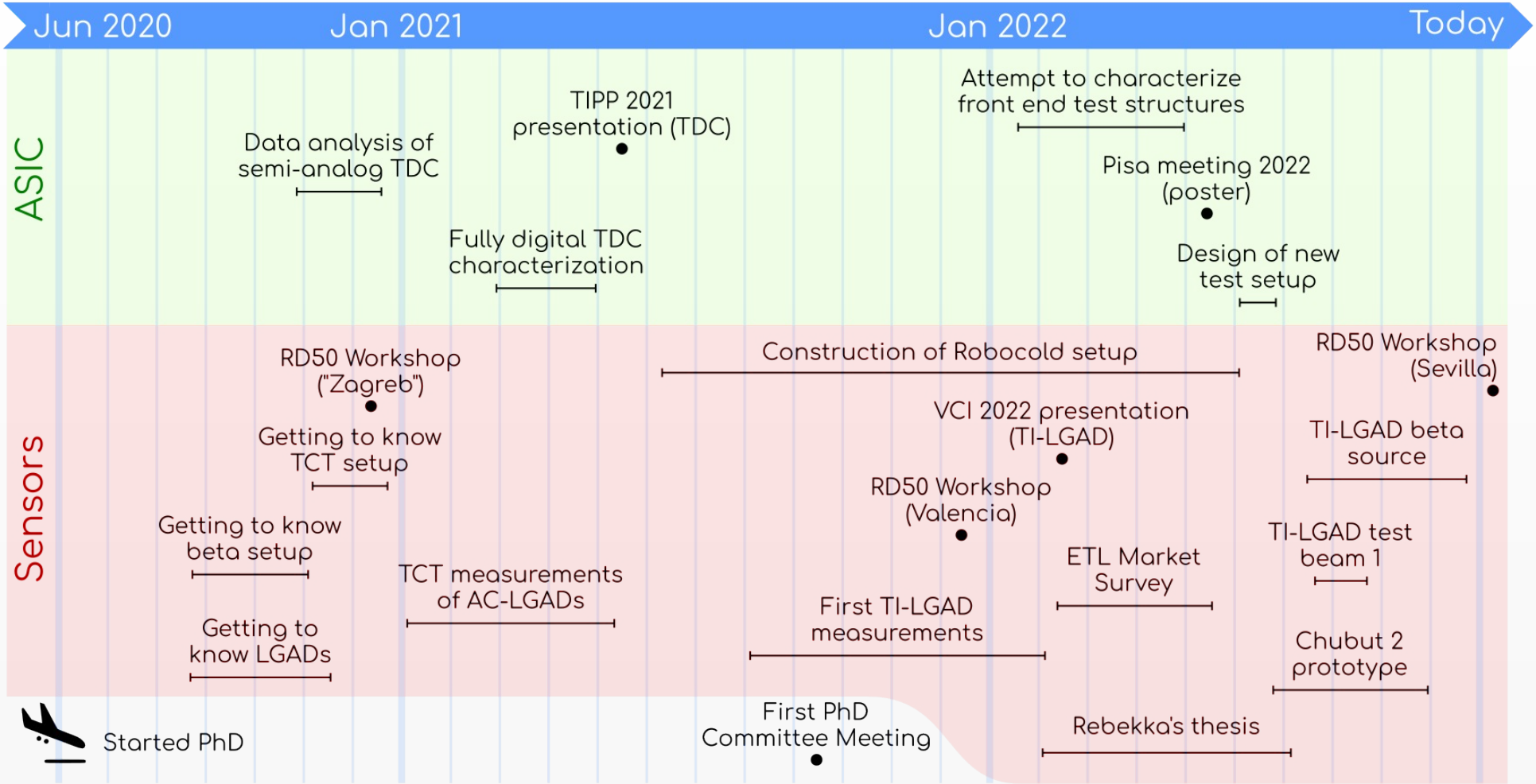
2nd PhD Committee Meeting

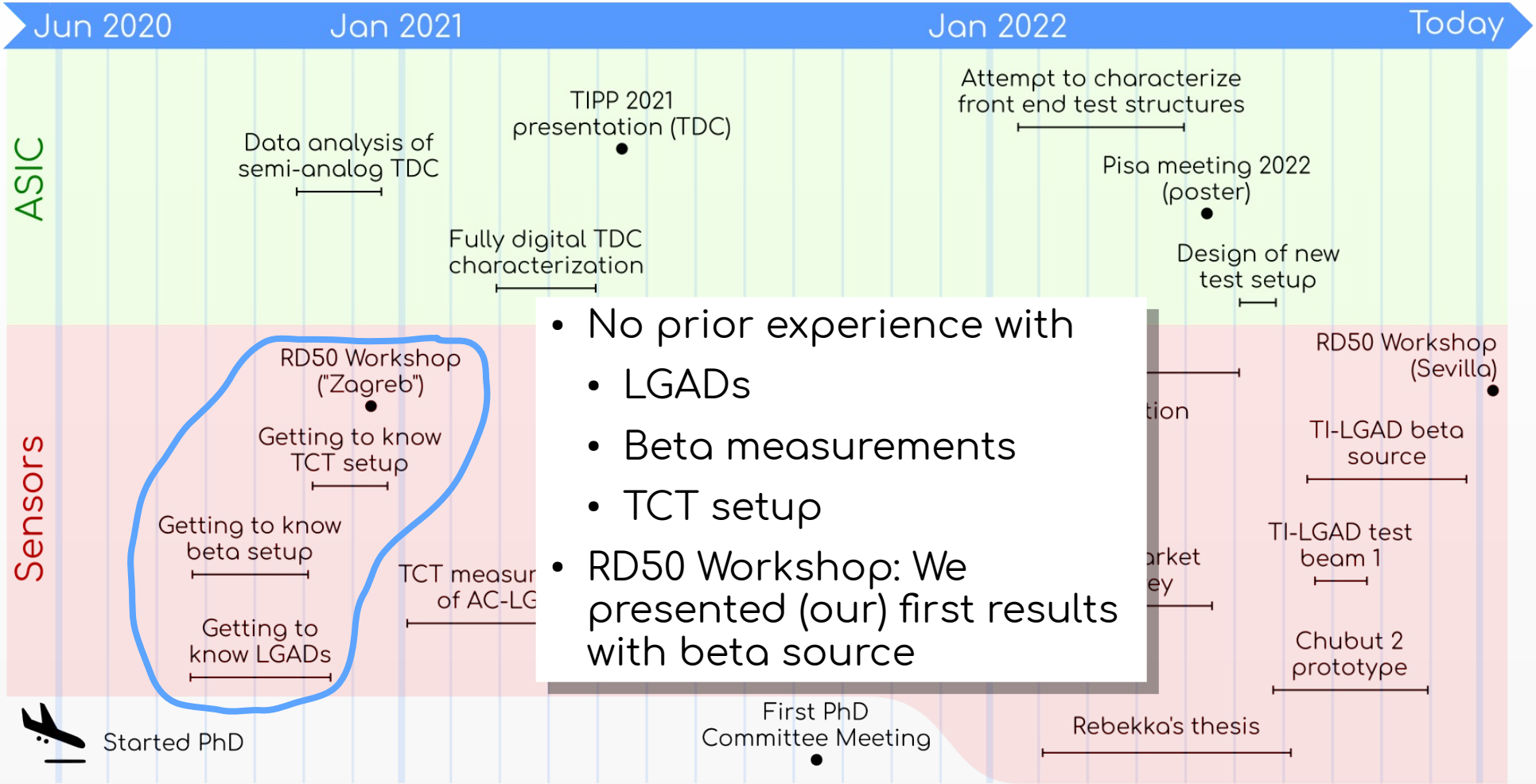
21 November 2022

Matias Senger

Presentation layout

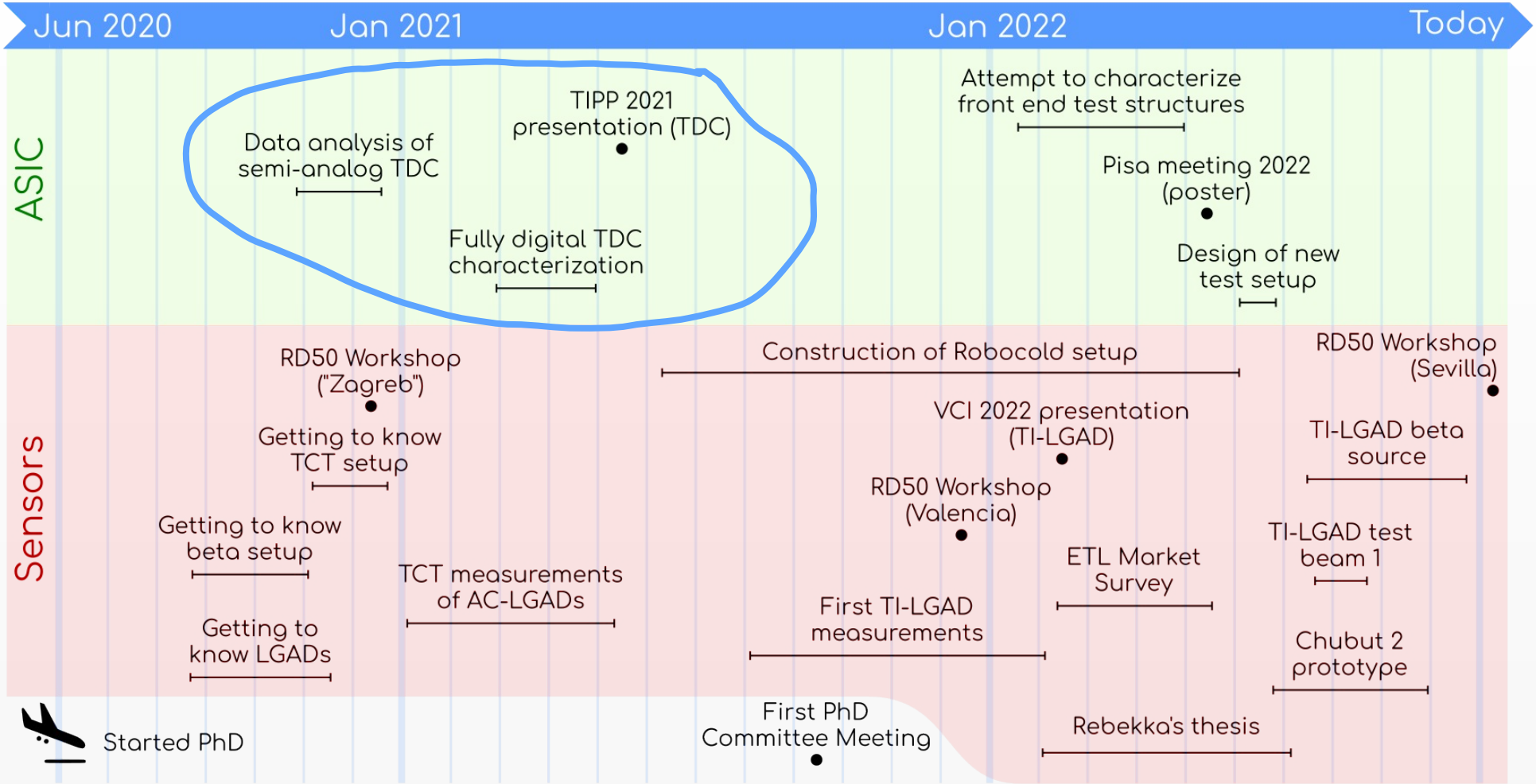


Very first activities



- No prior experience with
  - LGADs
  - Beta measurements
  - TCT setup
- RD50 Workshop: We presented (our) first results with beta source

TDCs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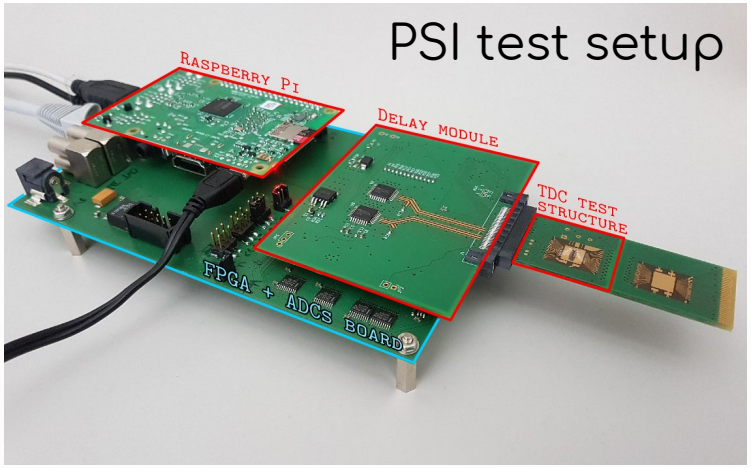
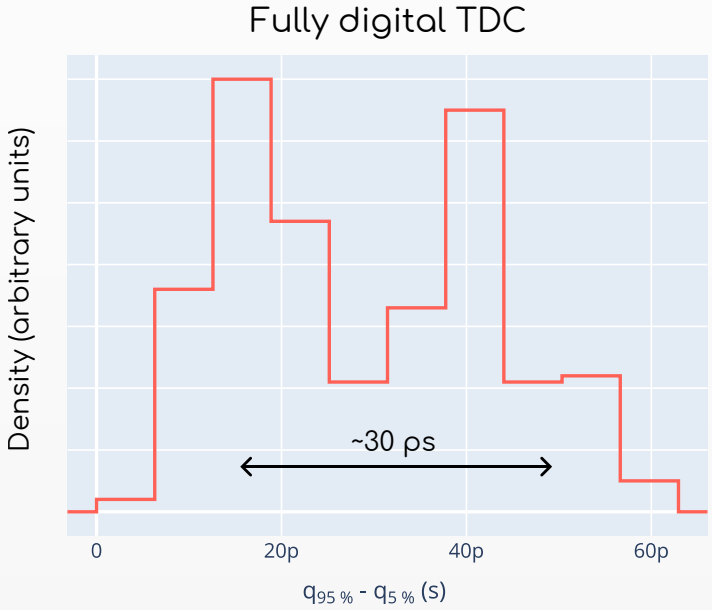
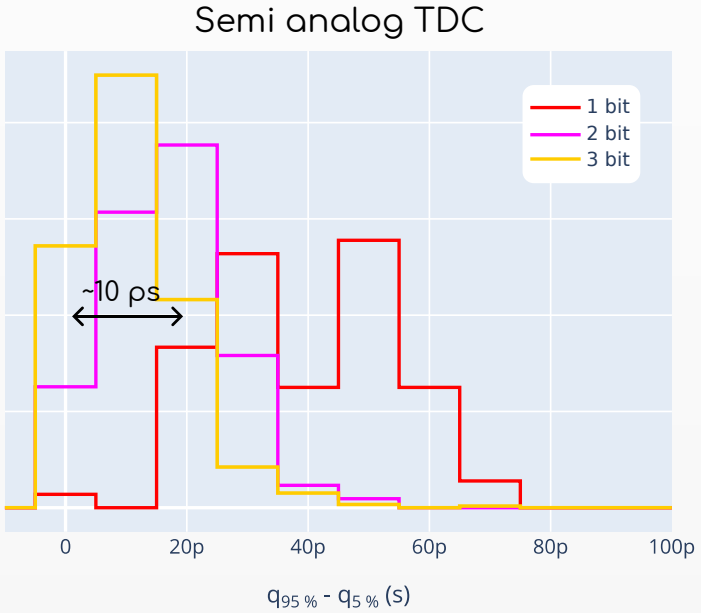
Rebekka's thesis

