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HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

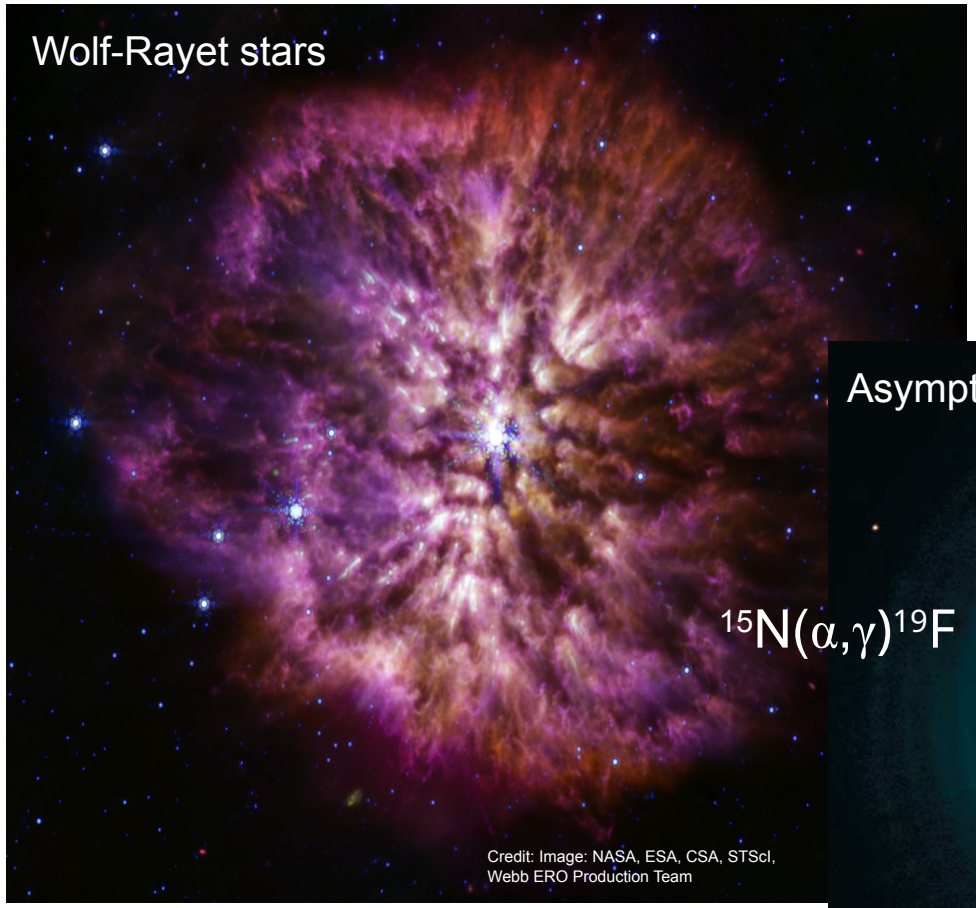
Low energy resonances in the $^{15}N(\alpha,\gamma)^{19}F$-reaction

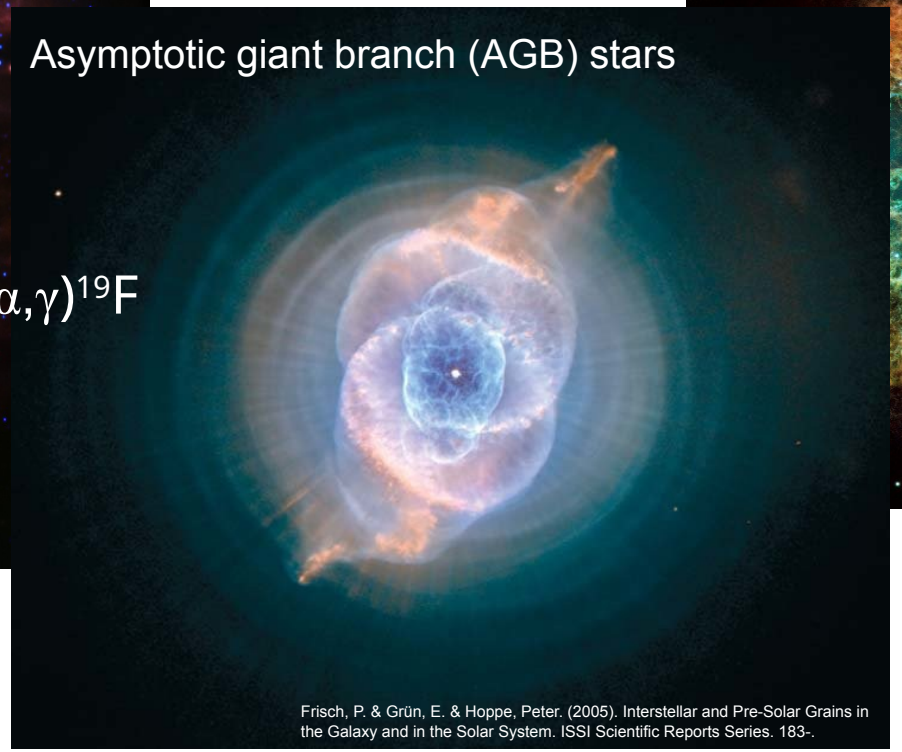
Peter Hempel

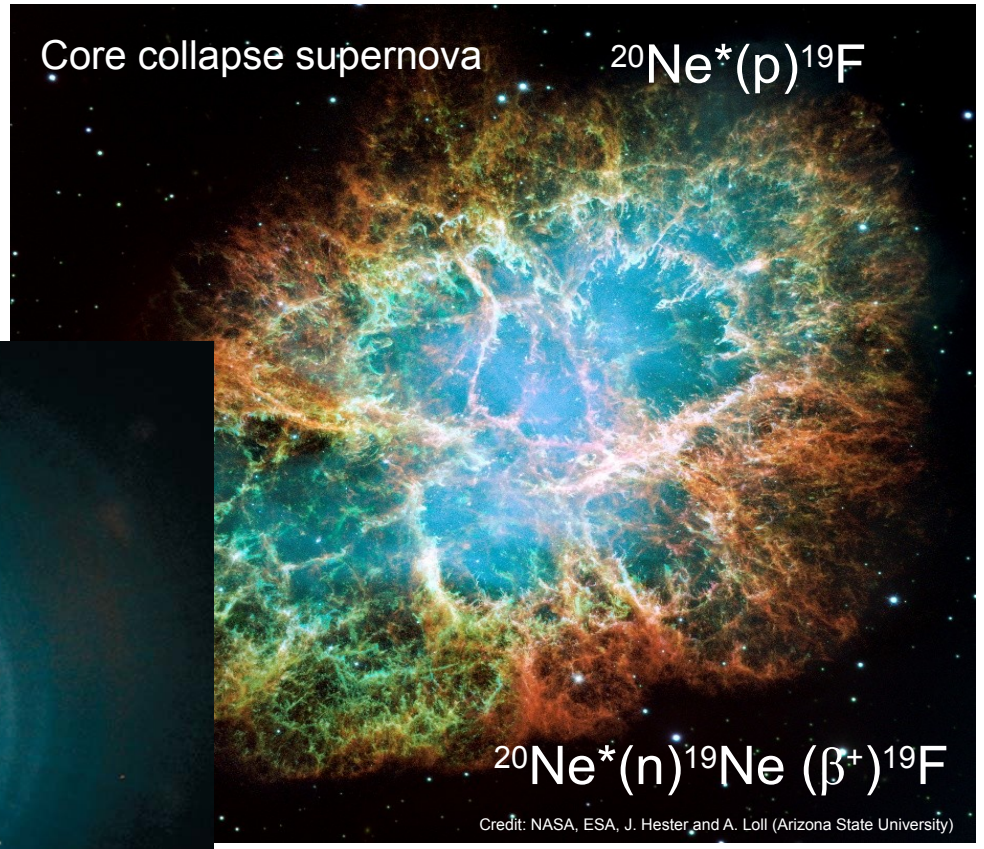
Institute of Radiation Physics · Department of Nuclear Physics · Felsenkeller · Peter Hempel · p.hempel@hzdr.de · www.hzdr.de

