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The development of the STRASSE silicon tracking system and the liquid hydrogen target

Mădălina Enciu

and on behalf of **Alexandra Stefănescu**

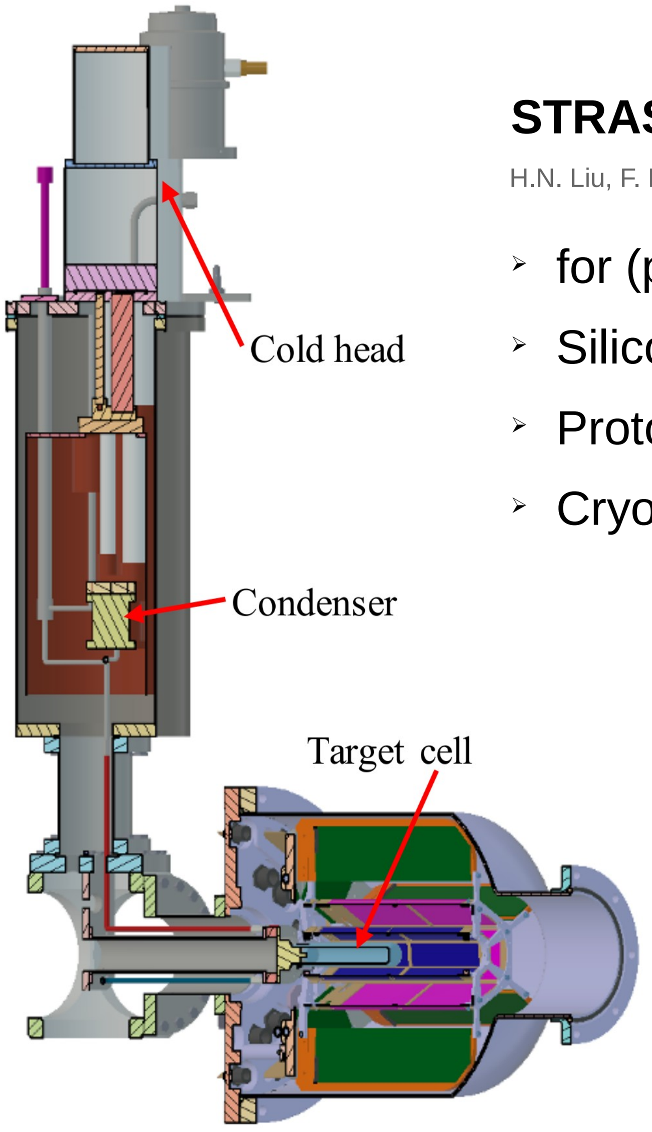
IKP, TU Darmstadt

SAMURAI International Workshop

Daejeon, Korea, July 14th - 16th 2024

SFB 1245

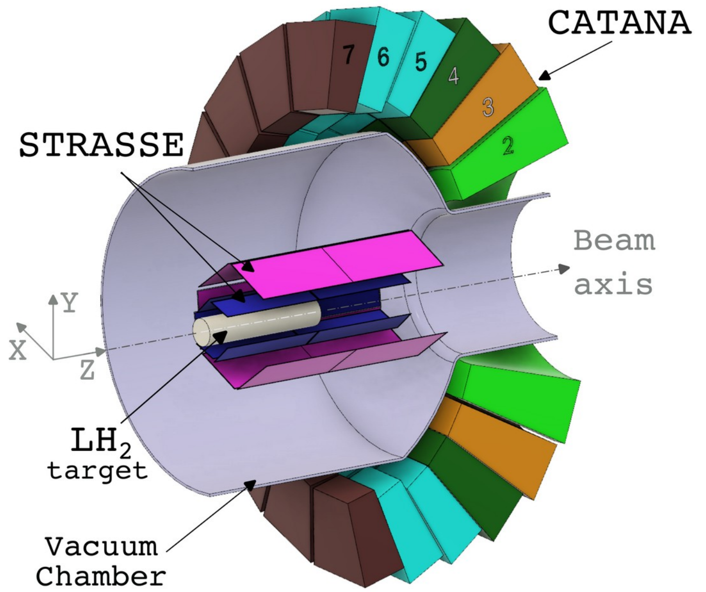
STRASSE: General overview



STRASSE: (**S**ilicon **TRA**cker for **S**pectroscopy at **SA**MURAI **E**xperiments)

H.N. Liu, F. Flavigny, The European Physical Journal A 59, 121 (2023)

- for (p,2p) and (p,3p) reactions at RIKEN in Japan compatible with CATANA+
- Silicon tracker (two layers of DSSSDs)
- Prototype: PFAD
- Cryogenic liquid hydrogen target



STRASSE Collaboration

TU Darmstadt (Germany): A. Obertelli, U. Bonnes, M. Enciu, A. Enciu, A. Frotscher (now BNL, USA), E. Plastinin, A. Stefanescu, C. Xanthopoulou

Beijing Normal University (China): H. Liu

LPC (France): F. Flavigny, D. Goupillère, A. Matta

TiTech (Japan): K. Horikawa, K. Isobe, Y. Kondo, H. Lee, T. Matsui, T. Nakamura, Y. Satou

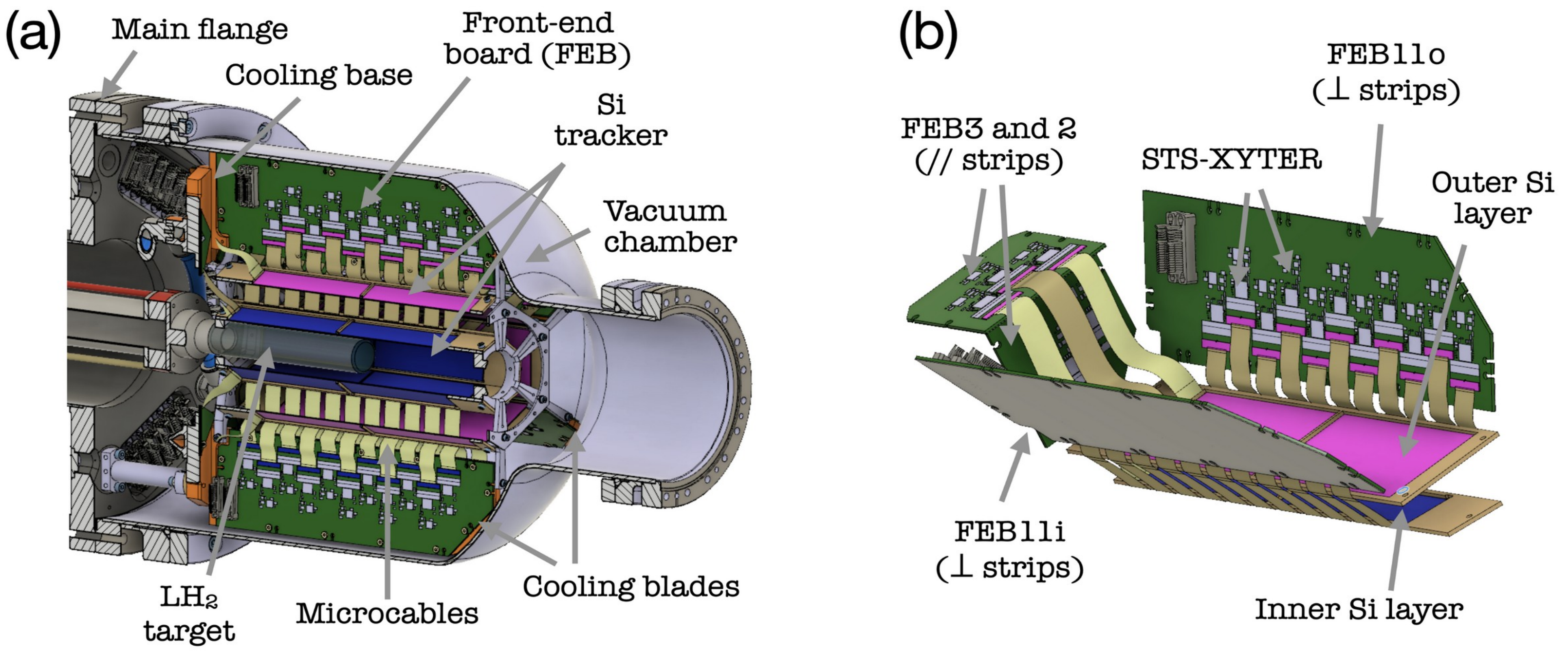
RIKEN (Japan): P. Doornenbal, T. Isobe, H. Otsu, M. Sasano, J. Tanaka, Y. Togano, T. Uesaka, H. Wang

