I. Strong pair correlation in the (core+4n) ^{18}C and ^{20}O nuclei

II. Study of ^{28}F and location of island of inversion

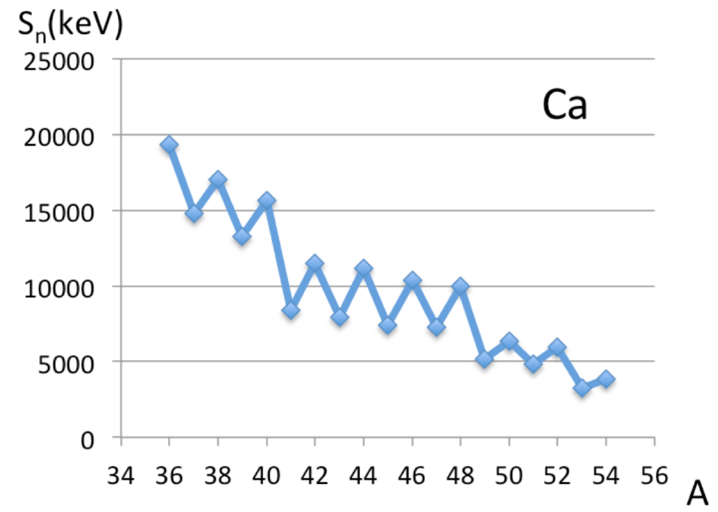
O. Sorlin (GANIL), A. Revel (GANIL-LPC), M. Marques (LPC) et al.

R3B SAMURAI

COMEX 6- Cape Town, Nov 2, 2018

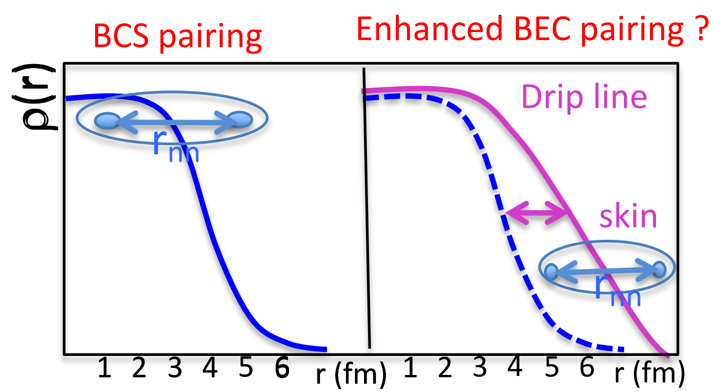
Pair correlations and Nuclear superfluidity

Pair correlations play essential role in atomic nuclei
- Oscillations in S_n values
- g.s. spin 0^+ of even-even nuclei
- Moment of inertia << rigid value
- Enhanced pair transfer *(see e.g. Cavallero)*
- Cooling of Neutron Stars, glitches



Role of 4n correlations on nuclear superfluidity ?

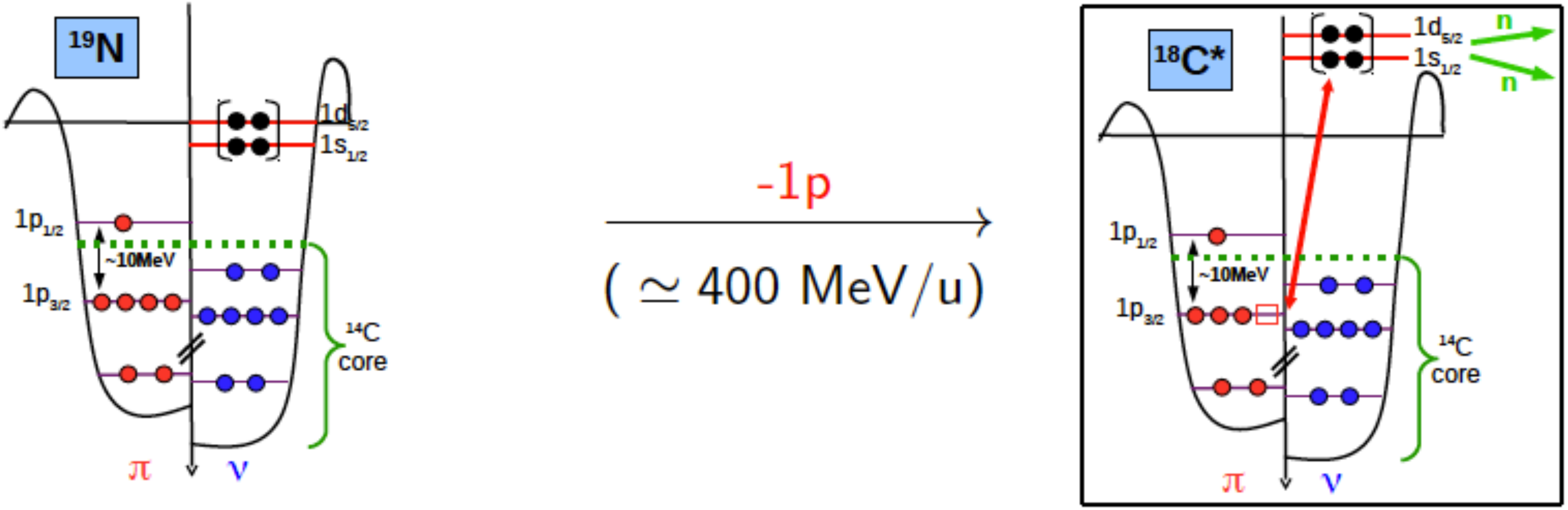
Pairing scheme towards drip-line: from BCS to BEC ?
(e.g. Hagino et al. PRL99 (2007))