DRESDEN concept

Origin of ^{19}F







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Origin of ^{19}F

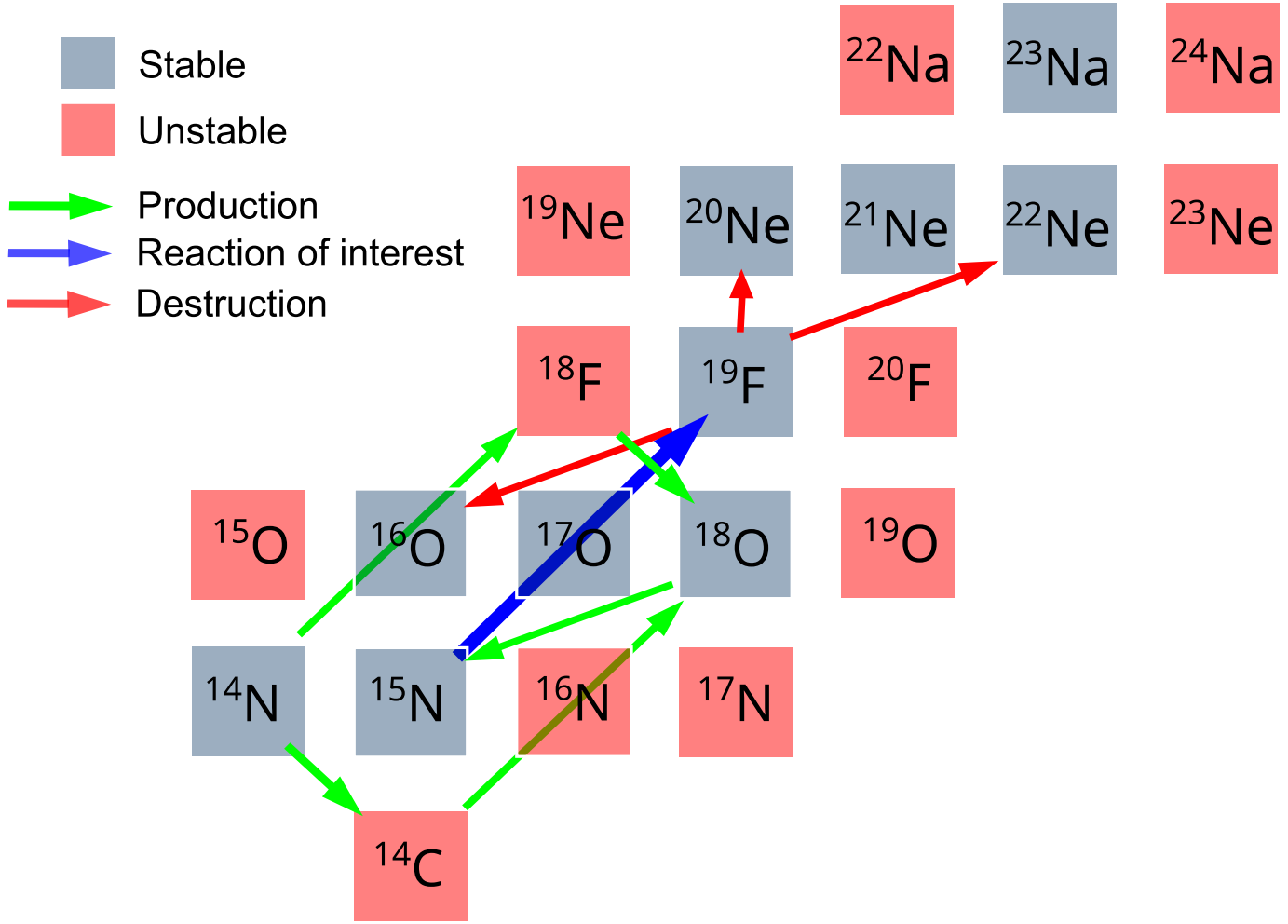
$^{14}N(\alpha,\gamma)^{18}F(\beta^+)^{18}O(p,\alpha)^{15}N$

$^{14}N(n,p)^{14}C(\alpha,\gamma)^{18}O(p,\alpha)^{15}N$

$^{15}N(\alpha,\gamma)^{19}F$

$^{19}F(p,\alpha\gamma)^{16}O$ $^{19}F(p,\gamma)^{20}Ne$

$^{19}F(\alpha,p)^{22}Ne$



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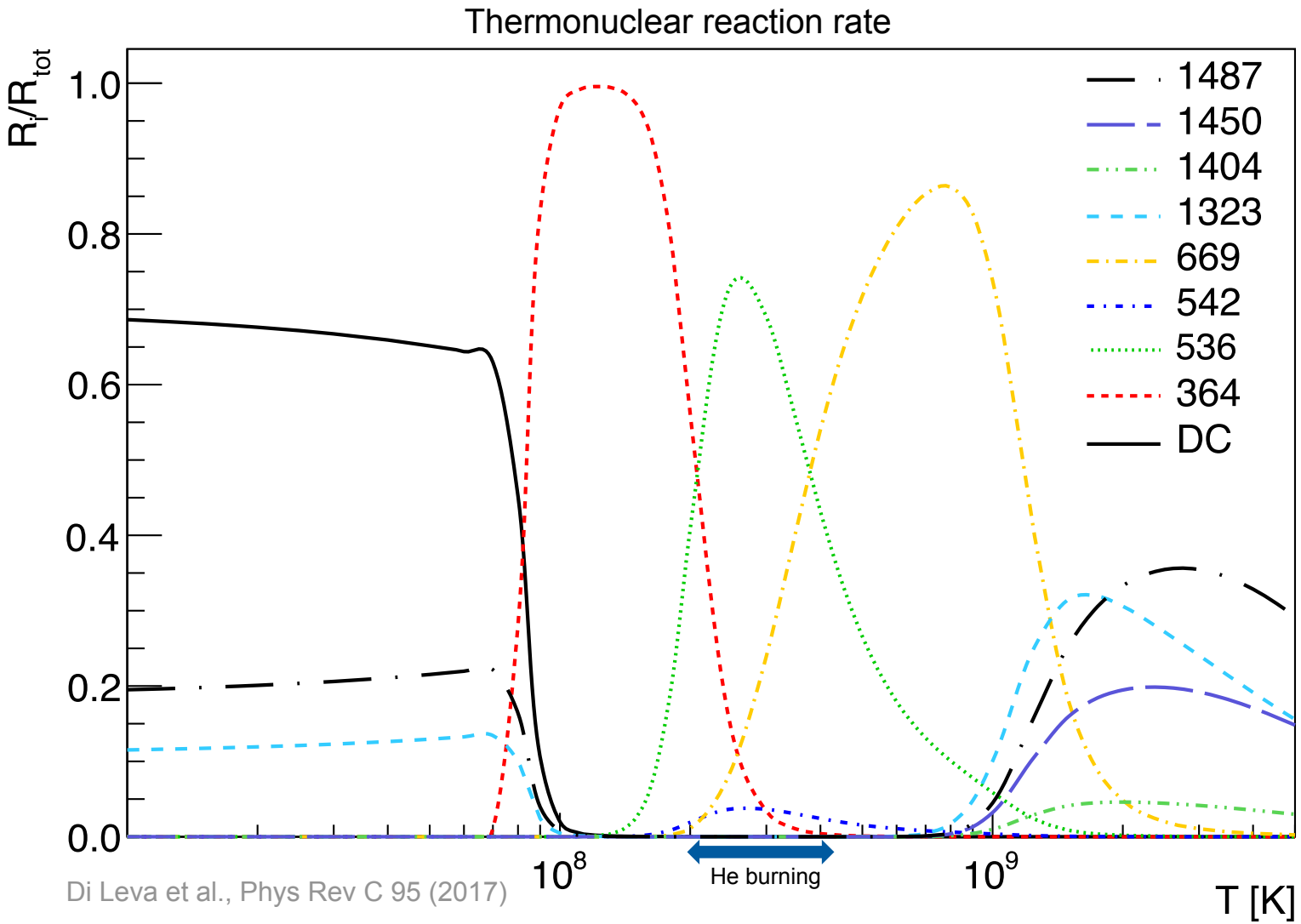
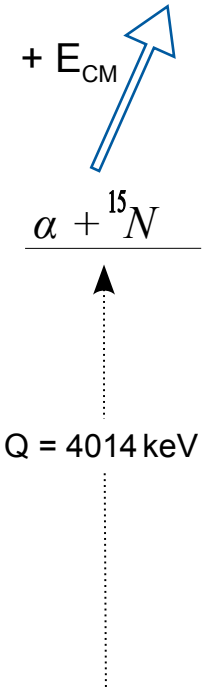
$^{15}N(\alpha,\gamma)^{19}F$ – dominated by many narrow resonances



