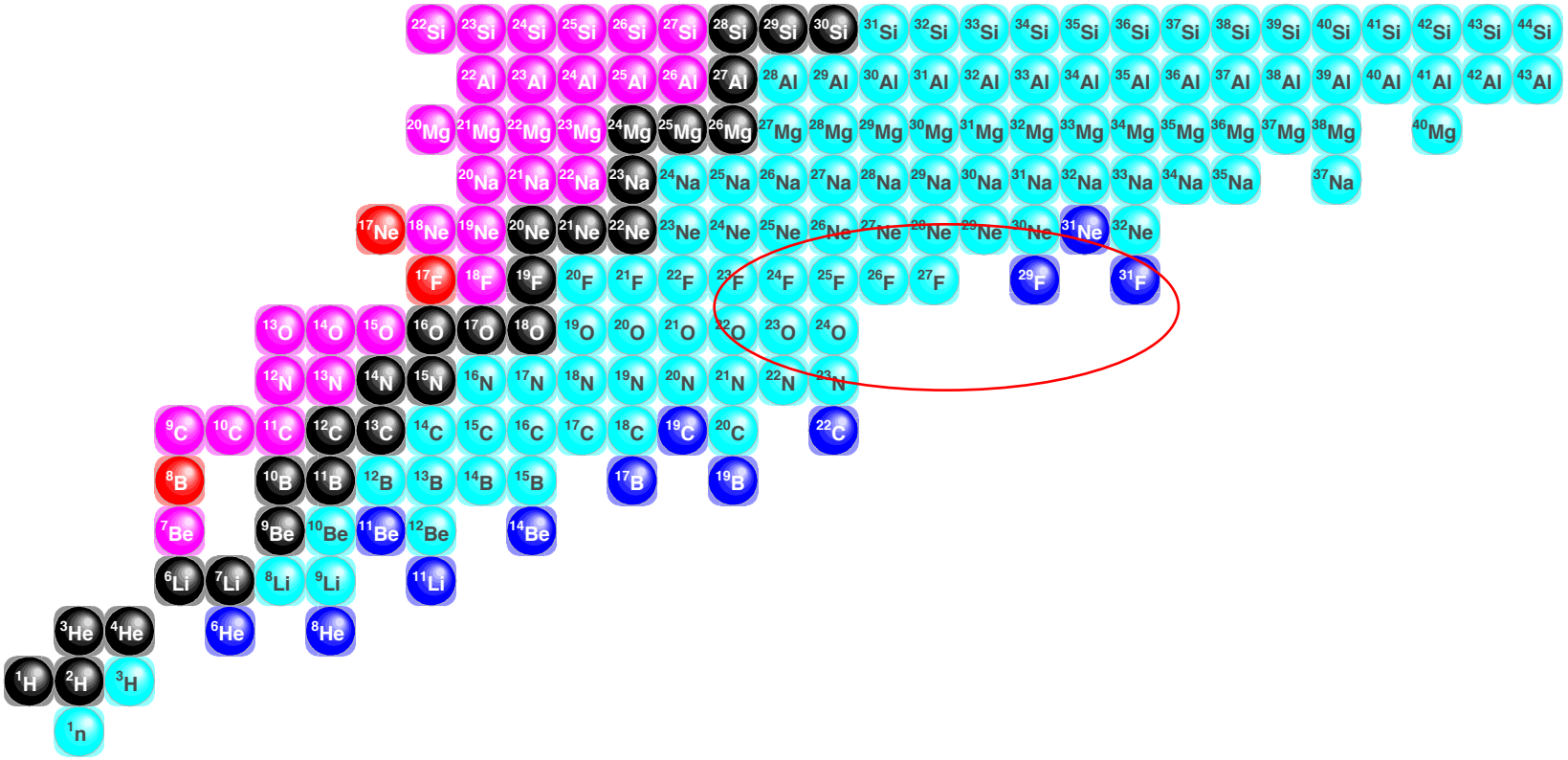
Probing the effect of the continuum: results on ^{26}F and ^{14}B

M. Vandebrouck, A. Lepailleur, O. Sorlin,
R^{3}B collaboration

marine.vandebrouck@cea.fr

Motivation



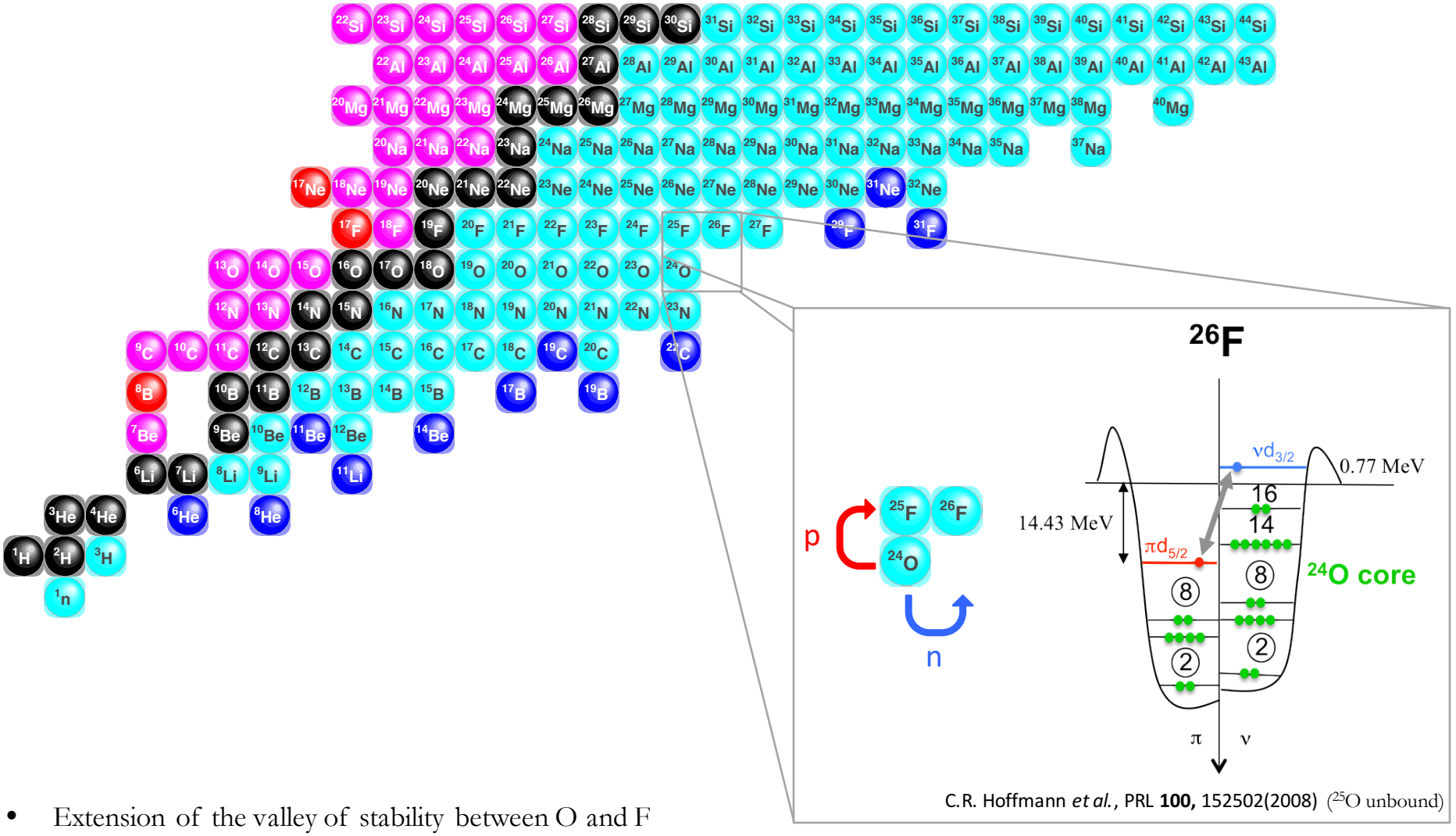
- Extension of the valley of stability between O and F

