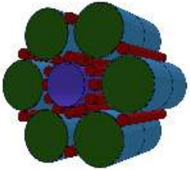
^{22}Ne(α, n)^{25}Mg deep underground
IAEA Technical Meeting on (alpha,n) Reaction Nuclear Data Evaluations and Data Needs



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European Research Council
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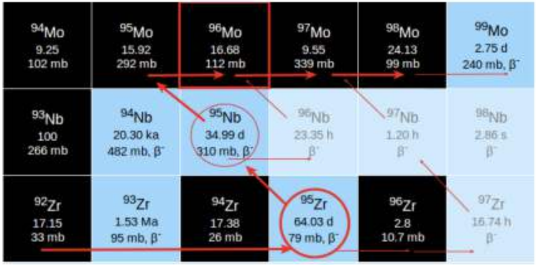
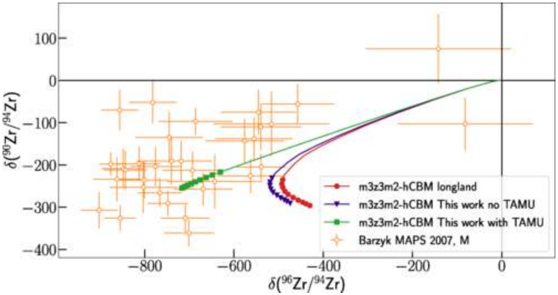
^{22}Ne$(\alpha, [n, \gamma])^{25,26}$Mg

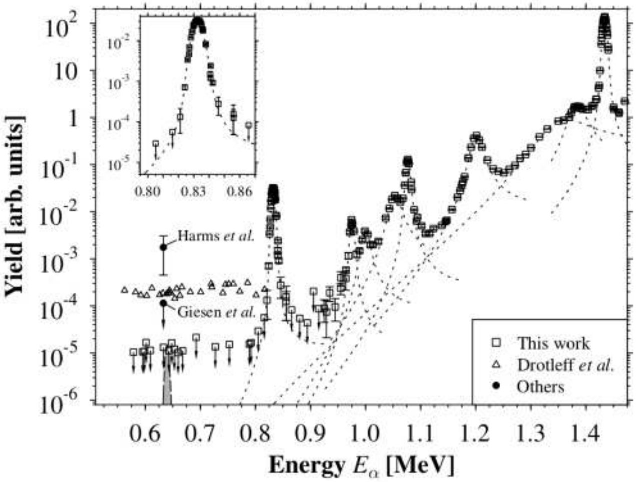




Adsley et al. PRC 103, 015805

- ^{22}Ne$(\alpha, n)^{25}$Mg contributes during late stages of main s process
- Determines branch point population
- Main source for weak s process
- Mg isotope observations in stellar atmospheres

(Direct) State of the Art



- Jaeger et al. 2001
- External background limiting factor ($>$ 100 cts/hour)

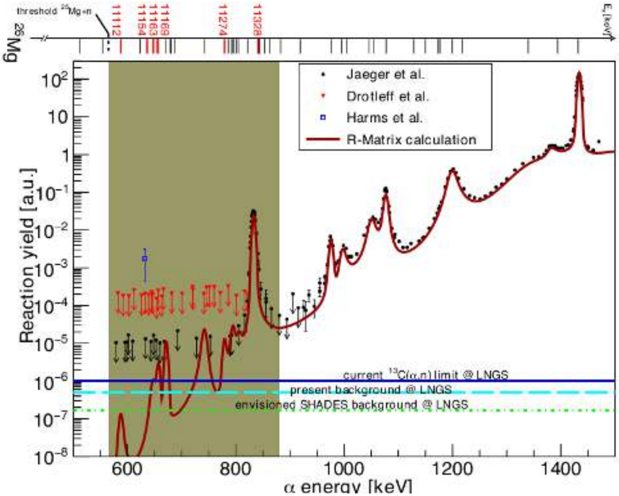
Low-energy states

Table 1. Properties of states in ^{26}Mg between the neutron threshold and the 832 keV resonance. Values taken from [15], except for the last row, which is from [14].

