Felsenkeller shallow-underground accelerator laboratory for nuclear astrophysics

Status report

NAVI Nuclear Astrophysics Virtual Institute

TECHNISCHE UNIVERSITÄT DRESDEN

Partner von DRESDEN concept exzellenz-dresden.de

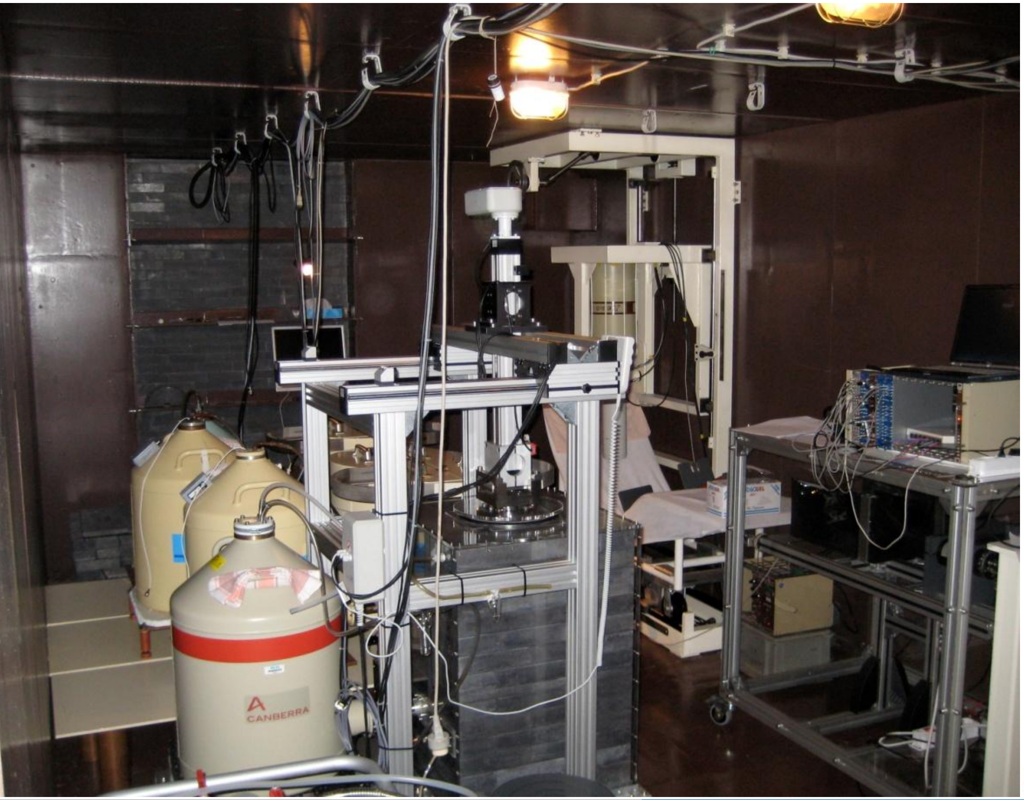
HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Outline

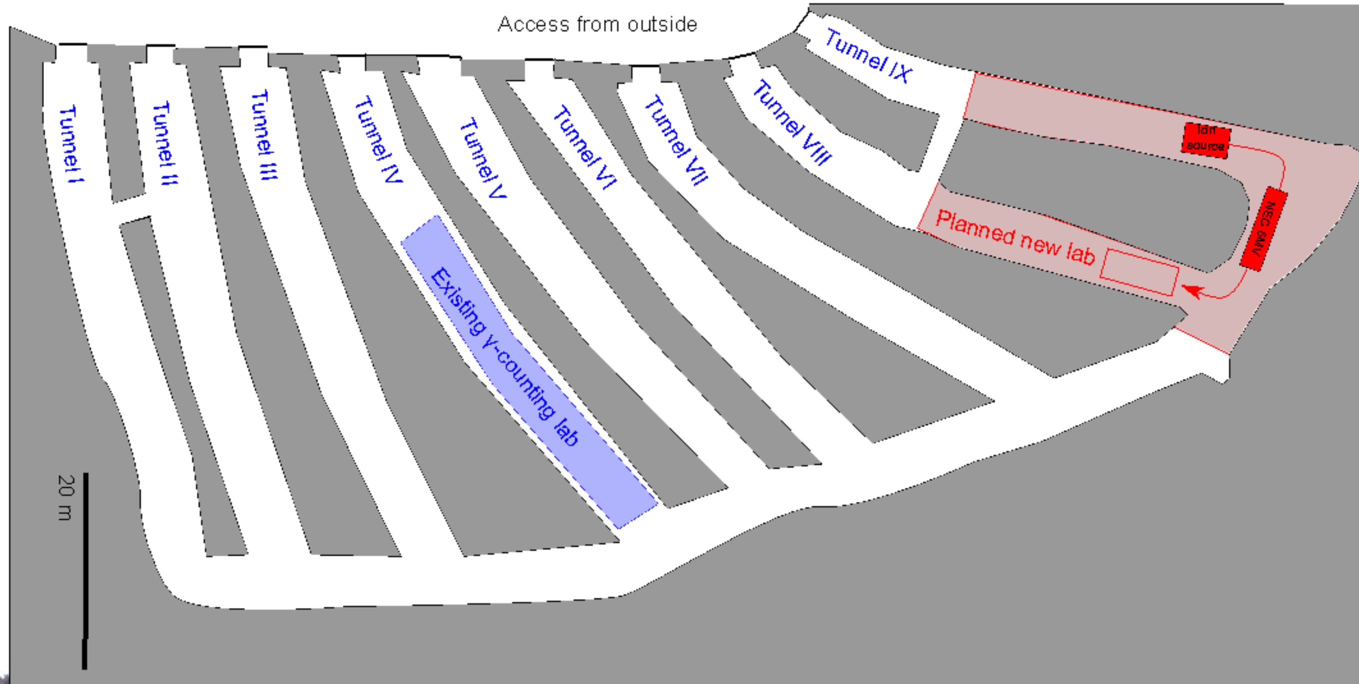
- The Dresden Felsenkeller site
- Different background components in Felsenkeller
- Felsenkeller accelerator status
- Experiments

Dresden Felsenkeller, below 47 m of rock

- γ-counting facility for analytics, established 1982
- Deepest underground γ-counting lab in Germany
- Contract enabling scientific use (since 2009)
- 4 km from TU Dresden, 25 km from HZDR campus

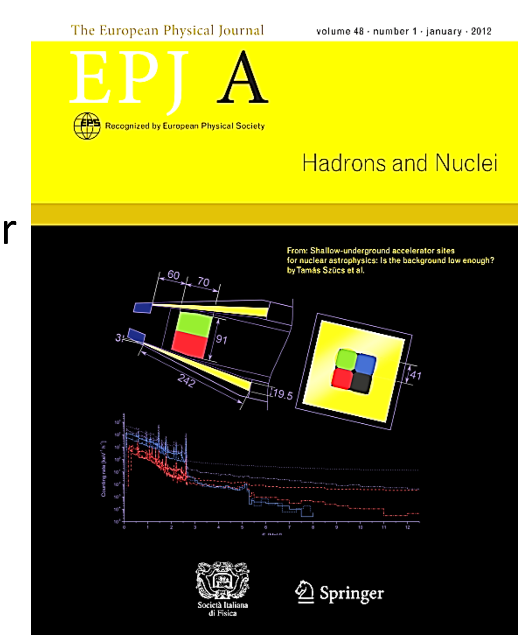


Why not place a used accelerator in Felsenkeller?

