Resonant elastic scattering experiment with active and non-active targets

Laurie DIENIS, GANIL

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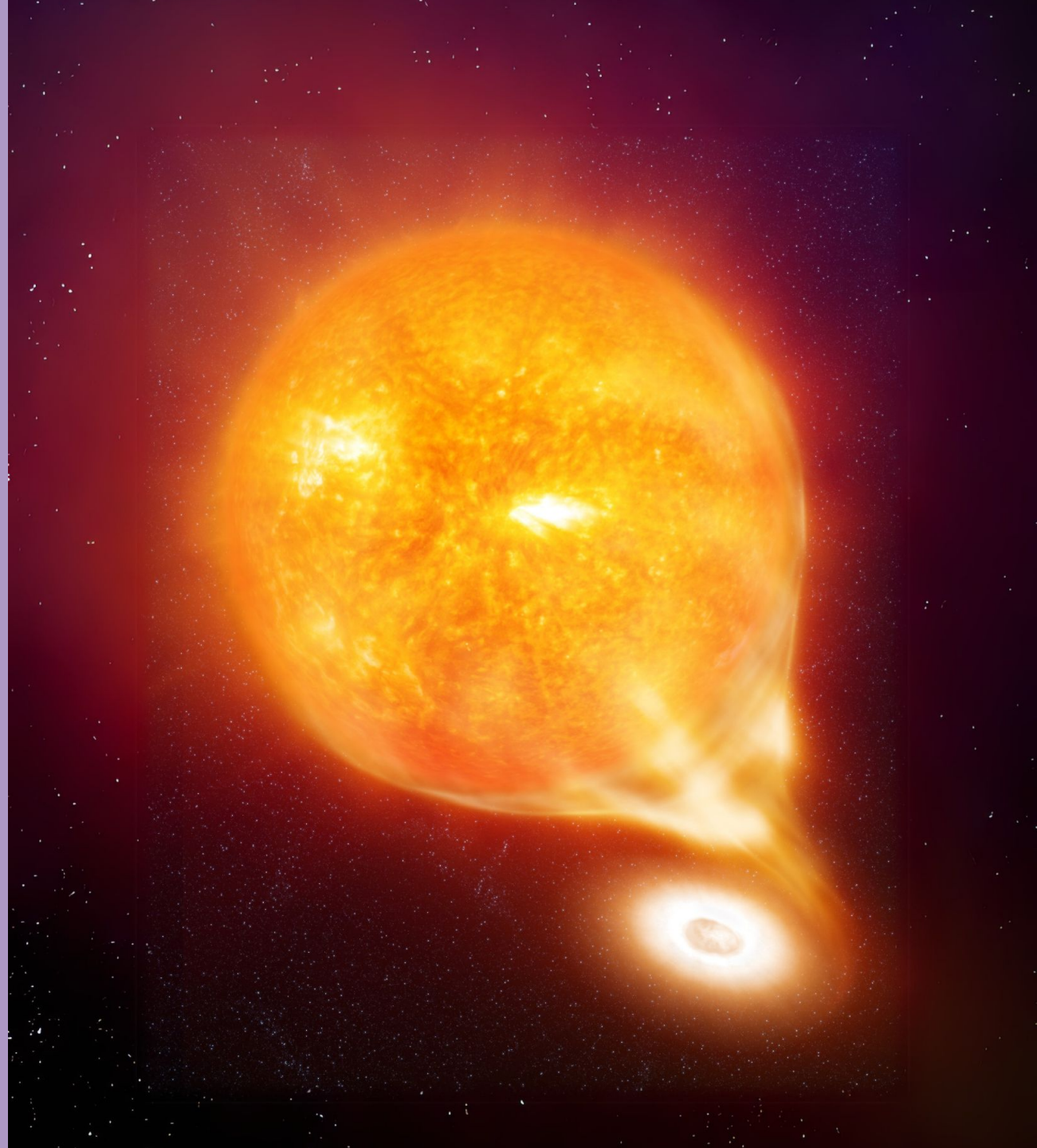
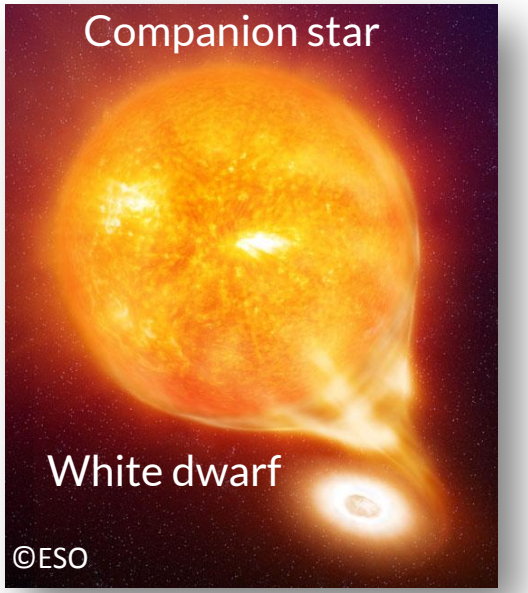
GANIL

Experiment with non-active target :
High resolution spectroscopy of ^{19}Ne to determine the production of ^{18}F in novae



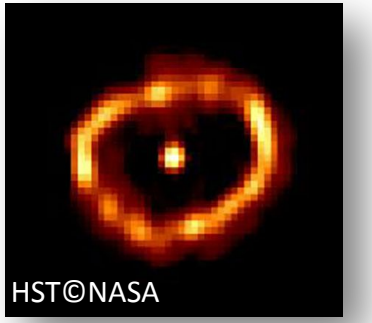
Astrophysical interest : Nova outburst

Matter accretion
-> explosive hydrogen burning



10^4 – 10^5 L_{sun}

Nova Centauri (2013)



Nova Cygni (1992)

Impact

Abundances of elements (^{13}C, ^{15}N, ^{17}O)
Composition of presolar grains

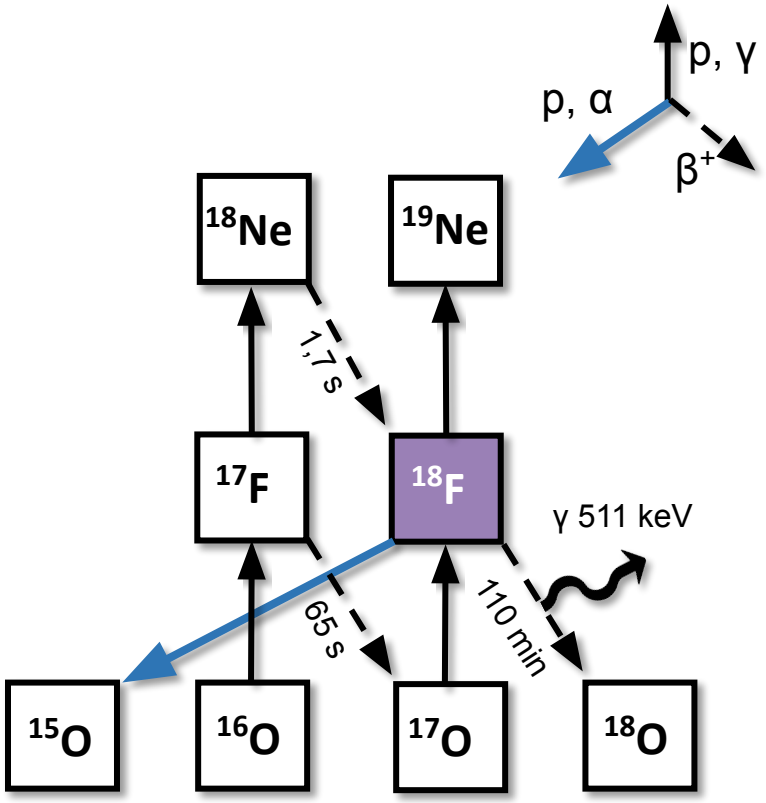
Uncertainties

White dwarf mass
Admixed matters
Accreta metallicity
Dynamics of accretion and ejecta
Other parameters

} Ejected ^{18}F mass

Direct novae observations

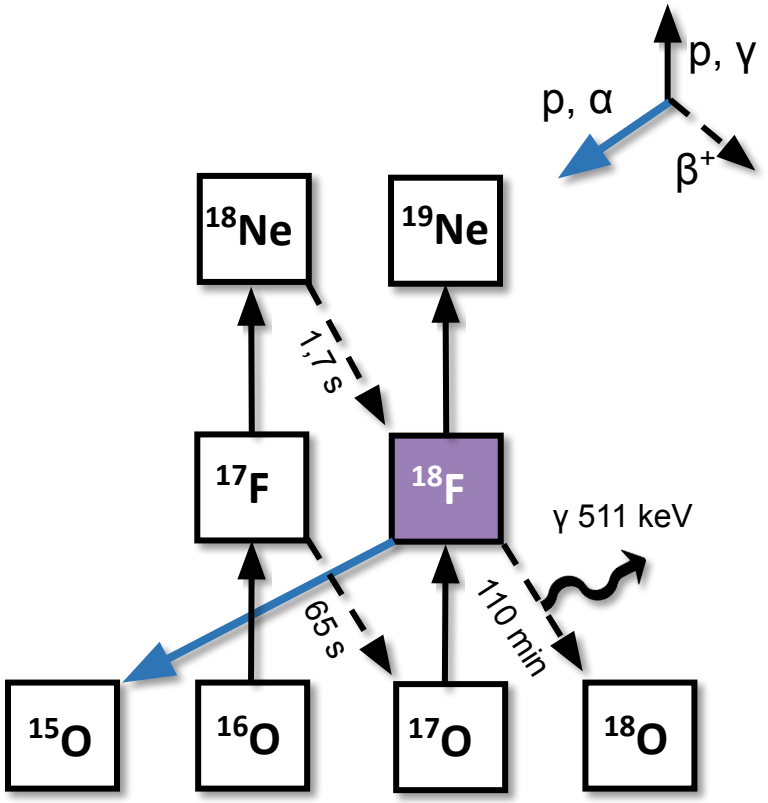
Observed in all wavelengths, not yet with low MeV γ rays



Classical novae (CO and ONe)

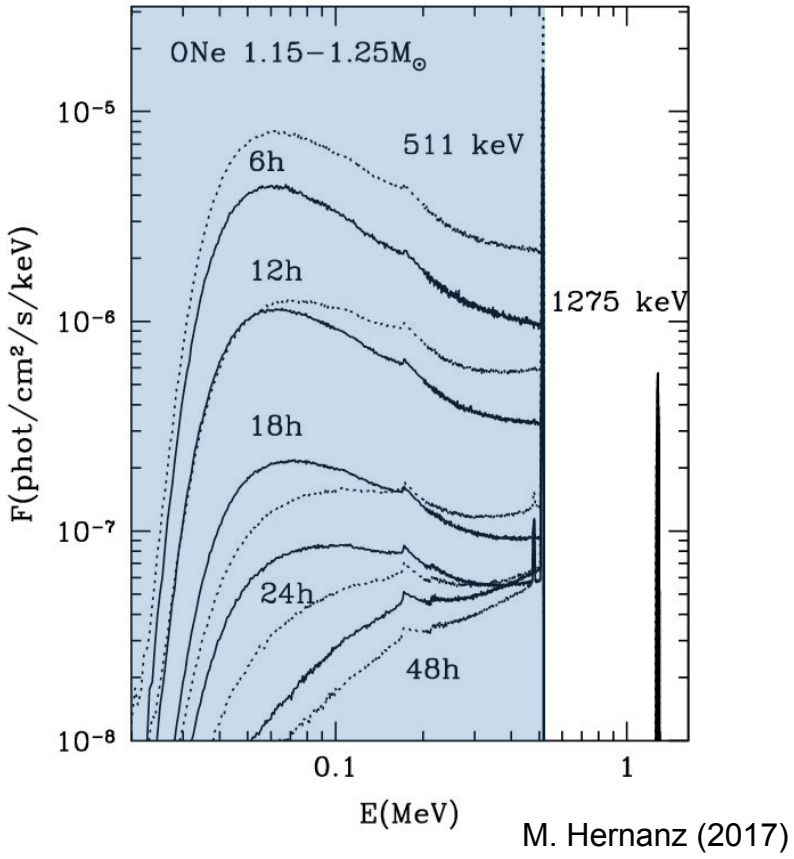
Direct novae observations

Observed in all wavelengths, not yet with low MeV γ rays



Classical novae (CO and ONe)

