R&D towards an atomic hydrogen source for future neutrino mass experiments


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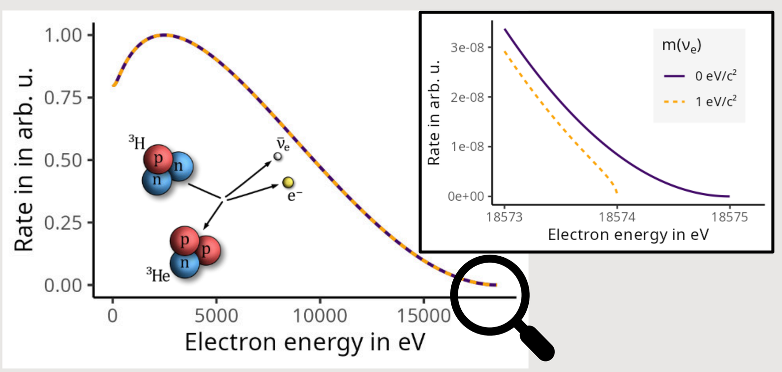
KATRIN++

- Next generation direct neutrino mass experiment
- Use KATRIN/TLK infrastructure for R&D phase (about 7 years) to identify and develop scalable technology

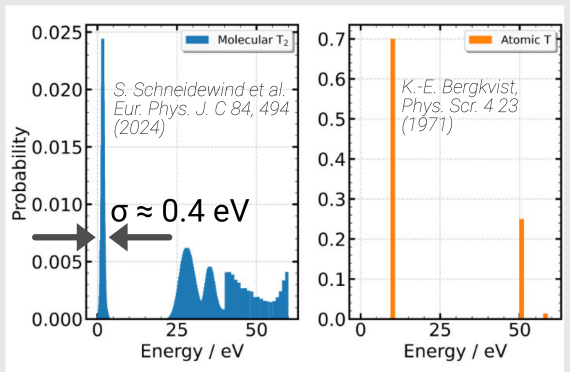
See poster #558!

KATRIN beamline

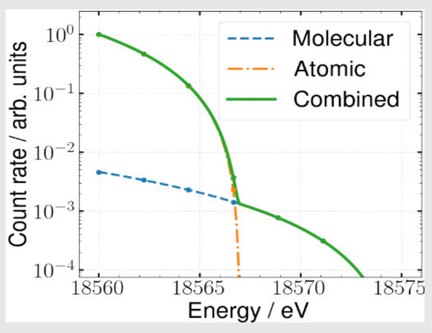
Goal: Generate mK-cold tritium atoms as beta-decay source for future neutrino mass experiments to avoid limiting systematic effects from molecular tritium.



Neutrino mass influences the beta-decay spectrum especially in the region of the endpoint



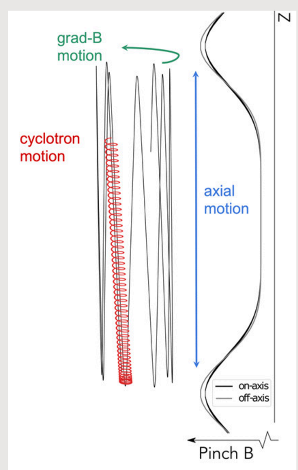
Final states of molecular and atomic tritium.



Effect of molecular background in an atomic tritium source

The Project 8 experiment

- Direct neutrino mass measurement, using atomic tritium source and cyclotron radiation emission spectroscopy (CRES).
- Neutrino mass sensitivity: 40 meV – probes inverted ordering!