Di Leva et al., Phys Rev C 95 (2017)



J^π	^{19}F-Levels	E_X [keV]	E_{CM} [keV]
$3/2^+$		5501	1478
$7/2^+$		5464	1450
$7/2^-$		5418	1404
$1/2^+$		5337	1323
$5/2^+$		5107	1093
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$3/2^-$		4556	542
$5/2^+$		4550	536
$7/2^+$		4378	364
$9/2^-$		4033	
$7/2^-$		3999	
$3/2^+$		3908	
$9/2^+$		2780	
$3/2^+$		1554	
$3/2^-$		1459	
$5/2^-$		1346	
$5/2^+$		197	
$1/2^-$		110	
$1/2^+$		0.0	

measure

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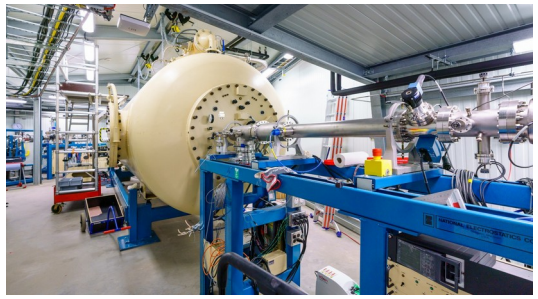
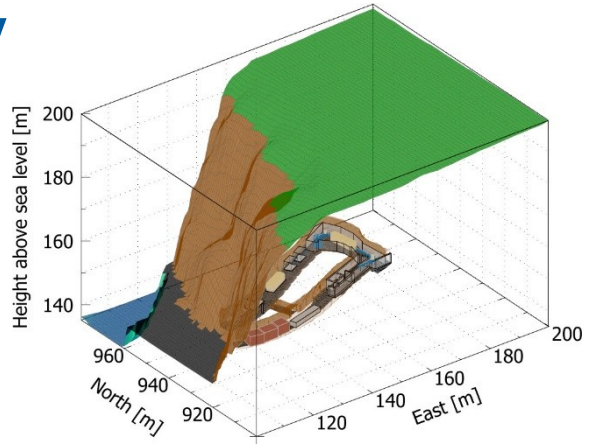
Felsenkeller laboratory

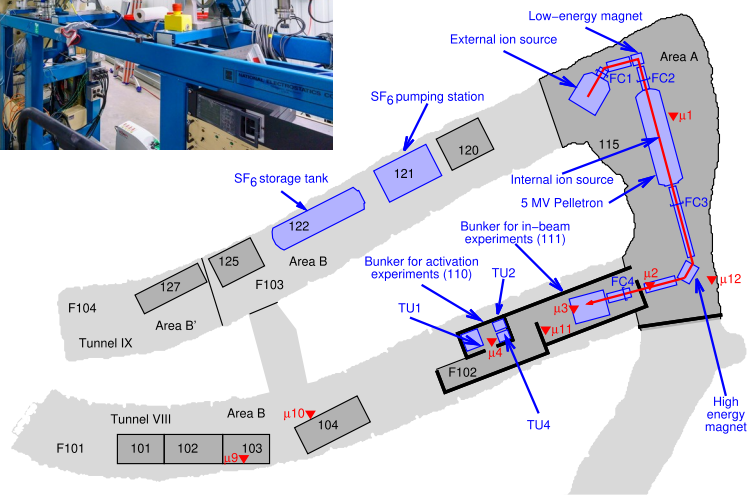
Felsenkeller:

- located in Dresden, Germany
- 5 MV Pelletron accelerator
- α-beam intensity: 10 µA





D. Bemmerer et al., Felsenkeller, EPJA (2025)



D. Bemmerer et al., Felsenkeller, EPJA (2025)

Reduction of background:

- Muons: average energy ~ 20 GeV
  flux reduction: **40**
- Neutrons: energy: thermal + 1 MeV
  flux reduction: **168**

D. Bemmerer et al., EPJA (2025) “The Felsenkeller shallow-underground laboratory for nuclear astrophysics”

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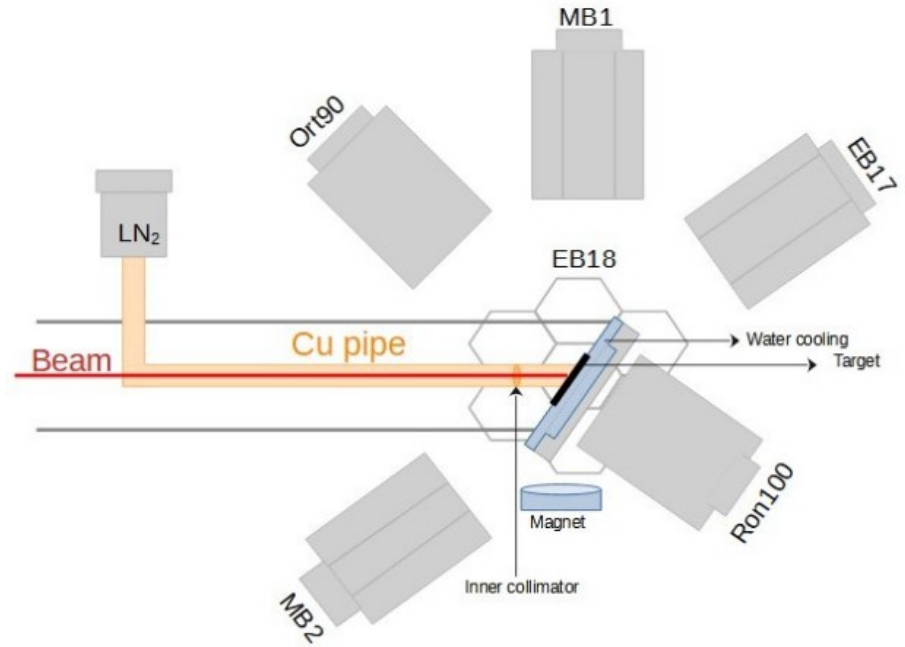
$^{15}N(\alpha,\gamma)^{19}F$ – High energy campaign