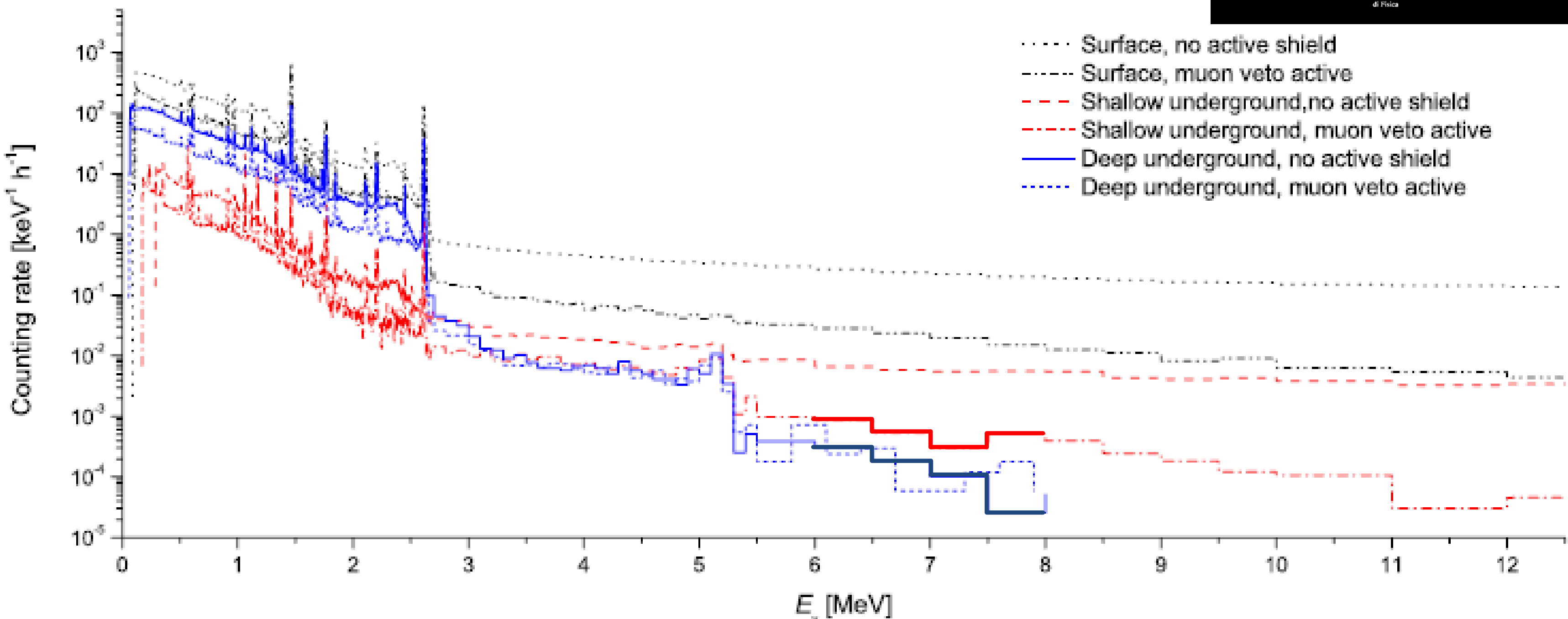


- Industrial area
  (former Felsenkeller brewery)
- Additional space available underground

Background, in a typical HPGe detector for nuclear astrophysics



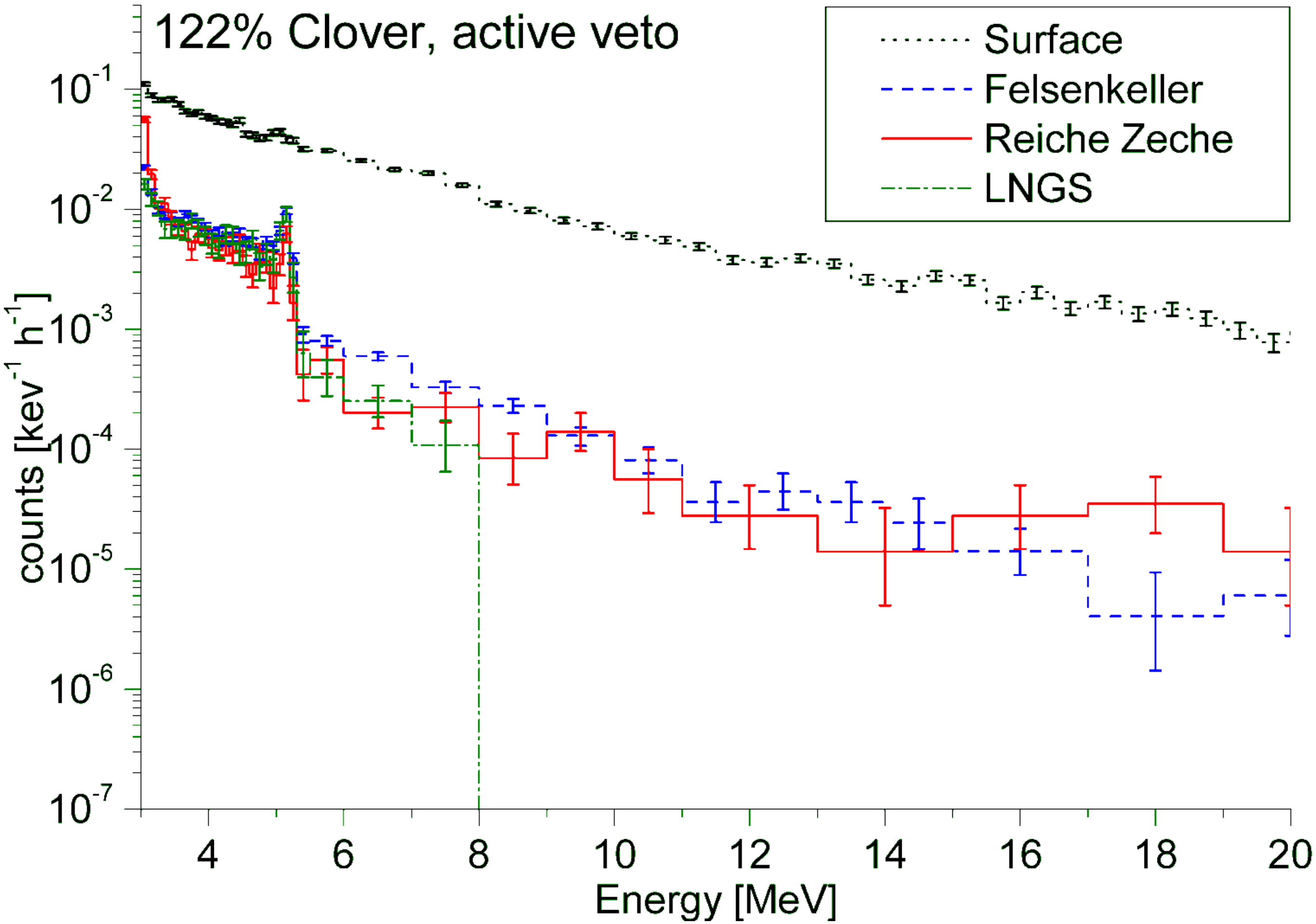
- Combination of active veto and 110 m.w.e. shielding gives a factor of 500 background reduction.
- Final value close to deep-underground background.
- New data at Freiberg mine (400 m.w.e. shielding) confirm and extend this conclusion. [T. Szücs *et al*, EPJA, accepted]



