Study Committee B1

Insulated cables

Paper 11073_2022

Advanced Analysis of Partial Discharges and Breakdowns on HVDC Power Cables

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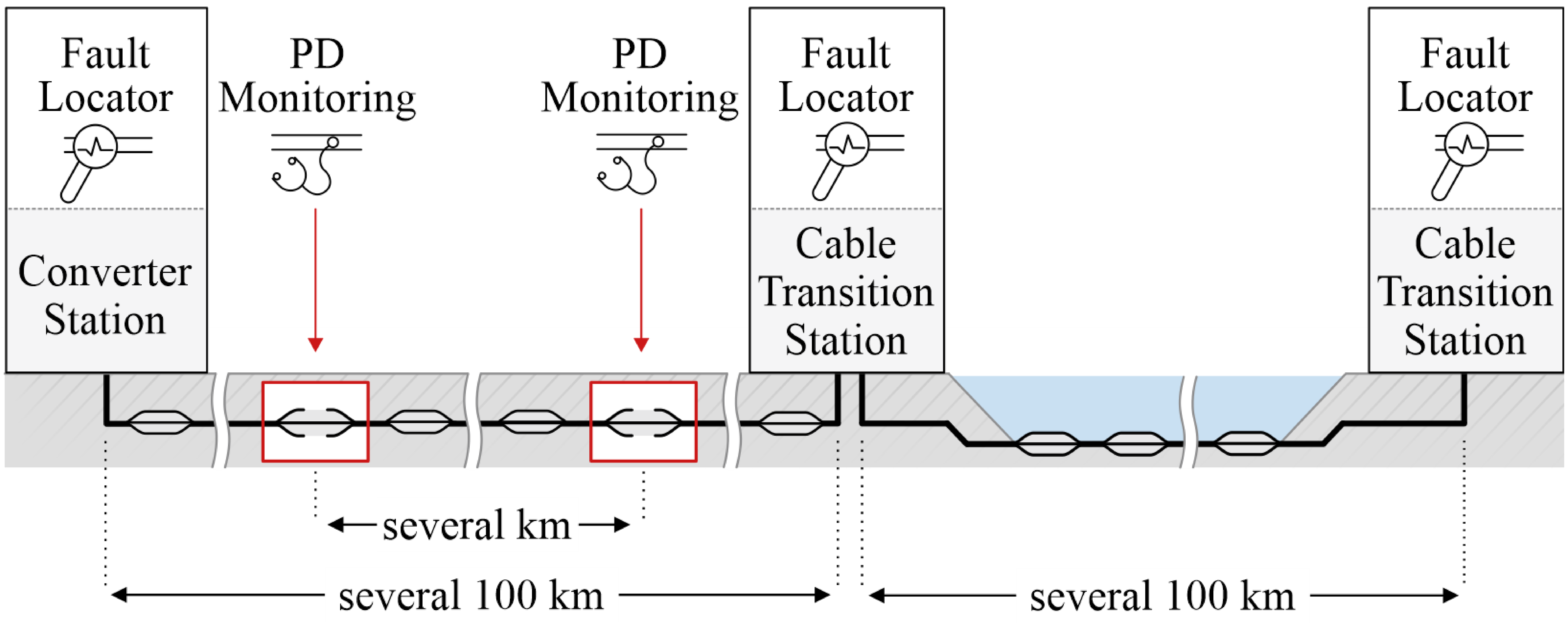
- **Background:**

Generation from renewables ⇨ Need for bulk energy transportation ⇨ HVDC cable systems as a key technology

- **Desire**: Increase of reliability and availability of HVDC cable systems.
- **Problem**: Well-known approaches for PD assessment are not applicable for HVDC cables due to low repetition rates, the lack of phase information, costs.
- **What's the solution?**
  - Advanced PD evaluation for predictive maintenance of the whole cable system in combination with capability of pinpointing a sudden breakdown.
- **How it works?**
  - New approach to evaluate PD under DC: "TruePD", plus
  - A fault locator coupled with a High Frequency Current Transformer (HFCT) or with a conventional divider.
- **Technologies that made it possible:**

High-sensitive coupling to cable	Advanced signal processing
State-of-the-art FPGAs	Machine learning methods

- **Aim of the paper:**
  - Explain the basics of the TruePD and do the proof of concept by measurements at a cable test line,
  - Compare fault localisation accuracies resulting from standard coupling with a divider and the coupling established via an HFCT.