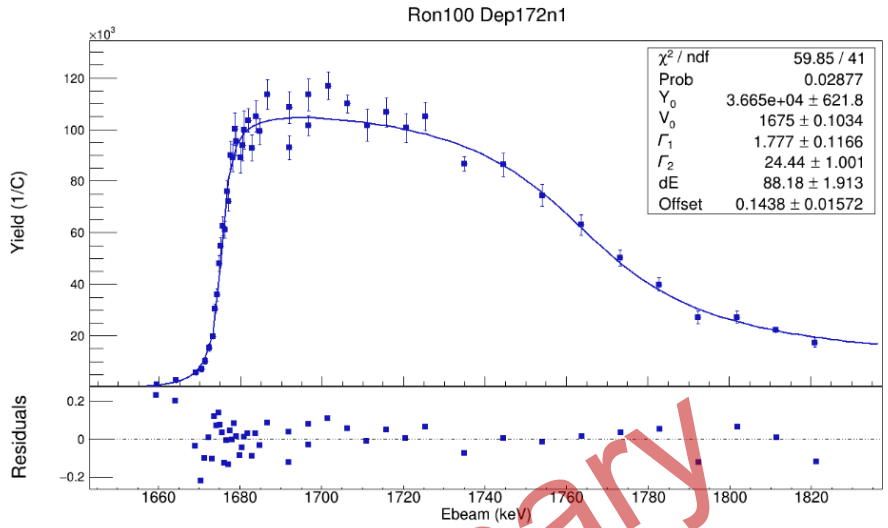
E_{CM} = 1093 - 1478 keV

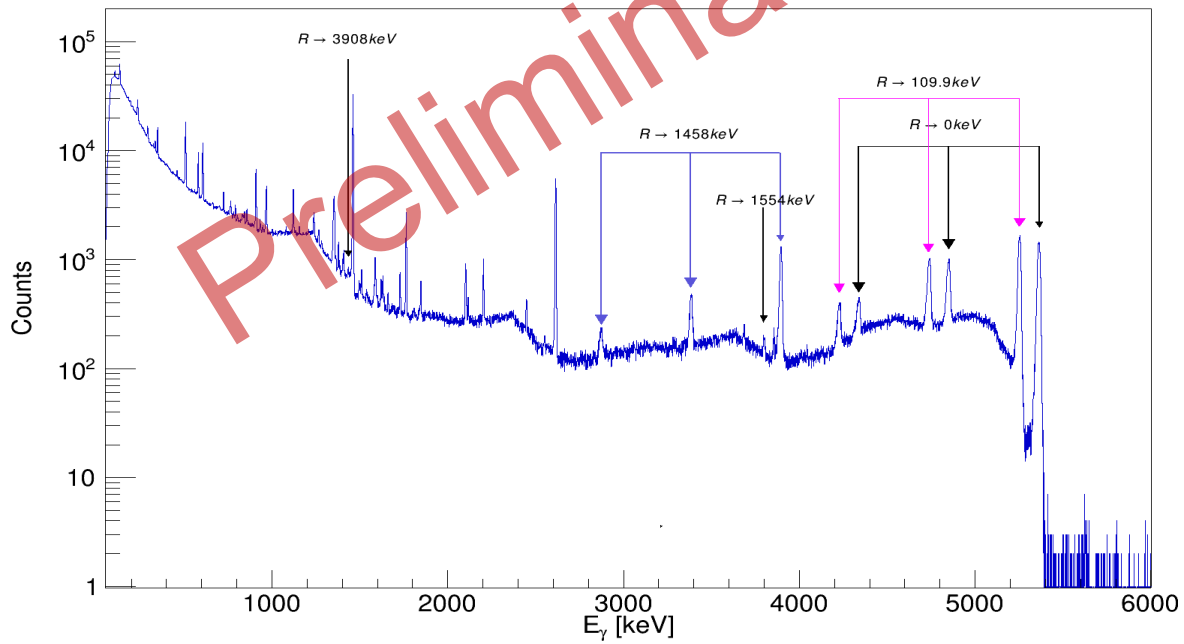
HPGe detection system:

- Resonance strength, energy and angular distribution
- Solid target: $Ta^{15}N$ (~ 10^{18} atoms/cm^2)



E_r = 1323 keV





Preliminary

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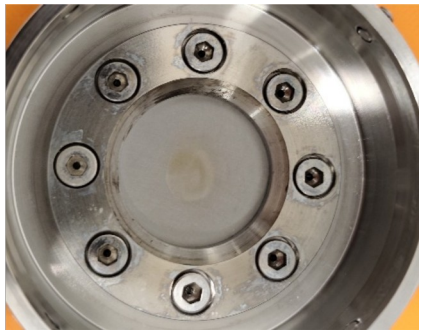
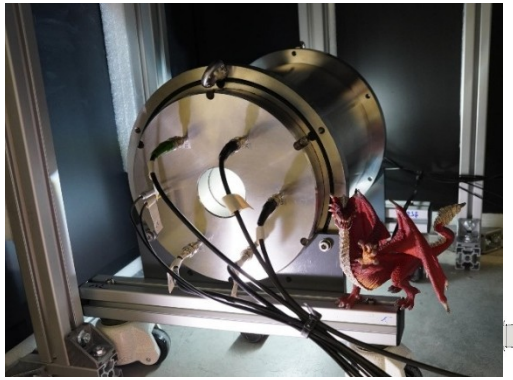
$^{15}N(\alpha,\gamma)^{19}F$ – High efficiency campaign

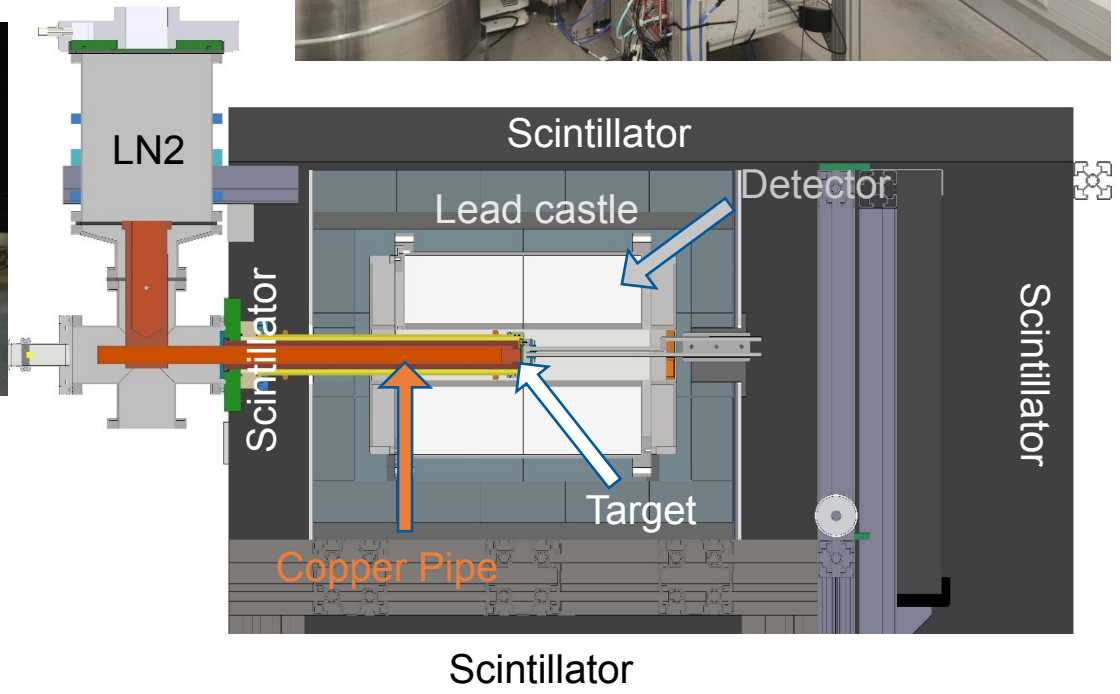
E_{CM} = 364 – 1093 keV

Detector: 4π BGO – γ-ray detector (Felsenkeller Total Absorption Spectrometer - FeliciTAS):

- borehole (6 cm) detector
- 12 crystals
- SiPM readout
- 40 % efficiency @ 5 MeV







Solid target:

- $Ta^{15}N$ (~ 10^{18} atoms/cm²)
- Water cooled

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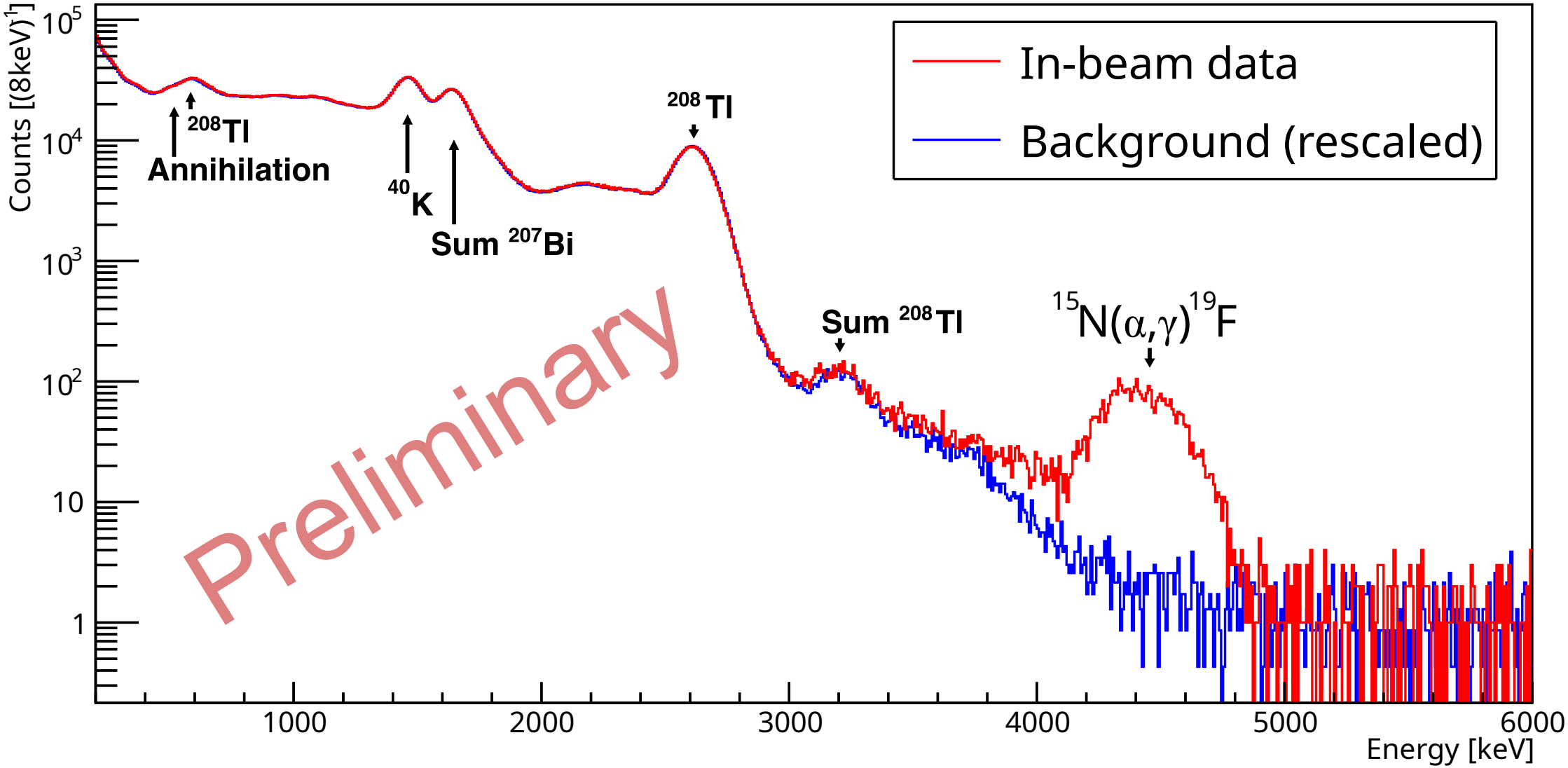
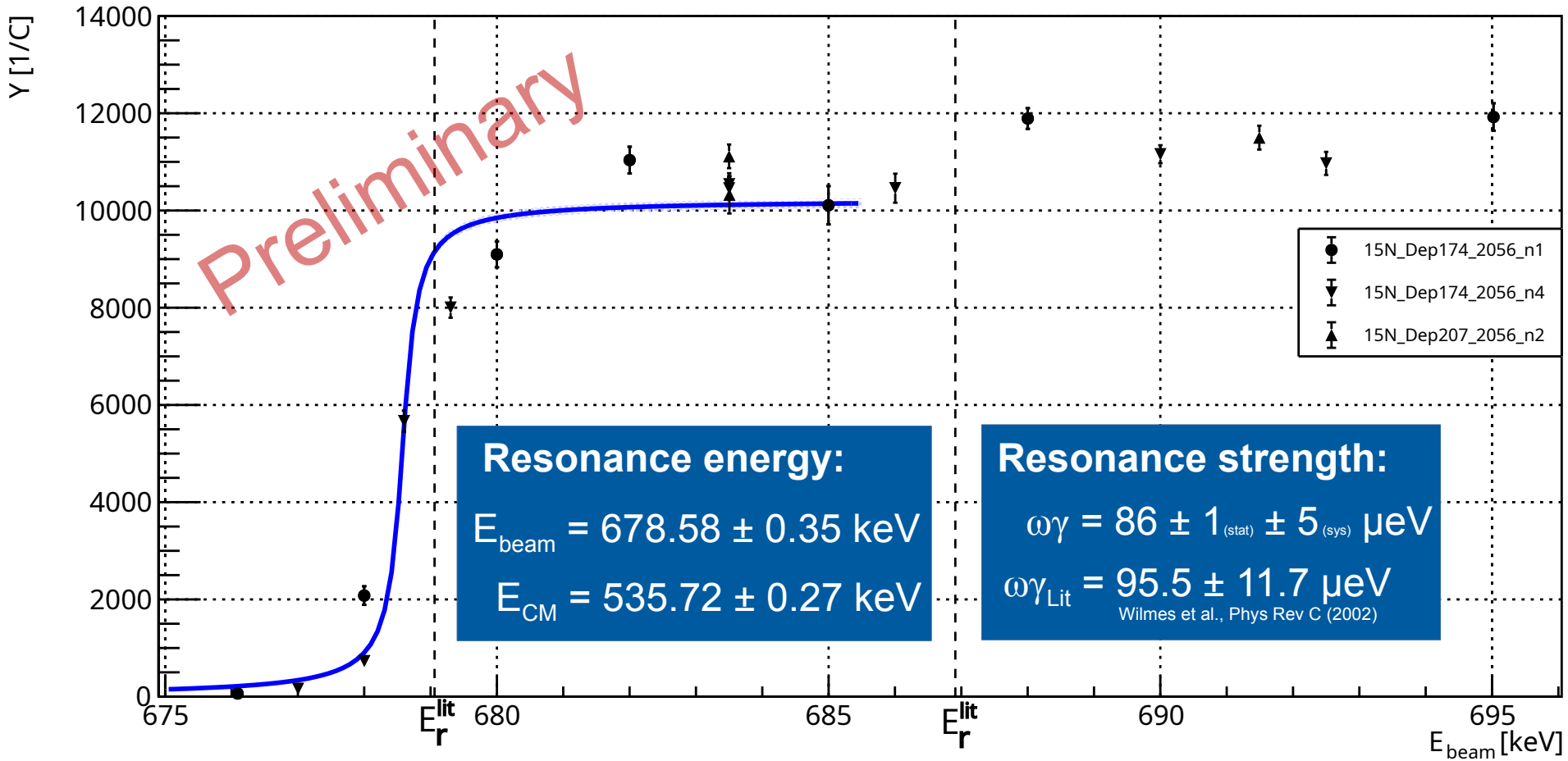
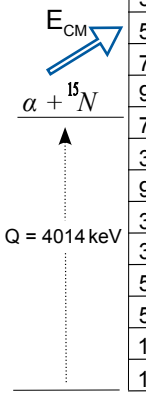
$^{15}N(\alpha,\gamma)^{19}F$ – Spectra of the 536 keV resonance