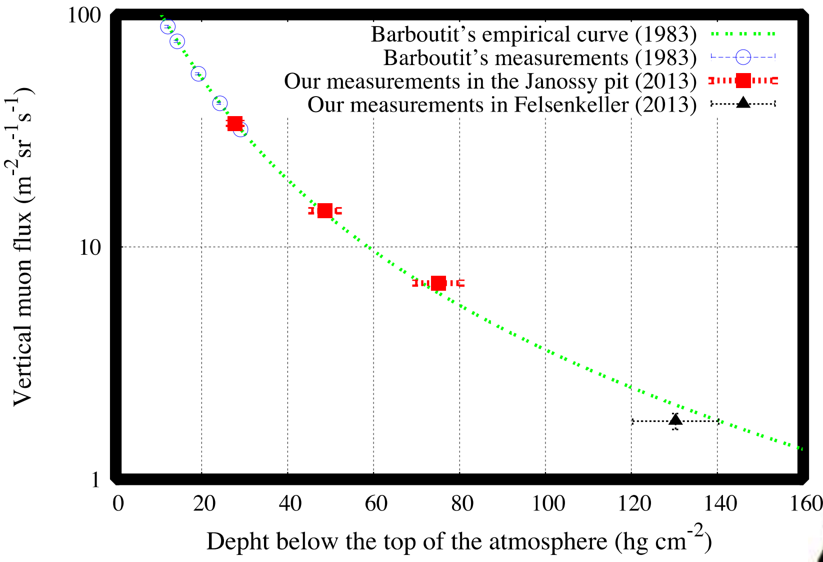
T. Szücs *et al*, EPJA **48**, 8 (2012)

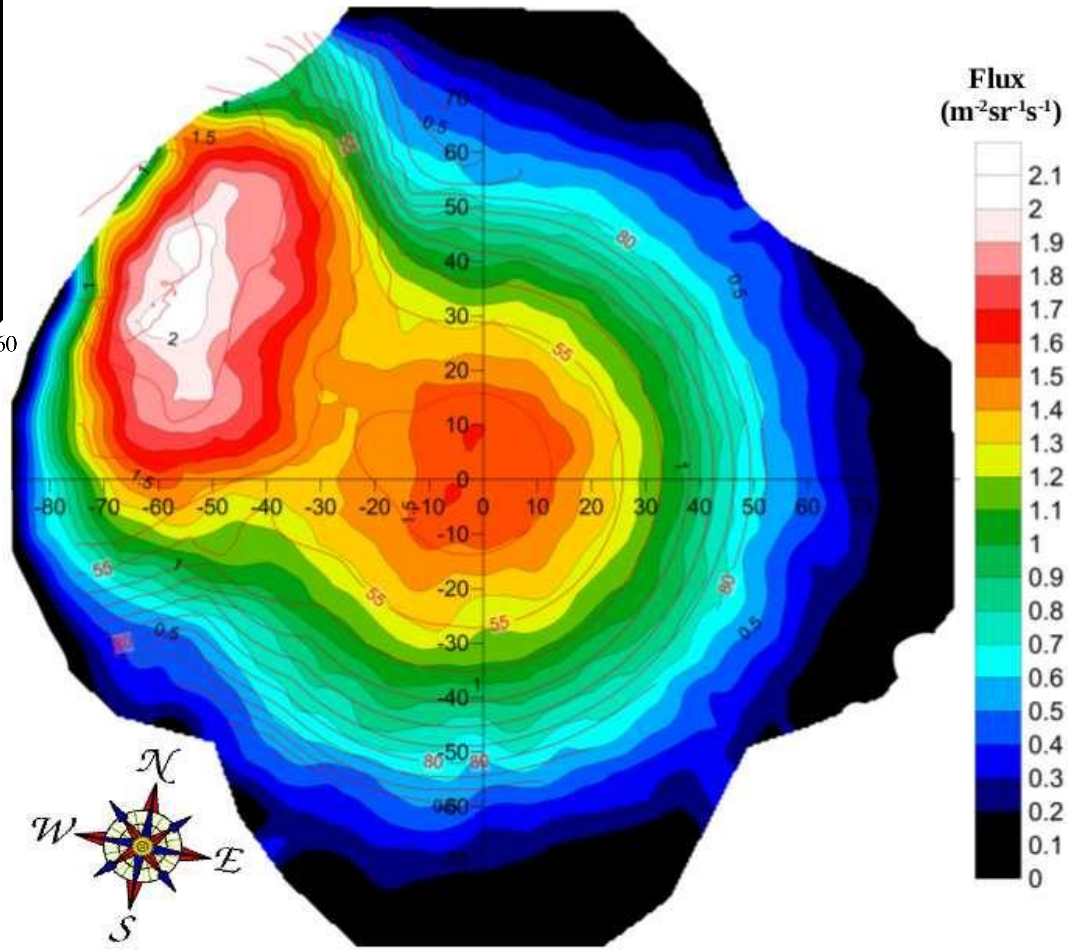
Medium depth underground site: Reiche Zeche, Freiberg/Sachsen

At Freiberg mine (Reiche Zeche, 400 m.w.e. shielding) the vetoed background is consistent with that at deep underground (LNGS) [T. Szücs *et al*, EPJA, accepted]