Find a mechanism to suddenly promote pairs in the continuum
Study of core+xn, haloes/ drip line nuclei, molecular states ...

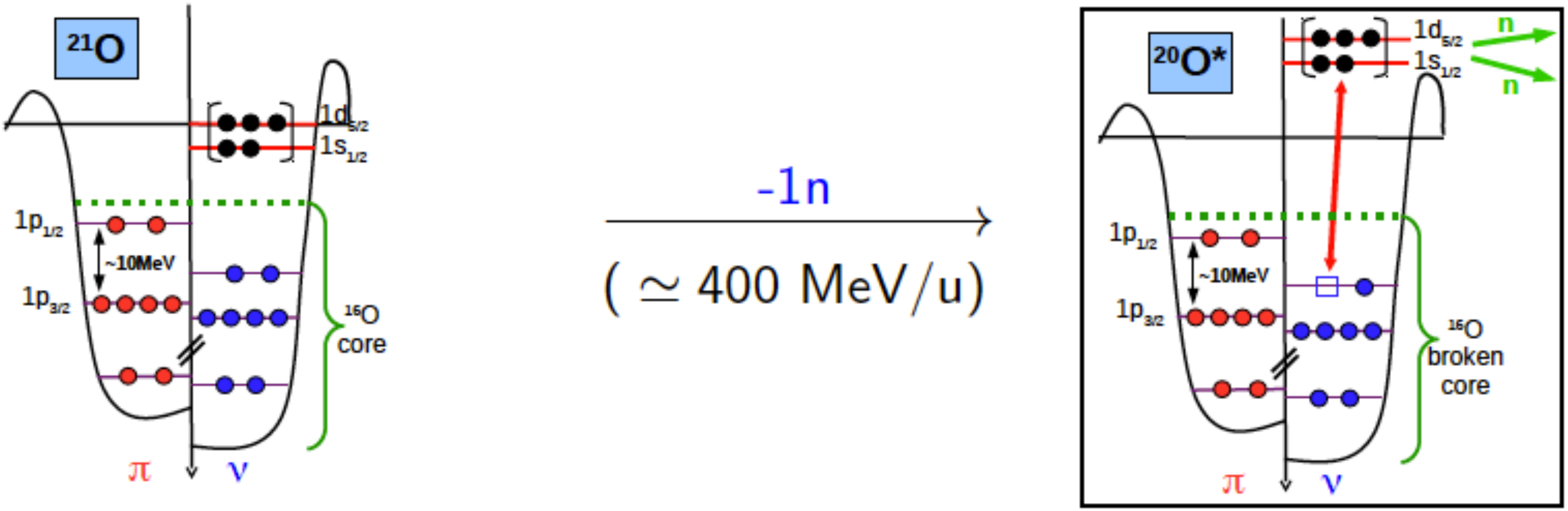
Determine the fraction of direct and sequential decay -> pair correlation
Determine the average distance r_{nn} between neutrons from studying complete kinematics

Experimental method to reveal nn correlations in ^{18}C ($^{14}C+4n$)



