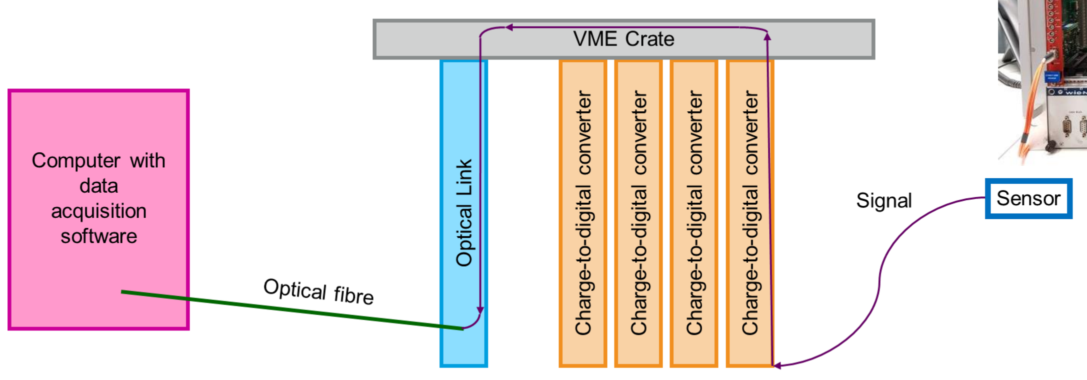
DESIGN OF THE STRIP DETECTOR FOR NOVEL ACCELERATORS AT SINBAD (STRIDENAS)

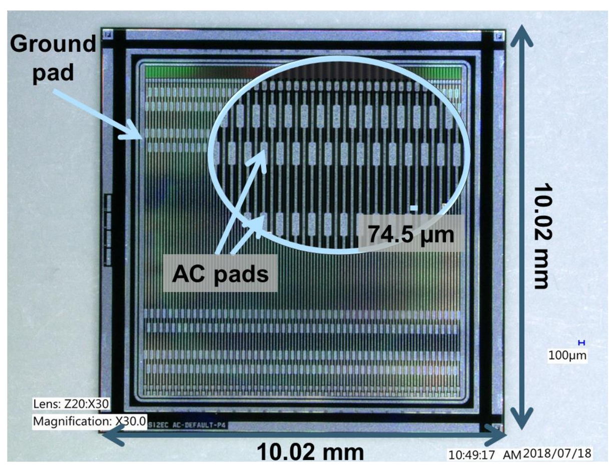
Developed as an internal DESY collaboration combining the expertise of the accelerator R&D group, the ATLAS detector group and DESY technical groups.

COMPONENTS

- PCB with 64 readout channels.
- Sensors glued and bonded to PCB.
- PCB can be placed in a dedicated holder.
- CAEN charge-to-digital converters.
  - Dynamic range: 0 – 900 pC
  - Dual range: 25 fC and 200 fC resolution





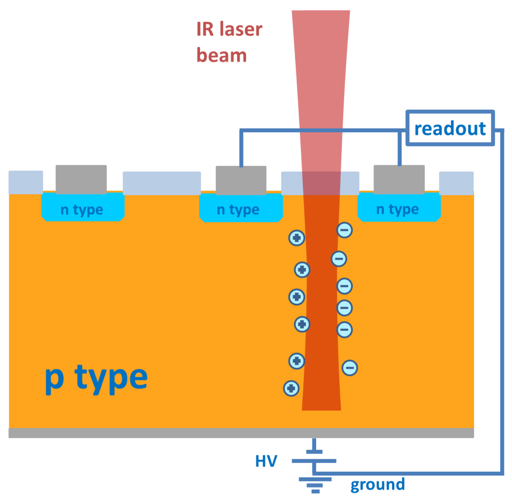


	Unit	Value
Size	mm²	10.02 x 10.02
Strip		n
Bulk		p
# of Strips		103
Strip Pitch	µm	74.5
Thickness	µm	310