Felsenkeller, muon flux measurement





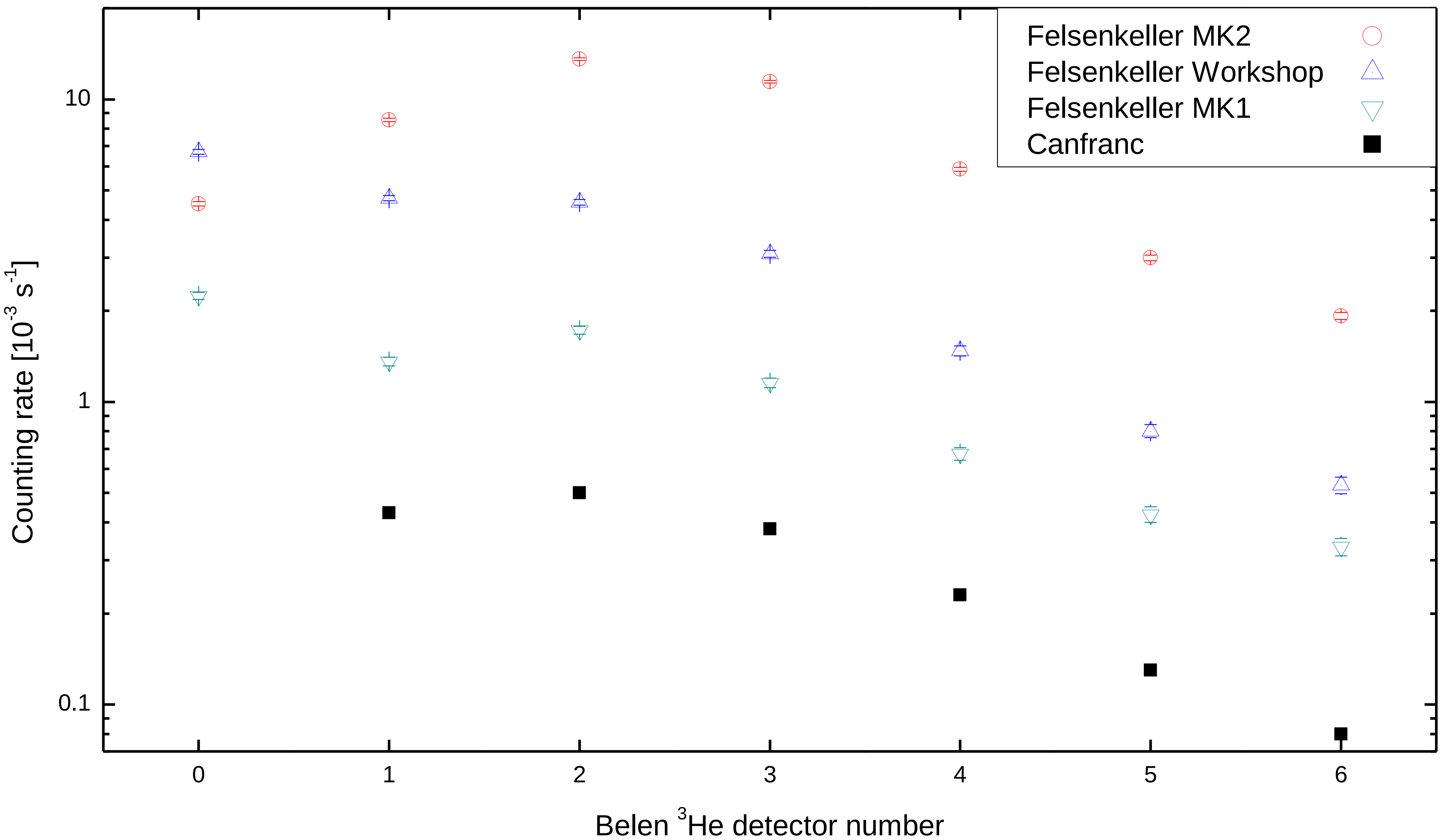
Rock overburden 130 m.w.e., slightly higher than in the nearby existing low-activity lab (110 m.w.e.)

Neutron background at Felsenkeller

- ^{3}He counters from BELEN
- Polyethylene matrices with different thickness to gain energy information
- Data taking in three different room at the Felsenkeller counting lab is done
- The same setup has been used at deep underground at Canfranc, Spain

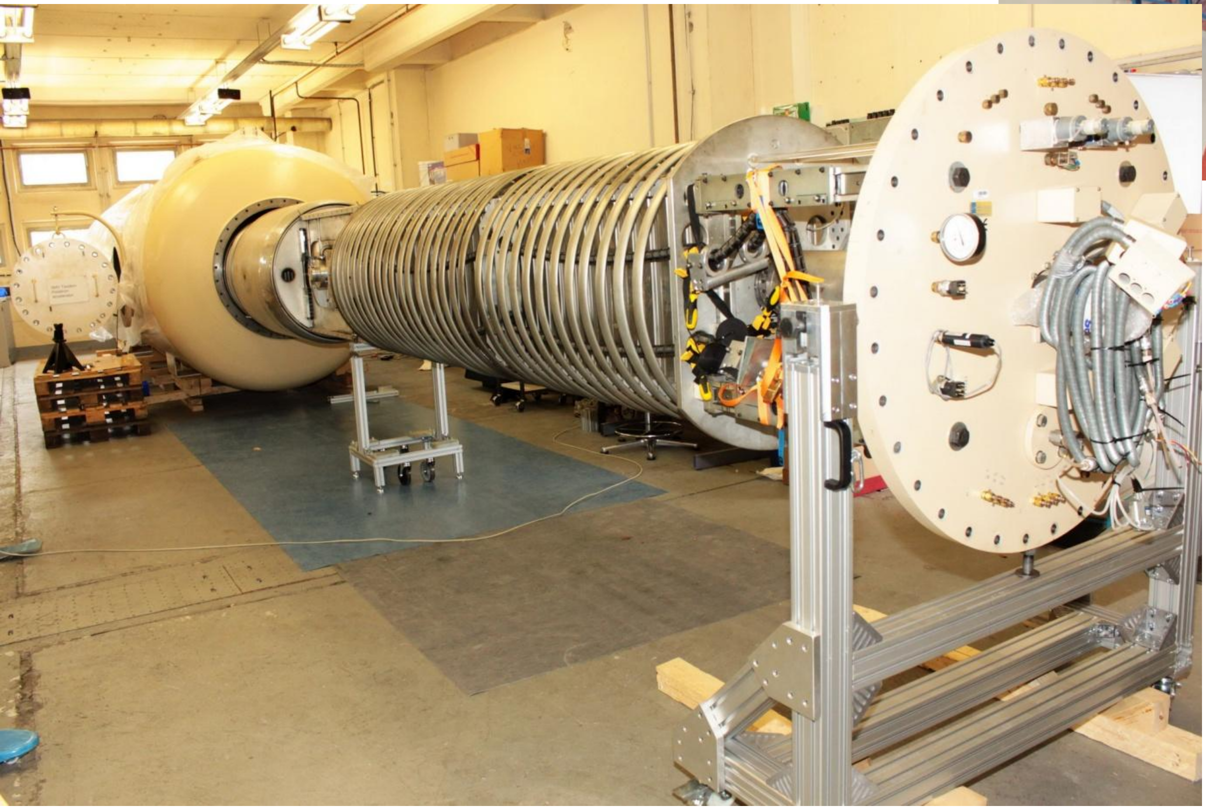
  [Jordan et al, Astropart. Phys. **42**, 1 (2013)]

Neutron background at Felsenkeller, measured rates



5 MV Pelletron

- High voltage tank opened
- Pellet chains dismounted and cleaned
- High voltage terminal dismounted