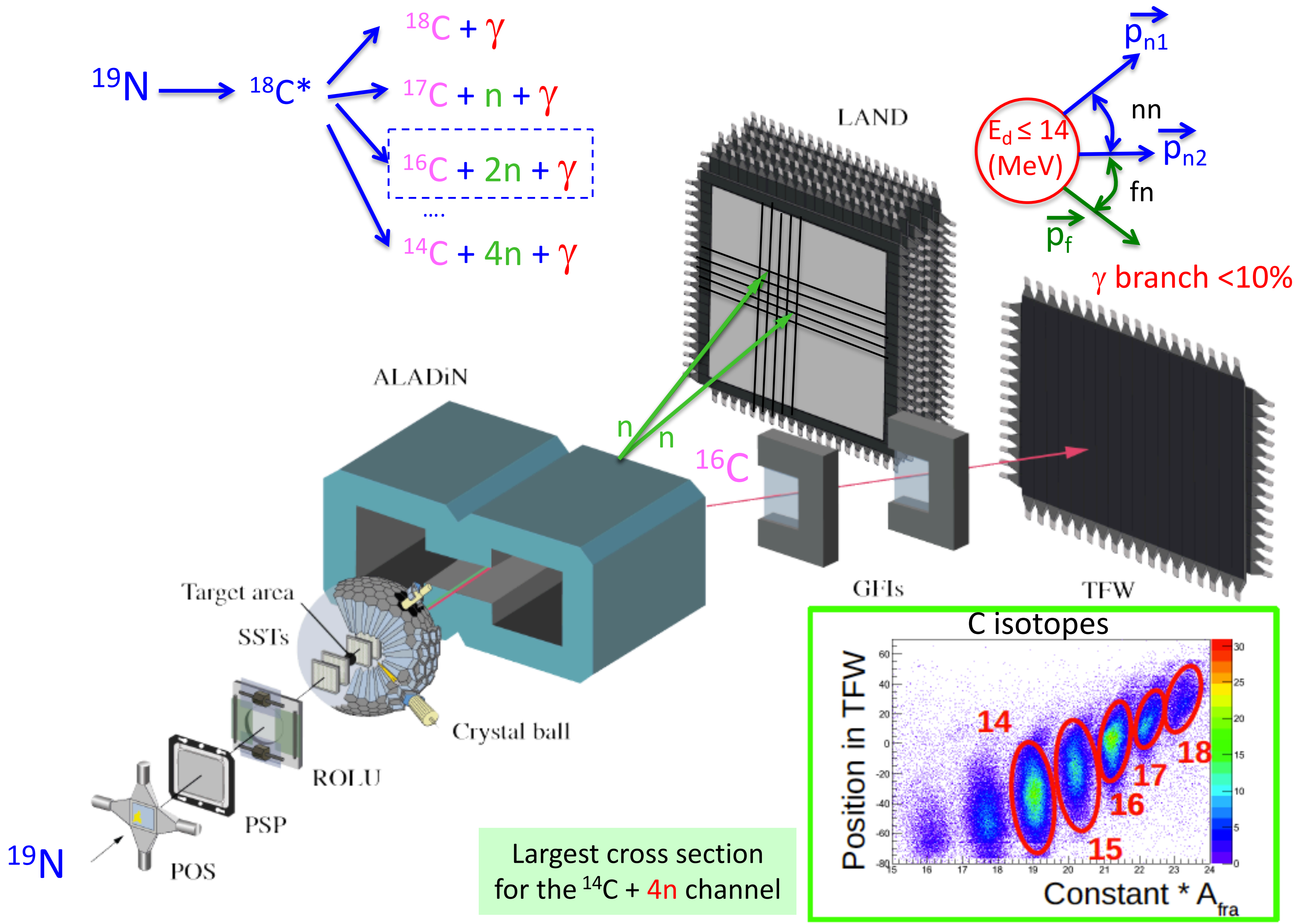
- High energy proton knock-out (p,2p)
  →Quasi-free reaction at GSI
- Deeply bound proton
  →Promote neutrons into the continuum
- Neutron correlations unaffected by proton knock-out ?
- Deduce correlations from subsequent decay patterns

Experimental method to reveal nn correlations in ^{20}O (^{16}O+4n)