Emissions from ^{18}F



M. Hernanz (2017)

Direct novae observations

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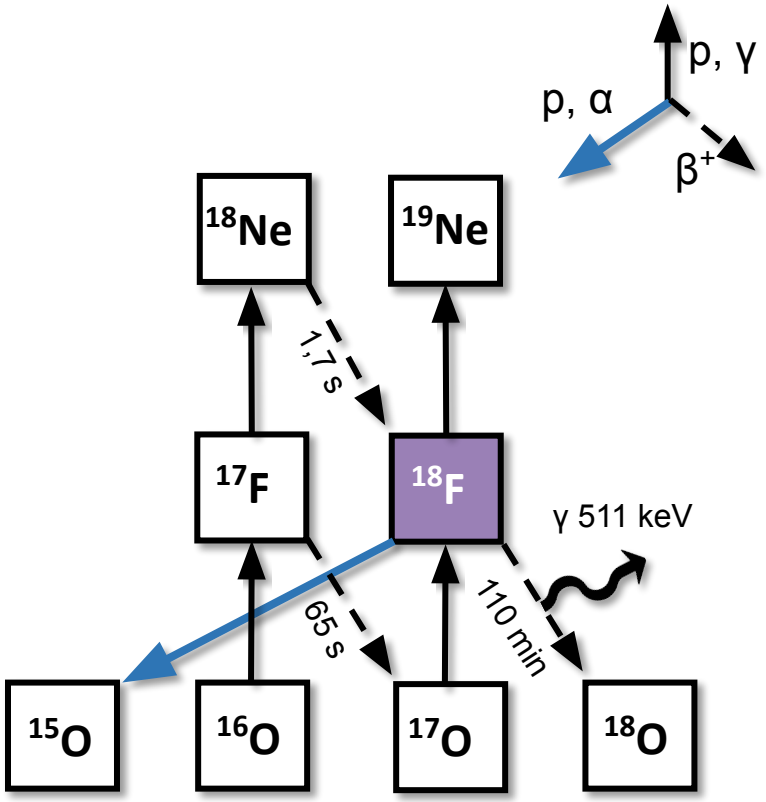
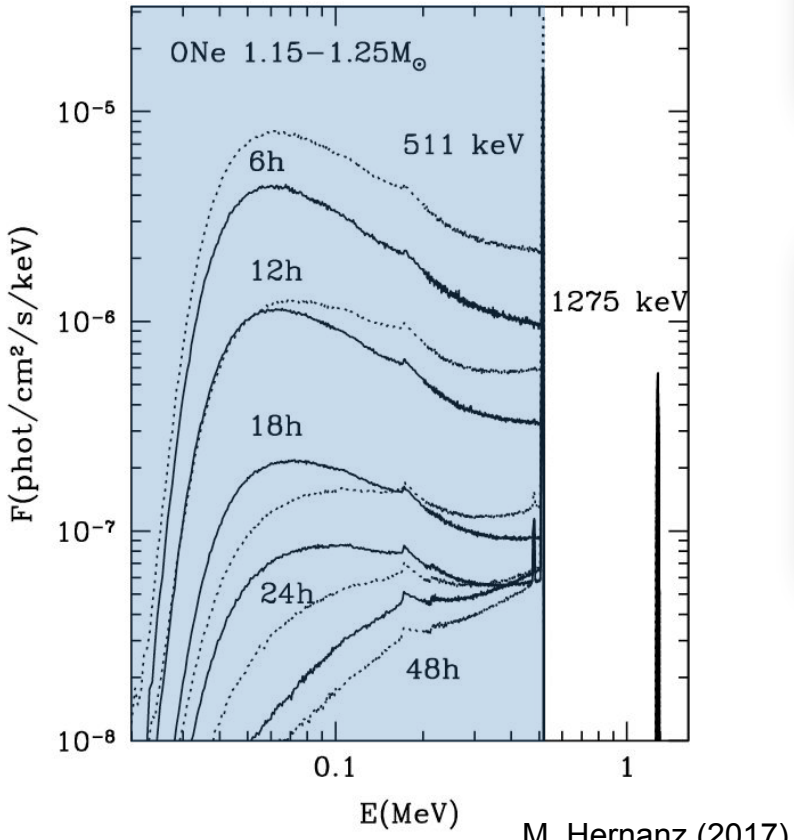


Classical novae (CO and ONe)

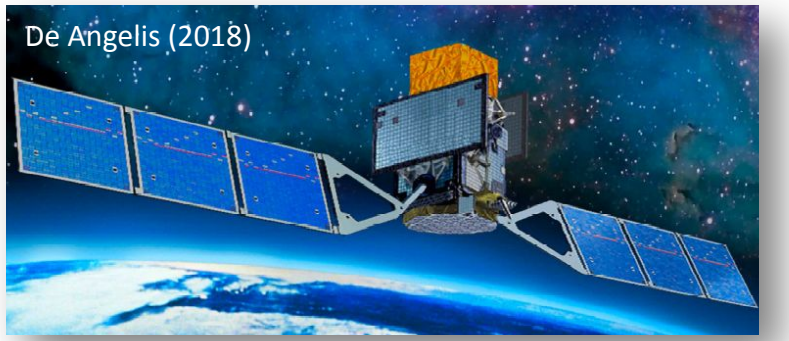
Emissions from ^{18}F



M. Hernanz (2017)

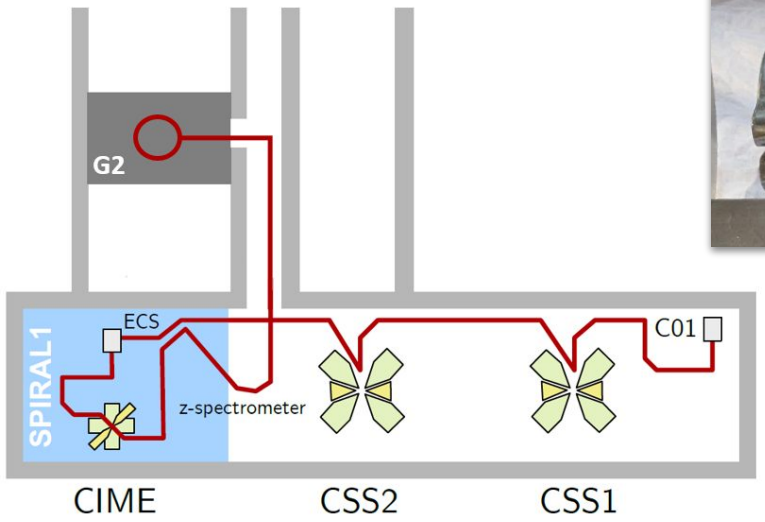
COSI – launch : 2027

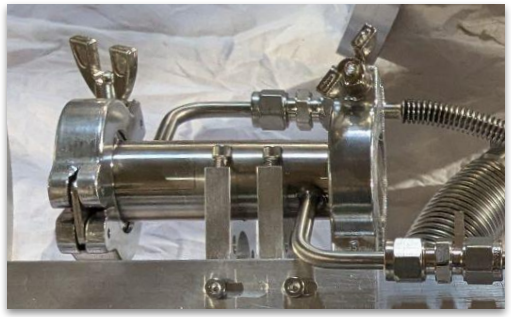
e-ASTROGAM – launch : 2029 ?



- Abundance of ^{18}F
- Maximum detectability distance

Experimental setup for the spectroscopy of ^{19}Ne





$\alpha(^{15}O,^{15}O)\alpha$

Ge detector

Radioactivity of ^{15}O ($T_{1/2}$ = 122 s)

~10 counts/s

E_γ = 511 keV

^{15}O beam

α

^{4}He

34 cm

9 cm

Gaseous target (^{4}He)

Pressure = 350 Torr

+

Ti windows

thin entrance 2,6 µm

thick exit 6 µm -> Beam stopped at exit

Si detector

FWHM = 17 keV

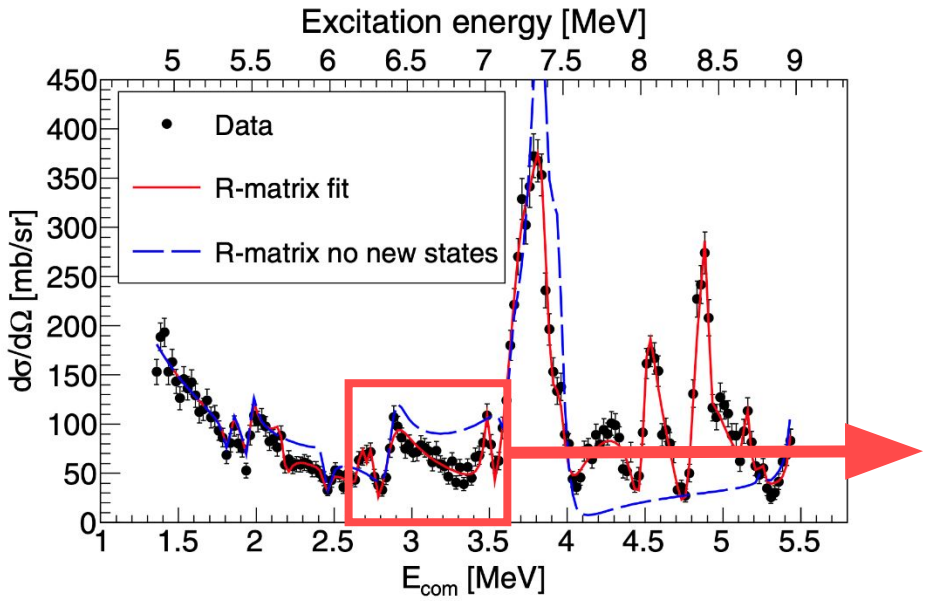
Angular coverage (lab) = [0, 2]°

^{15}O beam from SPIRAL1 :