TDCs characterization

- 2 designs
  - Fully digital (by Stephan Wiederkehr)
  - Semi analog (by Beat Meier)
- Me:
  - Analysis of data for semi analog design
  - Full testing+analysis of fully digital design







Presentation and proceeding

- Presented at TIPP 2021 conference (link).
- Proceeding? Last week I received signs of life!

Development of a timing chip prototype in 110 nm CMOS technology

L Caminada[1,2], B Kilminster[1], A Macchiolo[1], B Meier[2], M Senger[1] and S Wiederkehr[1,2]

[1]Universität Zürich, Physik-Institut, Winterthurerstrasse 190, CH-8057, Zurich, Switzerland
[2]Paul Scherrer Institut, Forschungsstrasse 111, 5232 Villigen PSI, Switzerland

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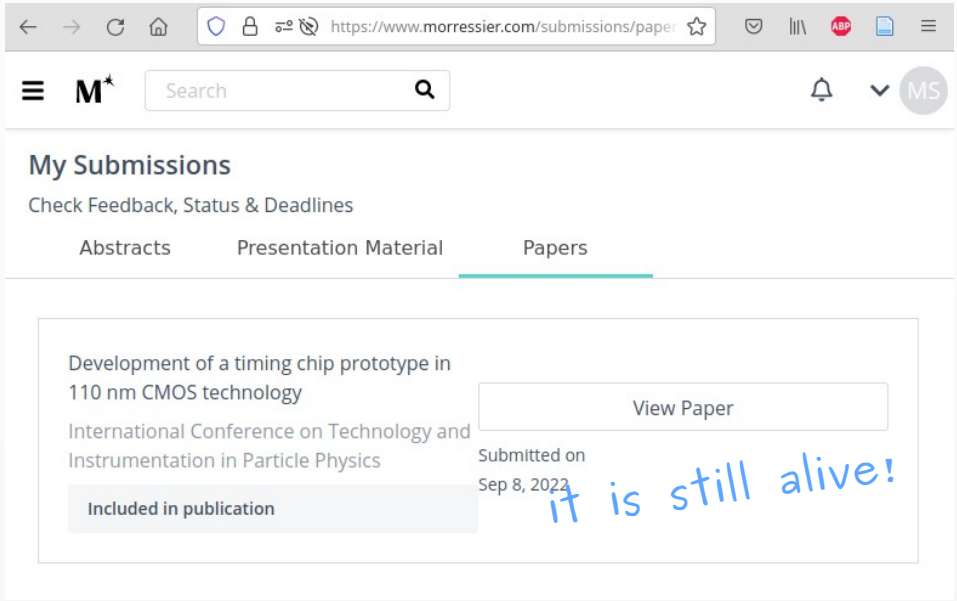
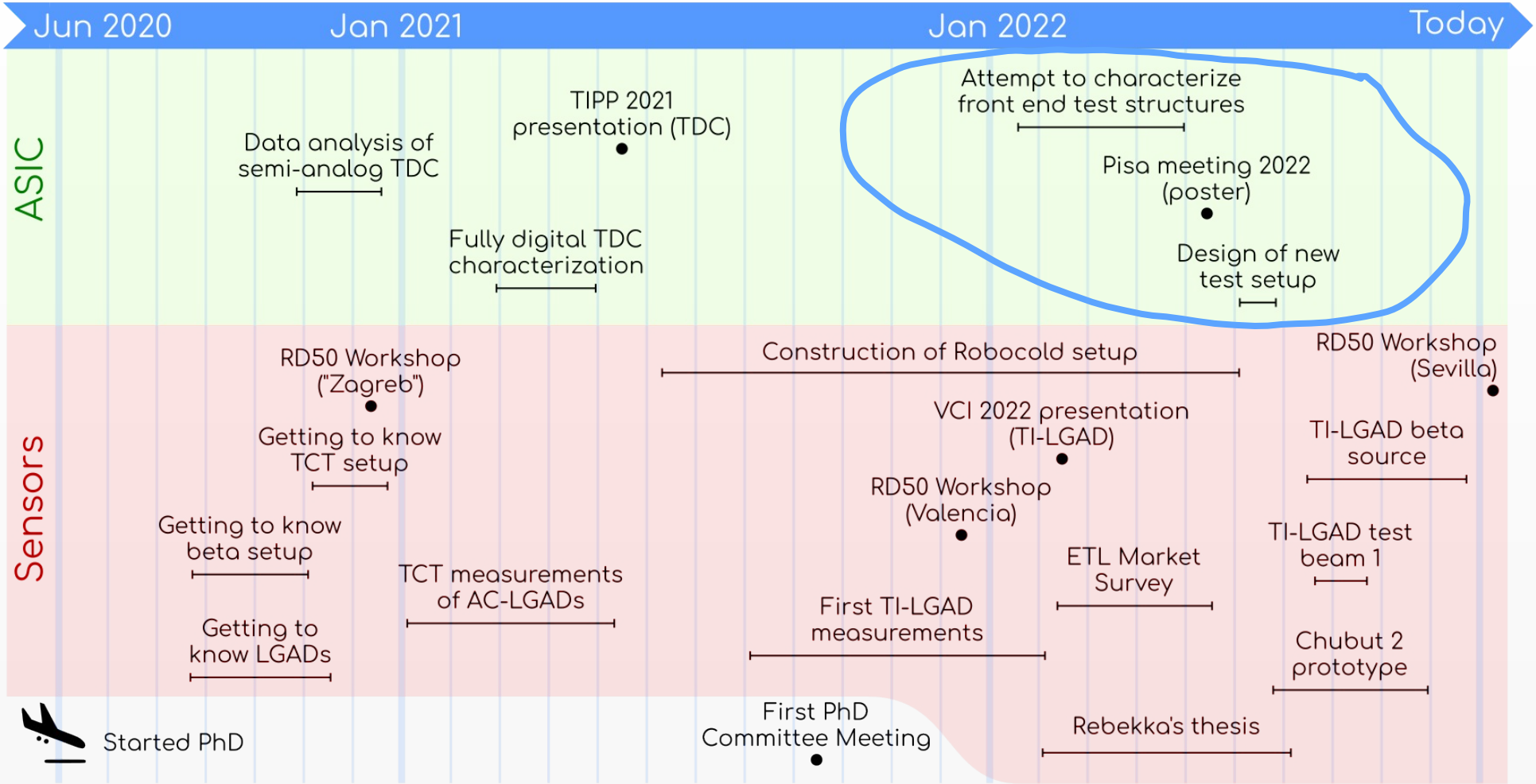
Abstract. We present a readout chip prototype for future pixel detectors with timing capabilities. The prototype is intended for characterizing 4D pixel arrays with a pixel size of 100×100 µm^2, where the sensors are Low Gain Avalanche Diodes (LGADs). The long term focus is towards a possible replacement of disks in the extended forward pixel system (TEPX) of the CMS experiment during the High Luminosity LHC (HL-LHC). The requirements for this ASIC are the incorporation of a Time to Digital Converter (TDC) in the small pixel area, low power consumption, and radiation tolerance up to 5×10^{15} n_{eq} cm^{-2} to withstand the radiation levels in the innermost detector modules for 3000 fb^{-1} of the HL-LHC (in the TEPX). A prototype has been designed and produced in 110 nm CMOS technology at LFoundry and UMC with different versions of TDC structures, together with a front end circuitry to interface with the sensors. The design of the TDC will be discussed, with the test set-up for the measurements, and the first results comparing the performance of the different structures.

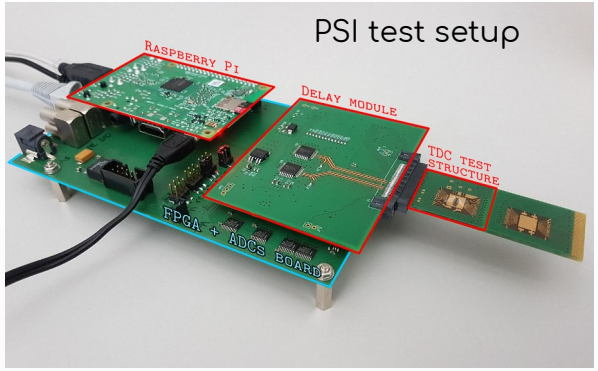


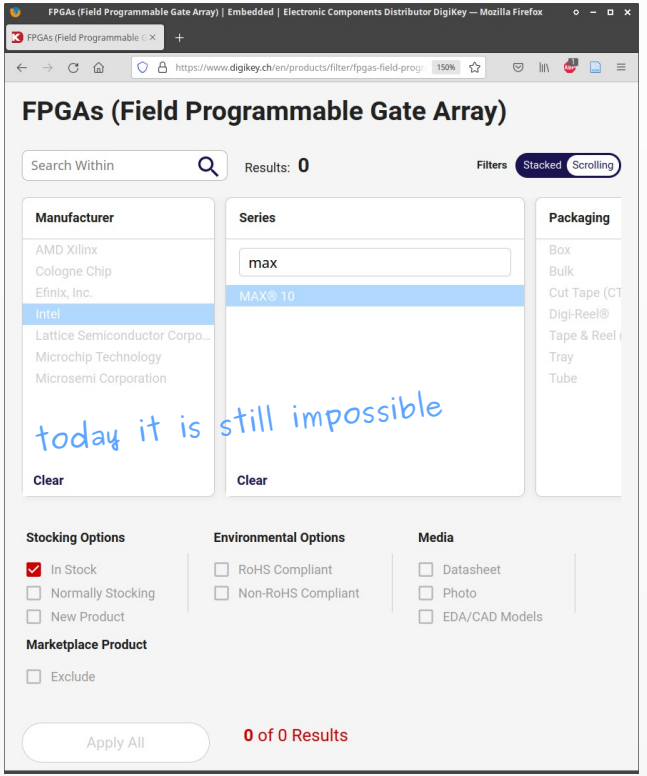
ASIC front end



Attempt to characterize the front-end structure

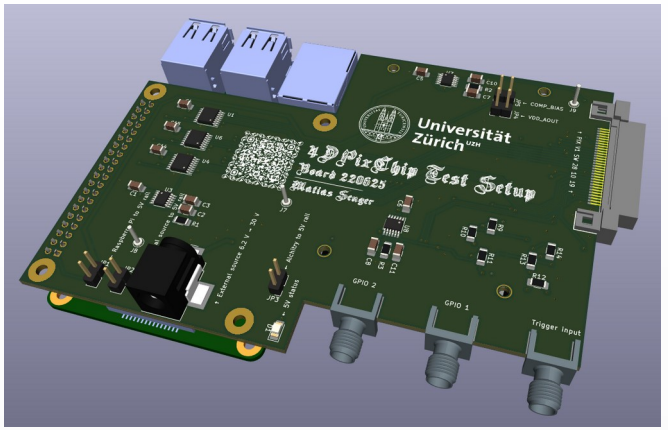
- Test structures:
  - TDCs.
  - Front end.
- Began writing software and firmware for the front end.
- One day the FPGA stopped responding:
  - Neither me nor the electronics workshop was able to “fix it”.
  - Impossible to buy Intel FPGA replacements anymore.
- Could not do the characterization in time for the Pisa conference. ☹

