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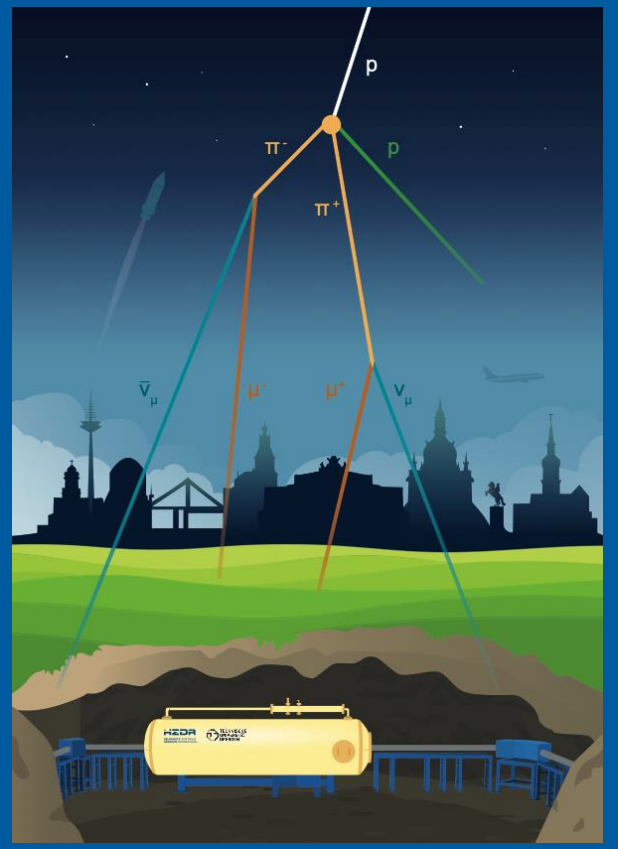
The XVIII International Conference on Topics in Astroparticle and Underground Physics (TAUP2023)

Underground laboratories: parallel session 5
30.08.2023

Investigation of the γ-ray angular distribution of the $^{3}He(\alpha,\gamma)^{7}Be$ reaction at the Felsenkeller shallow-underground laboratory



Anup Yadav

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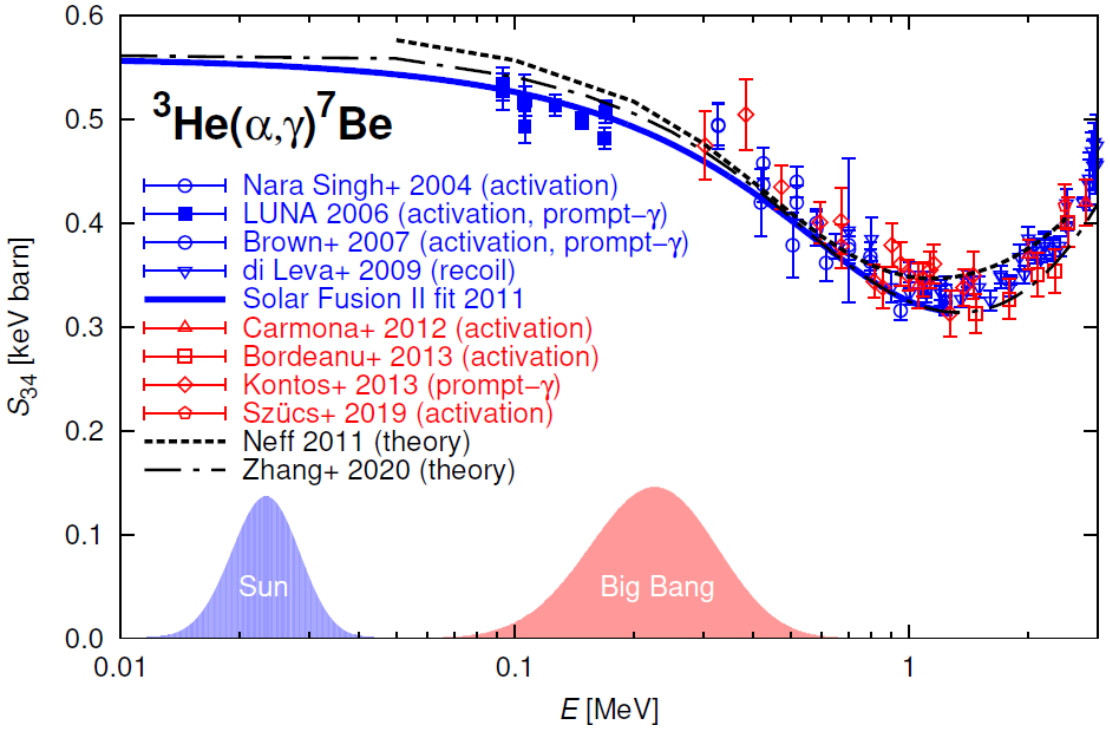
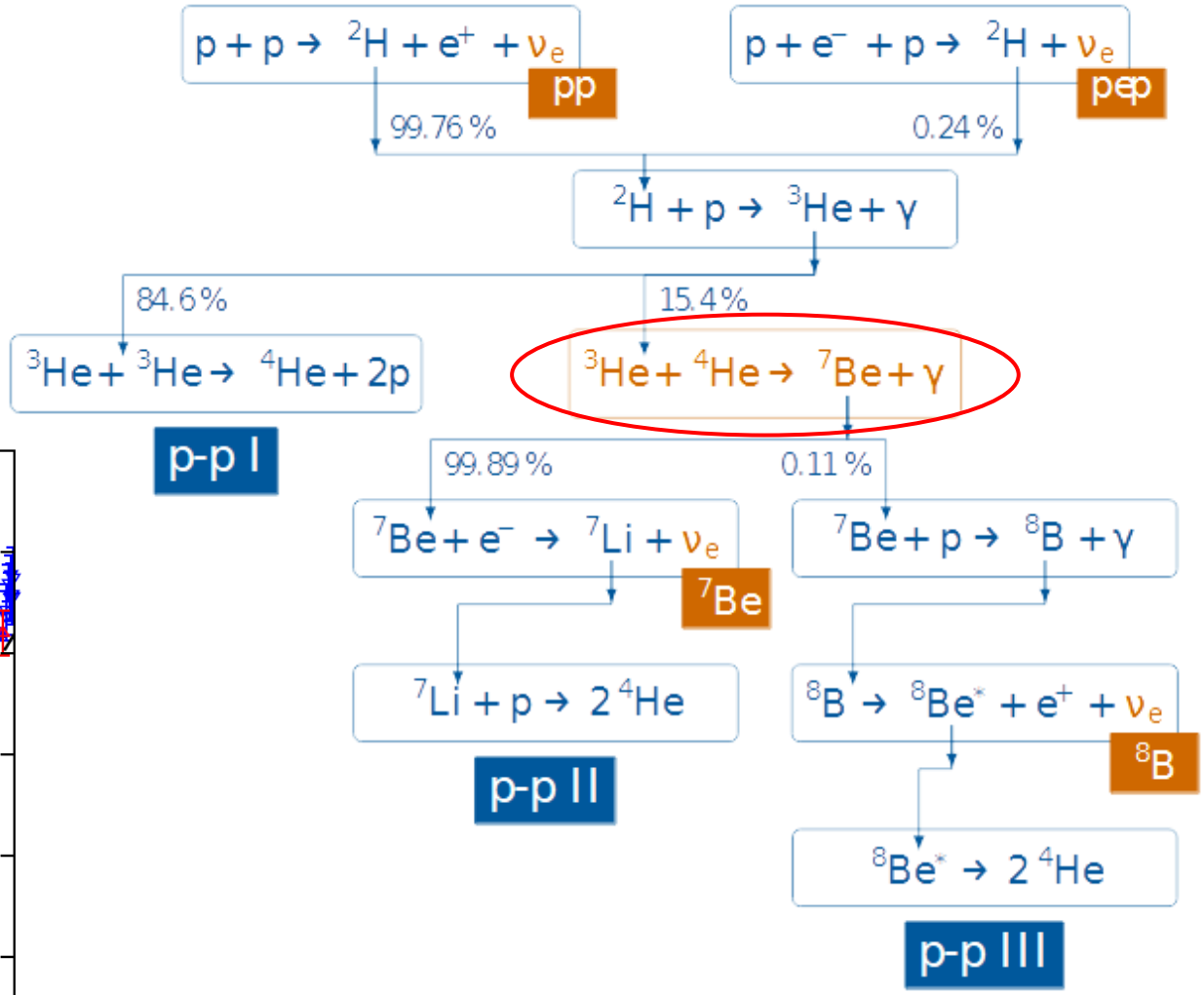
Motivation

- BBN & stellar hydrogen burning
- Affects ^{7}Be and ^{8}B neutrino flux
- Affects abundance of primordial ^{7}Li