- $I_{beam} = 10^6$ pps
- E_{beam} = 1.8 MeV/u (spread 0.1%)
- Purity > 97%

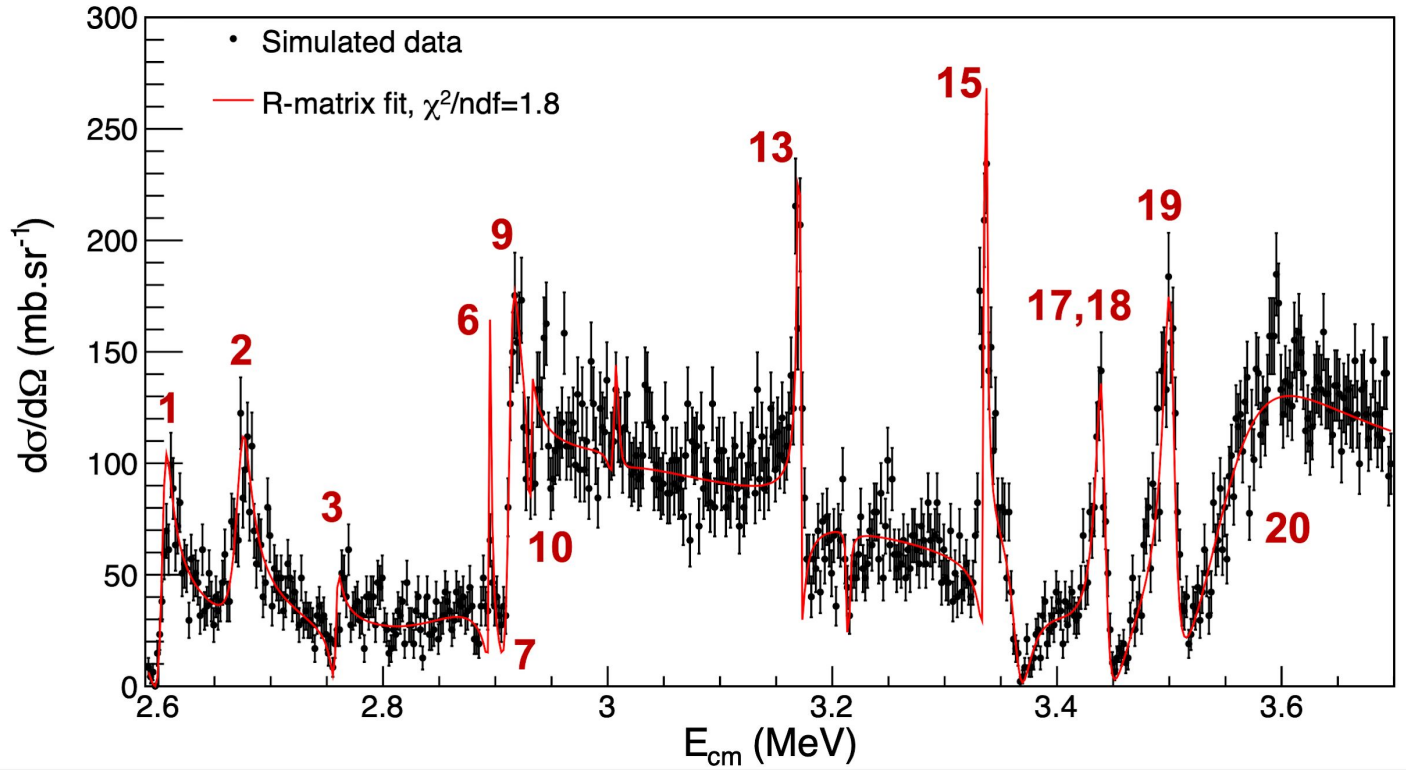
Simulated results for the spectroscopy of ^{19}Ne

Elastic $^{15}O(\alpha,\alpha)^{15}O$ reactions probing levels in ^{19}Ne at $E_x \in [-0.3, +0.6]$ MeV from S_p



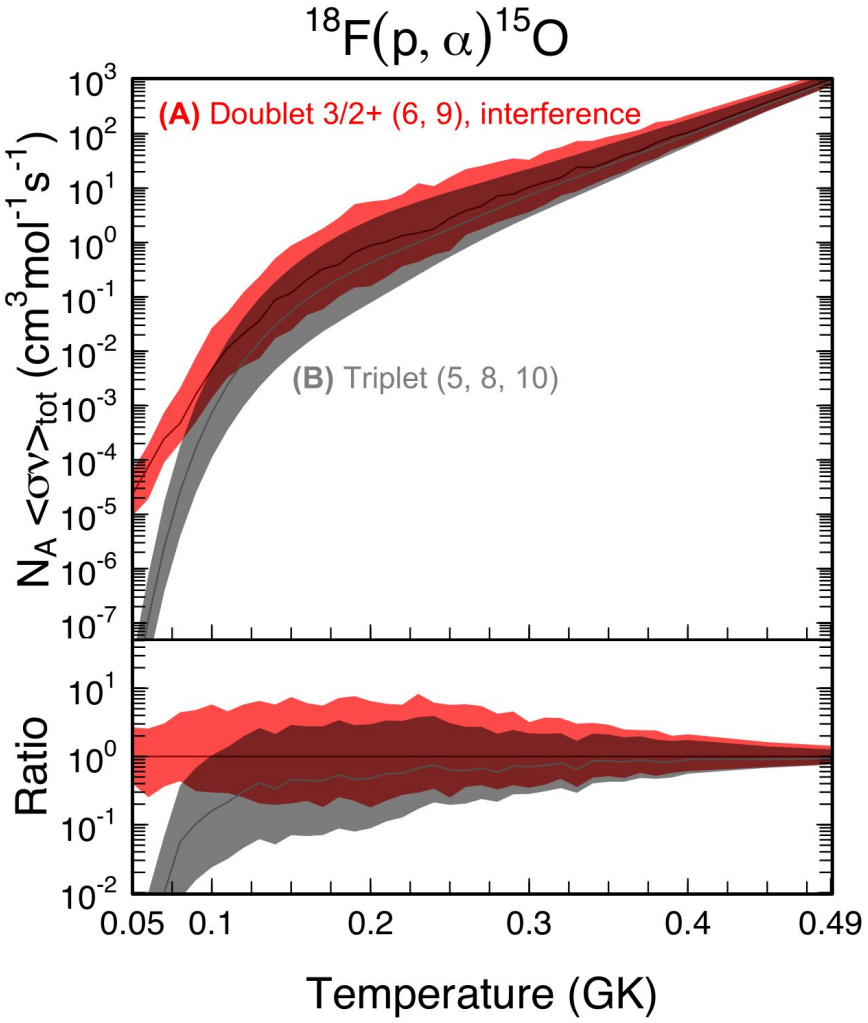
Torresi et al. (2007)

Present Experiment



E_{cm} resolution < 5 keV

Impact on the reaction rate $^{18}F(p,a)^{15}O$



	M_{ejec} (10^{-6} $M_\odot$)			
	^{16}O	^{18}O	^{18}F	^{19}F
Rate (A)	1.1	8.5×10^{-6}	1.1×10^{-5}	6.3×10^{-7}
Rate (B)	1.1	1.7×10^{-5}	3.9×10^{-5}	1.1×10^{-6}

Factor 3.5 between the ejected mass calculated with the two rates

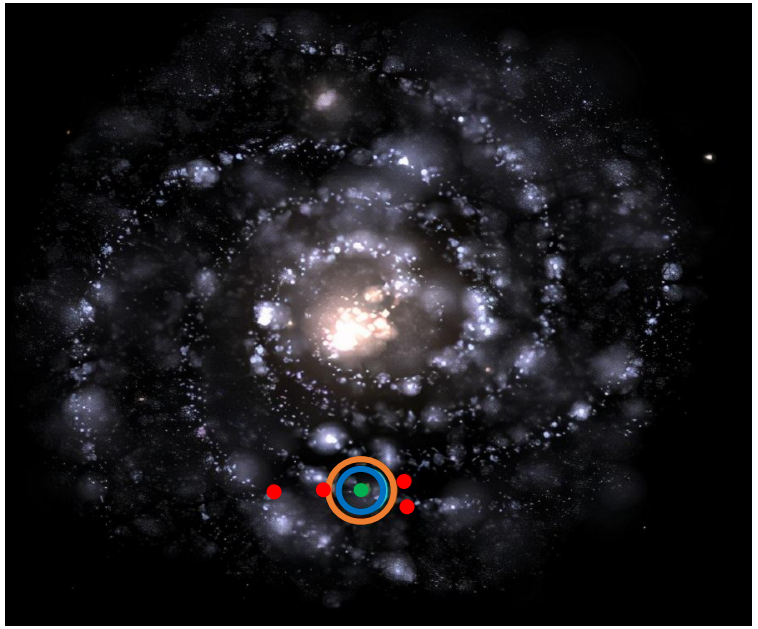
Maximum detectability distance impacted by a factor 1.9

Astrophysical impact

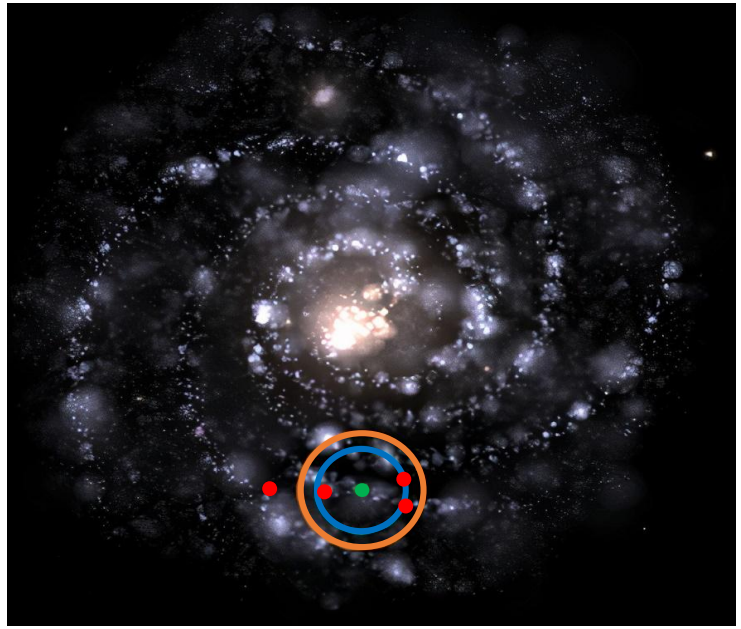
High resolution spectroscopy of ^{19}Ne (σ_{cm} < 5 keV) at GANIL to constrain :

- ^{18}F(p,α)^{15}O rate
- ^{18}F production in nova outbursts
- detection of ^{18}F γ rays in novae for future space telescopes

