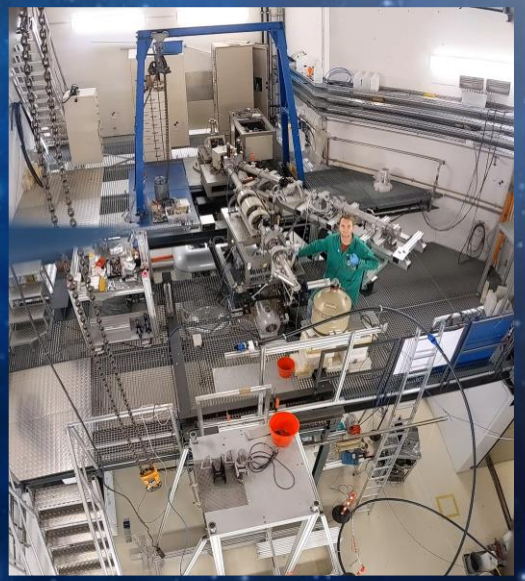
Nuclear (Astro-)physics at the DT neutron generator of TU Dresden

Steffen Turkat

ChETEC-INFRA 5th General Assembly and Transnational Access User Meeting
Dreikönigskirche Dresden

18.09.2025



TECHNISCHE UNIVERSITÄT DRESDEN

INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS

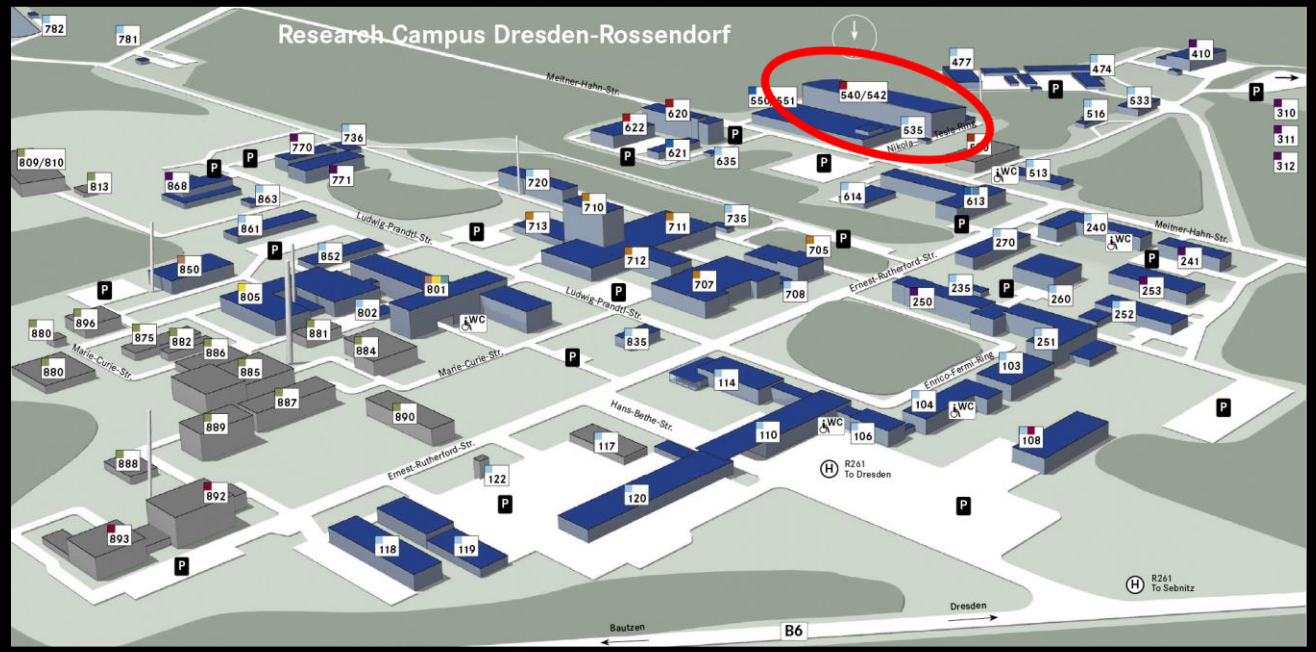
HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

ChETEC INFRA

The DT neutron generator of TU Dresden

- **Operated by:** Institute for Nuclear and Particle Physics of TU Dresden
- **Location:** Helmholtz-Zentrum Dresden-Rossendorf
  - **Ion Beam Center** (6 MV, 3 MV, 2 MV, 500 kV, 40 kV)
  - **Felsenkeller Laboratory** (5 MV, Low background γ-counting)
  - **HAMSTER** (1 MV AMS)
  - **ELBE** (40 MeV electrons)
  - **DT generator** (350 kV deuterons & protons)