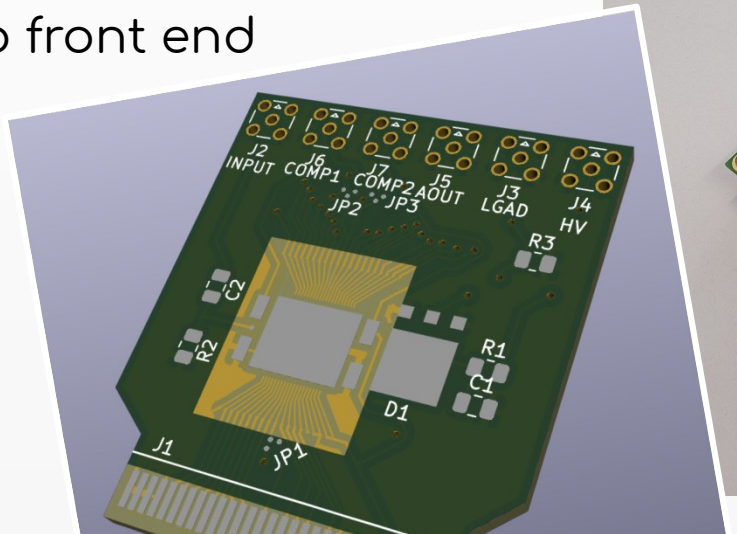


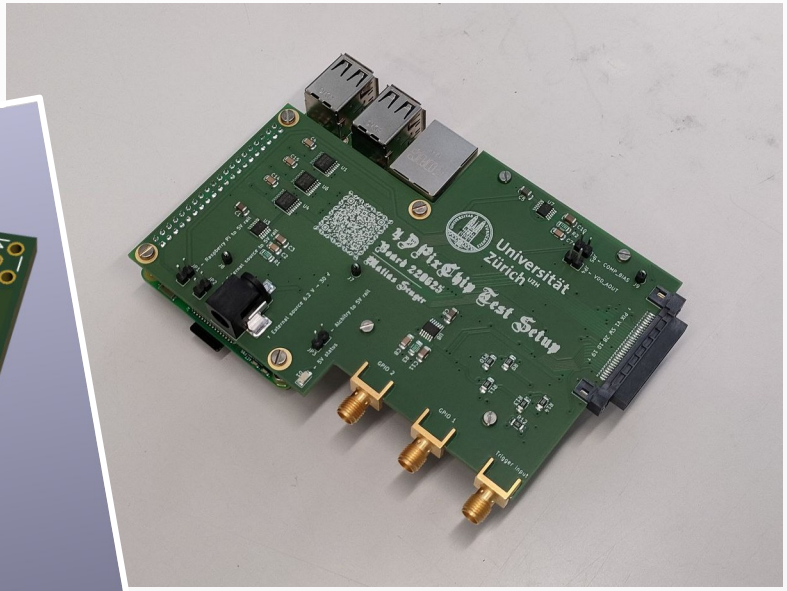


New test setup

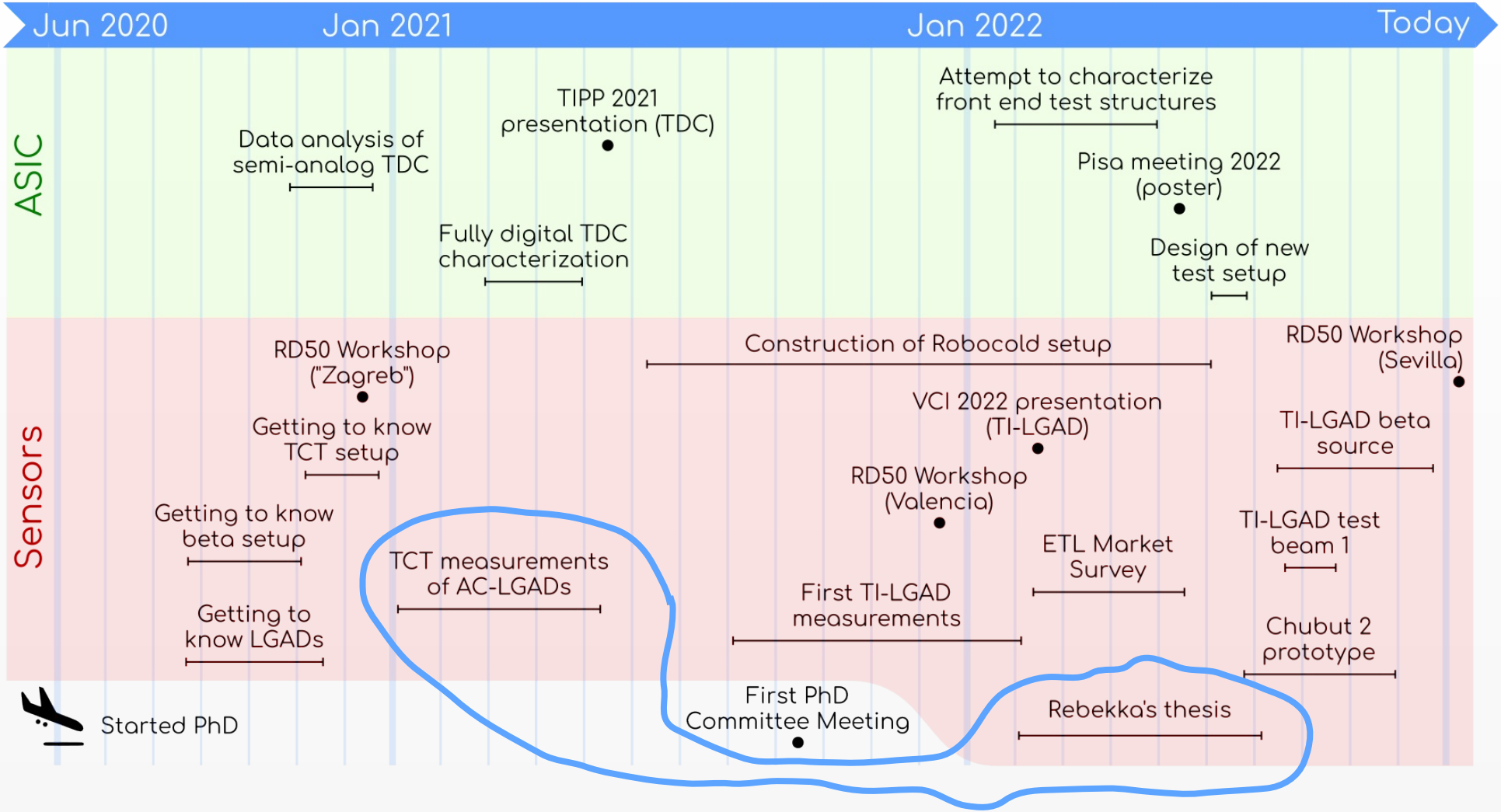
- Since the test setup cannot be fixed, I designed a new one from scratch.
- It was produced, not yet tested.
- Carrier board with option for:
  - External test signal.
  - LGAD right next to front end structure.







AC-LGADs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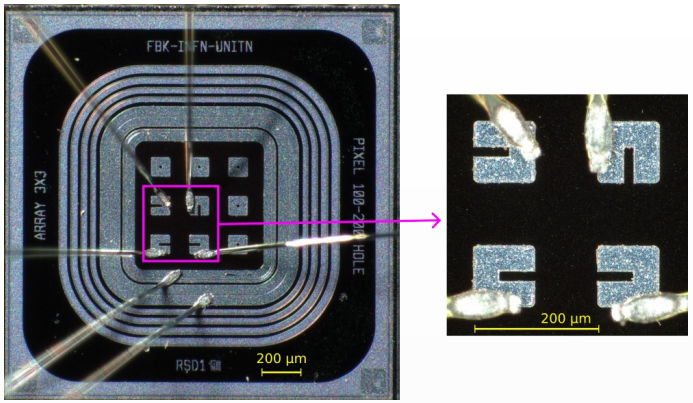
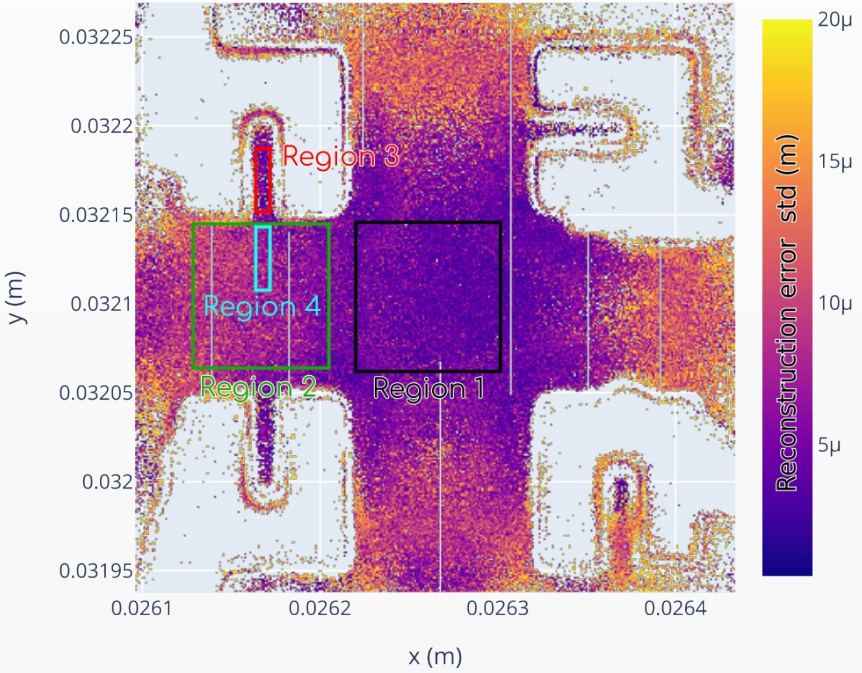
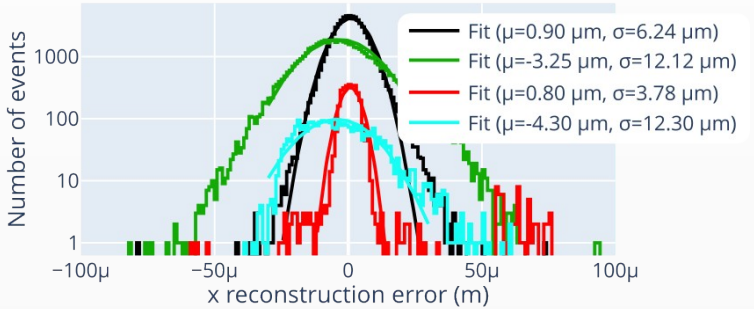
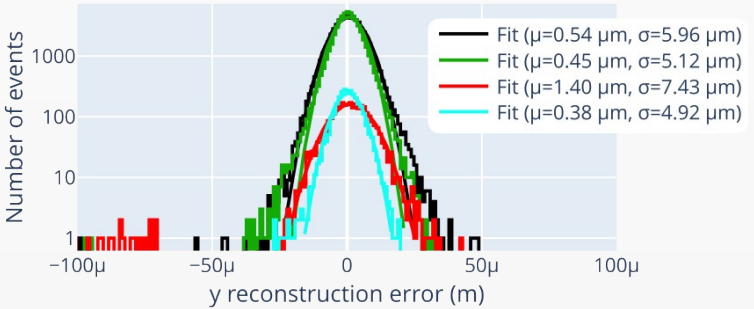
AC-LGADs

- Was my first experience with sensors.
- Only TCT studies.
- Applied machine learning.
- Got interesting results.
- Didn't make a systematic study.
- Nothing was ever shown outside UZH.



