Direct and Indirect measurements of $^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ

EXPERIMENTAL STUDY OF $^{22}Ne(\alpha,\gamma)^{26}Mg$ NEAR-THRESHOLD STATES AT LOW ENERGY AND ITS CROSS SECTION FOR NUCLEAR ASTROPHYSICS

Daniela Mercogliano, Andreas Best
Unina & INFN-Na
daniela.mercogliano@unina.it

LUNA Laboratory for Underground Nuclear Astrophysics
INFN Istituto Nazionale di Fisica Nucleare
Università degli Studi di Napoli Federico II
erc European Research Council Established by the European Commission
MUR Ministero dell'Università e della Ricerca

^{22}Ne(α, γ)^{26}Mg with EASγ

Outline

Astrophysical Motivation

LUNA
Laboratory for Underground Nuclear Astrophysics

INFN
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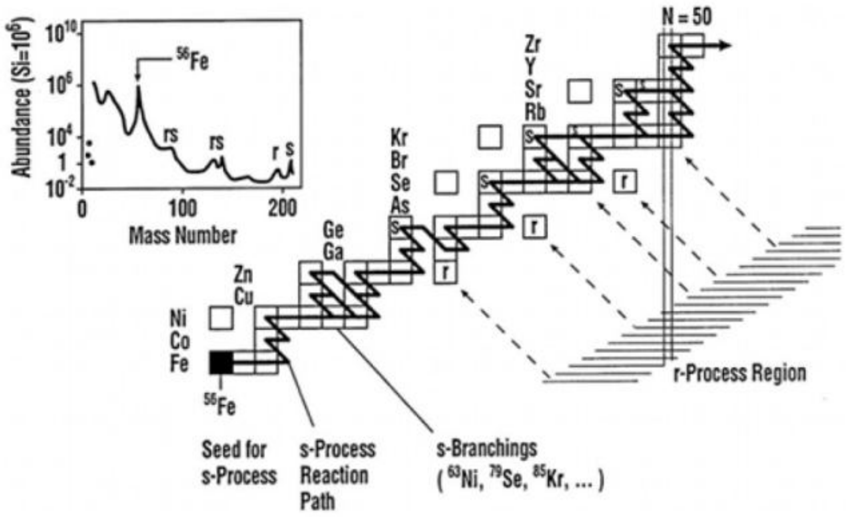
erc
European Research Council
Established by the European Commission

MUR
Ministero dell'Università e della Ricerca

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ - Astrophysical motivation

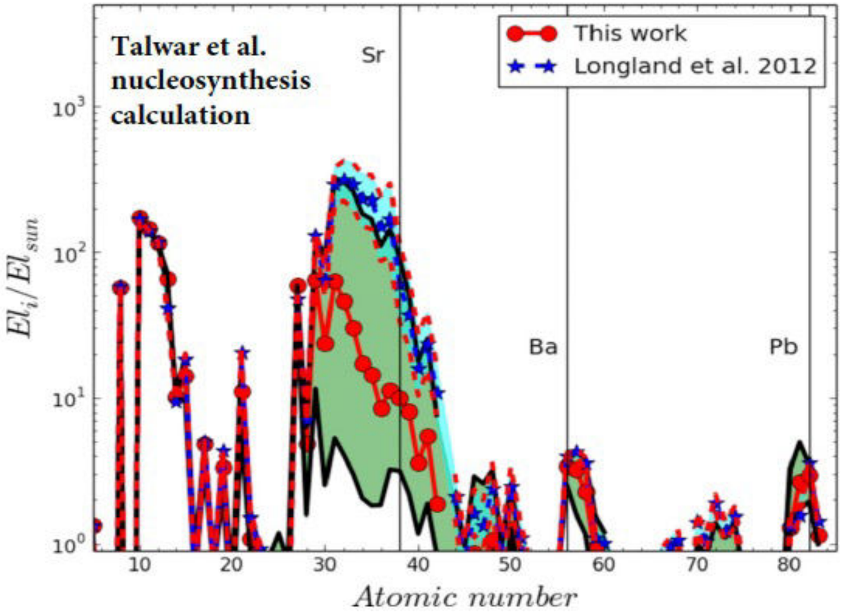


He-burning of ^{22}Ne

$^{22}Ne(\alpha,n)^{25}Mg$ Q=-478 keV

$^{22}Ne(\alpha,\gamma)^{26}Mg$ Q=10614.7 keV

Need to determine the reaction rates for both channels



The $^{22}Ne(\alpha,\gamma)^{26}Mg$ reaction is crucial for:

- understanding of isotopic ratios of Mg in AGB atmosphere
- nucleosynthesis of the long lived γ-ray emitter ^{60}Fe
- weak s-process in massive stars and the nucleosynthesis beyond Fe

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ

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State of the art

Astrophysical Motivation

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – State of the art

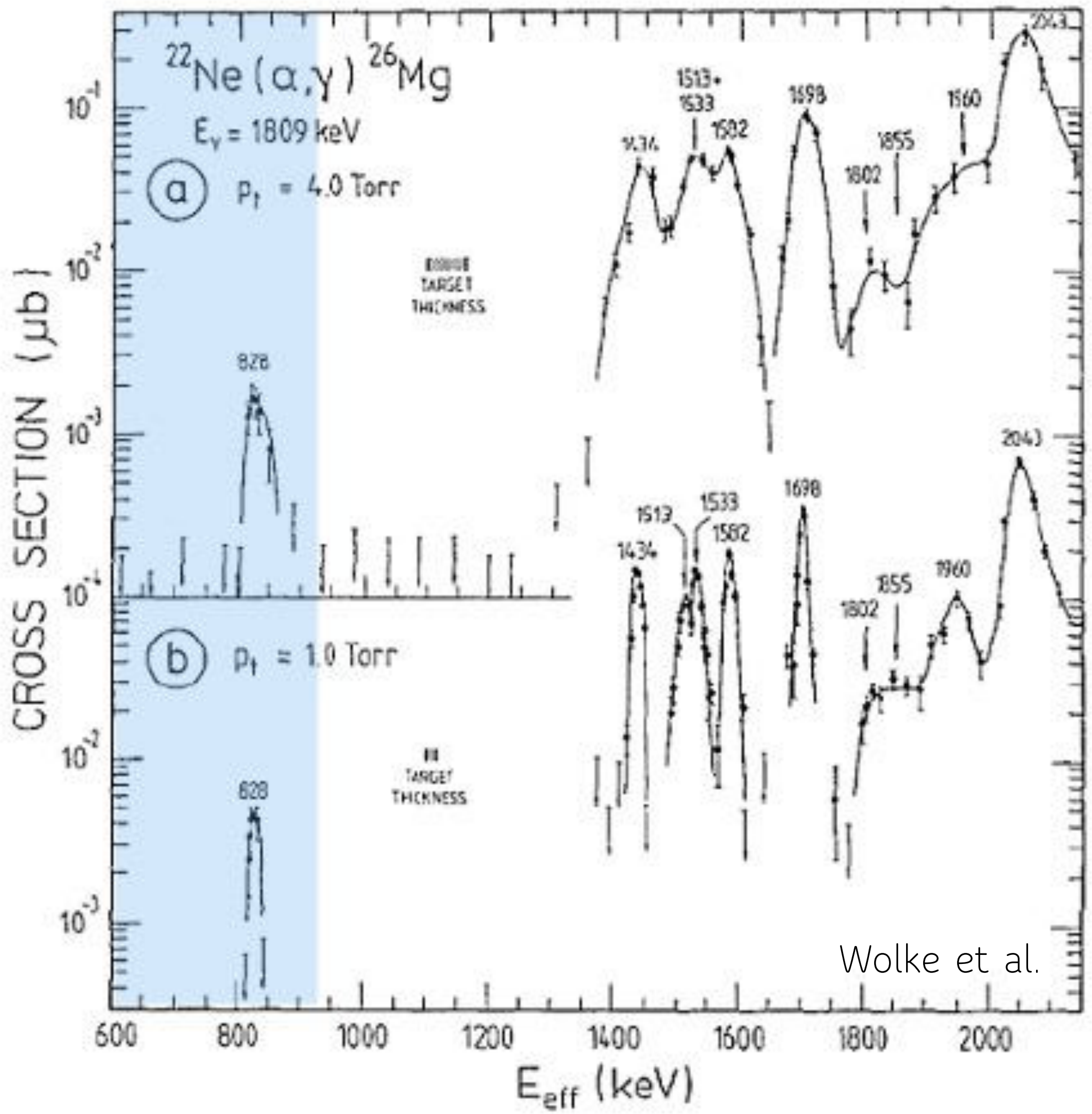
Main experimental challenges:

- High density state of ^{26}Mg

- Very low value of energy and cross-section

Do we have satisfying available data?

- No data from direct measurements below 830 keV
- Discrepancies in indirect data
- Γ_α known only as UL



$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ

Outline

State of the art

Astrophysical Motivation

The EASγ project

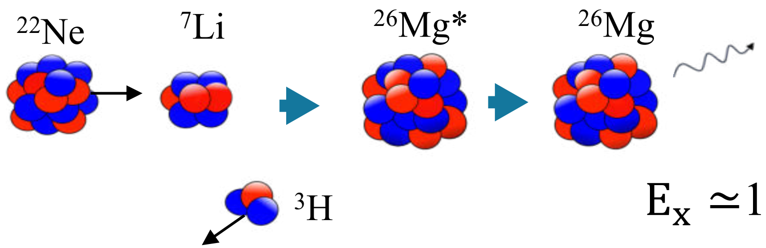
Purpose

Experimental study of $^{22}Ne(\alpha,\gamma)^{26}Mg$ in the energy range of astrophysical interest (600-900) keV

TRIUMF $^{7}Li(^{22}Ne,t)^{26}Mg$ → MC simulation → Bellotti IBF $^{22}Ne(\alpha,\gamma)^{26}Mg$

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Indirect measurement

Study of ^{26}Mg states via $^{7}Li(^{22}Ne,t)^{26}Mg$ in inverse kinematics near α particle threshold



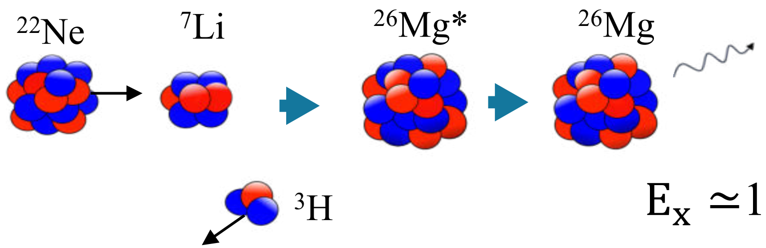
$E_x \simeq 11 MeV$

^{26}Mg excited states will be reconstructed using triple coincidence detection:

- gamma rays
  - heavy recoil
    - light ejectile

^{22}Ne(α, γ)^{26}Mg with EASγ – Indirect measurement

Study of ^{26}Mg states via ^{7}Li(^{22}Ne,t)^{26}Mg in inverse kinematics near α particle threshold



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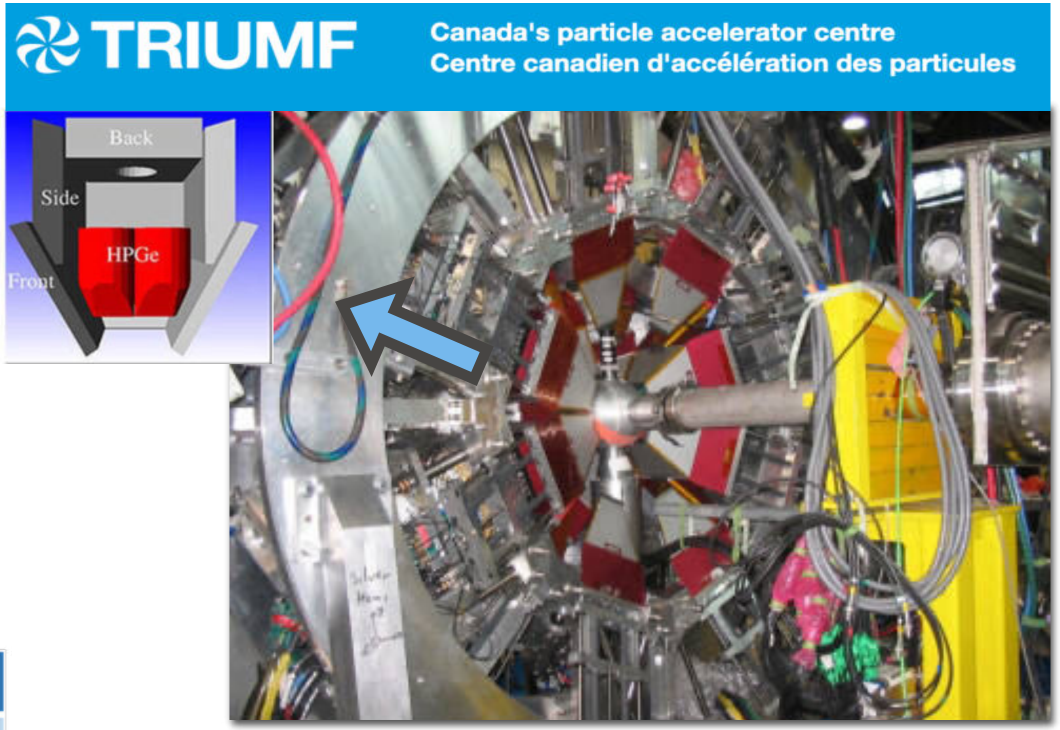