https://stadtplan.dresden.de/



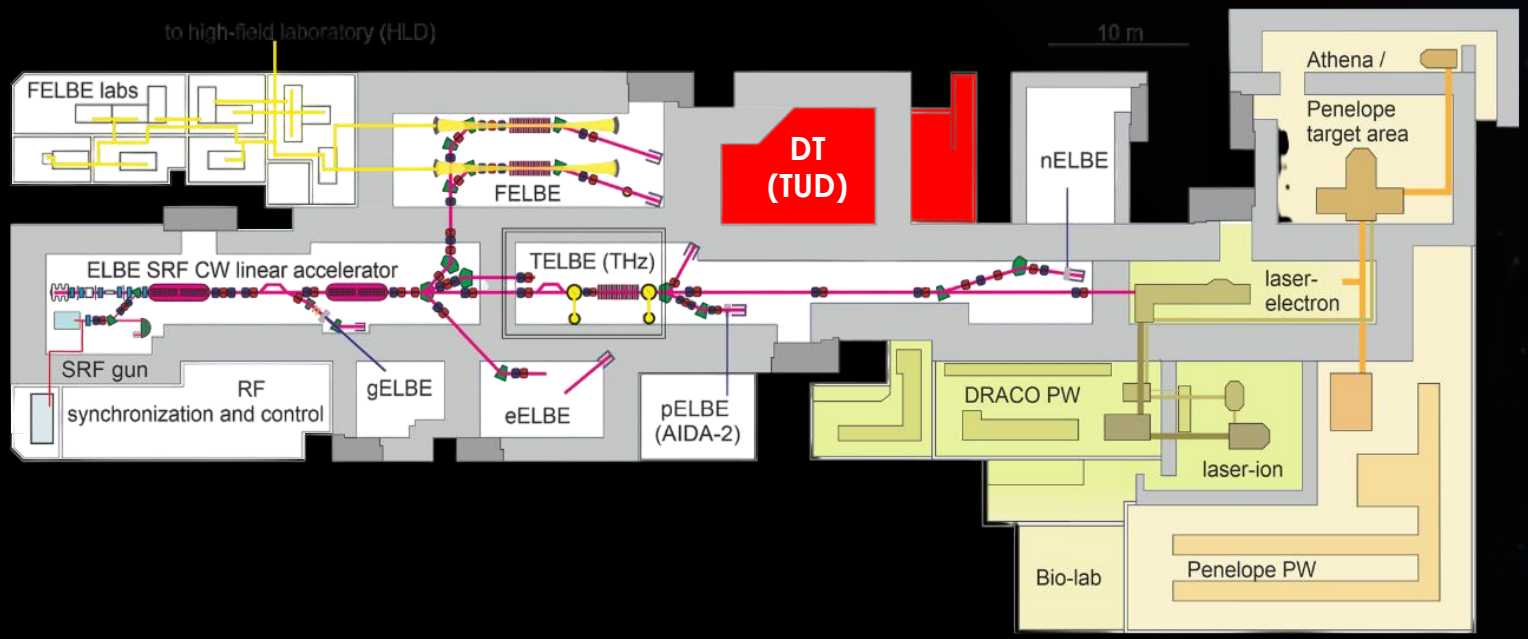
The ELBE facility at HZDR

40MeV superconducting electron linear accelerator

- FELBE, gELBE, nELBE, pELBE, TELBE, …

DT generator of TU Dresden

- Neutron generator for 14 MeV neutrons with up to 10^{12} s^{-1}

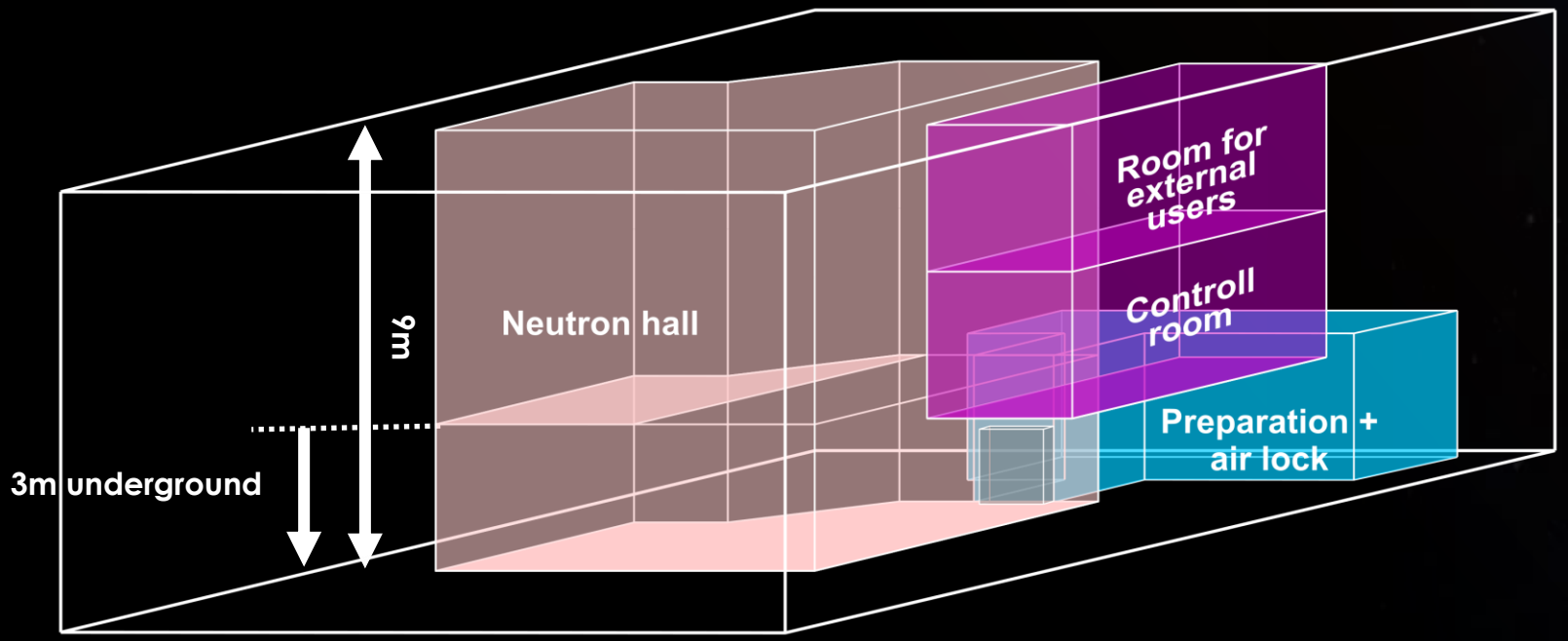


https://stadtplan.dresden.de/

Later today:
Guided tour through ELBE & the DT generator

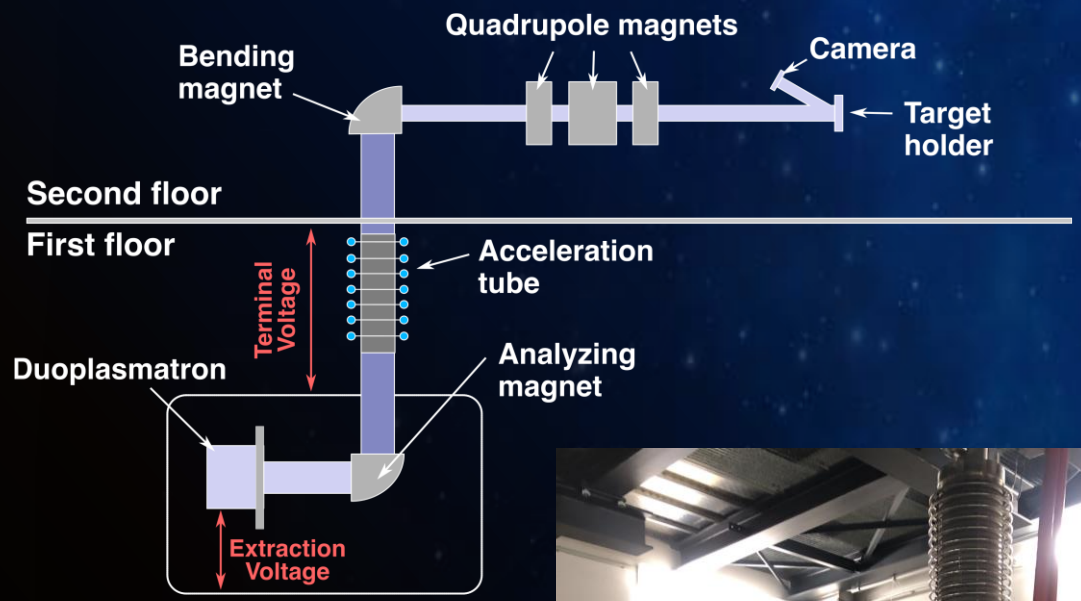
The facility of the DTG

- Laboratory in use since 2005
- **Divided into four sections:**
  - Controll room
  - Room for external users
  - Preparational rooms
  - Neutron hall (75 m², 2.4 - 3.6 m concrete walls)

