# Development of Highly Integrated Low-mass Signal Readout Electronics for the LEGEND Experiment

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NEVTRINO 2018
4–9 June
Heidelberg
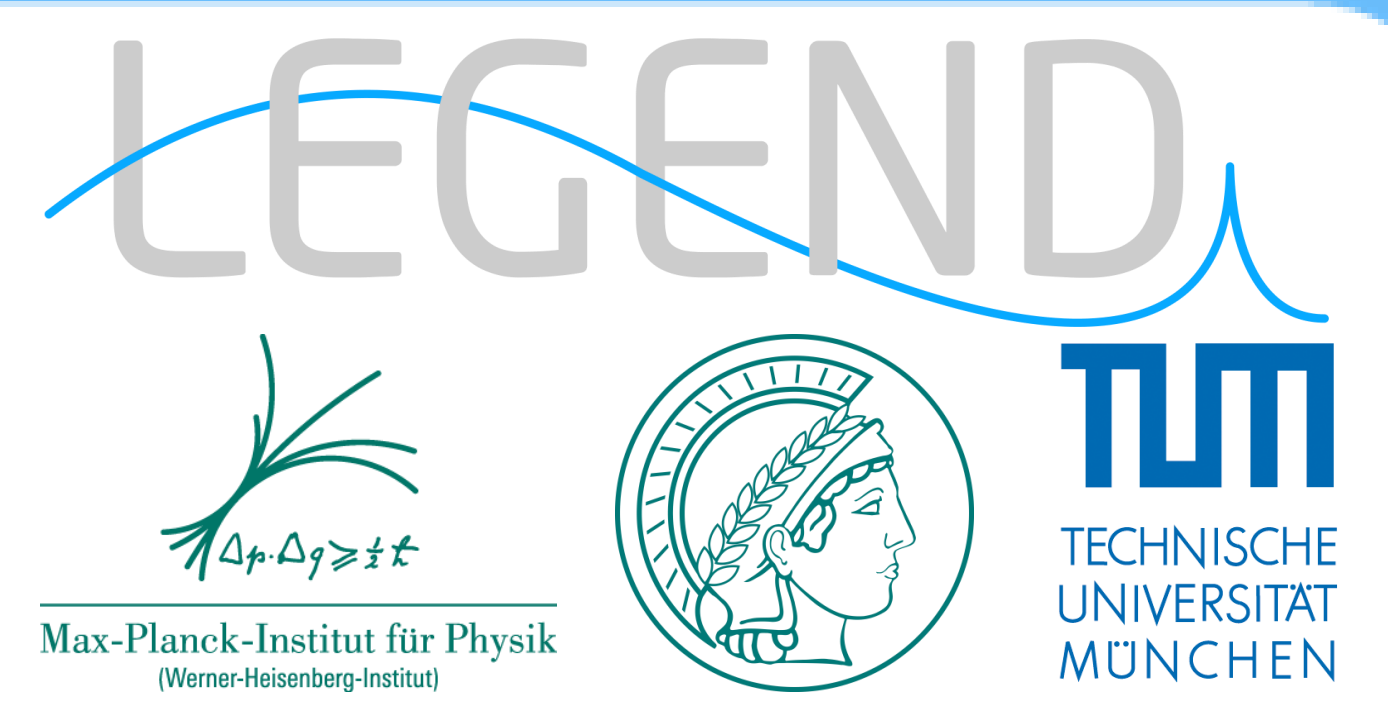
LEGEND

Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay (LEGEND)

Mission

*The collaboration aims to develop a phased, ^{76}Ge based double-beta decay experimental program with **discovery potential** at a half-life beyond 10^{28} years, using existing resources as appropriate to expedite physics results.*
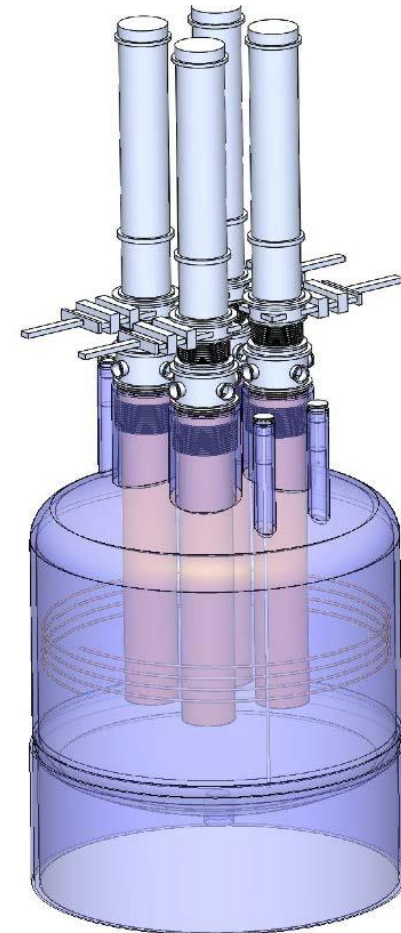
Staged approach

