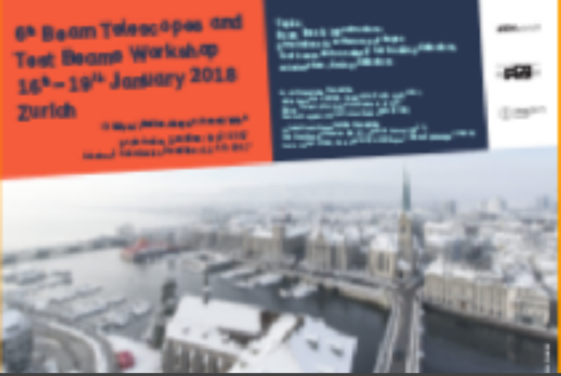
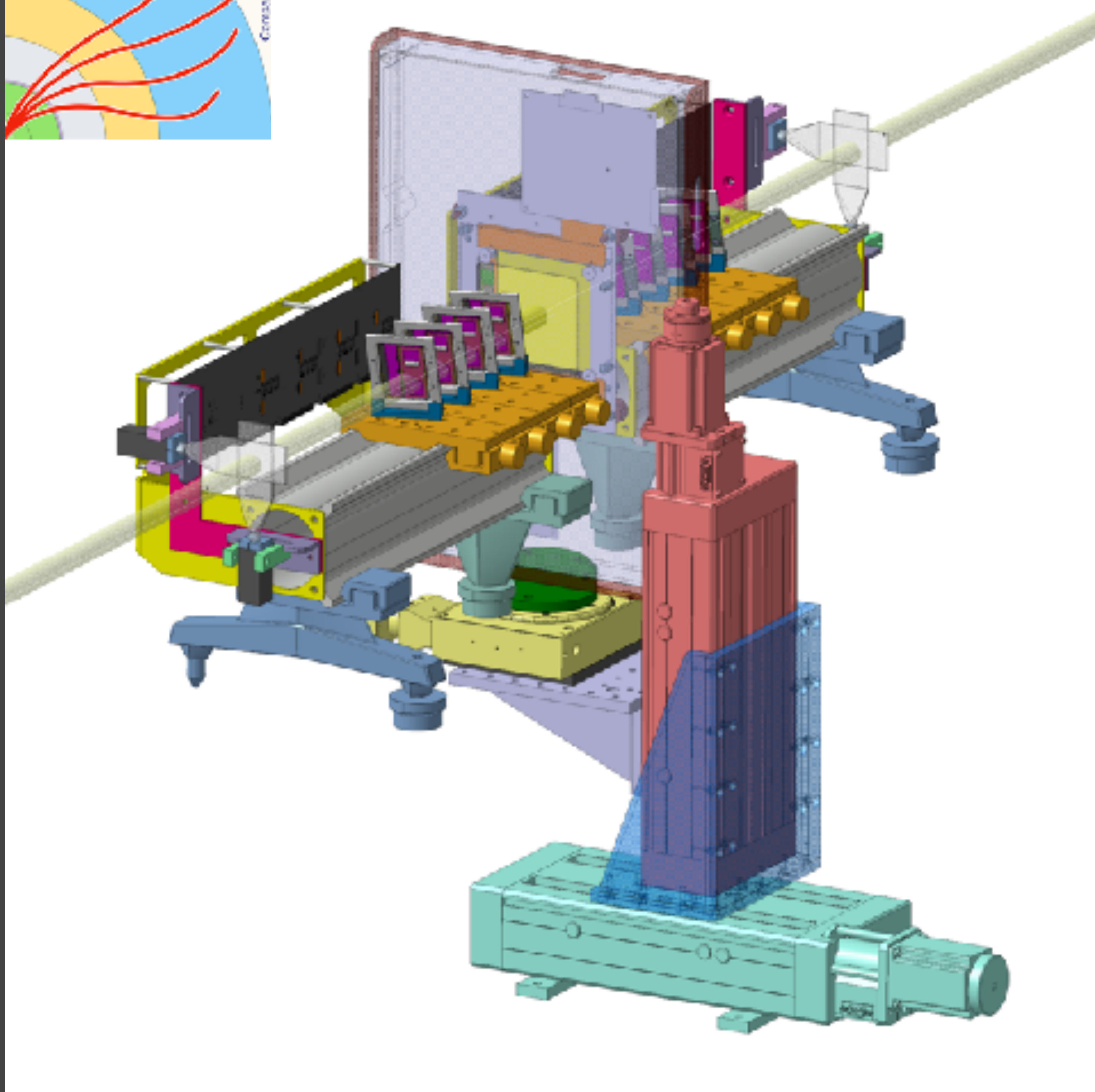
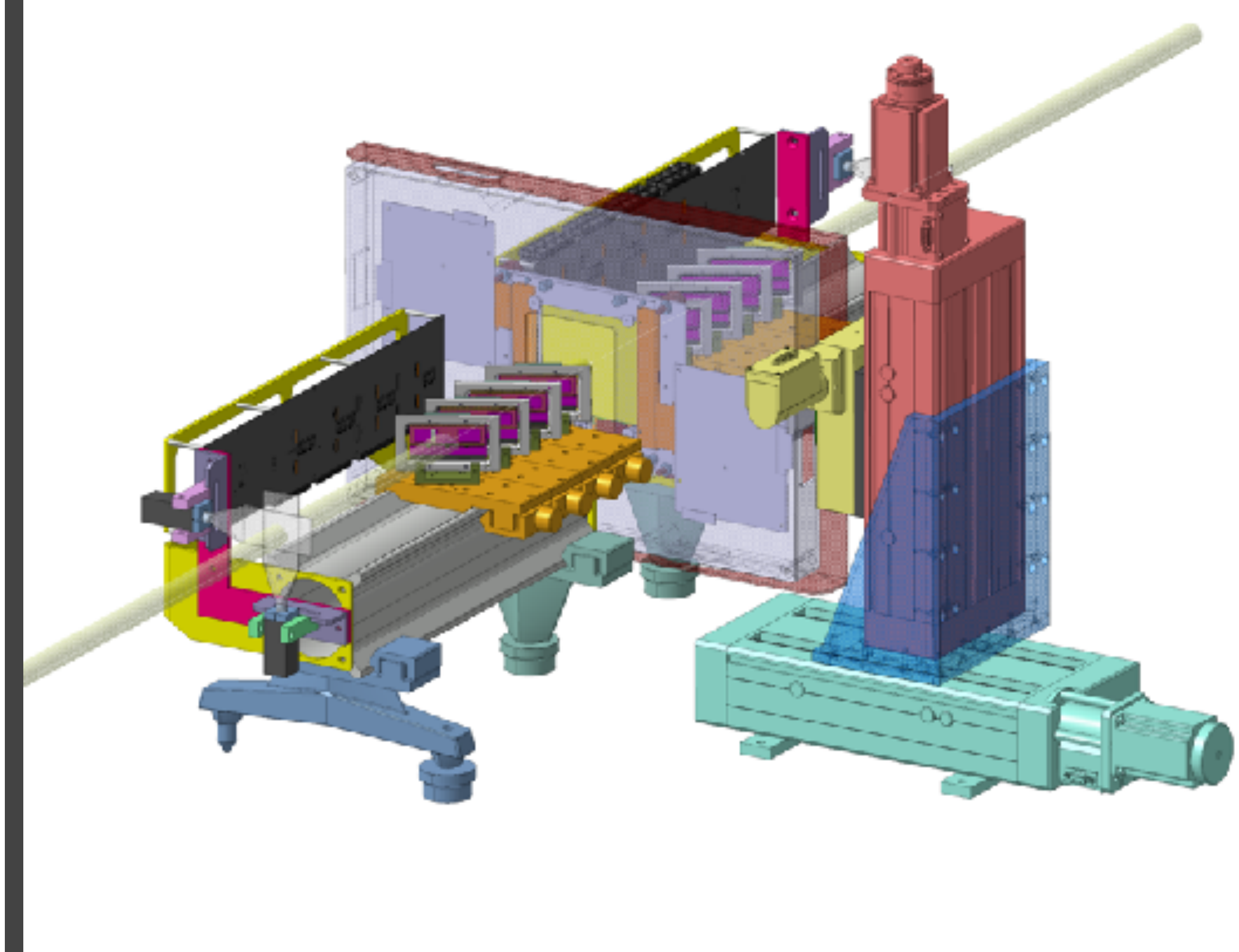


6th Beam Telescopes and Test Beams Workshop 2018

16-19 January 2018
Zurich, Switzerland
Europe/Berlin timezone

A new CMS Telescope for HL-LHC silicon detectors

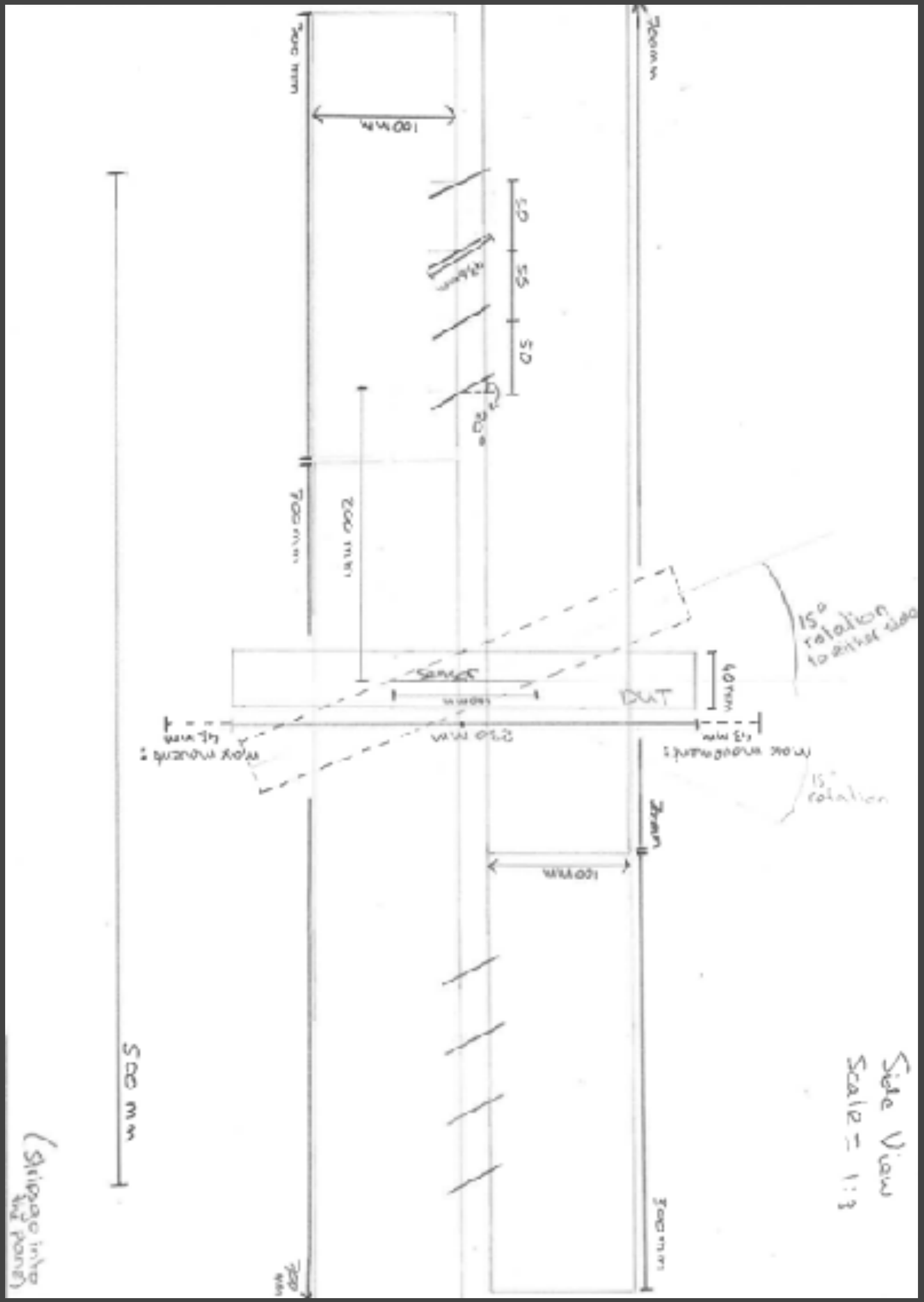




Nikkie Deelen - 17.01.2018 - 6th BTTB Workshop

Content

- A new telescope for CMS;
- Building blocks of the new telescope;
- Telescope electronics;
- Telescope mechanics;
- Software for readout;
- Simulations:
  - Telescope + DUT;
  - Radiation studies;
- Summary.