3-body forces and continuum effect are essential to reproduce the O/F drip line

T. Otsuka *et al.*, PRL **105,** 032501(2010)

G. Hagen *et al.*, PRL **108,** 242501(2012)

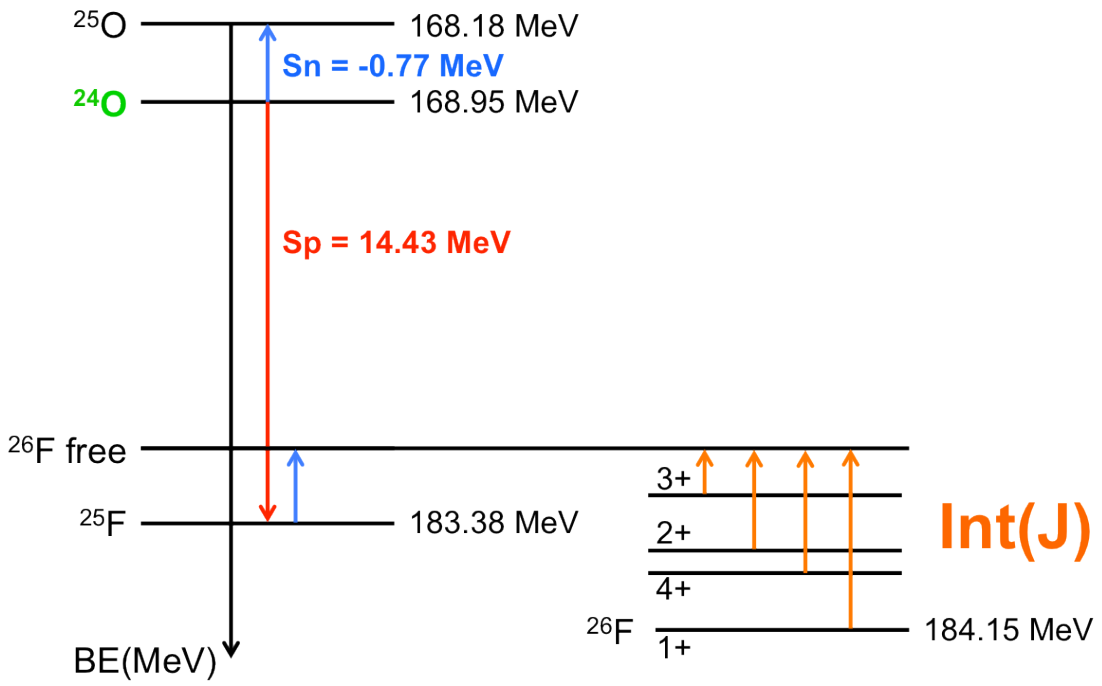
Motivation

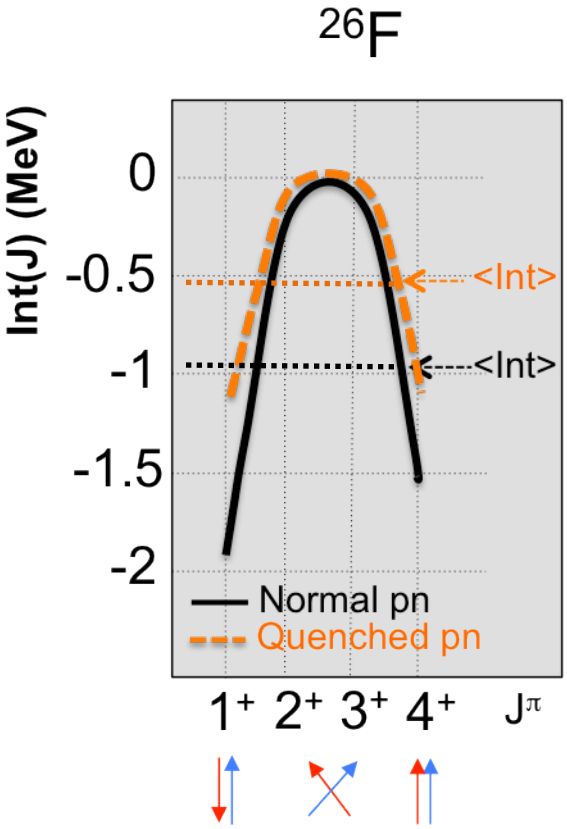


- Extension of the valley of stability between O and F
- ^{24}O doubly magic
- ^{26}F ≈ ^{24}O core + 1p + 1n : coupling $(\pi d_{5/2})^1(\nu d_{3/2})^1$ ➡ $J^\pi = 1^+, 2^+, 3^+, 4^+$ multiplet.

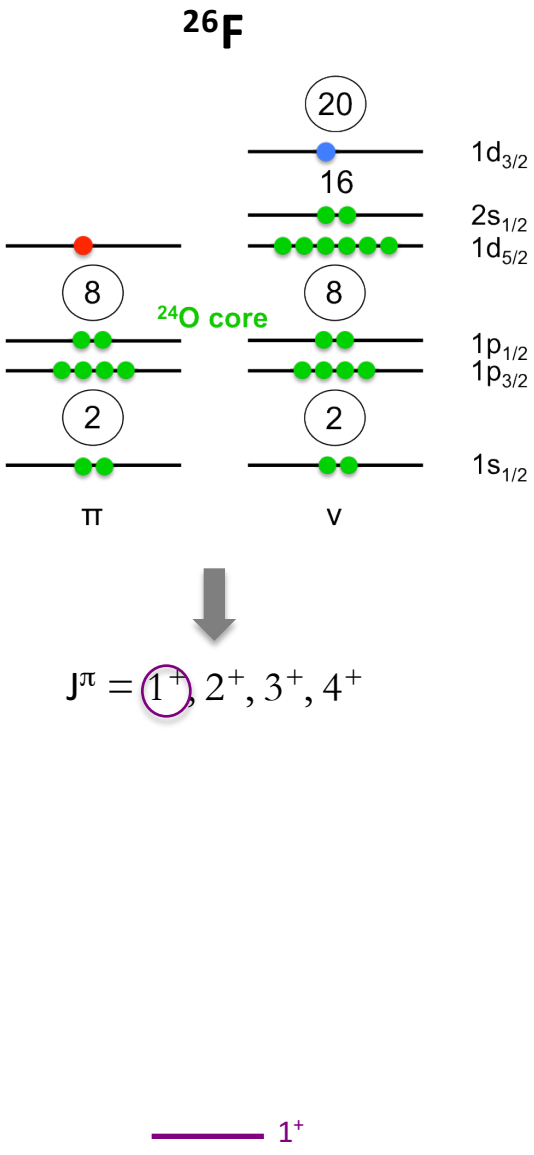
Interaction energy

- Comparison between the exp. BE $J^\pi = 1^+, 2^+, 3^+, 4^+$ w/ ^{24}O core + 1p + 1n
  ➡ definition of the **interaction energy Int(J)**



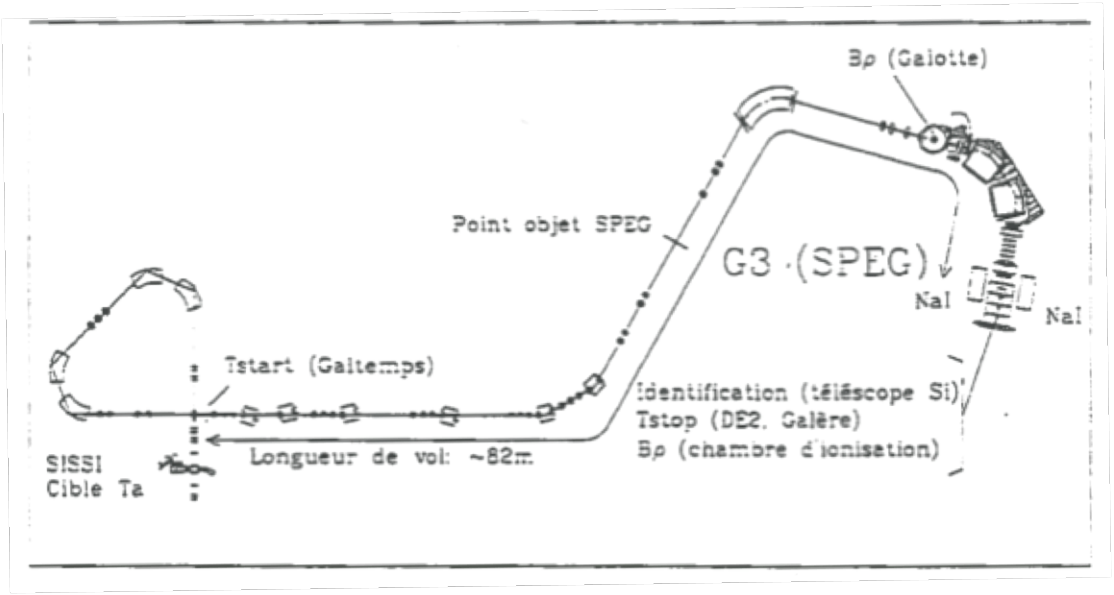


- Representation of the p-n coupling w/ **parabola of interaction energy**
  Mean value gives access to the **average p-n interaction** (monopole term)
  Amplitude depends on the **residual interaction**
- Effect of the continuum ➡ large p-n asymmetry of BE ➡ reduced amplitude and mean value are expected