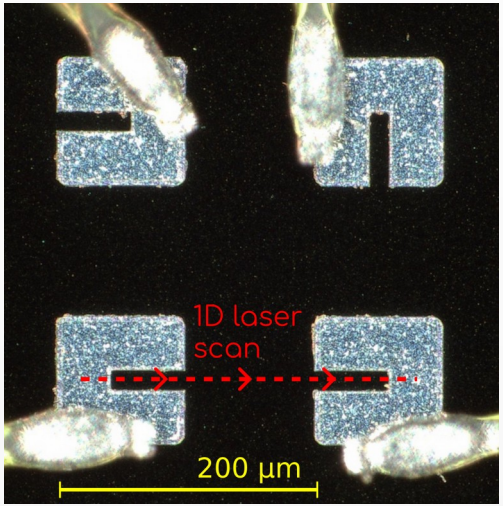


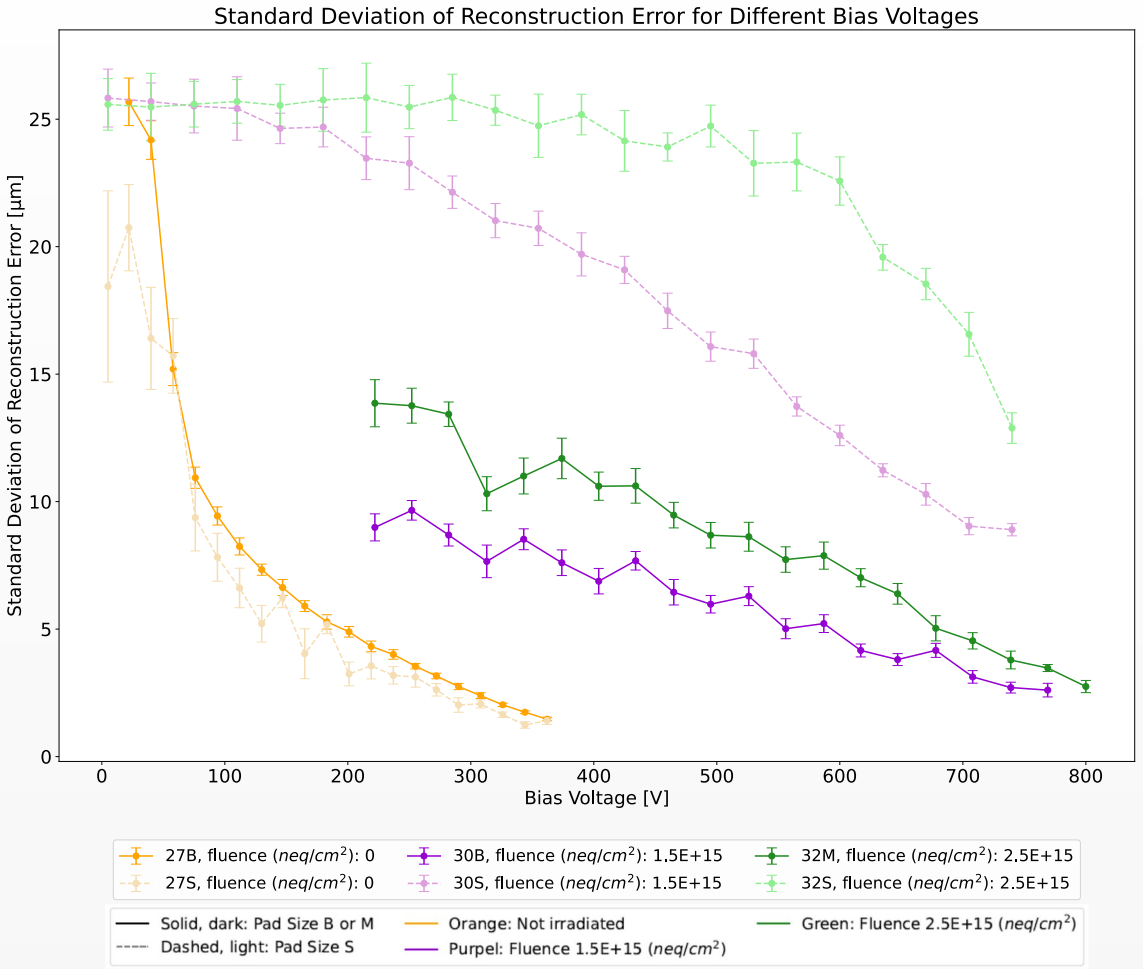




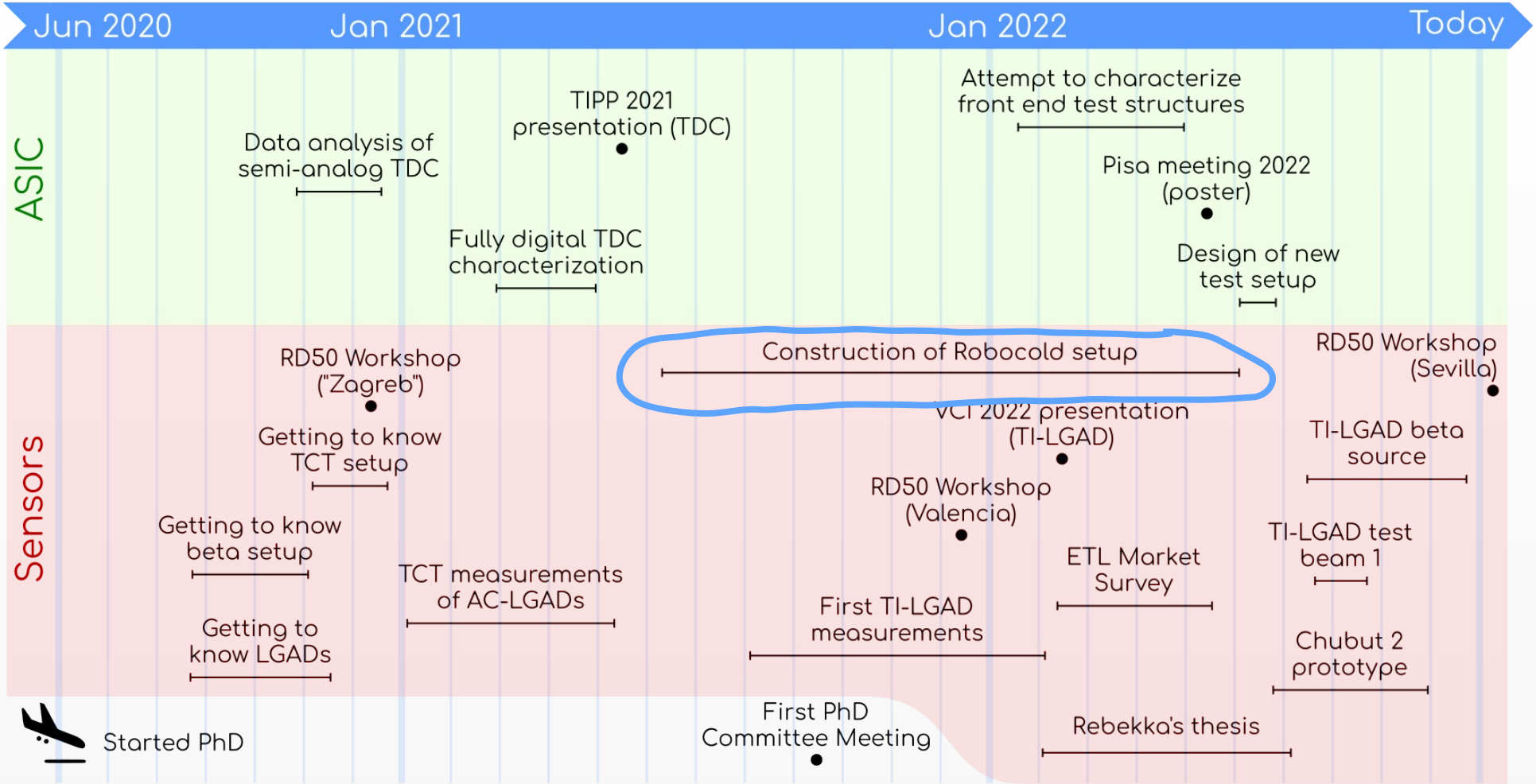
AC-LGADs after irradiation

- Rebekka's bachelor thesis: A systematic study of AC-LGADs at different fluences.
- Position resolution degradation after irradiation.
- 1D TCT scans at different voltages.
- 6 sensors tested.



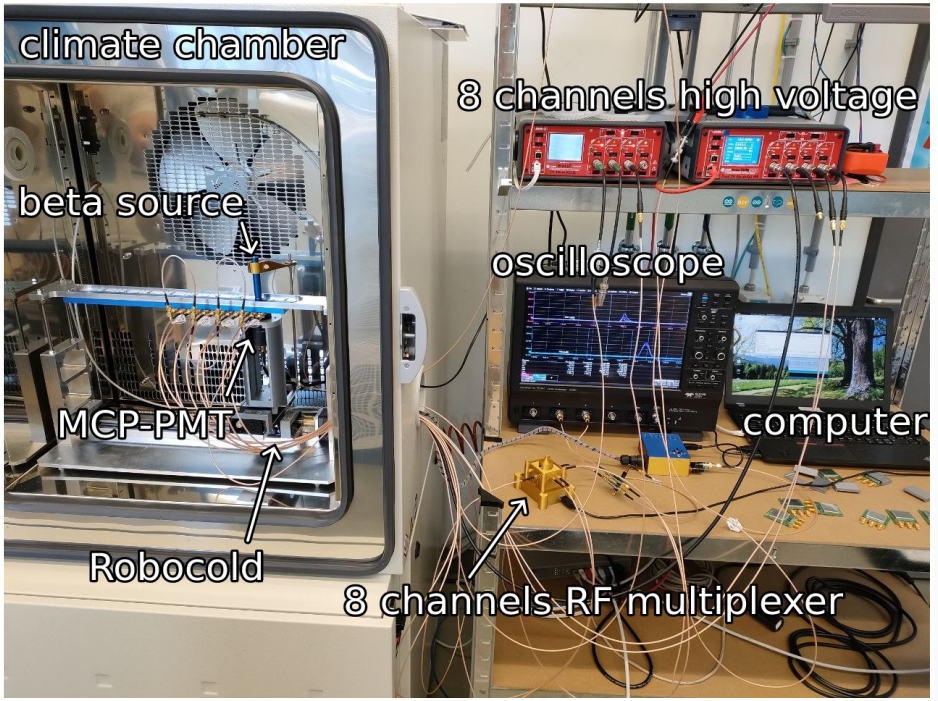


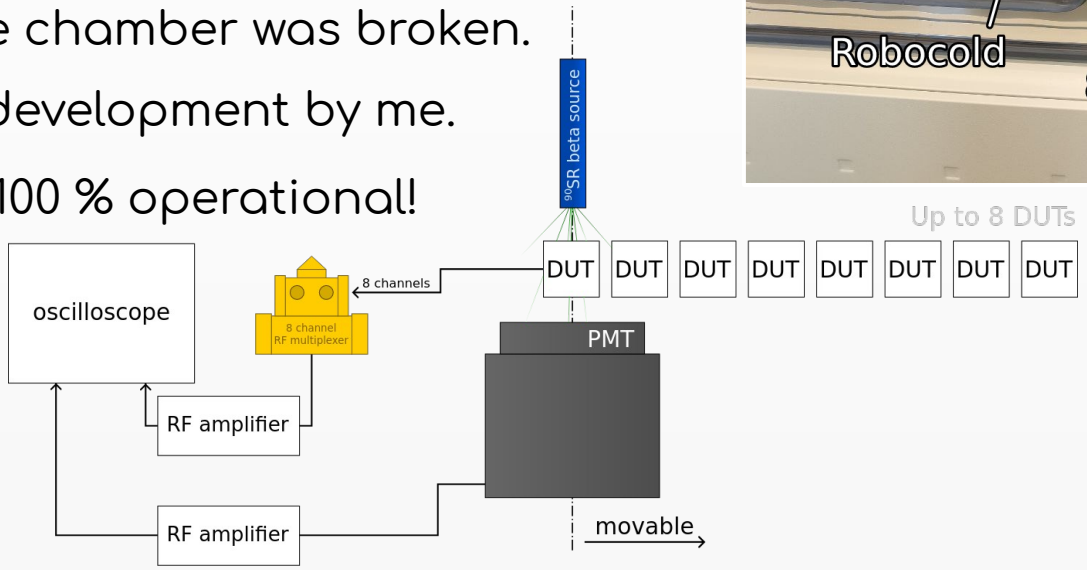
UZH beta setup

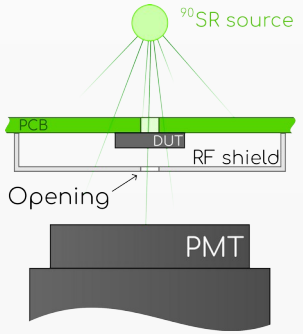


Robocold setup

- Goal: Automate beta measurements for long term tests on ETL sensors.
- Commissioning took long time because:
  - PMT delivery time.
  - Climate chamber was broken.
  - Lot of development by me.
- It is finally 100 % operational!



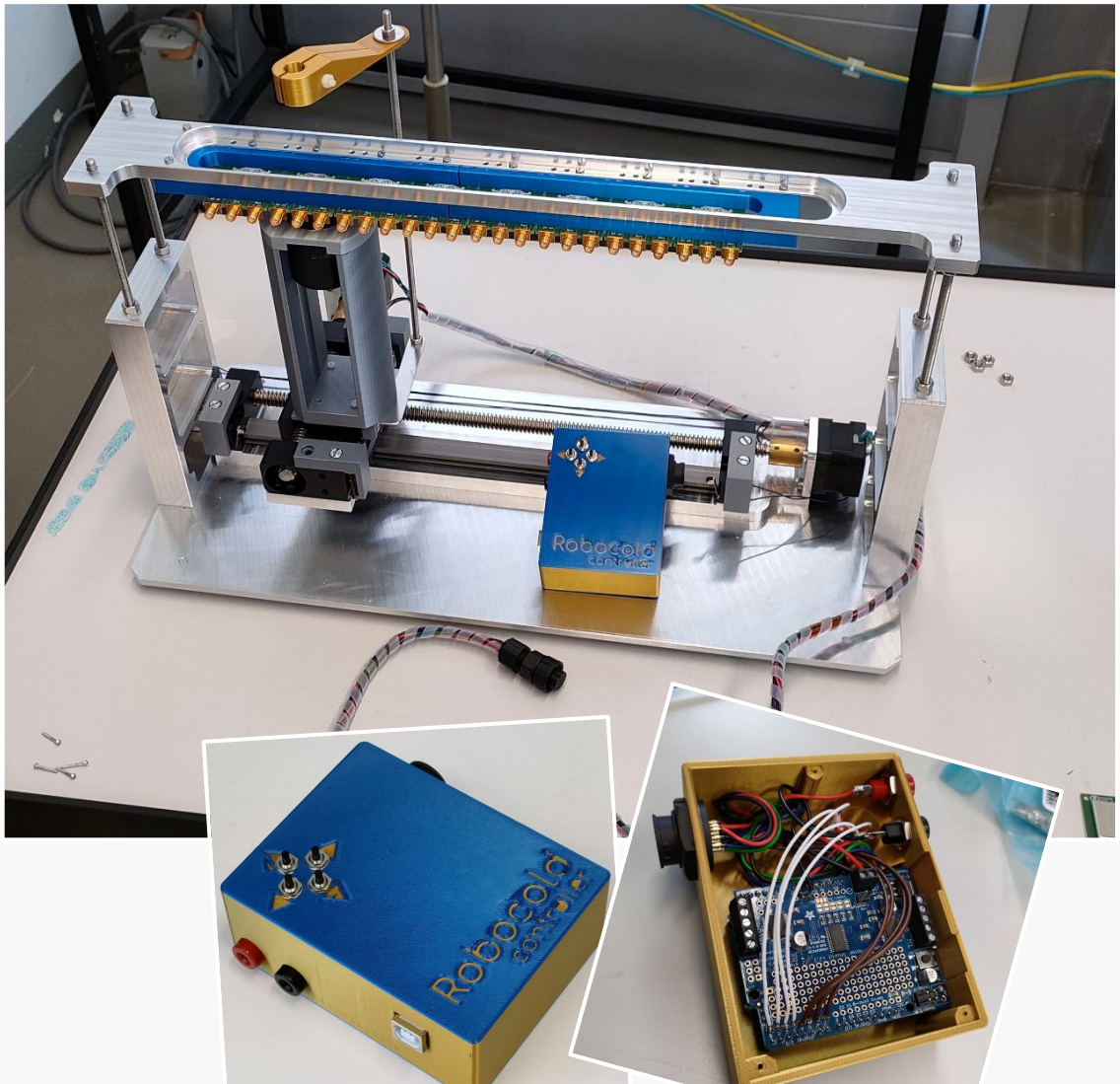




[1] https://github.com/SengerM/ChubutBoard
[2] https://msenger.web.cern.ch/the-robocold-beta-setup/