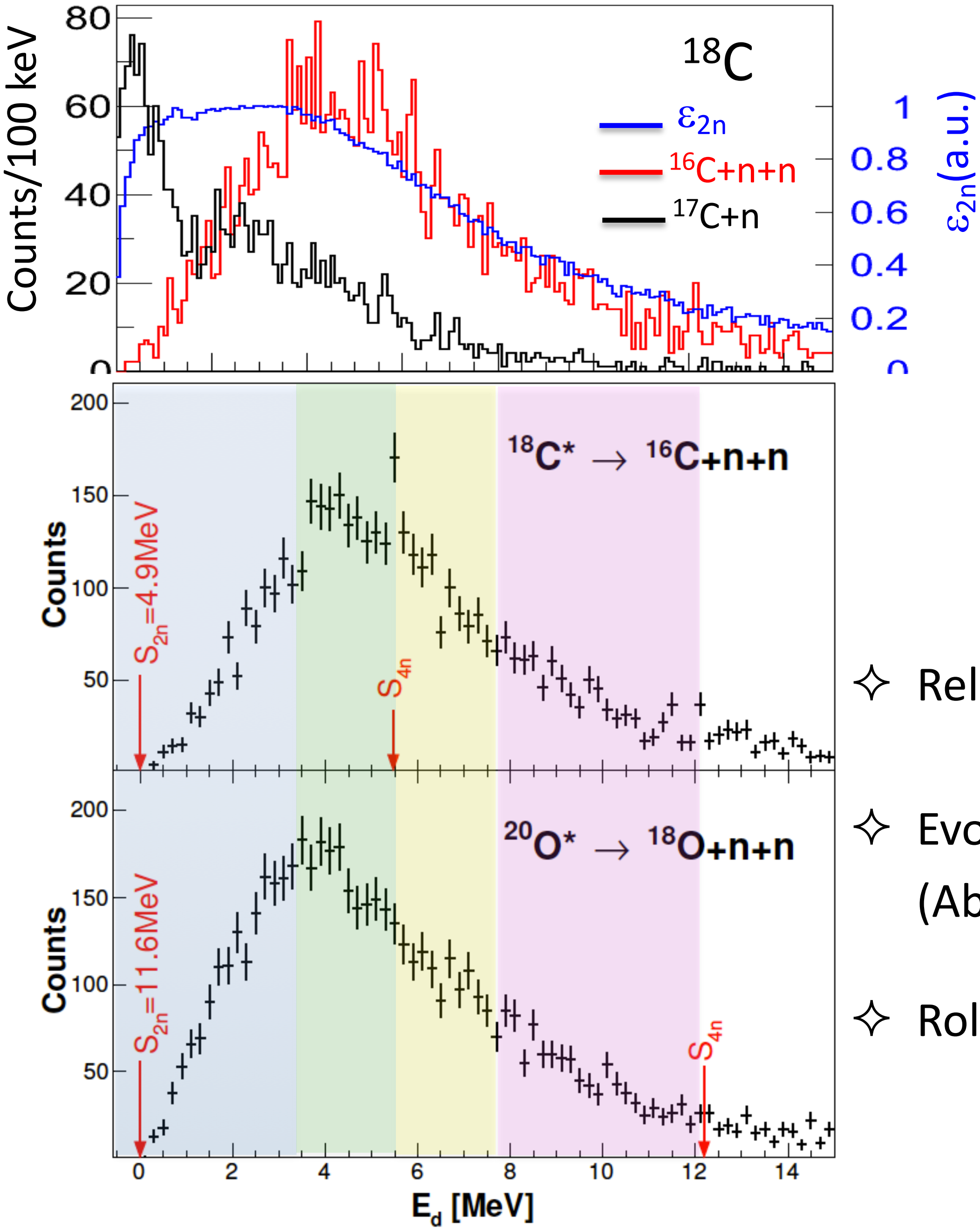


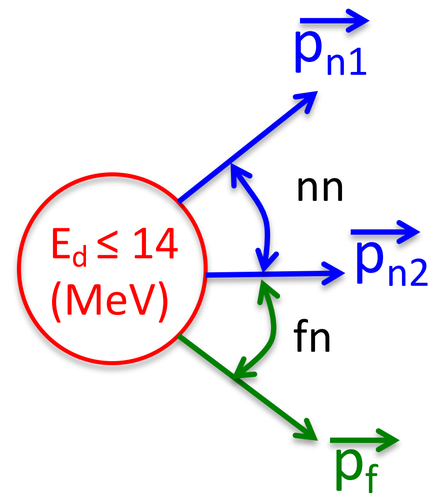
- High energy neutron knock-out (p,pn)
  →Quasi-free reaction
- Deeply bound neutron
  →Promote neutrons into the continuum
- Neutron correlations likely affected by neutron knock-out
- Qualitative/quantitative differences between ^{20}O and ^{18}C isotones?

Fully inclusive study of fragment-n-n correlations at R³B / GSI



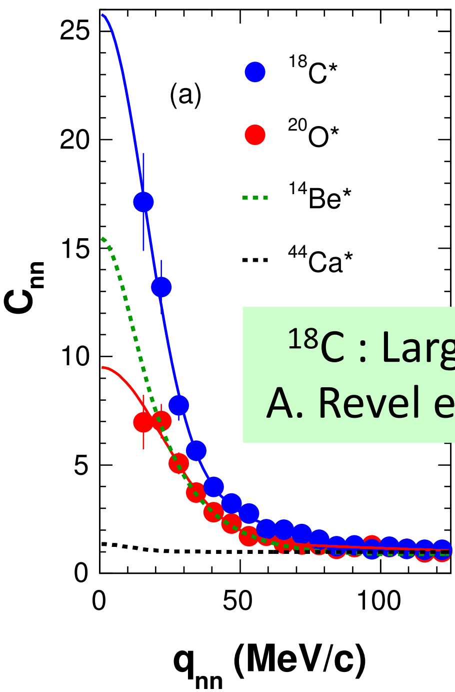
Decay energy in the 2n decays in ^{18}C and ^{20}O