$^{15}N(\alpha,\gamma)^{19}F$ – 536 keV resonance

Resonance yield curve E_{res} = 679 keV





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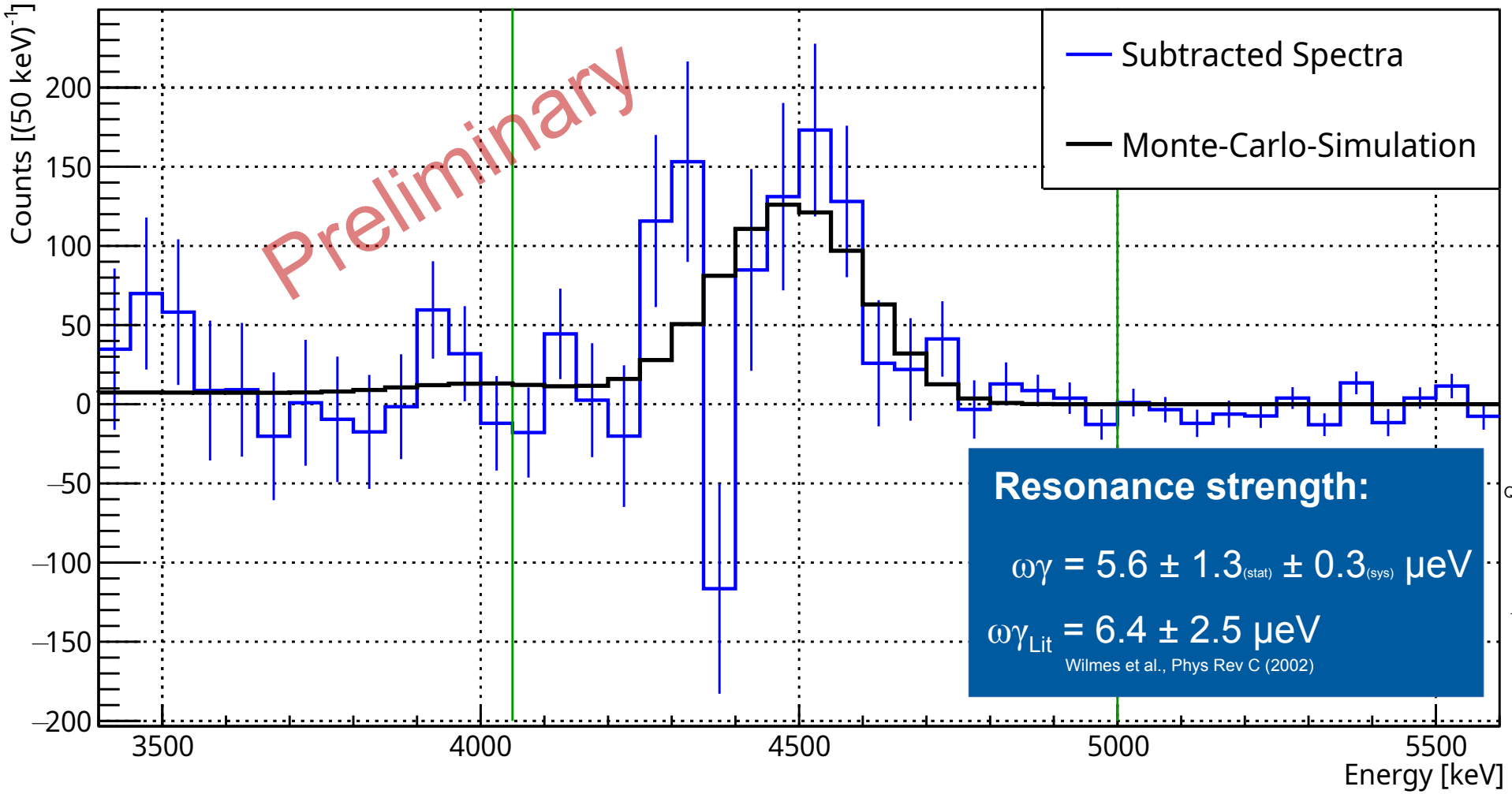
$^{15}N(\alpha,\gamma)^{19}F$ – 542 keV resonance

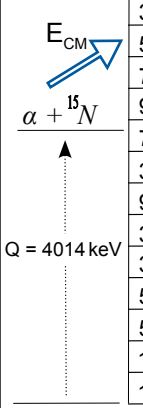


Resonance strength:

$\omega\gamma = 5.6 \pm 1.3_{(stat)} \pm 0.3_{(sys)}$ μeV

$\omega\gamma_{Lit} = 6.4 \pm 2.5$ μeV

Wilmes et al., Phys Rev C (2002)



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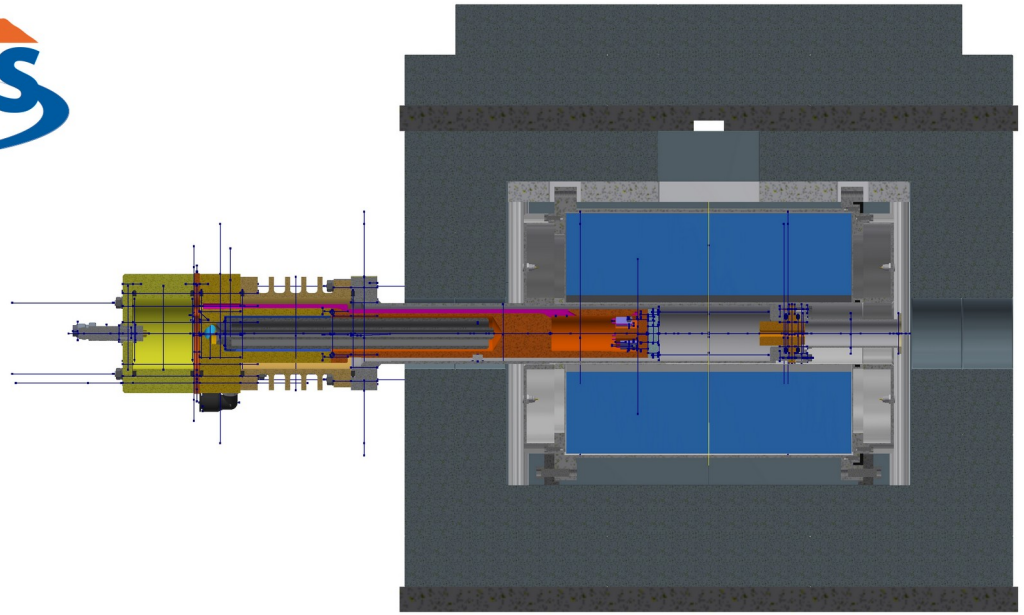
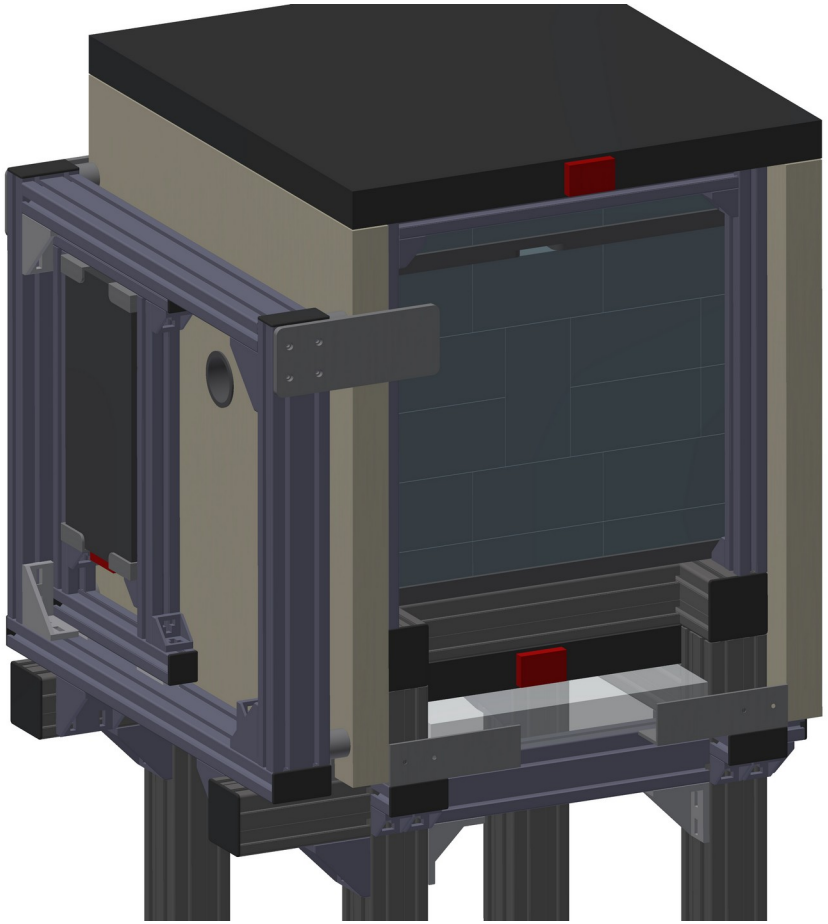
Outlook