Study of the 1^+ ground state in ^{26}F

- Mass measurement by time-of-flight technique using SPEG spectrometer

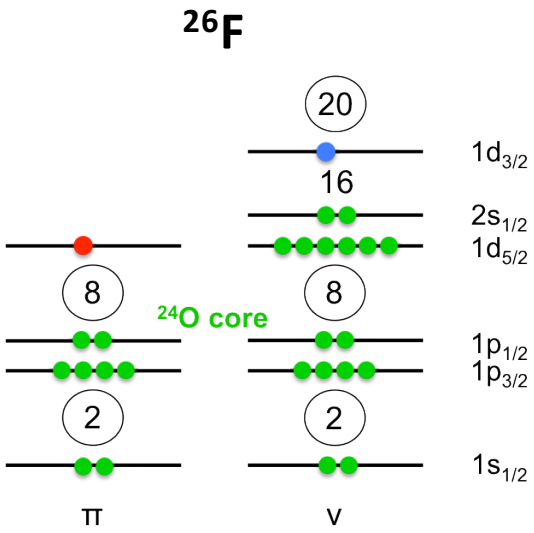


$BE(^{26}F)_{1+} = 184.232$ MeV

B. Jurado *et al.*, PRL **100,** 152502(2008)

- Beta decay of ^{26}F to ^{26}Ne , $J^\pi = 1^+$ identified as the ^{26}F ground state

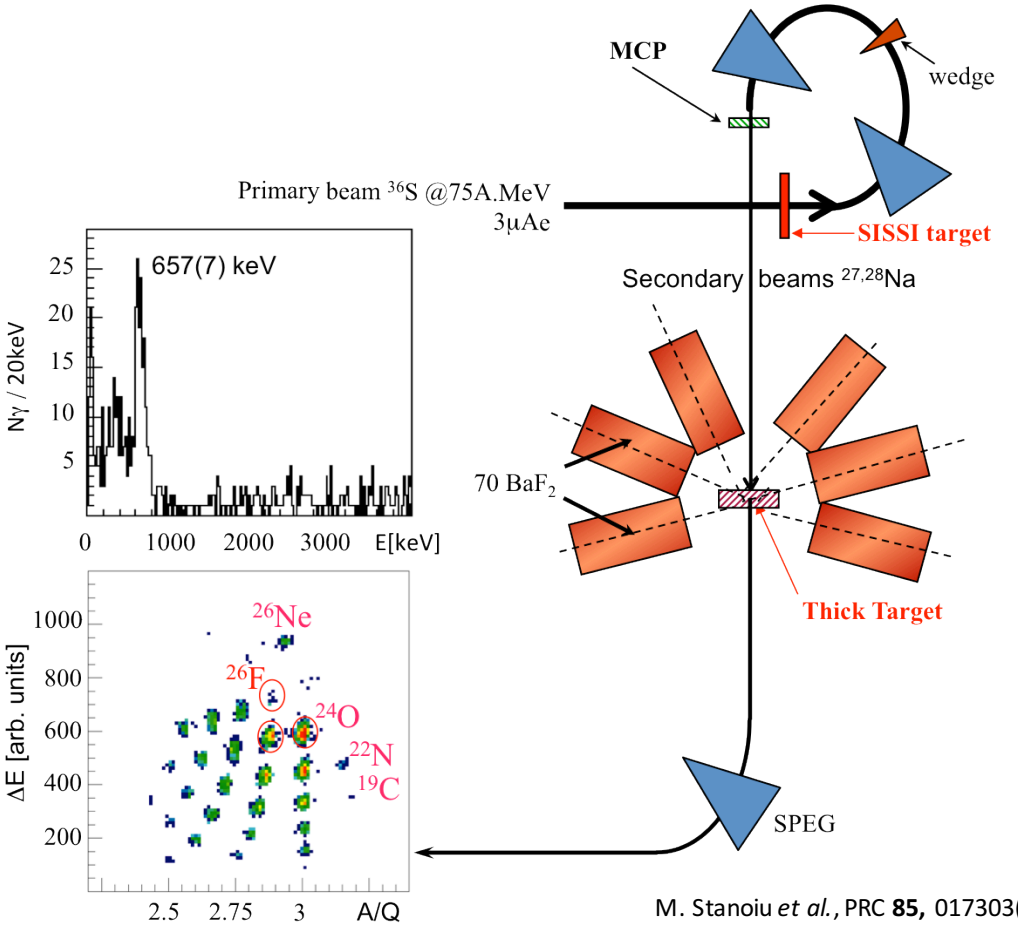
A.T. Reed *et al.*, PRC **60,** 024311(1999)



$J^{\pi} = 1^+, (2^+), 3^+, 4^+$

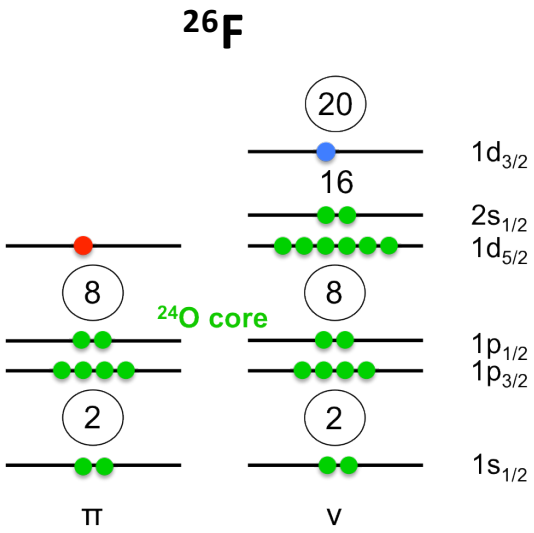
Study of the 2^+ excited state in ^{26}F

- In-beam γ-ray spectroscopy of ^{26}F produced from ^{27,28}Na secondary beams

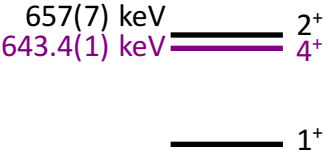


M. Stanoiu *et al.*, PRC **85,** 017303(2012)

State of the art



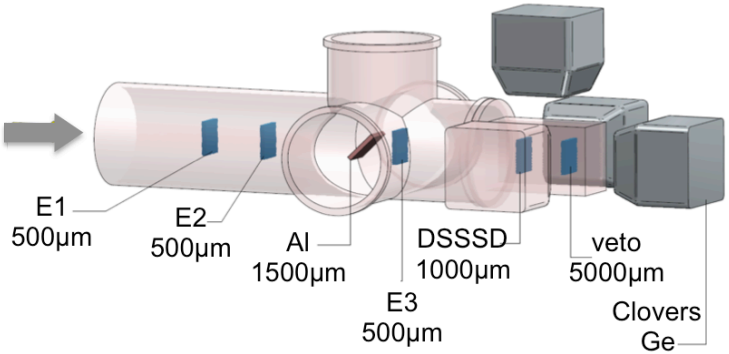
$J^{\pi} = 1^+, 2^+, 3^+, (4^+)$

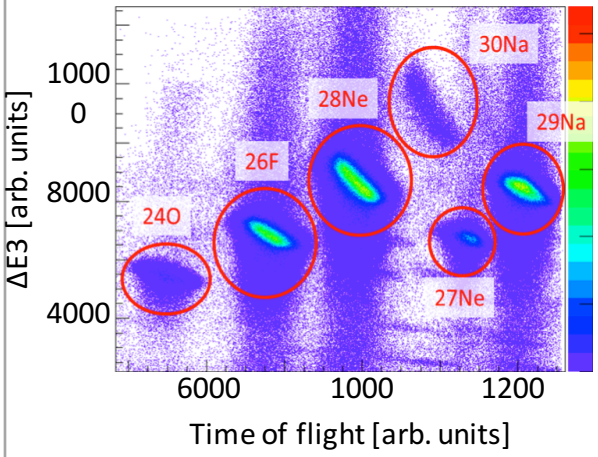


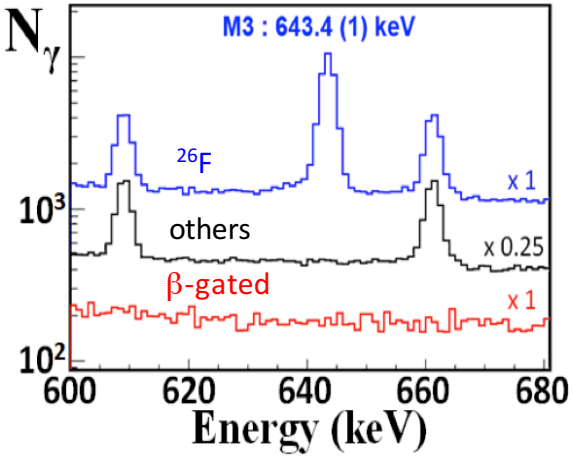
Study of the 4^+ isomer in ^{26}F

- Implantation of ^{26}F in DSSSD and detection of decay γ-ray of the isomer

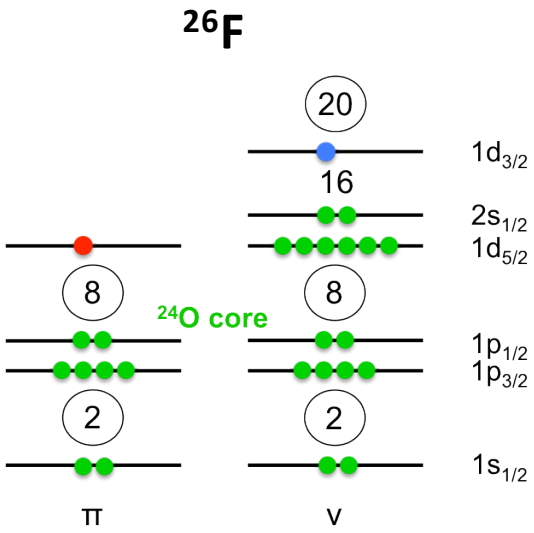
Primary beam
^{36}S @78A.MeV
2μAe
Be target
Secondary beam
^{26}F 6pps