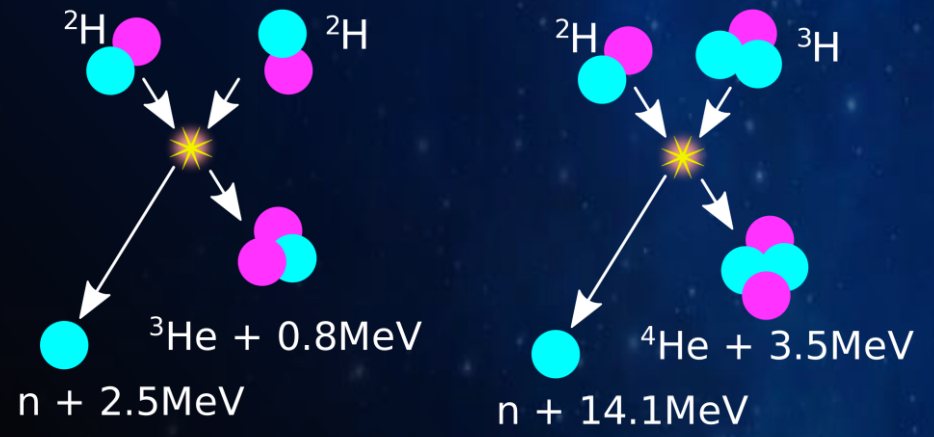


The ion beams

- **Duoplasmatron** (HVEE - Model 358)
  - Operation with deuterium since 2005
  - **Operation with protons since 04/2025**
- **Beam acceleration**
  - Cockcroft-Walton HV module (+ ext. motor generator)
  - E_{beam} = 10 - 350 keV (50 kV EV + 300 kV TV)
- **Main operation mode: DC operation**
  - Continuous target currents of up to 10 mA
- **Pulsed operation** (up to 1 mA, currently not installed)
  - **Aim**: Time-of-flight measurements, transmission etc
  - MHz repitition with 30 ns pulse width
  - Hz - kHz repitition with 10 - 100 µs pulse width



Targets and neutron production

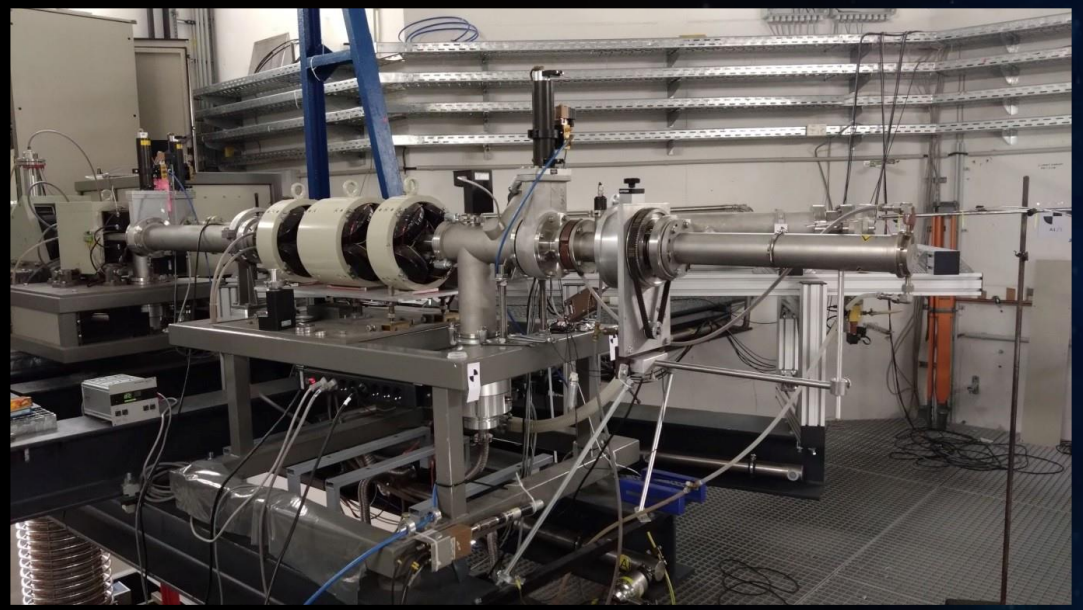


Production of intense neutron fields

- Tritium targets (20 Ci or 0.74 TBq)
  - 14.1 MeV neutrons via ^{2}H(^{3}H,n)^{4}He
  - **Neutron yield: Up to 10^{12} s^{-1}**
- Deuterium targets
  - 2.5 MeV neutrons via ^{2}H(^{2}H,n)^{3}He

Neutron monitoring

- Silicon detector at 180°
- Via ^{2}H(^{3}H,n)**^{4}He** **and** ^{2}H(^{2}H,**p**)^{3}H



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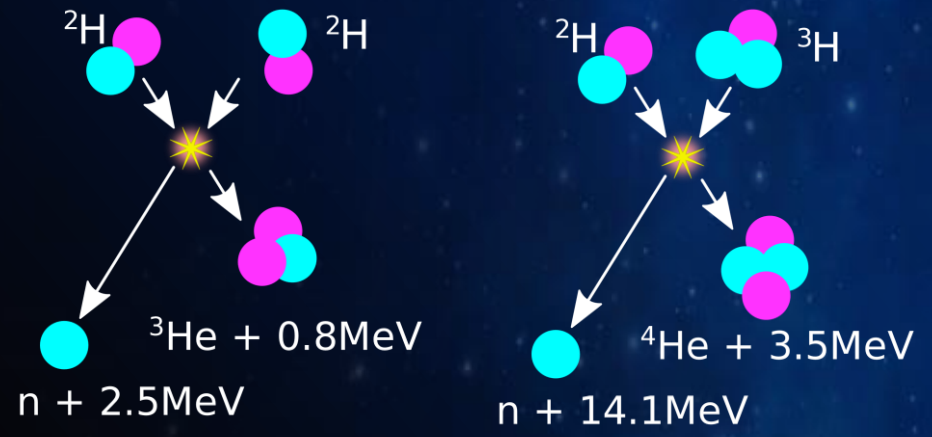