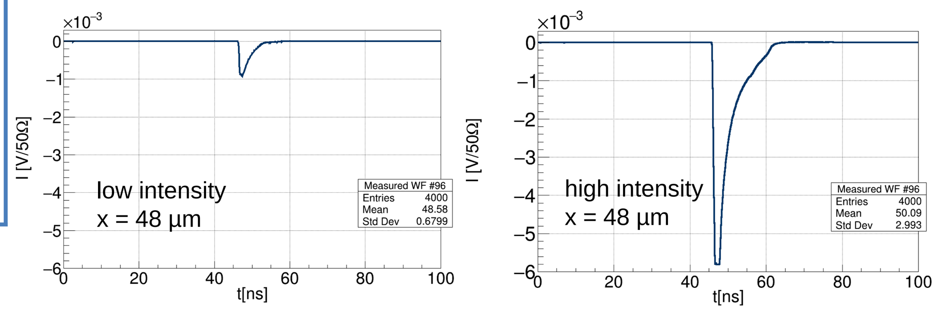
Requirements

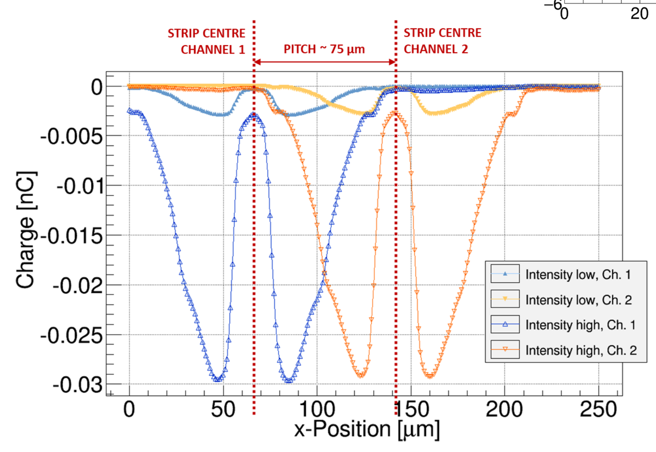
- 100 µm range resolution.
- Charge range: 1 fC – 40 fC
- Withstand ~10^6 e^- per shot.
- Shielded from light.
- UHV-compatible in final setup.

TRANSIENT-CURRENT TECHNIQUE MEASUREMENTS



- Investigate **signal length** and **transverse spread**.
- Measurements with **infrared** light.

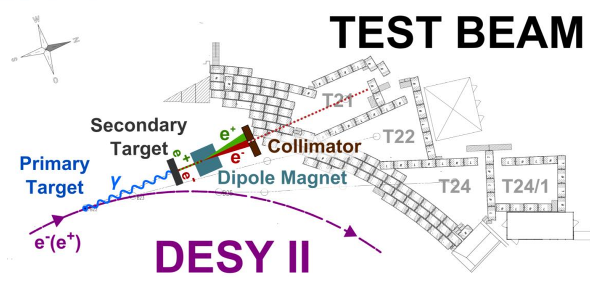




- Position scan to investigate signal spread.
- No transverse spread towards neighbouring strip is visible.

DESY II TEST BEAM FACILITY

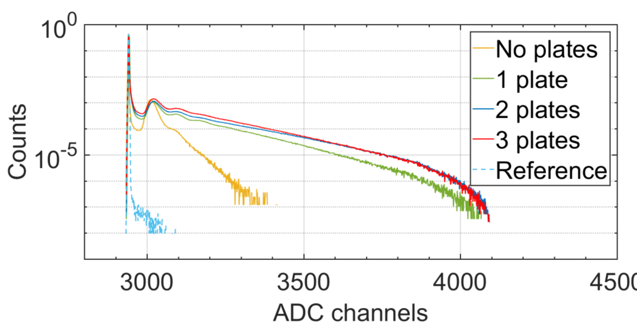
- Electron energies: 1 – 6 GeV
- Single electrons needed for detector tests.
- Particle rate up to ~ 40 kHz.
- Provides infrastructure for experiments.