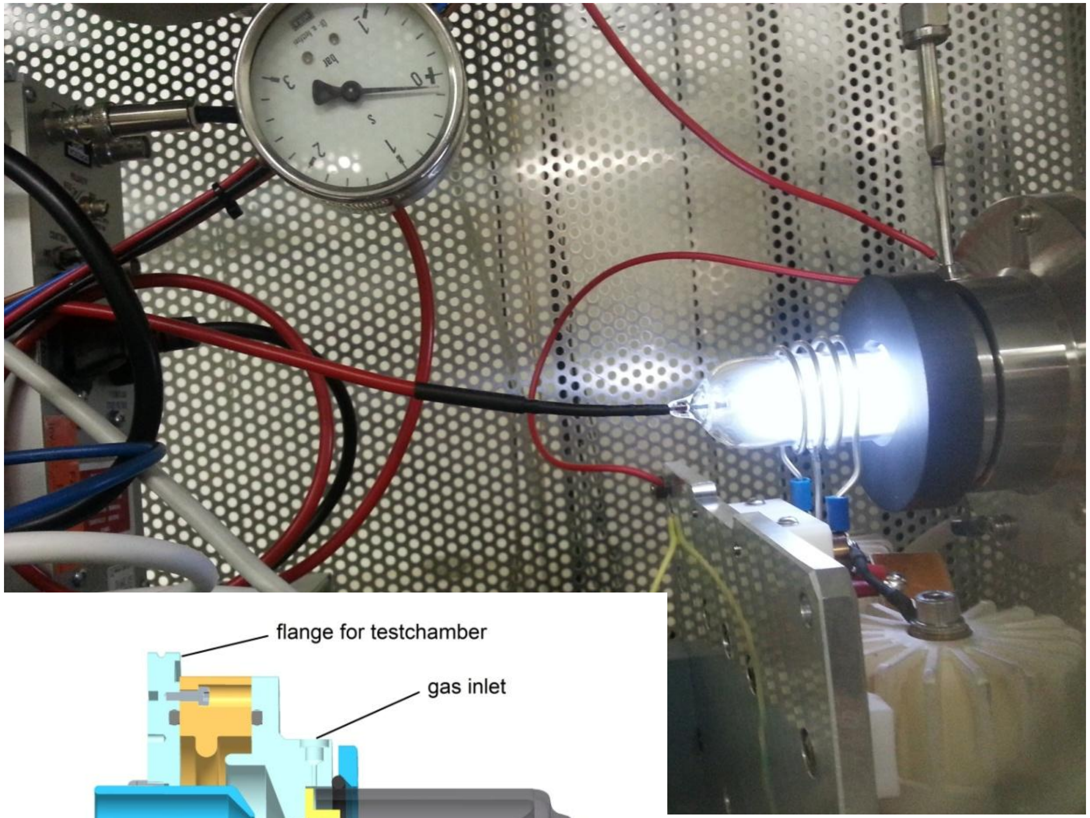


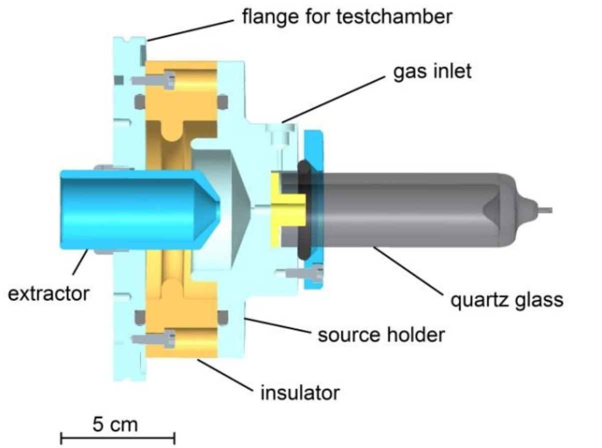
MC-SNICS 134 sputter ion source

- 100 µA C^- beam
- 100 µA H^- beam
- No useful He^- beam

Radio frequency ion source, to be installed on high voltage terminal

- Home-made model, based on RF ion source on terminal of HZDR 2 MV van de Graaf accelerator, in operation since late 1970s (!)
- RF emitter based on Russian high power valves
- Electrostatic deflector in order to send the beam to the beam line still under development
- Working plasma discharge
- Tests show successful extraction of 100 µA He^+ current, aimed for 100 µA H^+, He^+





Construction, funding, staff

Total investment needed+funded 1 M€

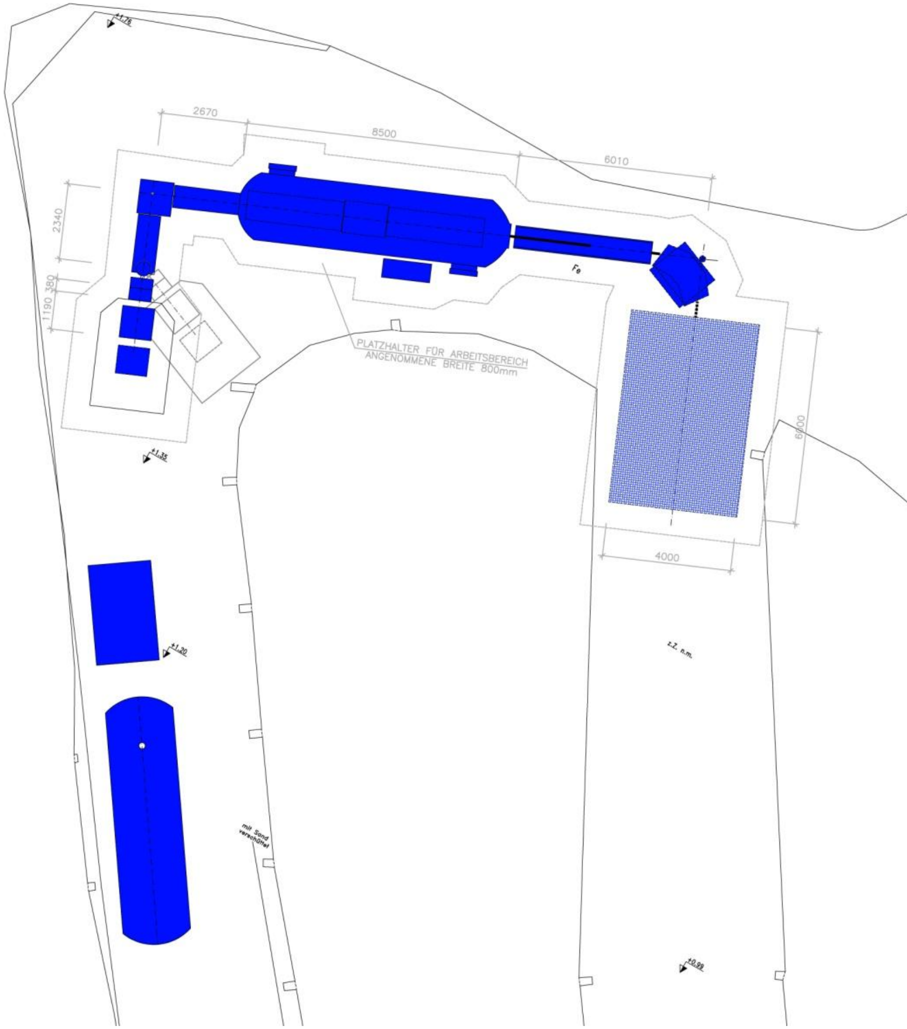
- Purchase and transport of Pelletron (spent)
- Construction (TU Dresden, Excellence Initiative „support the best“, K. Zuber, approved 2014)
- Planning, infrastructure, reserve (HZDR, Vienna, and NAVI; pledged)