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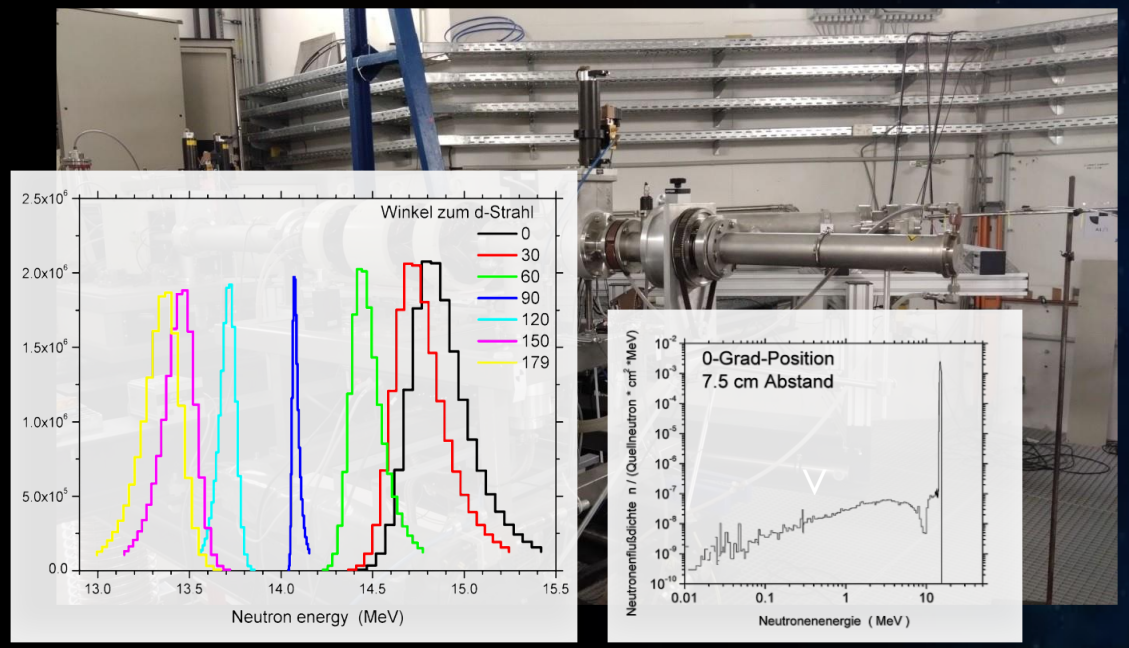
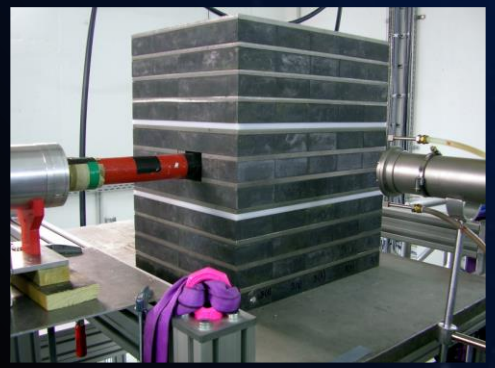
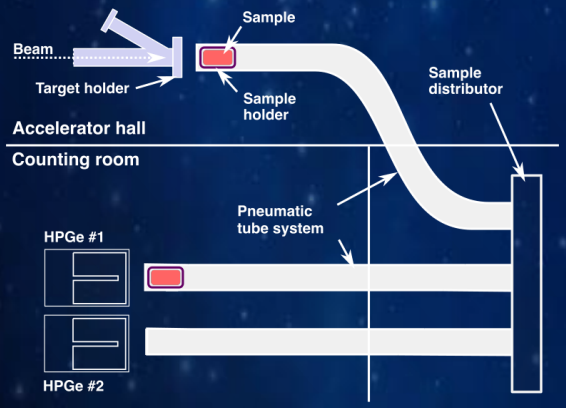


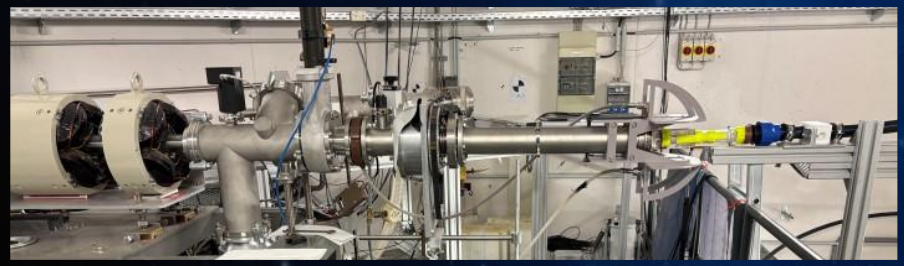
The history of DTG: Fusion research





Fusion research

- Most intense DT fusion neutrons in Europe
- Relevant for inertial and magnetic confinement fusion

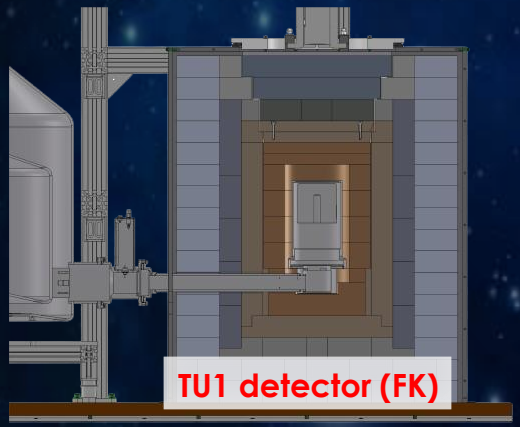


Neutron activation analyses

- Pneumatic tube system for activated samples
- Transport to HPGes within 11s (short-living radio nuclei)

Collaborations & local synergies

- **KIT, ITER & Wendelstein 7-X** (Breeding blankets, radiation resistance etc.)
- **GERDA/LEGEND & XLZD** (Neutron activation analysis)
- **Research reactor AKR-2**
- **Helmholtz-Zentrum Dresden-Rossendorf**
  - **Felsenkeller laboratory** (5 MV Pelletron + TU1 detector) ← Presentation by Konrad
  - **DREAMS & HAMSTER** (Accelerator Mass Spectrometry) ← Stay tuned for Johannes
  - **Ion Beam Center**



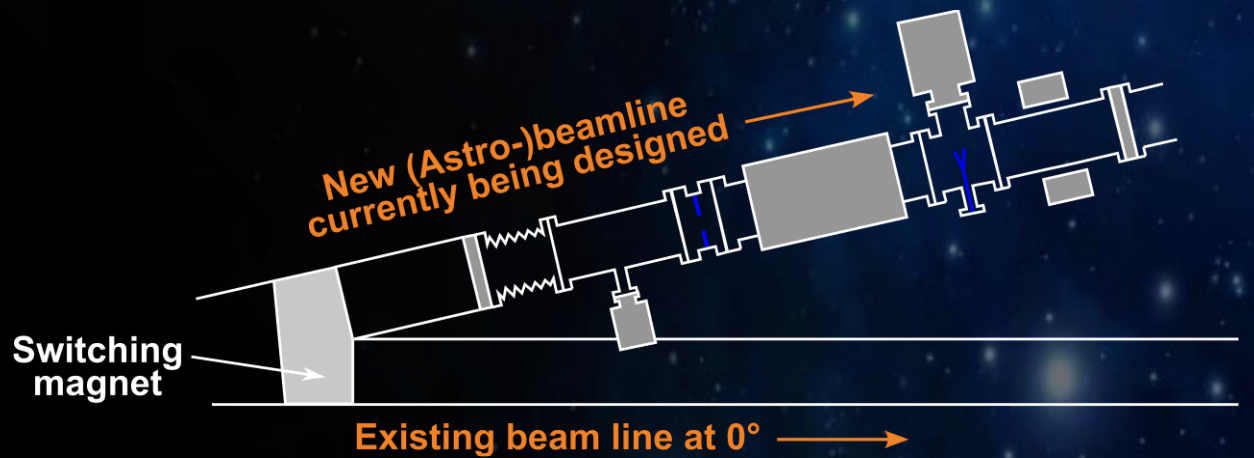
S. Turkat et al., Astrop. Phys. 148 (2023) 102816

The future of DTG: Nuclear astrophysics

Upgrade from 'pure neutron production' to 'accelerator facility'