A new telescope for CMS

No dedicated CMS telescope for Phase II Tracker modules (HiLumi upgrade) at CERN:

AIDA Telescope is used at CERN.

https://www.sciencedirect.com/science/article/pii/S1875389212017889

- **New tracker modules / DUT** have binary output:
  - Large range of thresholds to be scanned to qualify the signal;
  - Ideal situation: limiting factor is the ~MHz trigger rate capability of the readout chips.

  ➡ This is ~100x faster than the ~9kHz readout rate of the AIDA telescope.

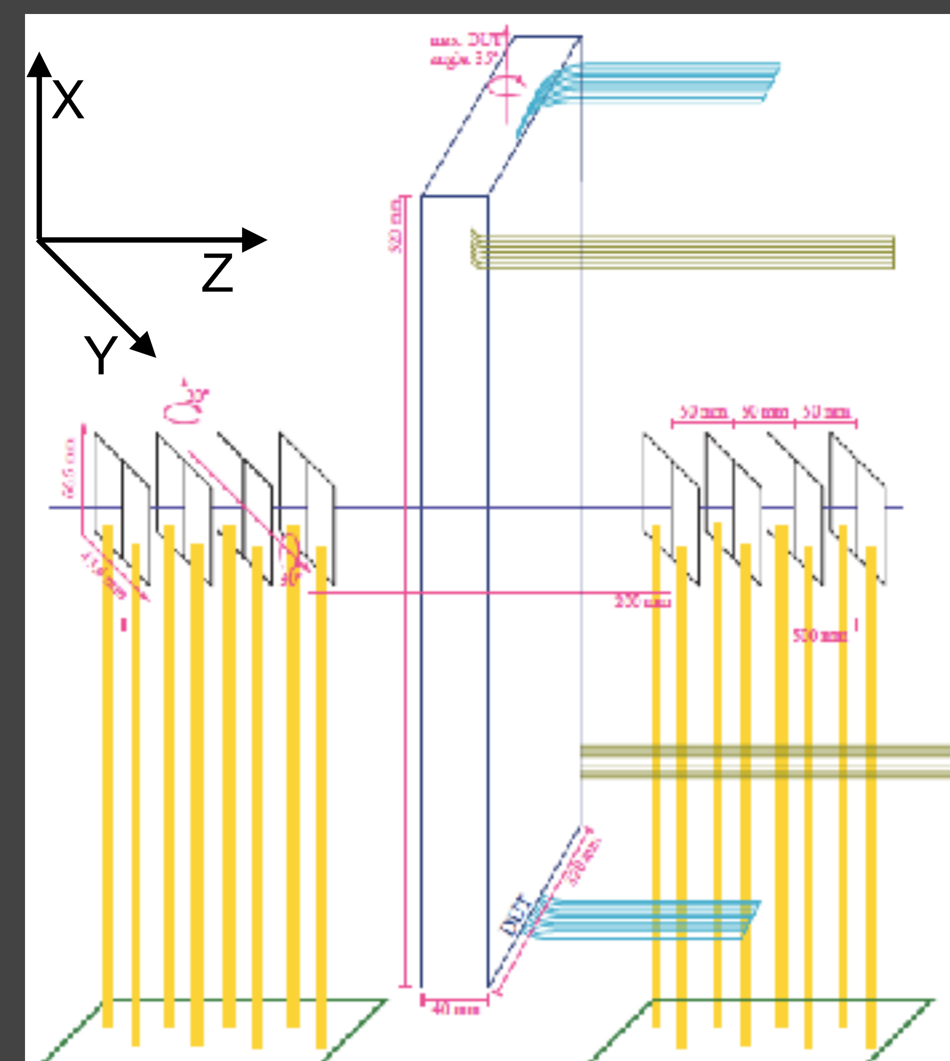
- New tracker modules have 25 ns integration time:
  - Ideally these modules should be tested at nominal rate.

  ➡ AIDA telescope has 112.9 μs (~4600x lower) integration time, this means a large pile-up at nominal tracker module rate.

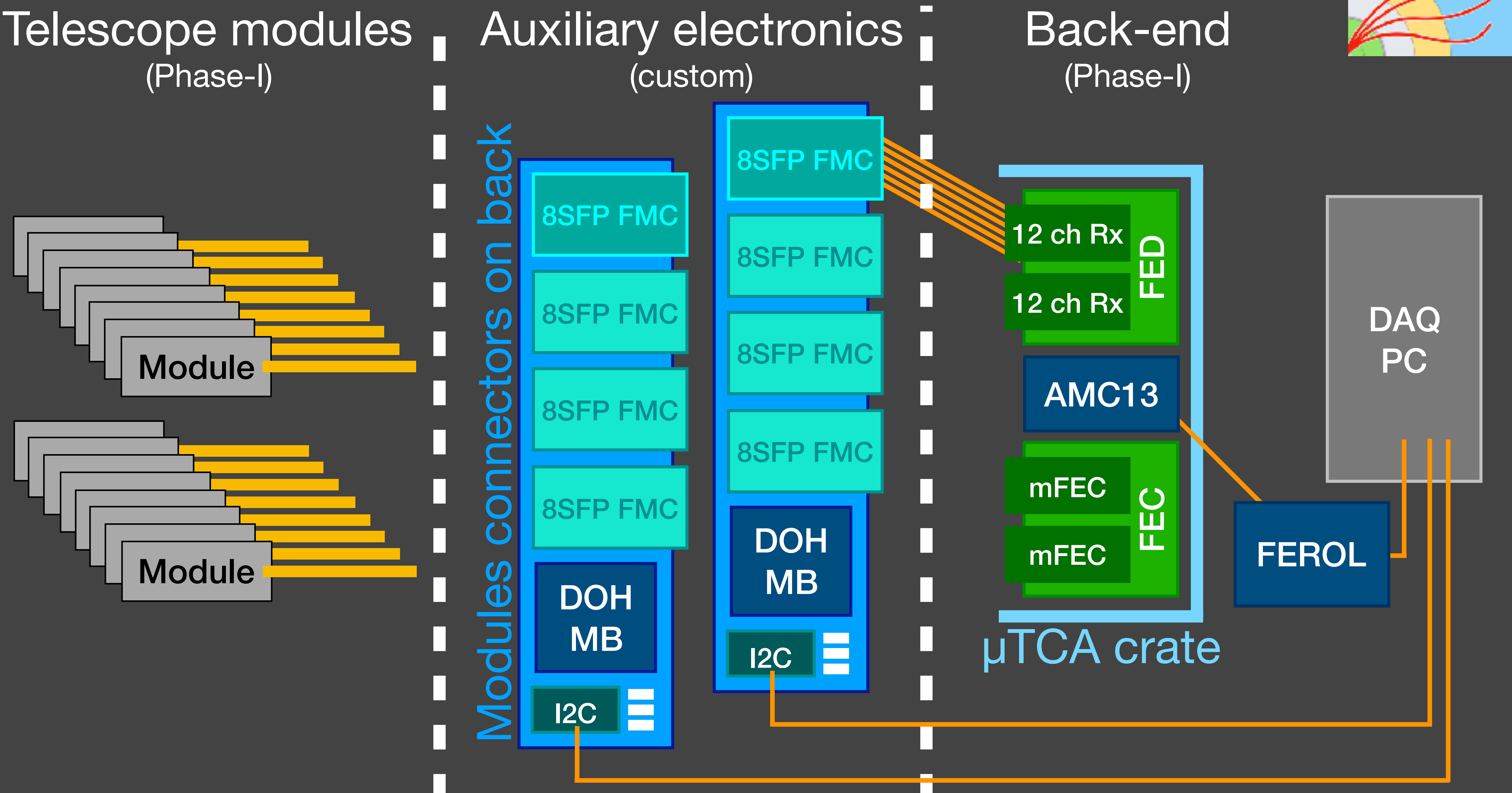
Building blocks of the new telescope

- Grade-C Barrel Pixel modules, from the production of the CMS Phase-I pixel detector:
  - ➡ Dead pixels, high IV-curves;
  - ➡ Use them as is, including their short sacrificial cables.
- Can take particle rate of ~200 MHz/cm^2
  - ✓ Compared to highest rate of Phase-II Outer Tracker DUT ~50 MHz/cm^2

- Four planes on either side of the DUT to compensate for the dead areas;
- Two BPIX modules per plane for an active area of 2 x 16.2 x 64.8 mm^2 (21 cm^2);
- Planes are positioned at an angle with respect to the beam axes to allow for charge sharing;
  - 20° tilt angle around x-axes;
  - 30° skew angle around y-axes;
- Resolution for high energy p or μ is expected to be better than 14 μm.



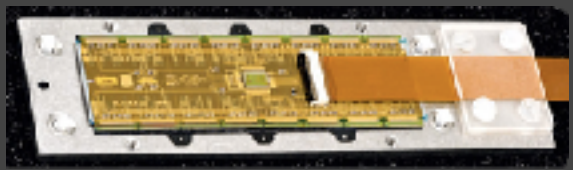
Telescope Electronics



- Take BPIX readout as a template and adapt to our needs:
  - ✓ This means no exceptionally thin/flexible PCBs, commercial cables, off-the-shelve I^2C master and so on.