Rate A



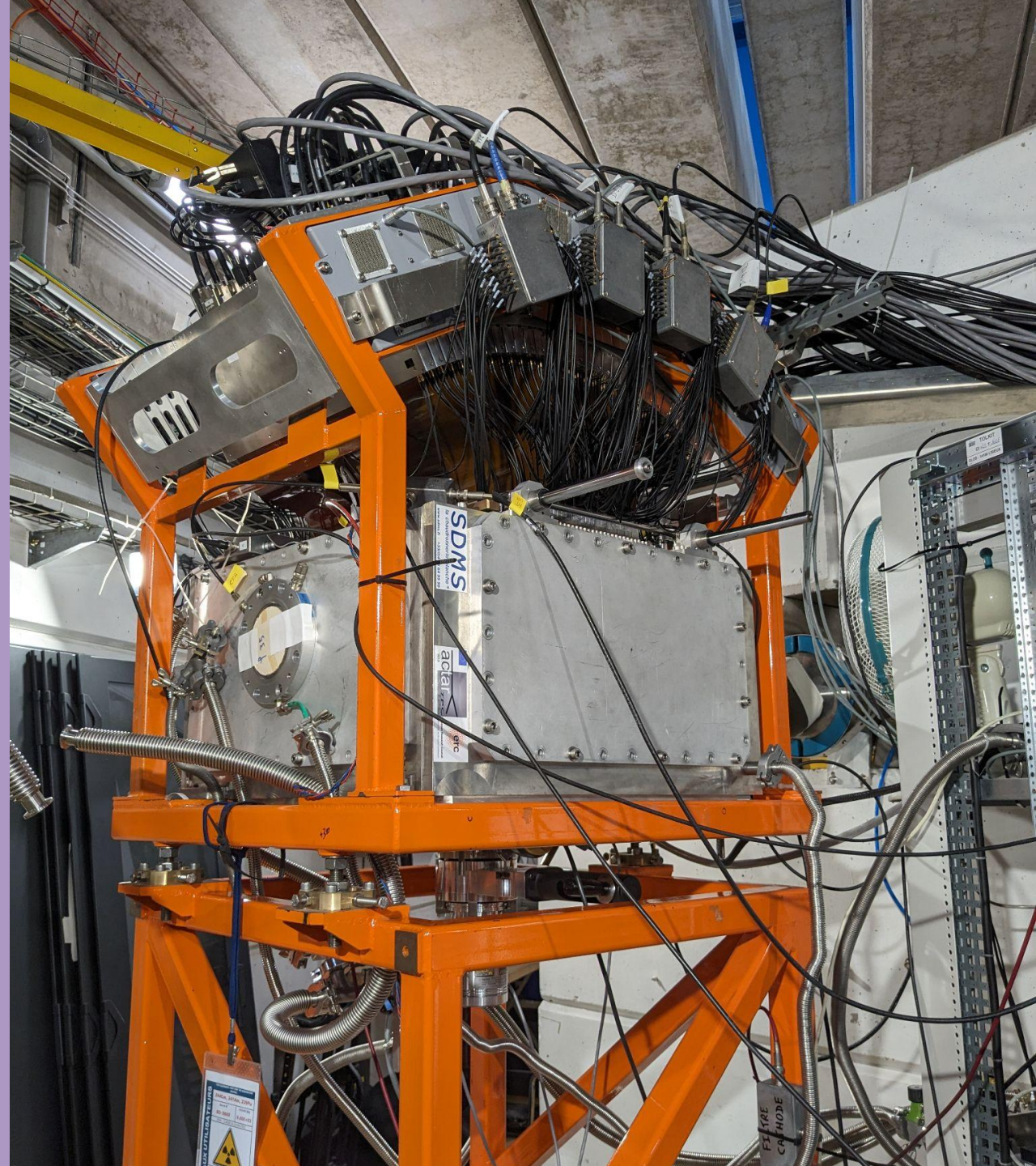
Rate B



Flux in ^{18}F from ONe novae
Sun
COSI
e-ASTROGAM

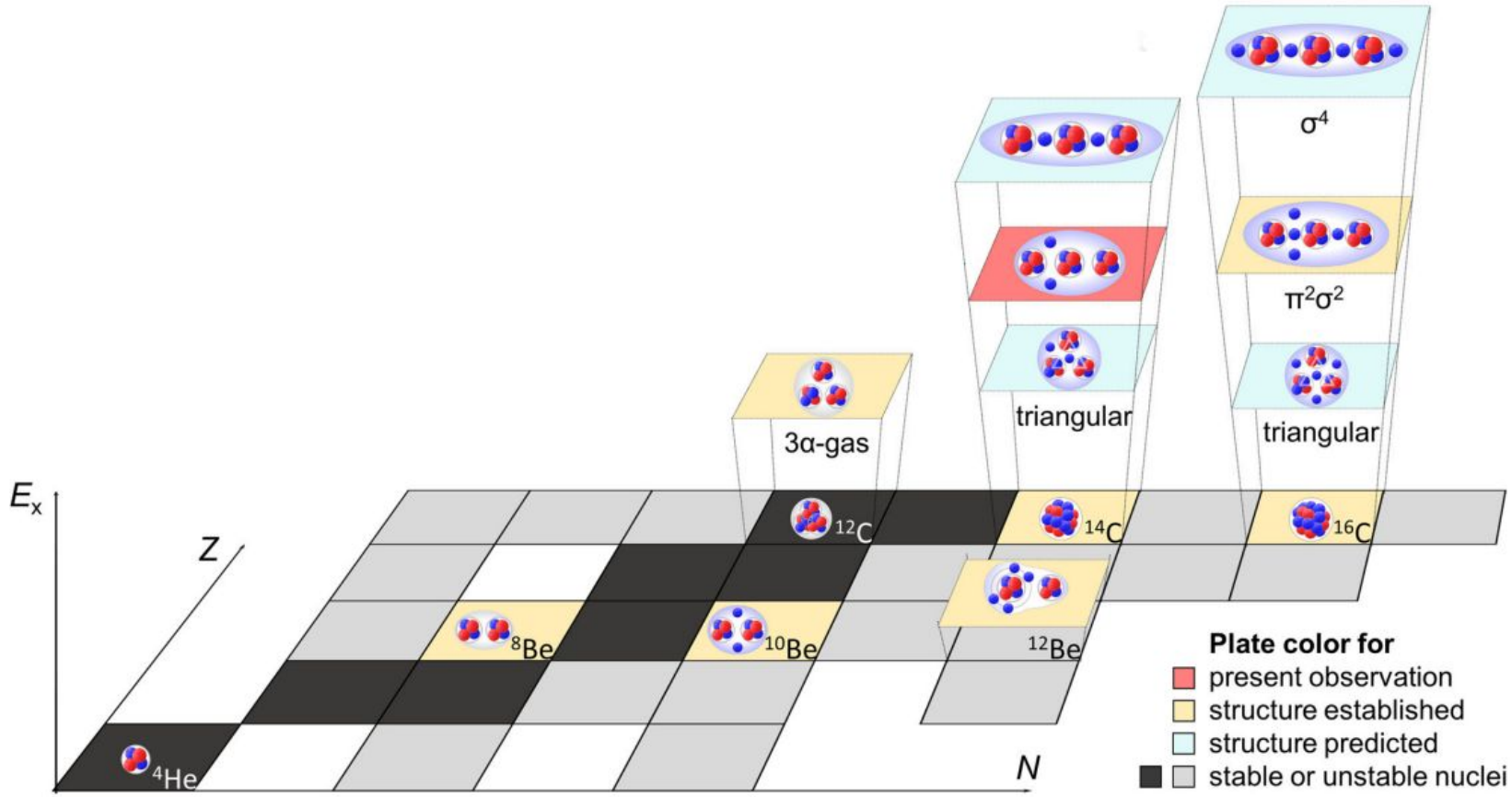
-> Frequency ~ 1 event / 6 yr

Experiment with active target (ACTAR TPC) : ^{12}Be structure in multi-threshold vicinity