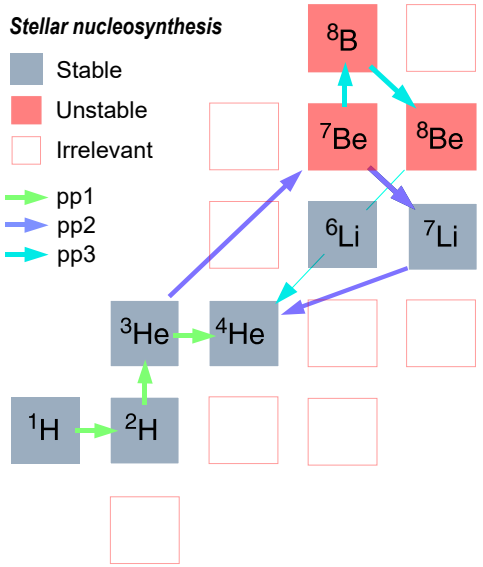
The $^3He(\alpha,\gamma)^7Be$ reaction

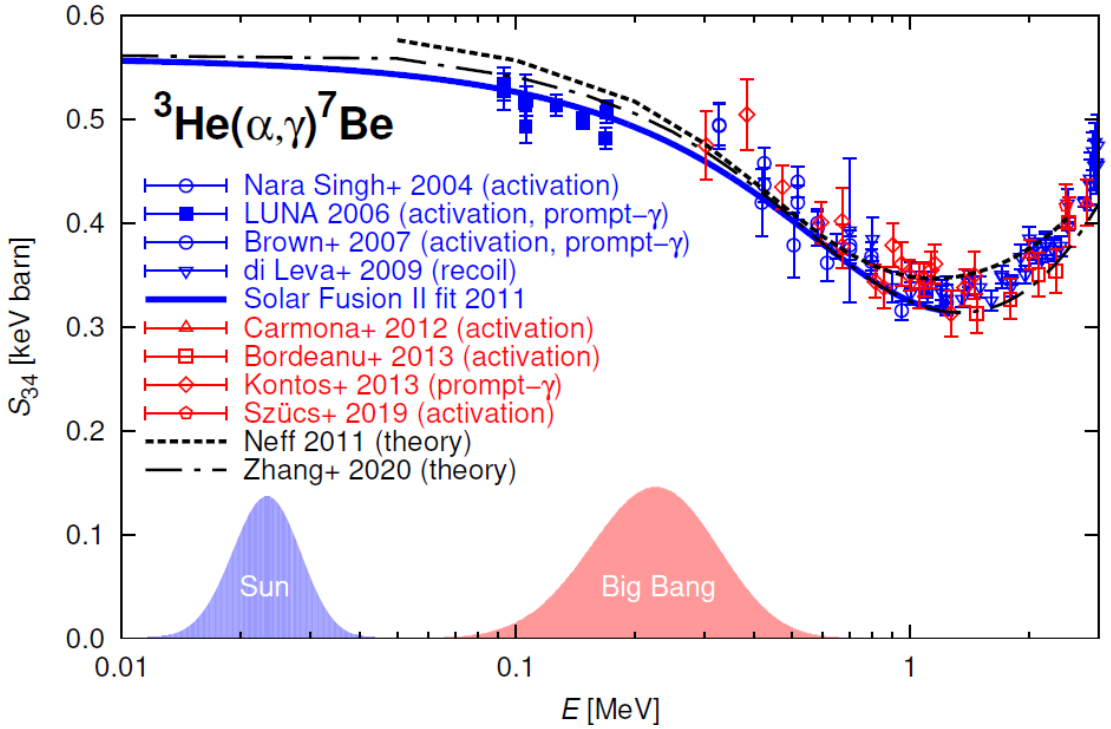
Problems

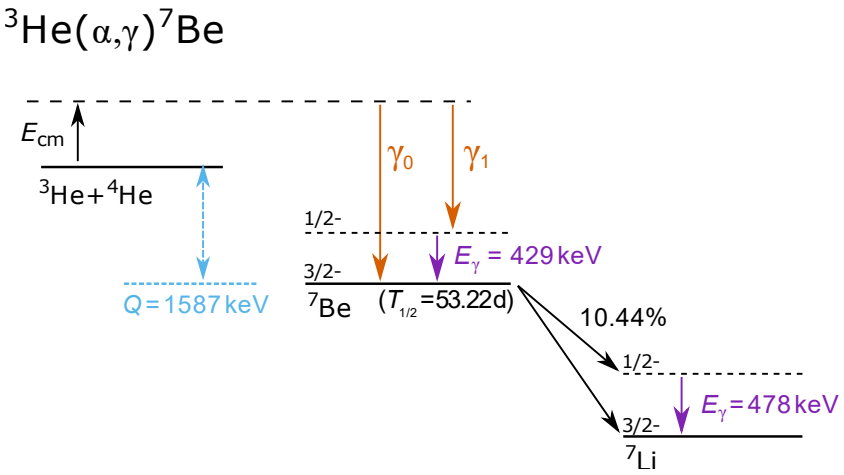
- Only one distinct measurement at ‘low energies’
- No experimental data for γ-ray angular distribution

Aims

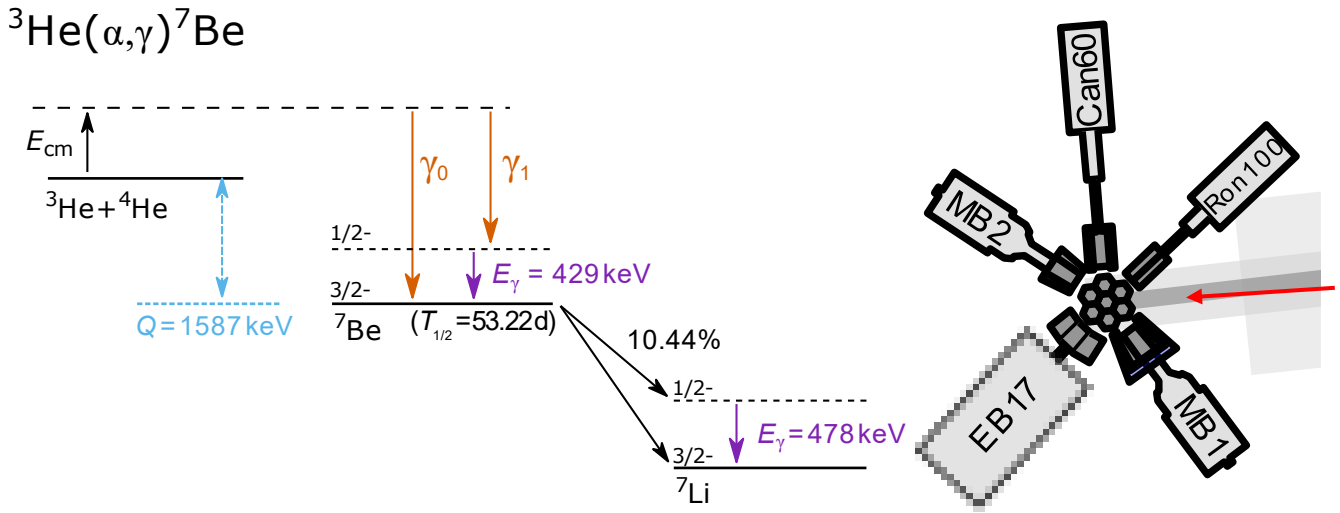
- Connect LUNA data to others
- First measurement of γ-ray angular distribution







The $^{3}He(\alpha,\gamma)^{7}Be$ reaction at Felsenkeller

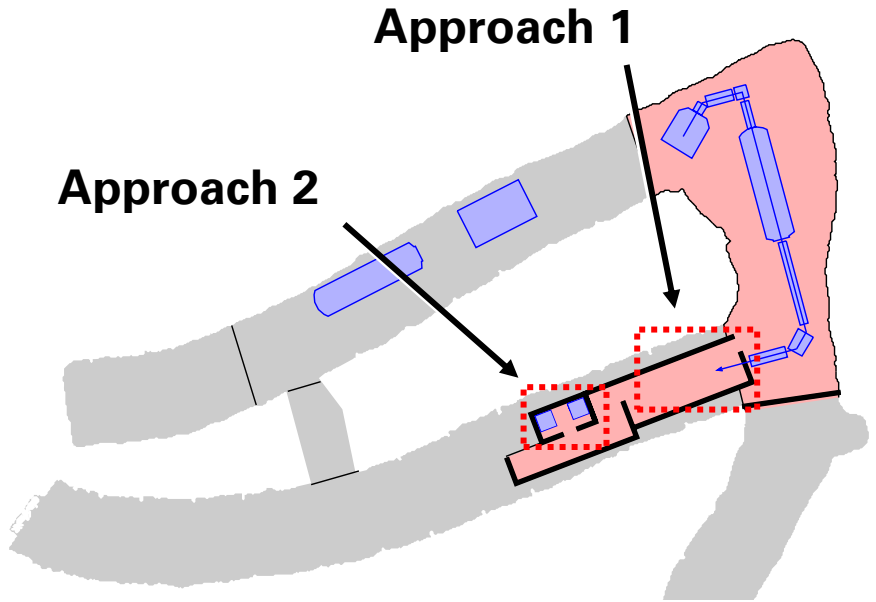


Approach 1: Measuring the prompt γ-rays

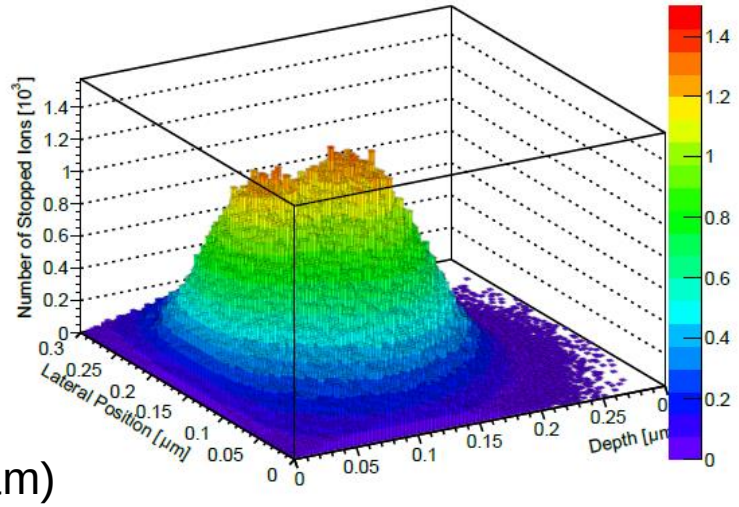
- Inbeam measurement with 22 HPGe detectors
- **Angular distribution for**
  - **Search for both γ_0 and γ_1**

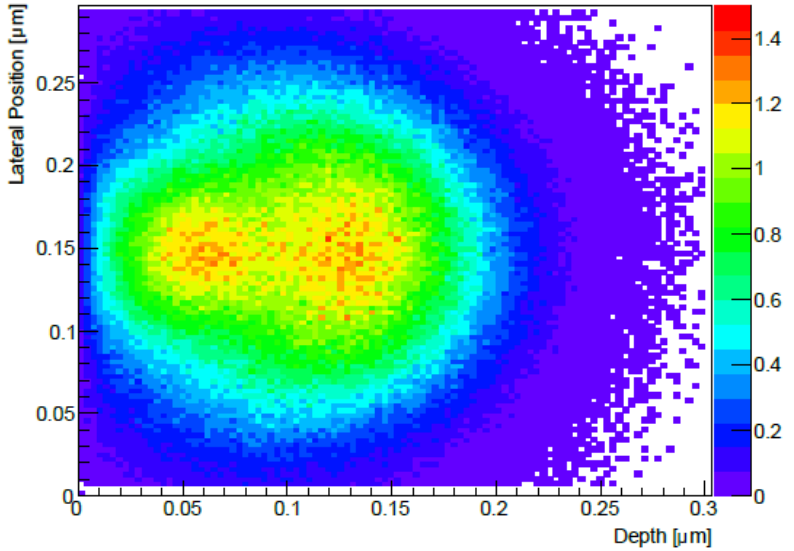
Approach 2: Activation analysis of ^{7}Be

- Offline analysis on the 478 keV γ-line
- New ultra-low background HPGe setup at FK
  - Comparable to the worlds most sensitive HPGes