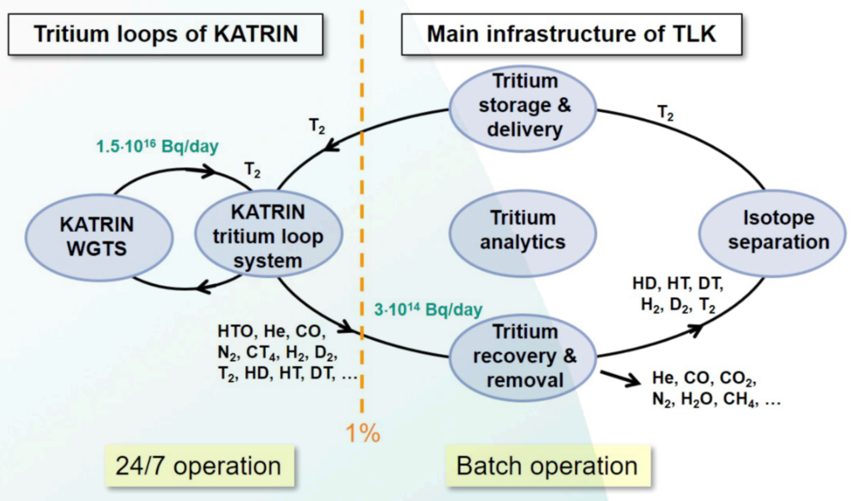


Tritium Laboratory Karlsruhe – TLK

- Licensed for 40 g tritium
- Two missions:
  - Fuel cycle for fusion reactors
  - KATRIN experiment
- 57 people including graduate/PhD students
- 2.2 M€/year base funding for operation
- 38 FTE base funding for personnel

View of the TLK

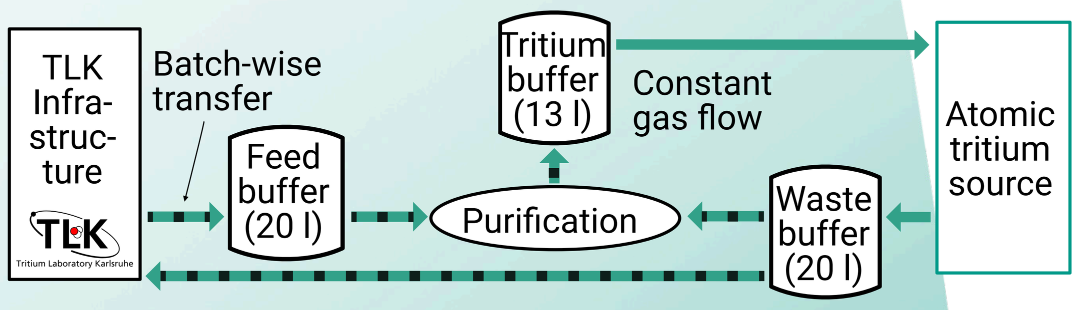
Successful operation of a large variety of experiments since 1993



Closed tritium cycle for recycling and purifying tritium in gram amounts

Tritium gas supply for atomic source

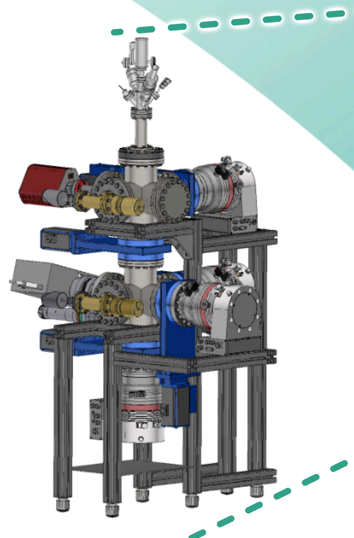
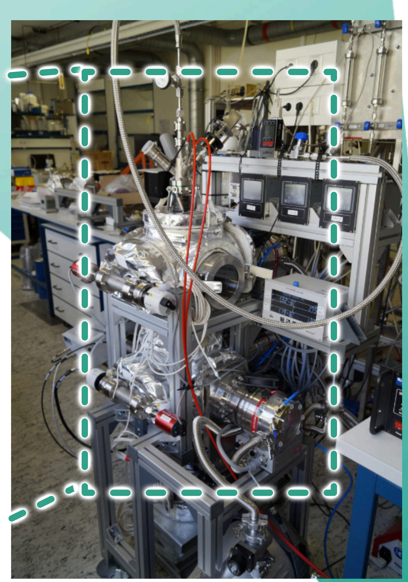
- Design adapted from the KATRIN tritium loop system.
- Throughput possible up to 20 sccm (20 % of KATRIN).
- In-loop regeneration of gas



Path towards first tritium atoms

Goal: Demonstrate tritium operation in *simple setup*.