First phase:
- Up to 200kg of Ge
- Modification of existing GERDA infrastructure at LNGS
- BG goal: 5x lower, 0.6 cts/(FWHM·t·yr)
- Sensitivity > 10^{27}yr
- Start by 2021

Subsequent phases:
- 1000kg of Ge (staged)
- BG goal: 30x lower, 0.1 cts/(FWHM·t·yr)
- Sensitivity > 10^{28}yr
- Location: TBD
- Required depth under investigation

52 institutions, ~250 members

Univ. of New Mexico
L'Aquila Univ. and INFN
Gran Sasso Science Inst.
Lab. Naz. del Gran Sasso
Univ. of Texas
Tsinghua Univ.
Univ. of Cal. Berkeley and LBNL
Leibniz Inst. for Crystal Growth
Comenius Univ.
Lab. Naz. del Sud
Univ. of North Carolina
Sichuan Univ.
Univ. of South Carolina
Jagiellonian Univ.
Banaras Hindu Univ.
Tech. Univ. Dortmund
Tech. Univ. Dresden

Joint Res. Centre Geel
Chalmers Univ. of Technology
Max Planck Inst. für Kernphysik
Dokuz Eylül Univ.
Queens Univ.

Univ. of Tennessee
Argonne Natl. Lab.
Univ. of Liverpool
Univ. College London
Los Alamos Natl. Lab.

Lund Univ.
INFN Milano Bicocca
Milano Univ. and INFN Milano
Natl. Res. Center Kurchatov Inst.
Natl. Res. Nucl. Univ. MEPhI
Max Planck Inst. für Physik
Tech. Univ. of Munich
Oak Ridge Natl. Lab.
Padova Univ. and INFN Padova
Czech Tech. Univ.
Princeton Univ.
North Carolina State Univ.
South Dakota School Mines Tech.
Univ. of Washington
Academia Sinica
Univ. Tübingen
Univ. of South Dakota
Univ. of Zürich
Joint Inst. Nucl. Res.
Inst. Nucl. Res. Russ. Acad. Sci.