Running cost will be covered by HZDR

- Rent for the tunnel
- Electricity, liquid nitrogen
- Scientist
- Engineer

Executive project

- Drafts exist, to be updated by spring 2015
- Permissions hoped for by fall 2015
- Construction phase should be 3 months
- Beam available starting spring 2016



NAVI TECHNISCHE UNIVERSITÄT DRESDEN DRESDEN concept HZDR

Felsenkeller accelerator: access, use, program

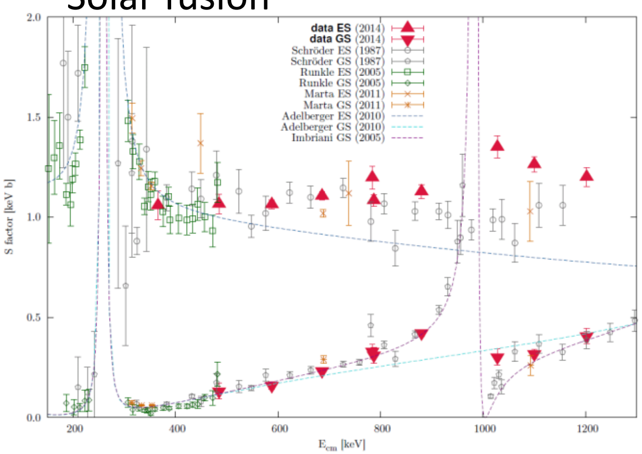
Collaboration between HZDR and TU Dresden

- Kai Zuber (TU Dresden)
- Daniel Bemmerer (HZDR)
- Independent scientific advisory board to advise on program, users, and development

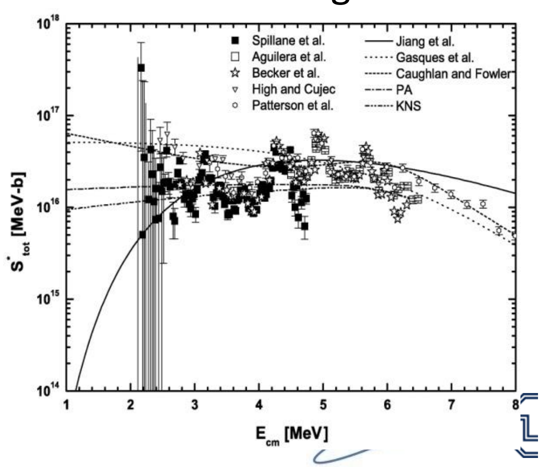
Planned use

- In-house research by HZDR and TU Dresden
  - Solar fusion — Day one experiments $^{3}He(\alpha,\gamma)^{7}Be$ and $^{14}N(p,\gamma)^{15}O$
  - Carbon burning — Day two experiment $^{12}C(^{12}C,p)^{23}Na$
- Outside scientific users from any field of science welcome, no charge for beam time
- No (more) plan for partial commercial use

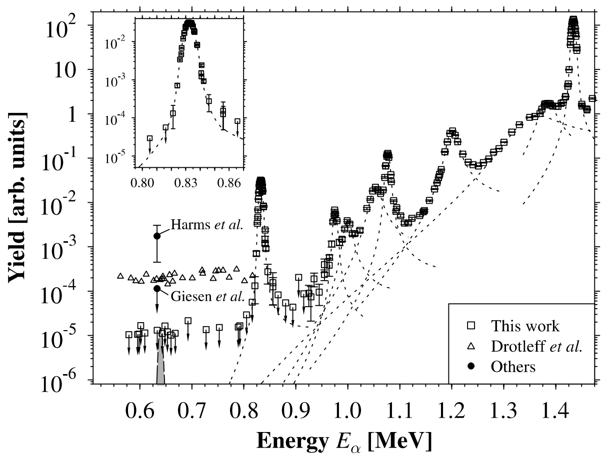
Solar fusion



Carbon burning



s-process neutron sources



Collaboration HZDR – GANIL : Level widths of ^{15}N

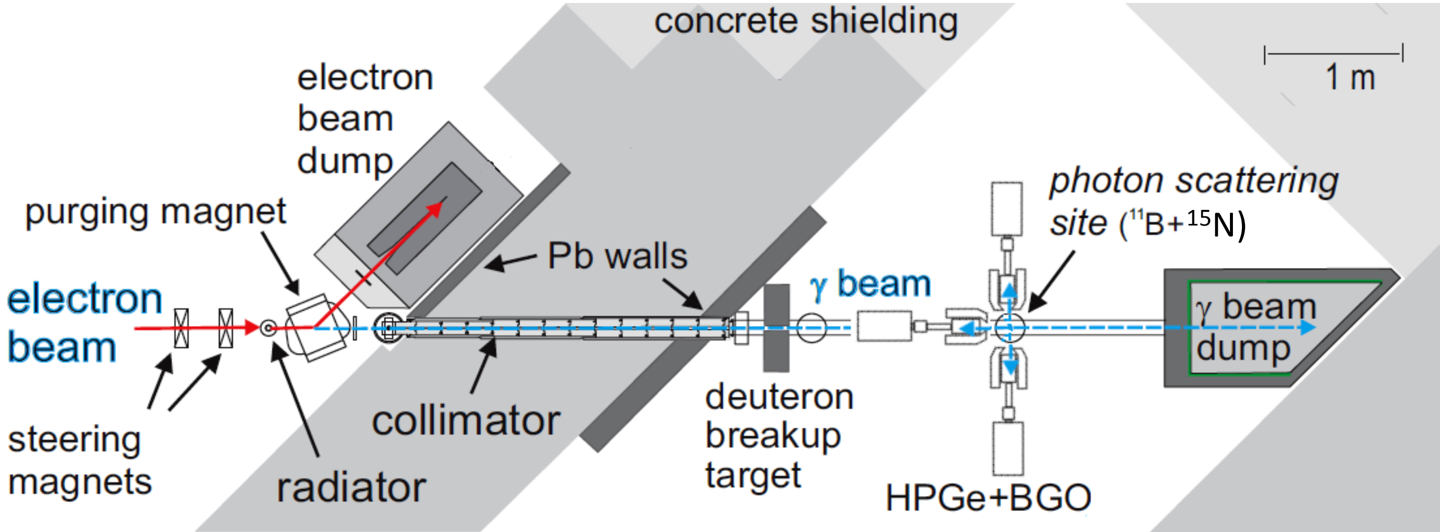
- ^{15}N is the mirror of the astrophysically important ^{15}O
- Level lifetimes by DSAM (Doppler Shift Attenuation Method) were recently measurement in ^{15}N and ^{15}O [1]
- ^{15}N levels are used to validate the analysis method [1]
- Latest compilation from 1991 [2]
- Literature values are based mostly on one NRF (Nuclear Resonance Fluorescence) measurement [3] from 1981, with limited precision in some cases
- Aim of the measurement to provide better reference data for the DSAM
- Update the literature by more precise level width data