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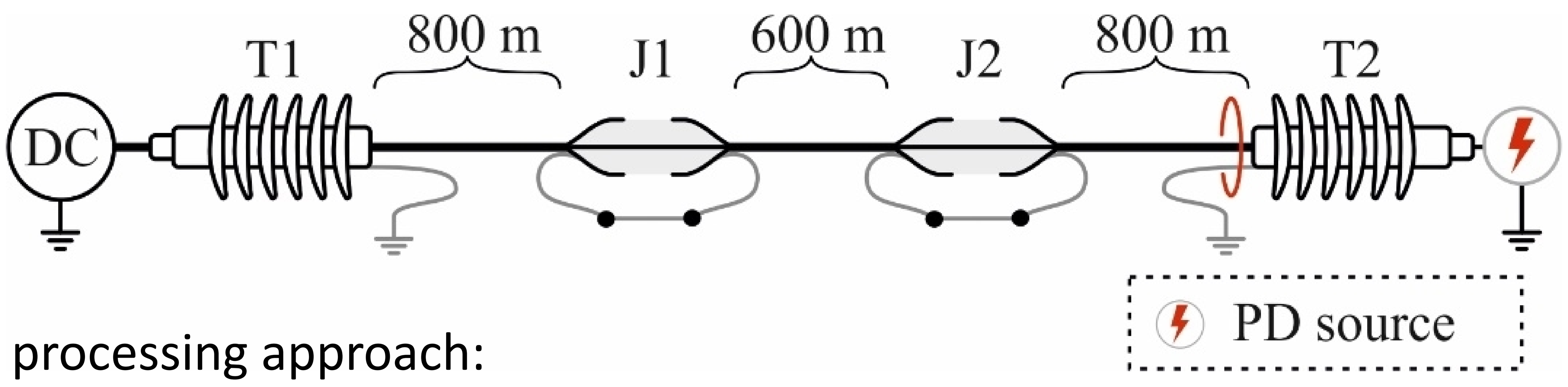
continued