Target preparation





Target

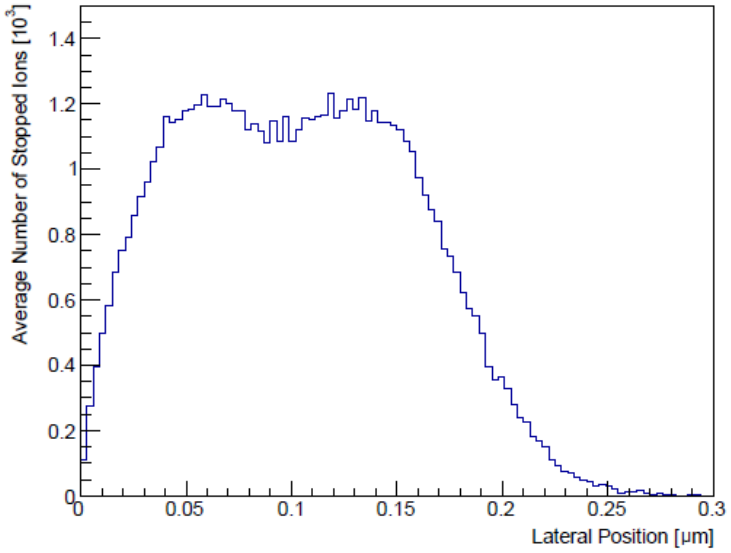
- Tantalum disk (220 µm)

^{3}He Implantation

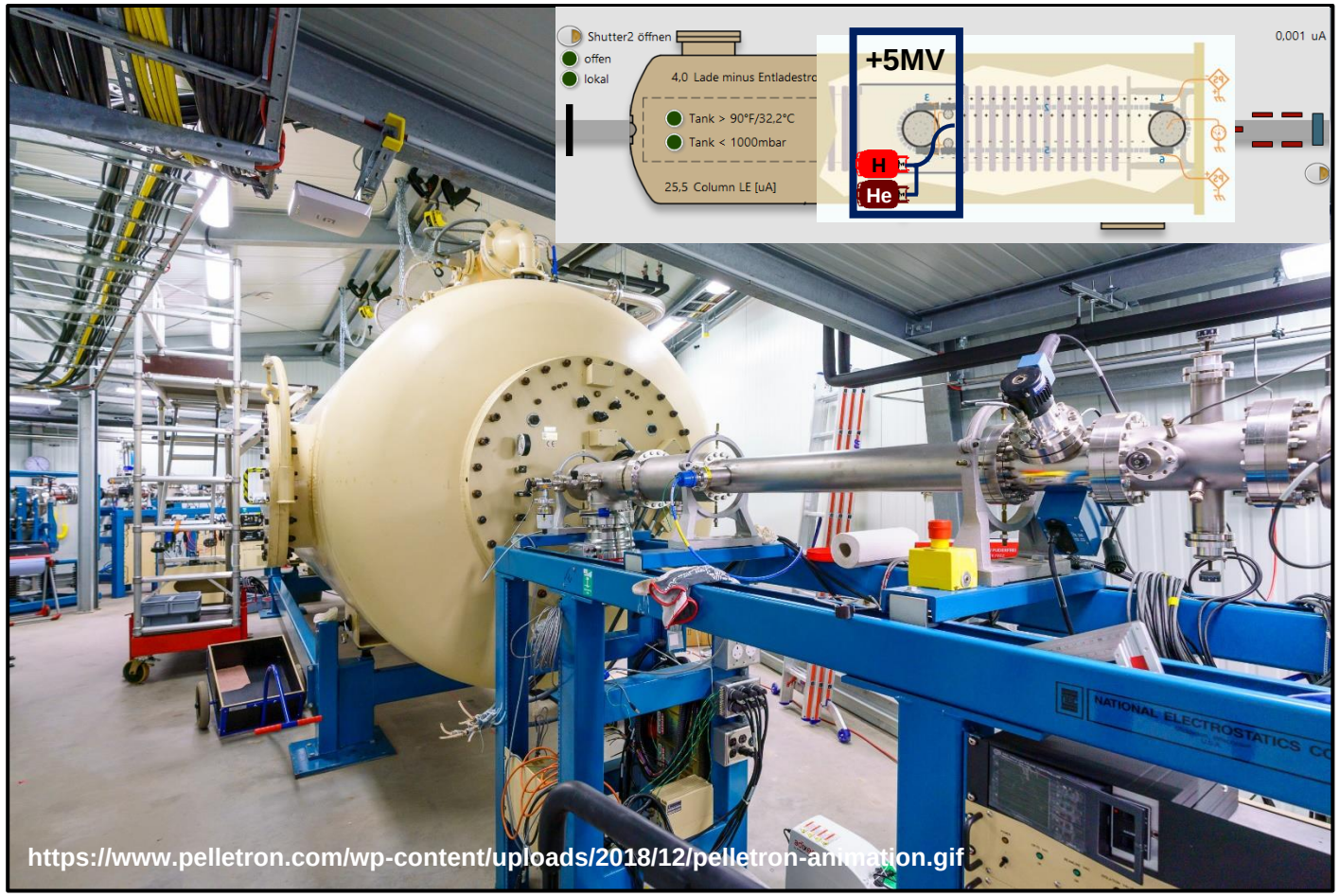
- Location: Ion Beam Center at HZDR
- Using 40 kV ion implanter

Target characteristics

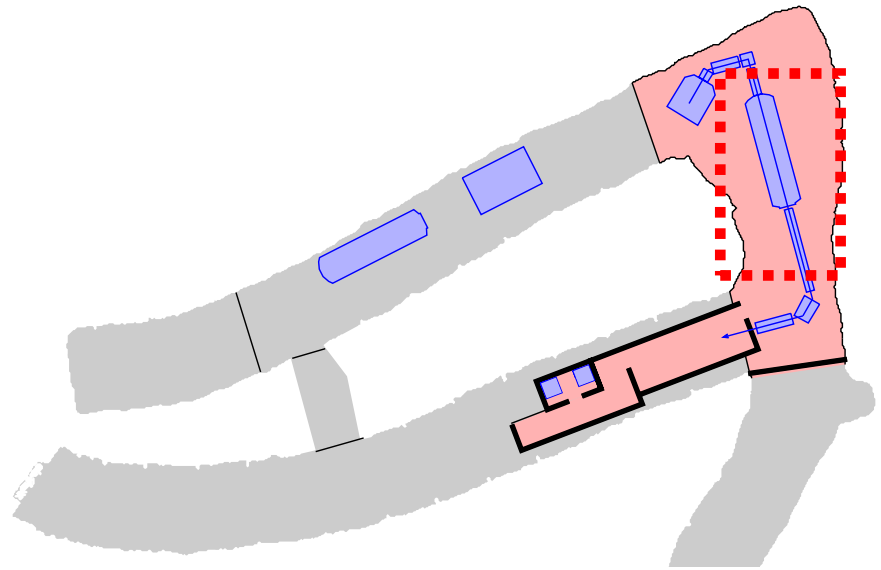
- ^{3}He in tantalum backing (~180 nm)
- Implantation energy 10 keV & 35 keV
- Aimed areal density of 1x10^{18} at/cm^2



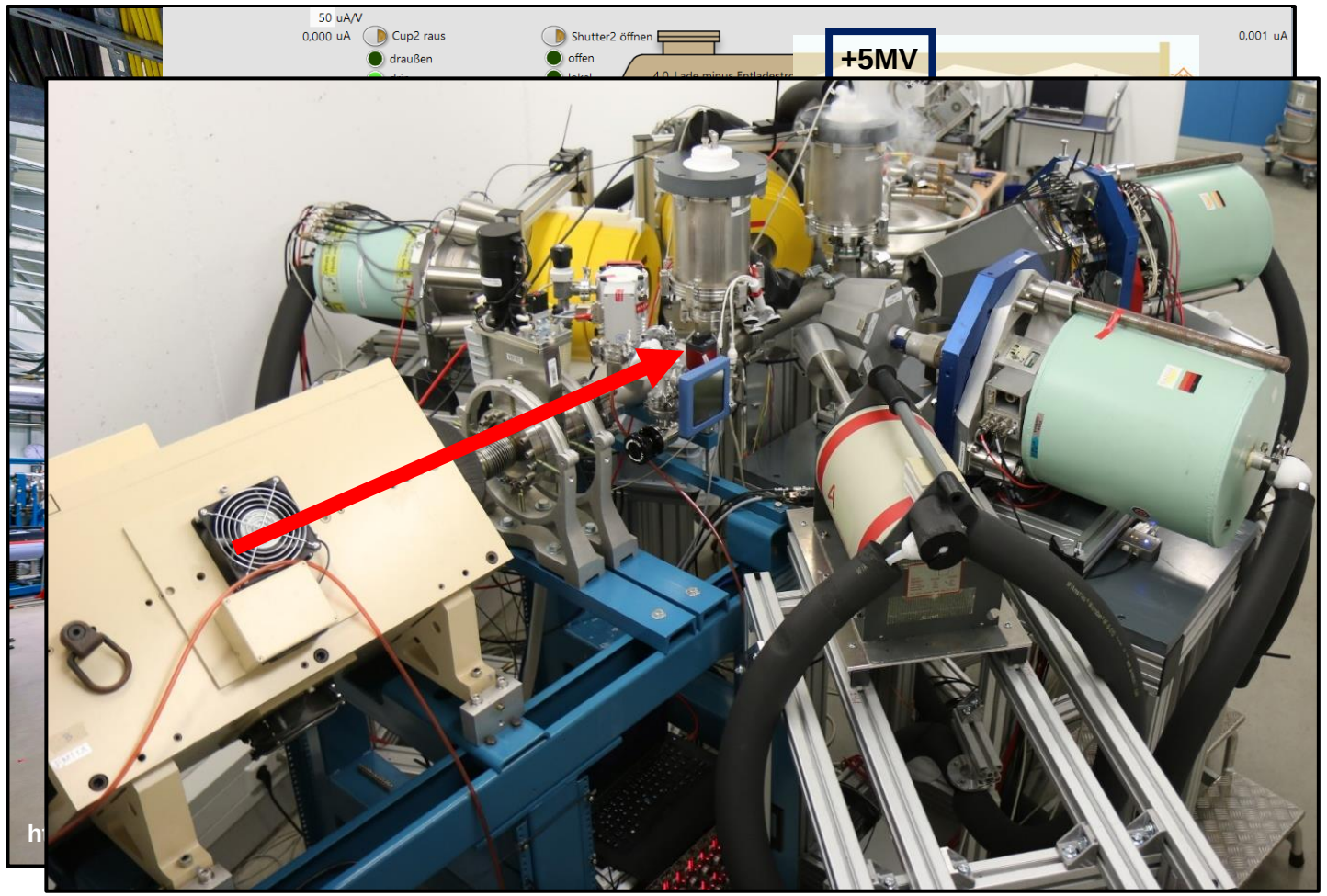
Providing a ^{4}He ion beam at Felsenkeller