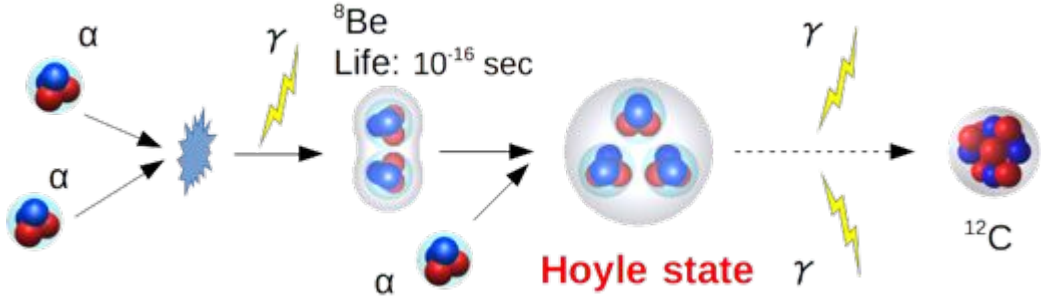


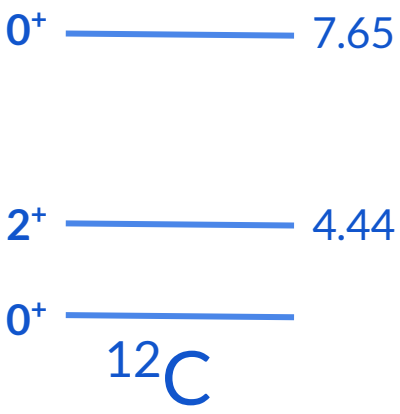
Physics motivation : Clusters

- Light nuclei -> cluster configuration where nucleons are grouped in clusters



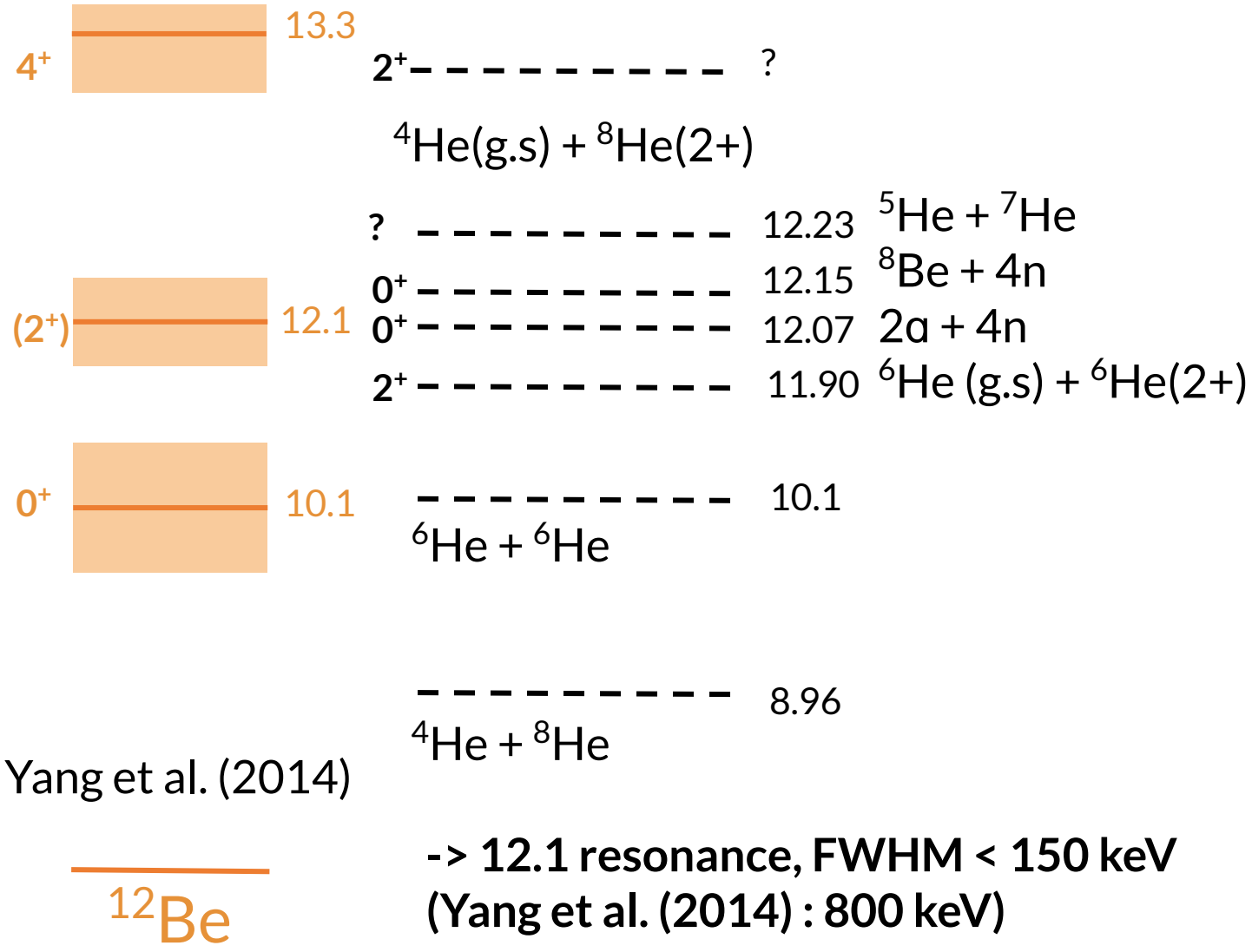
Physics motivation : ^{12}Be states





7.37

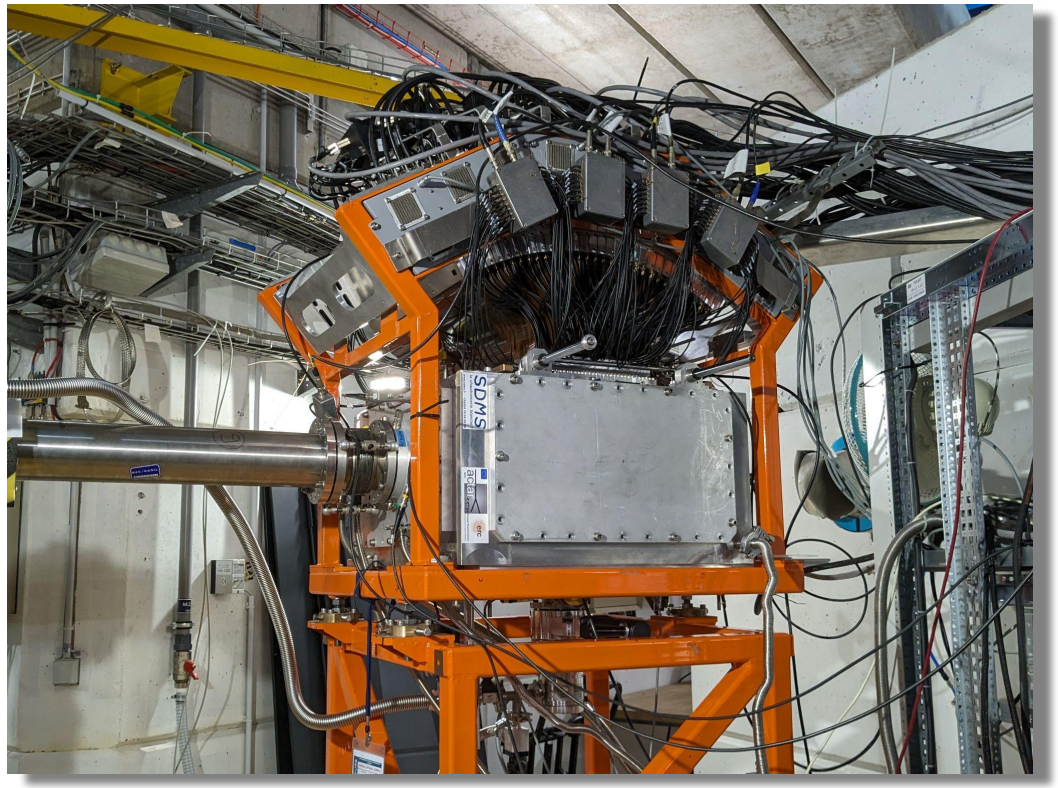
^{8}Be + α

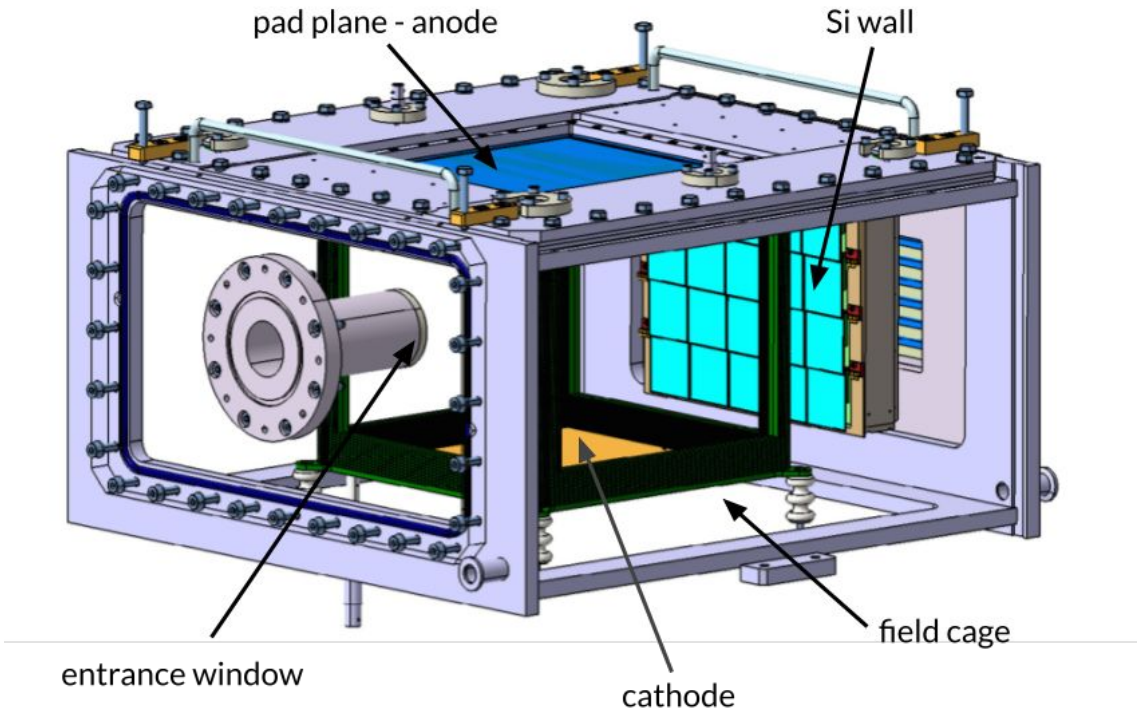


-> 12.1 resonance, FWHM < 150 keV
(Yang et al. (2014) : 800 keV)

Experiment method

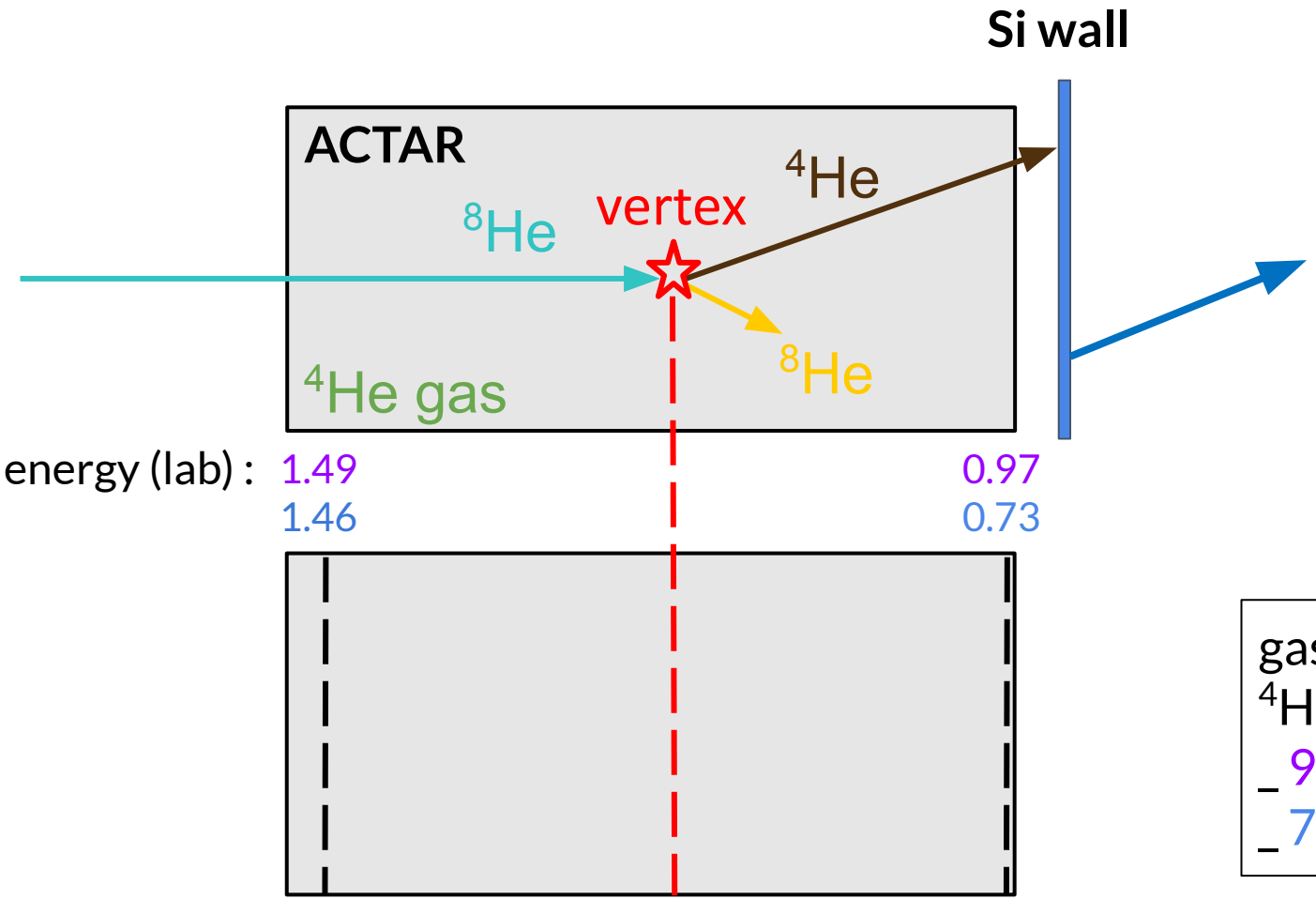
- Resonant elastic scattering reaction α(^{8}He, ^{8}He)α -> population of ^{12}Be states
- ^{8}He beam at 1.8 MeV/u , and ACTAR TPC filled with ^{4}He gas