GSI (Germany): J. Heuser, R. Kapell, J. Lehnert, V. Panin, C. Schmidt, C. Simons

TU München (Germany): R. Gernhäuser, B. Michael

Rikkyo university (Japan): S. Takeshige

Silicon Tracker: Characteristics



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Outer DSSSD:

Thickness: 300 µm

Active area: 121 x 62.6 mm

Strip number: 605 + 315 strips

Strip pitch: 200 µm

Inter-strip separation: 100 µm

Inner DSSSD:

Thickness: 200 µm

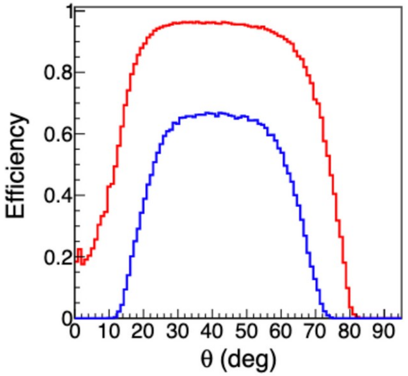
Active area: 122 x 30 mm

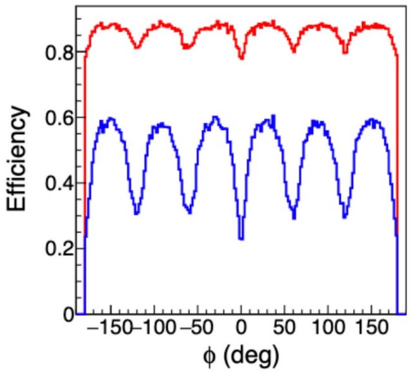
Strip number: 610 + 150 strips

Strip pitch: 200 µm

Inter-strip separation: 100 µm

Silicon Tracker: Characteristics





- Efficiency: 85% (1p), 49% (2p) in (p,2p)
- Missing mass resolution: 1.7 MeV
- Vertex resolution < 1mm

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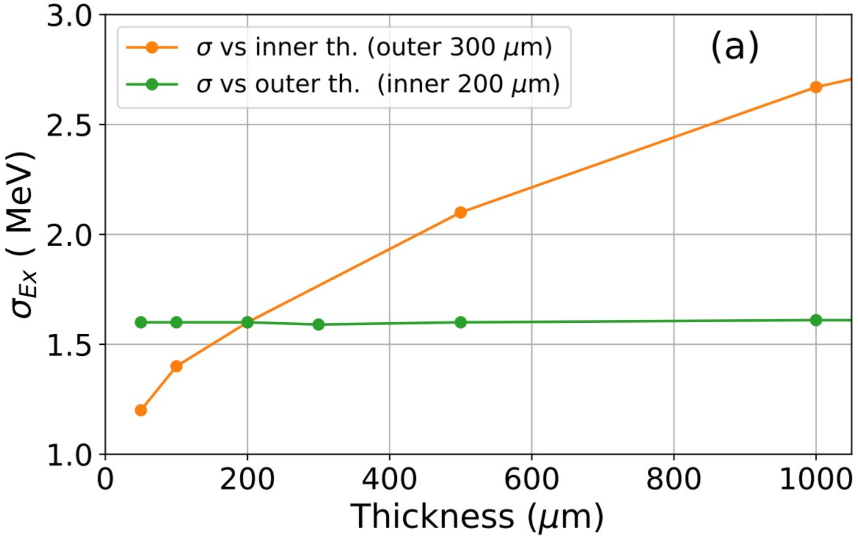

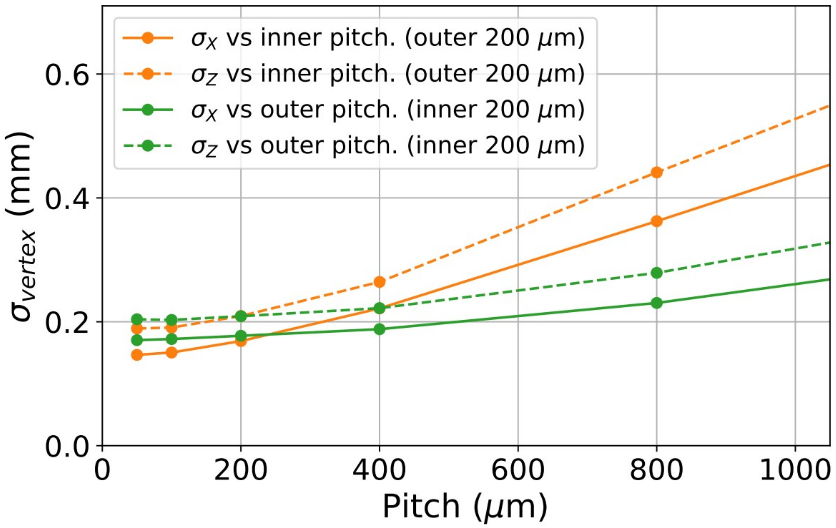

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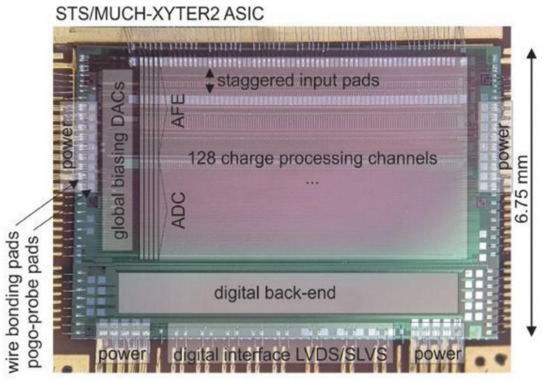
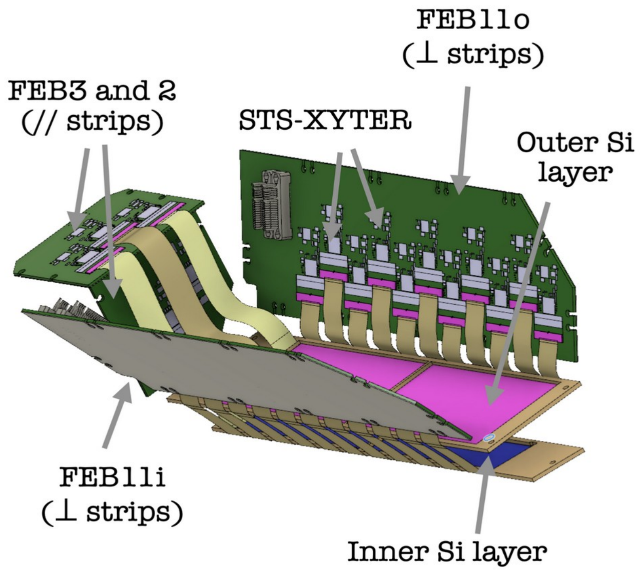
Silicon Tracker: Electronic Readout

XYTER chip 2.2
- Chip developed for STS, CBM, FAIR
- 128 channels / chip
- 8 ns deadtime / channel
- 14-bit time measurement
- 5-bit amplitude measurement
- No self-triggering → Continuous readout
- ENC: 550e$^-$ + 45e$^-$/pF





One segment (1/6) of STRASSE Si tracker

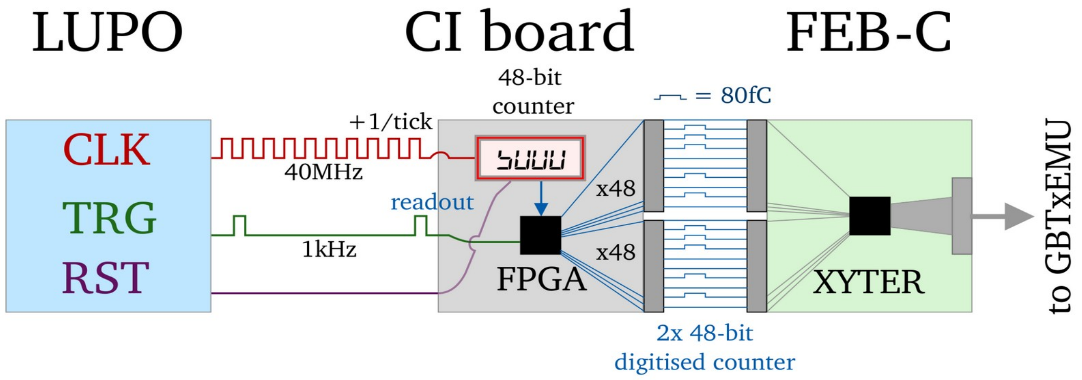
→ 1x FEB2 (with 2 ASICs)

→ 1x FEB3 (with 3 ASICs)

→ 1x FEB11i (with 11 ASICs)

→ 1x FEB11o (with 11 ASICs)

RIBF trigger integration method:



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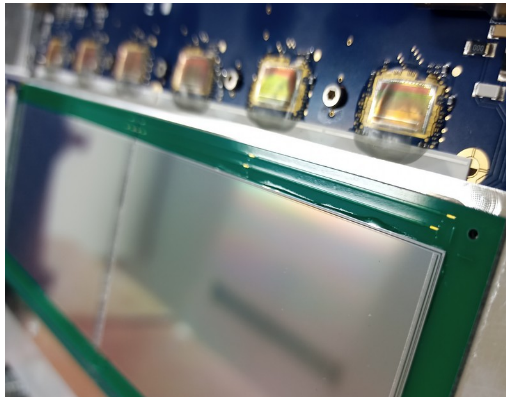
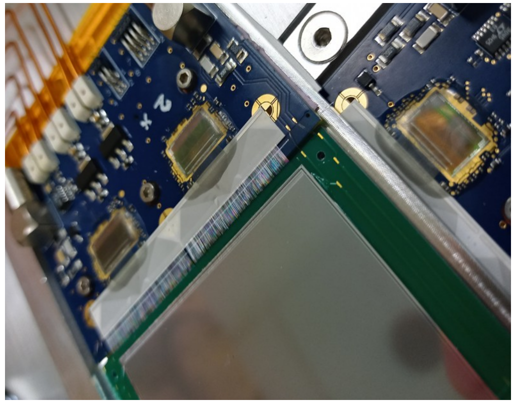
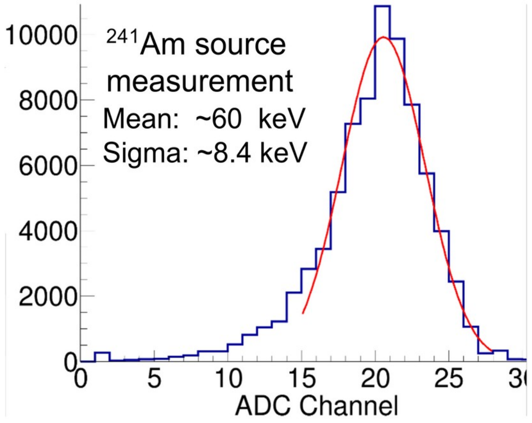
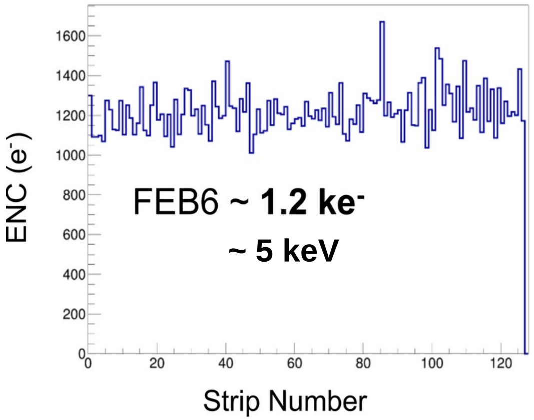
PFAD (Prototype): Silicon Tracker

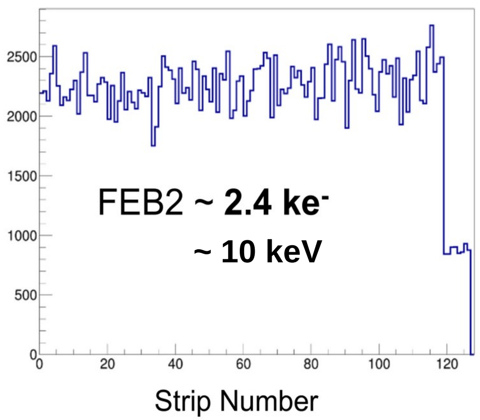
PFAD → 1/3 of the STRASSE Si tracker
- same front-end XYTER chips
- same back-end readout electronics











SSDs:
- thickness: 100 μm
- active area: ~16cm x ~5cm
- strip number:
248 parallel strips
768 perpendicular strips
- pitch size: 100 μm

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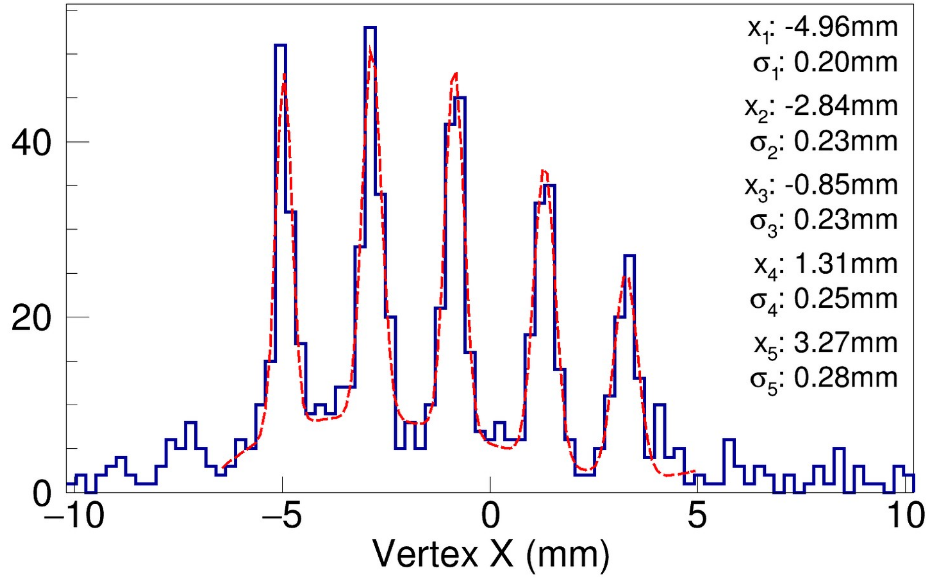
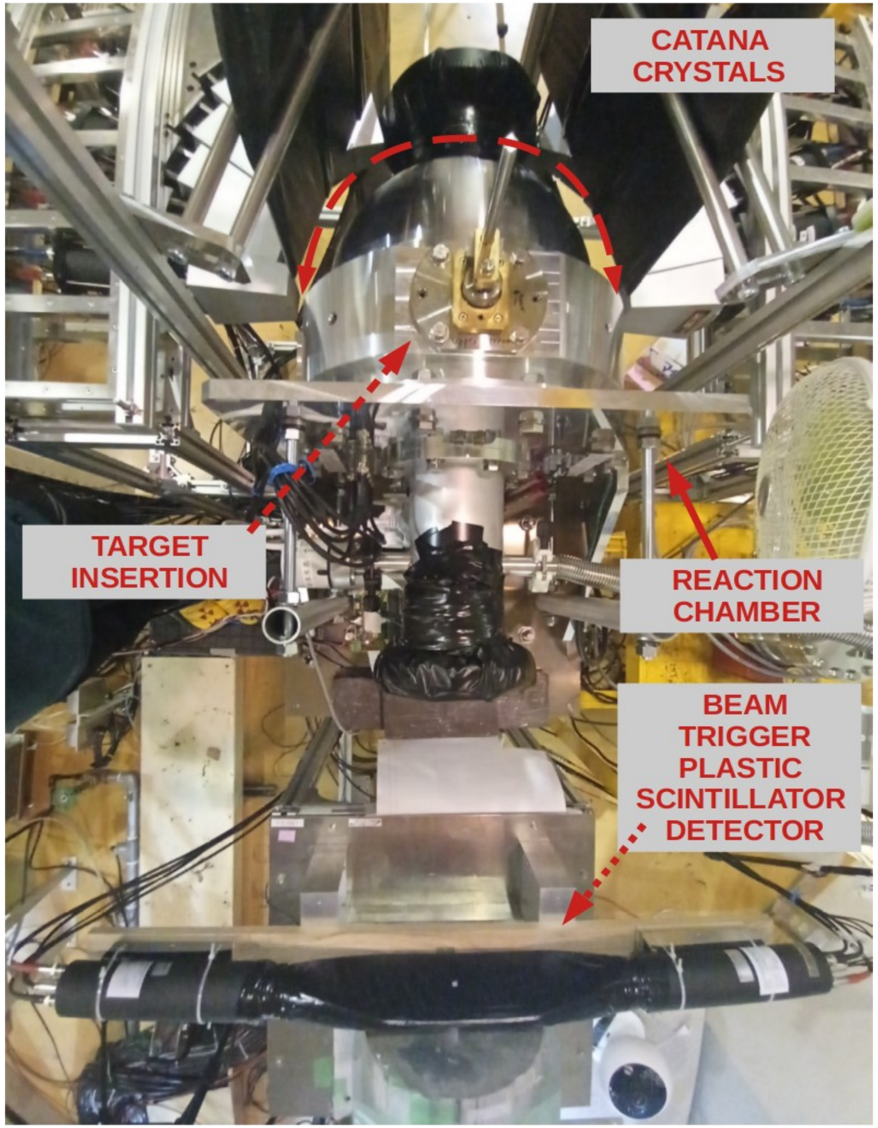
PFAD (Prototype): Commissioning at HIMAC