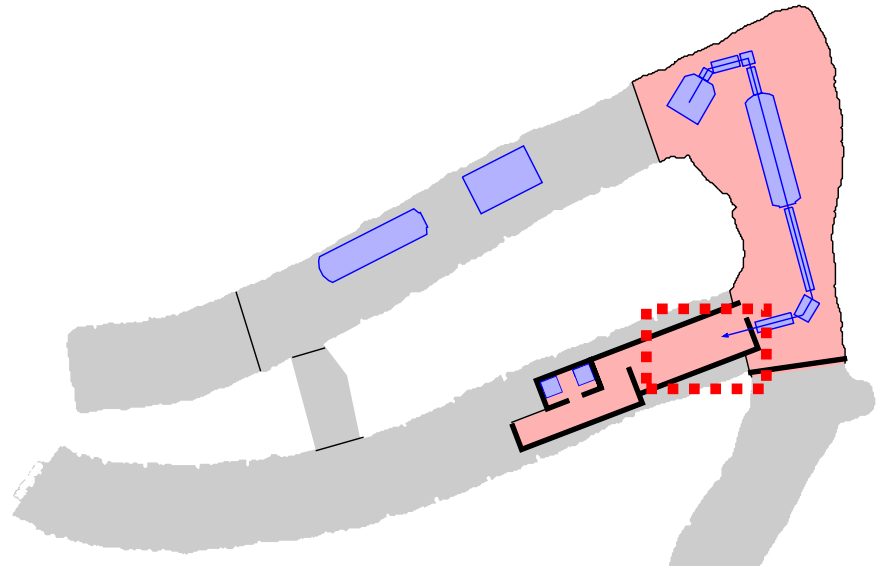
- **Internal radio frequency ion source**
  - $^{4}He^{+}$ beam in single ended mode



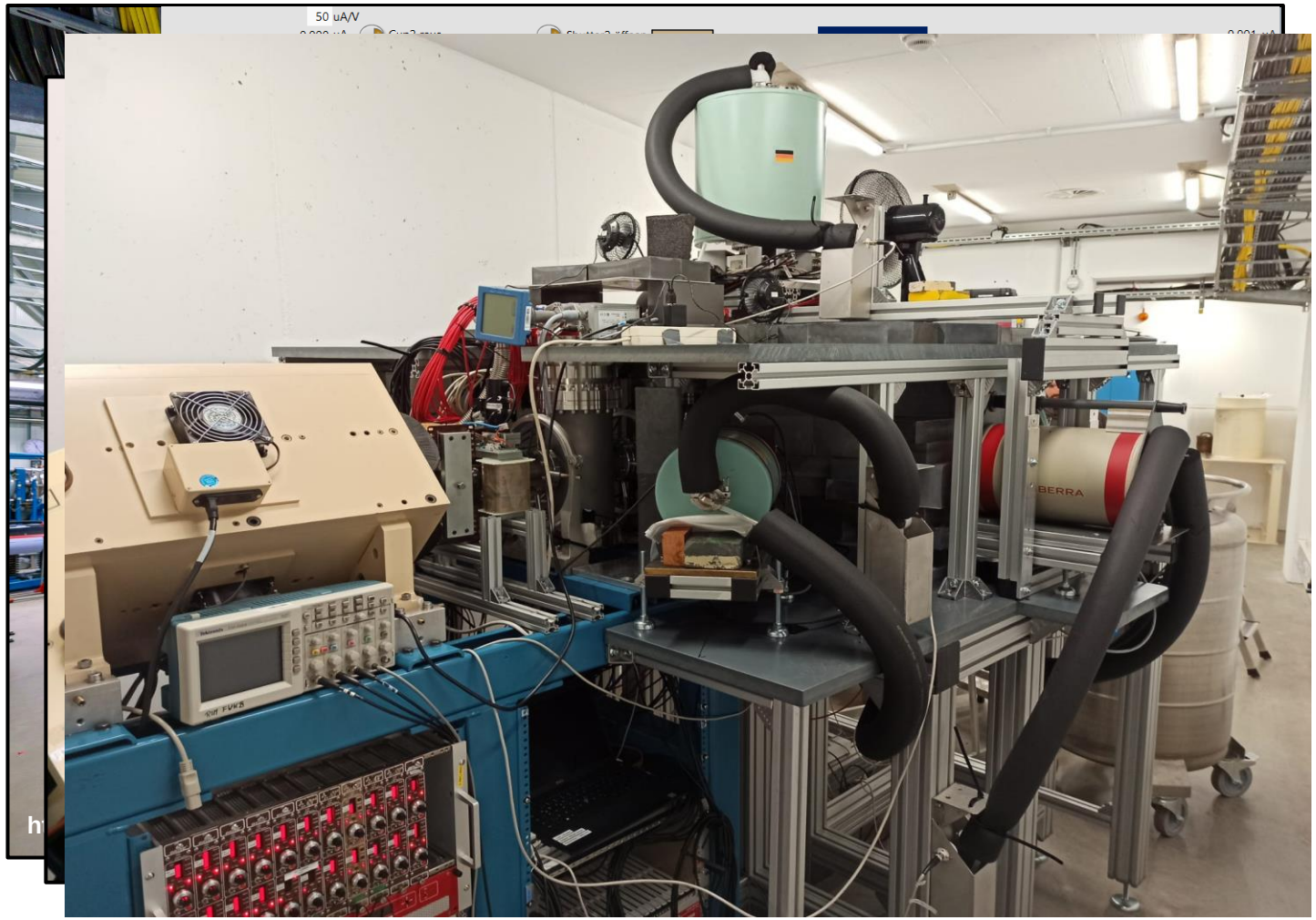
Providing a ^{4}He ion beam at Felsenkeller



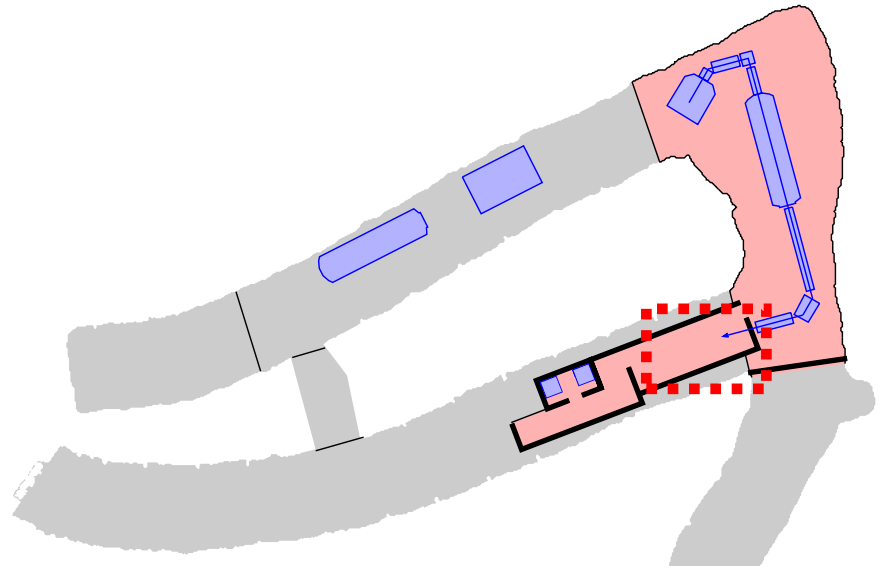
- **Internal ion source**
  - $^{4}He^{+}$ beam in single end mode
- **Experimental setup**
  - 22 HPGes surrounding target



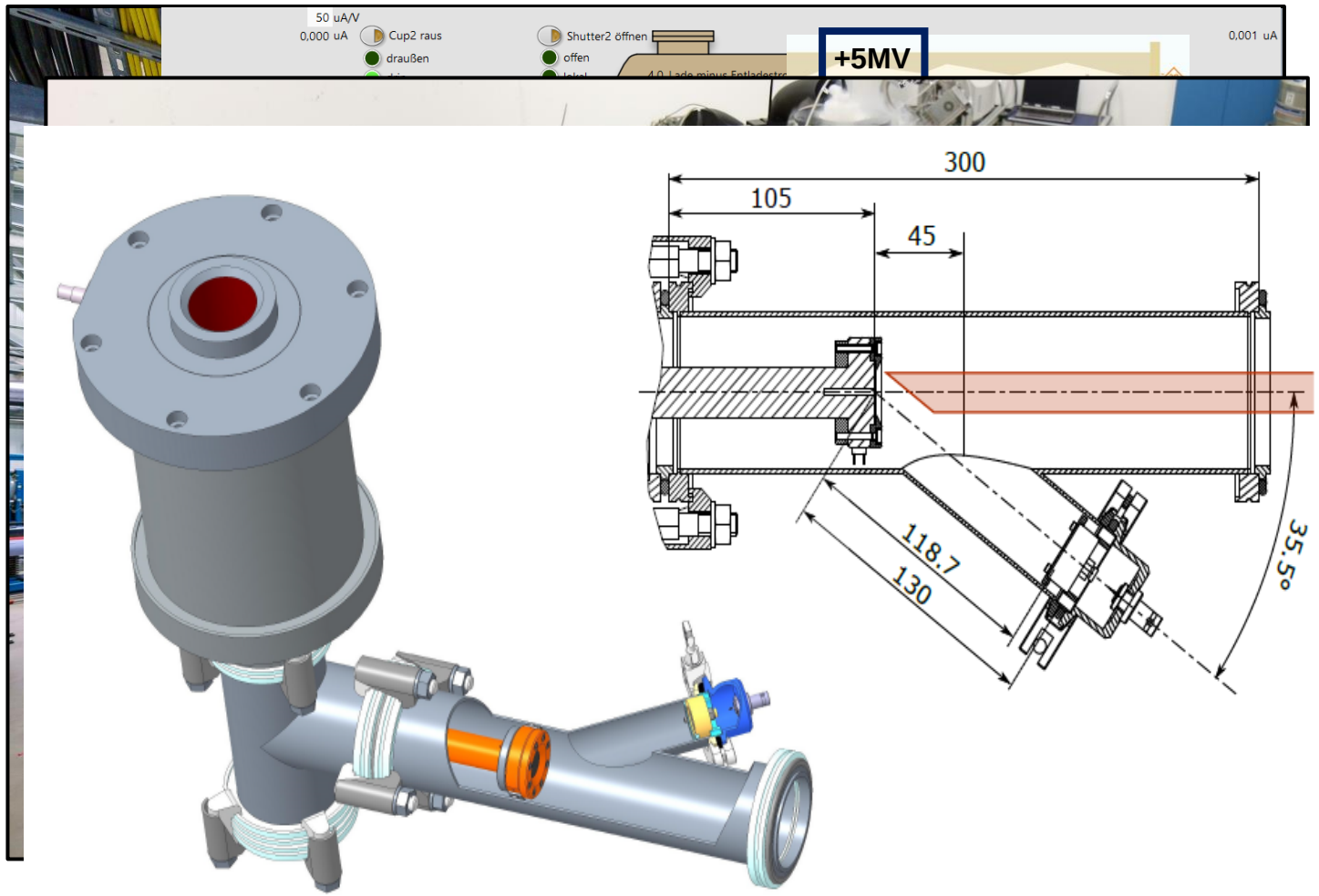
Providing a ^{4}He ion beam at Felsenkeller