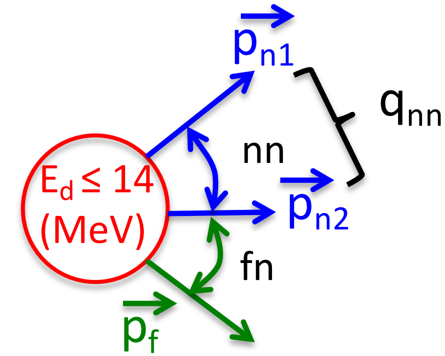


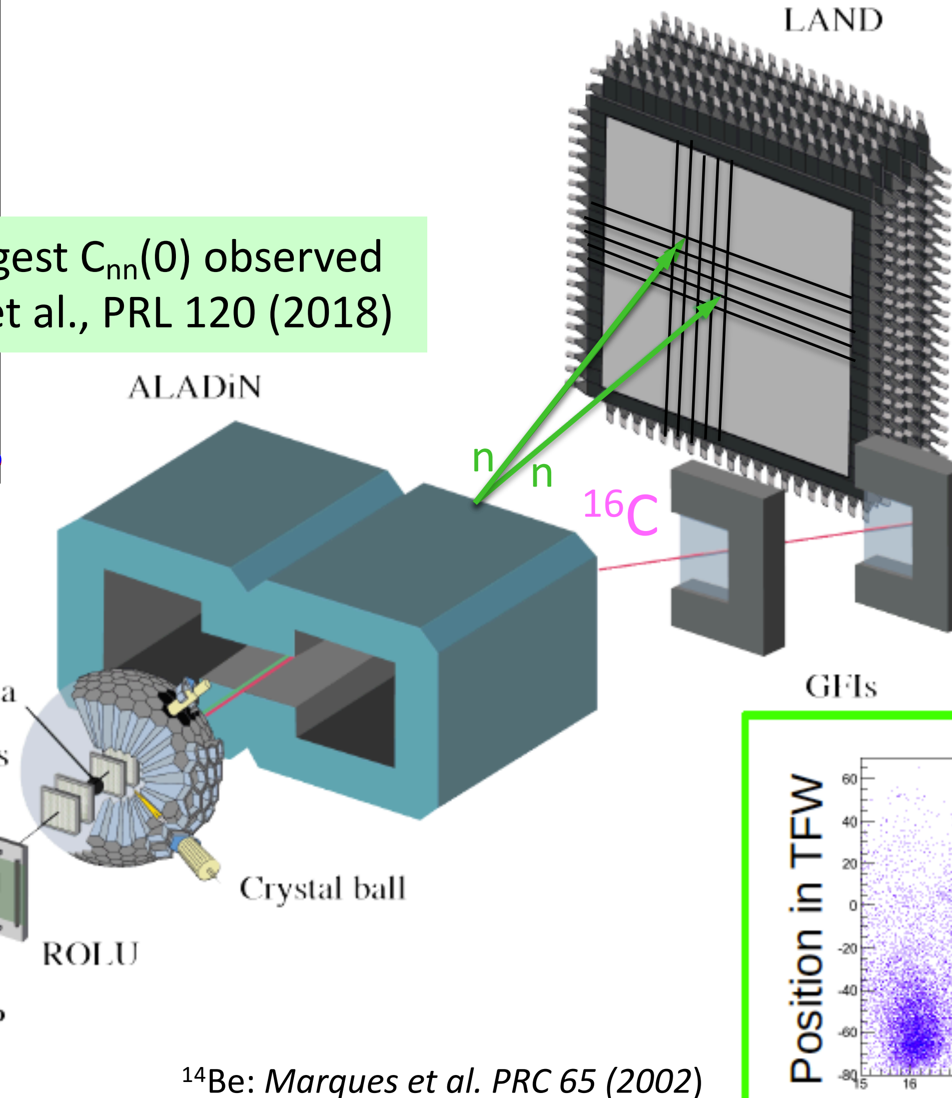
- ✧ Relatively large ε_{2n} efficiency of LAND
- ✧ Evolution of correlations with E_d ≤14 MeV (About same range of E_d for ^{18}C & ^{20}O)
- ✧ Role of the reaction mechanism?