STRIDENAS FUNCTIONALITY TESTS

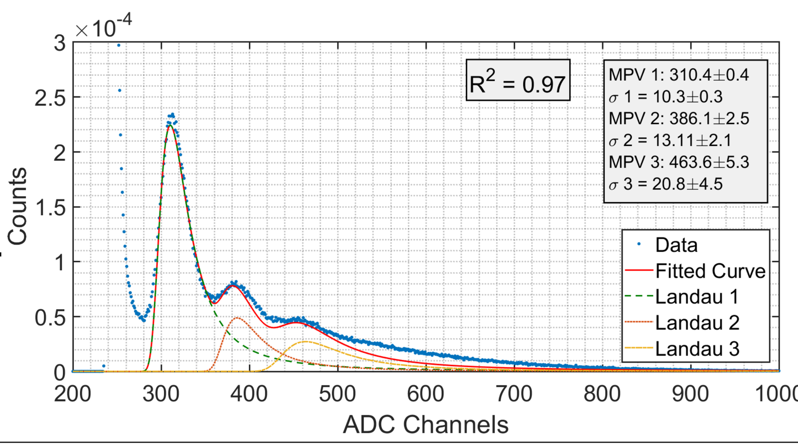
READOUT ELECTRONICS TEST WITH PHOTOMULTIPLIER SIGNALS

- Different charge integration gates.
- Use of iron plates to produce particle showers and increase the number of incoming particles.
- Example measurements with a 15 µs gate signal.

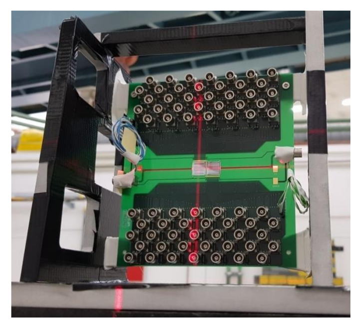


Triple Landau fit 1µs gate signal

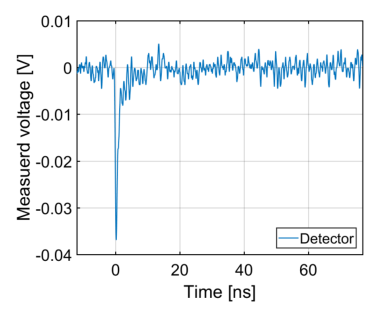
- Peak-to-peak distance ~15 pC.
- Agrees well with expected value from PMT.



SENSOR TESTS WITH AMPLIFIER

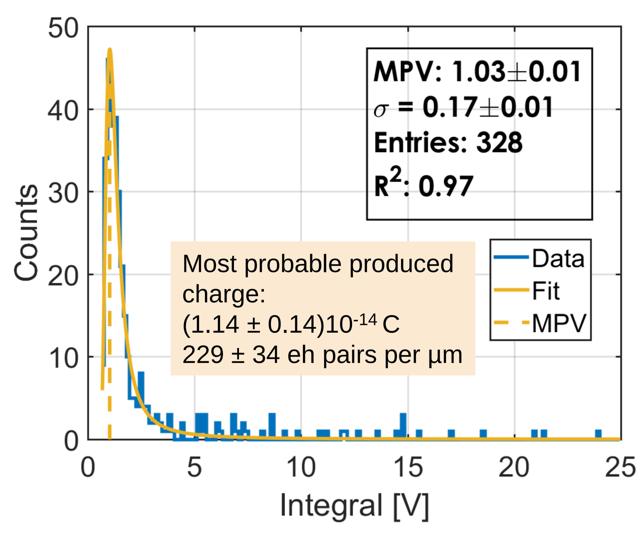


- STRIDENAS detector measurement unsuccessful due to early breakdown of the sensors.
- Measurements repeated with functional sensor and 40 dB Femto amplifier.
- Signal connected to oscilloscope.
- Area under the signal is proportional to the produced charge inside the sensor.
- Varies according to the Landau distribution.
- Histogram of waveform integrals with Landau fit.



$$Q = \frac{L_C}{A\,R}\int_{t_s}^{t_f} U\,dt \sim \frac{L_C}{A\,R}\, I_M\, \Delta t$$

L_C = signal loss compensation
A = amplification factor
R = impedance of system
U = measured voltage
t_s, t_f = starting and final time boundaries
I_M = MATLAB integral
Δt = actual data spacing



CONCLUSION AND OUTLOOK

- ✓ Successfully detected single electrons.
- ✓ Successful sensor tests with a high electron intensity simulated with laser beam.
- ✓ Readout electronics tested successfully for high intensities with signals from photomultipliers.
- ✓ Amplifier needed to reduce noise introduced by meter long cables.

- ▸ Repeat high intensity measurements with incoming electrons.
- ▸ Development of suited signal amplification.
- ▸ Build vacuum compatible setup. First discussions with the DESY vacuum group are ongoing.
- ▸ Implementation at the ARES spectrometer.

ACKNOWLEDGEMENTS
The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).

DESY. SINBAD ATLAS EXPERIMENT Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG DESY TEST BEAM. MT ARD