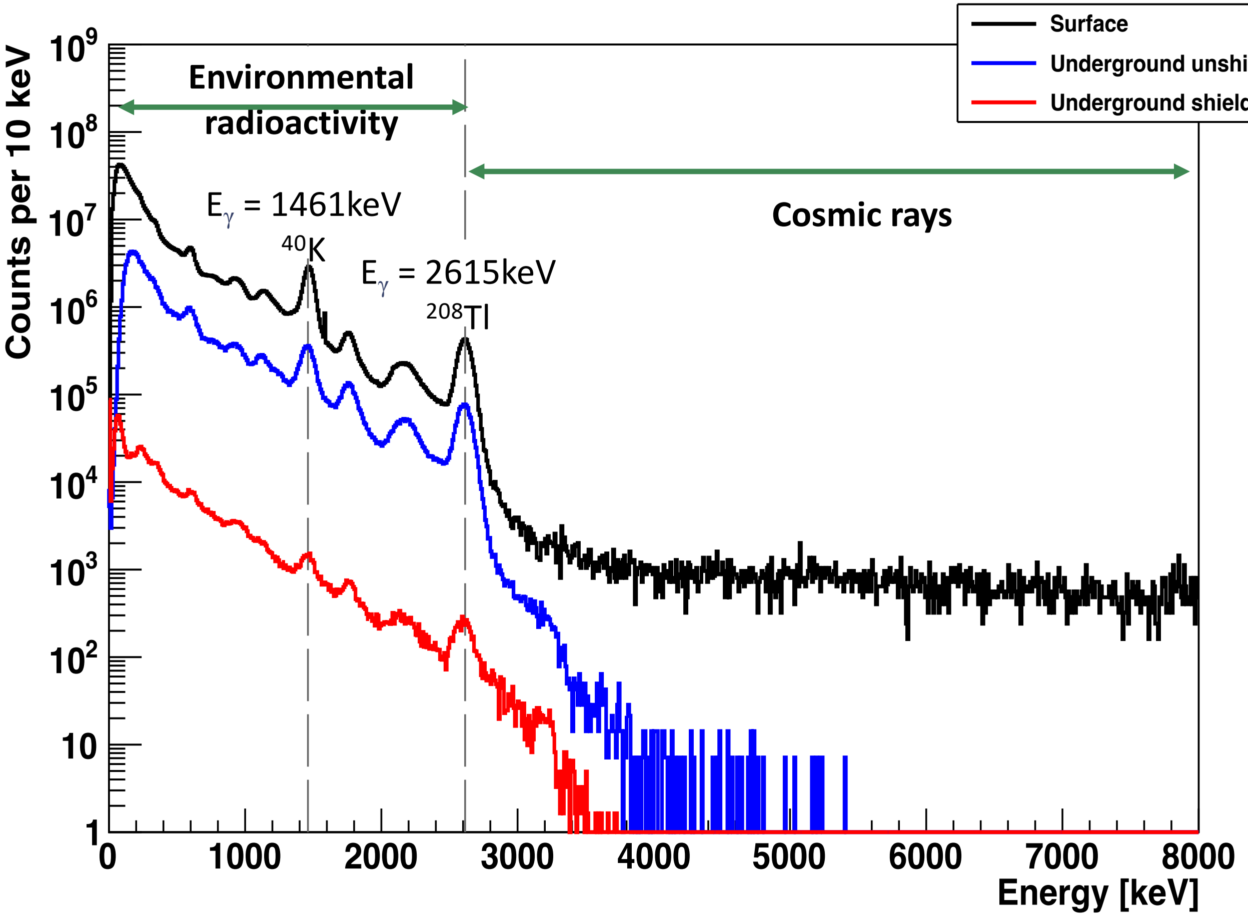
^{26}Mg excited states will be reconstructed using triple coincidence detection:

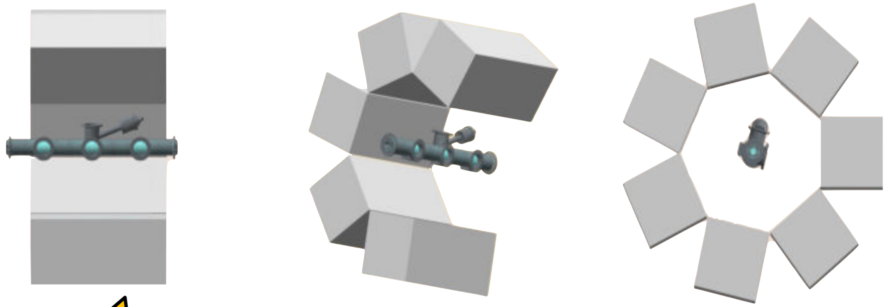
- gamma rays → TIGRESS
- heavy recoil → EMMA+IC
- light ejectile → Si detector

Observable	Level parameter
Kinetic energy of ^{3}H	Excitation energy of ^{26}Mg hence resonance energy
Shape of angular distribution	Constraint on spin parity of a level
Absolute value of angular distribution	ANC for bound states and Γ for unbound states

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Direct measurement

Direct measurement of $^{22}Ne(\alpha,\gamma)^{26}Mg$ in the range 600-900 keV deep underground