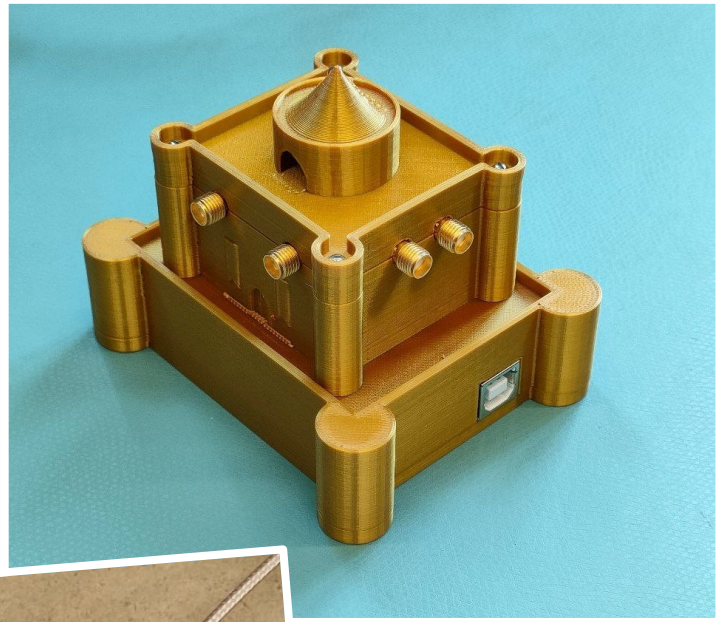
Robocold

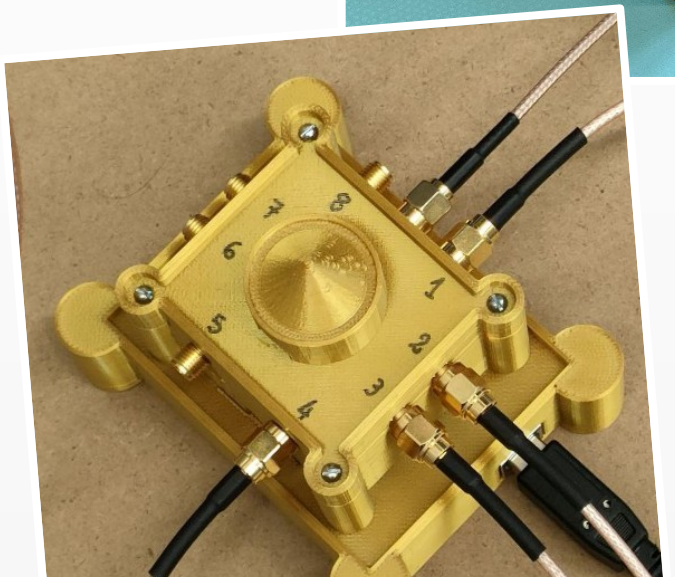
- The rockstar of the setup:
- Fully designed by me.
- Implemented by our mechanics workshop and myself.
- Not trivial to make it work at low temperatures (had to tweak the stages).
- Hosts up to 8 boards, the PMT and the beta source.
- Also:
  - Robocold controller firmware.
  - Robocold Python interface.



The Castle (multiplexer)

- 8→1 RF multiplexer.
- Allows to use a single oscilloscope.
- Analog Devices evaluation board + Arduino controller.
- Exclusive 3D printed housing.
- Python interface.
- SNR degradation negligible.

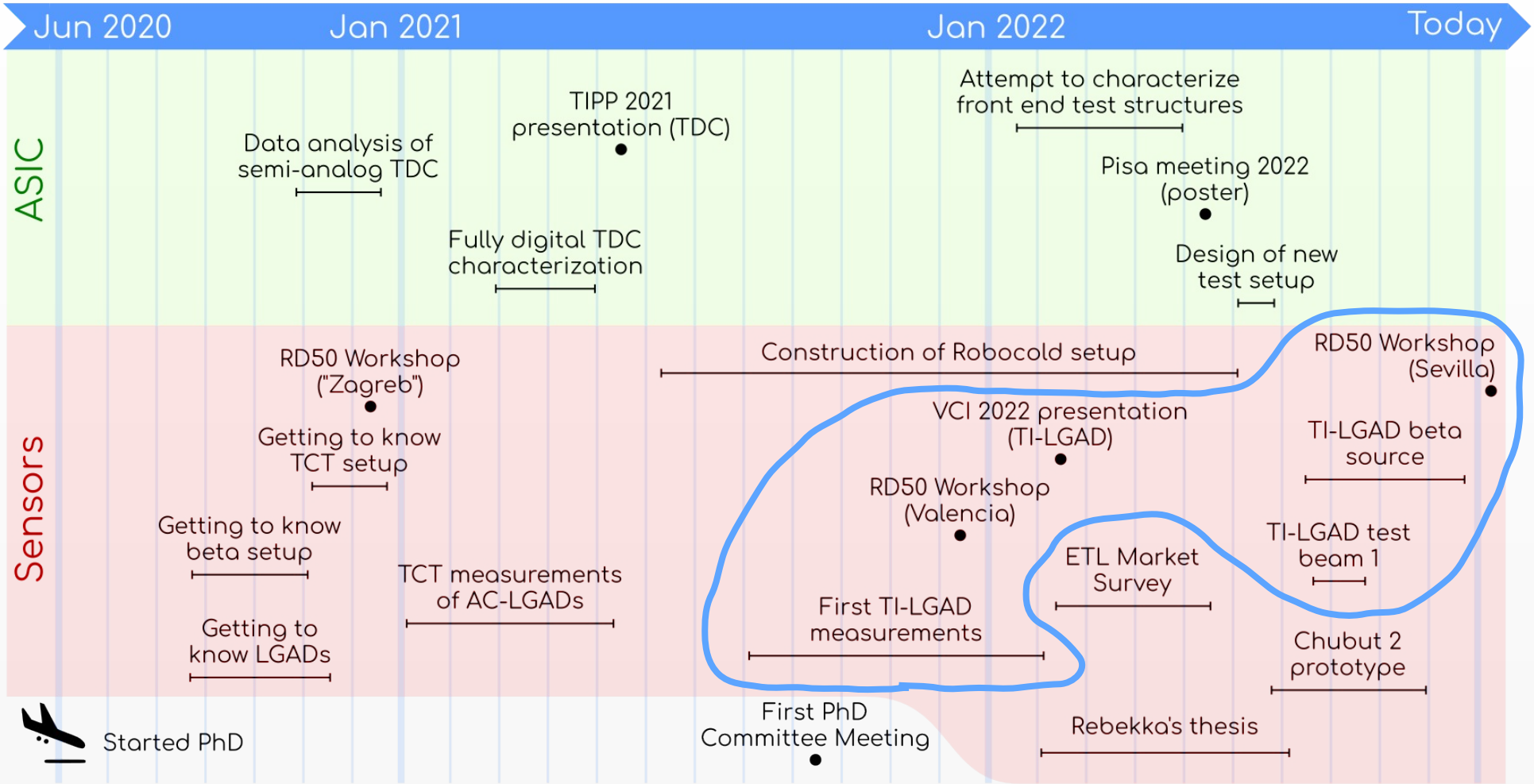




Setup performance

- I am super happy with the performance of the setup.
  - Time resolution down to ~25 ps was measured.
  - Fully automated tests.
  - Saves a lot of time.
- Measures:
  - Time resolution.
  - Charge.
  - Auto-trigger rate (working on this).
  - Hit efficiency estimation (may be possible using a reference detector, not there yet).

TI-LGADs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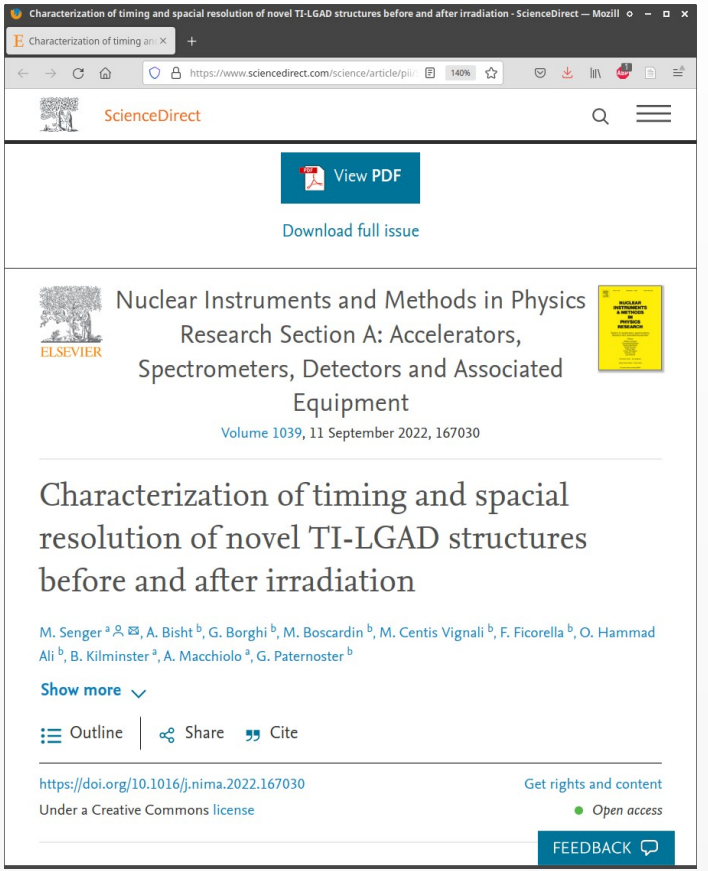
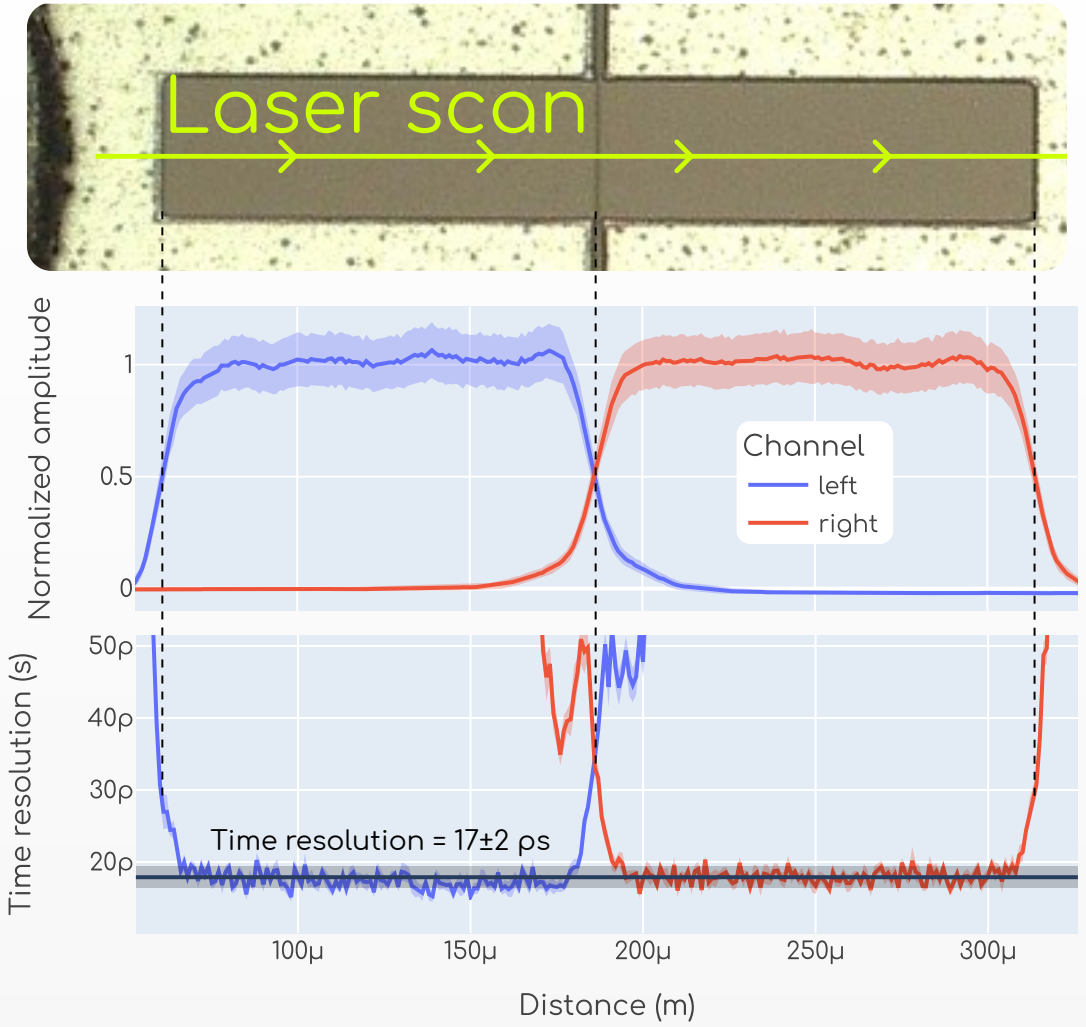
TI-LGADs

- Systematic study of first production using test samples[1].
  - TCT setup:
    - Inter-pixel distance.
    - Time resolution uniformity.
  - Beta setup:
    - Time resolution.
    - Charge.
  - Test beam:
    - Time resolution.
    - Charge.
- All done both before and after irradiation.