New target setup:

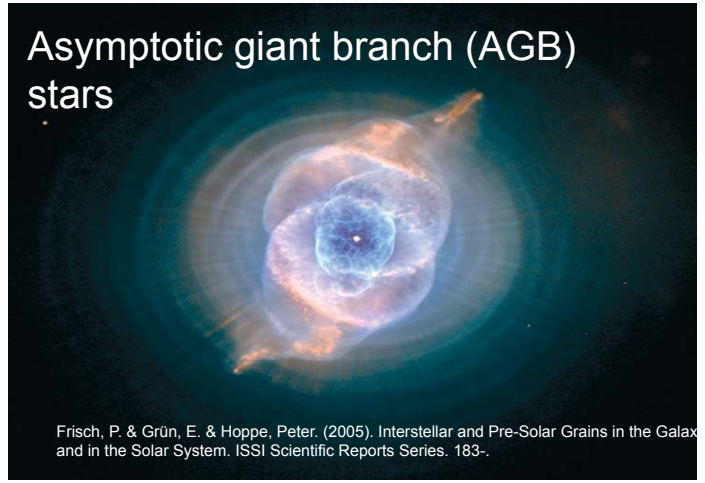
- 10 cm lead shield
- New solid target holder design (less passive material)
- Extended gas target + FeliciTAS
- E_R = 364 keV resonance (LUNA, M. Lukyanova PhD thesis)

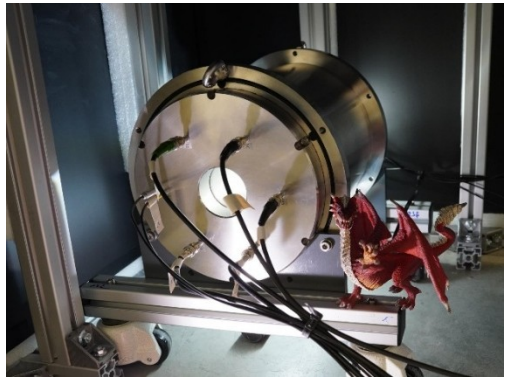


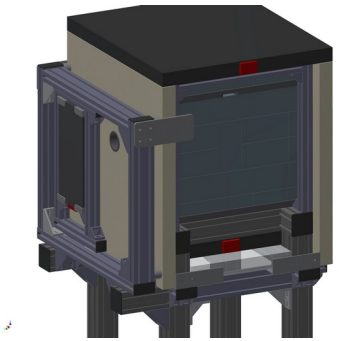


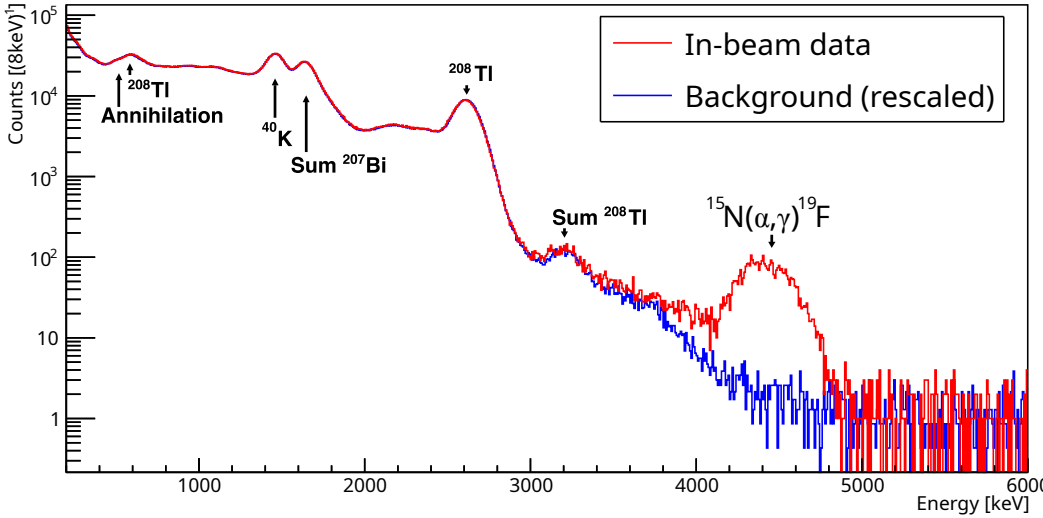
$^{15}N(\alpha,\gamma)^{19}F$ - Summary

- fluorine production in AGB and Wolf-Rayet-Stars
- Felsenkeller + FeliciTAS
- 536 keV-resonance: scan successfully done → resonance strength + energy
- 364 keV-resonance: long runs on top (same beam energy) → upper limit
- direct capture runs at E_{beam} ~ 1600 keV
- New target setup planned