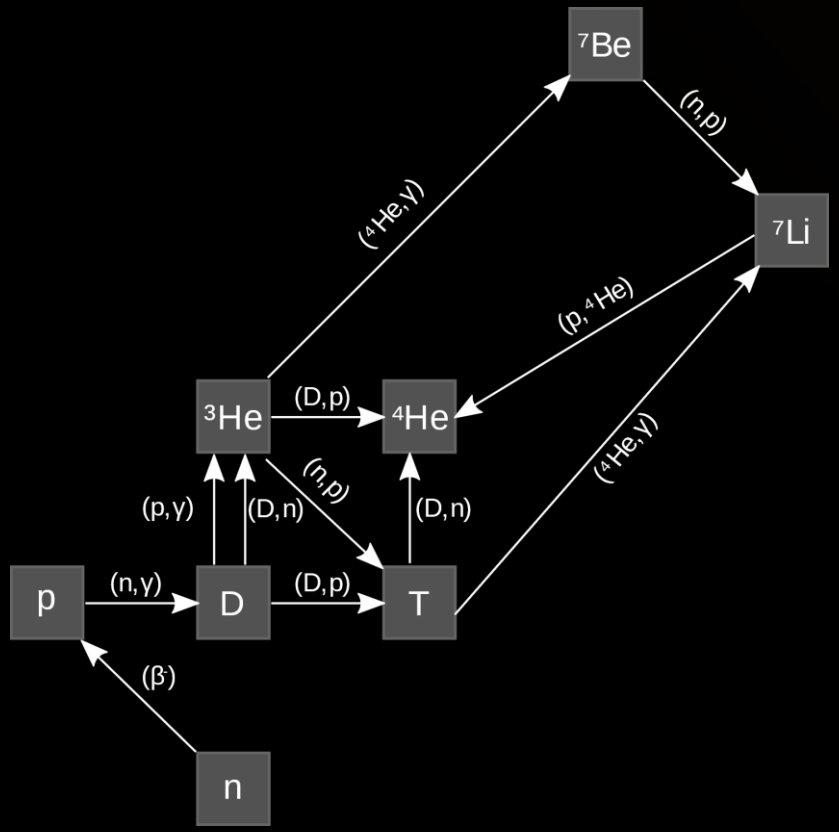
- Providing intense $^{1}H^{+}$, $^{1}H_{2}^{+}$, $^{1}H_{3}^{+}$ & $^{2}H^{+}$, $^{2}H_{2}^{+}$, $^{2}H_{3}^{+}$ beams
- Up to 350 keV and several mA of target current

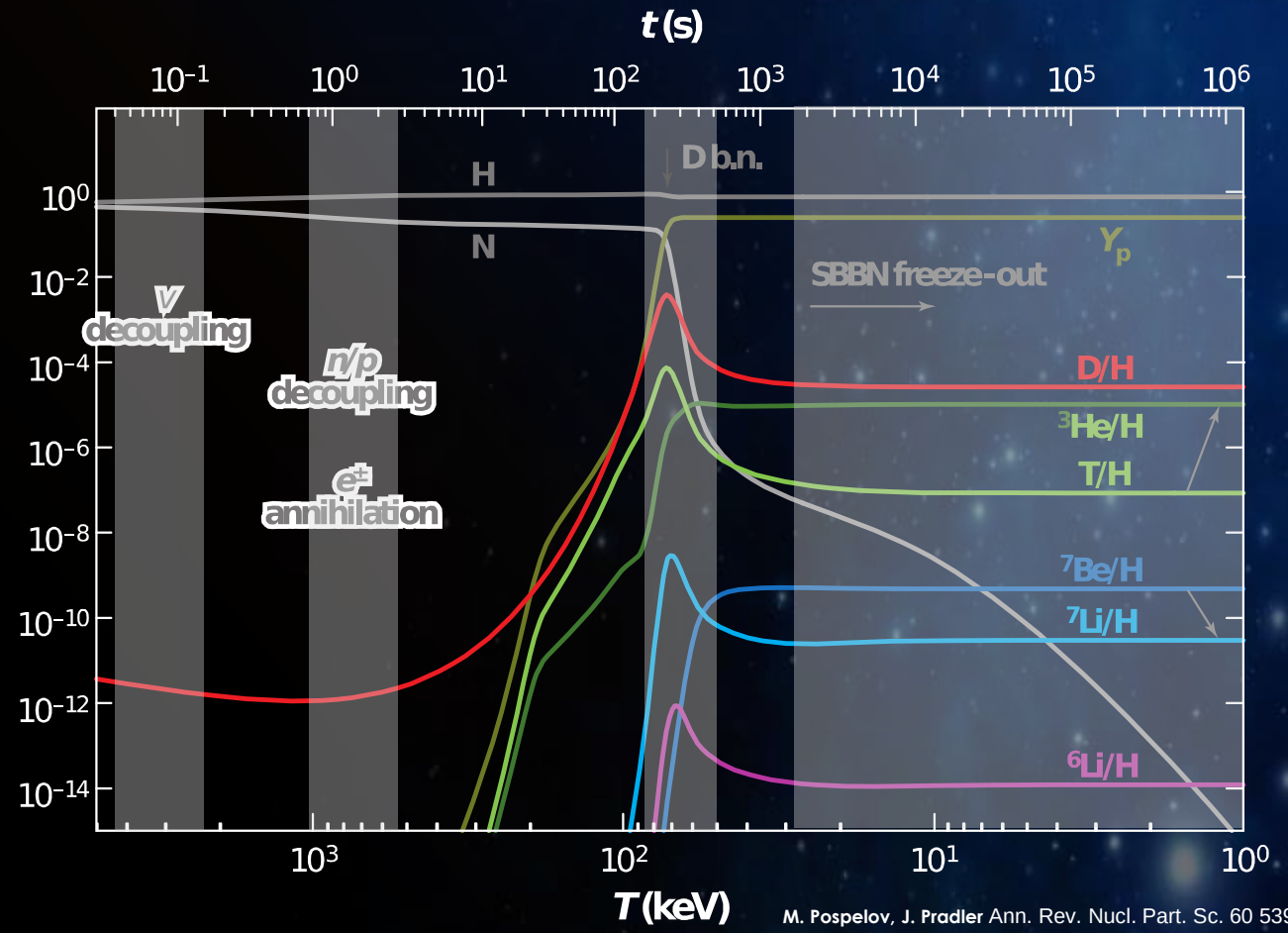
- **Phase I:** Suitability of TUD-NG as accelerator laboratory
  - Energy calibration & beam characterization
  - Successfully finished in Summer 2025 (stay tuned for publication)
- **Phase II:** New (second) beam line at TUD-NG
  - Tritium-free 'Astro' beam line
  - Currently being designed
- **Phase III**: Commissioning
  - Investigation of $d(d,p)^{3}H$ and $d(d,n)^{3}He$ in 4π
  - Cover entire BBN range of E_{cm} = 10 - 170 keV