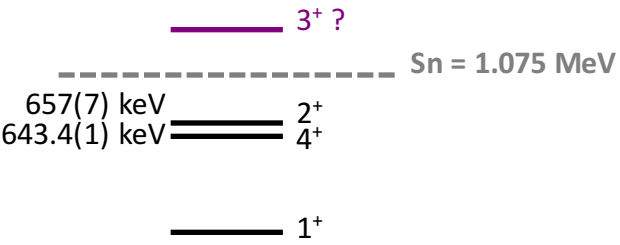




A. Lepailleur *et al.*, PRL **110,** 082502(2013)

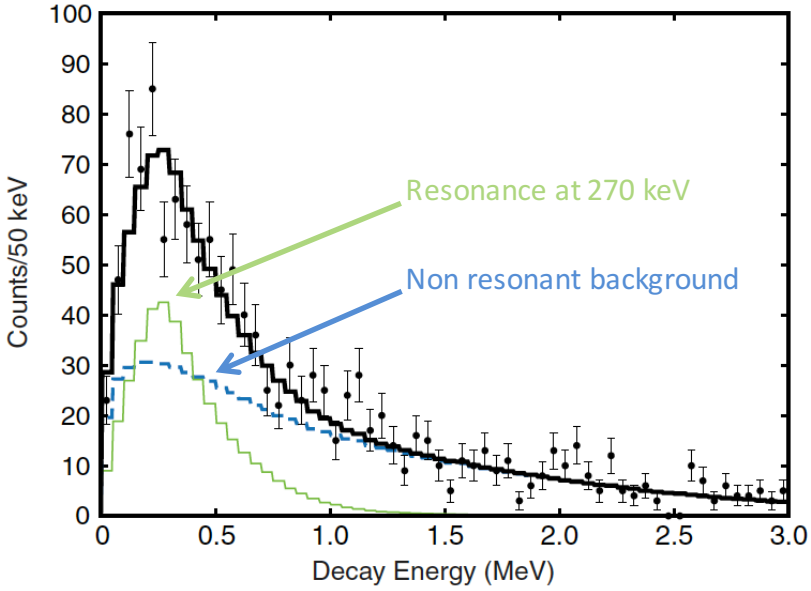


$J^{\pi} = 1^+, 2^+, 3^+, 4^+$



Candidate for the 3^+ unbound state in ^{26}F

- Resonance populated at 270 keV above the neutron threshold in ^{26}F from charge-exchange reaction



N. Frank *et al.*, PRC **84,** 037302(2011)

➡ **Spin assignment ?**

Setup

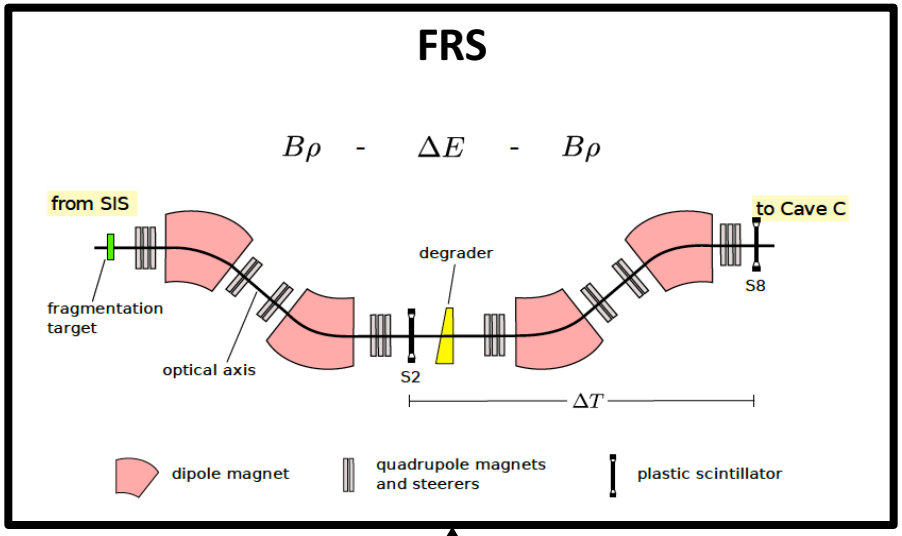
- **1 proton-knockout** reaction in ^{27}Ne to populate ^{26}F unbound states and characterize the resonances

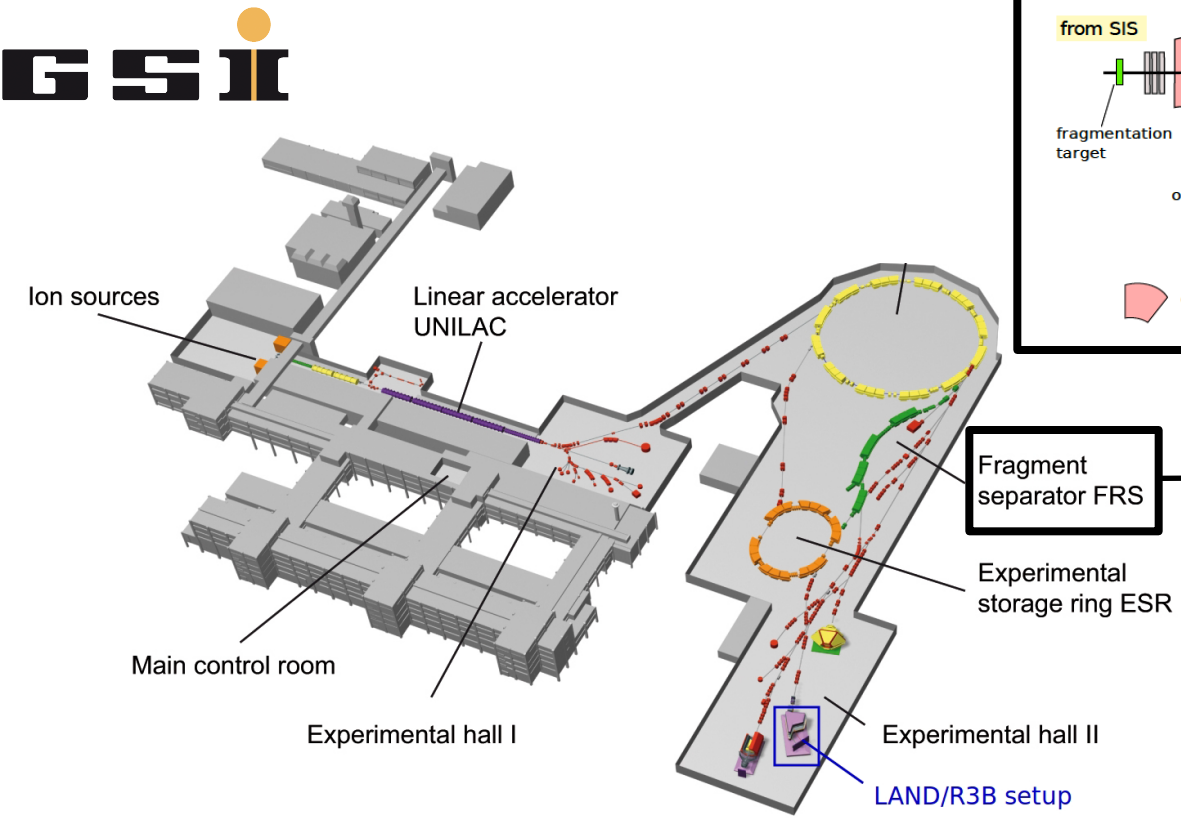
^{40}Ar → (fragmentation) → ^{27}Ne → (-1p) → ^{26}F* → ^{26}F + γ / ^{25}F + n (+γ)