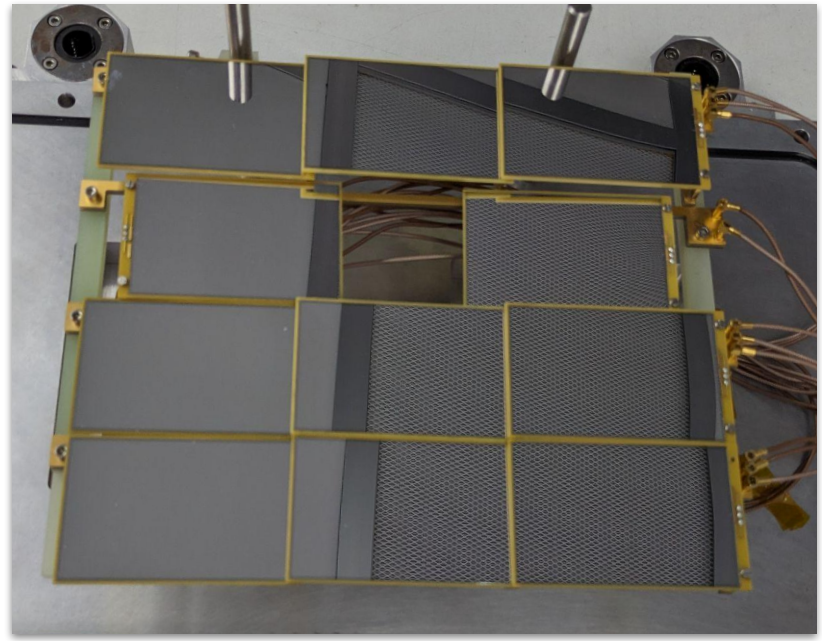




→ presented by Thomas Roger

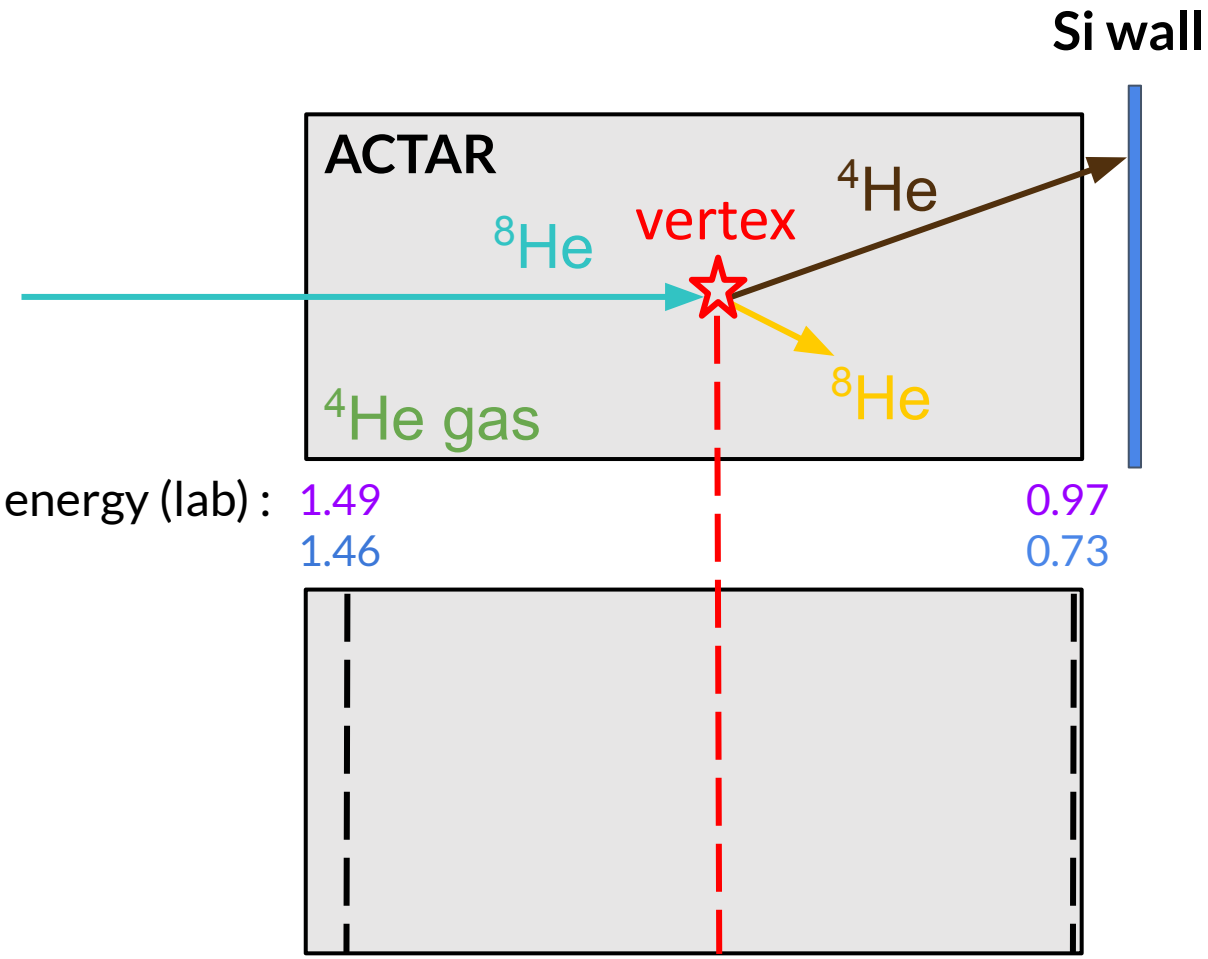
Experiment method : α(^{8}He,^{8}He)α

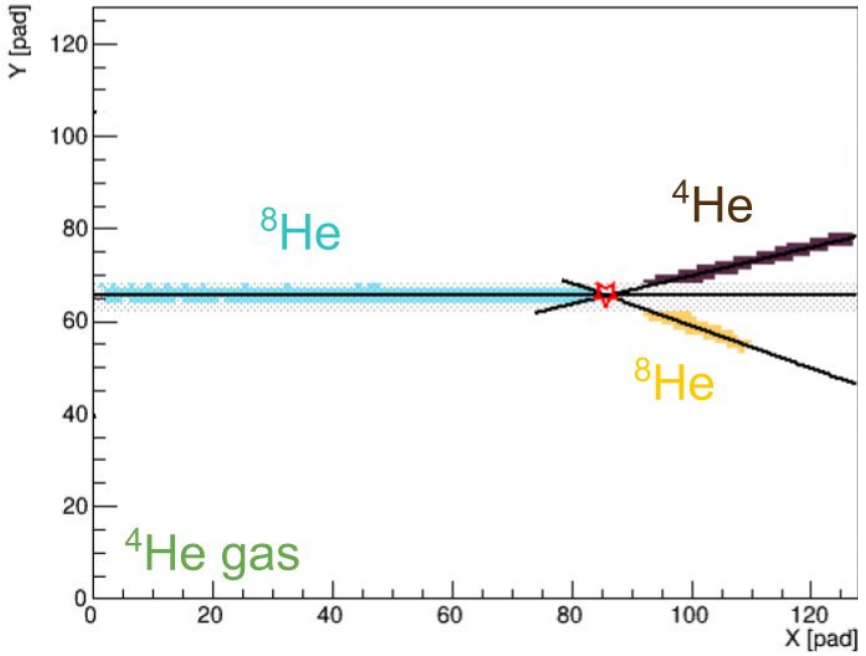




gas :
^{4}He (97%) + iC_4H_{10} (3%)
_ 900 mbar
_ 700 mbar

Experiment method : α(^{8}He,^{8}He)α



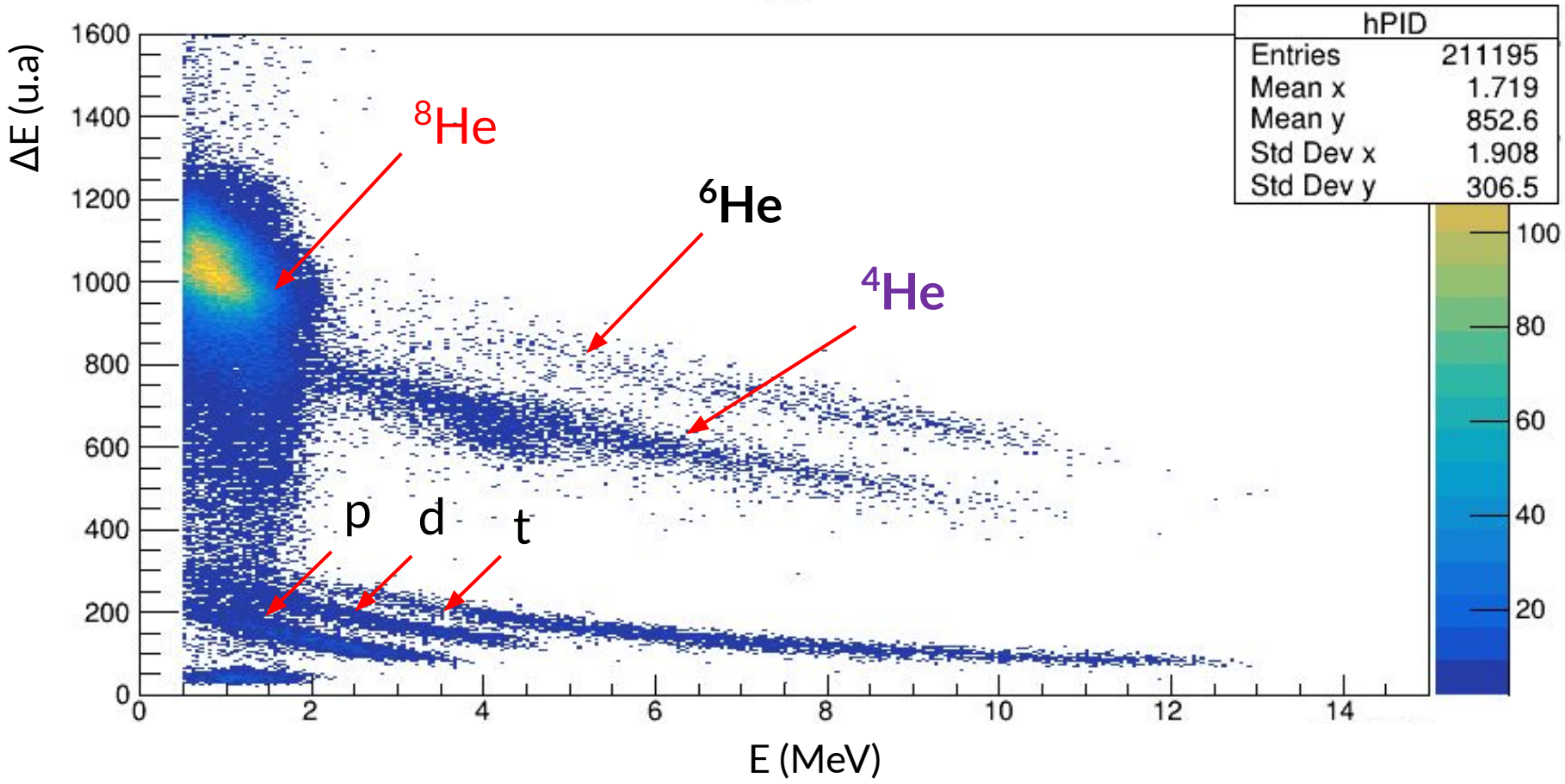


^{8}He energy (lab) : 1.49 1.46 | 0.97 0.73

Corresponding E*(^{12}Be) : 13.0 12.9 | 11.1 10.5

gas :
^{4}He (97%) + iC_4H_{10} (3%)
_ 900 mbar
_ 700 mbar

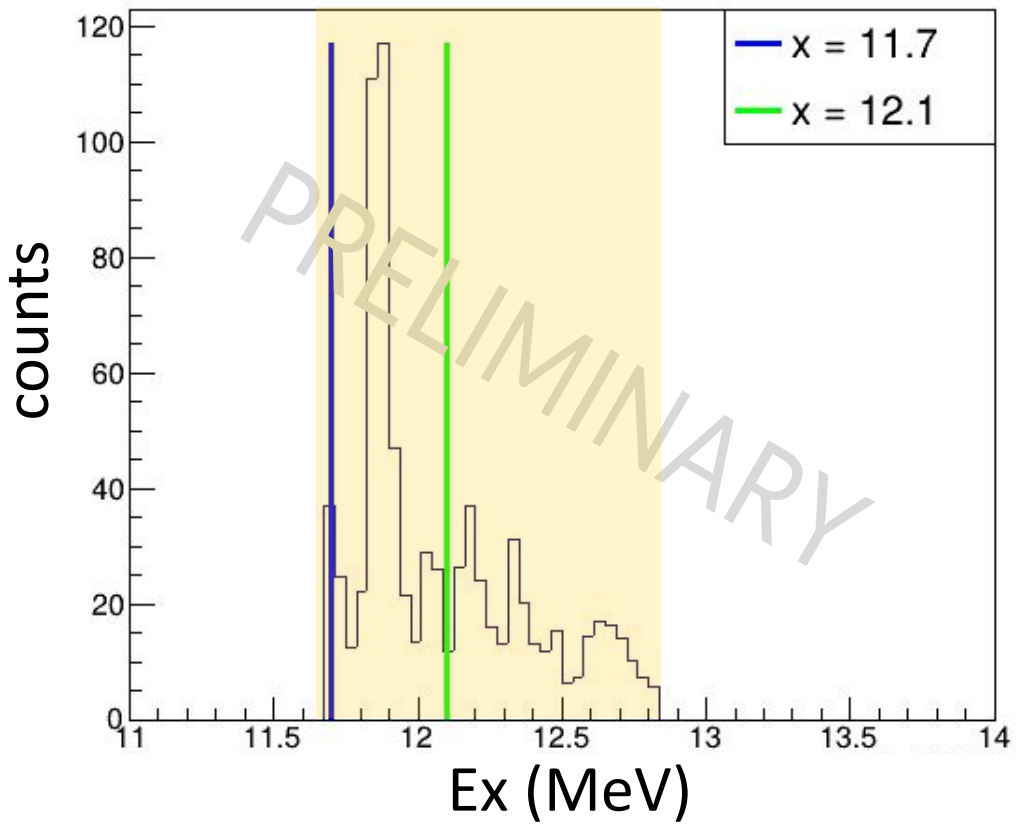
Preliminary results : Particle identification