E_n [keV]	E_x [keV]	E_α [keV]	Jπ	Neutron width [eV]
19.92	11112	589	2+	2095
72.82	11163	649	2+	5310
79.23	11169	656	3-	1940
187.95	11274	779	2+	410
194.01	11280	786	3-	1810
243.98	11328	843 ?	?	171
235 [14]	11319	832	2+	Total width = 250 eV

- nTOF study of energies and neutron widths (Massimi et al. PLB 768 (2017), 1)
- 832 keV res still a bit unclear w.r.t. n/α channel, energy
- No α widths are known
- Many other indirect data campaigns, not conclusive

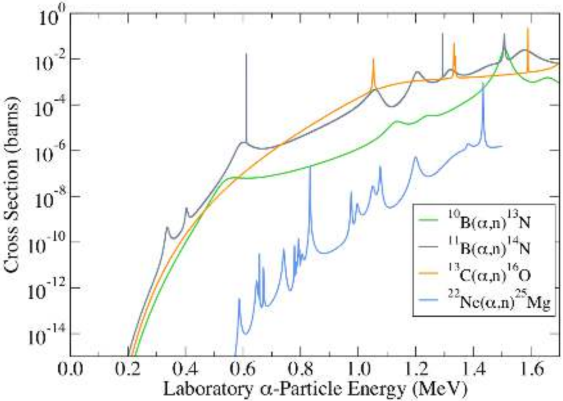
$^{22}Ne(\alpha, n)^{25}Mg$



R matrix courtesy of R. J. deBoer, University of Notre Dame/JINA

- Capabilities on surface exhausted (20+ years since last data)
- Current lowest data 2 reactions/minute
- Covered one resonance close to Gamow
- Many states that can contribute
- **300 keV of upper limits. . .**

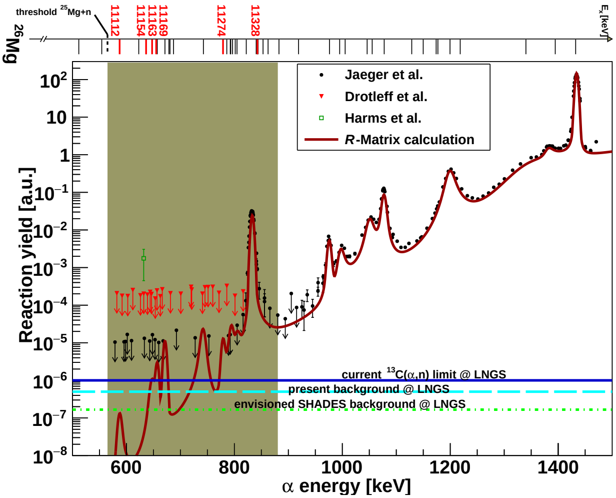
Beam-induced backgrounds



- Q-values:
  - ^{22}Ne = - 478 keV
  - ^{10}B = 1059 keV
  - ^{11}B = 158 keV
  - ^{13}C = 2216 keV

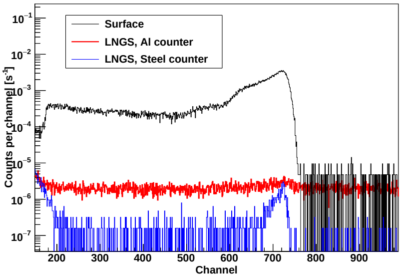
At least 600 keV gap - any kind of energy ID helps

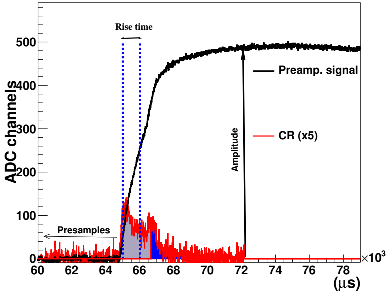
What to do?



- Suppression/identification of beam-induced background
- Drastic external background reduction
- Large beam current increase
- → measure underground
- → use new MV accelerator at INFN-LNGS Bellotti Ion Beam Facility

Background reduction





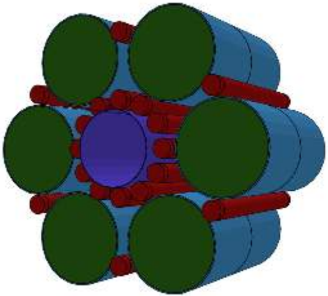
- Deep underground @ LNGS: Suppression of (thermal) neutron background by > 1000
- Additional clean detector material & PSD
- Extended gas target with enriched ^{22}Ne
- Coincidence/Anticoincidence (at high count rates)
- Total background $\approx$ 1 count/hour

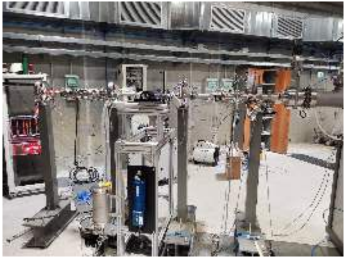
New MV accelerator

Ion specie	Beam intensity (eμA)	
	TV range 0.3 MV–0.5 MV	TV range 0.5 MV–3.5 MV
$^{1}H^{+}$	500	1000
$^{4}He^{+}$	300	500
$^{12}C^{+}$	100	150
$^{12}C^{+2}$	60	100