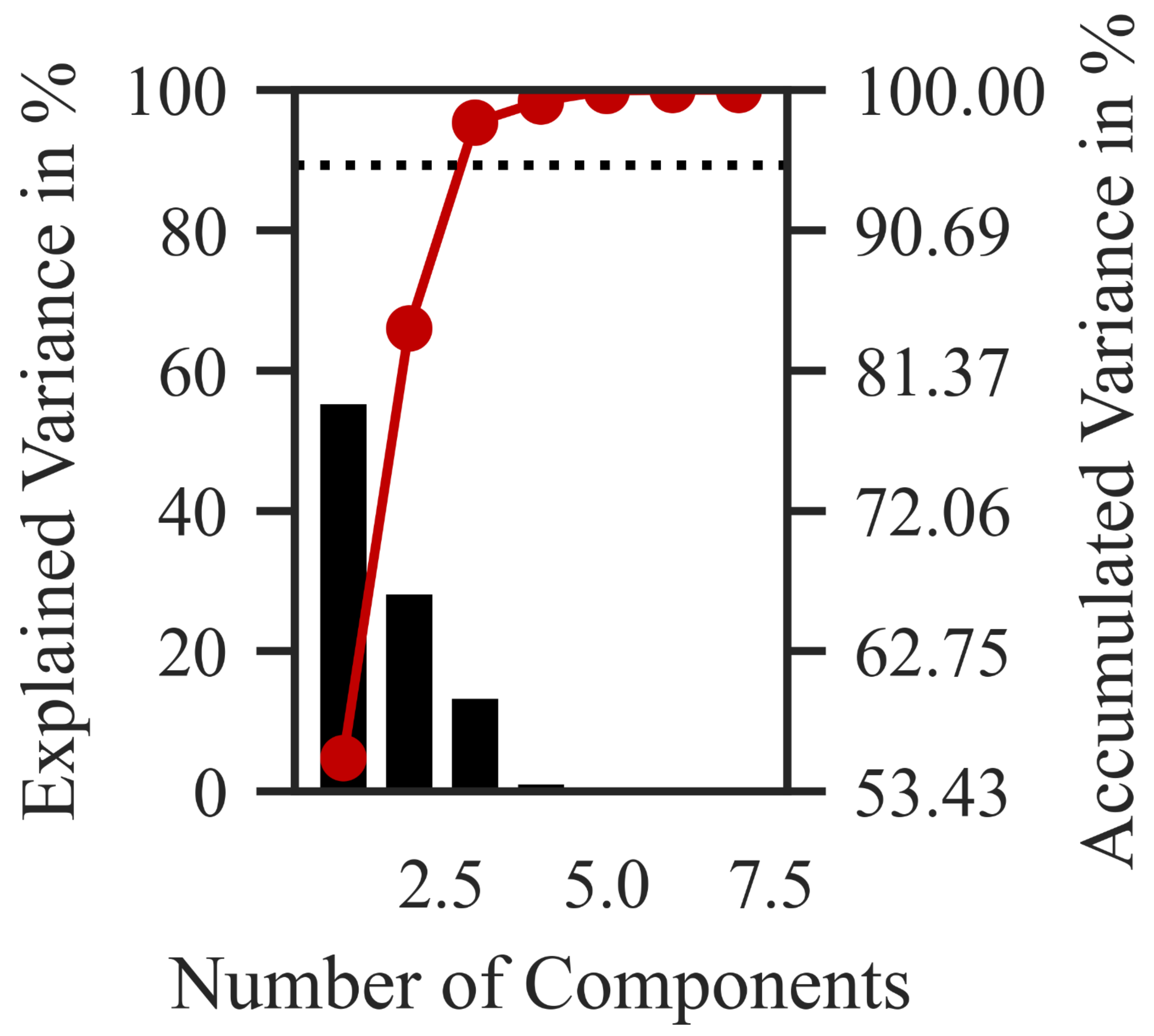
Advanced Analysis of PD Measurement

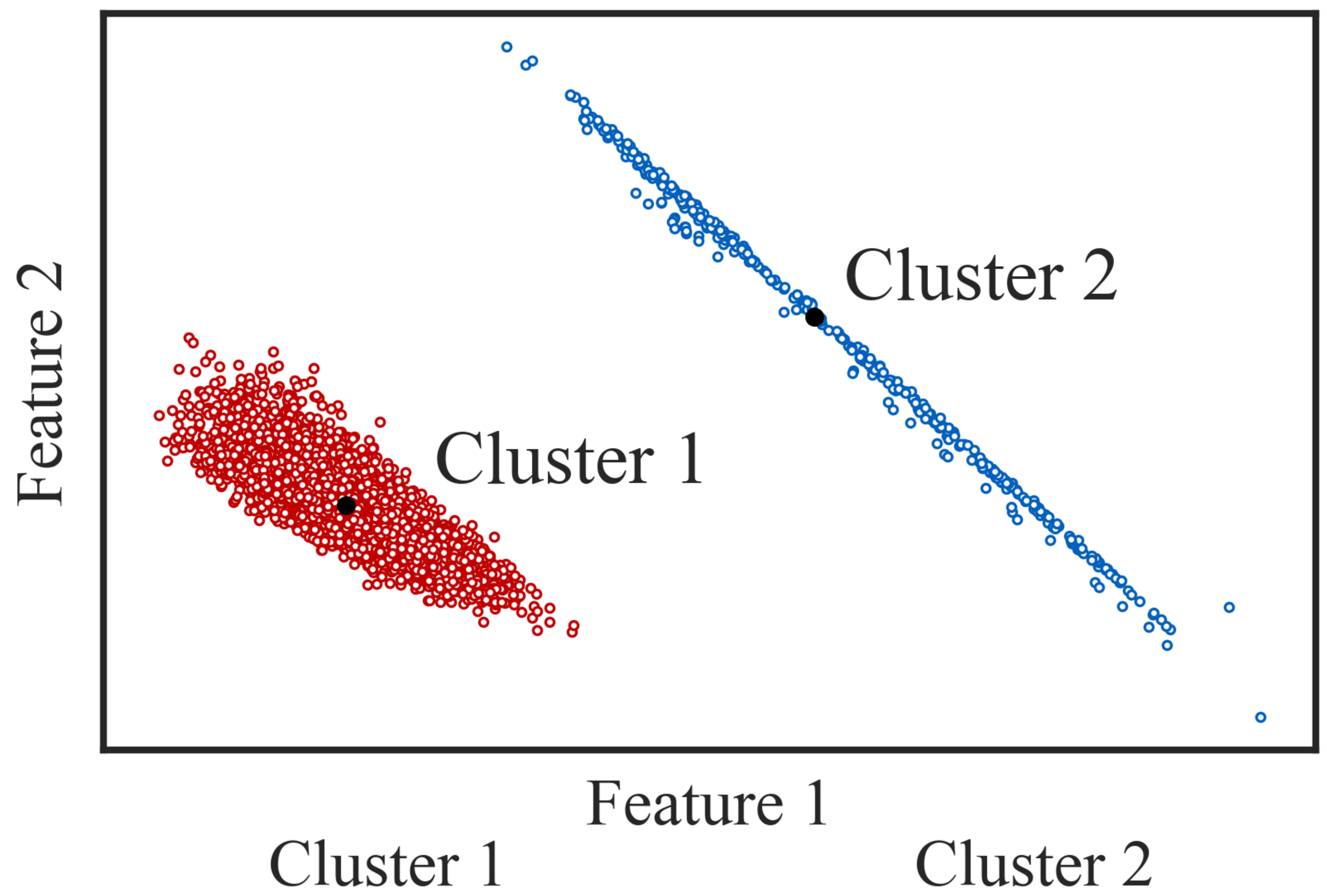
- **Aim of the experiment:** Demonstration of the TruePD approach.
- **Experimental setup**: DC source, 2.2 km cable line, a corona discharge, HFCT, recording hardware.