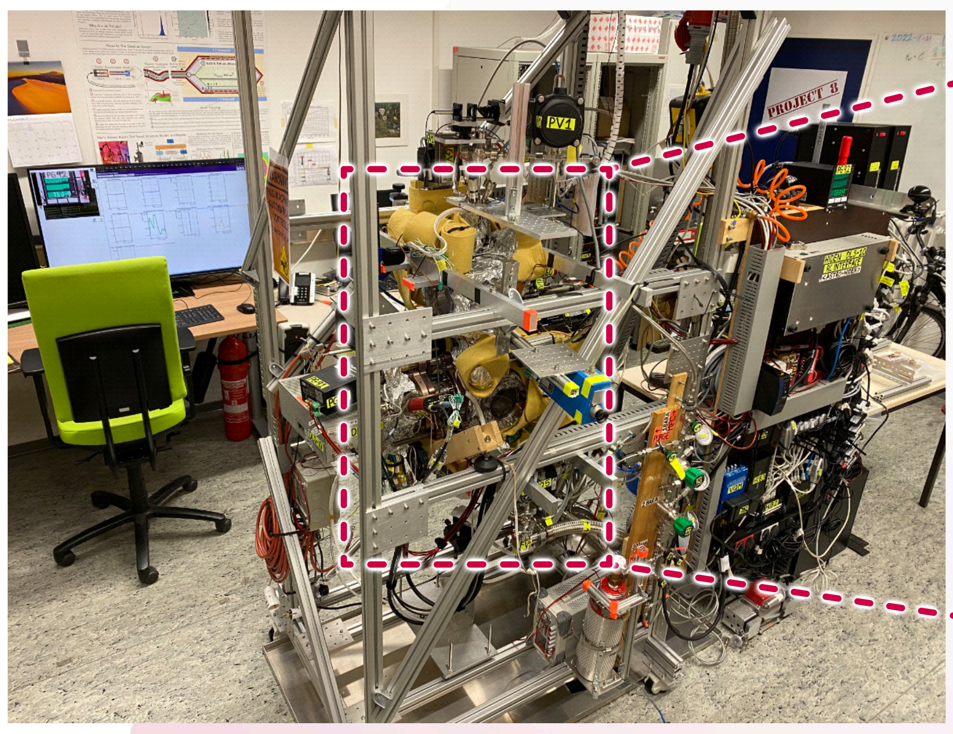
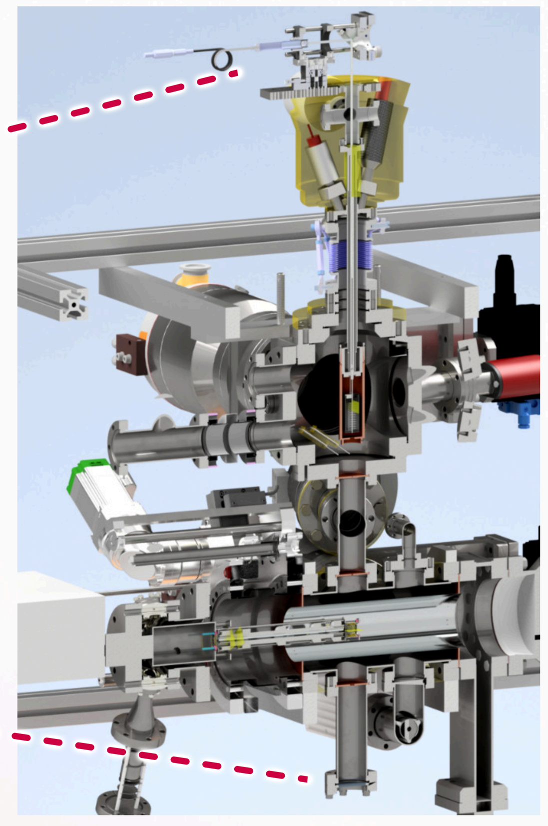
- Built setup with standard vacuum parts
- Use setup for investigating:
  - Tritium compatibility
  - Tritium recovery
  - Isotopic effects
- Determine atomic fraction by quadrupole mass spectrometer.
- Reduce detection of scattered particles with skimmers.

First tritium atoms expected in 2024!

Mainz Atomic Test Stand – MATS

Goal: Design and development of cold atomic hydrogen beam, with throughput 0.002 - 20 sccm.