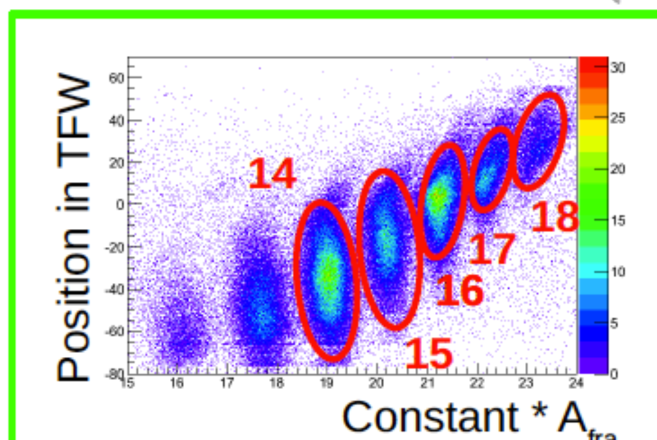
n-n correlation function in ^{18}C and ^{20}O



^{18}C : Largest $C_{nn}(0)$ observed
A. Revel et al., PRL 120 (2018)



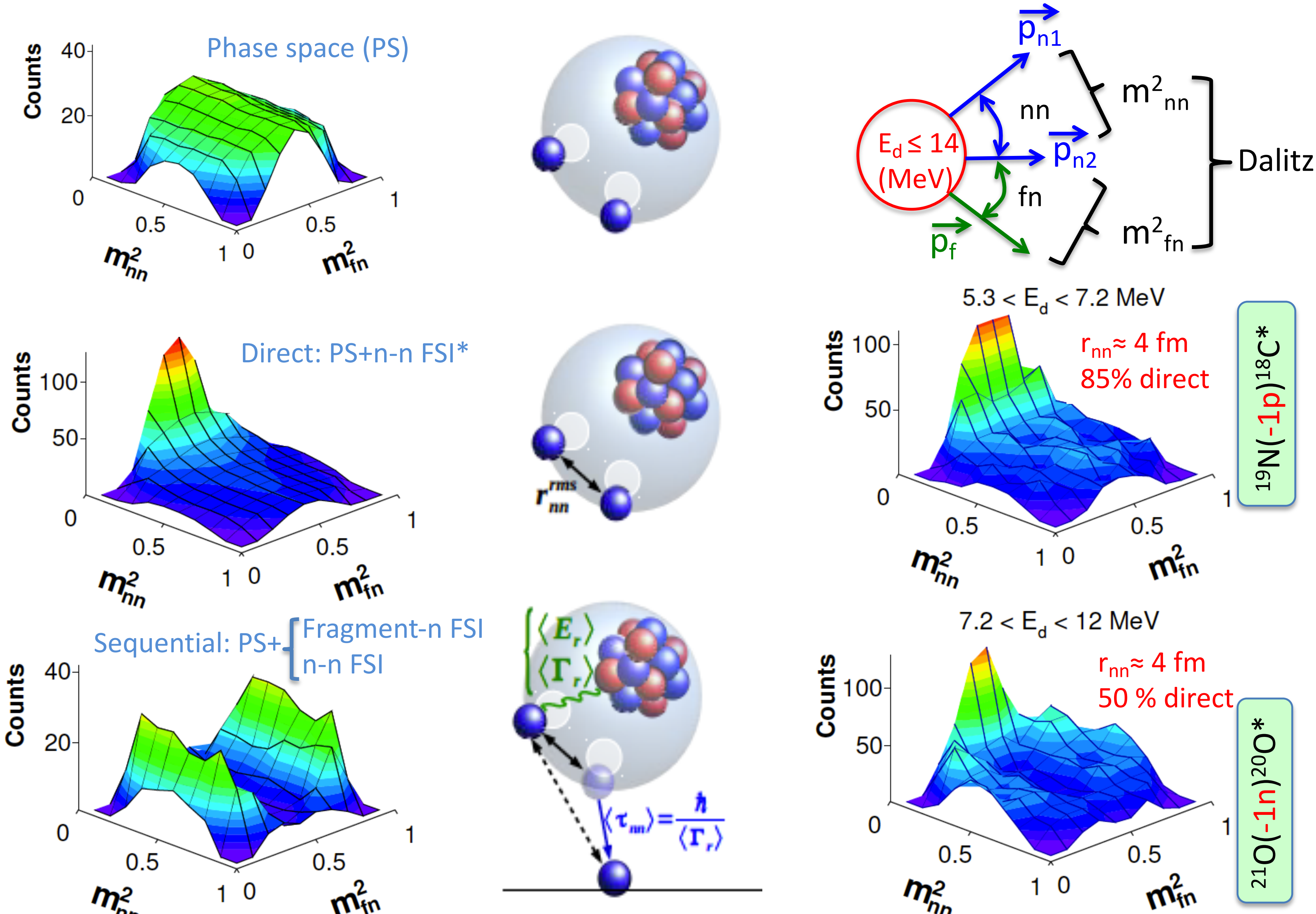




^{19}N

^{14}Be: *Marques et al. PRC 65 (2002)*
^{44}Ca: *Colonna et al. PRL 75 (1995)*

Dalitz plots and n-n correlations in ^{18}C and ^{20}O (core + 4n systems)