490 MeV/nucleon

^{27}Ne

^{25}F ^{26}F



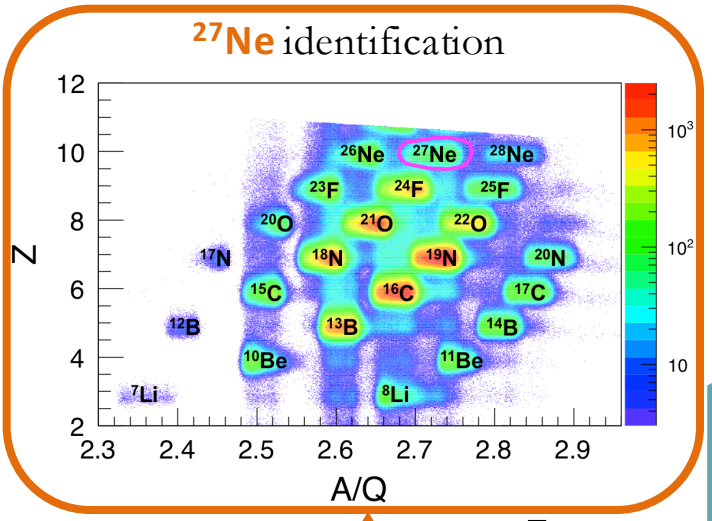


Setup

Picture Sebastian Altstadt

$^{27}Ne \xrightarrow{-1p} {}^{26}F^* \rightarrow {}^{26}F + \gamma$

$^{26}F^* \rightarrow {}^{25}F + n\ (+\gamma)$



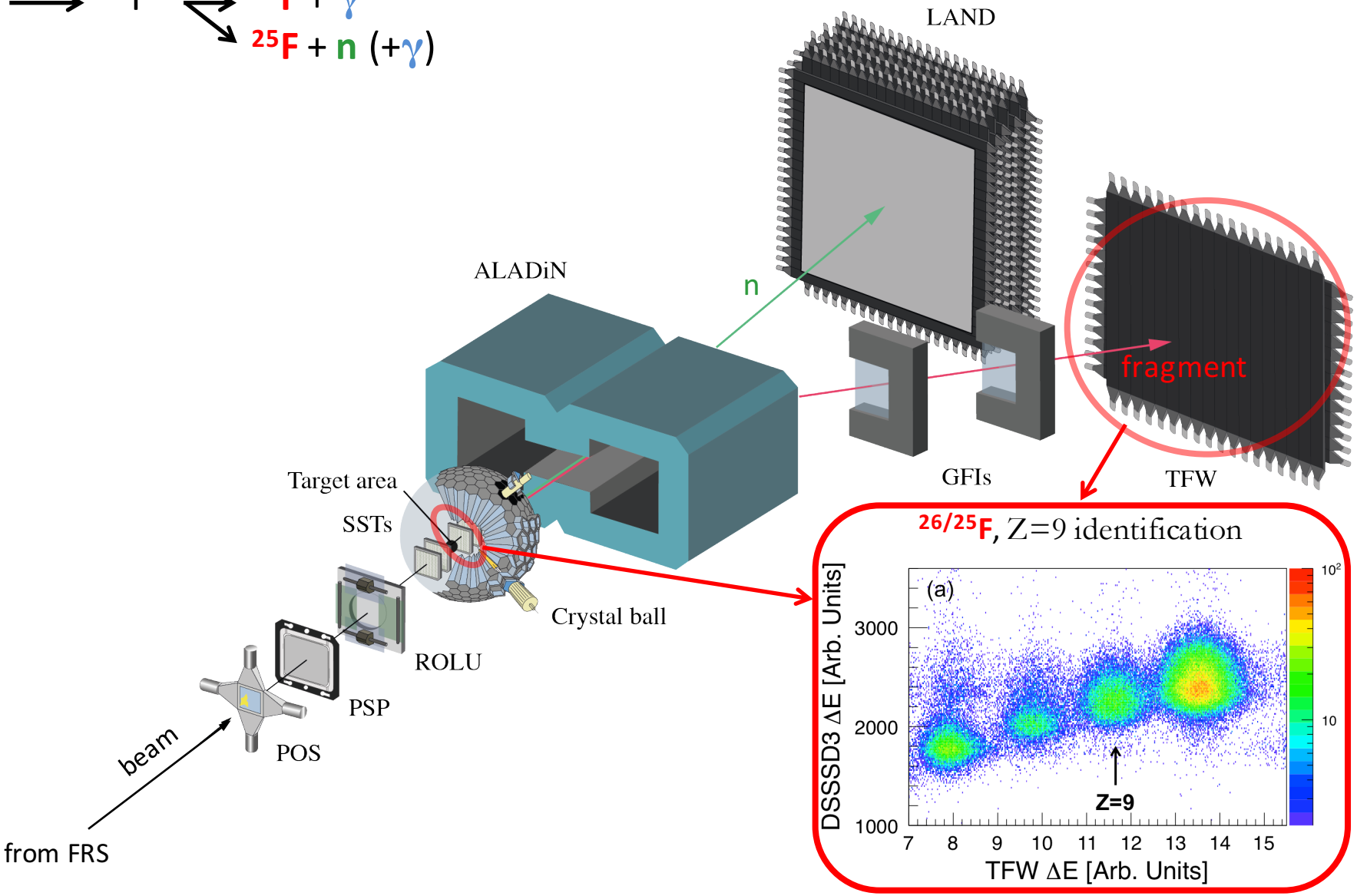
^{27}Ne
432 MeV/nucleon
$2.5\ 10^5$ nuclei

Setup

Picture Sebastian Altstadt

$^{27}Ne \xrightarrow{-1p} {}^{26}F^* \rightarrow {}^{26}F + \gamma$

$^{26}F^* \rightarrow {}^{25}F + n\ (+\gamma)$



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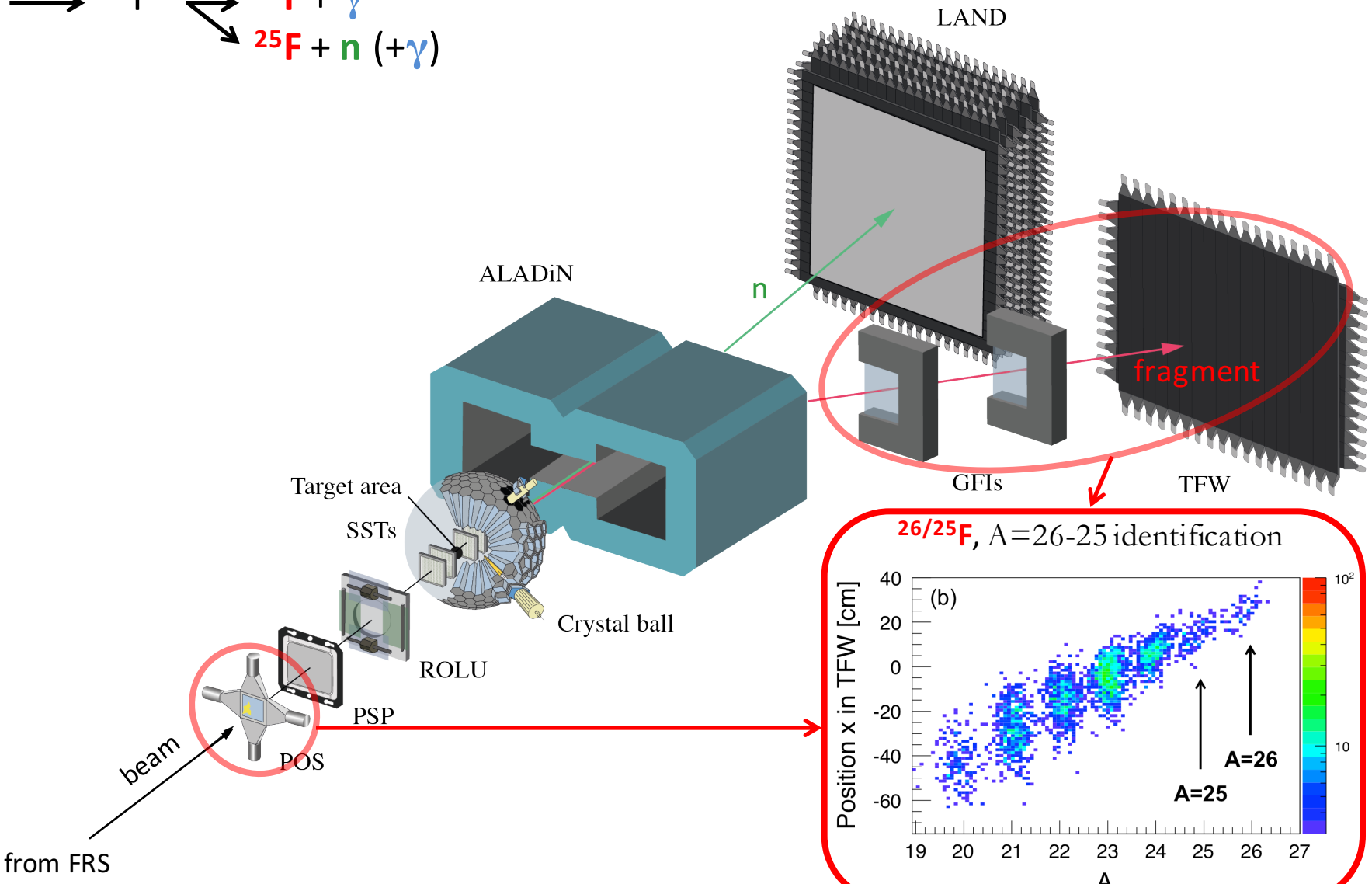