Big Bang nucleosynthesis

The impact of d(d,p)^{3}H & d(d,n)^{3}He





M. Pospelov, J. Pradler Ann. Rev. Nucl. Part. Sc. 60 539 (2010)

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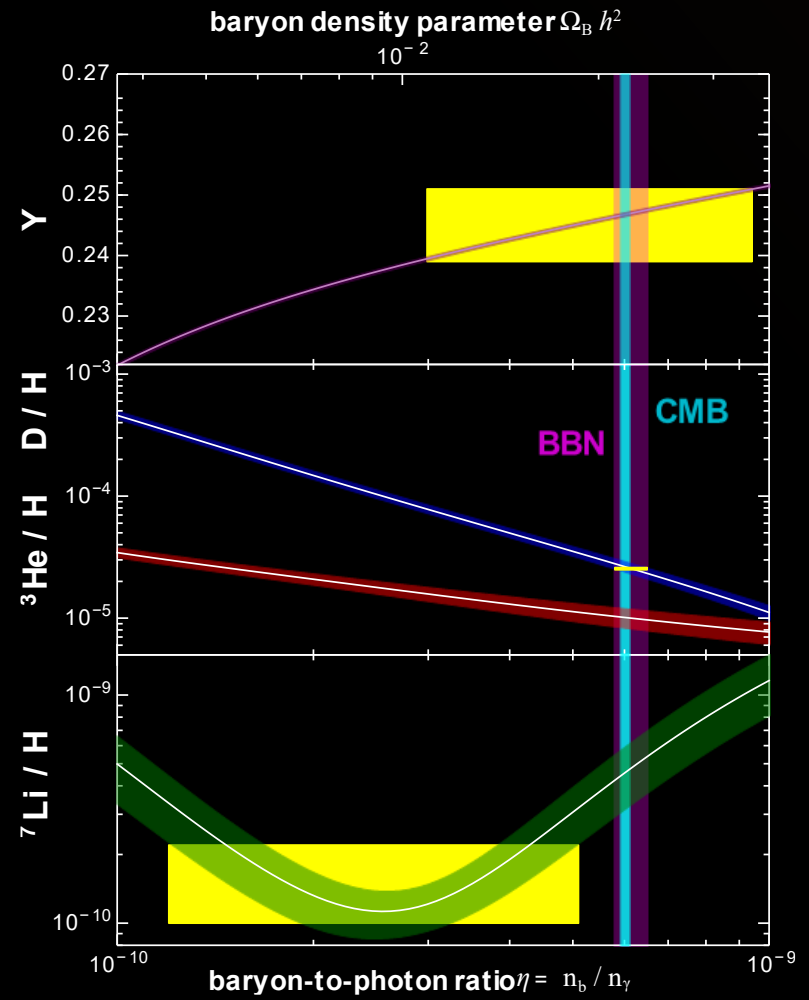