$\eta_{FEP} = 10\%$ for $E_\gamma = 4$ MeV

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ

Outline

State of the art

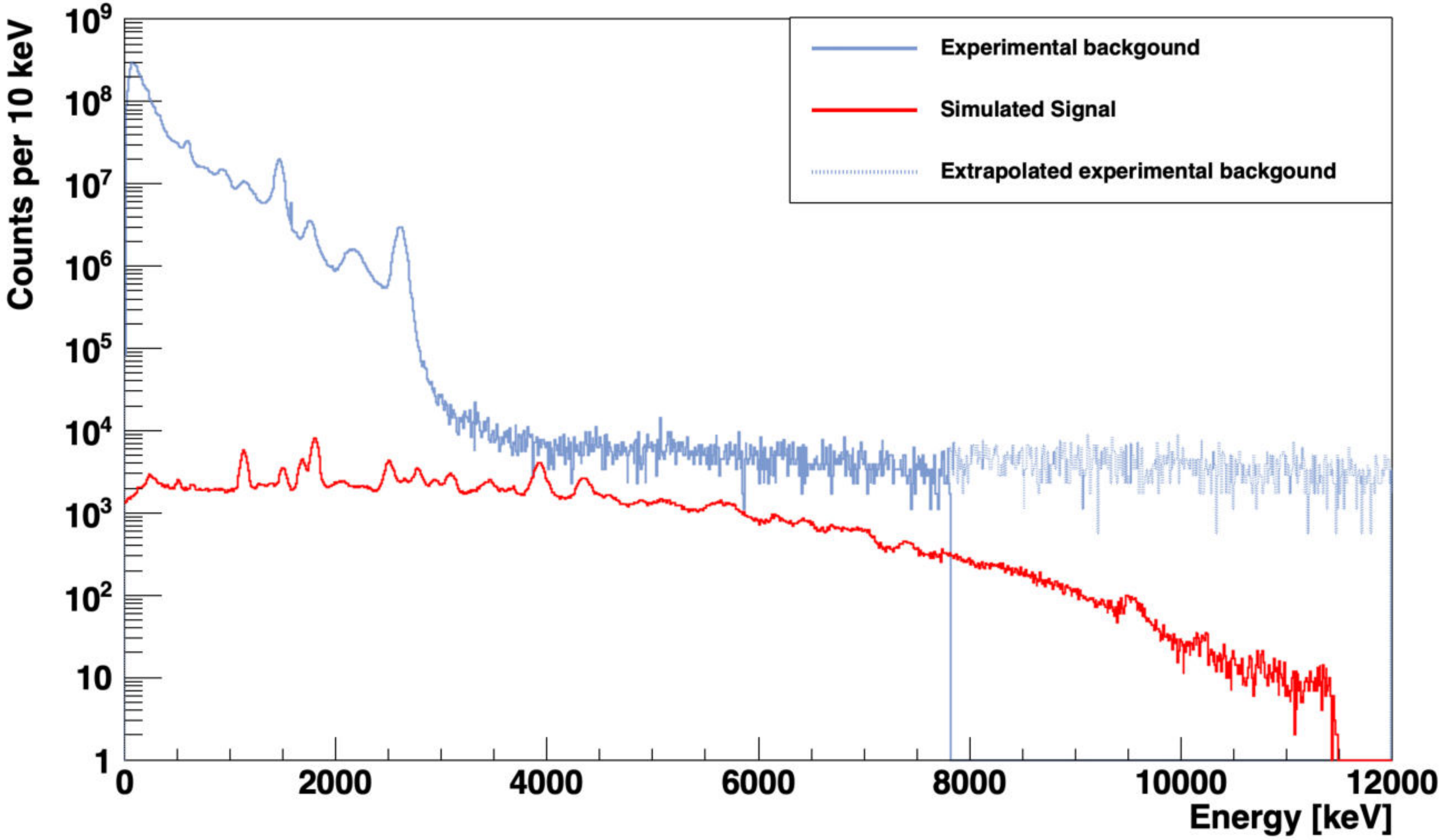
Simulation: preliminary results

Astrophysical Motivation

The EASγ project

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11329.1 keV

Simulated signal vs Background on surface – unshielded



Simulation:

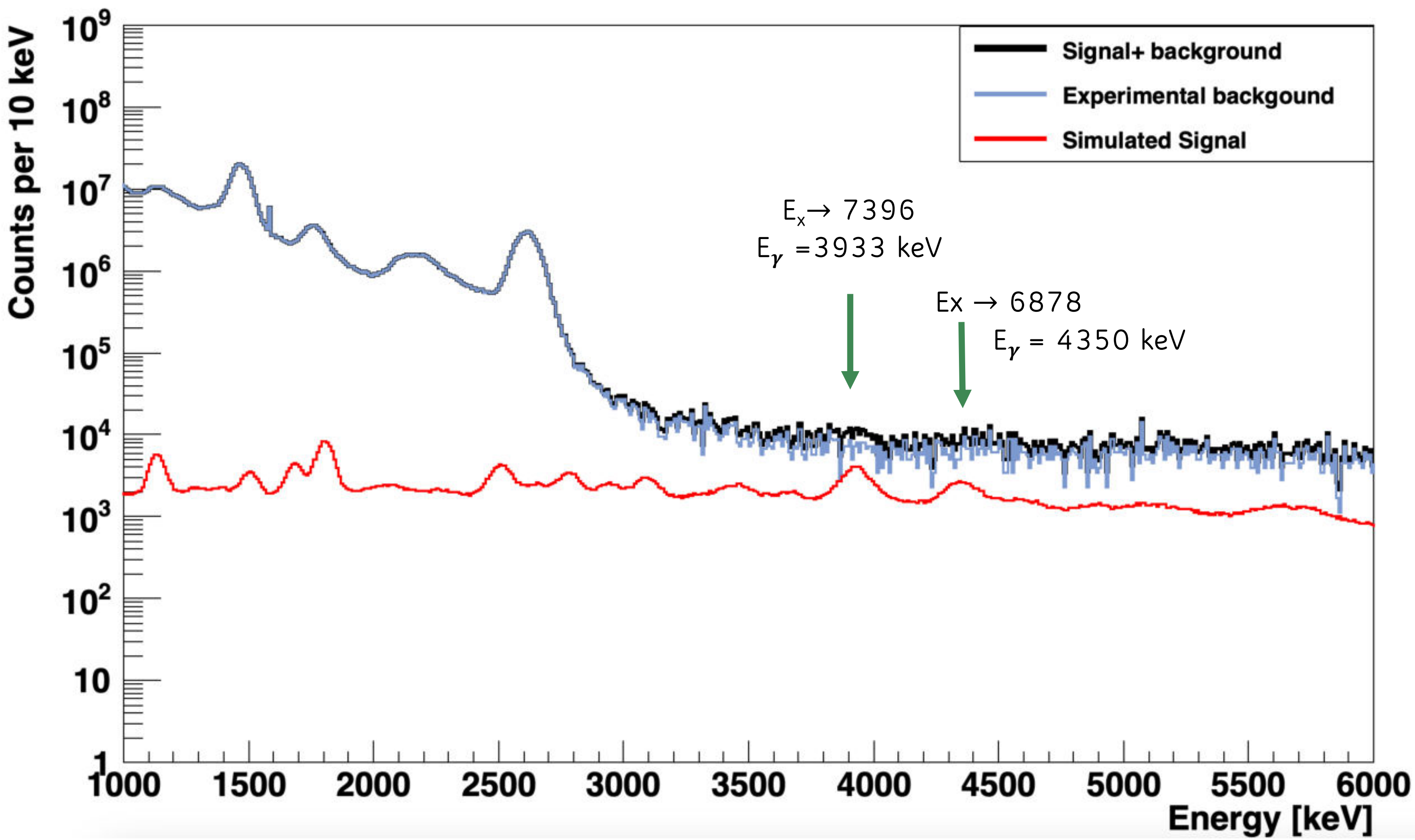
Ecm = 706.6 keV
$\omega\gamma_{Hunt} = (4.6 \pm 1.2) \cdot 10^5 eV$
Yield = 14033 counts/h