Telescope Electronics design

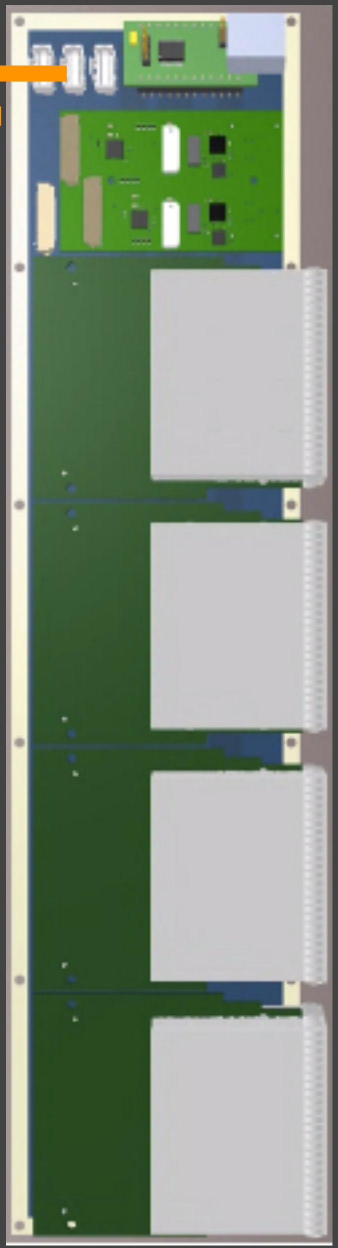
Modules



I²C master

Power connectors

Currently being design, expected delivery 02/18



Back

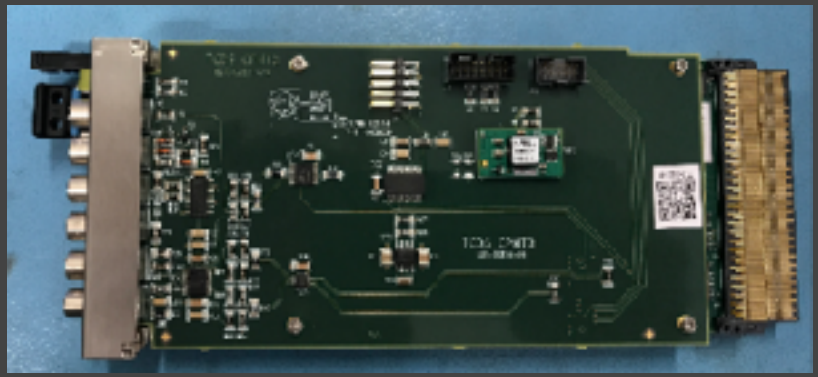
Front

T. Kiss & Cerntech

Module connectors

Front-end **D**river

Advance **M**ezzanine **C**ard13

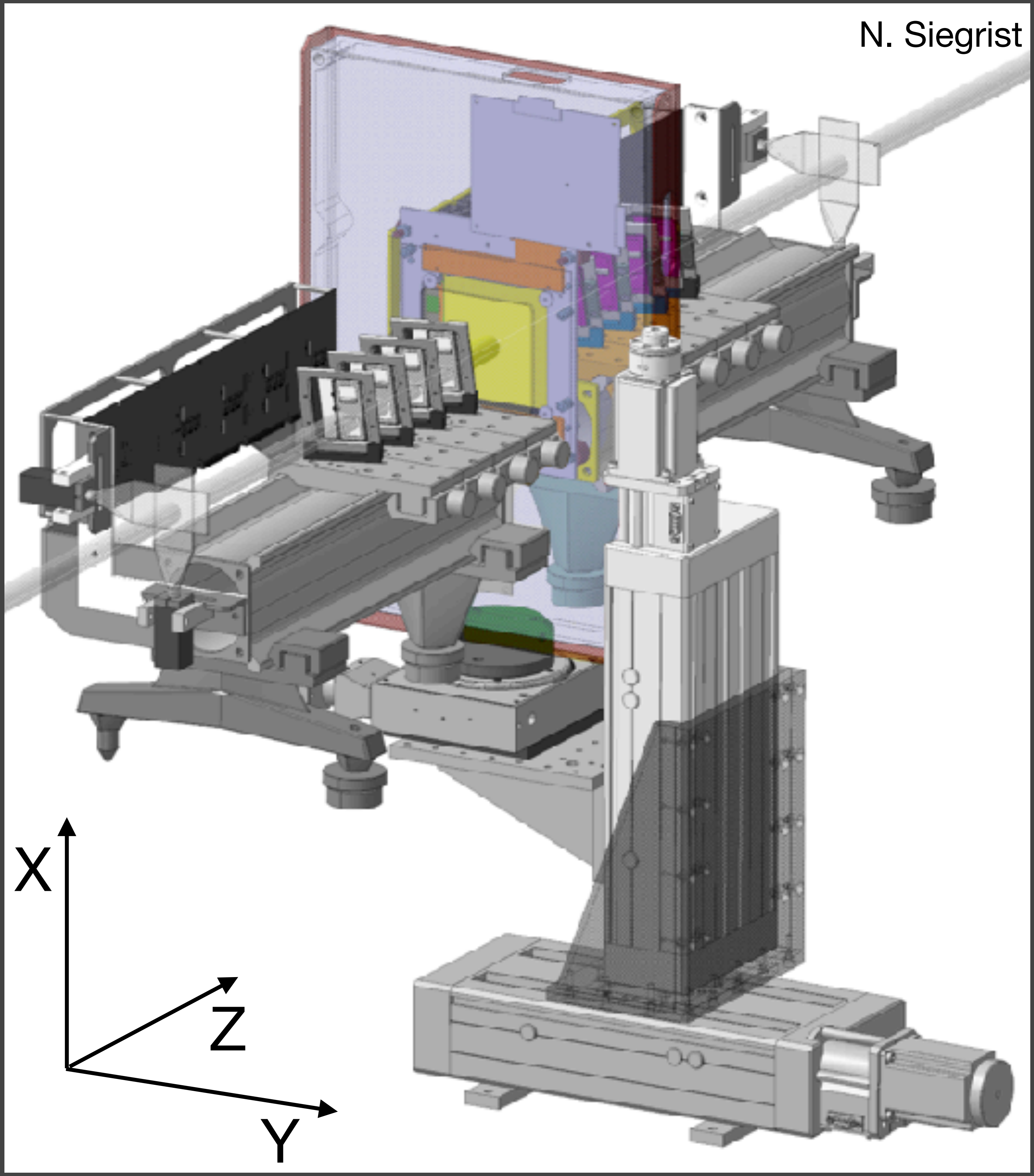


Front-end **C**ontroller

Front-**e**nd **R**eadout **O**ptical **L**ink

Design for a large DUT
(box size = 550 x 350 x 40 mm^3):

- **Two modules in a frame** form one telescope plane;
- Frame is mounted on a **block** that can hold the plane in different positions (angles);
- Block is mounted on **carriage** that can slide over a rails;
- **Auxiliary electronics** mounted close to the modules, on the rails;
- **Four scintillators** for triggering, mounted on the rails as well;
- When ***rails slide apart*** (more DUTs in center) the auxiliary electronics and scintillators move as well —> no stress on module cables;
- ***Actuators*** for DUT, translation in X/Y, rotation around X.



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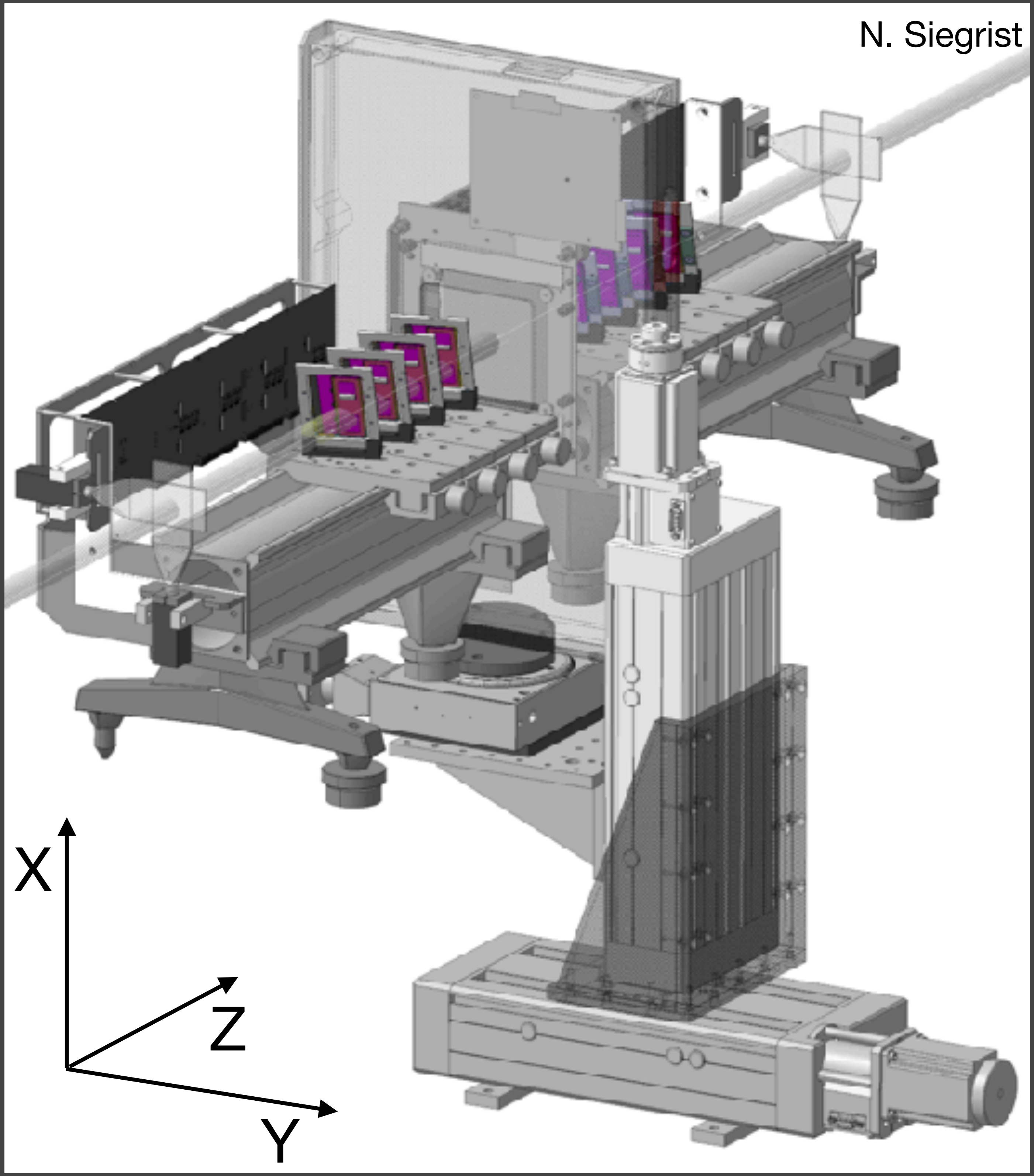

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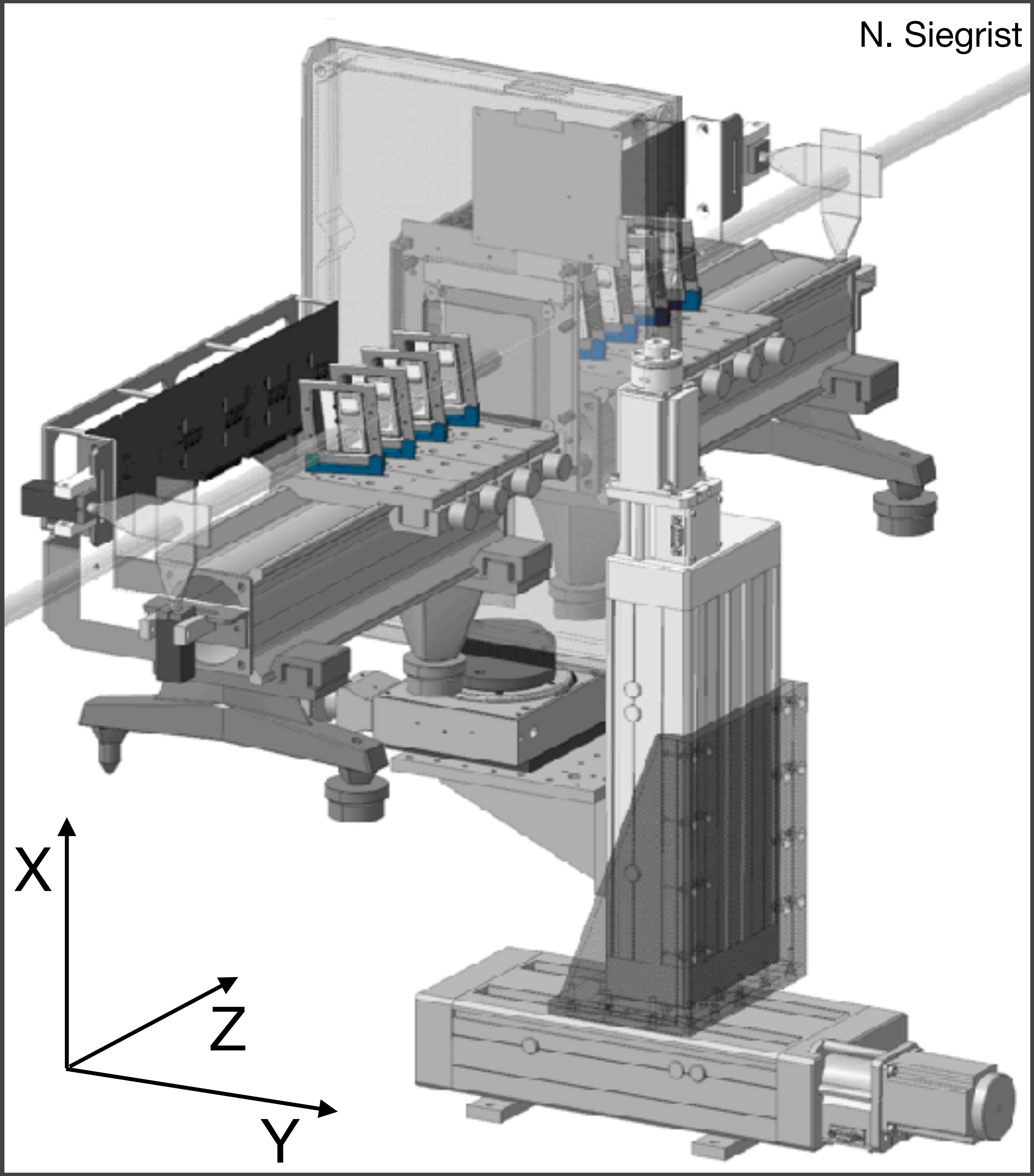