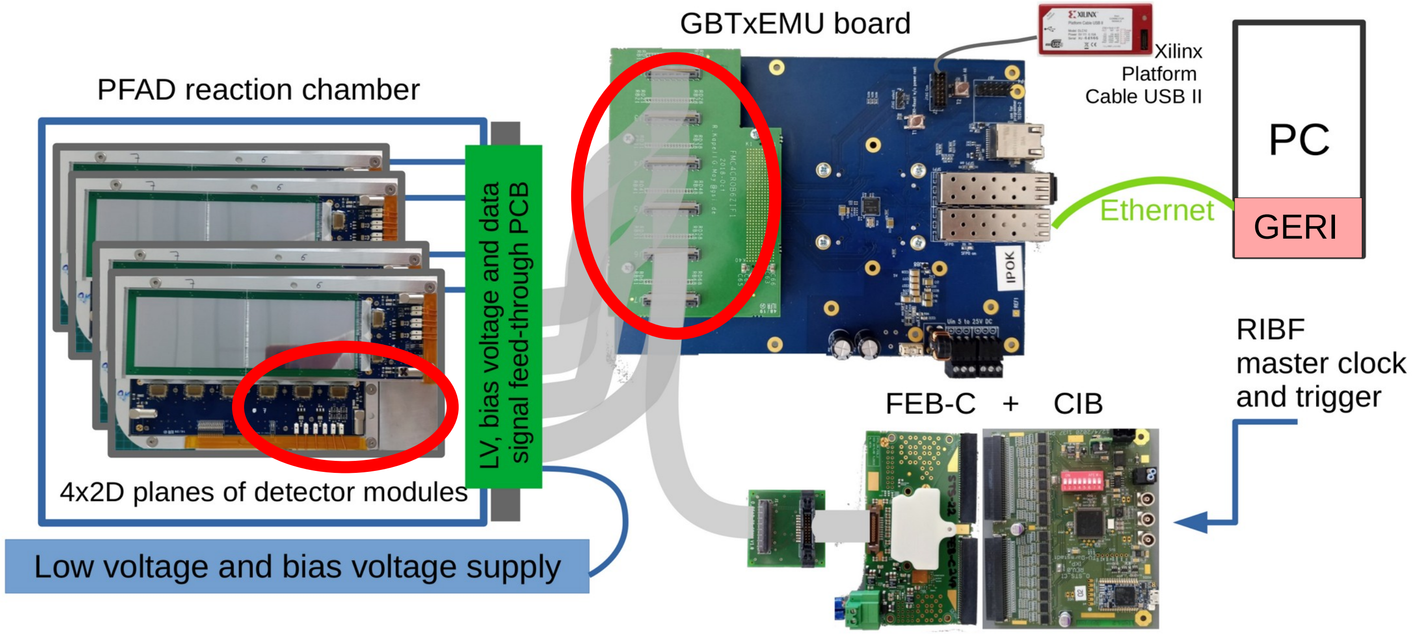
First test experiment at HIMAC:
- Commissioning of PFAD (9-11 May, 2022)
- proton beam @110MeV and 230MeV
- on CH_2 target (1 mm + 0.1 mm + XY wires)
- PFAD + part of CATANA
- sub-mm vertex reconstruction resolution





Ongoing analysis by Matsui-san (TiTech)

PFAD Electronics Upgrade with GERI board



Major upgrade:

- GERI board for faster data readout
- Developed by W. Zabolotny (Warsaw University of Technology)
- Data rate with IPbus: 0.5 Gbit/s
- Data rate with GERI: 7.8 Gbyte/s

➢ New data acquisition software with GERI (W. Zabolotny, A. Enciu, T. Isobe)

Other minor improvements:

- Change of the mezzanine boards
- Clock signal routing for FEB2 and FEB6 from the mezzanine board
- Change of connectors and cables for improving the signal quality
- Cooling and grounding improved

  (U. Bonnes, A. Enciu, A. Stefanescu)

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STRASSE/PFAD Data structure

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The XYTER chip provides:

- 14-bit timestamp
- 5-bit ADC (energy)
- 7-bit channel identifier
- 8-bit identifier of the ASIC + GBTxEMU provided by the GERI board

LSB = 6.25ns @ 80MHz
TSMSB<8> changes every 1600ns
Full TS cycle = 100.4 μs
Maximum hit rate:
5.3 Mhit/s per ASIC uplink

Timestamp bits:

13	12	11	10	9	8	7	6	5	4	3	2	1	0

Types of data frames (24-bit) received from the ASICs:

- **Hit frame** 7-bit channel address + 5-bit ADC + timestamp <7:0> + timestamp (overlap) <9:8>
- **TSMSB frame** timestamp <13:8> x 3 copies
- Dummy hits
- Other types of frames

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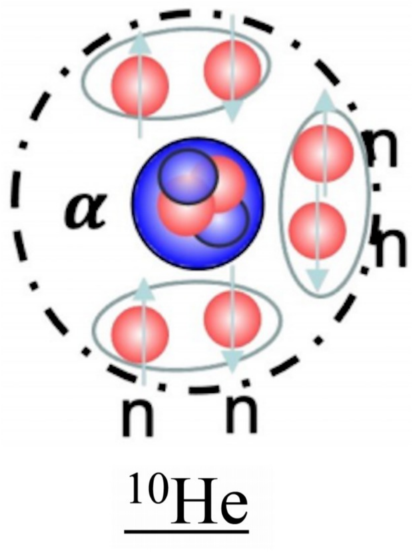
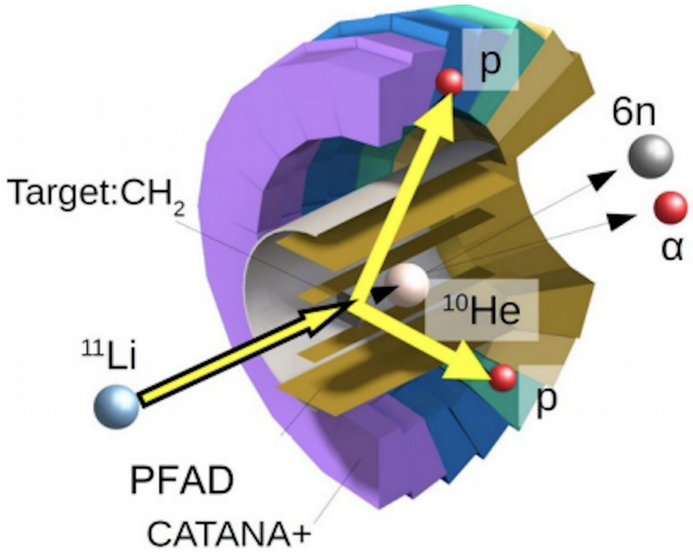
PFAD (Prototype): first RIKEN experiment

Study of multi-neutron configurations in ^{10}He via **^{11}Li(p,2p)^{10}He**

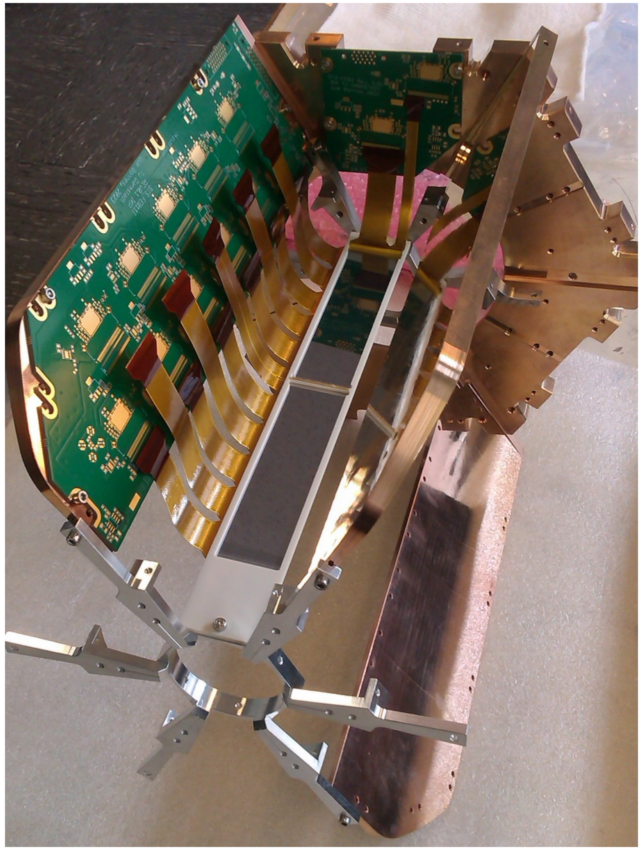
Spokesperson: T. Nakamura

- PFAD ran reliably during the beam time
- a few hours of instability of the PFAD DAQ server
- Energy thresholds: FEB2 80keV and FEB6 40keV
- Energy range up to ~300keV
- 2x FEBC+CIB for the RIBF trigger integration