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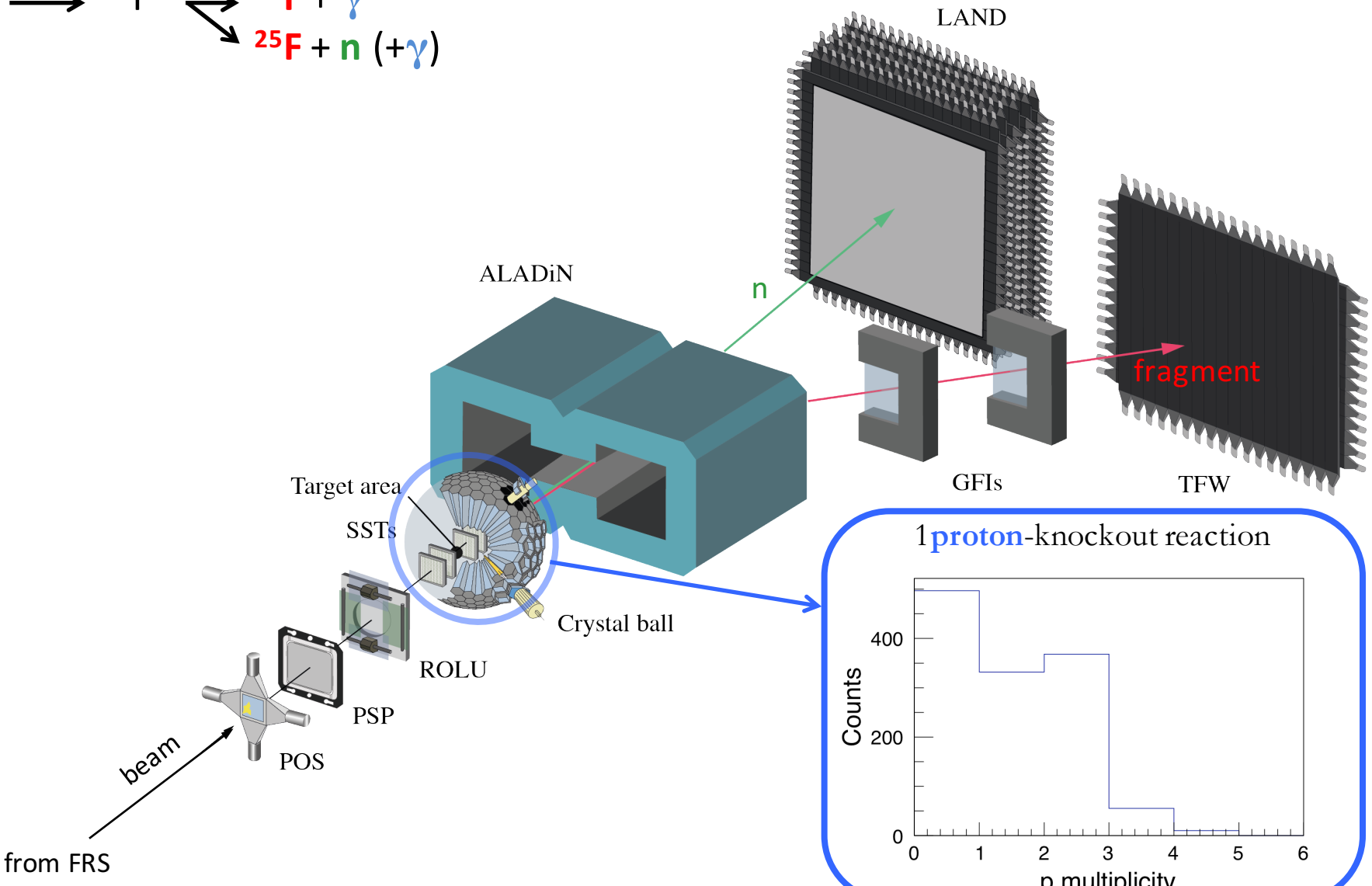

Setup

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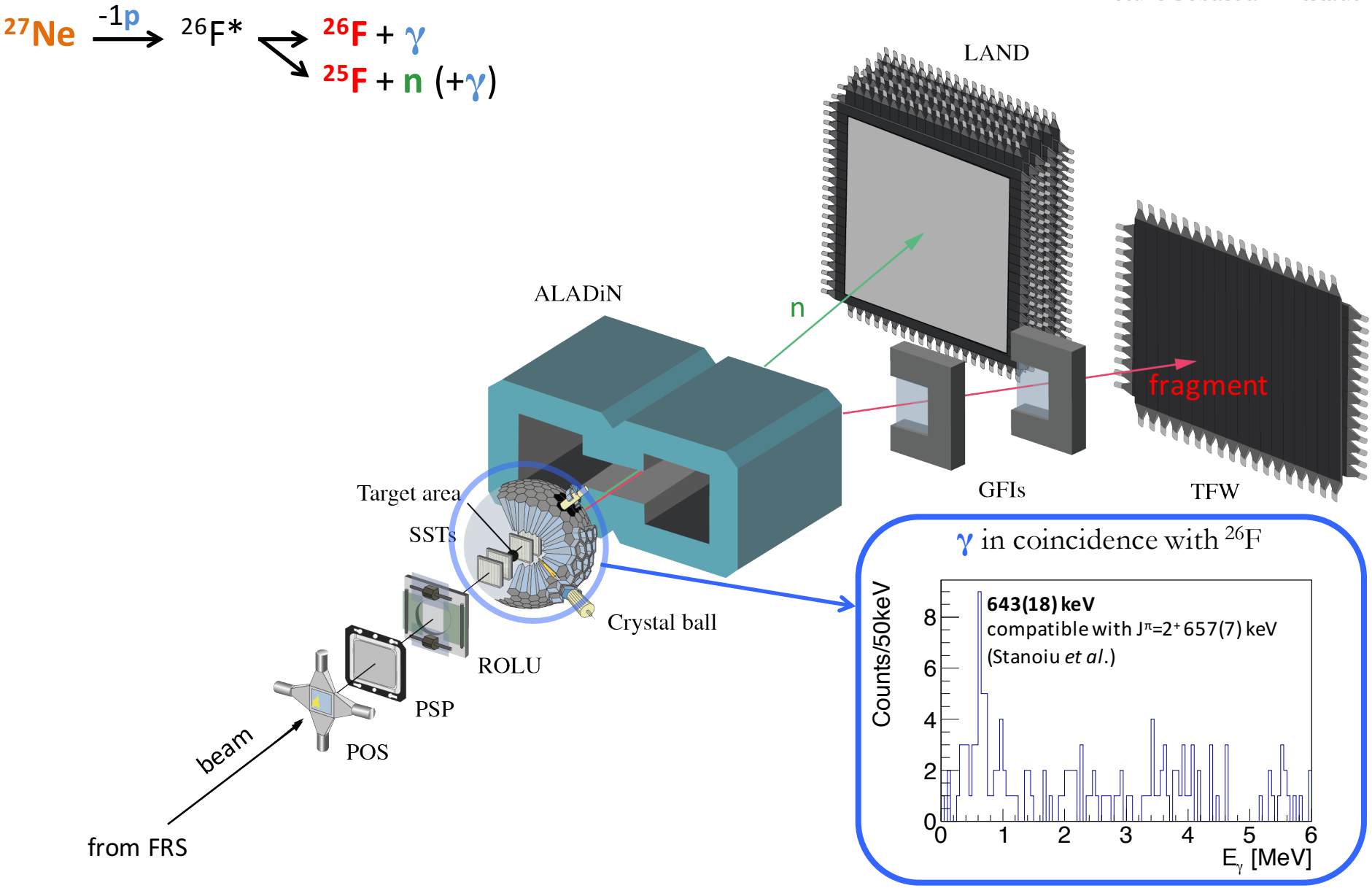
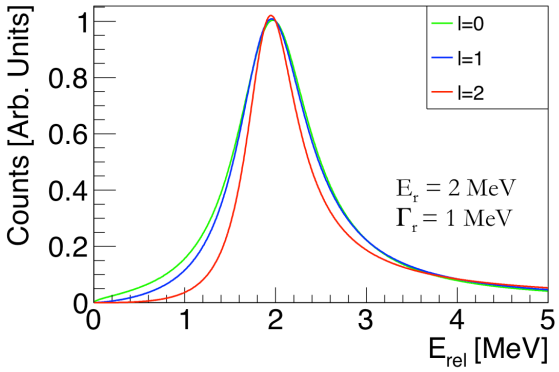