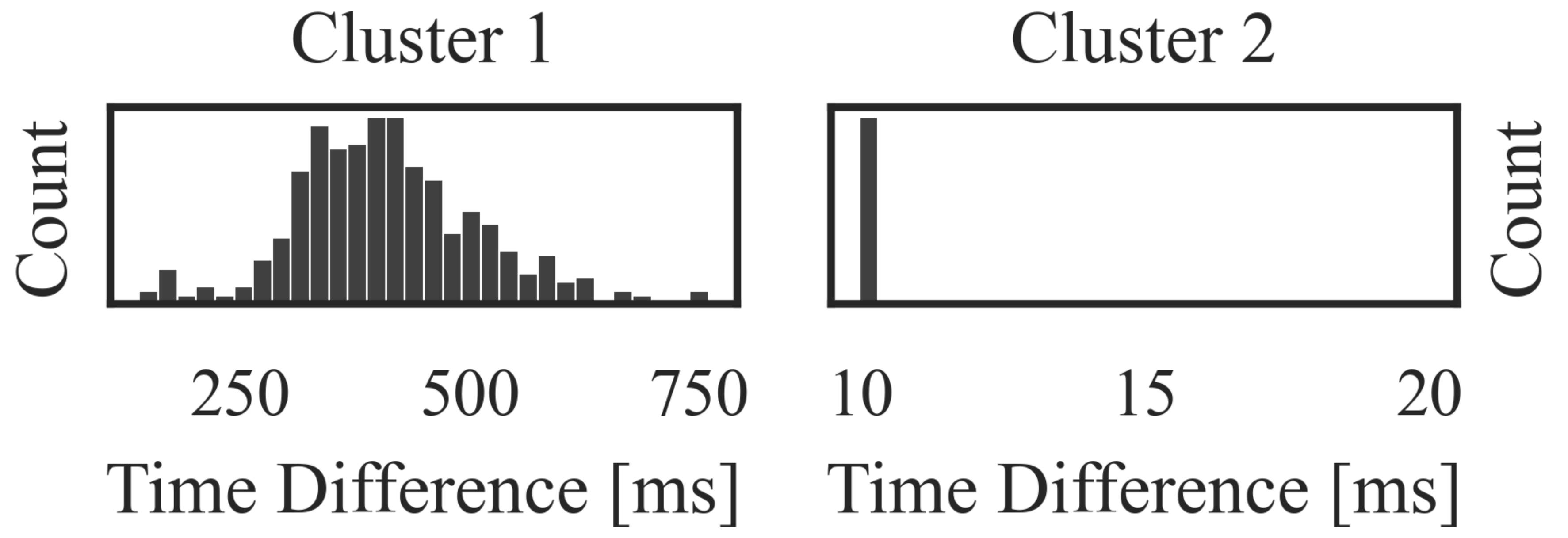
Signal processing approach:

LPC Coefficients → Principal Component Analysis → Clustering by K-means → Sorted Signals