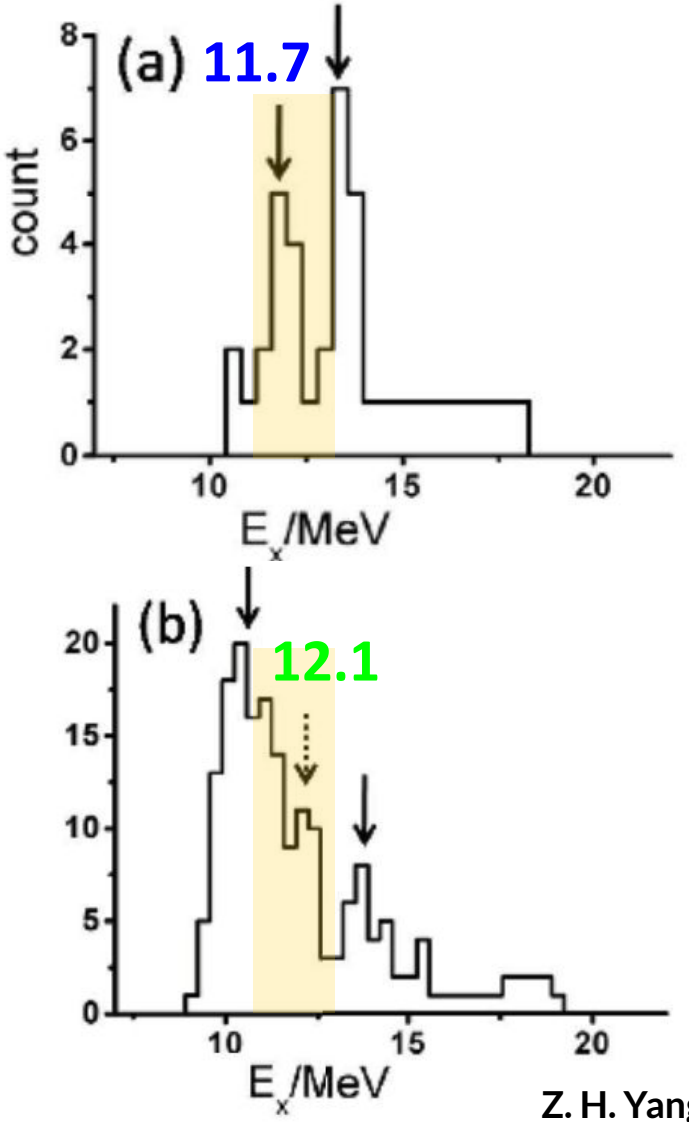
- gas in ACTAR : ^{4}He (97%) + iC_4H_{10} (3%)
- contamination : ^{12}C(^{8}He,^{8}He)^{12}C

Preliminary results

This experiment
resolution (FWHM) < 150 keV

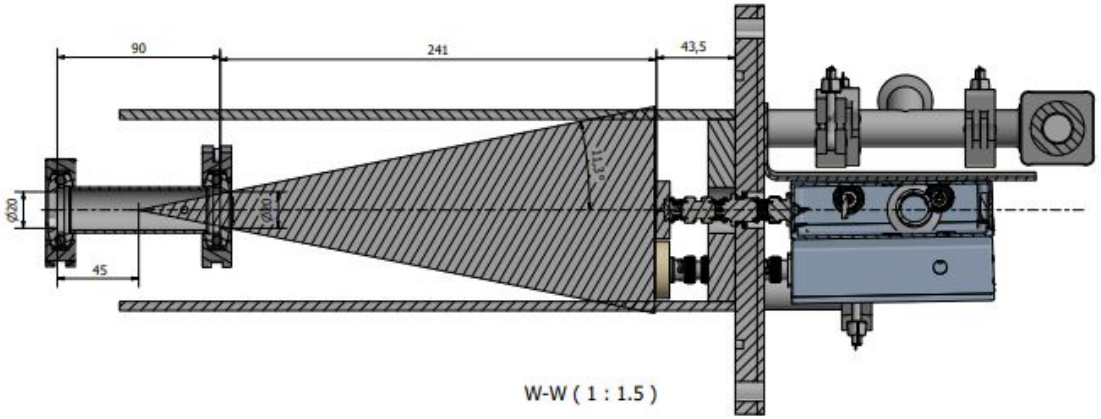


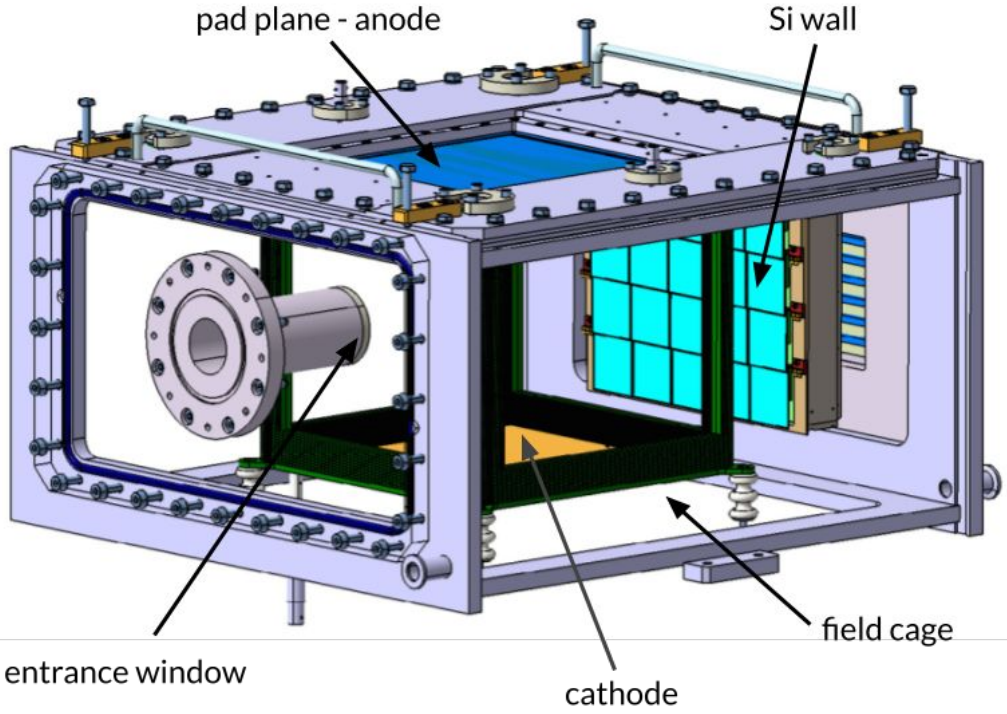
Previous experiment
resolution (FWHM) ≈ 800 keV



Z. H. Yang and Y. L. Ye (2014)

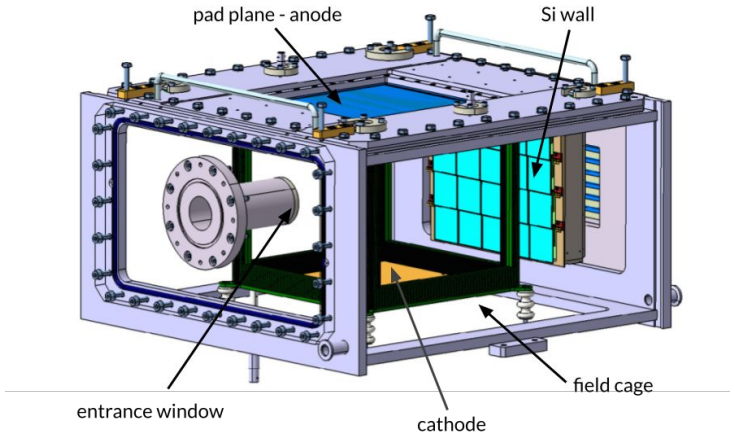
Comparison of the two experiments methods

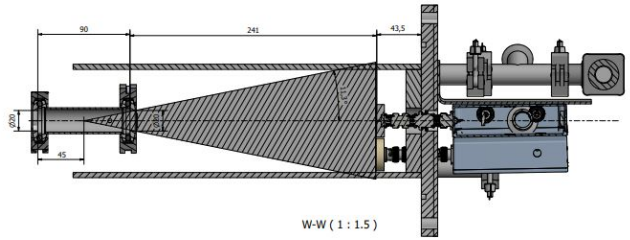




Conclusion

	Active target	Non-active target
Energy Resolution	High	Very high
Angular Coverage	High	Limited to conserve the energy resolution
Electronic Noise	Higher	Lower
Contaminations	Lower	Higher
Beam Intensity Requirement	Lower	Higher
Angular Distribution Analysis	Feasible due to full angular coverage	Limited, may require additional detectors





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Thank you for your attention !

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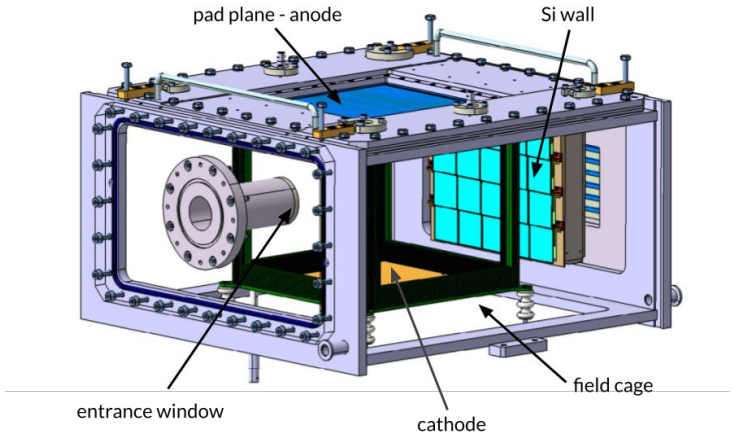
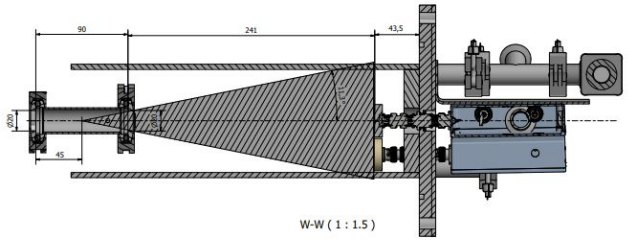
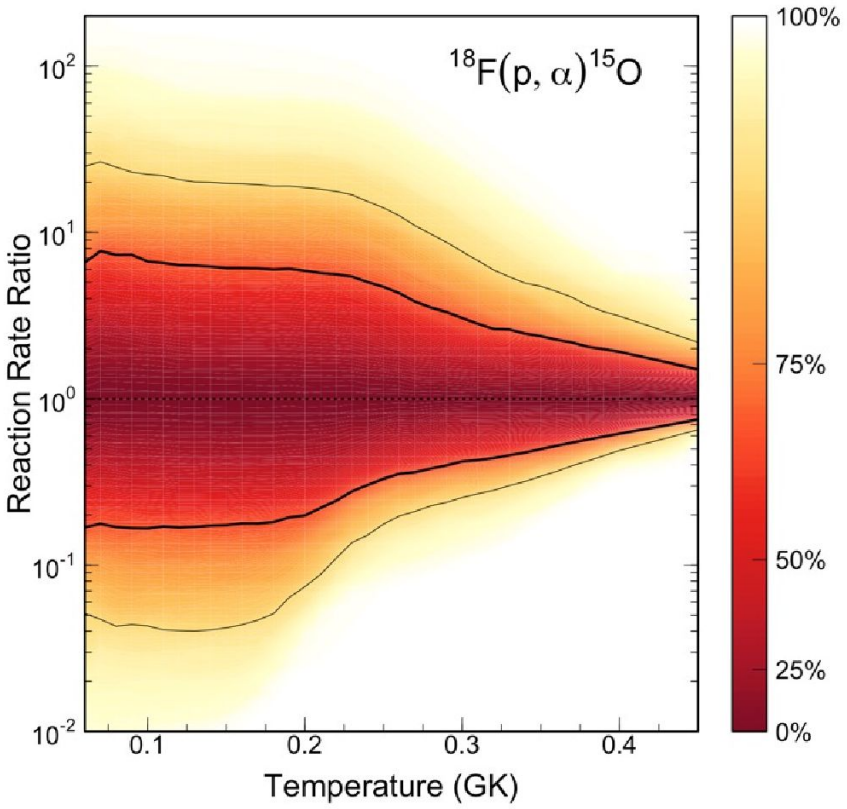