Analysis procedure

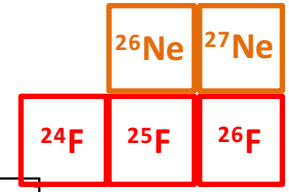
- Detection all particles + momenta ➡ Study ^{26}F unbound states w/ **invariant mass method**
- Relative energy of the system (fragment + n) = (^{25}F+n) : $E_{rel} = \sqrt{m_f^2 + m_n^2 + 2(E_f E_n - p_f p_n \cos\theta)c^2} - m_f c^2 - m_n c^2$
- Resonances described by **Breit-Wigner** line shape

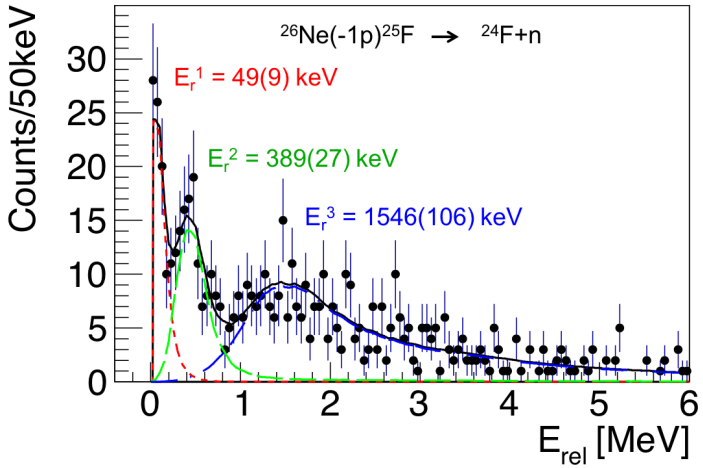


✓ Strong cross-section around Er
✓ Shape depends on l_n = 0,1,2
✓ Characterized by **Er** et **Γr**

➡ Convoluted by the LAND response matrix
➡ Functions used to fit the relative energy spectra

- Check the analysis procedure on the channel ^{26}Ne $\xrightarrow{-1p}$ ^{25}F* $\longrightarrow$ ^{24}F + n (+γ)





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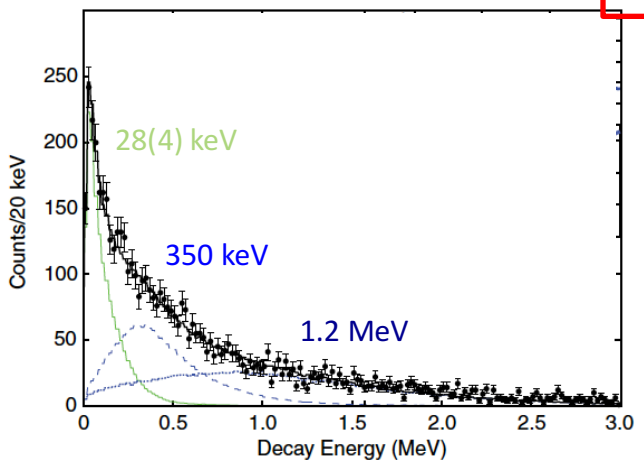
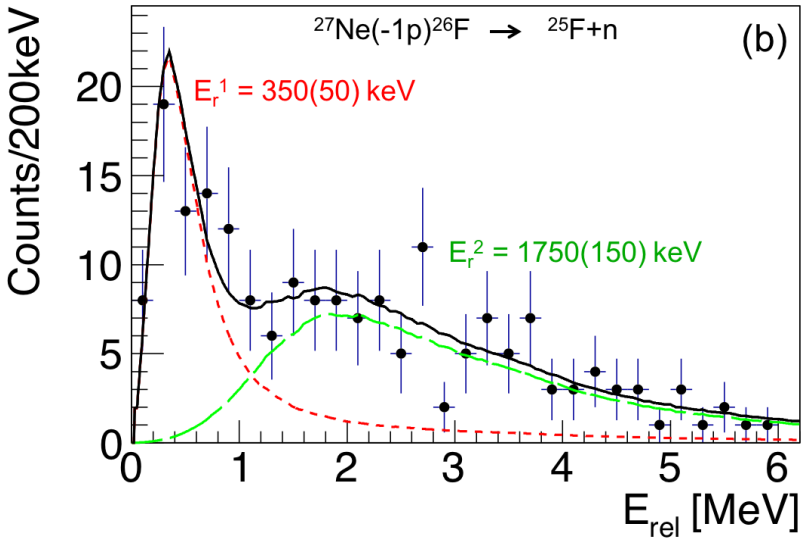


N. Frank *et al.*, PRC **84,** 037302(2011)

Results

$^{27}Ne \xrightarrow{-1p} {}^{26}F^* \longrightarrow {}^{25}F + n\ (+\gamma)$



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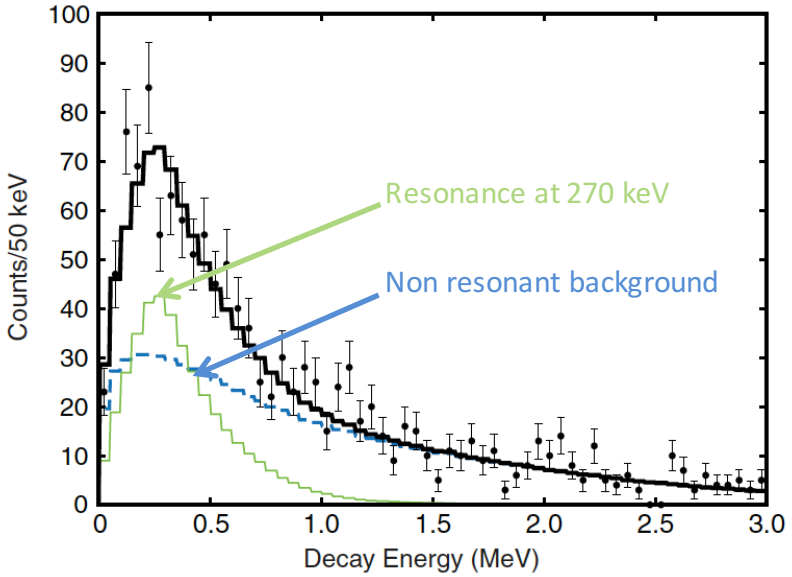


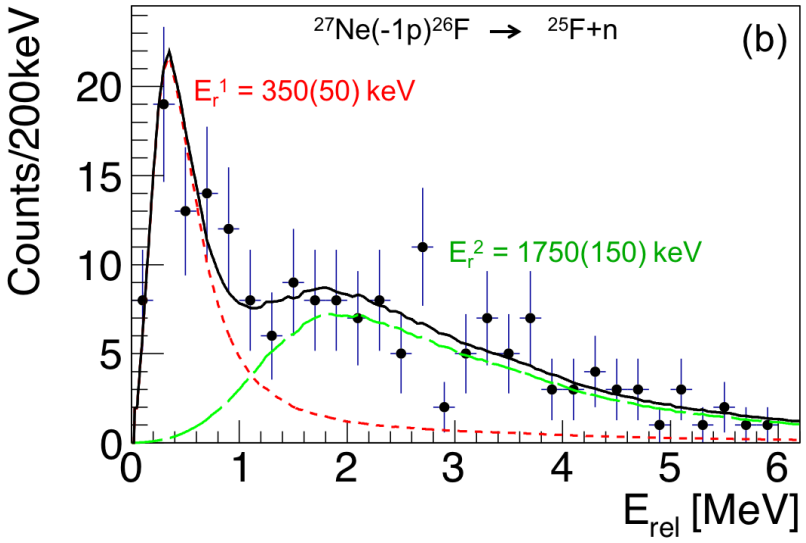
N. Frank *et al.*, PRC **84,** 037302(2011)