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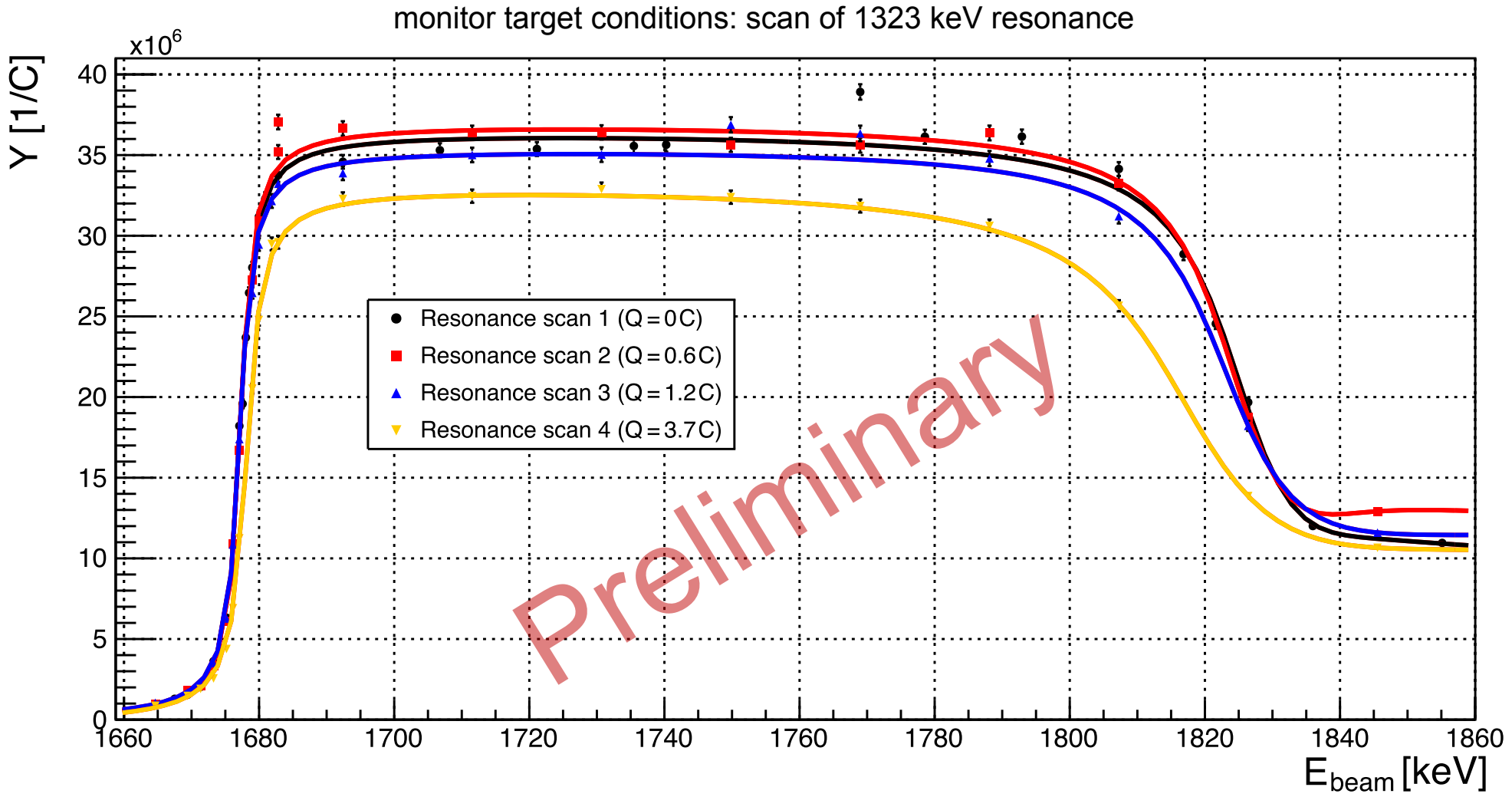
$^{15}N(\alpha,\gamma)^{19}F$-reaction

Target stability

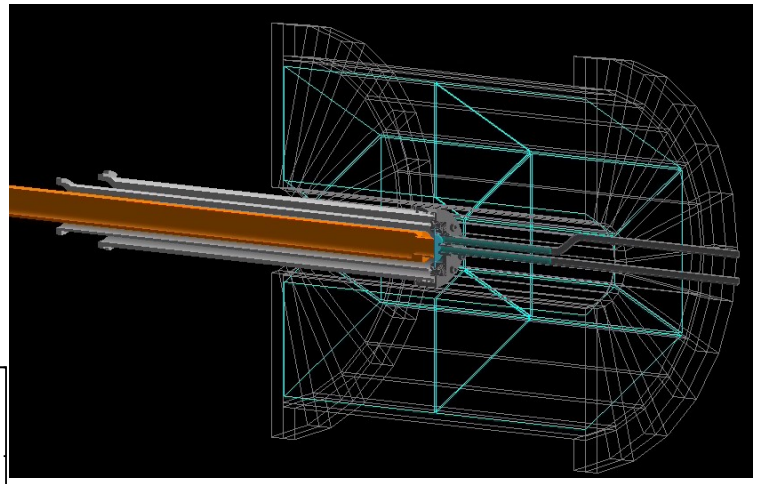


$^{15}N(\alpha,\gamma)^{19}F$-reaction

FeliciTAS

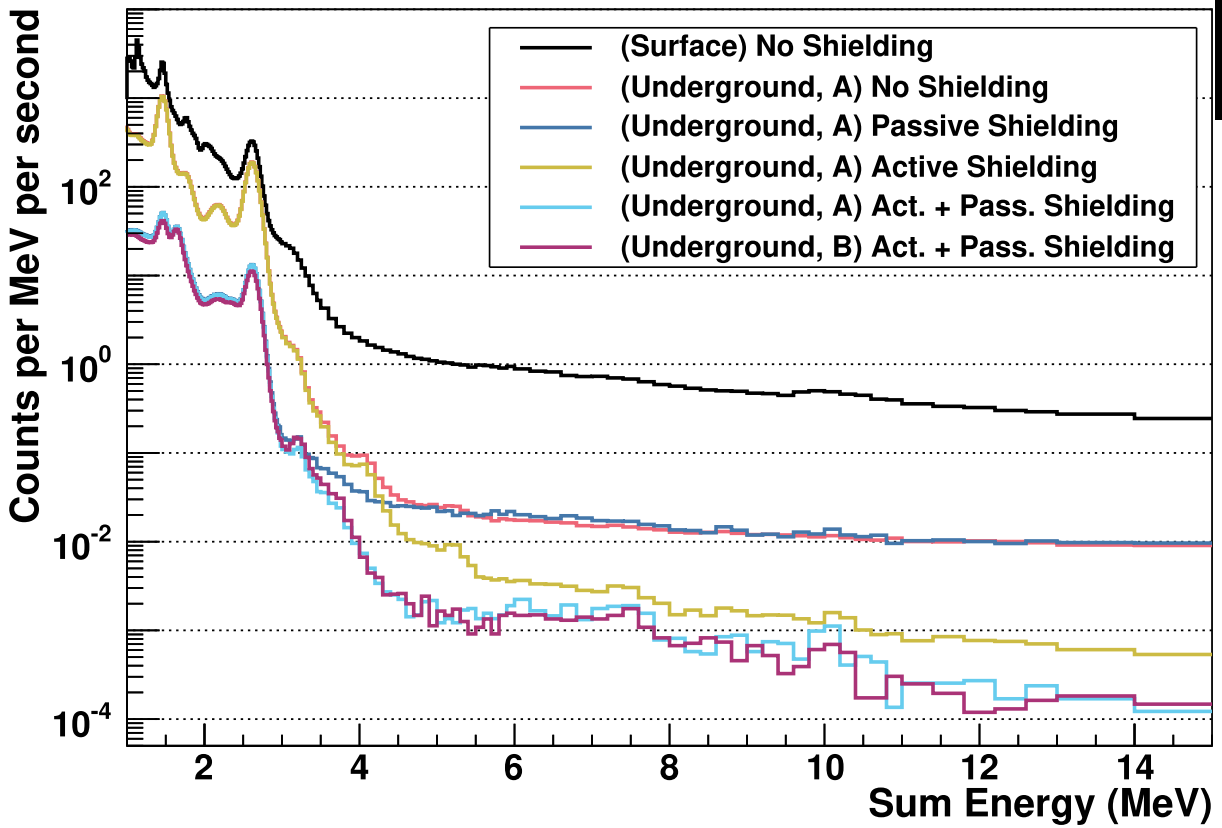
Simulation of the setup:

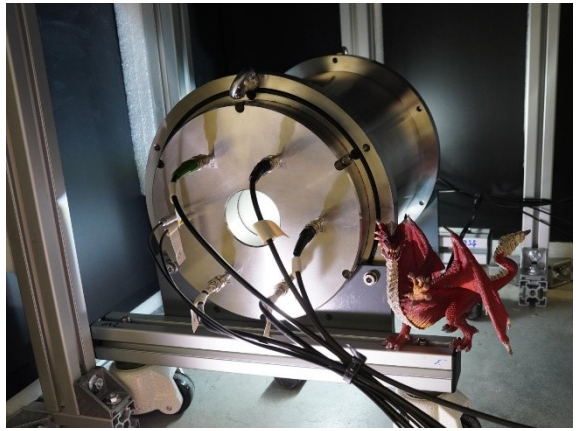
- Geant4
- import CAD model
- fine tune with:
  - calibration sources
  - $^{27}Al(p,\gamma)^{28}Si$



Background reduction:

- rock overburden
- veto-plates
- lead castle





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