[1] Probably this is the most detailed study of this technology so far?

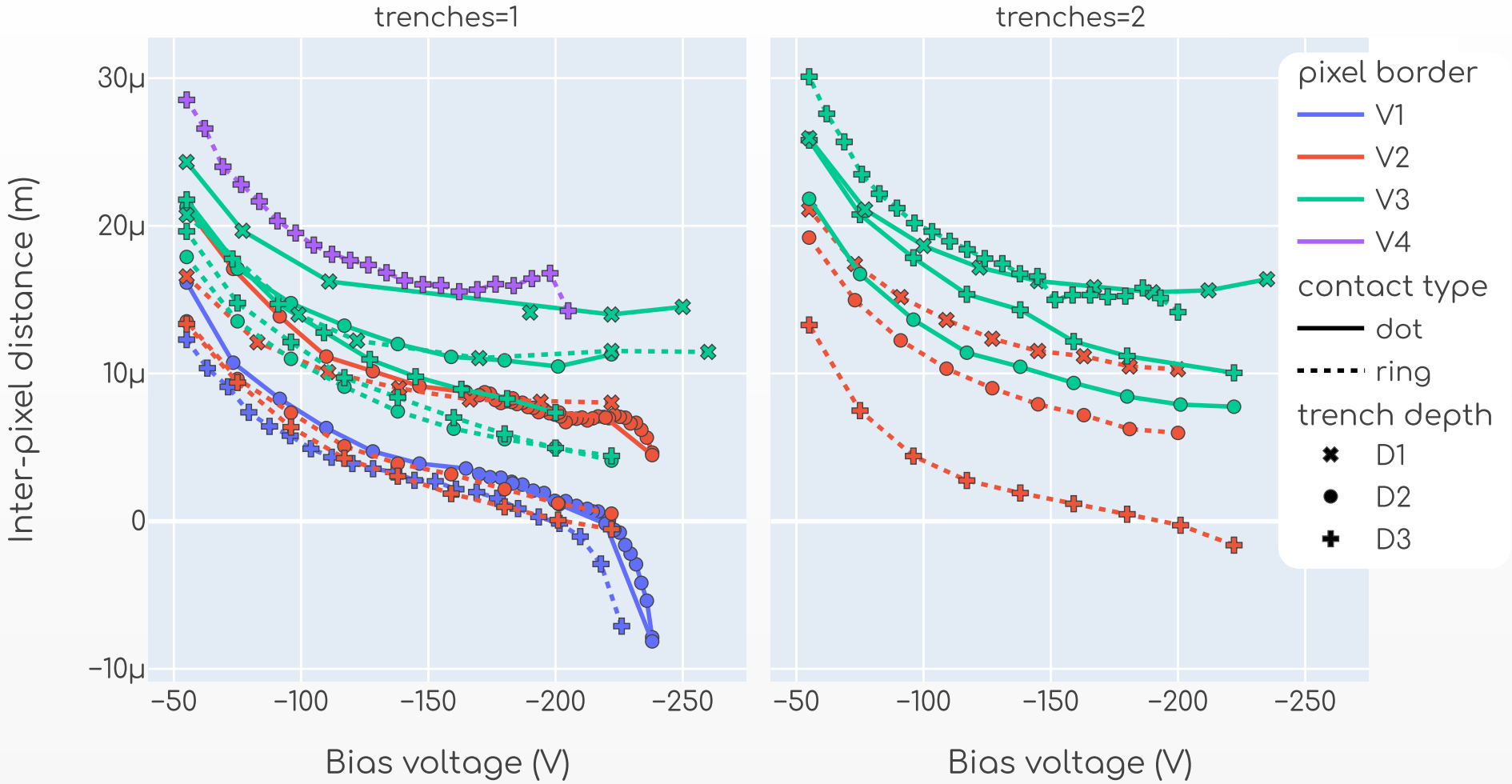
Studies with TCT setup



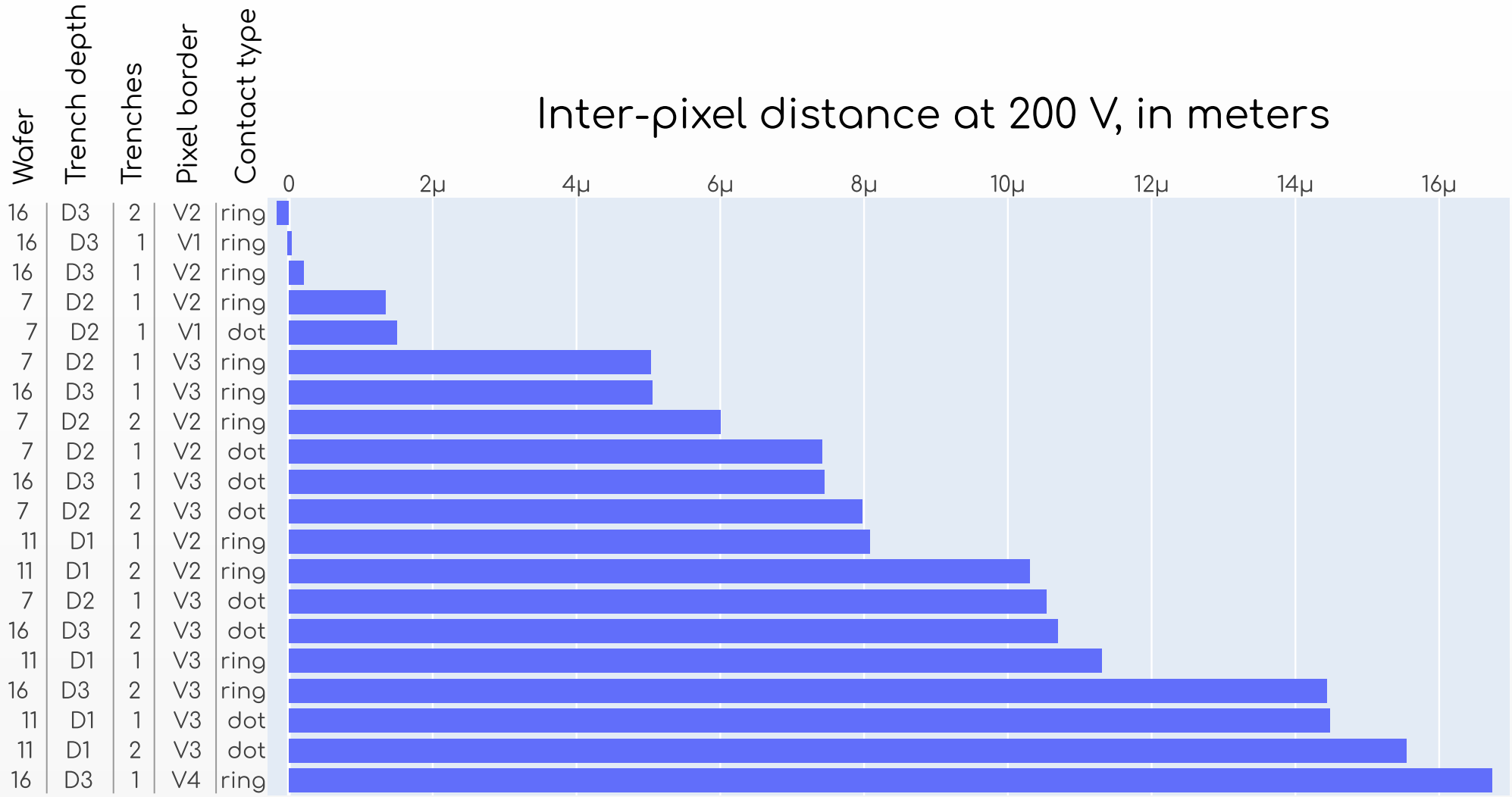
- Time resolution very uniform until pixel edges.
- All tested devices show this behavior.
- Laser ⇒ missing Landau fluctuations ⇒ absolute value not very relevant.

Inter-pixel distance vs bias voltage

- All non irradiated samples, all at -20 °C



Spotted best design patterns for trenches

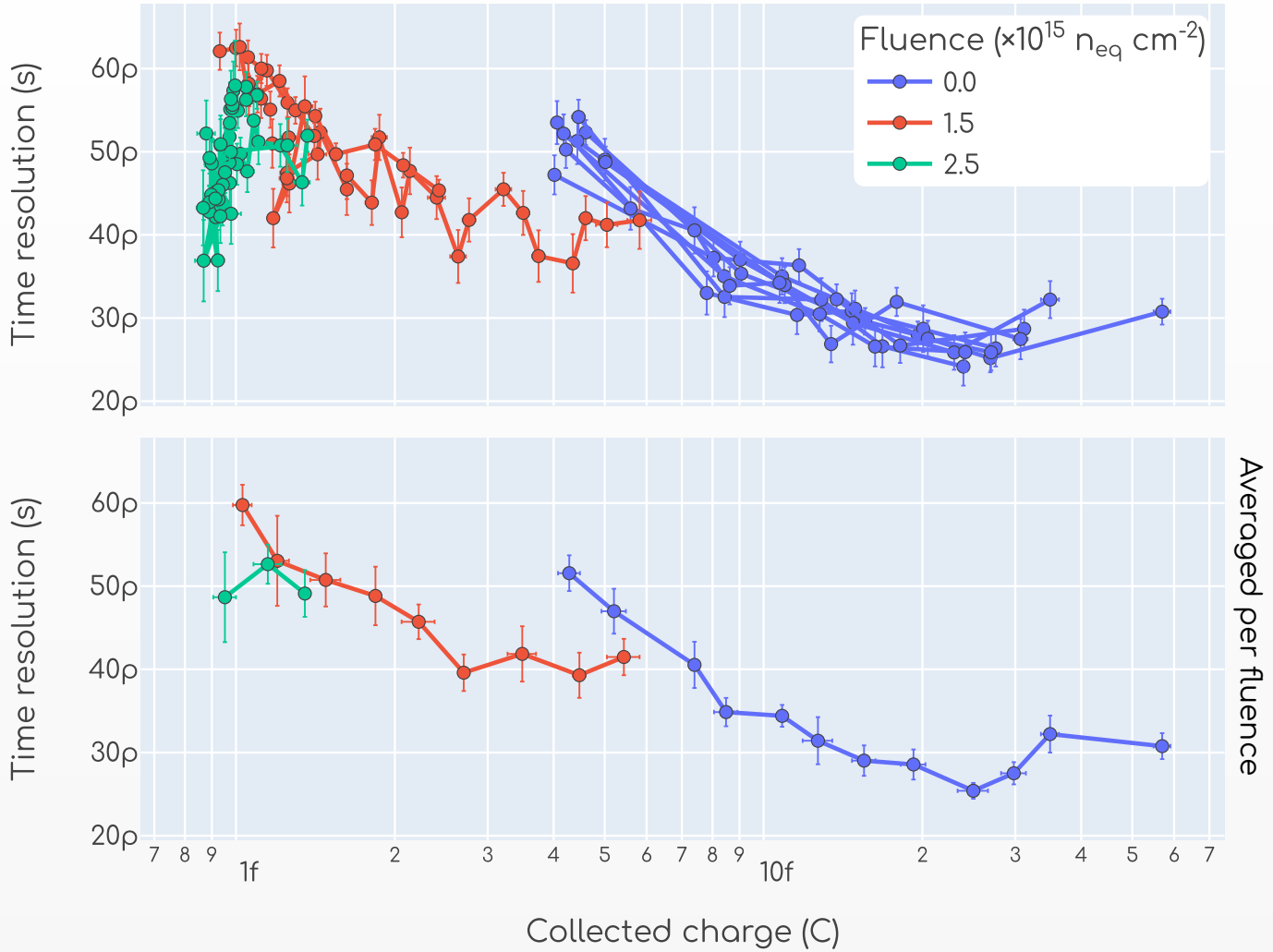


Results from beta source

- Constant fraction discriminator different for each fluence:
  - 20 % for 0
  - 40 % for 1.5
  - 50 % for 2.5

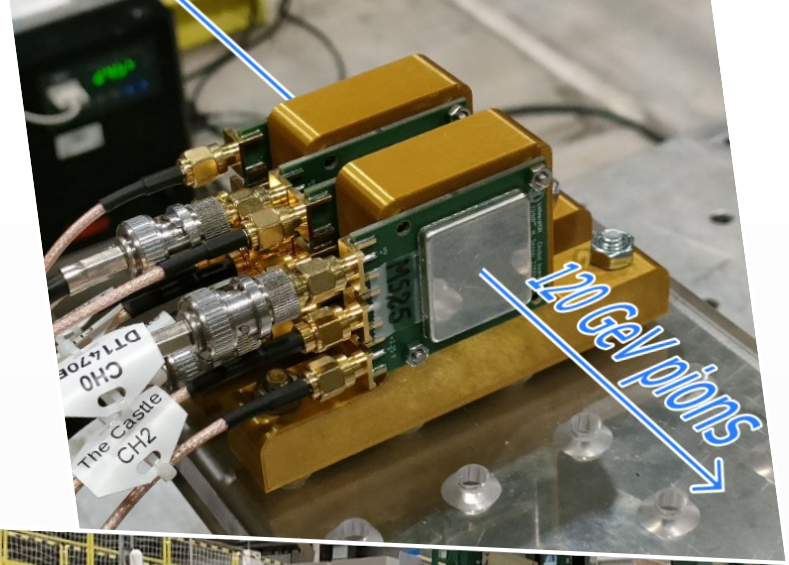
- Top plot: Each line is a different device.
- Bottom plot: Average per fluence.