December 6-9, 2017
Lawrence Berkeley National Laboratory, Berkeley, California
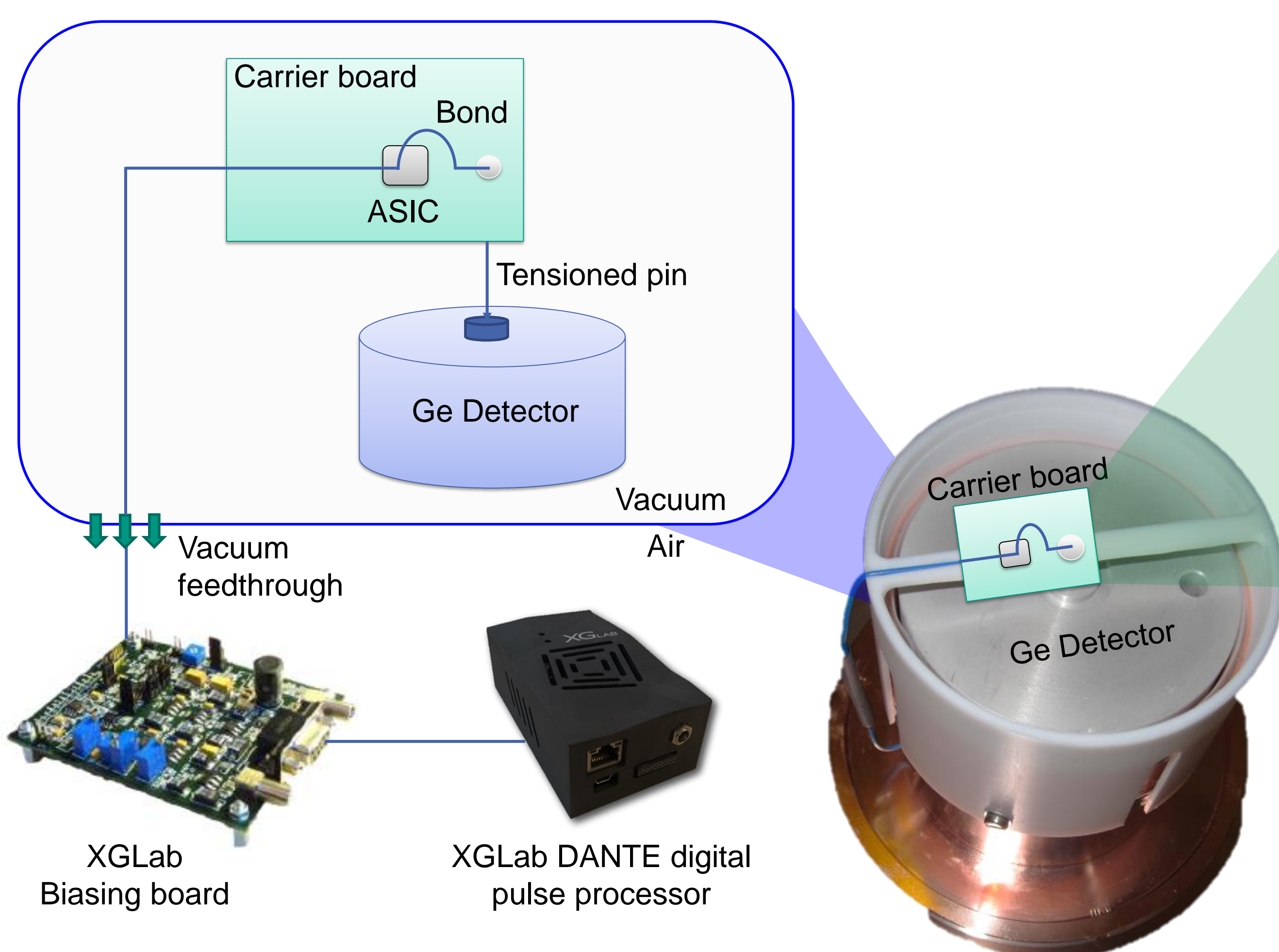**LEGEND Collaboration Meeting and Analysis Workshop**