[1] C. Michelagnoli *et al.*, Phys. Rev. Lett., submitted
[2] F. Ajzenberg-Selove, Nucl. Phys. A **523**, 1 (1991)
[3] R. Moreh *et al.*, Physical Review C **23**, 988 (1981)

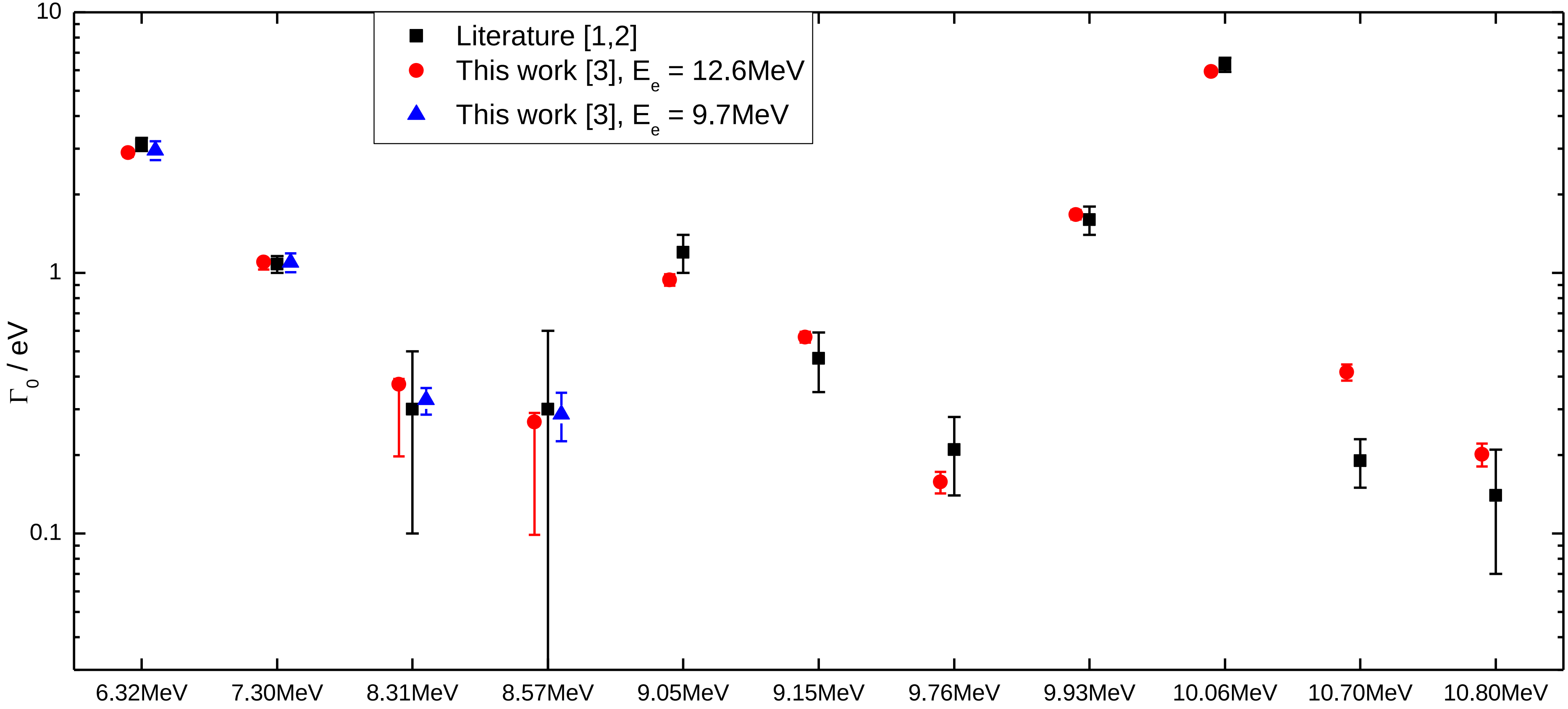
Collaboration HZDR – GANIL :

The $^{15}N(\gamma,\gamma')$ experiment @ HZDR

- The gamma scattering cross section is proportional to the level width
- Levels were excited by bremsstrahlung
- Scattered γ-rays detected 4 HPGe with BGO anticompton shield at 2 angles: 127° and 90°
- Targets were solid nitrogen compounds enriched in ^{15}N