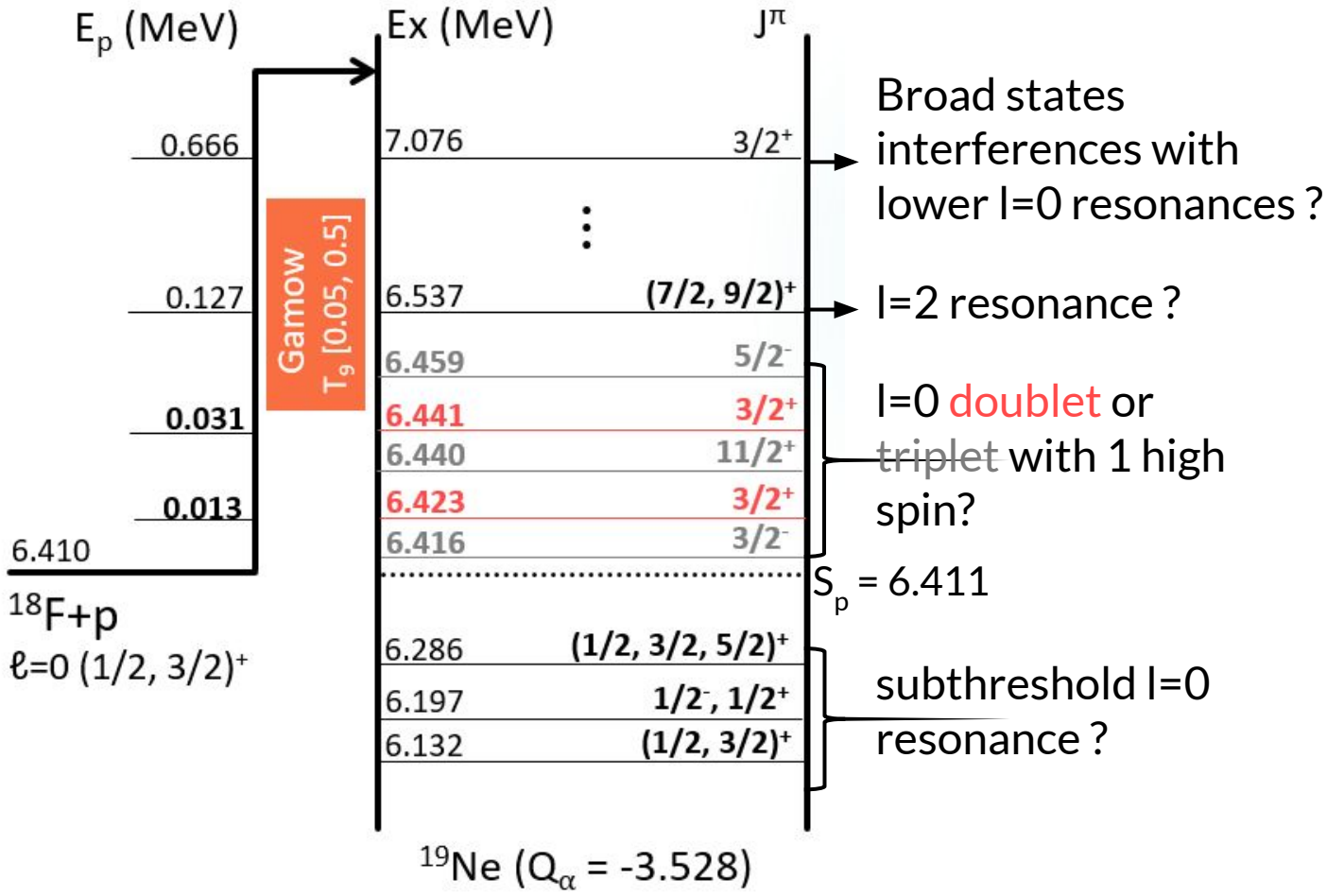
Backup slides

Current status in $^{18}F(p,\alpha)^{15}O$



Rate uncertainties > x10

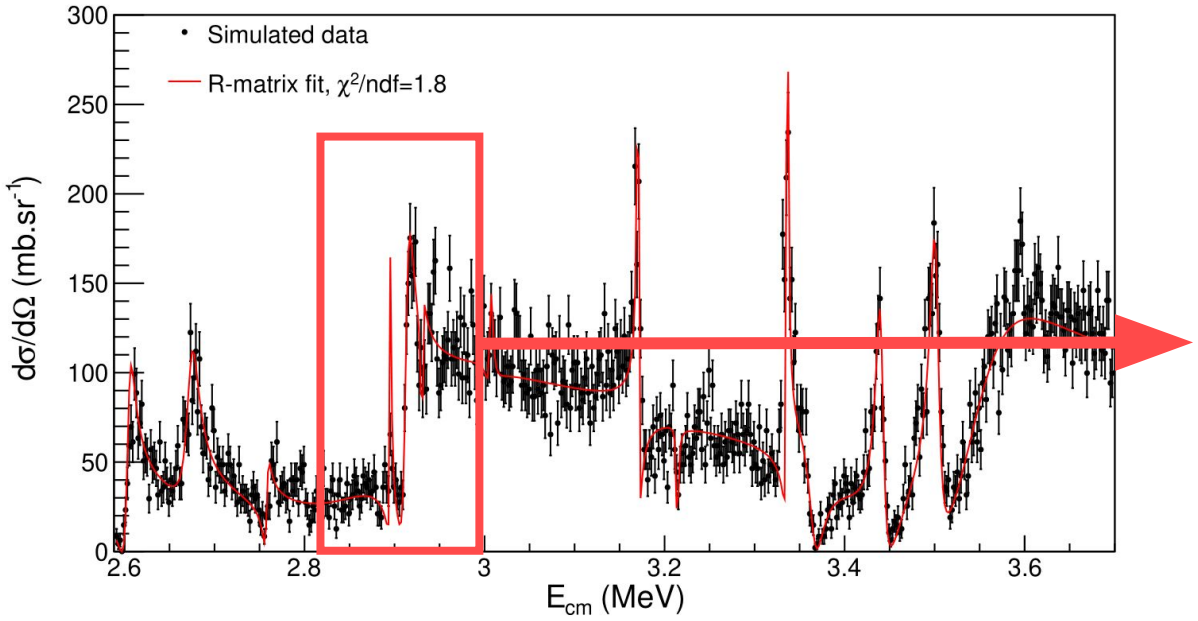
^{18}F > x3, det. distance > x2

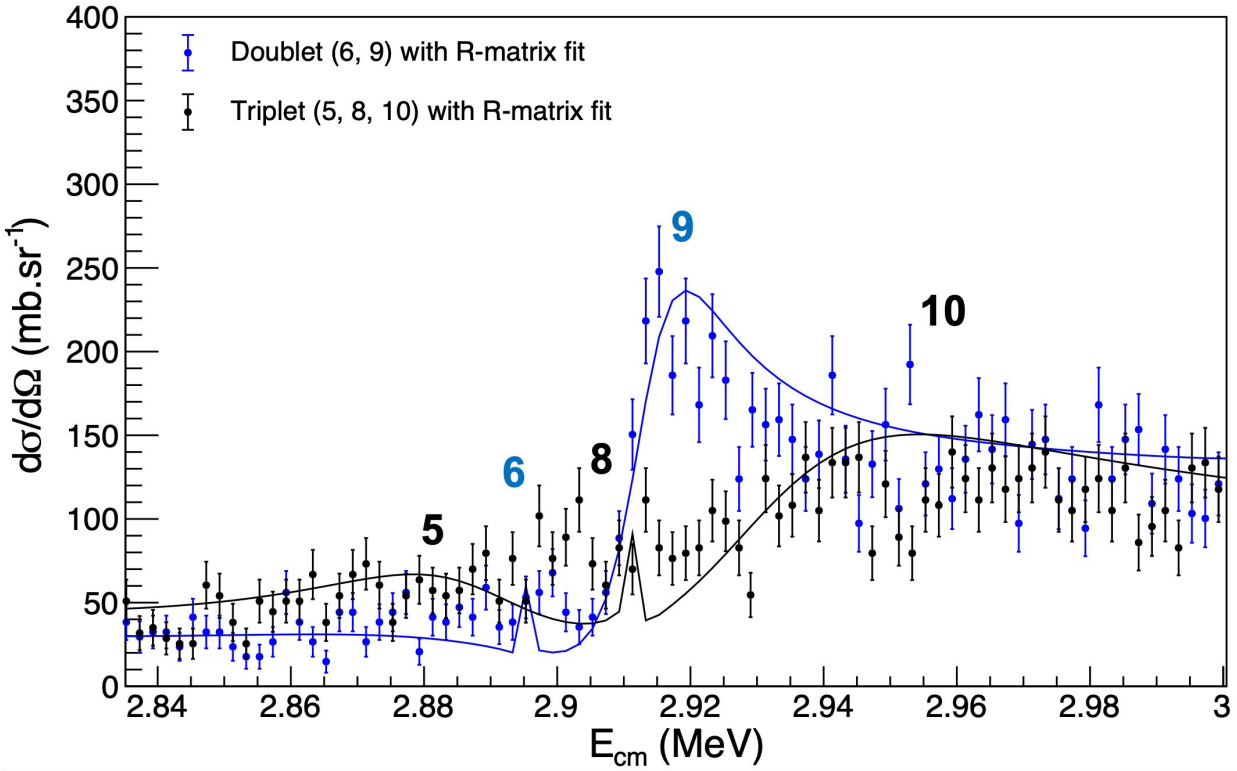


Compound nucleus

Simulated results for the spectroscopy of ^{19}Ne

- Identification of l=0 states near S_p



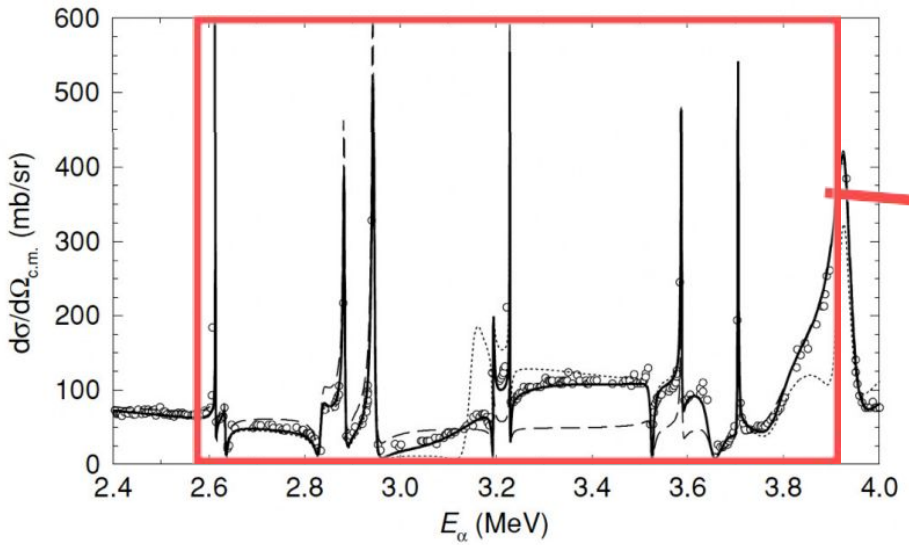


- State spectroscopy : Γ_α resolution down to 2 keV, E_x resolution < 5 keV

Simulated results for the spectroscopy of ^{19}Ne

Calibration via elastic α(^{15}N, ^{15}N)α reaction probing analog levels in ^{19}F

Levels in ^{19}F at Ex ∈ [6, 7] MeV
Measurement Smotrich (1961) and reanalysis Bardayan (2005)



Bardayan (2005)

Present experiment