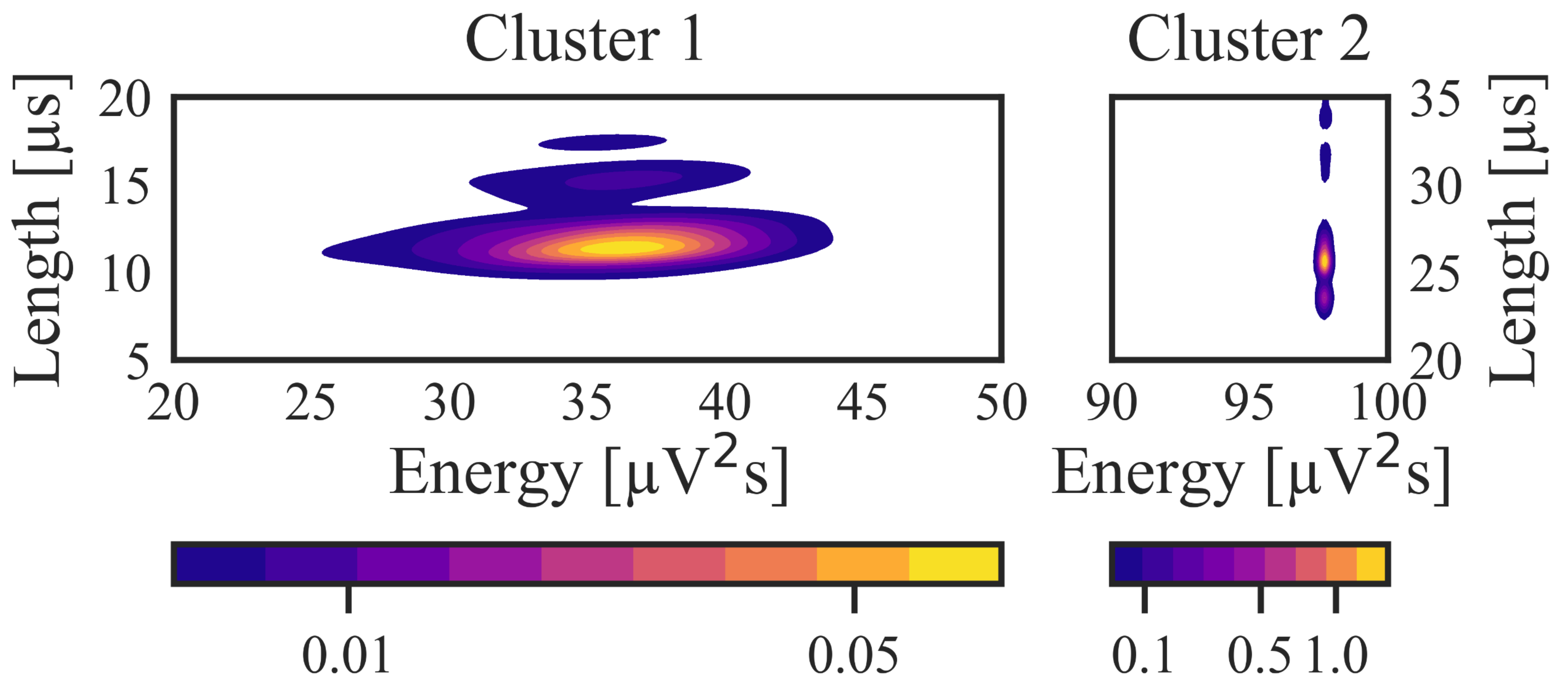




Time difference between two signals of the same source



Signal energy shows broad distribution for cluster 1, and stability for cluster 2



Conclusion

→ Real-time signal processing and machine learning algorithms can be used to classify different PD sources and monitor their behaviour. This opens the road to predictive maintenance.