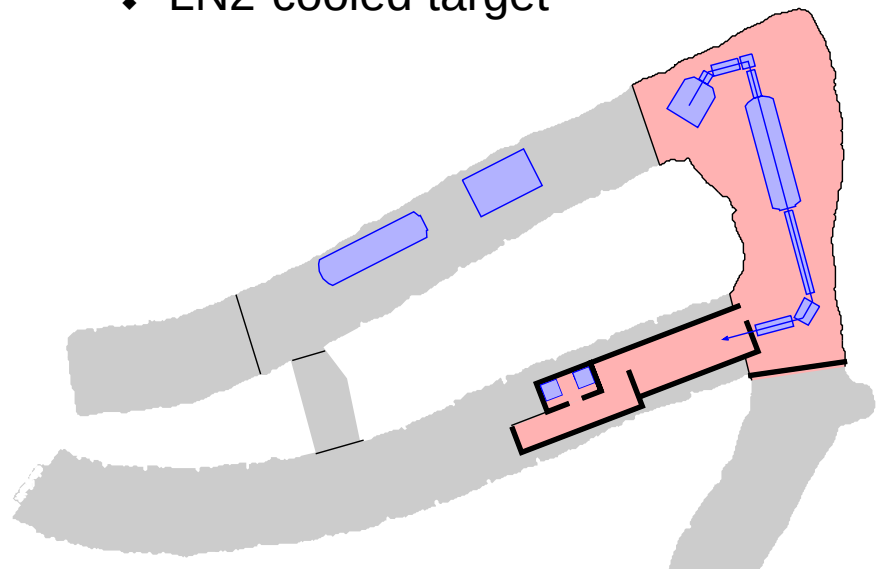
- **Internal ion source**
  - $^{4}He^{+}$ beam in single end mode
- **Experimental setup**
  - 22 HPGes surrounding target
  - Lead castle around the setup



Providing a ^{4}He ion beam at Felsenkeller

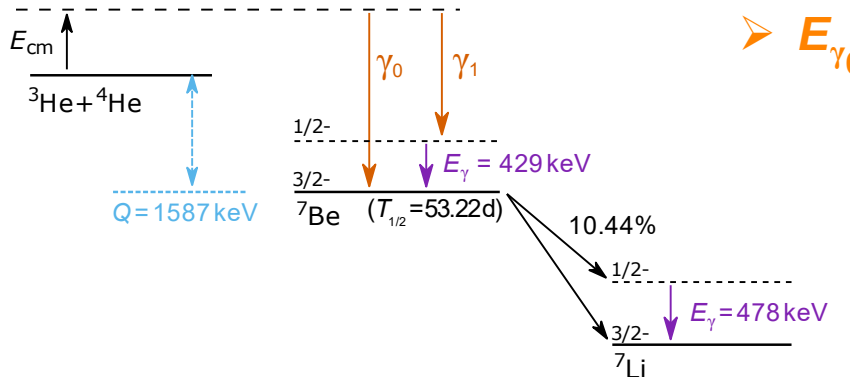


- **Internal ion source**
  - $^4He^+$ beam in single end mode
- **Experimental setup**
  - 22 HPGes surrounding target
- **Target area**
  - Y-shaped pipe „for viewport"
  - LN2-cooled target