Ground state gamma widths in ^{15}N

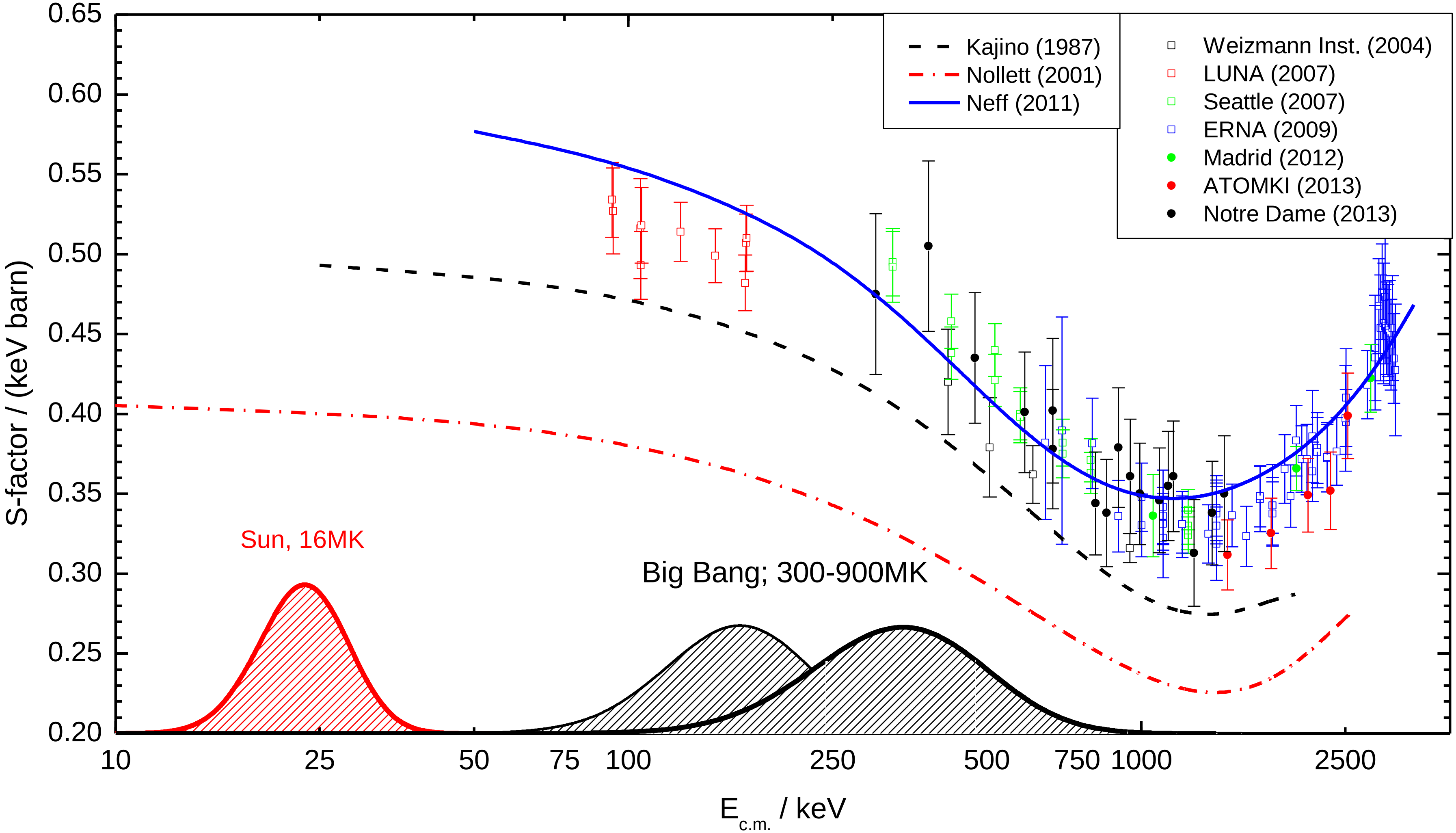


[1] R. Moreh *et al.*, Physical Review C **23**, 988 (1981)

[2] F. Ajzenberg-Selove, Nucl. Phys. A **523**, 1 (1991) (compilation)

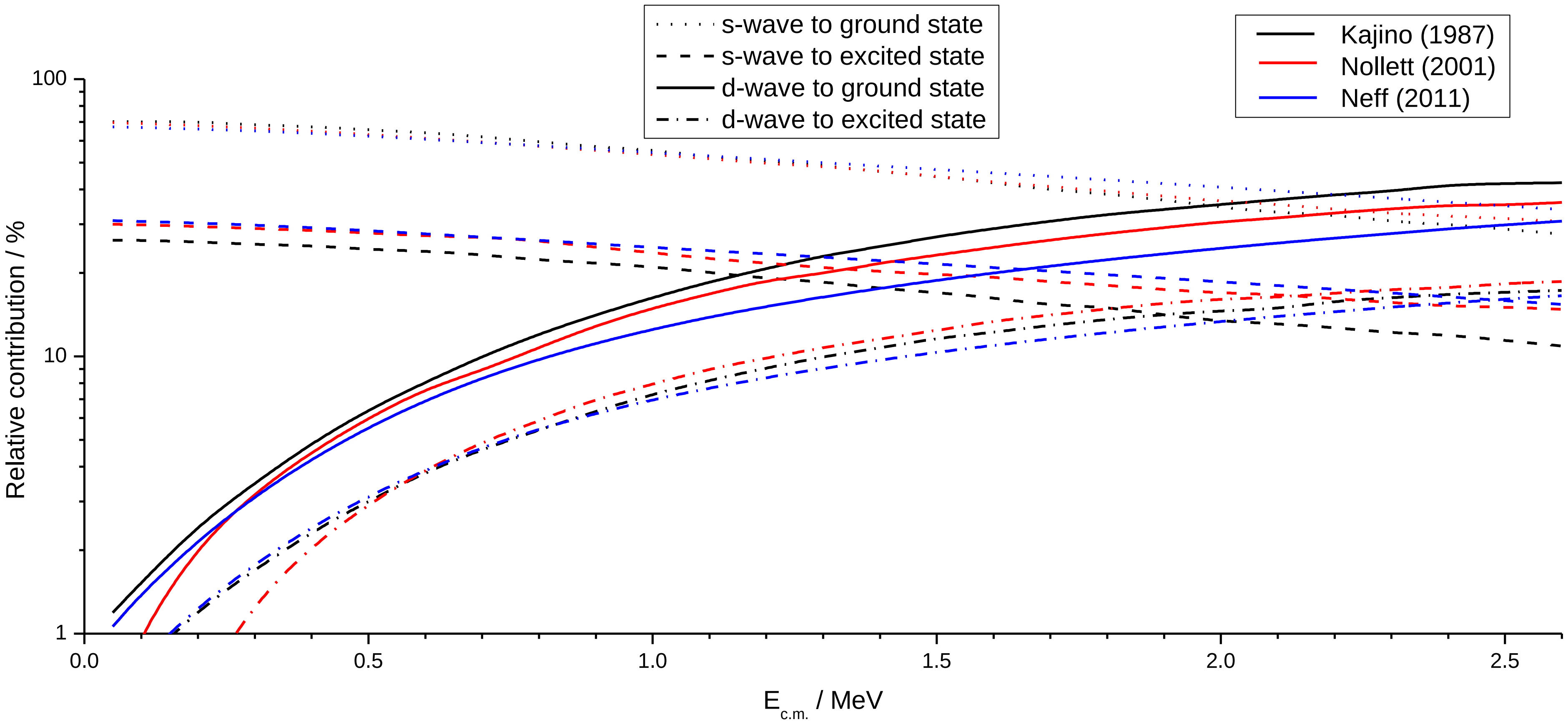
[3] T. Szücs, C. Michelagnoli *et al*, in preparation

Planned first experiment at Felsenkeller (theory support from GSI): $^3He(\alpha,\gamma)^7Be$ prompt gamma ray angular distribution for solar fusion



Planned first experiment at Felsenkeller (theory support from GSI): $^{3}He(\alpha,\gamma)^{7}Be$ prompt gamma ray angular distribution for solar fusion

- Theoretical calculations predicts different s- and d-wave contribution to the direct capture



Planned first experiment at Felsenkeller (theory support from GSI): $^3He(\alpha,\gamma)^7Be$ prompt gamma ray angular distribution for solar fusion

- Experimental angular distribution data will constrain theoretical investigations
- Interpretation of the data and comparison with theoretical work will be done in collaboration with T. Neff and H. Feldmeier (GSI)

Summary

- Gamma, muon and neutron background in Felsenkeller have been measured
- Felsenkeller accelerator will be available early 2016 with H, He and C beams
- $^{15}N(\gamma,\gamma')$ experiment have been done in collaboration between HZDR and GANIL
- $^{3}He(\alpha,\gamma)^{7}Be$ prompt gamma ray angular distribution will be measured at Felsenkeller with theory support from GSI