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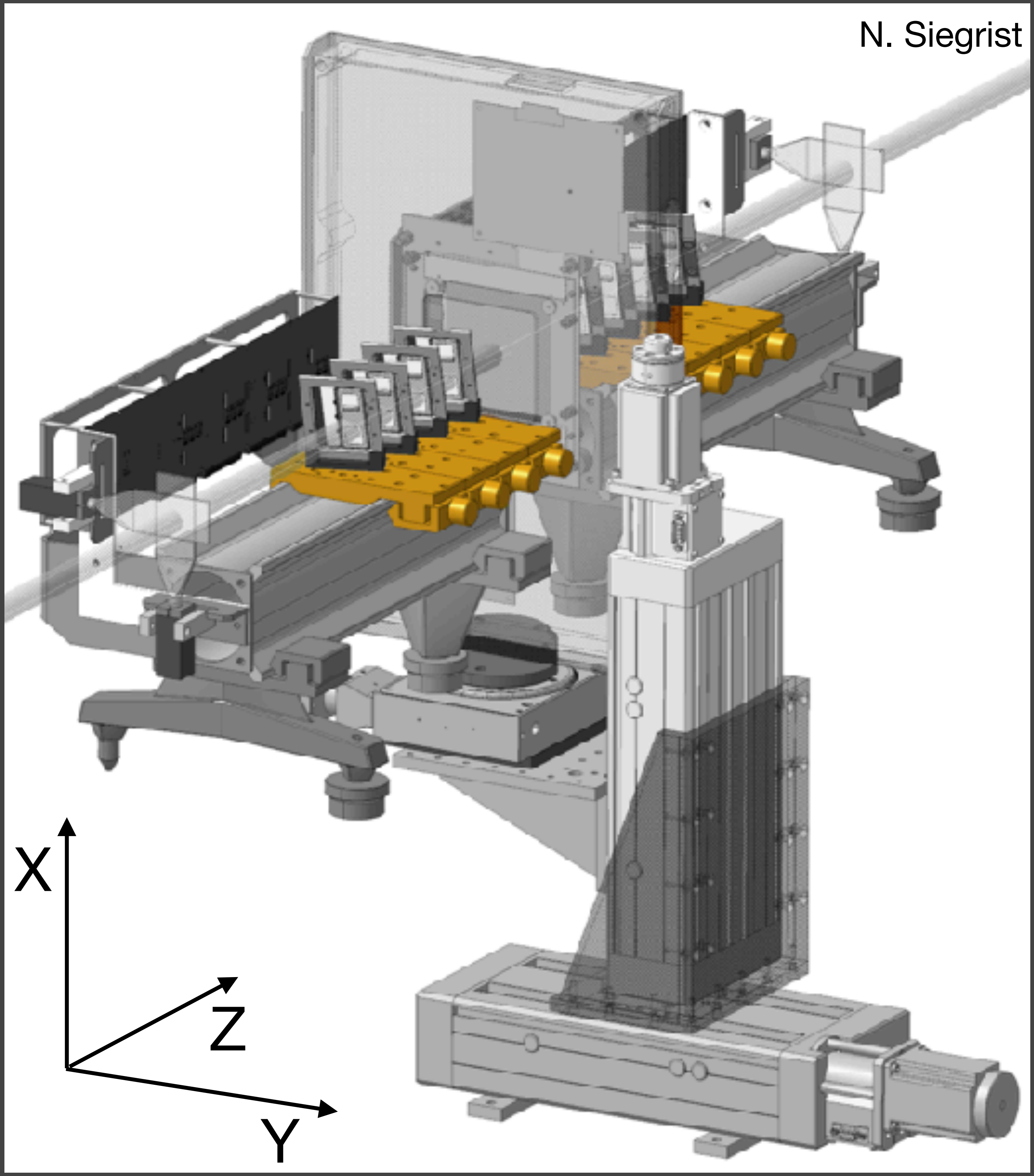

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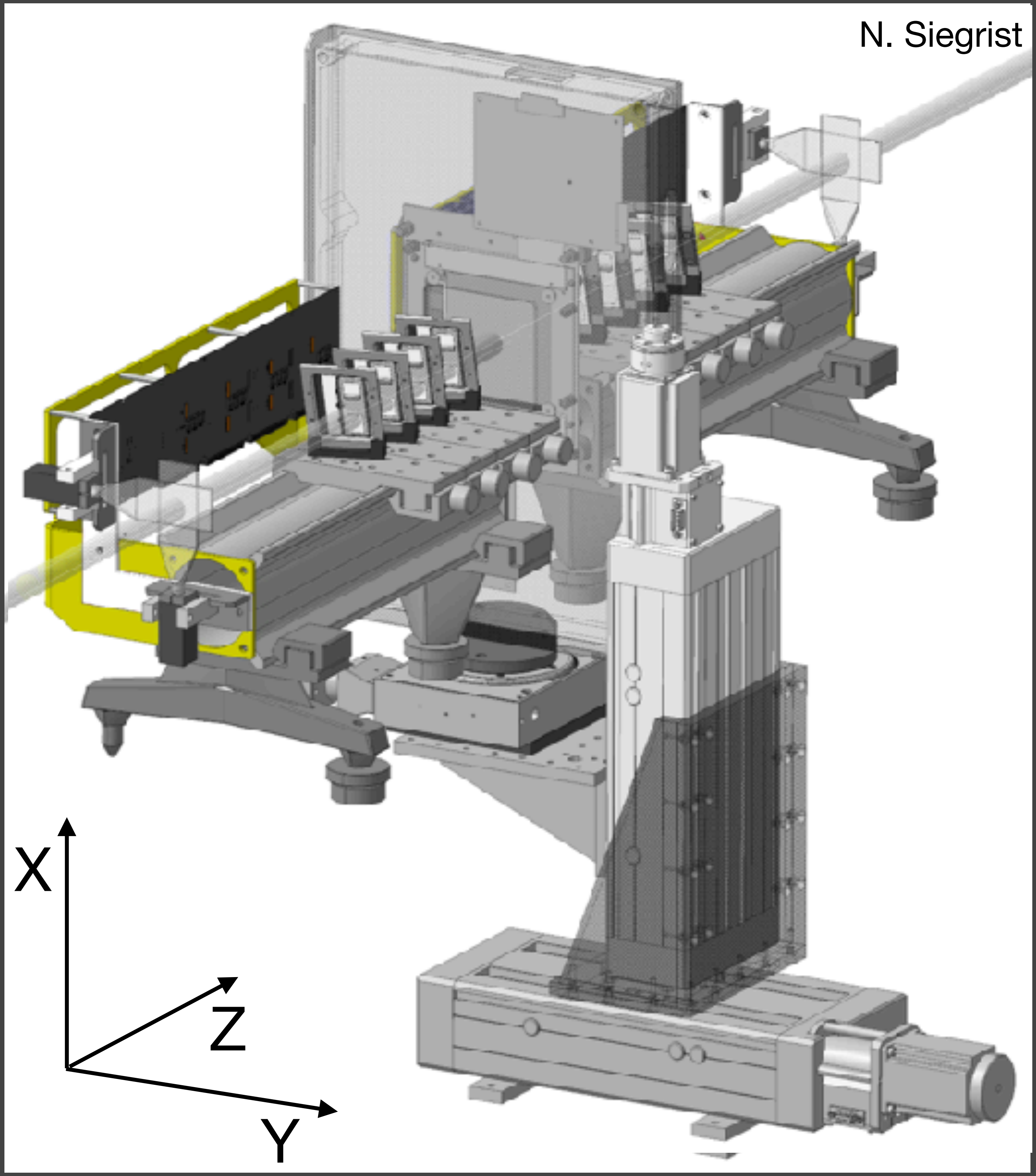

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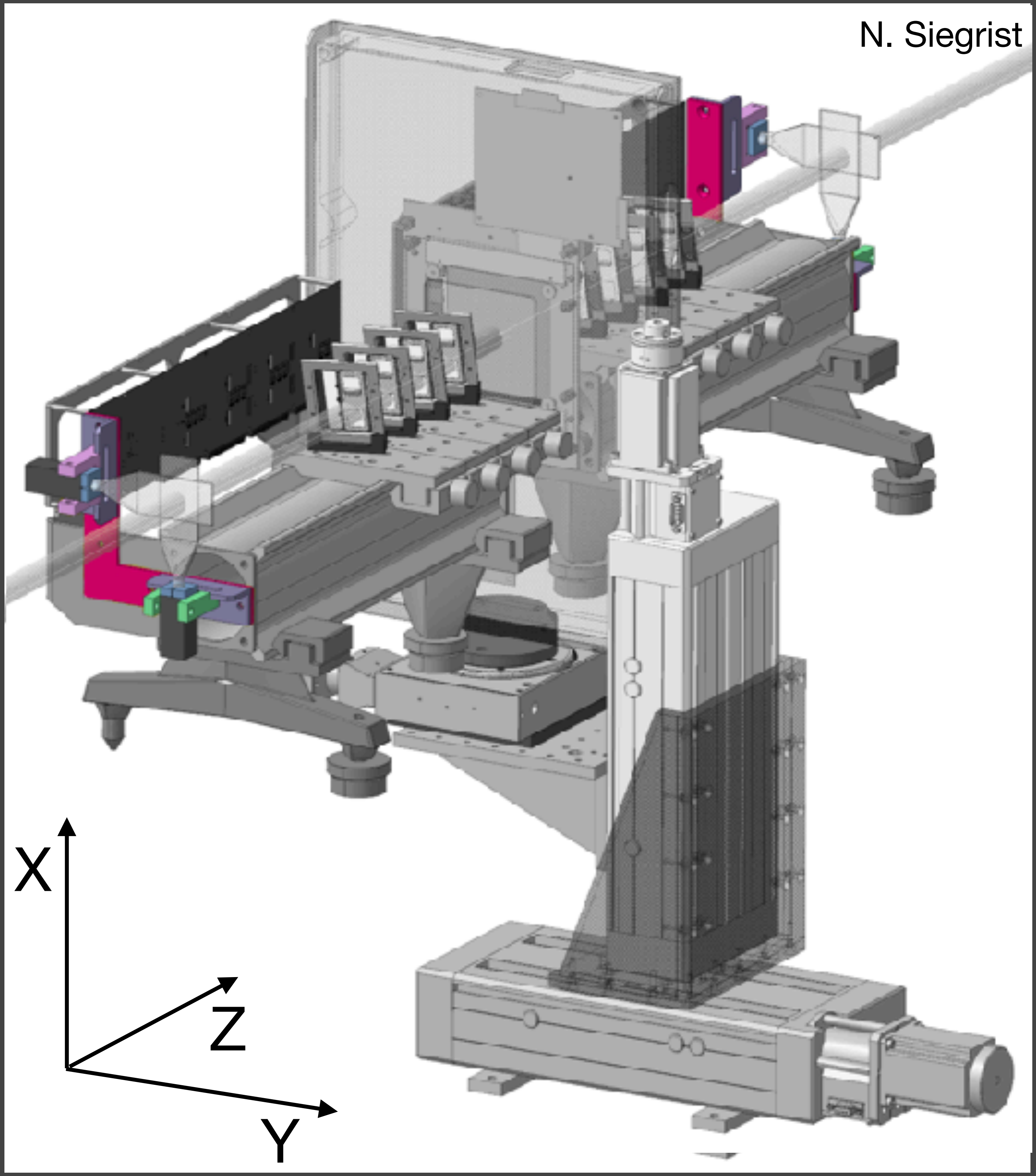