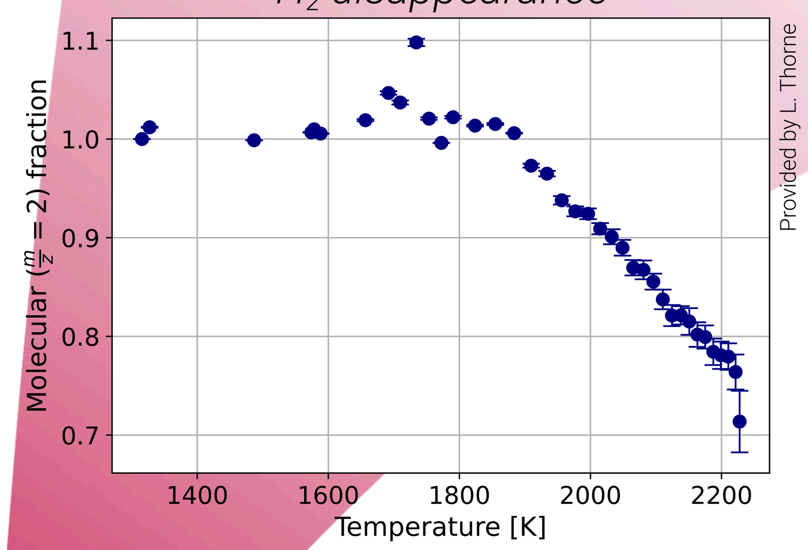
- **Current status**: Determine the efficiency of atom production at different flows.
- **Next step**: Atom beam cooling from 2500 K to 160 K, via cold surface collisions.

Diagnostic tool development

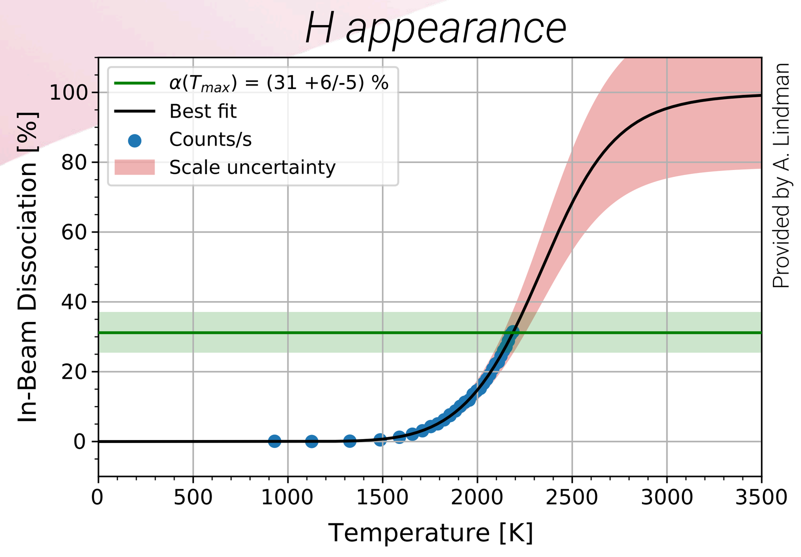
- Monitoring atomic fraction, beam shape and temperature.
- Setup and tools are tritium-compatible.

See poster #532!

H_2 disappearance



H appearance



- Atomic fraction estimation from mass spectrometer, using two complementary techniques: H appearance and H_2 disappearance.
- **Challenges**:
  1. Temperature range limits absolute scale estimation in H signal
  2. Detector efficiency estimation
  3. Equilibrium condition

KAMATE – Karlsruhe Mainz Tritium Experiment

K A M A T E

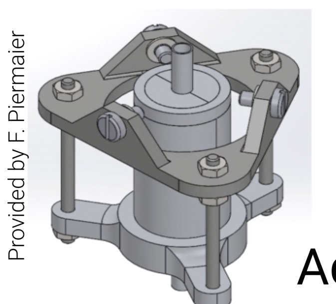
KAMATE 0.5:
Identify best source at MATS with inactive hydrogen: thermal dissociation vs. RF-discharge.

Tectra h-flux

SVT RF

MBE Komponenten HABS

KAMATE 1.0:
Operate KAMATE 0.5 setup at TLK with tritium.