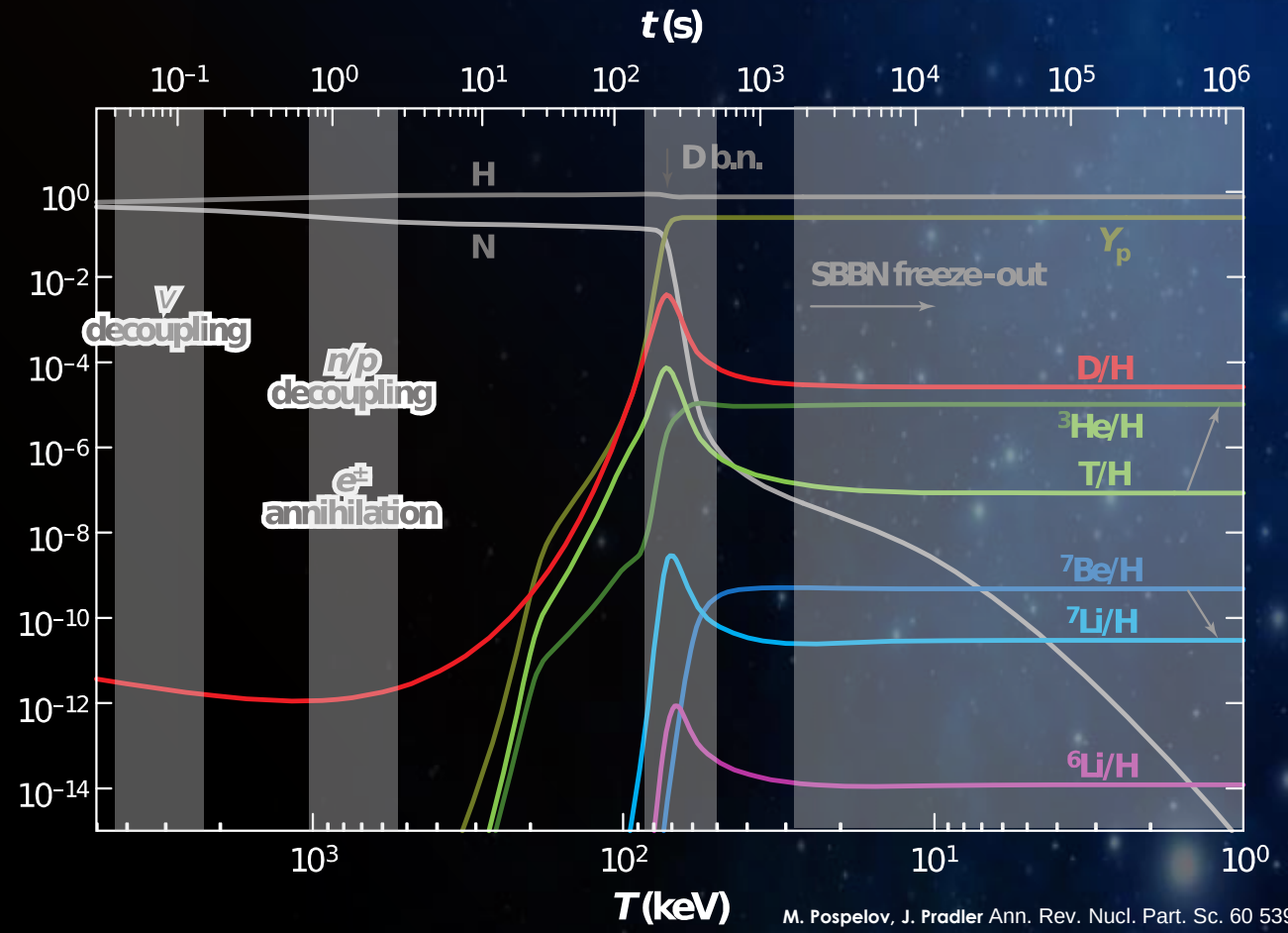

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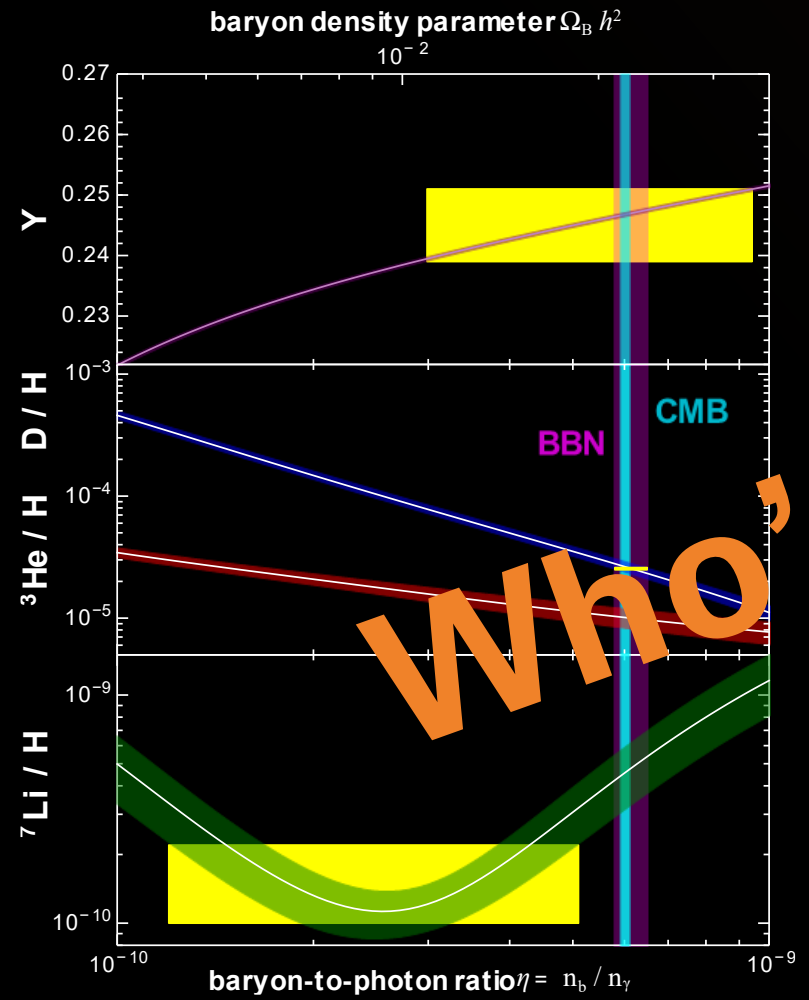
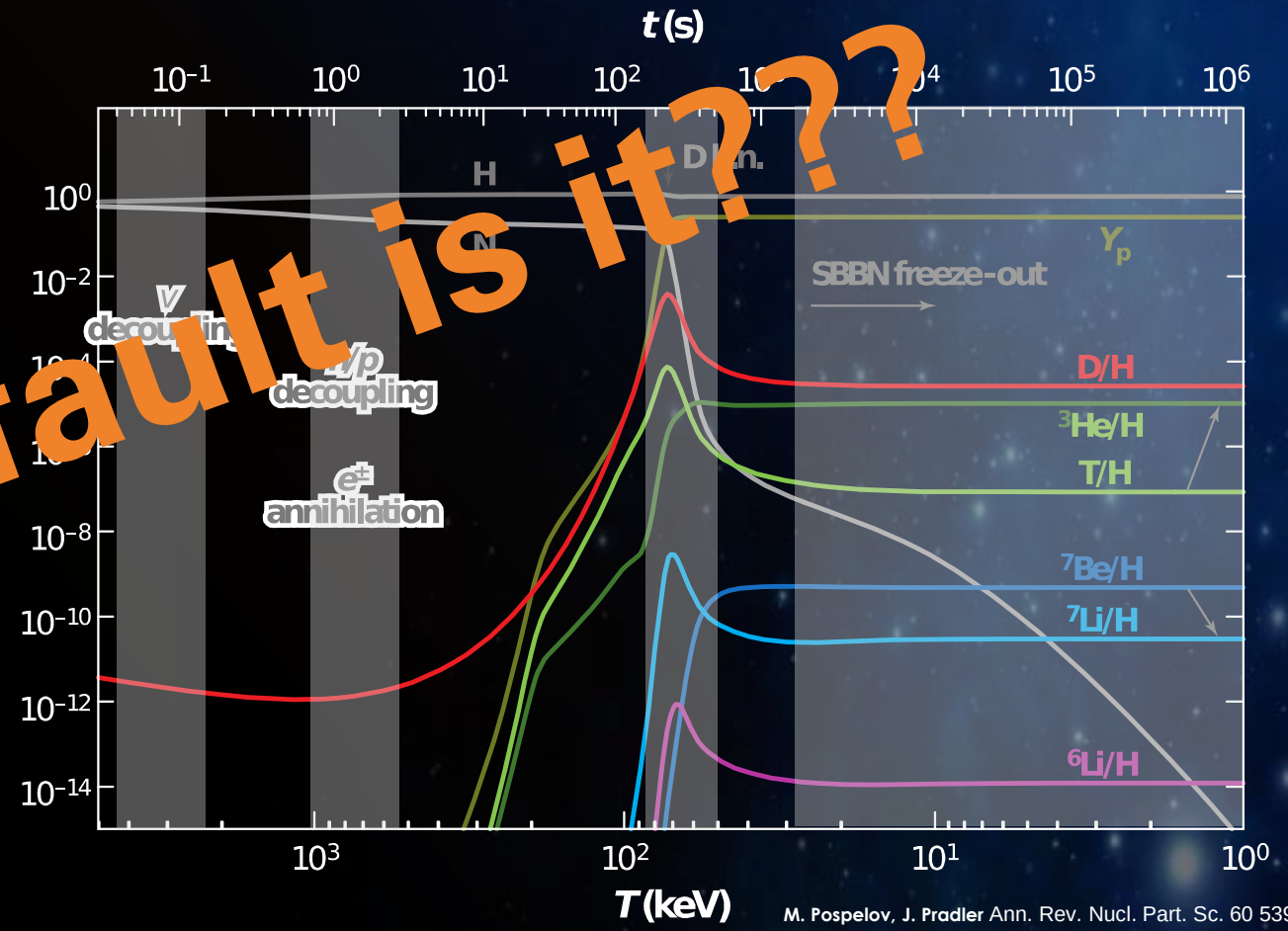
Big Bang nucleosynthesis

The impact of d(d,p)^{3}H & d(d,n)^{3}He

Reaction	d(d,n)^{3}He	d(d,p)^{3}H	d(p,γ)^{3}He	^{3}He(d,p)^{4}He	p(n,γ)d	^{3}He(n,p)t
Contribution to D/H unc.	61%	27%	12%	< 0.05%	< 0.05%	< 0.05%





Who's fault is it???