Approach 1: γ-ray angular distribution

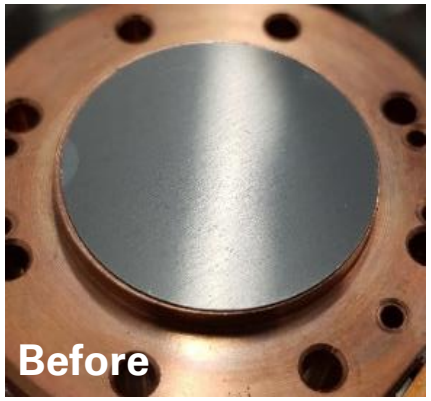
$^3He(\alpha,\gamma)^7Be$

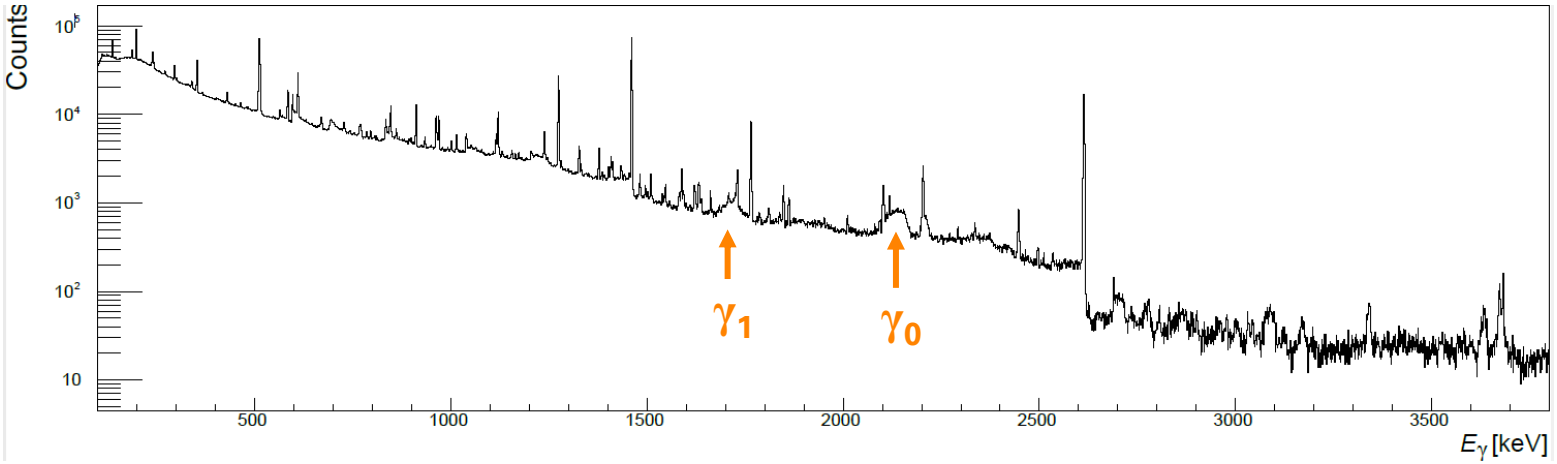


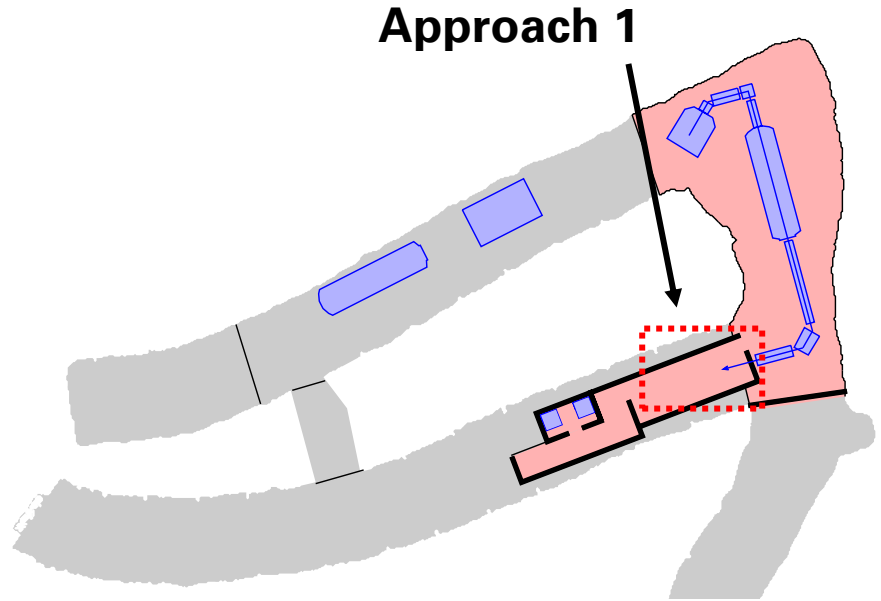
➢ $E_{\gamma_0} \approx Q + E_{cm}$

$\approx$ 1587 keV + 580 keV

$\approx$ 2167 keV

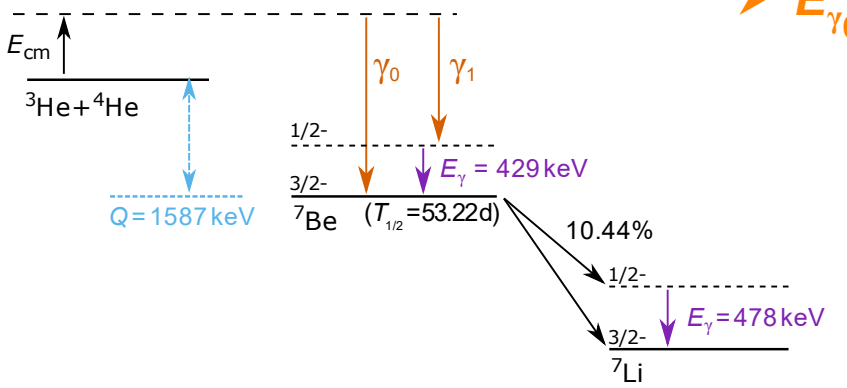




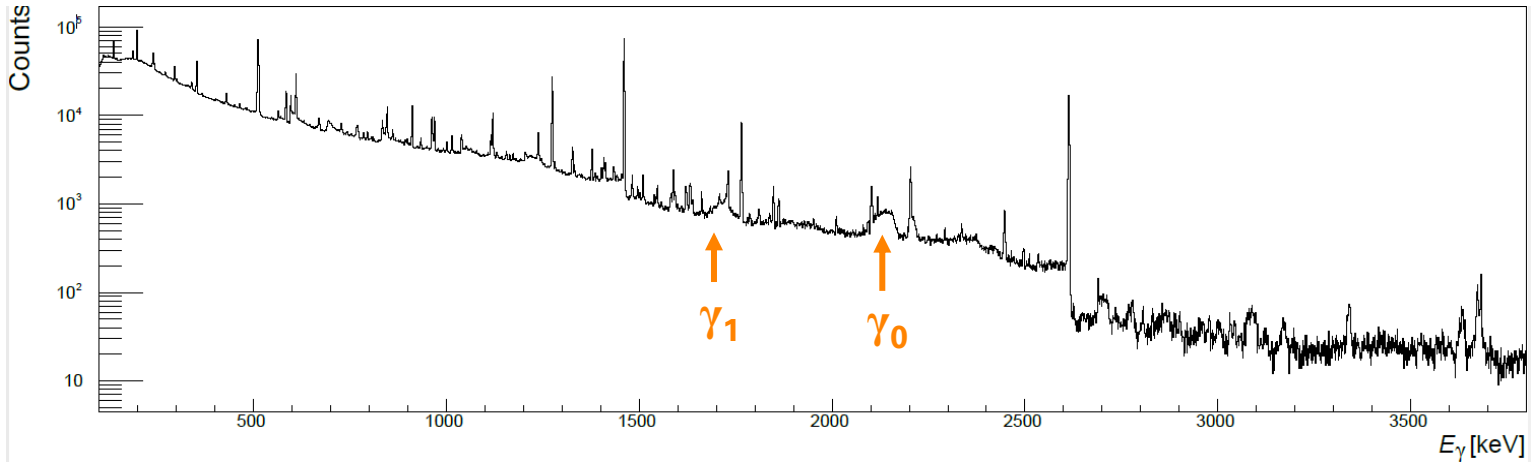


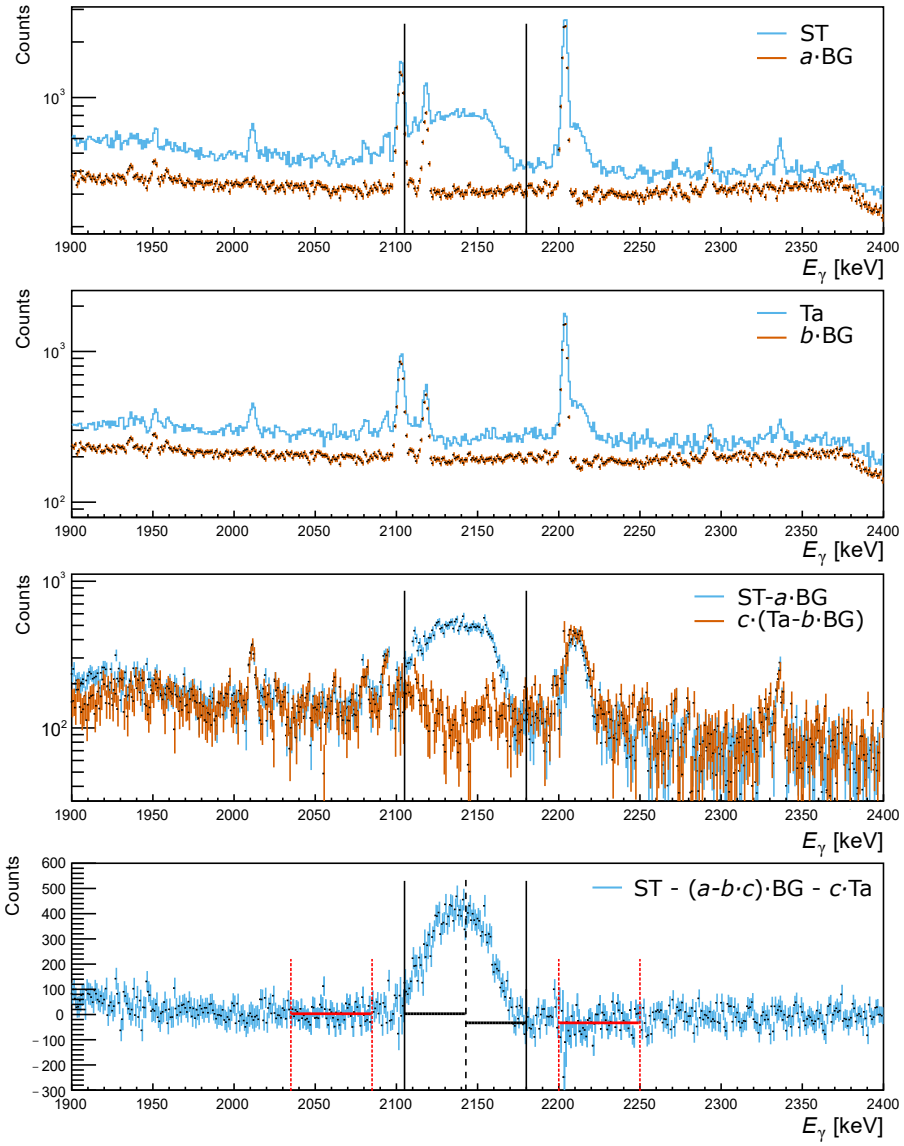
Approach 1: γ-ray angular distribution

$^3He(\alpha,\gamma)^7Be$

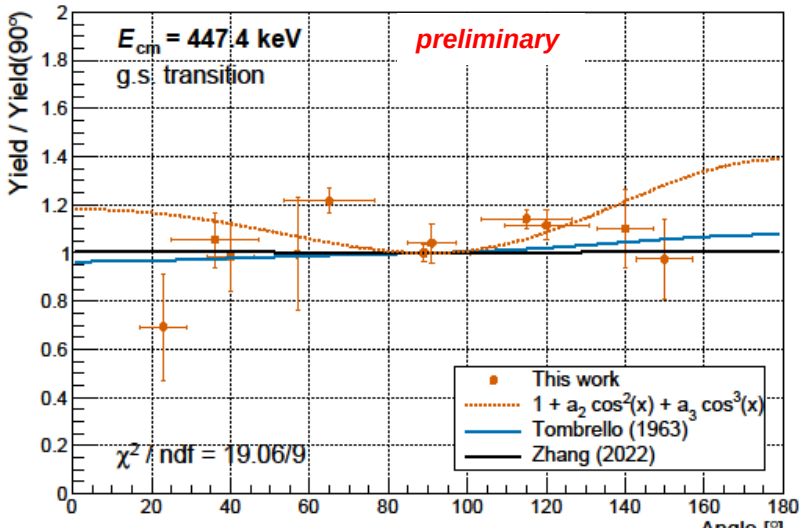


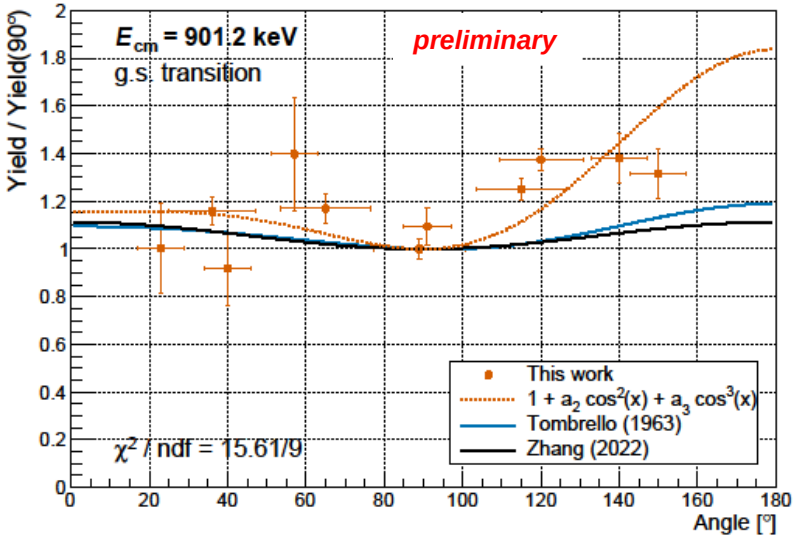
- $E_{\gamma_0} \approx Q + E_{cm}$
  $\approx$ 1587 keV + 580 keV
  $\approx$ 2167 keV