I=300 μA
Runtime = 120 h

η_{FEP} = 10% for E_γ = 4 MeV

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11329.1 keV

Simulated signal + Background on surface – unshielded



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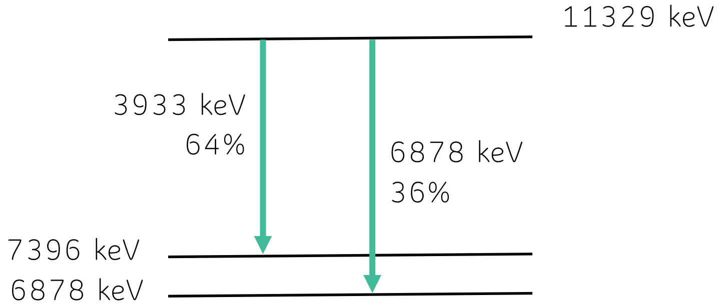
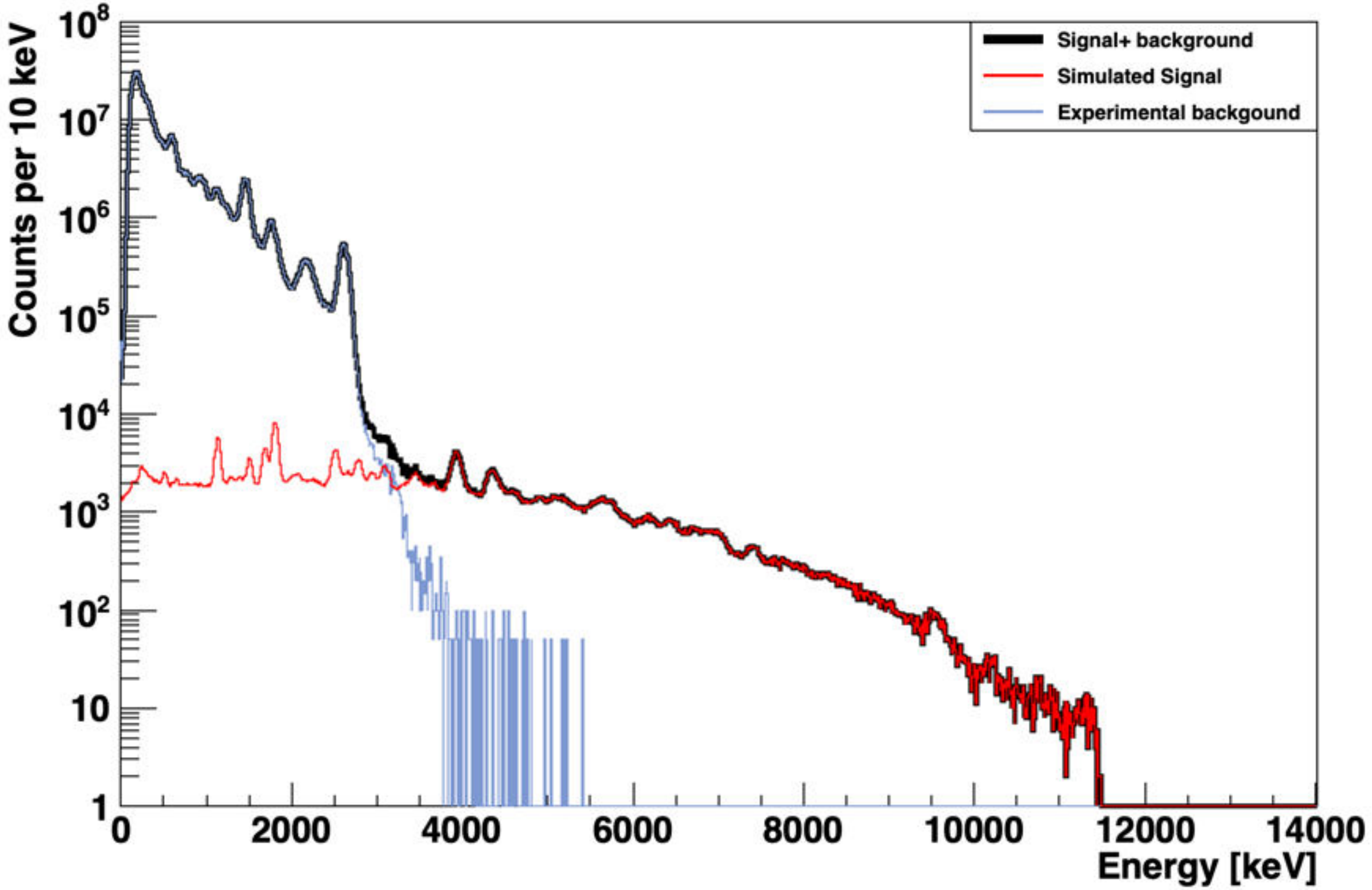


$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11329.1 keV

Simulated signal + Background undeground – unshielded



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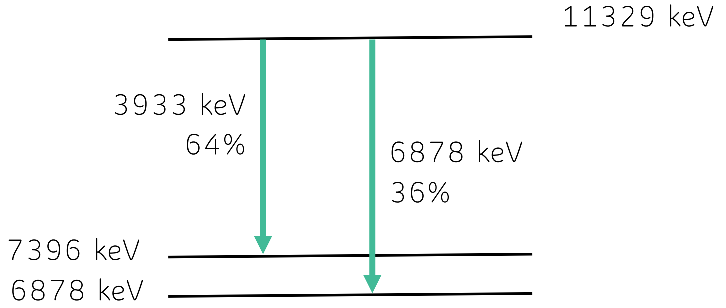

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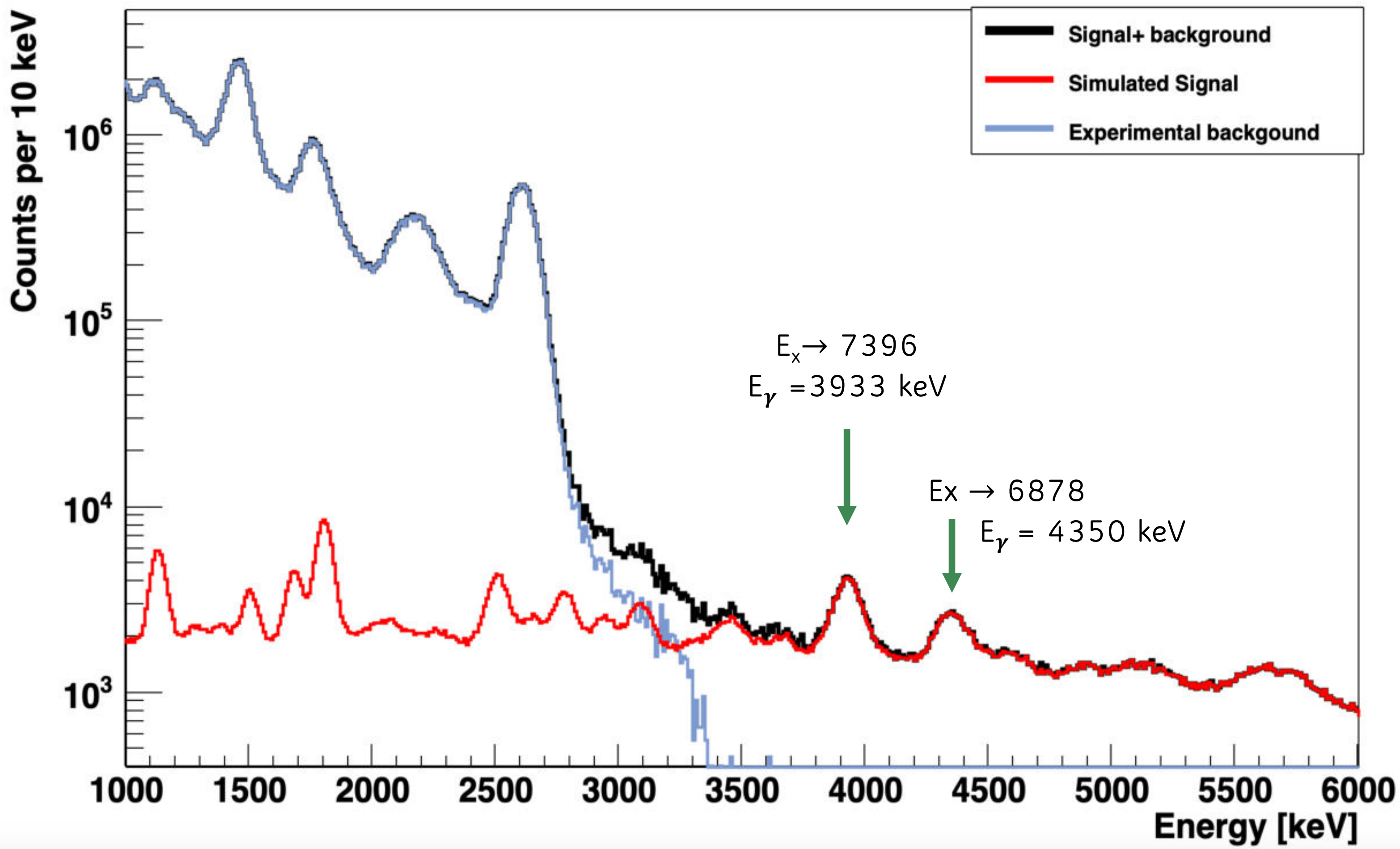