Signal readout electronics for Germanium detectors

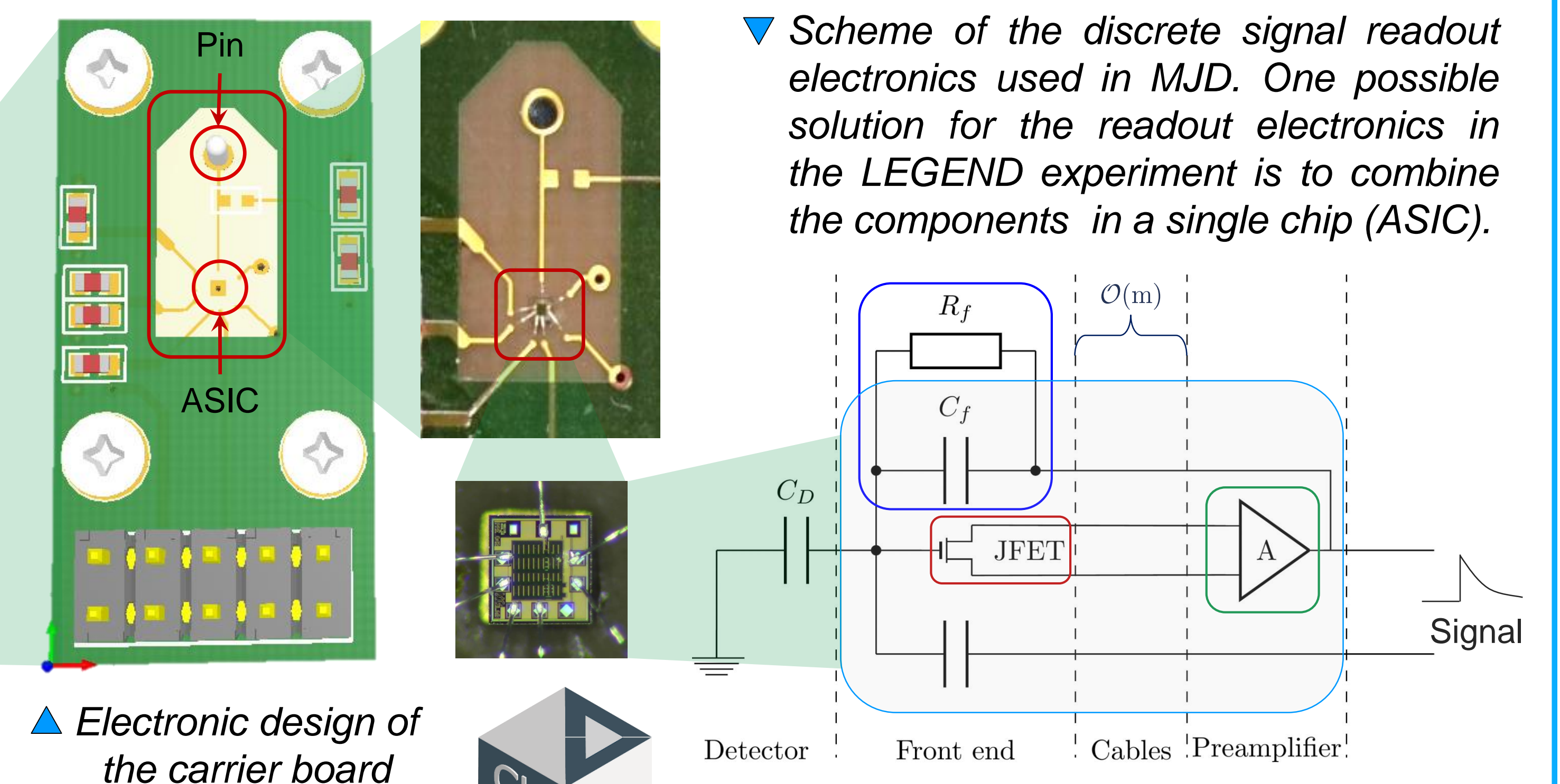### Readout electronics in the context of $0\nu\beta\beta$ decay
- For a good energy resolution and low electronic noise
- → Place readout electronics as close as possible to detector
- Readout components contribute dominantly to background budget
- → Front end mass should be as low as possible
- → Use *application specific integrated circuit (ASIC)* technology

Current readout solutions for Ge-based $0\nu\beta\beta$ decay experiments
- GERDA and MAJORANA DEMONSTRATOR (MJD) use discrete readout electronics consisting of several passive components (Field effect transistor (JFET), RC-circuit, Preamplifier)
- Many single components → contribute dominantly to background budget

▼ *Scheme of the discrete signal readout electronics used in MJD. One possible solution for the readout electronics in the LEGEND experiment is to combine the components in a single chip (ASIC).*

▲ *Electronic design of the carrier board*

▲ *Scheme of the ASIC readout system*

Carrier board
Bond
ASIC
Tensioned pin
Ge Detector
Vacuum
Vacuum feedthrough
Air
XGLab Biasing board
XGLab DANTE digital pulse processor