- Specifically designed to fit nuclear astrophysics needs
- Reaction rates of $< 1/\text{hour}$:
  - Beam current ($\approx 5\times$ Jaeger et al.): push signal-noise ratio
  - Current stability: measurements of the order of weeks
  - Energy stability: must not drift over long periods
- 300 - 3500 kV: cover entire astrophysical energy range
- Sen et al. NIM B 450 (2019), 390

Measurement strategy





- Need to measure very low event rates
- Require some sort of energy sensitivity
- Hybrid detector array: ^{3}He counters & liquid scintillator
- Coated apertures
- High efficiency + partially energy sensitive
- Gas target (recirculating) for long, uninterrupted runs

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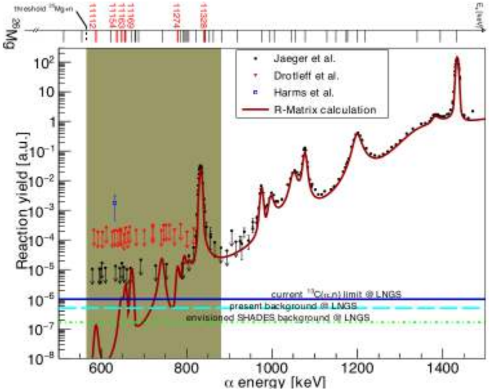
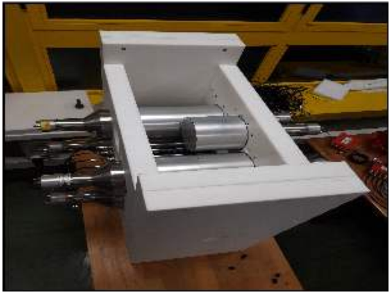
Goals



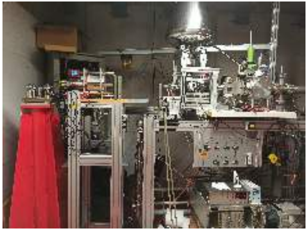
- Cover from threshold to 3.5 MeV
- Aim at two orders of magnitude improvement
- Efficiency determination with $^{13}C(\alpha, n)^{16}O$ (underground)
- Efficiency determination with $^{51}V(p, n)^{51}Cr$ (surface)
- Comprehensive *R* matrix analysis
- Perform nucleosynthesis calculations with new data

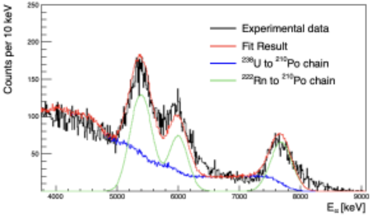
Status I

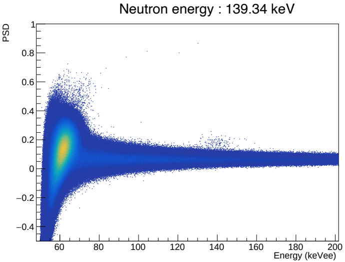


- 5(+1)-year, since February 2020
    - 1st target characterisation at CIRCE
    - Detector background investigated
    - Detector characterisation at FRANZ
- Assembled at LNGS in July/August
- Underground campaign at LUNA MV
- Data evaluation and astrophysical impact - collaboration with M. Pignatari/Budapest

Status II

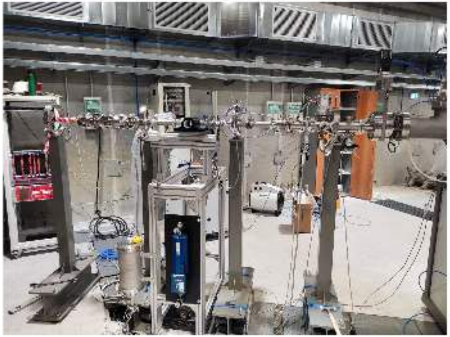


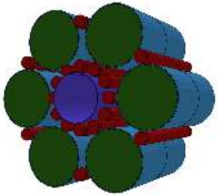




- Detector background investigated - submitted
- Detector characterisation at FRANZ - under analysis

Summary





- Steady influx of indirect data, need some direct input
- Push direct cross section into Gamow energy with SHADES
- Experimental campaign started last week - to continue through 2024
- IBF is a user facility - yearly proposal submission
- Strict neutron production limit of 2000/s