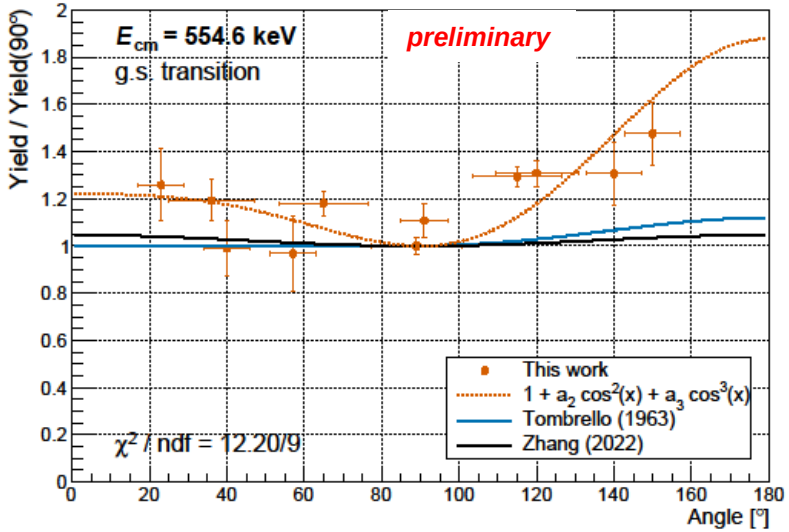


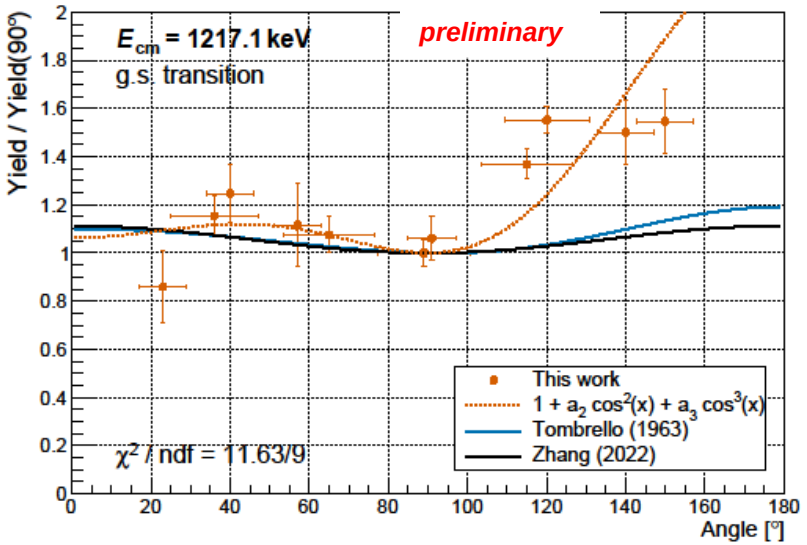


Approach 1: γ-ray angular distribution





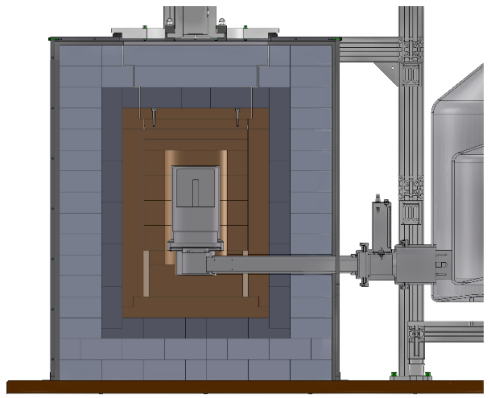




Approach 2 - Germanys most sensitive HPGe detector

Poster by : S. Turkat (B108 – ID 453)

- **HPGe with 163 % relative efficiency**
  - Able to measure samples with µBq
  - Recent publicationn: S. Turkat et al., Astropart. Phys. 148, 102816 (2023)

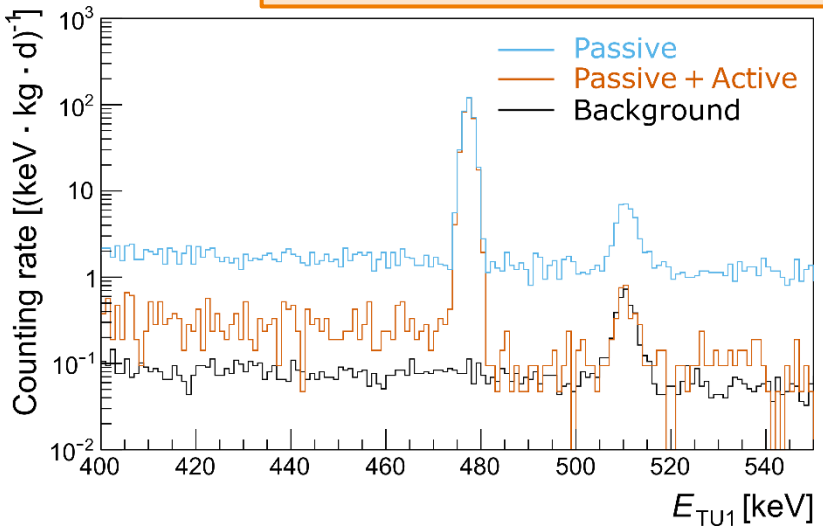


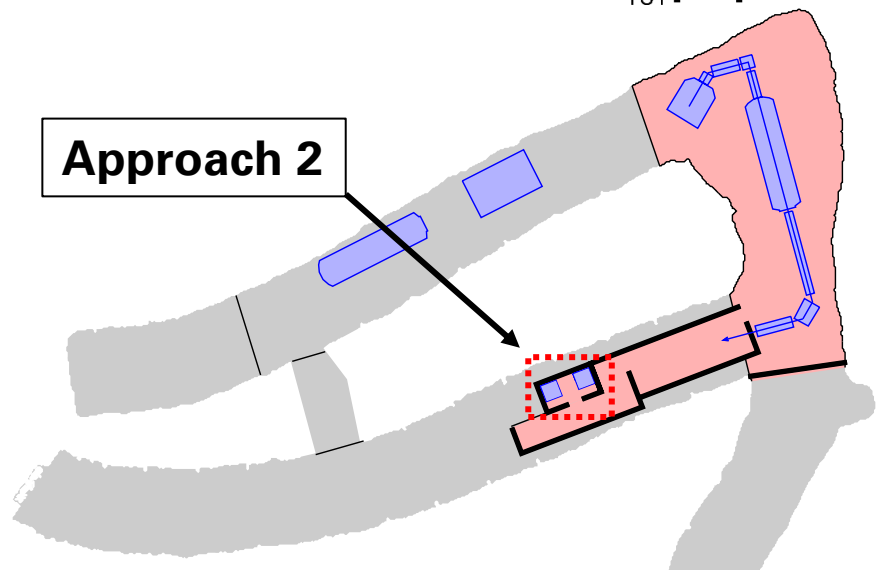
Passive shielding (x1/4300)

- 140 m.w.e. rock overburden
- 40 cm low activity concrete
- N_2 flushed box
- Lead and copper castle

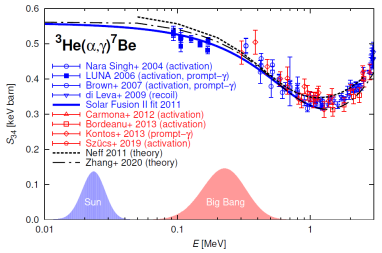
Active shielding (x1/17)

- Five scintillation panels
- Covering all angles



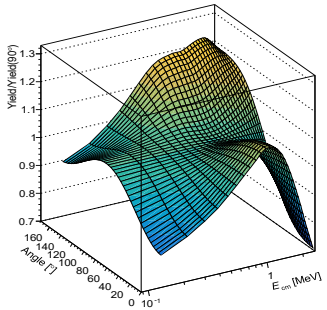


Summary & Outlook



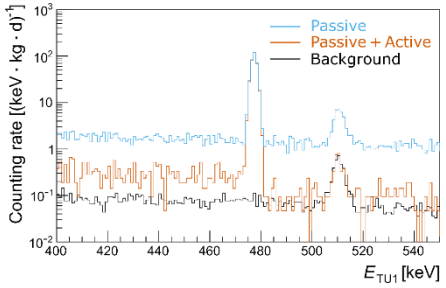
The ^{3}He(α,γ)^{7}Be reaction

- Investigating BBN and solar fusion processes



In-beam analysis

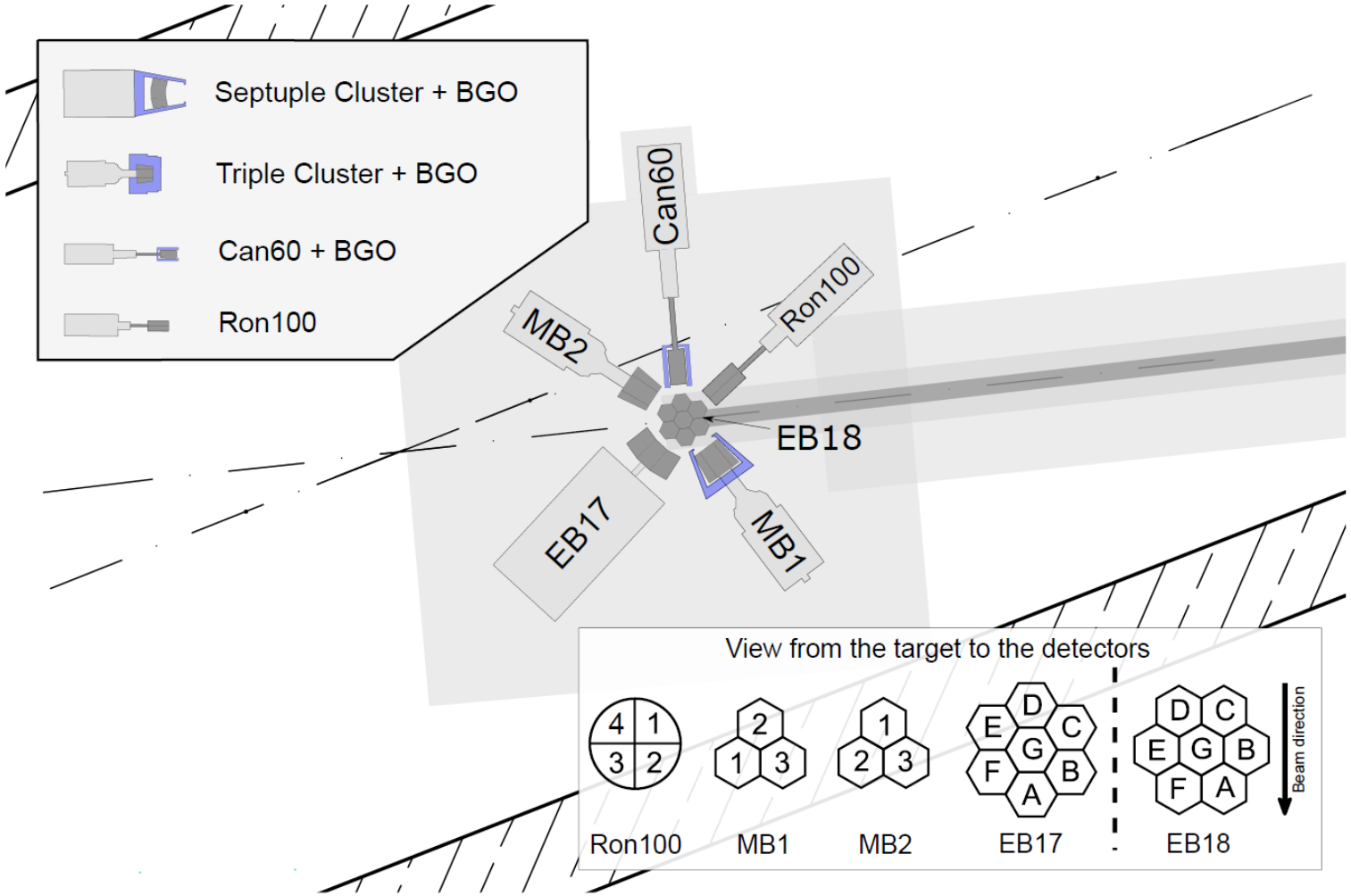
- Analysis of γ-ray angular distribution