M. Pospelov, J. Pradler Ann. Rev. Nucl. Part. Sc. 60 539 (2010)

Big Bang nucleosynthesis

The impact of $d(d,p)^3H$ & $d(d,n)^3He$

Reaction	$d(d,n)^3He$	$d(d,p)^3H$	$d(p,\gamma)^3He$	$^3He(d,p)^4He$	$p(n,\gamma)d$	$^3He(n,p)t$
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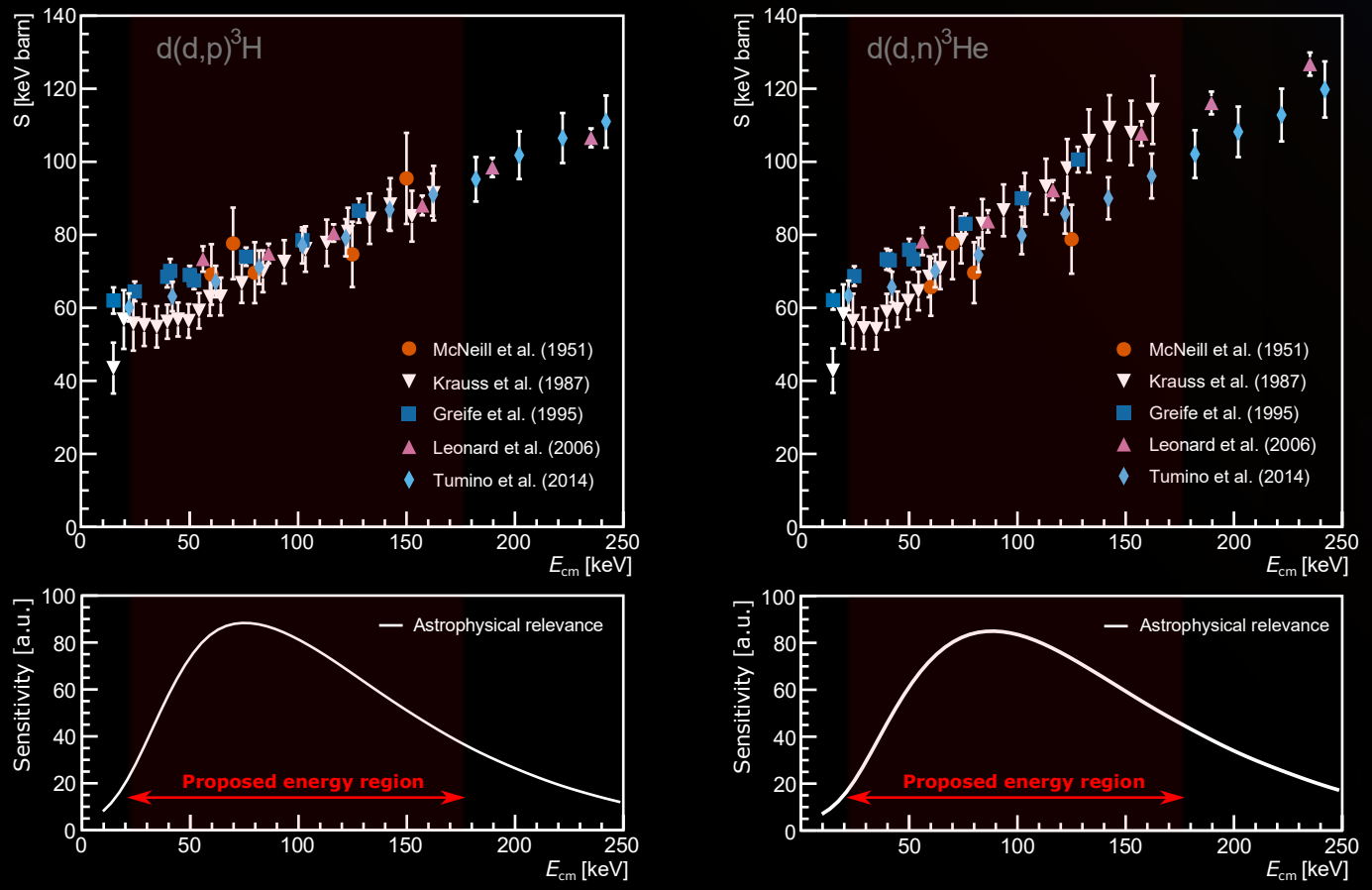
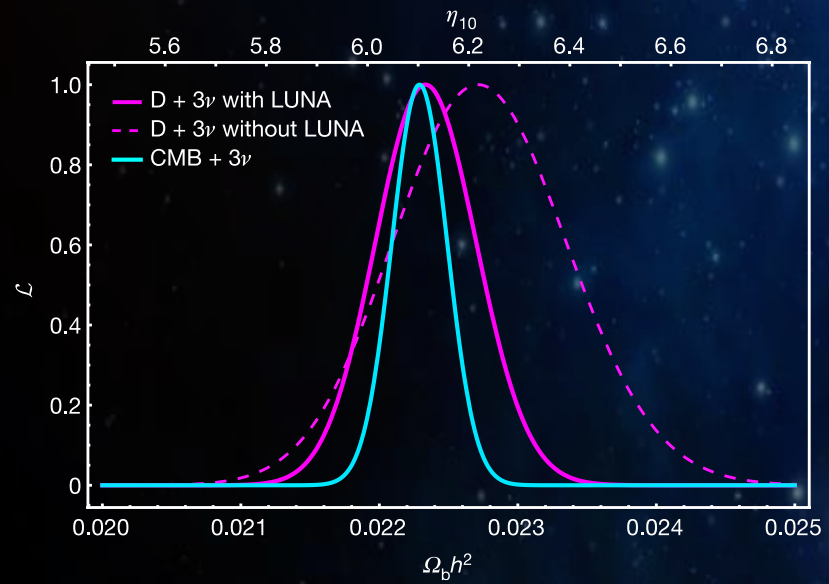


Feasibility at the DT generator

- $E_{cm} = 5$ keV with 1% stat. uncertainty
  - $I = 1$ µA, $\rho = 1E17$ at/cm² & $t_{meas} = 4$h
- DT generator: Several mA of deuteron beam
  - Statistics no problem, but systematics will be key!

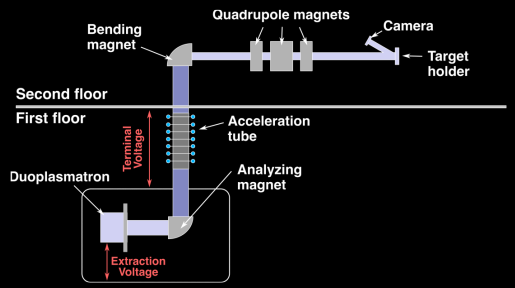


Adapted from: Mossa *et al.* *Nature* 587, 210–213 (2020)

Summary & Outlook

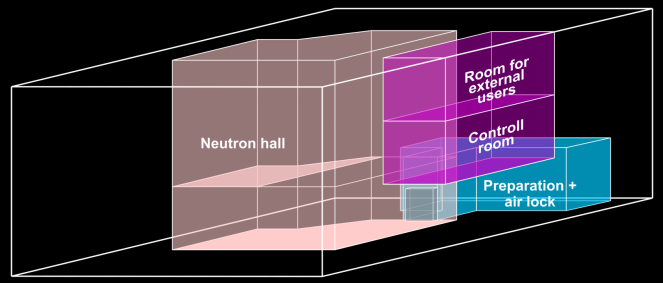
DT neutron generator of TU Dresden

- Intense proton and deuterium beams of several mA
- Beam energies of up to 350 keV
- Neutron production of up to 10^{12} n/s @ 14 MeV



Current scientific scope

- Most intense neutron flux in Germany
- Most intense DT neutron flux of Europe
- Fusion research, neutrino physics, Astrophysics, detector physics etc.



The future of the DT neutron generator

- Upgrade from 'pure neutron production' to **'accelerator facility'**
- Fusion research & **nuclear astrophysics**
- Cross section measurements, ion implantation, neutron TOF etc.