- **2 resonances** observed for the system (^{25}F+n)

l_n

Results

$^{27}Ne \xrightarrow{-1p} {}^{26}F^* \longrightarrow {}^{25}F + n\,(+\gamma)$



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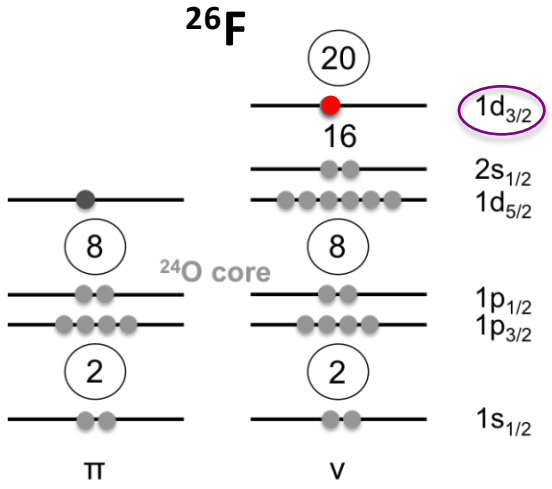
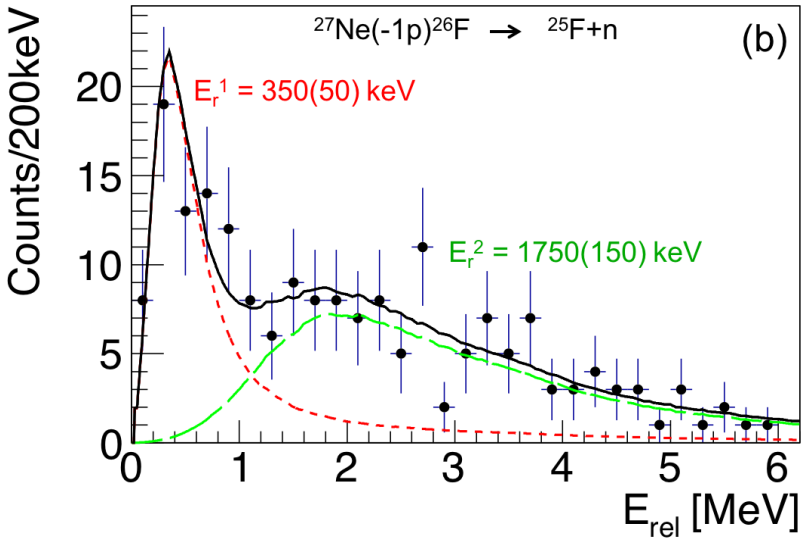
Resonance 1 at 350 keV : $\Gamma_r = 570 \pm 480$ keV
$\Gamma_{sp}(l_n=0) = 3080$ keV
$\Gamma_{sp}(l_n=2) = 74$ keV



- **2 resonances** observed for the system (^{25}F+n)
- Study of the width $\Gamma_r(E)$ of the resonances
  Comparison to Γ_{sp} : $\Gamma_r(E) = \sum_{l_n} C^2S\, \Gamma_{sp}(l_n, E)$ ➡ Resonance 350 keV mainly $l_n = 2$

Results

$^{27}Ne \xrightarrow{-1p} {}^{26}F^* \longrightarrow {}^{25}F + n\,(+\gamma)$



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Resonance 1 at 350 keV : $\Gamma_r = 570 \pm 480$ keV
$\Gamma_{sp}(l_n=0) = 3080$ keV
$\Gamma_{sp}(l_n=2) = 74$ keV

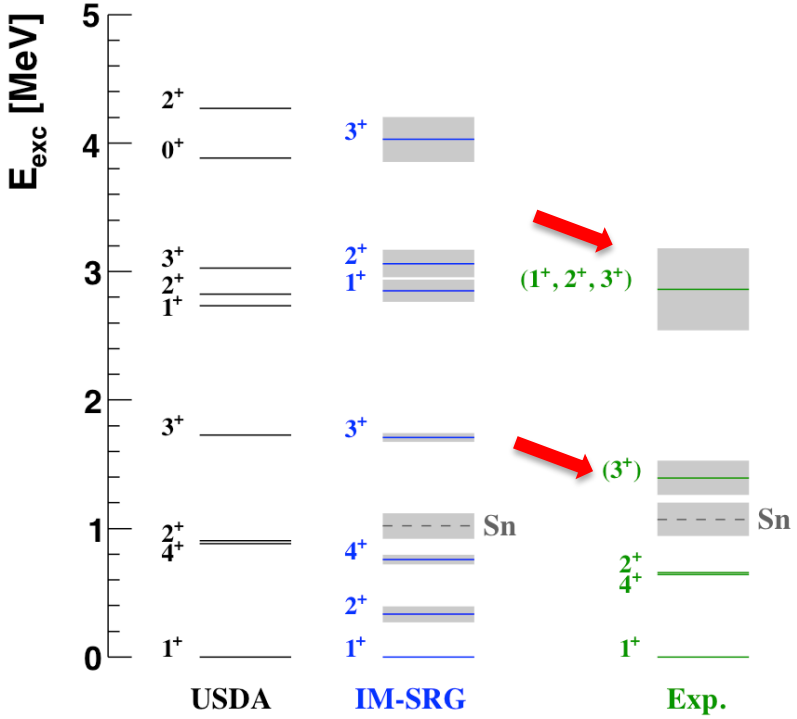
Resonance 2 at 1750 keV : $\Gamma_r = 4200 \pm 2500$ keV
$\Gamma_{sp}(l_n=0) = 7941$ keV
$\Gamma_{sp}(l_n=2) = 2966$ keV

- **2 resonances** observed for the system (^{25}F+n)
- Widths obtained assuming "simple Breit-Wigner"

Comparison to Γ_{sp} : $\Gamma_r(E) = \sum_{l_n} C^2S\, \Gamma_{sp}(l_n, E)$ ⇒ Resonance 350 keV mainly $l_n = 2$
⇒ Resonance 1750 keV mix $l_n = 0$ and $l_n = 2$

Comparison to the models

Level scheme



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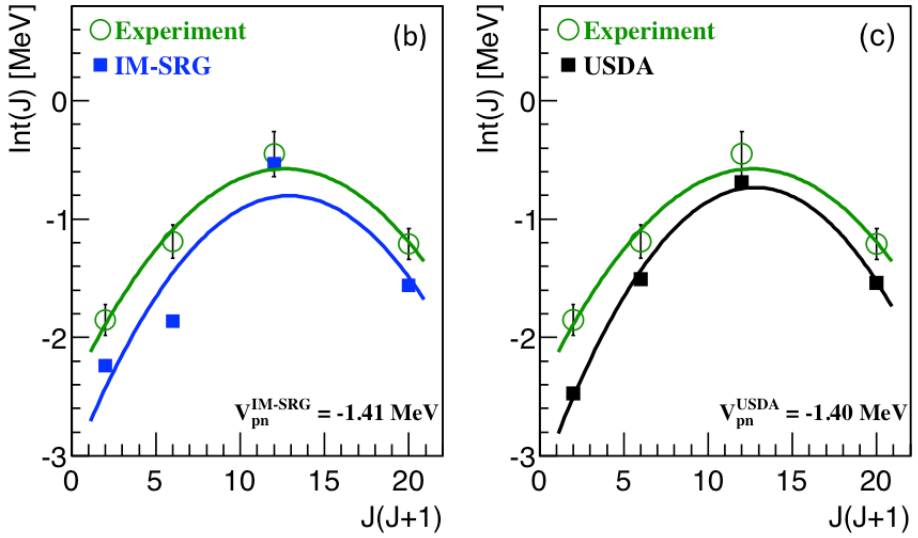
- Comparison to : - USDA phenomenological shell-model
  - ab initio valence space IM-SRG
- Shift in energy

➡ **Due to the lack of treatment of the continuum?**

Interaction energy



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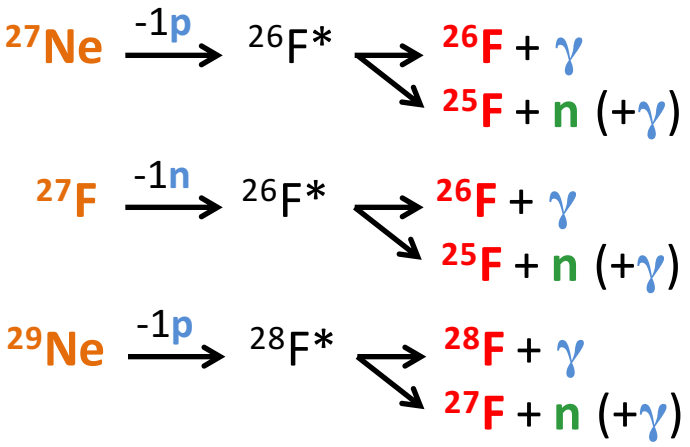
- Effective monopole interaction (J-averaged interaction energy) : V^{exp} = - 1.06 MeV
  V^{IM-SRG} = - 1.41 MeV
  V^{USDA} = -1.40 MeV
- Effective interaction weakened by about 30-40%

Conclusion

- Study of the **unbound states** in **^{26}F** populated in ^{27}Ne(-1p)^{26}F reaction using the **R3B/LAND** setup
- Identification of the 3^+ at 1.4 MeV and several contributions at higher energy
- Comparison to shell model using **realistic interaction** ➡ Need treatment of the continuum?
  Data gives new opportunity to constrain the models

Outlook



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A. Revel PhD thesis