Offline analysis

- New ultra-low HPGe counting

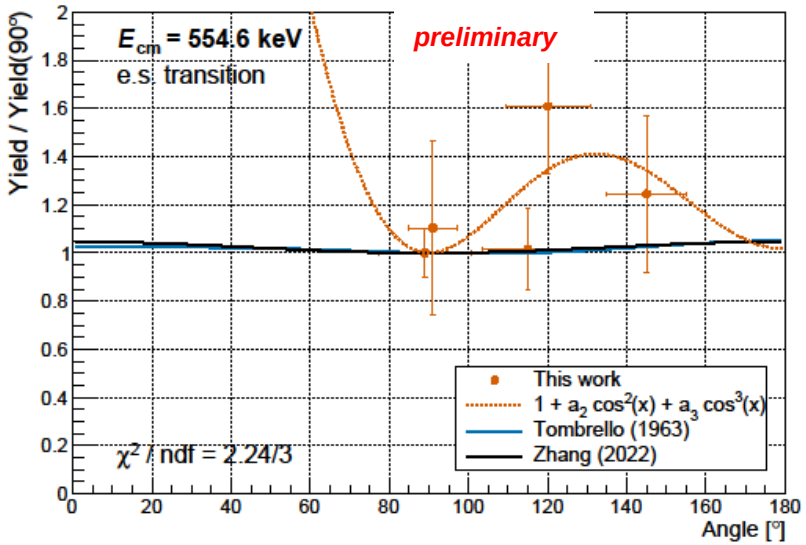
Experimental setup at Felsenkeller

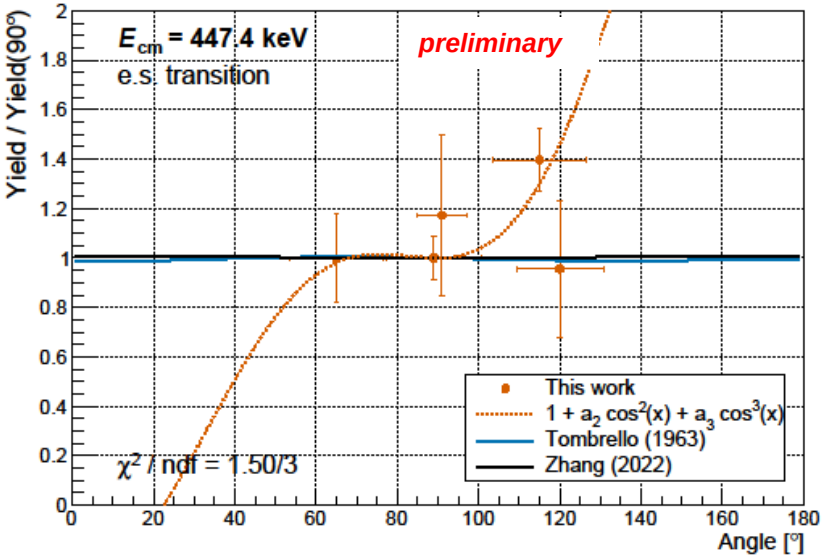


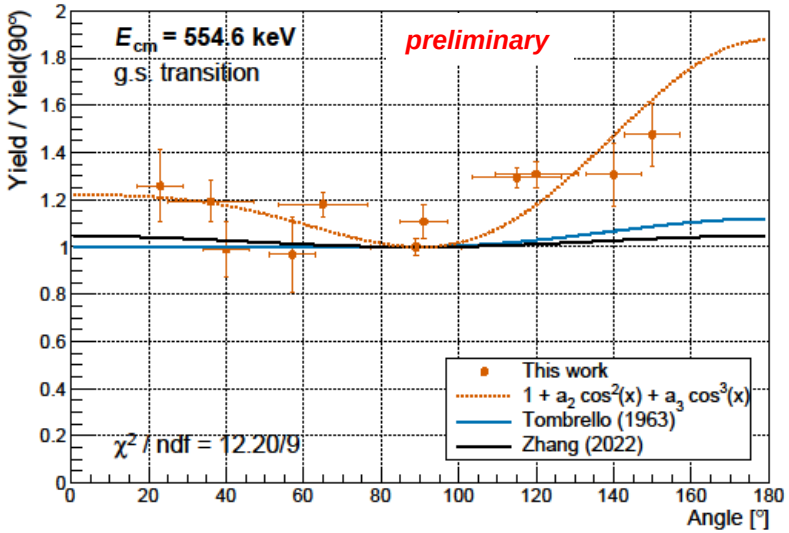
Angle	Detector	Remark
38°	MB2	3×60%
+38°	EB17	7×60% (GAMMAPOOL)
90°	EB18	7×60%, down-looking (GAMMAPOOL)
+90°	Can60	1×60%
-120°	MB1	3×60%
+145°	Ron100	1×100%

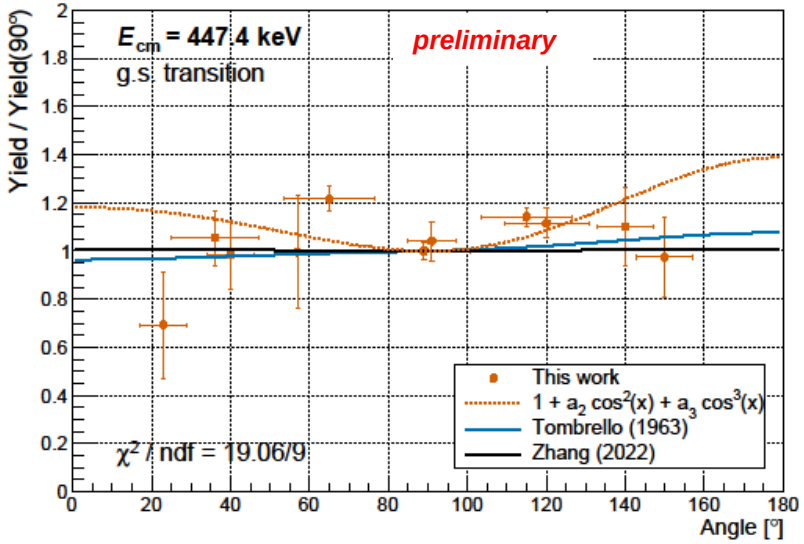
- 5 cm lead shielding
- 40× lower muon flux
- Clean backing to reduce (α,n) reactions

Approach 1: γ-ray angular distribution



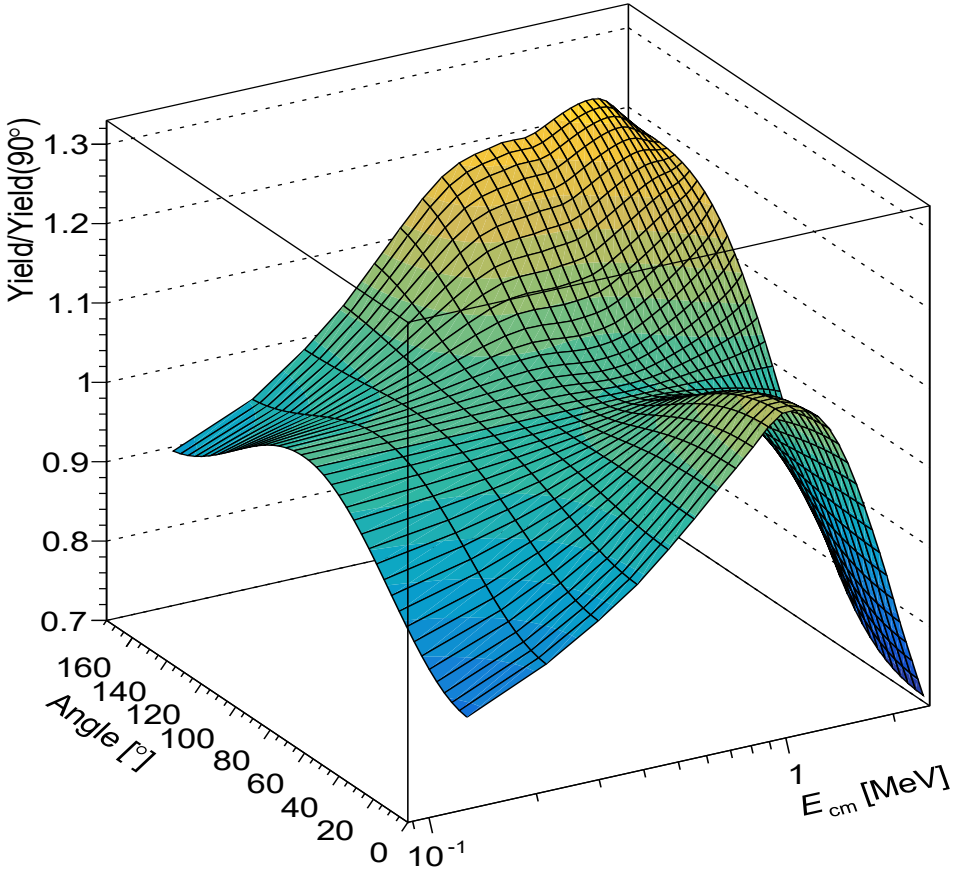






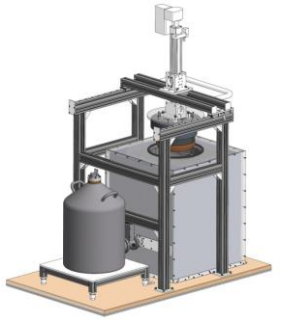
Approach 1: γ-ray angular distribution

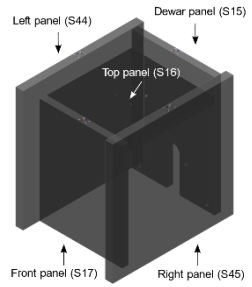
- **Theoretically predicted angular distribution**
  - Tombrello et al., Phys. Rev. 131, 2582 (1963)
  - Further studies by Zhang, Nollett et al.
- **Low energies (BBN window and below)**
  - Preferred perpendicular emission
- **High energies (Around 1MeV)**
  - Preferred forward and backward emission



Based on: T. Tombrello and P. Parker, *Physical Review* 131.6 (1963), p. 2582

Approach 2: Germanys most sensitive HPGe detector





Integrated counting rate [40 keV;2700 keV]

- **Passive:** R = 1982 (3) $kg^{-1}d^{-1}$
- **Passive & active:** R = 116 (1) $kg^{-1}d^{-1}$

Veto efficiency of the active veto

- Efficiency: 99.52(19) %