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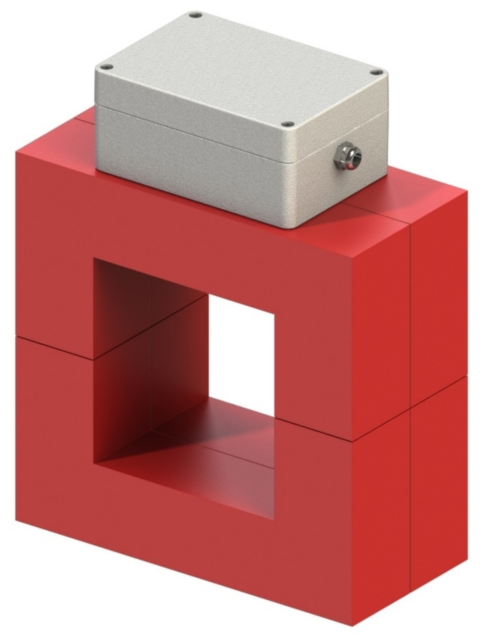
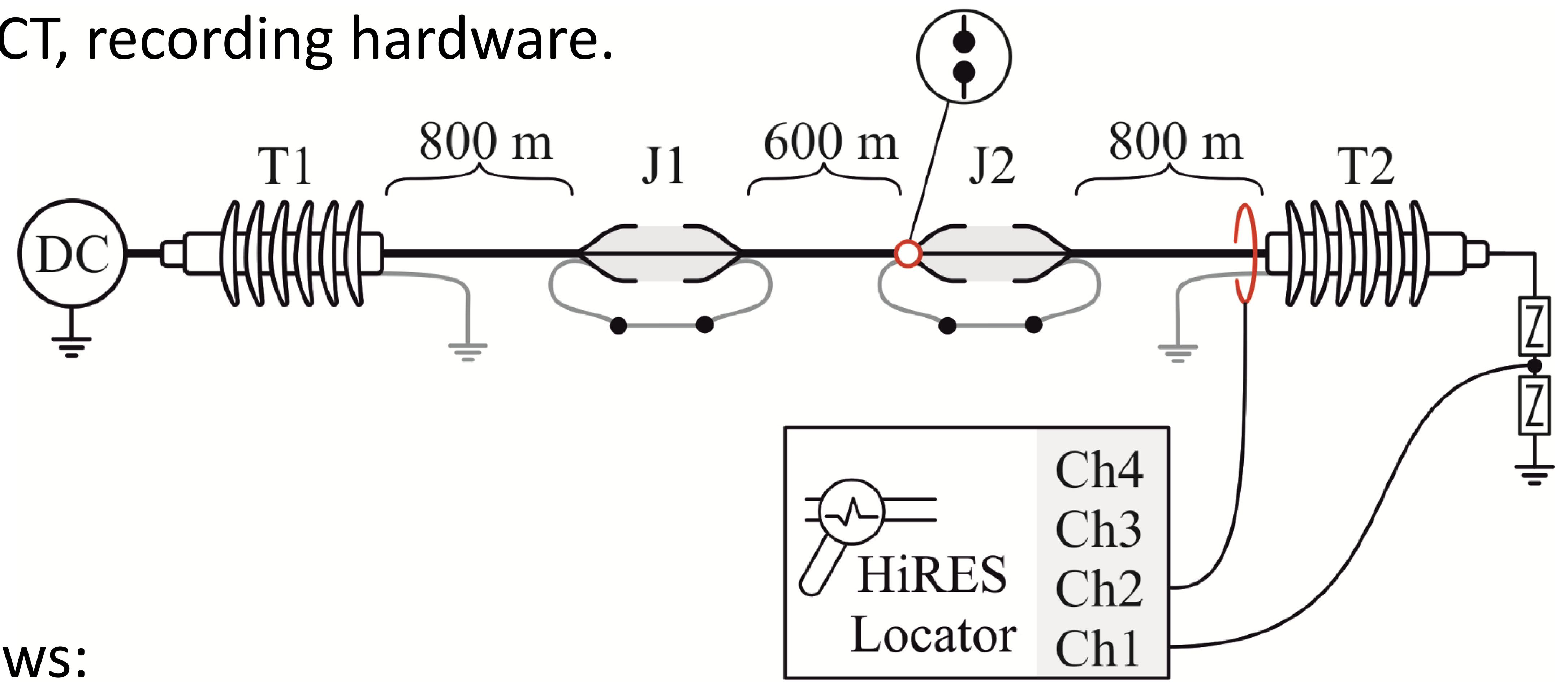
continued