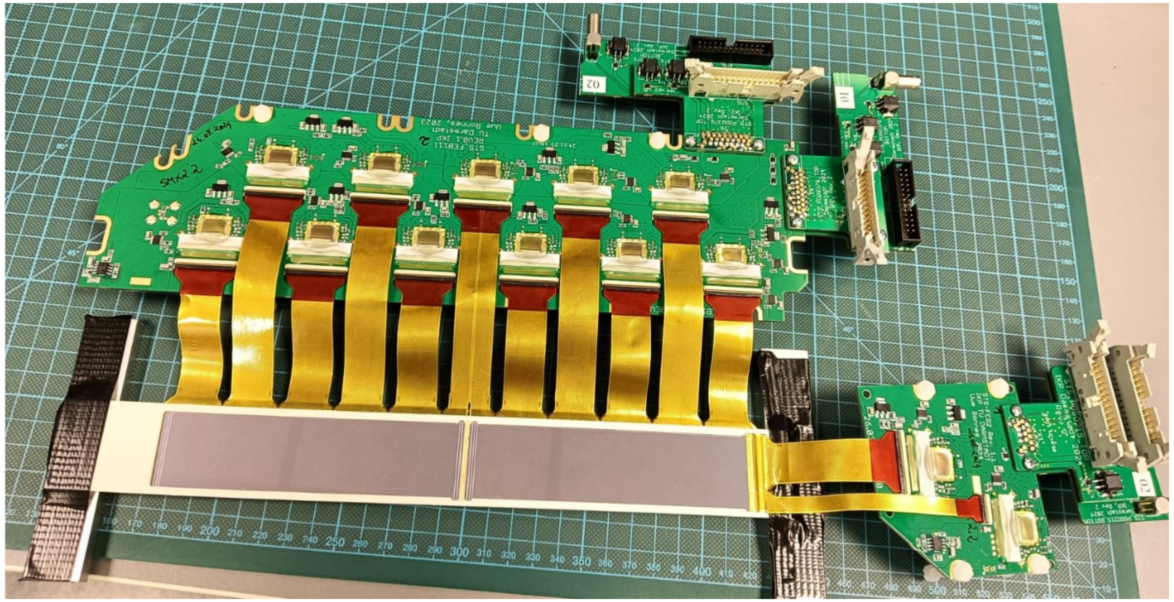


Silicon Tracker: Status – First STRASSE module

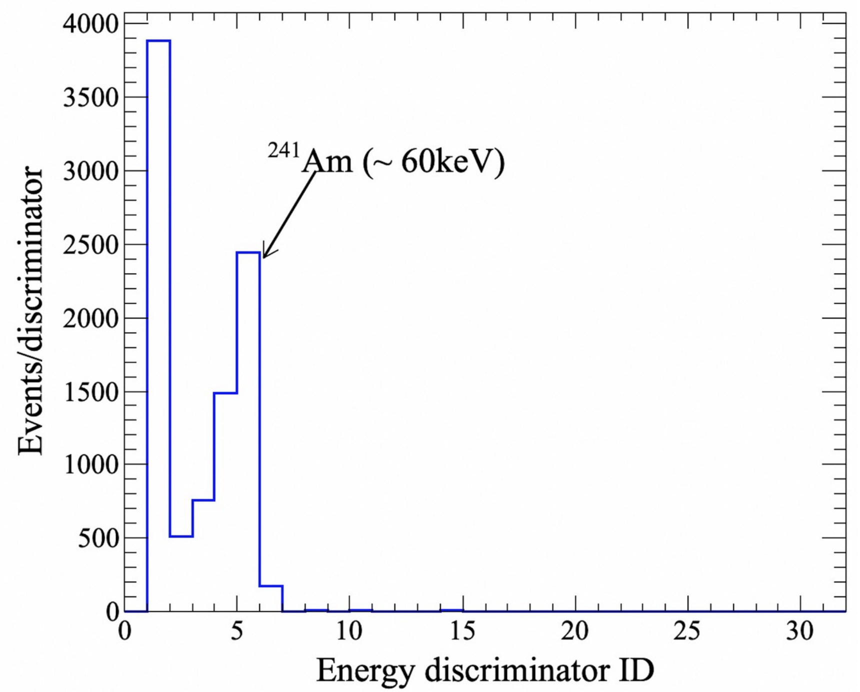


One (inner) segment of STRASSE
mounted on the mechanical support (LPC Caen)

- First segment of STRASSE fully equipped with FEBs, ASICs, Microcables and silicon sensors is being tested in lab (TU Darmstadt, A. Stefanescu, E. Plastinin)



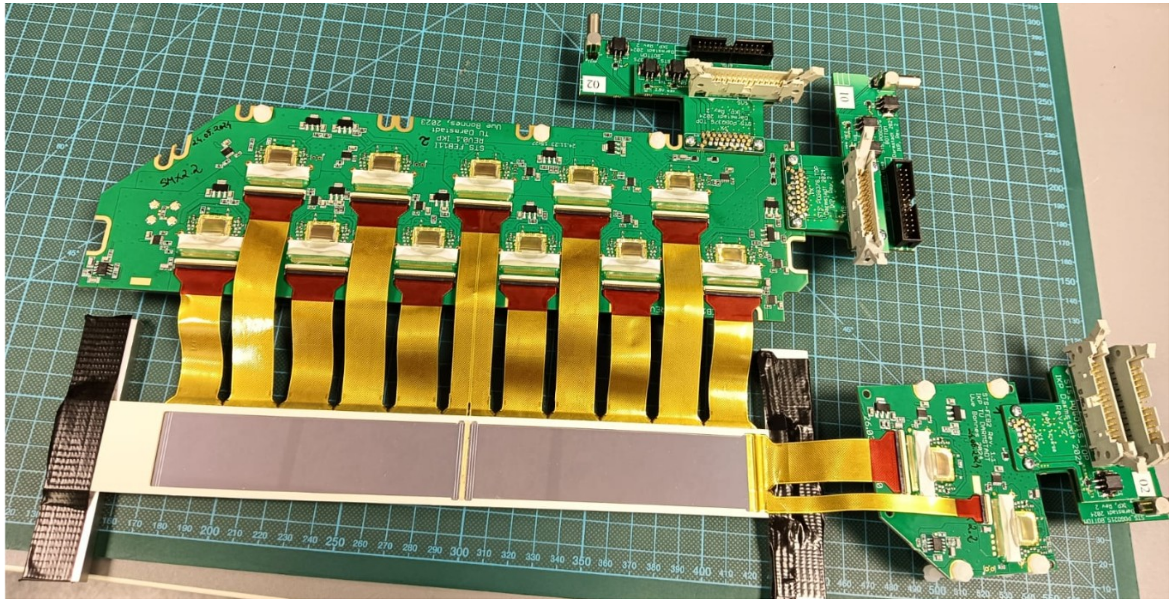
Silicon Tracker: Status – First STRASSE module



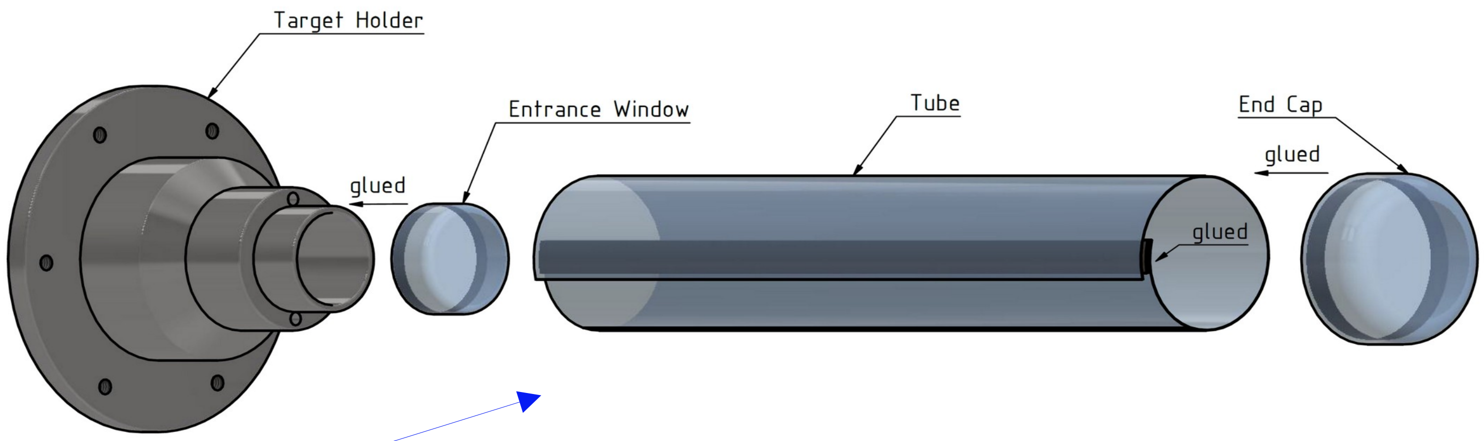
- Energy spectrum of ^{241}Am (~60keV)
- Electronic noise evaluated:

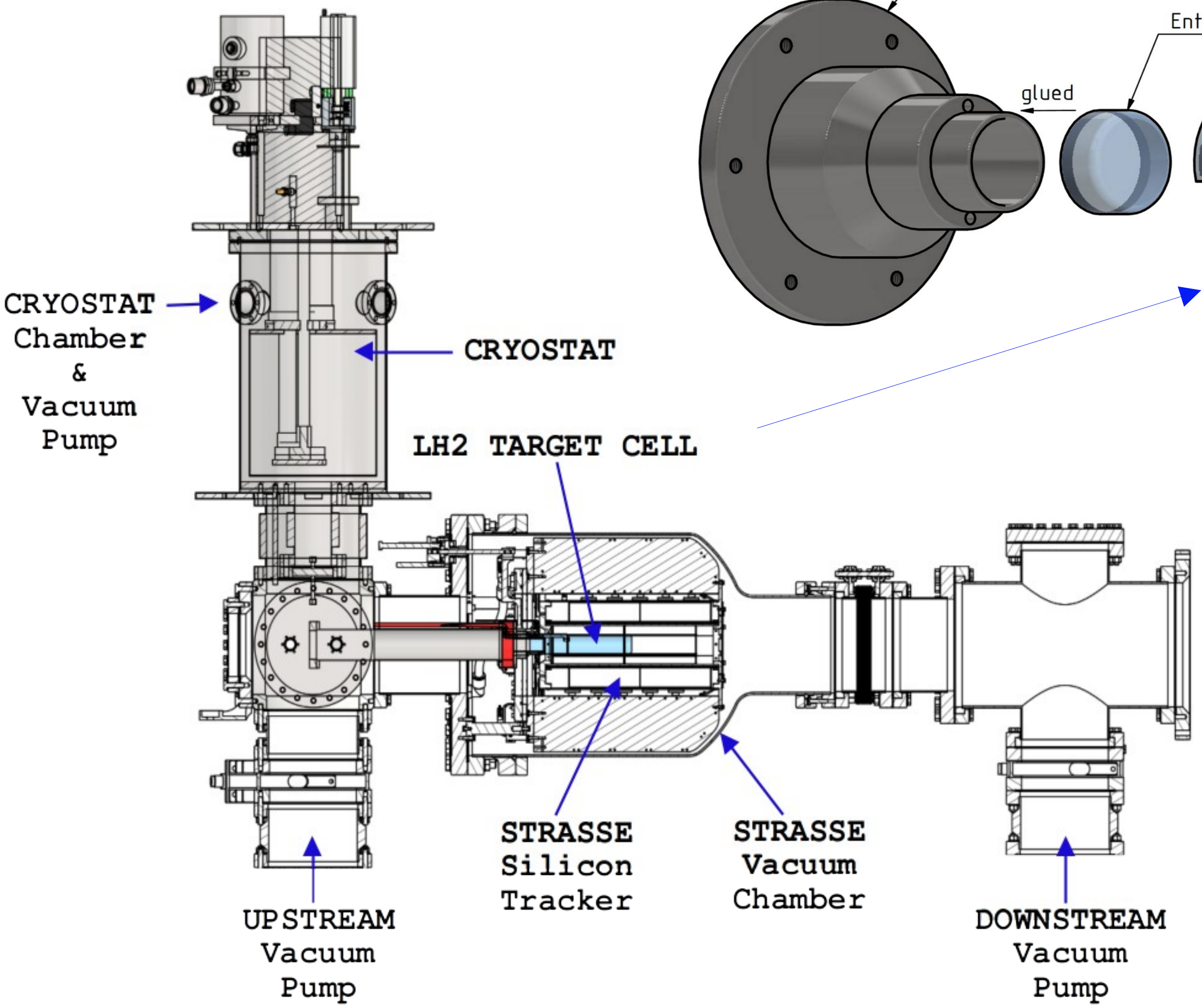
ENC (FEB11i): ~ 800 e$^-$

- First segment of STRASSE fully equipped with FEBs, ASICs, Microcables and silicon sensors is being tested in lab (TU Darmstadt, A. Stefanescu, E. Plastinin)



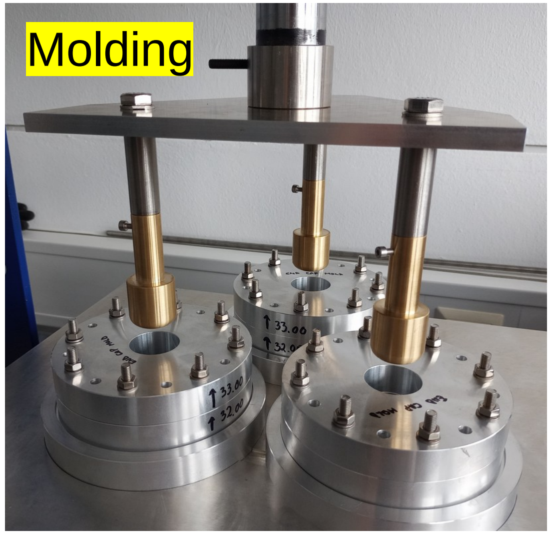
Liquid hydrogen target

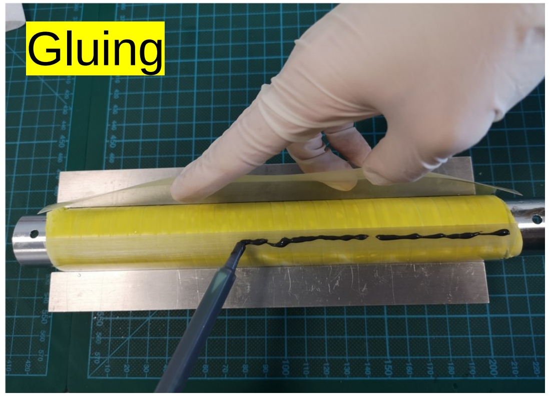




- Liquid hydrogen target for proton-induced reactions
- Target cell made out of Mylar (170 um thickness)
- 150mm effective length and 31mm diameter
- Operated below 20K with liquid hydrogen
- Cryostat made by **Cryo.TransMIT**
- Target Cell made at **IKP, TUDa**
- Gas system to be built at **CERN**

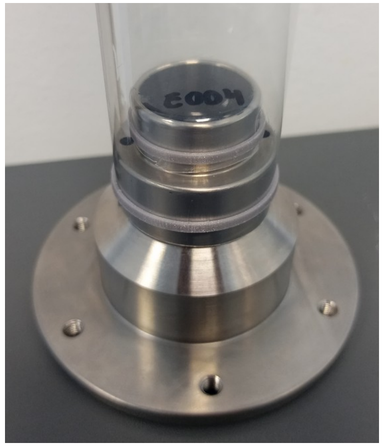
Target cell production

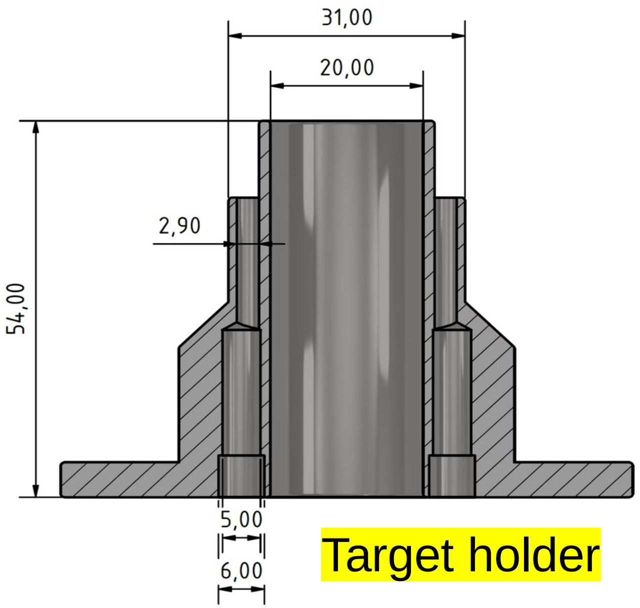


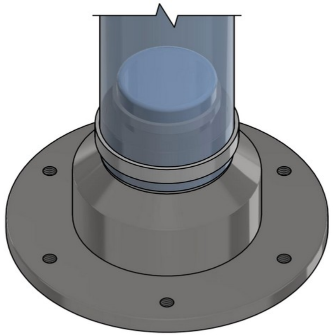


Production of the target cells at TUDa:

- Target cell made out of Mylar
  - 150mm effective length
  - 31mm diameter
  - 170um (+/- 12um) thickness
- Thermoformed and glued (structural epoxy)
  - breaking pressure > 11bars







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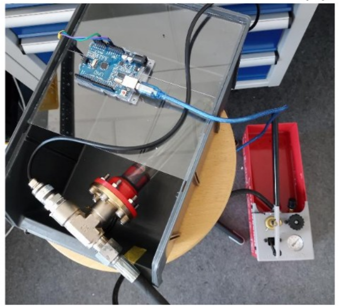
Target cell testing

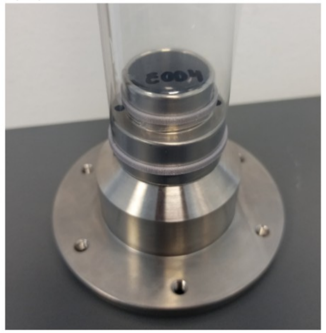
(a)

(b)

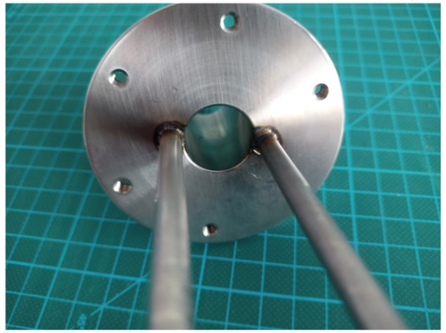
(c)



(d)



(e)



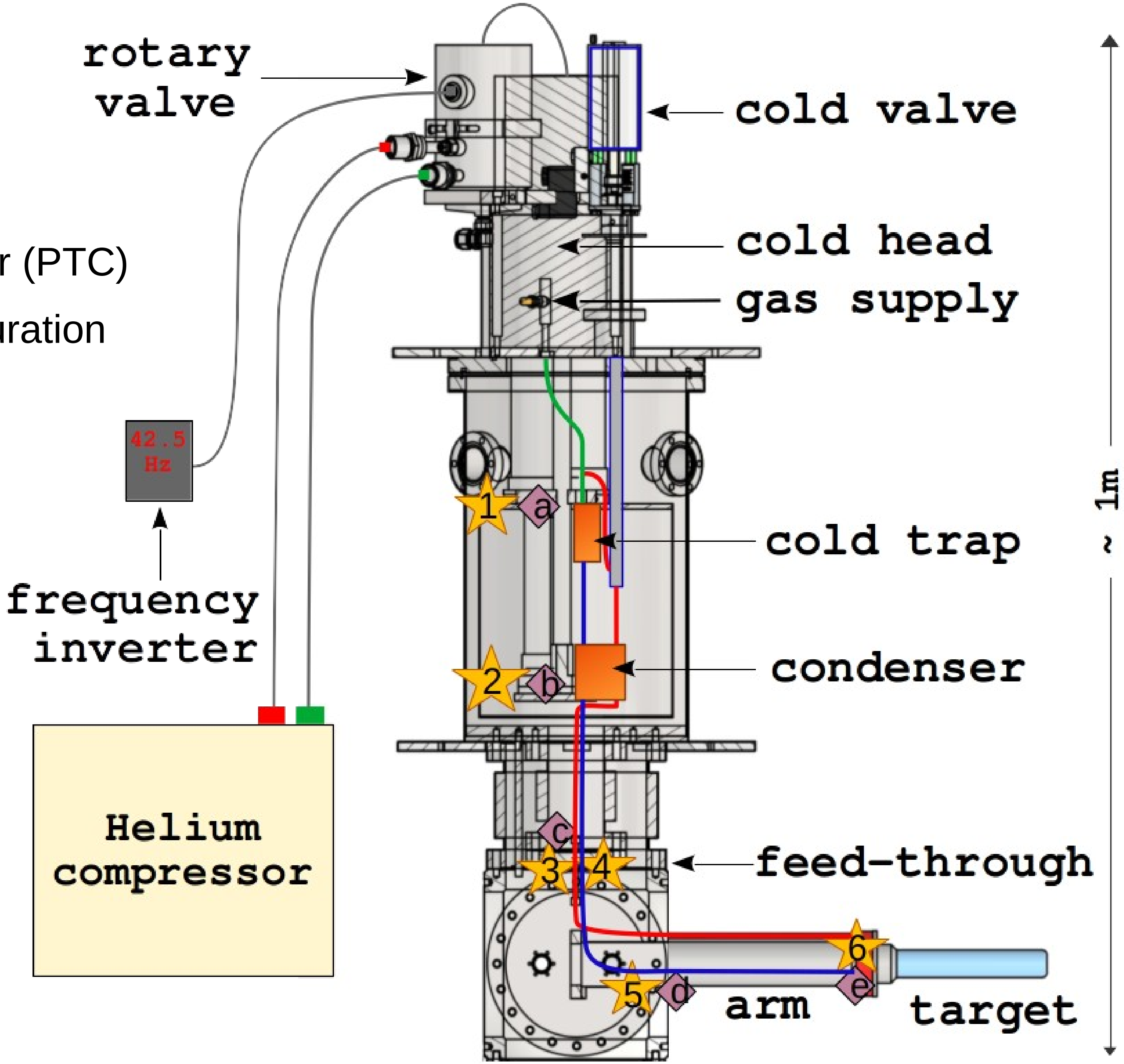
The following tests were performed:

- High pressure test with water at room temperature
  - Several targets were tested
  - Breaking pressure >11bar (consistently)
- Robustness test after several cycles of submerging in LN_2 (Thermal shock)
  - Water test to withstand 8 bar for benchmarking before cooling
  - 8bar-water test repeated after cooling cycles
- Breaking test with liquid nitrogen
  - Breaking pressure of 9 bar
  - Mylar became brittle → plastic expansion of the material
- Target cell used with liquid hydrogen

Work done together with
my colleague Christina Xanthopoulou

Cryostat

- GM-type pulse tube cryocooler (PTC)
- Rotary valve in remote configuration
- Thermosiphon loop principle
- 1st cold stage 46K
- 2nd cold stage 6K
- LH2 @ 14-20K
- Working pressure < 1bar