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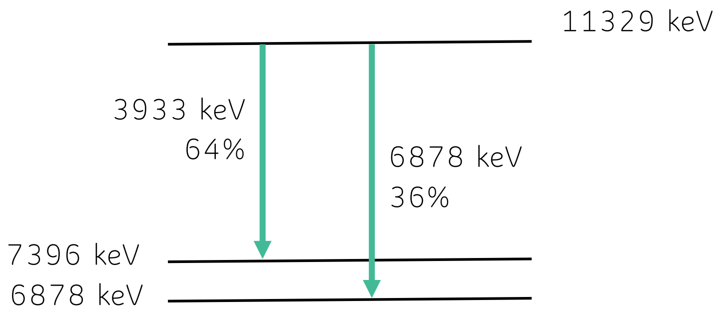
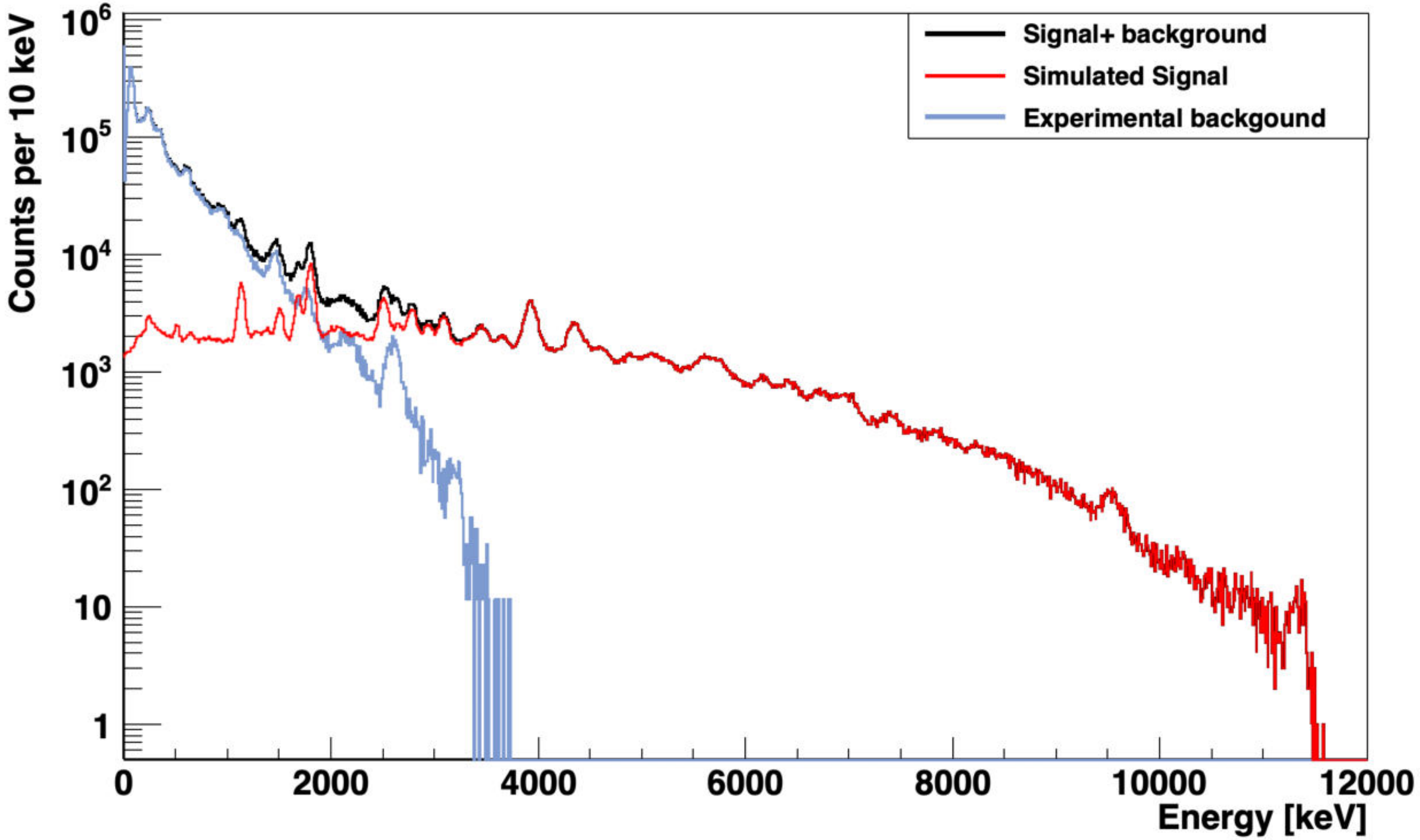


$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11329.1 keV

Simulated signal + Background underground – shielded



Simulation:

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Runtime = 120 h

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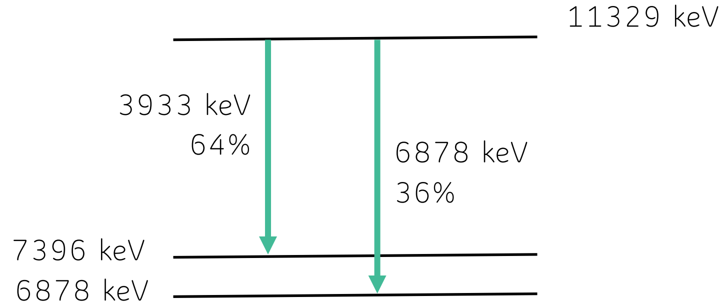
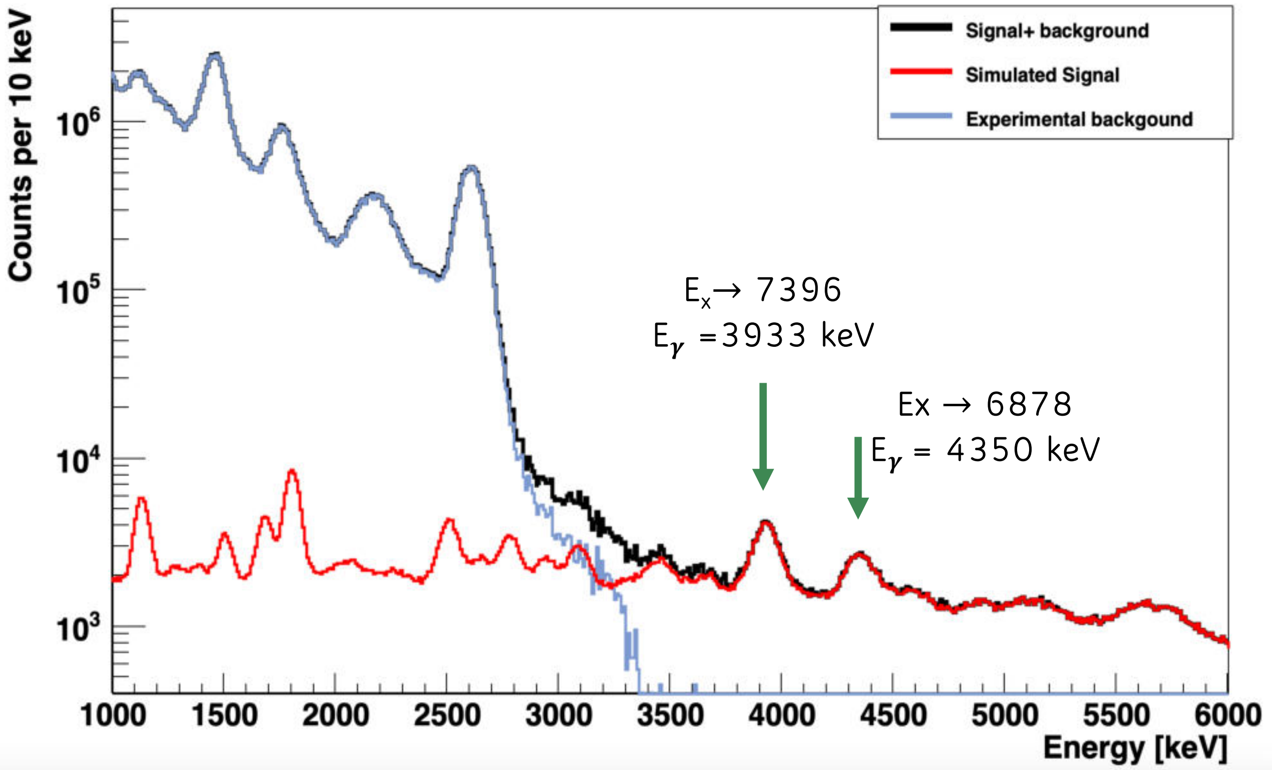
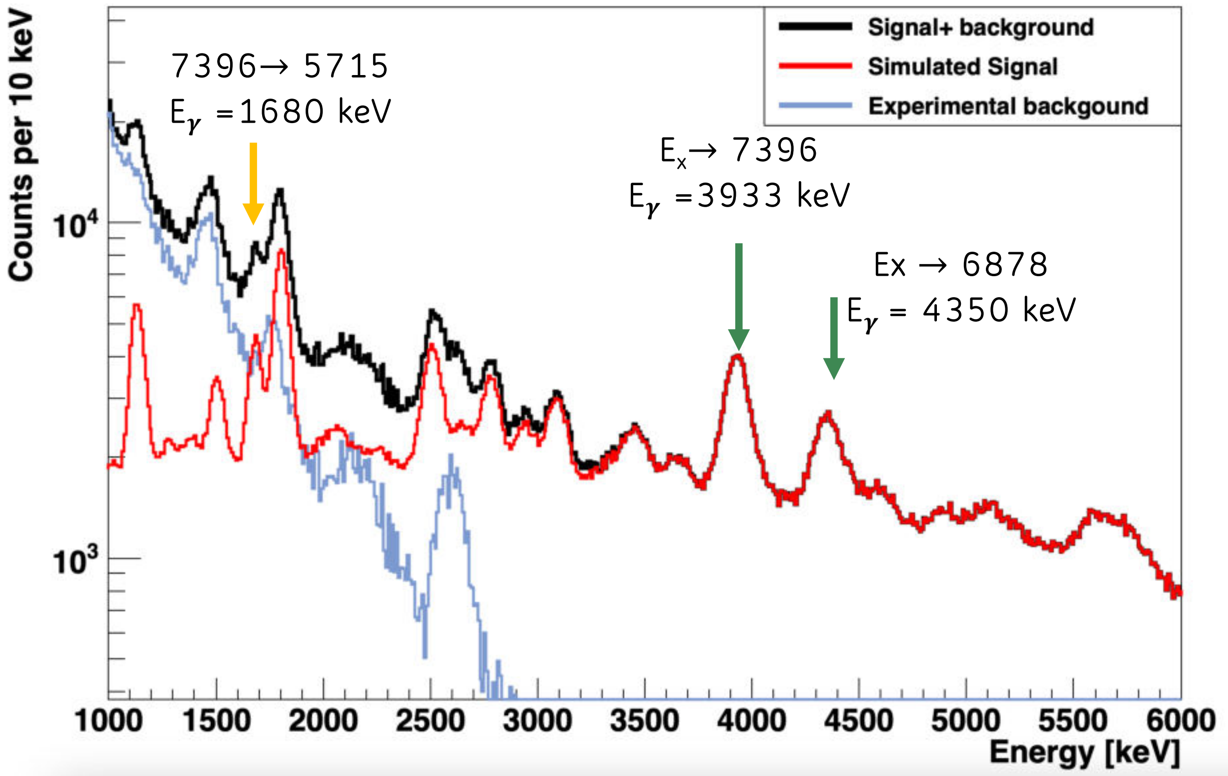


$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11329.1 keV

Underground measurement
unshielded vs shielded





$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11171 keV

Does an α cluster state exist at 11171 keV?

Giensen et al.	Not observed
Talwar et al.	observed
Texas A&M low energy	Not observed
Texas A&M high energy	observed

$$\omega\gamma_{11171} = \frac{\Gamma_\alpha \Gamma_\gamma}{\Gamma_\gamma + \Gamma_\alpha} \sim \Gamma_\alpha \sim 10^{-11}\ eV$$