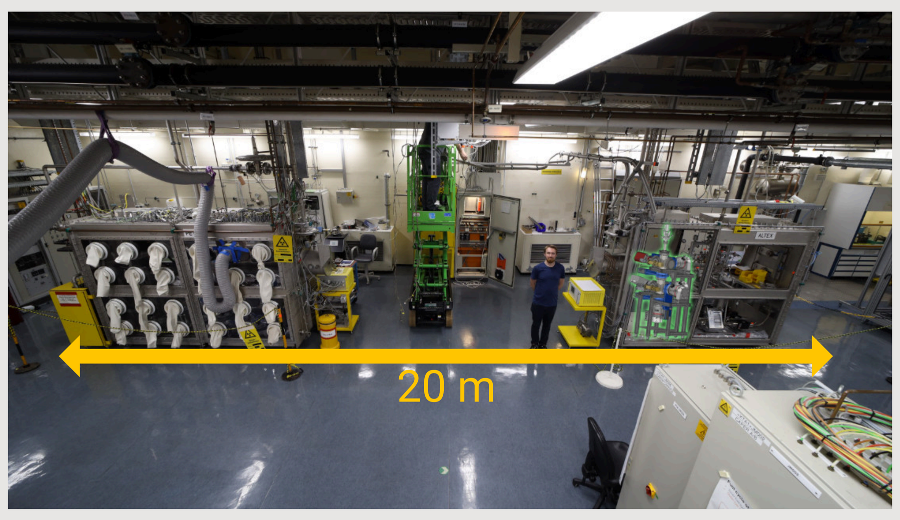


Accommodator

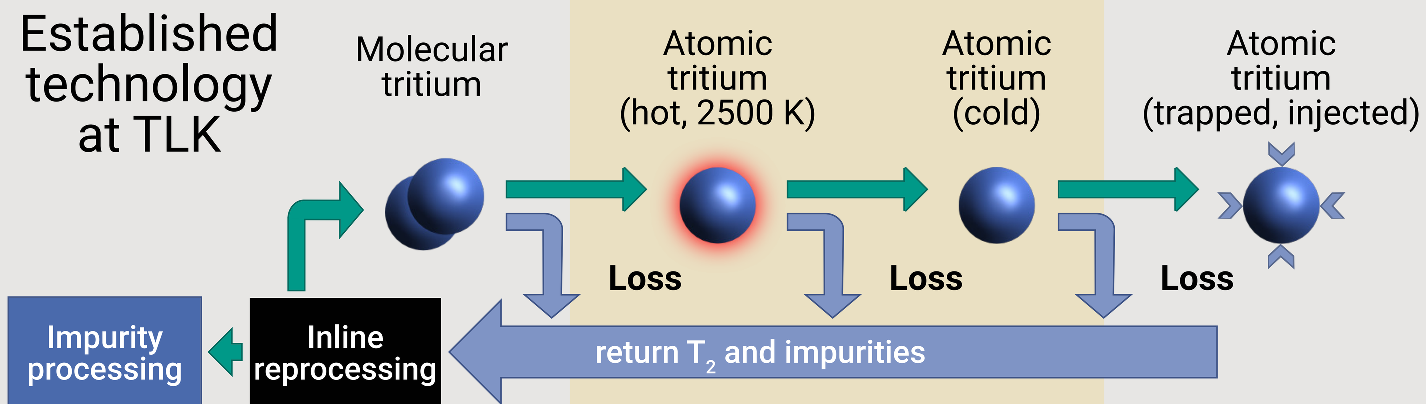
KAMATE 2.0:
Add accomodator as first stage cooling.

KAMATE 3.0:
Add nozzle for second stage cooling and beam temperature measurement setup (time of flight).

Next endeavor beyond KAMATE: Atomic Tritium Demonstrator – ATD



View into TLK – Allocated space for demonstrator



ATD joint working group

- *Mission:* Develop Atomic Tritium Demonstrator (at TLK). The ATD is key for future experiments, independent of detection techniques.
- *Challenges:* Cooling down to ≈ 10 mK and magnetic trapping of radioactive atoms.
- In the process of forming a joint working group with possible partners: KATRIN++, Project 8, QTNM, atom physics communities, …