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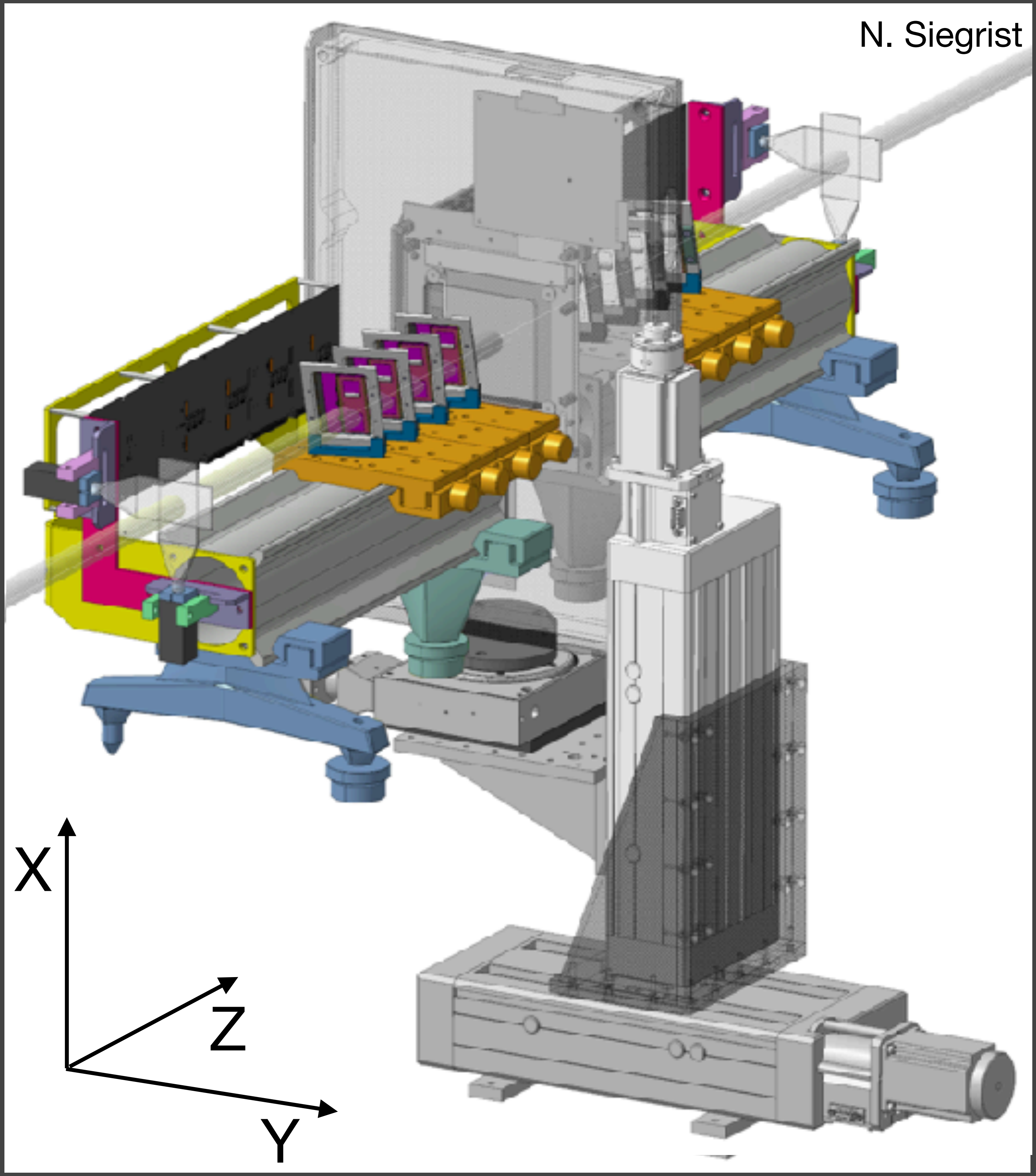

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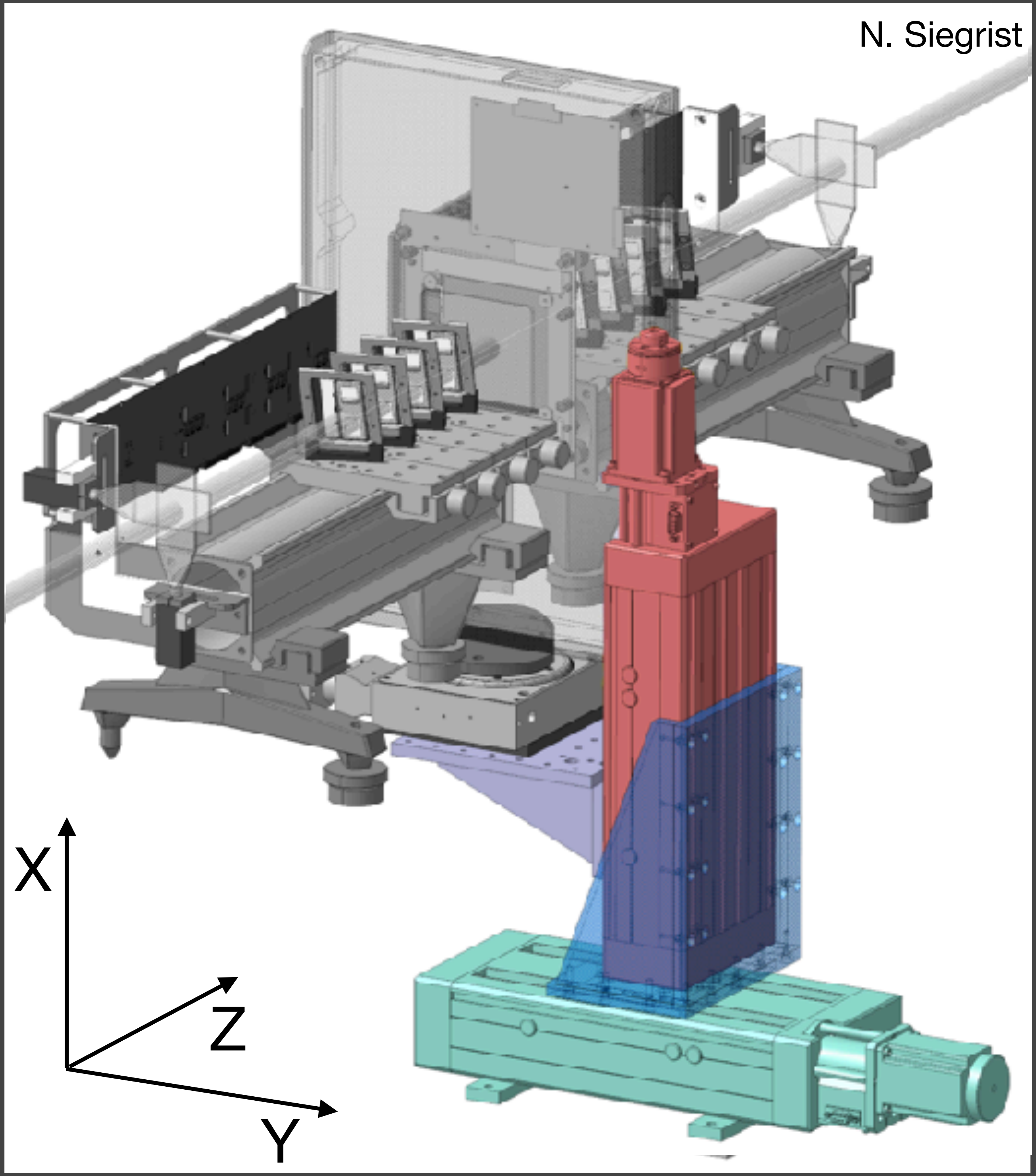