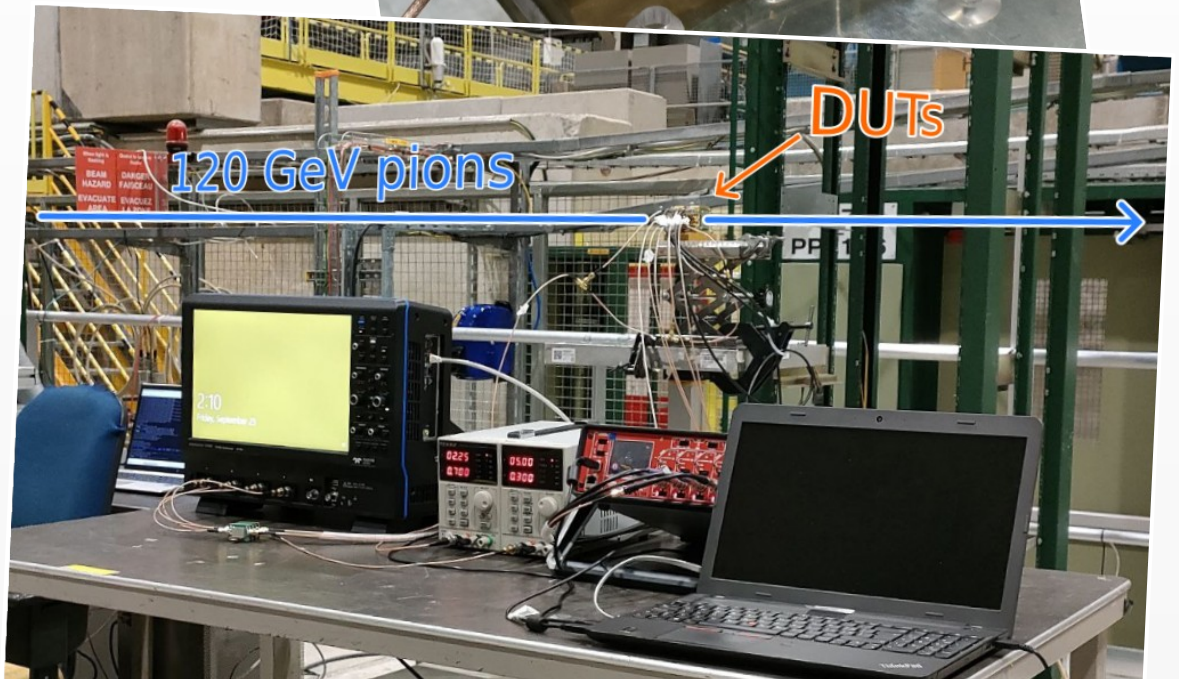
- We don't observe systematic dependence with trenches design.



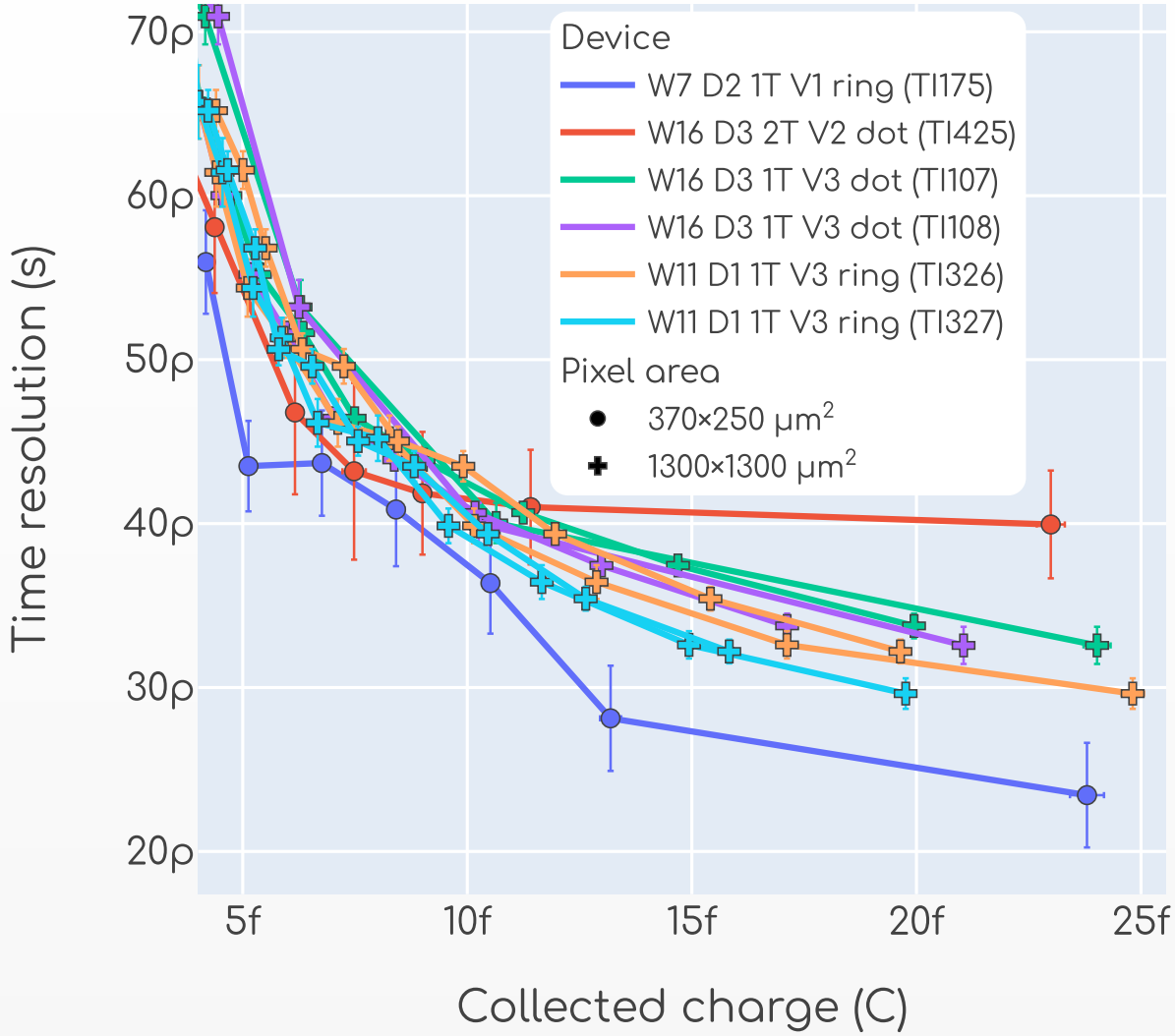
Setup at the test beam

- No tracking.
- Same instruments and boards from our beta setup.
- Time resolution measured in pairs:
  - Identical devices → √2
  - Calibrated reference → subtraction in quadrature
- Room temperature.
- Only tested non-irradiated devices.



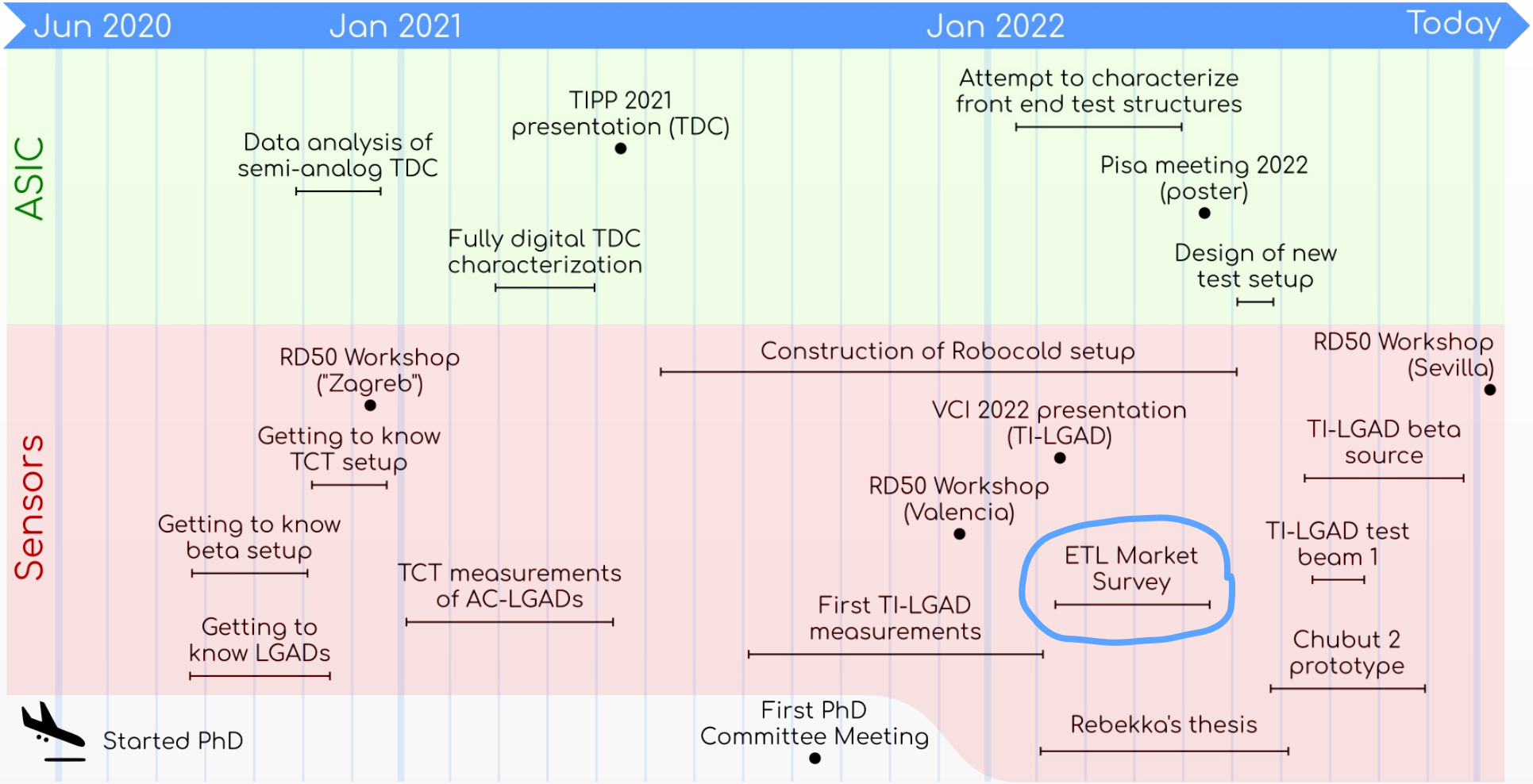


Test beam results



- Time resolution ~30 ps achieved at ~20 fC.
- No systematic influence of trenches design.