*Lednicky & Lyuboshits, SJNP 35 (1982) 770

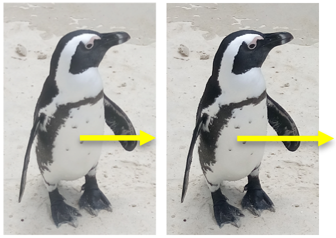
A. Revel et al., PRL 120 (2018)

Conclusions

Same pattern of Dalitz plots independently of E_d in ^{18}C and ^{20}O

^{18}C

E_d (MeV)	r_{nn}^{rms} (fm)	Seq. (%)	$\langle E_r \rangle$ (MeV)	$\langle \Gamma_r \rangle$ (MeV)
0–3.7	$4.0^{+0.6}_{-0.3}$	31 ± 14	1.5 ± 0.3	$1.0^{+0.8}_{-0.3}$
3.7–5.3	4.5 ± 0.6	17 ± 9	$2.0^{+1.3}_{-0.3}$	1.5 ± 0.3
5.3–7.2	4.2 ± 0.4	12 ± 7	$1.5^{+0.8}_{-0.3}$	$1.5^{+0.3}_{-0.8}$
7.2–12	3.7 ± 0.1	18 ± 4	1.5 ± 0.3	1.5 ± 0.3



$q_{nn} \approx 0$
$m^2_{nn} \approx 0$

^{18}C* very stongly correlated system : about 85% direct emission
-> consequence of pair correlations and relatively short r_{nn} distance

^{20}O* displays weaker correlations: 50 % direct emission
-> the difference likely comes from the reaction mechanism leading to unpaired neutrons

Size of the neutron source corresponds to the mean distance between neutrons in A=20 nucleus

A. Revel et al., PRL 120 (2018)

Perpectives

Evolution of r_{nn}, C_{nn}, m^2_{ij} in other systems (halo, quasi-molecular states, drip line nuclei)

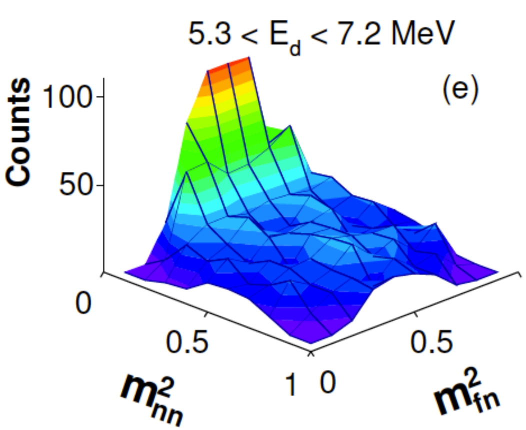
Study 4n correlations with R3B/ NeuLAND

EXPERIMENT

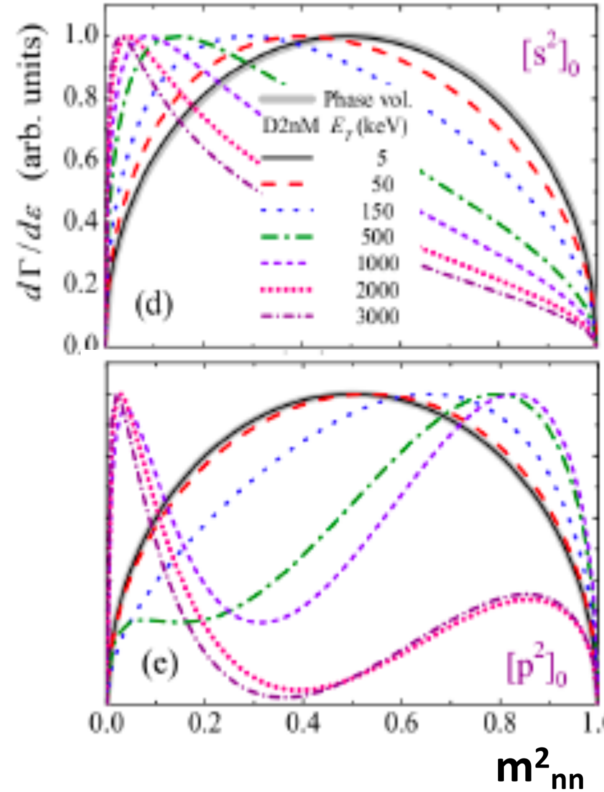
r_{nn}

C_{nn} (q_{nn})