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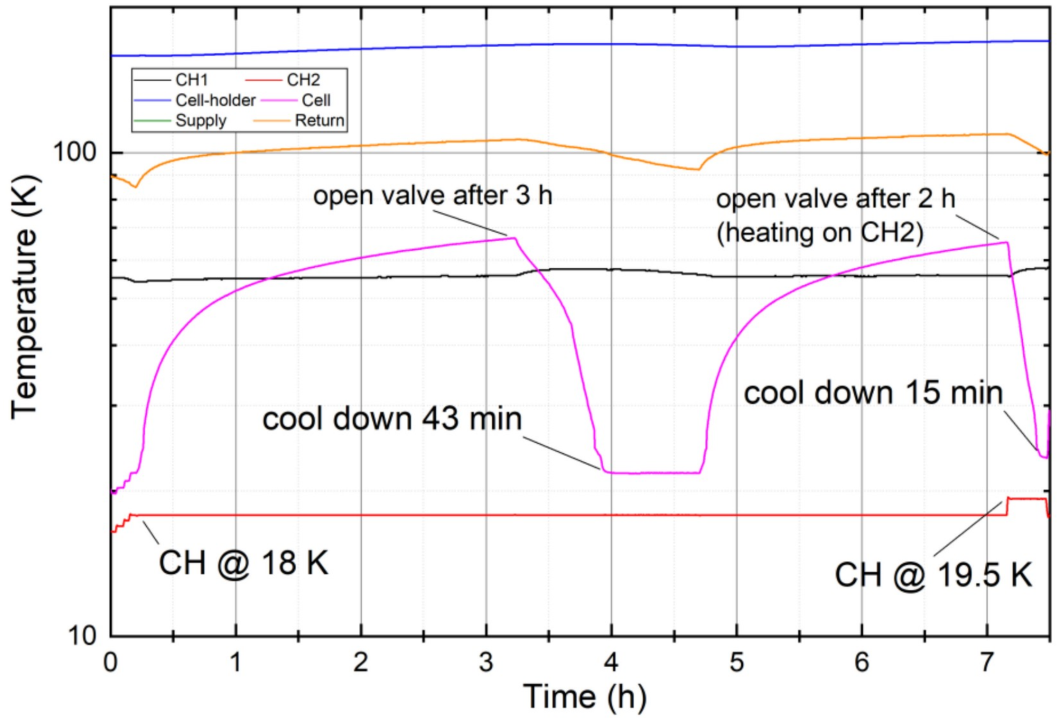
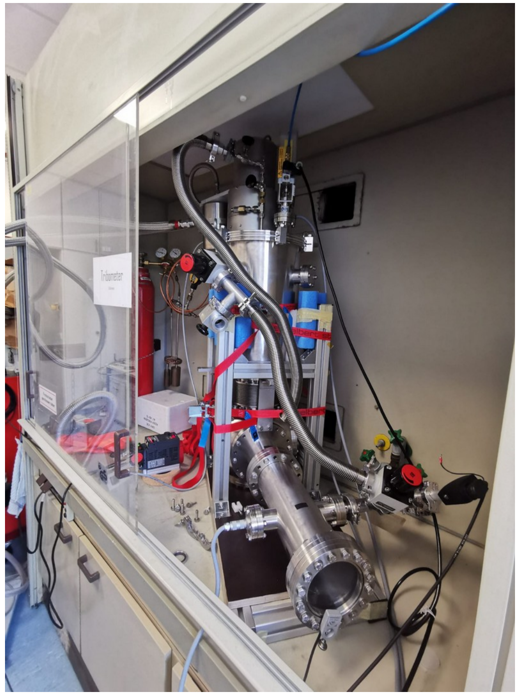
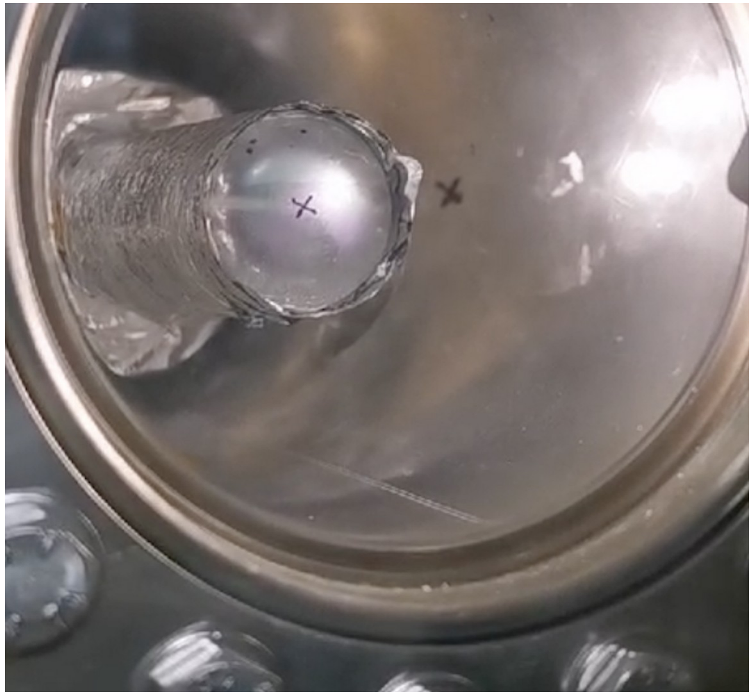
Cryostat







- Built by CryoTrans.MIT (Gießen)
- Ready and operated in June 2023
- Initial **cool-down in less than 12h** and **empty target** feature with **re-cooling in less than 1h**
- Training and instruction for operation November 2023
- Optimization and establishing operation procedures on the final setup ongoing (at GSI)

Liquid hydrogen target: Status

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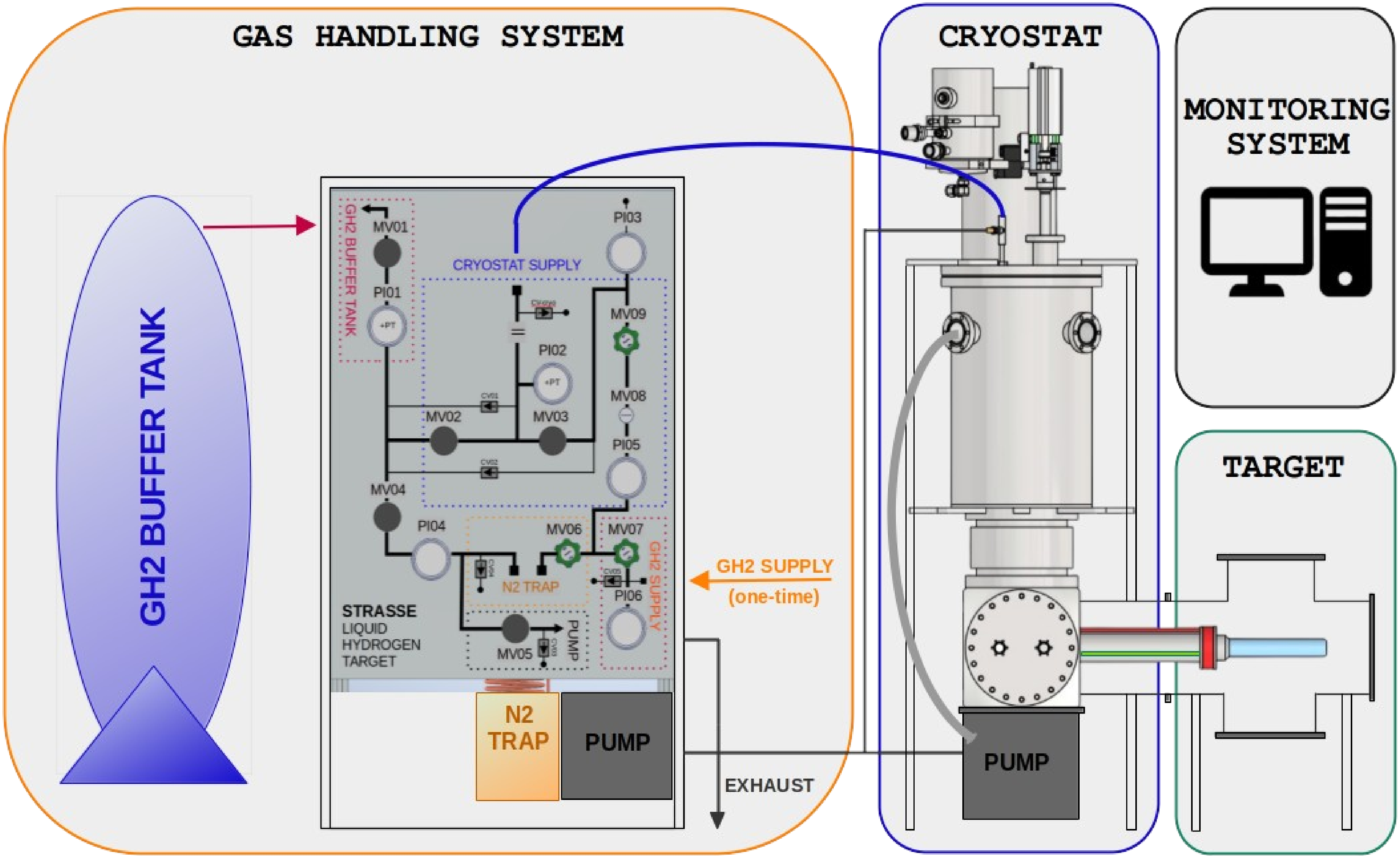

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Liquid hydrogen target: Status

- LH2 target system being tested (until Oct2024)
- Establish operation procedure
- Explore parameters for optimal operation

Work done together with my colleague Christina Xanthopoulou

Approved experiments with STRASSE

- **SAMURAI65 experiment: ^{56}Ti(p, 3p)^{54}Ca**

  Search for excited 0+ state in 54Ca

  Spokesperson: H. Liu

- **SAMURAI69 experiment: ^{A}O(p,2p)$^{A-1}$N**

  Momentum distribution of deeply-bound nucleons in $^{14-23}$O via (p,2p)

  Spokesperson: A. Obertelli

- **SAMURAI75 experiment: $^{10-20}$C(p,pn) and $^{40-52}$Ca(p,pn)**

  Study of neutron single-particle states in neutron-rich nuclei

  Spokesperson: Y. Matsuda and T. Nakamura

Overview and timeline of STRASSE

STRASSE: silicon tracking system and liquid hydrogen target

- Prototype silicon tracker, PFAD, built and commissioned (May 2022)
- Electronic readout upgrade
- PFAD for the ^{11}Li(p,2p) experiment SAMURAI47 (March 2024)
- First segment of STRASSE ready and tested in lab
- Mechanical check of the first segment of STRASSE
- **Silicon tracker ready for experiments in spring 2025**
- For the LH2 target, the cells produced and tested at TU Darmstadt
- The cryostat, made by Cryo.TransMIT ready in June 2023
- Full LH2 target system is tested at GSI until October 2024
- **LH2 target ready for experiments in winter 2024**