T = Room T (September)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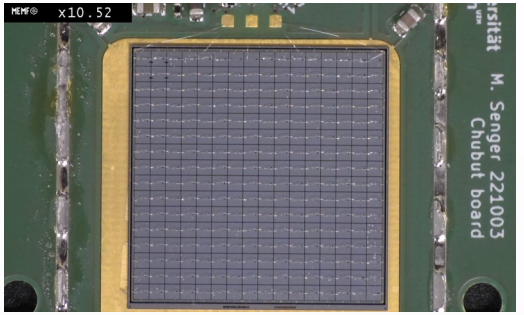
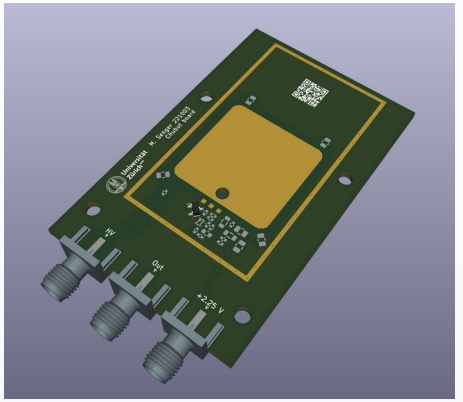
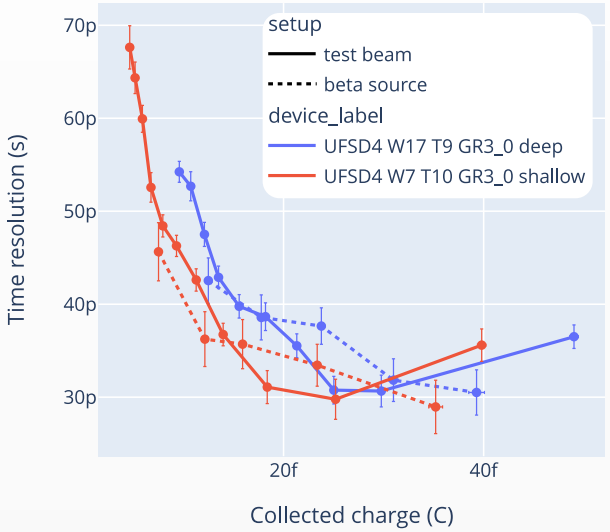
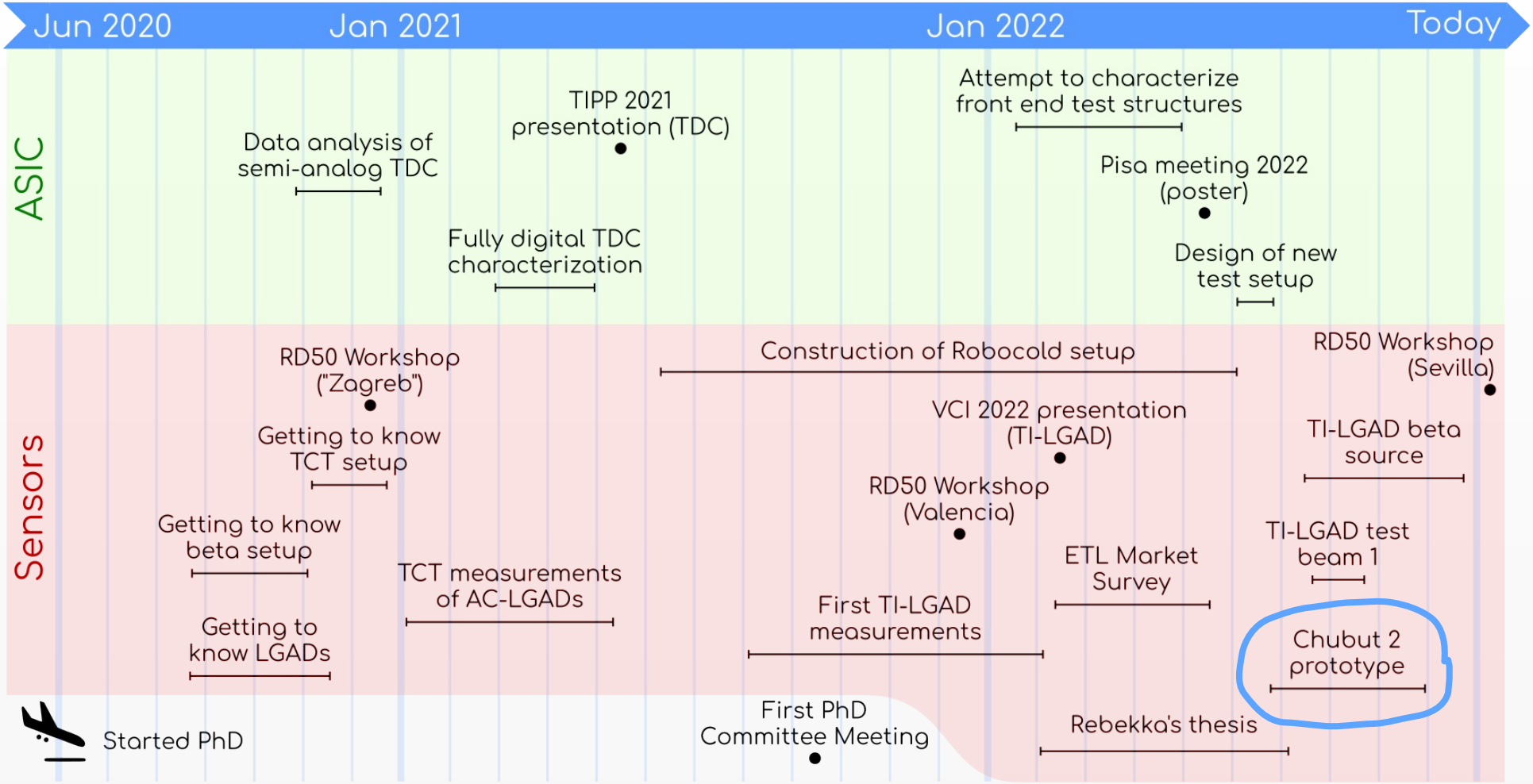




- Involved in testing and characterizing FBK (and Micron) samples:
  - Beta setup (pre-Robocold):
    - Time resolution.
    - Charge.
  - TCT:
    - Inter-pixel distance.
  - Test beam:
    - Time resolution.
    - Charge.



- TCT + beta source results: link.
- Test beam vs beta source comparison: link.
- Further measurements with the Robocold setup are ongoing as we speak.
- Designed and produced a single channel board for testing real ETL sensors (see pictures on current slide, link to first results).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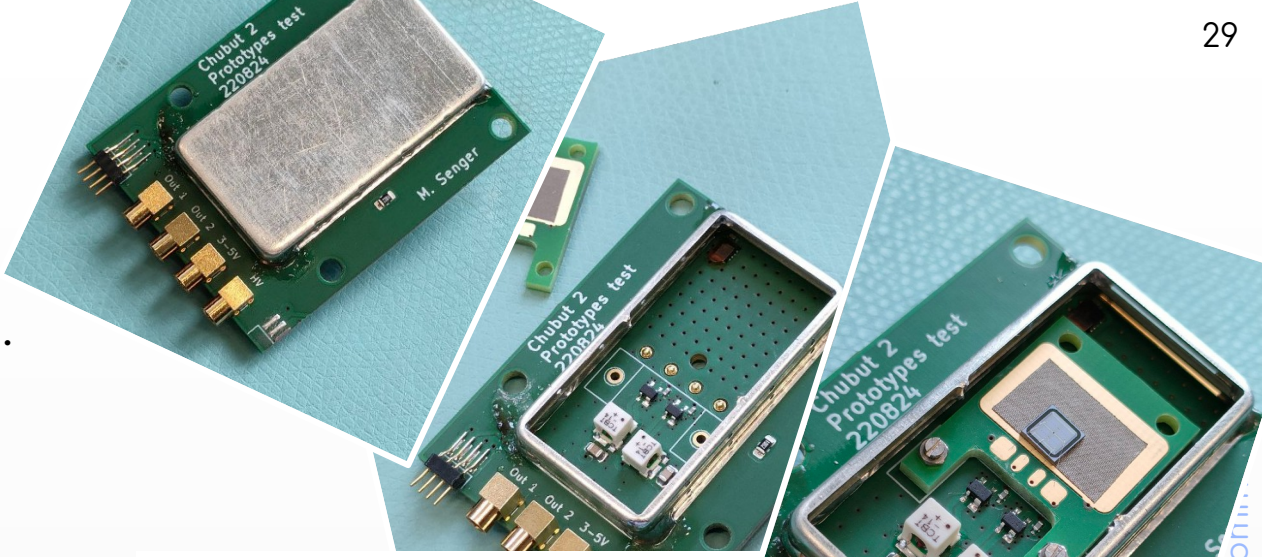
First PhD Committee Meeting
Rebekka's thesis

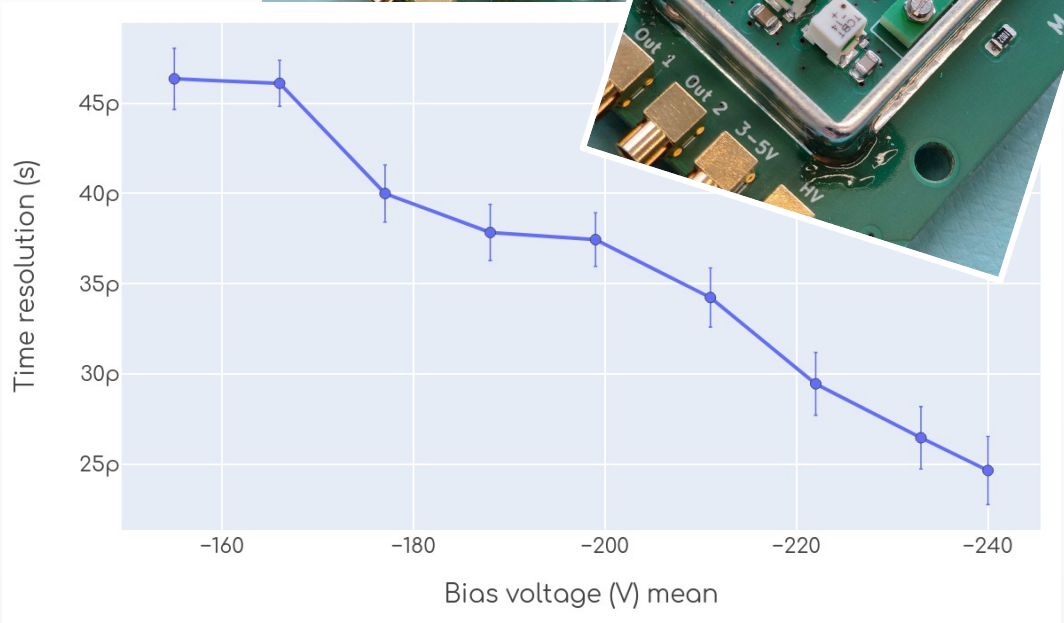
Chubut 2 prototype



- Multi channel readout board.
- Temperature+humidity built in.
- Main board + carrier board (valuable for whoever works in the lab, i.e. me).
- Prototype: looks very promising.
- More info link.

- Same board for TCT, Robocold and test beam.

One board to measure them all

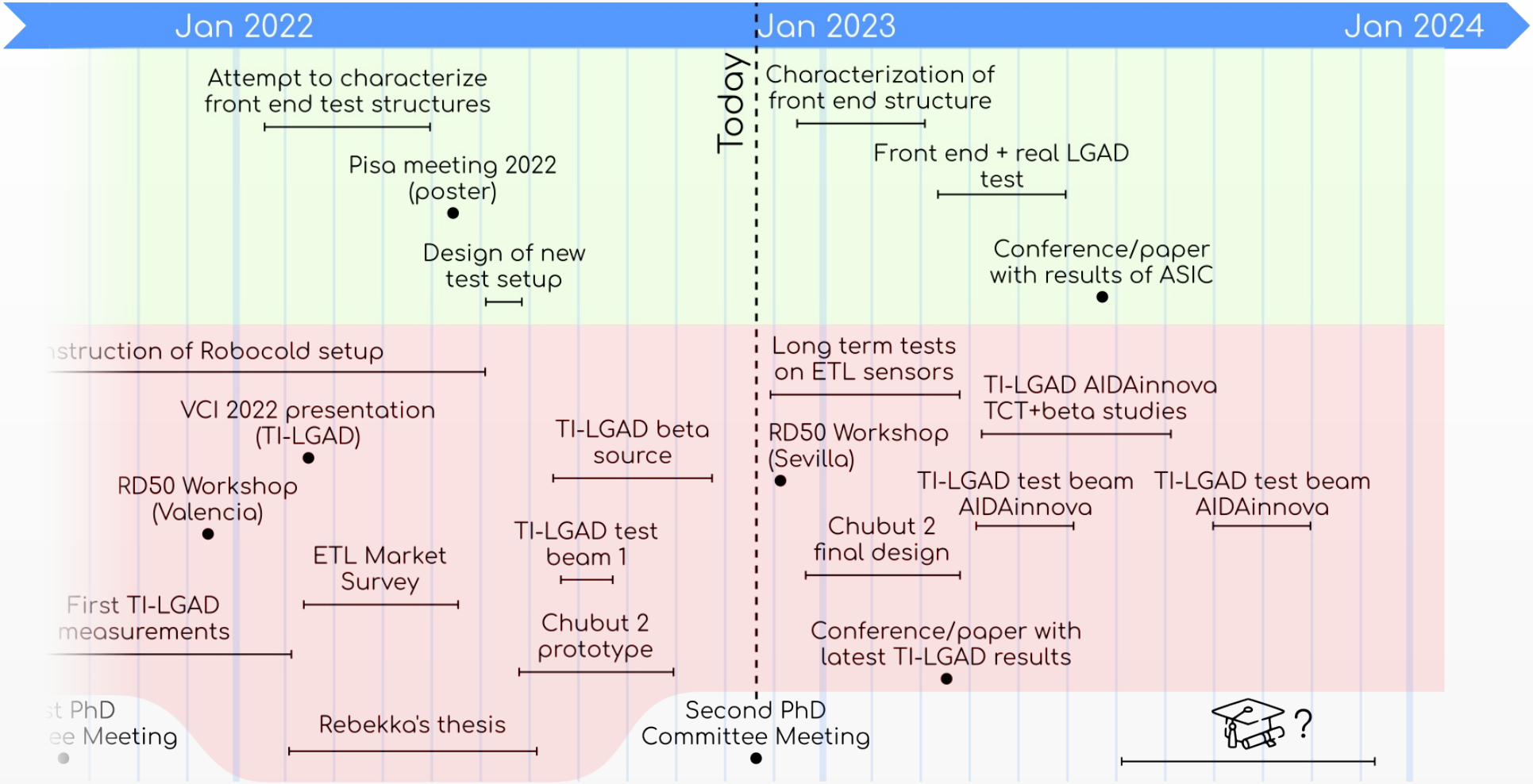


PhD process overview and conclusions

PhD process overview

- Teaching duties ~170 hours (out of 100 hours).
- Credits ~22 ECTS (out of 14).
  - Conference presentations (12 ECTS)
    - 37th RD50 workshop "Zagreb" (2 ECTS).
    - TIPP 2021 (2 ECTS).
    - 39th RD50 workshop Valencia (2 ECTS).
    - VCI 2022 (2 ECTS).
    - Pisa Meeting 2022 (2 ECTS).
    - 41st RD50 Workshop Sevilla (2 ECTS).
  - Courses (9 ECTS)
    - UZH Innovathon (3 ECTS).
    - PHY529 Advanced Topics in General Relativity and Gravitational Waves (6 ECTS).
  - Schools (1 ECTS)
    - Scientific Programming with Python (UZH) (1 ECTS).
- Publications
  - TI-LGAD TCT + beta + test beam (current results), submission/presentation by beginning of 2023.
  - TI-LGAD TCT characterization (proceeding), September 2022, NIMA. https://doi.org/10.1016/j.nima.2022.167030
  - TDC prototypes (proceeding), submitted may 2021 and still in process...

Conclusions




That's all Folks!