Carrier board
Ge Detector

Pin
ASIC

Detector | Front end | Cables | Preamplifier
R_f | C_f | C_D | JFET | A | Signal | $\mathcal{O}(m)$
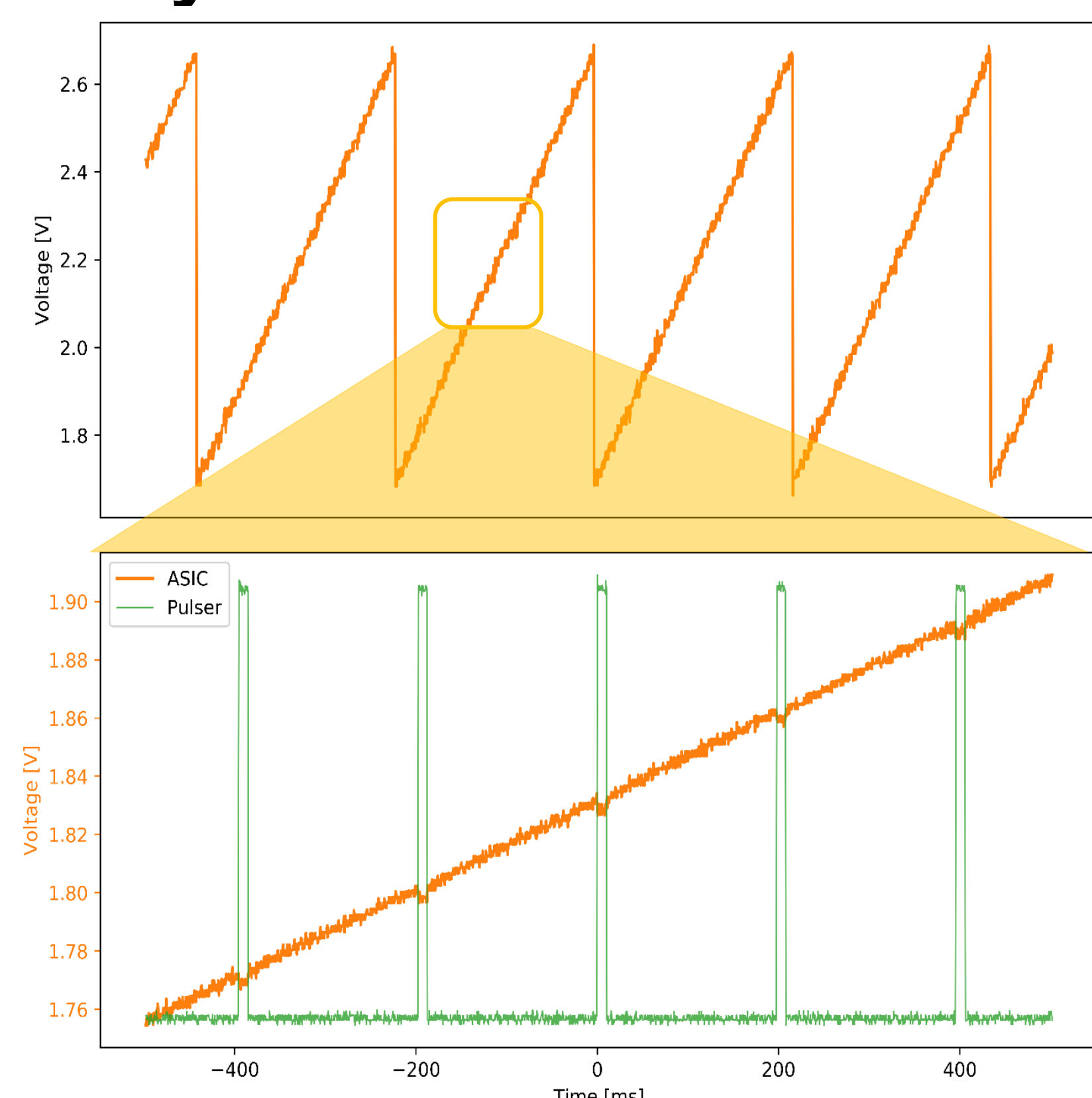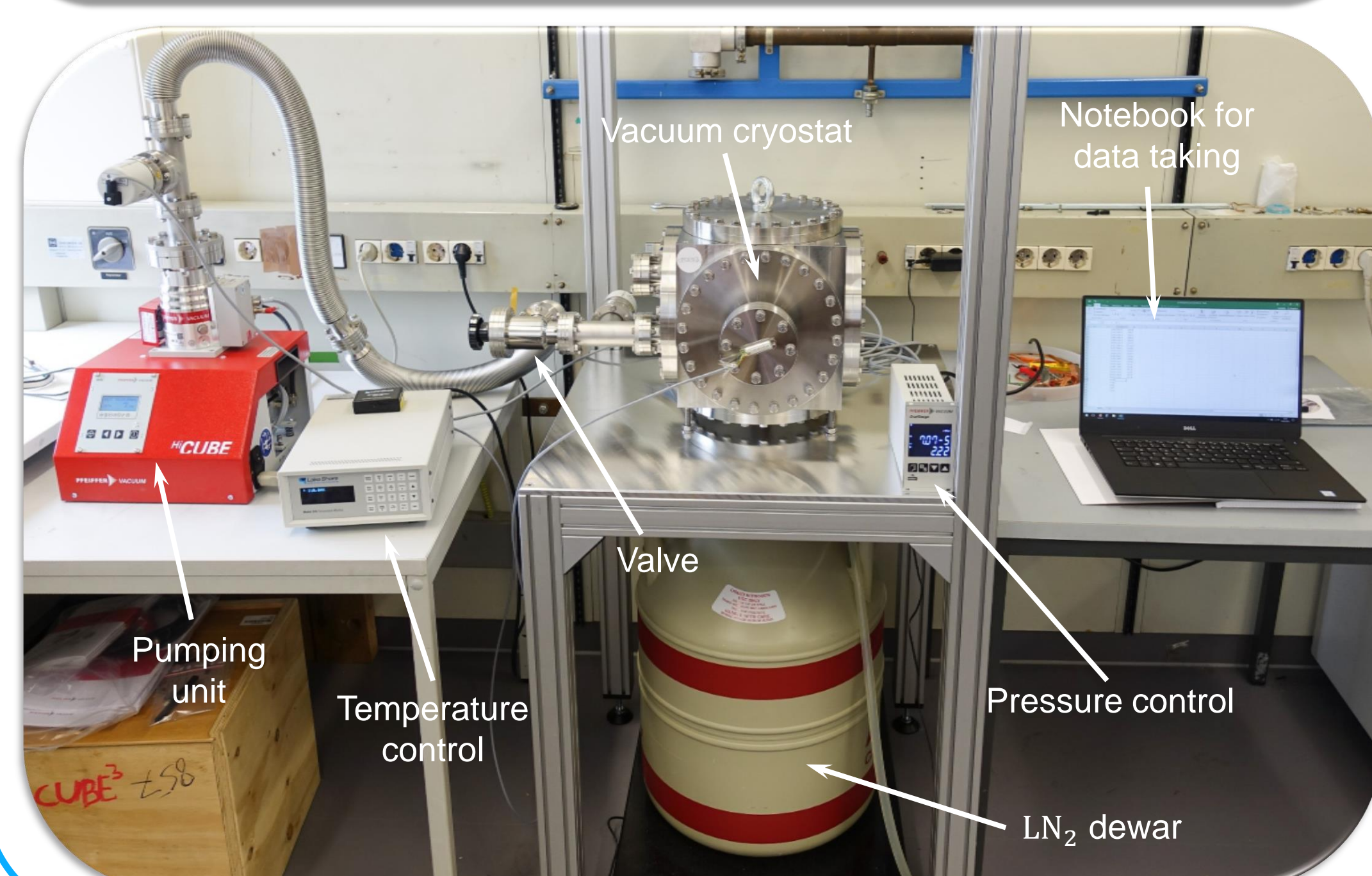
CUBE XGLab