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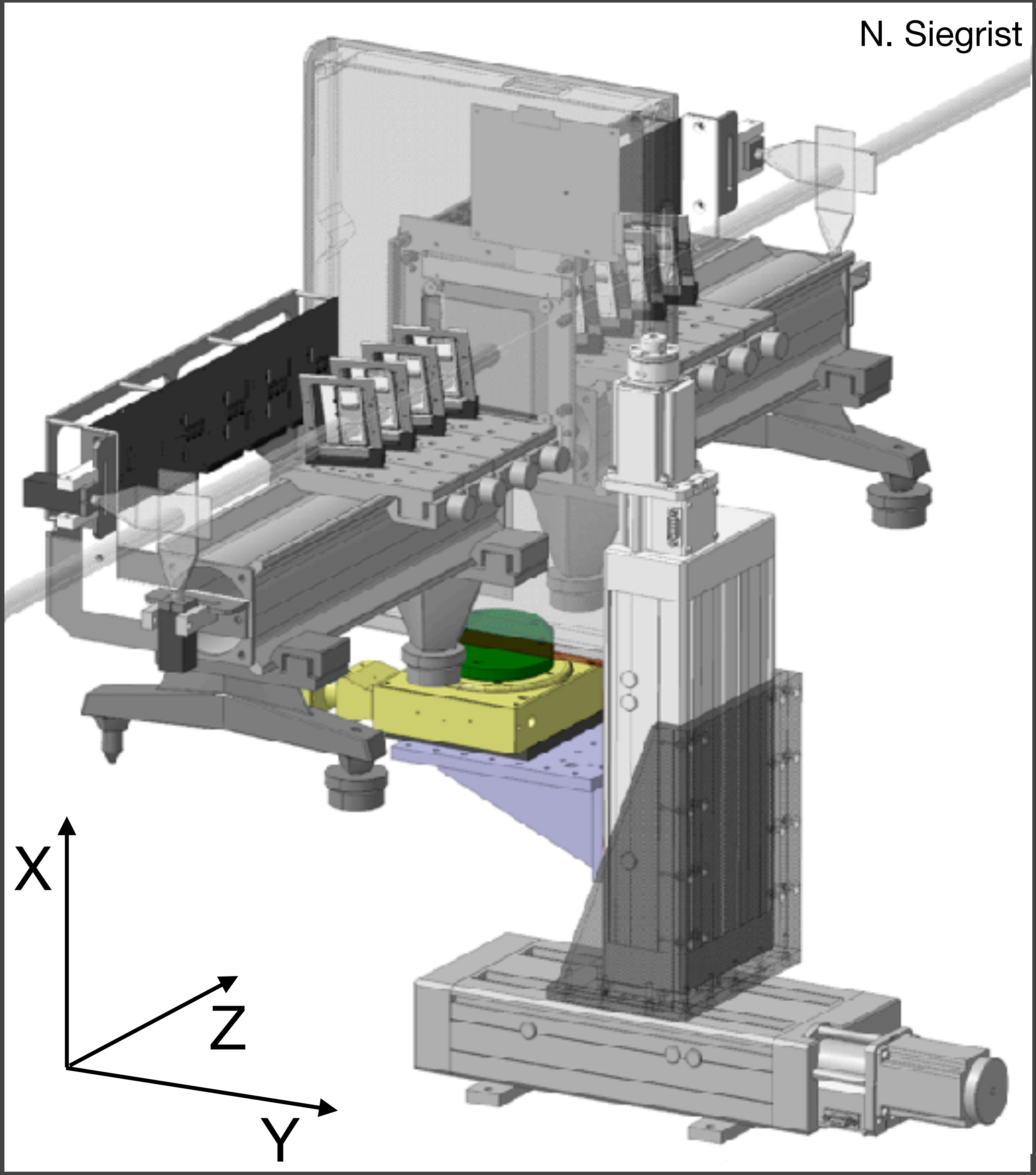
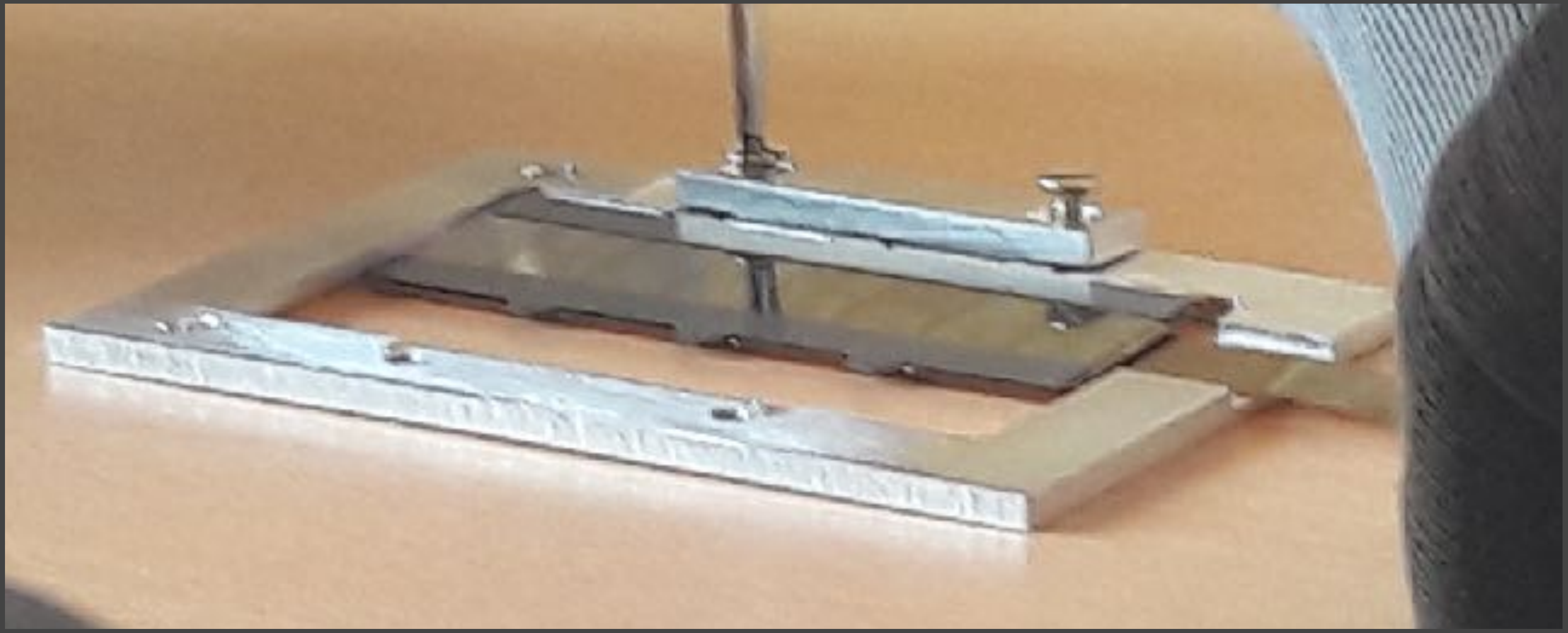


Module frames: how to hold the two modules in place?

- Problem: BPIX module have silicon nitrate strips with tiny ears to attach them to a frame. Ears are very tiny and very brittle!
- First idea: clamp ears between frame and aluminum strip:
  - Ears brake off by the littlest movement of the module;



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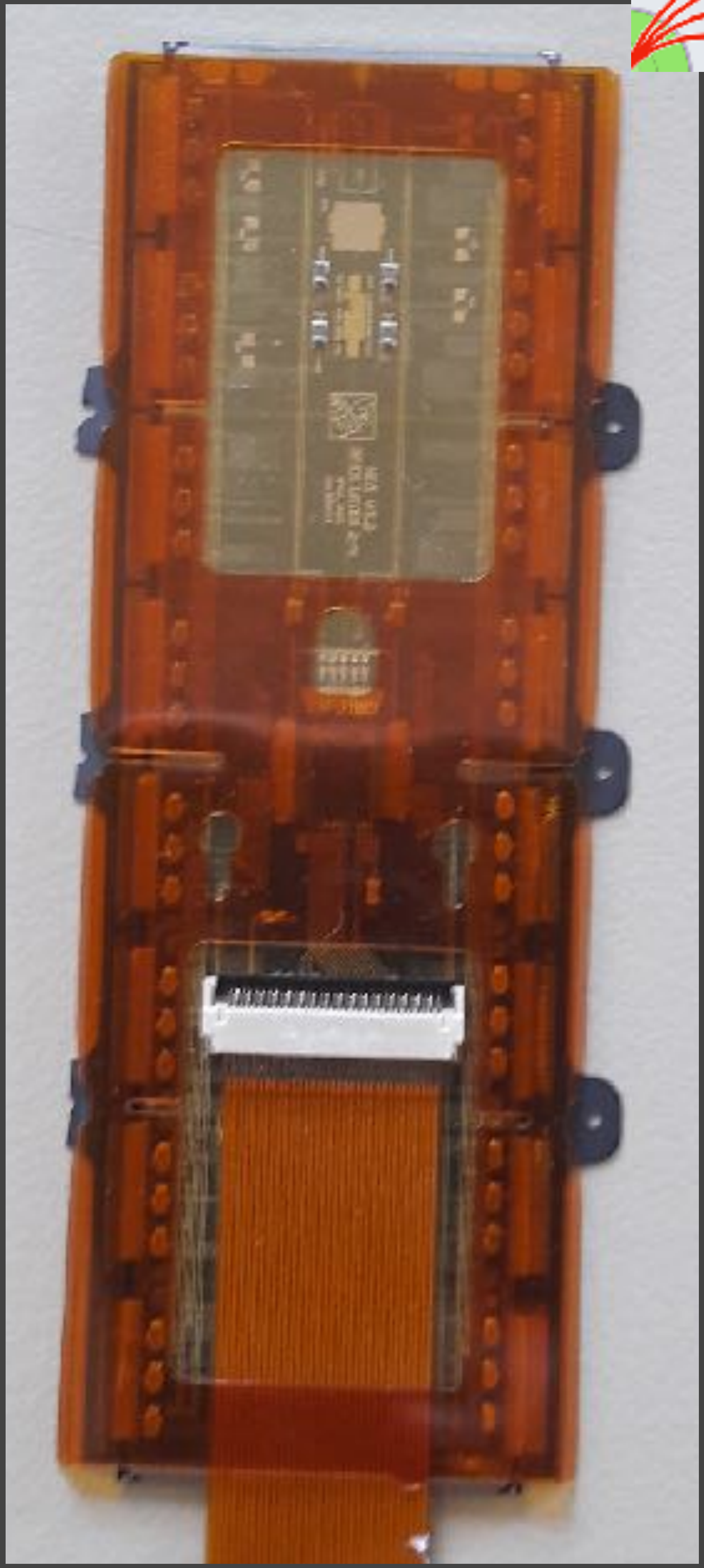
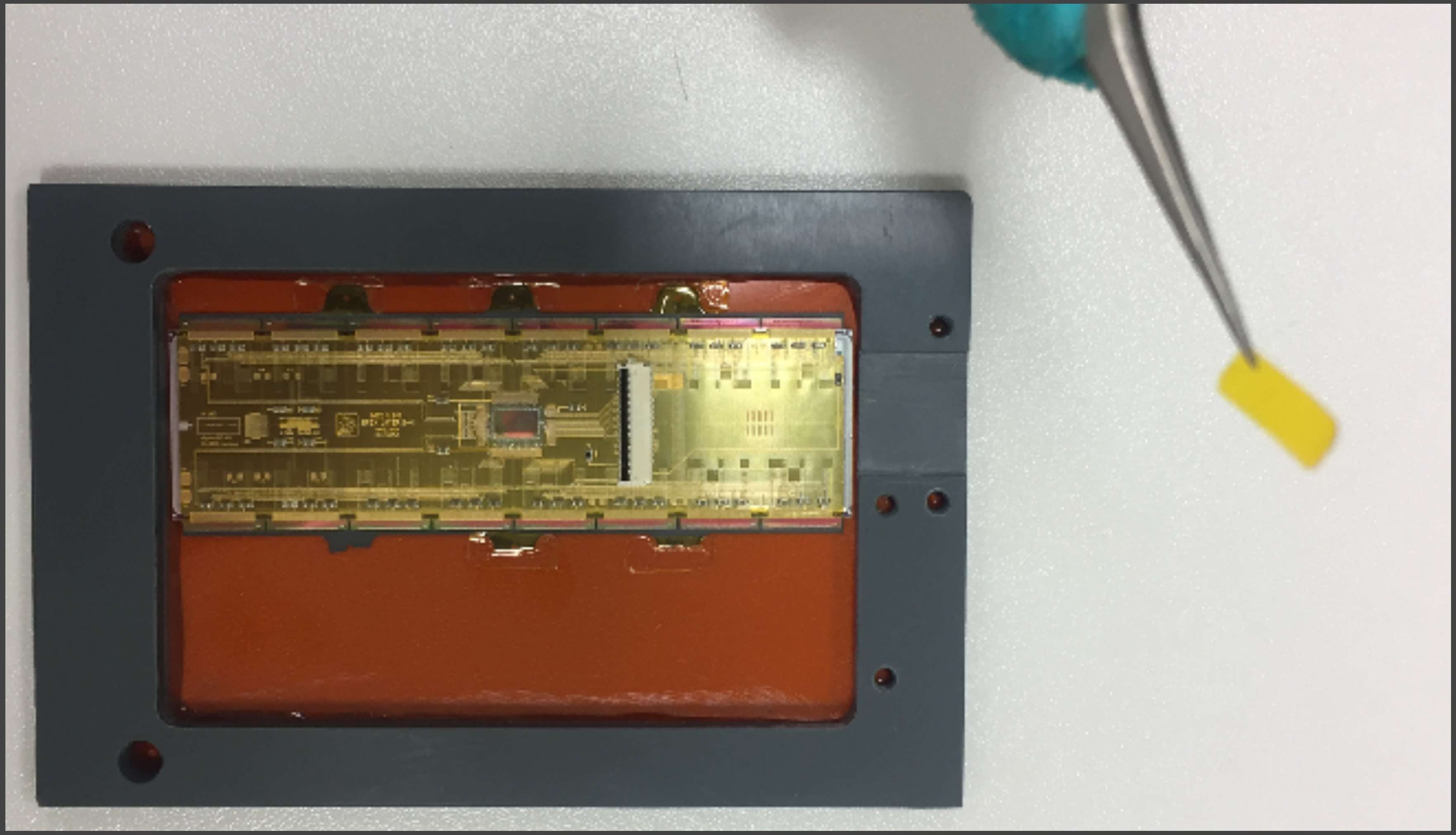


Open questions in mechanics

- Second idea: glue/stick modules on mylar sheet that is held in place by two frames:
  - Cooling: difficult to dissipate the heat, need for air cooling (computer fans);
  - CLICdp Timepix3 telescope at CERN is using computer fans as well, with similar power consumption (Martin Beuzekom - http://clicdp.web.cern.ch/content/vertex-detector-rd).