$$\text{Yield}_{11171}(\text{UL}) = 3.01 \cdot 10^{-21}\ counts/s$$

$I = 500\ \mu A$

N_γ in 40 days : 33

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11171 keV

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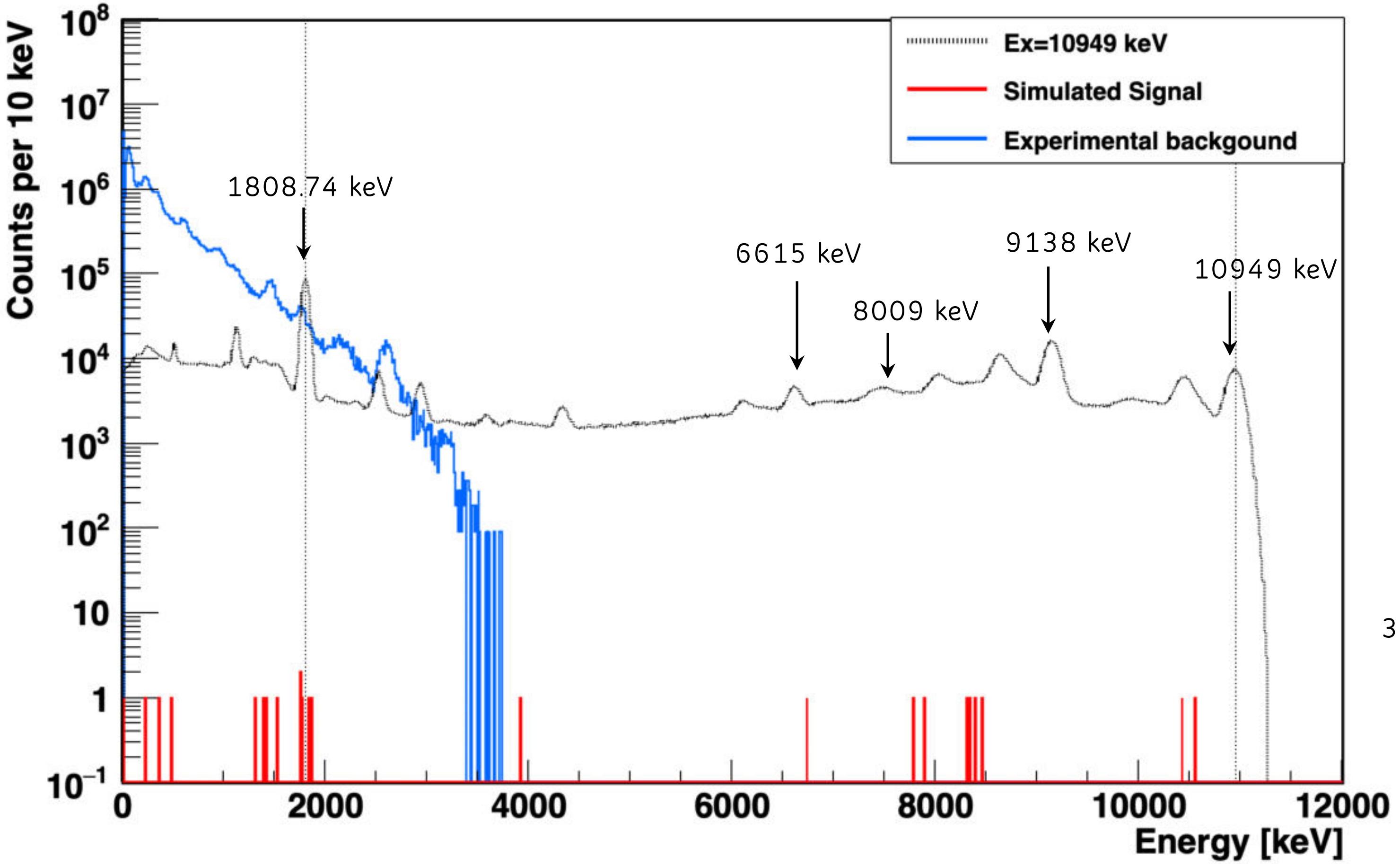
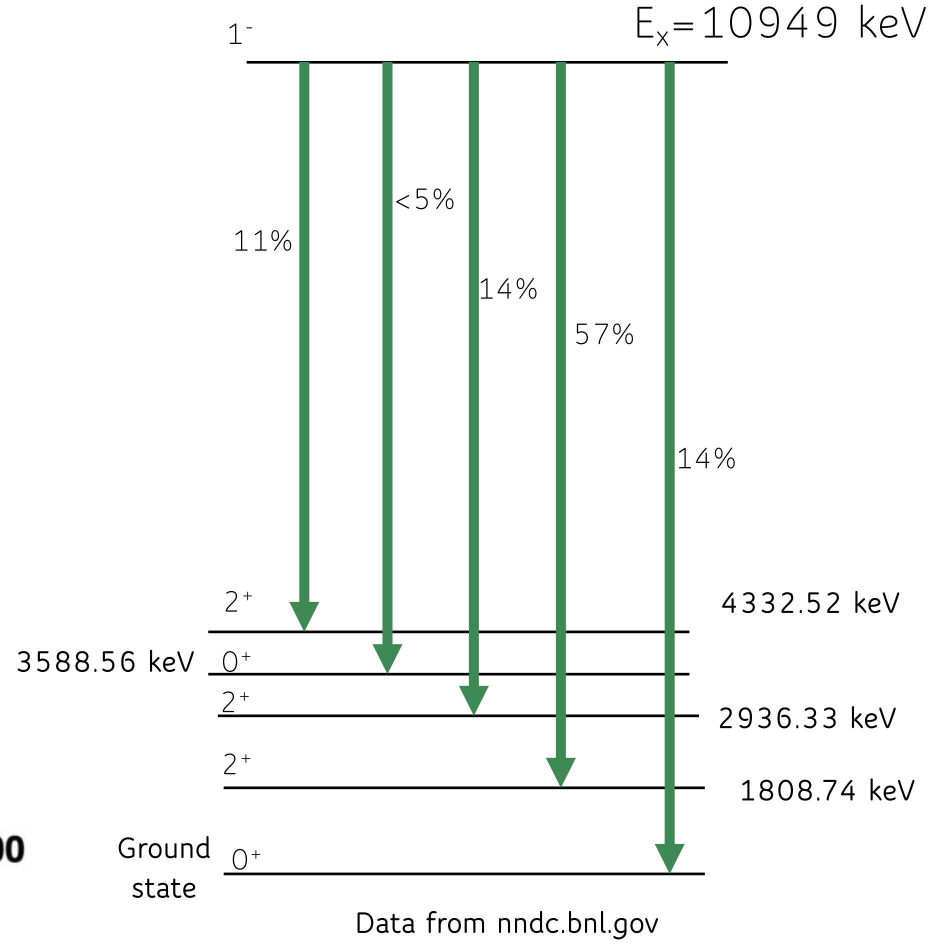
N_γ in 40 days : 33

…and no branching information!

$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Ex =11171 keV

Does an α cluster state exist at 11171 keV?





$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ

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- Astrophysical Motivation
- State of the art
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- Simulation: preliminary results
- Conclusions

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$^{22}Ne(\alpha,\gamma)^{26}Mg$ with EASγ – Conclusions

- $^{22}Ne(\alpha,\gamma)^{26}Mg$ stellar reaction rate crucial to understand several astrophysical open questions
- But still subjected to large uncertainties
- Difficulties in collecting data below the 830 keV resonance on surface lab due to the background
- EASγ will combine data from indirect and deep underground direct measurement to improve sensitvity
- Synergy with $^{22}Ne(a,n)^{25}Mg$ enhances our knowledge on the ^{26}Mg states above the n-threshold

New evaluation of the cross-section in the energy range of astrophysical interest

THANKS FOR THE ATTENTION !