ASIC readout technology
- ASIC technology enables the development of a highly integrated signal readout solution
- Charge sensitive amplifier, pre-amplifier and passive components combined in a **miniaturized single low-mass chip**
- CUBE ASIC provided by XGLab S.R.L. (Italy)

CUBE³ test stand at Technical University of Munich

CUBE³ experimental setup
- Highly customized vacuum cryostat with large experimental volume
- Pfeiffer HiCUBE 80 pumping unit and vacuum gauges
- Lake Shore temperature diode and monitor
- Canberra dewar for storage of liquid nitrogen (LN2)
- Setup easily adaptable to various detectors and front end boards

Vacuum cryostat
Notebook for data taking
Pumping unit
Temperature control
Valve
Pressure control
LN₂ dewar

Research objectives
- Test and characterization of the performance of the novel ASIC readout system with a p-type point contact (PPC) Ge detector
- Specific **research questions** to be investigated:
  - *What is the performance of the ASIC readout system?* (i.e. electronic noise, energy linearity, dynamic range)
  - *What is the pulse shape discrimination performance?* (i.e. discrimination between single [=signal] and multi [=background] site events)
  - *Can the ASIC readout system be operated in liquid argon (LAr) and what is its performance in it?*

ASIC
Pulser

▲ *First functionality measurements of the ASIC readout system with a test pulse generator. The events can be clearly seen on the ramp.*

▶ *Noise curve of the whole readout system at room temperature.*

FWHM 6 keV Mn-Kα (eV)
Peaking time (μs)