Software for readout of the telescope

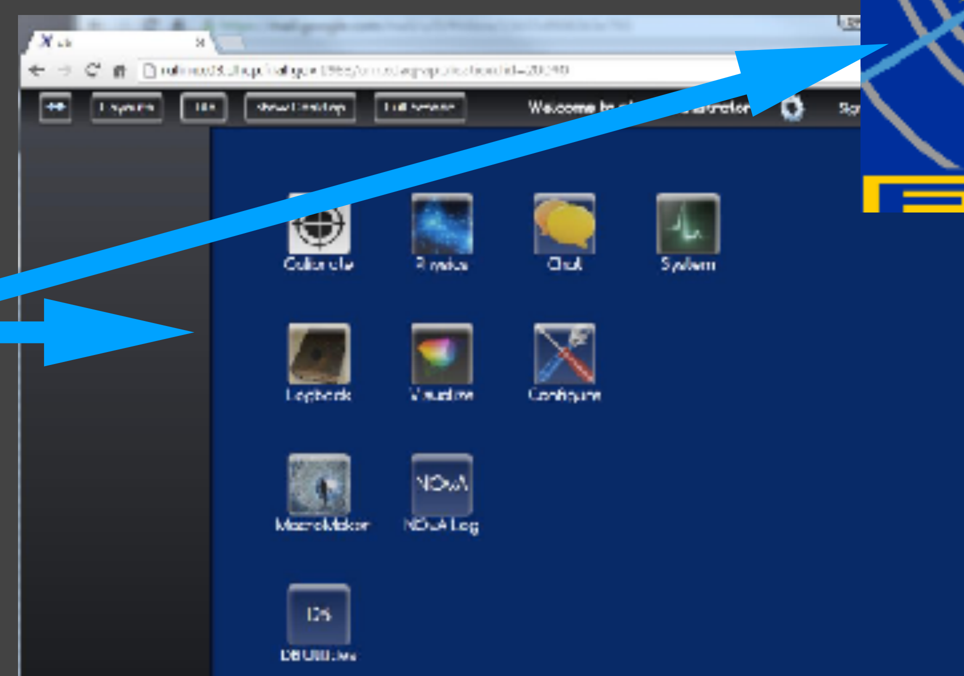
- Use Pixel Online Software in combination with a XDAQ application;
  https://gitlab.cern.ch/cmspos/PixelOnlineSoftware-phase1/tree/master
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/PixelOnlineSoftwareInstallation
  - Adapt the I²C programming to the commercial I²C master used in the telescope;
- XDAQ is used CMS-wide, also for the new tracker modules;
  https://svnweb.cern.ch/trac/cmsos
- Potentially to be integrated into EUDAQ or Fermilab's OTSDAQ.
  https://otsdaq.fnal.gov/

Telescope

Pixel Online Software

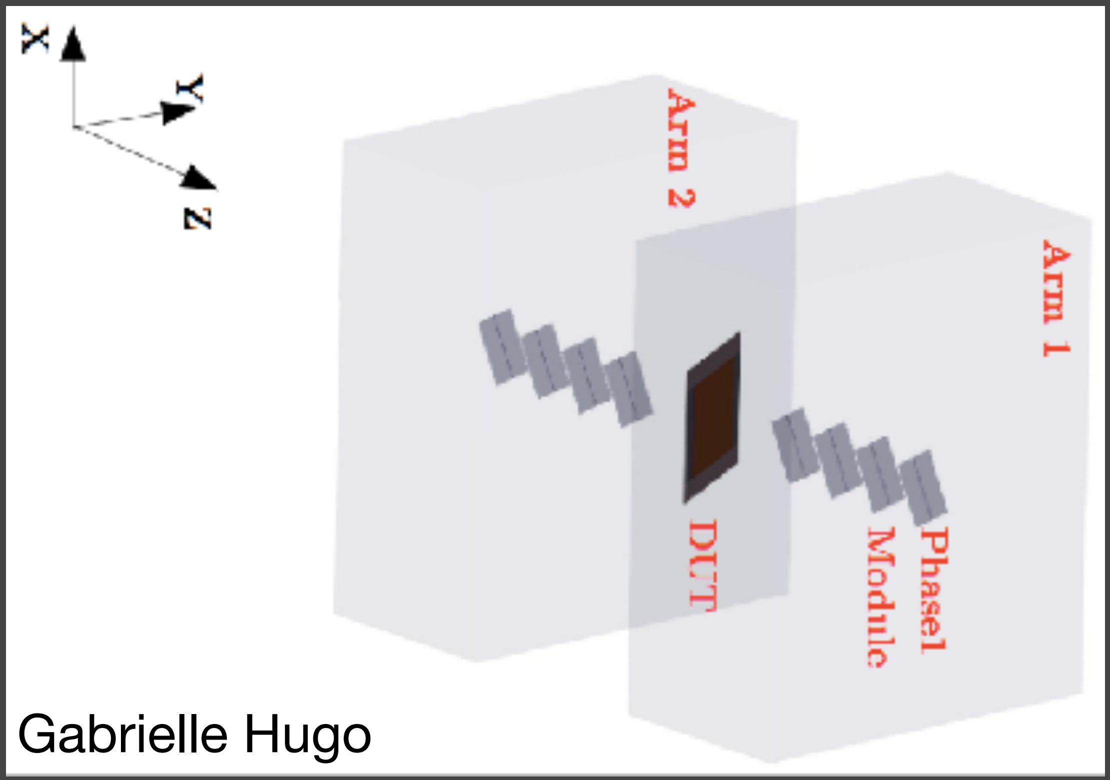
DUTs

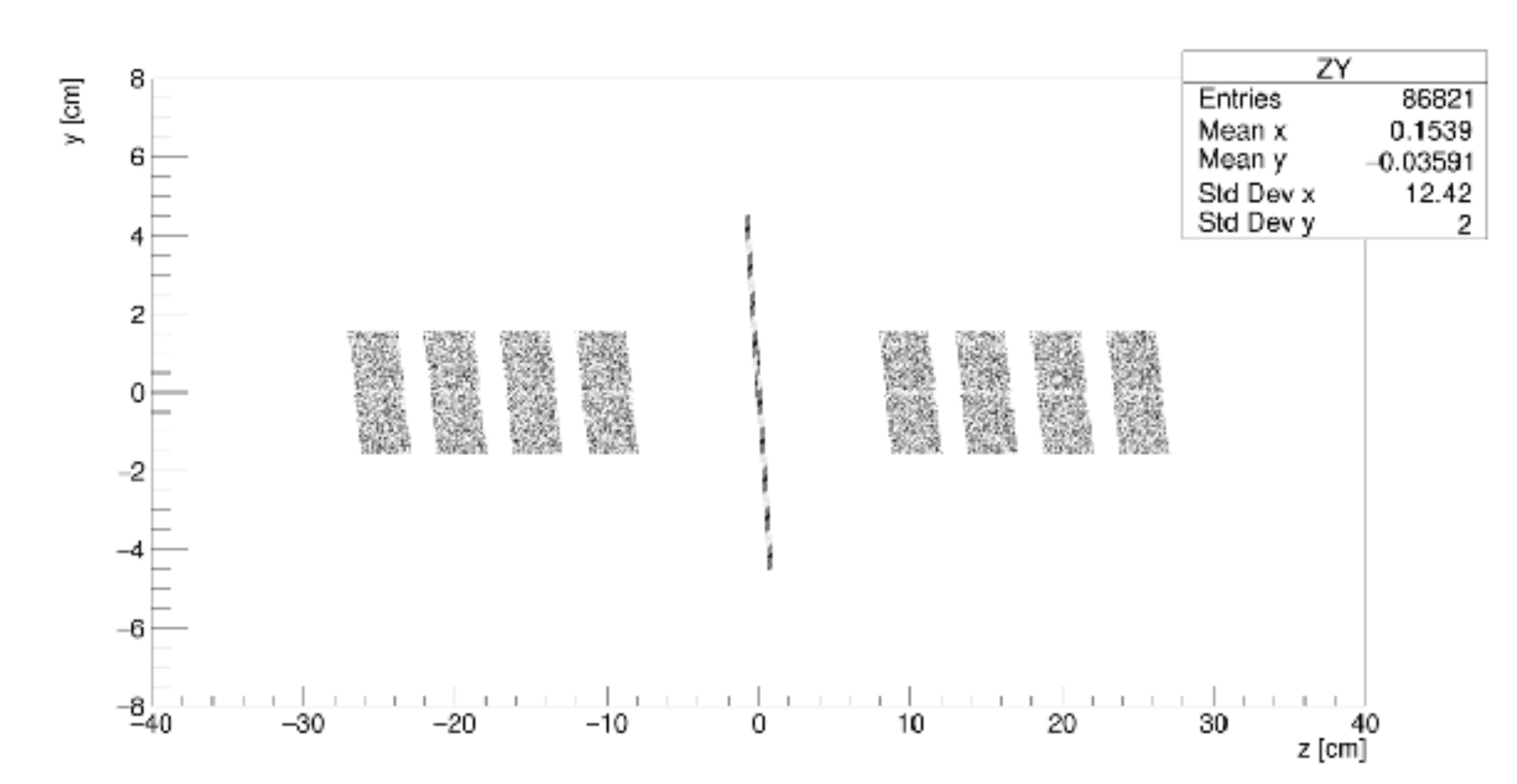
Phase-II Middleware



Simulations: Telescope + DUT

- Record beam test data in the CMS-SW format (standard CMS simulation and analysis framework);
- Use CMS-SW to:
  - Simulate the telescope + DUT;
  - Develop analysis for simulated and real data.
- This provides a direct comparison between upgrade simulations and beam test results;
- First steps: SimHits!