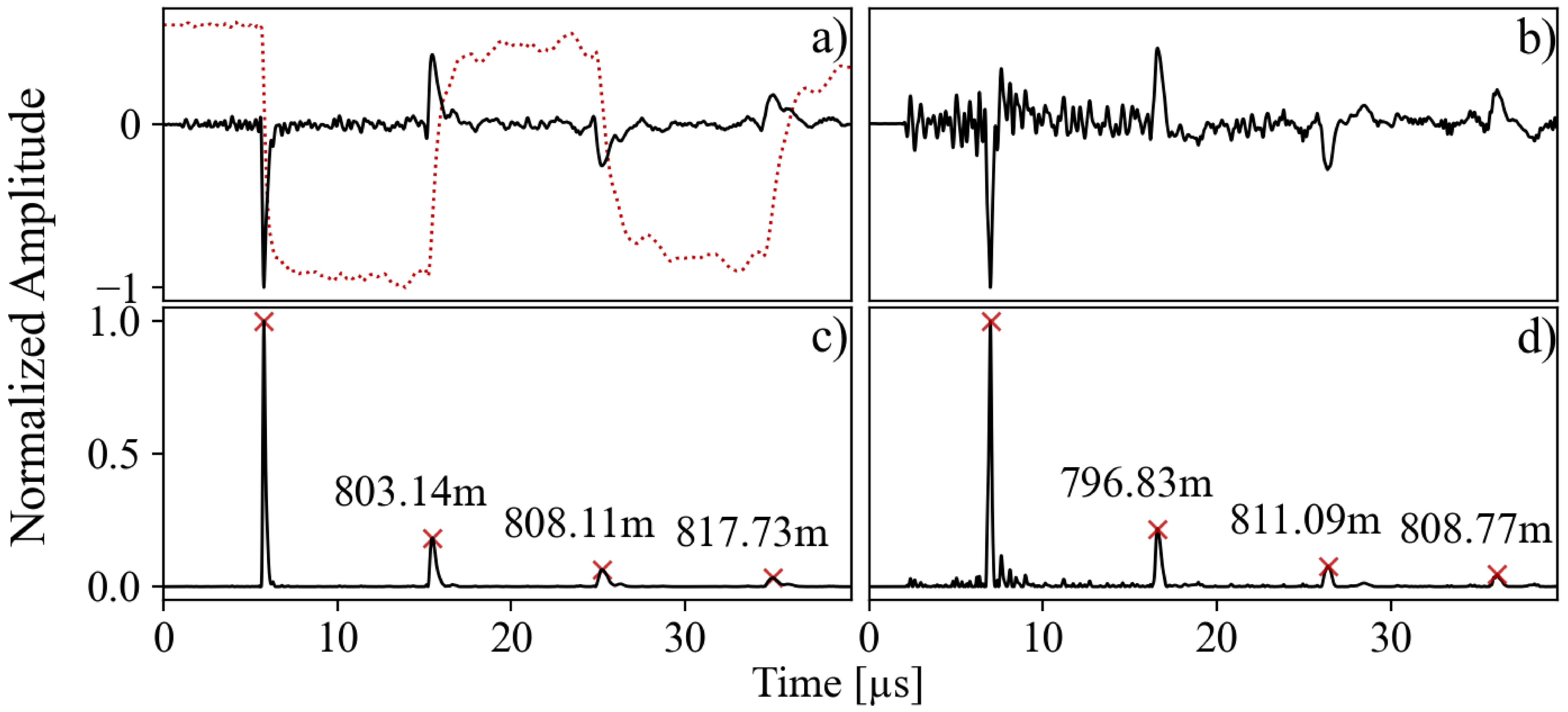
Fault Localization for Breakdown Measurement

- **Aim of the experiment:** Compare coupling methods in resulting accuracy of pinpointing the fault.
- **Experimental setup**: DC source, 2.2 km cable line energized to 10 kV, spark gap, voltage divider, HFCT, recording hardware.





The figures below shows:
a) Signal and reflections from the divider (dashed) & its 1st derivative (solid),
b) Displays signal measured with HFCT,
c) & d) show the squared curves and estimated distance-to-fault.



Coupling method	Divider			HFCT		
Reflection #	1	2	3	1	2	3
Fault distance	803 m	808 m	818 m	797 m	811 m	809 m
Inaccuracy related to total cable length	≈0.14%	≈0.37%	≈0.82%	≈0.14%	≈0.5%	≈0.41%

Conclusion

→ Localization error of a breakdown on the 2.2 km test line was less than 0.2%;

→ Both coupling methods: The divider and HFCT can be used for fault localization.