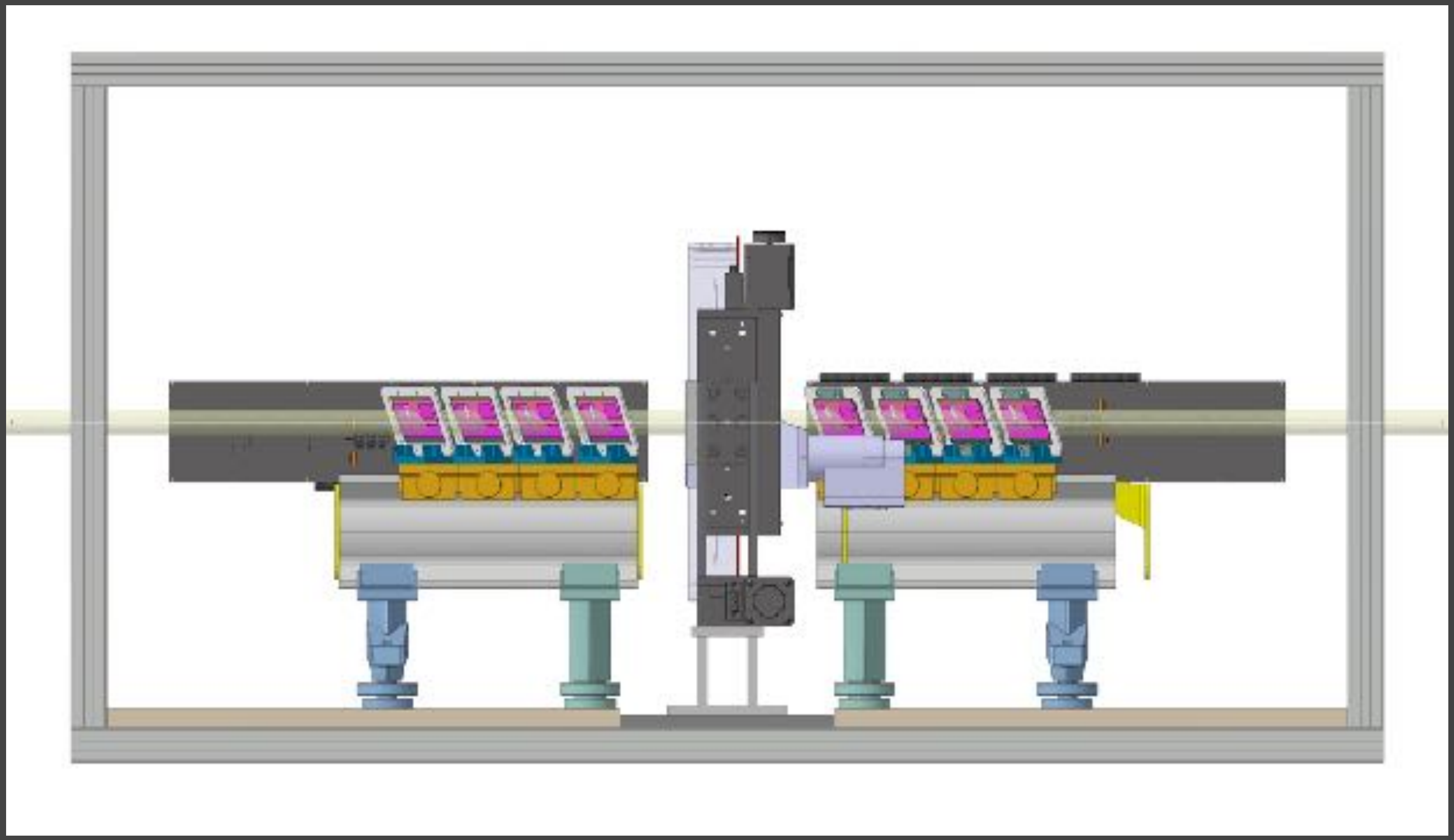




Simulations: Radiation studies

- Radiation studies have to be performed for high intensity particle beams to understand if extra shielding is needed;

- Planned to perform Fluka simulations to understand the dose that individual components may receive;
  - Is there a need for shielding in some places?



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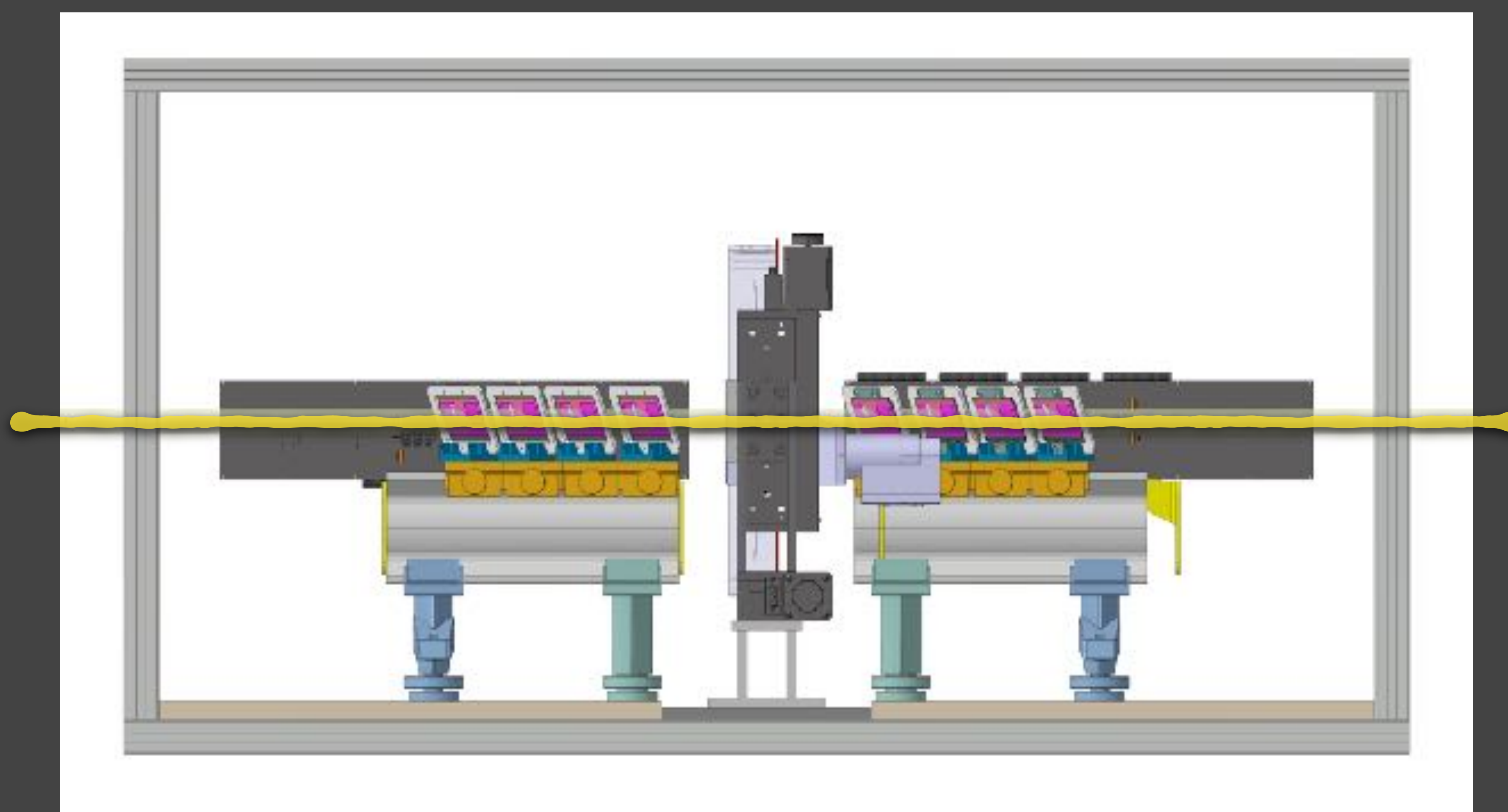

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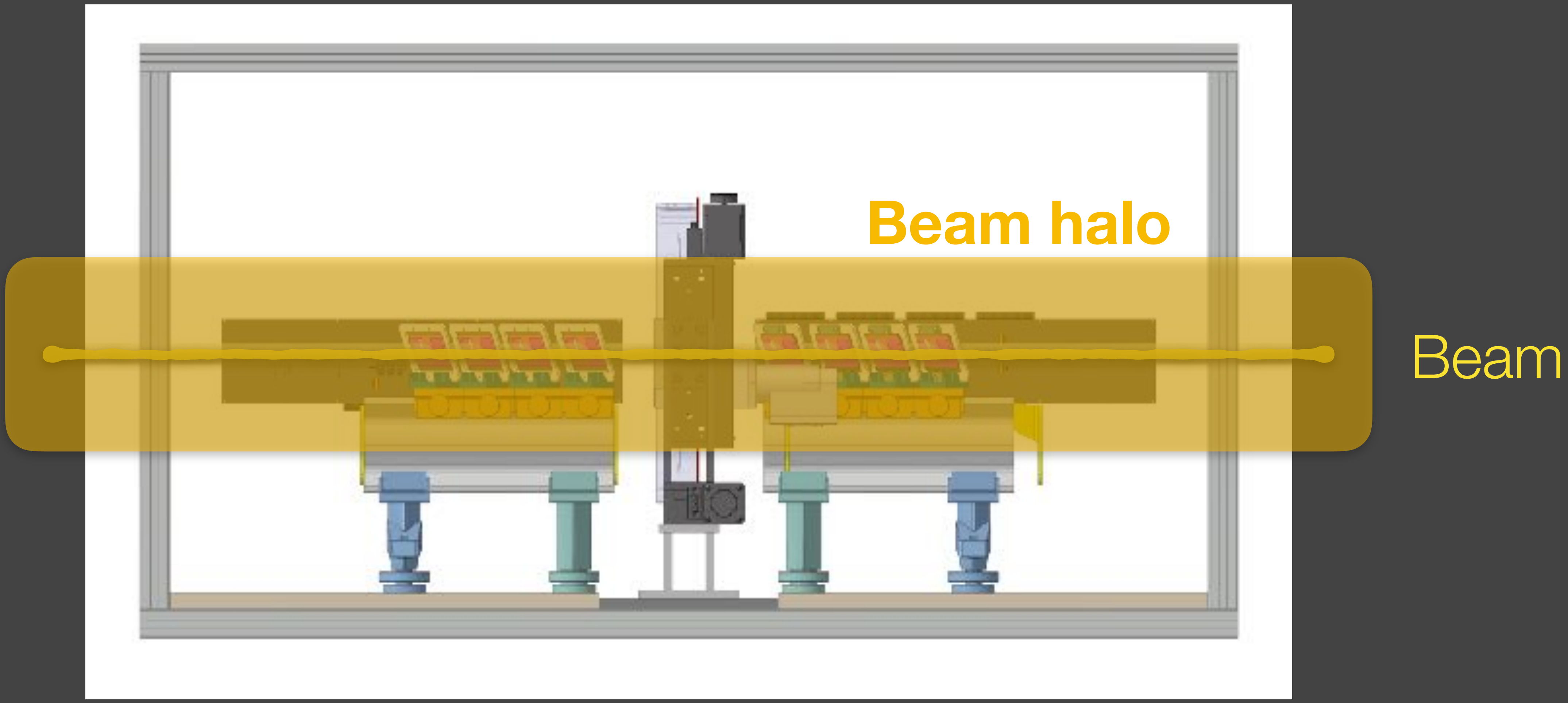

Summary

- A new CMS pixel telescope will be build in the first quarter of 2018:
  - ✓ Eight telescope planes in total;
  - ✓ Active area of 21 cm2;
  - ✓ Resolution expected to be better than 14 μm;
  - ✓ Can take particle rates of ~200 MHz/cm^{2}.

- The design phase is almost completed:
  - Last bit of the electronics design is the auxiliary electronics board, expected to be finished in January;
  - Mechanical design will be complete once a solution has been found to hold the modules in place.

- First steps towards customizing the Pixel Online Software have been made, modeling of the telescope has also recently started.

- Simulation campaign started with implementing the geometry of the telescope, Fluka simulations will follow later.

Back-up slides

Comparing telescopes with particle rates