m^2_{fn}, m^2_{nn}



THEORY



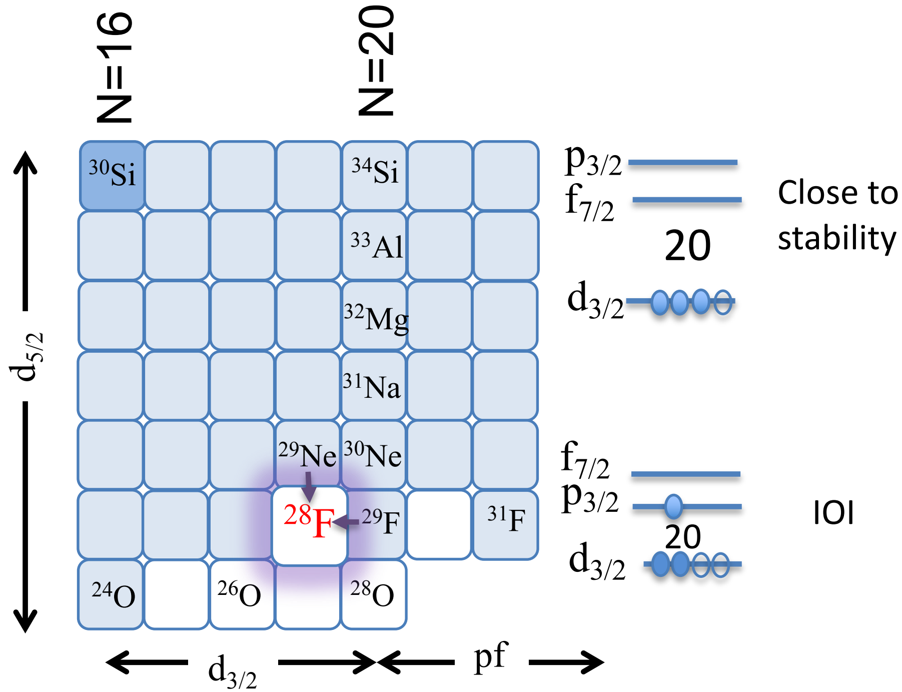
Grigorenko et al. PRC 2018

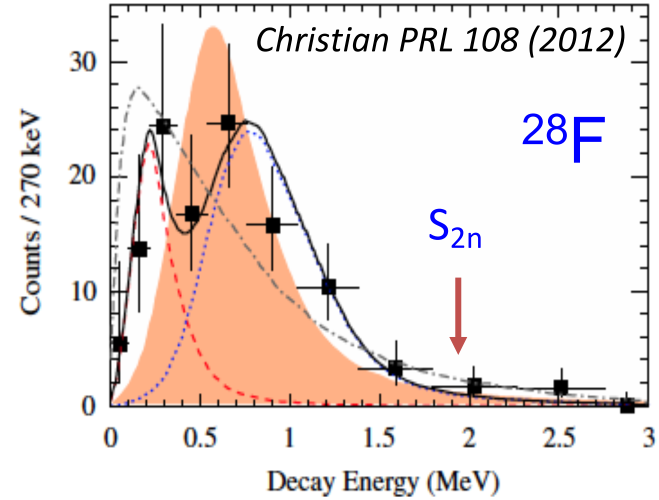
II. Study of ^{28}F and location of island of inversion

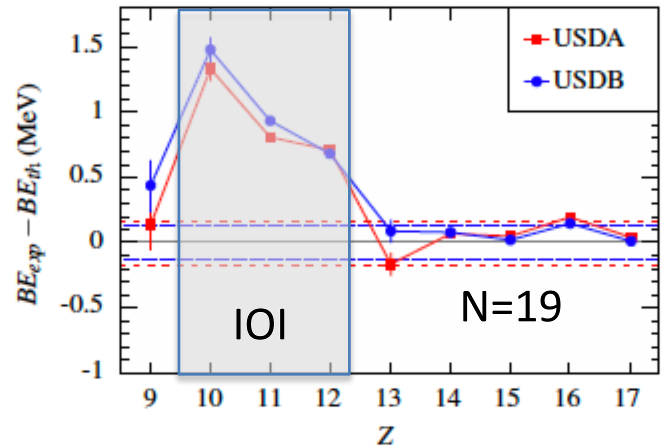
O. Sorlin (GANIL), A. Revel (GANIL-LPC), M. Marques (LPC) et al.

SAMURAI

Motivations for studying ^{28}F







^{28}F can be used to study pn interaction towards drip line

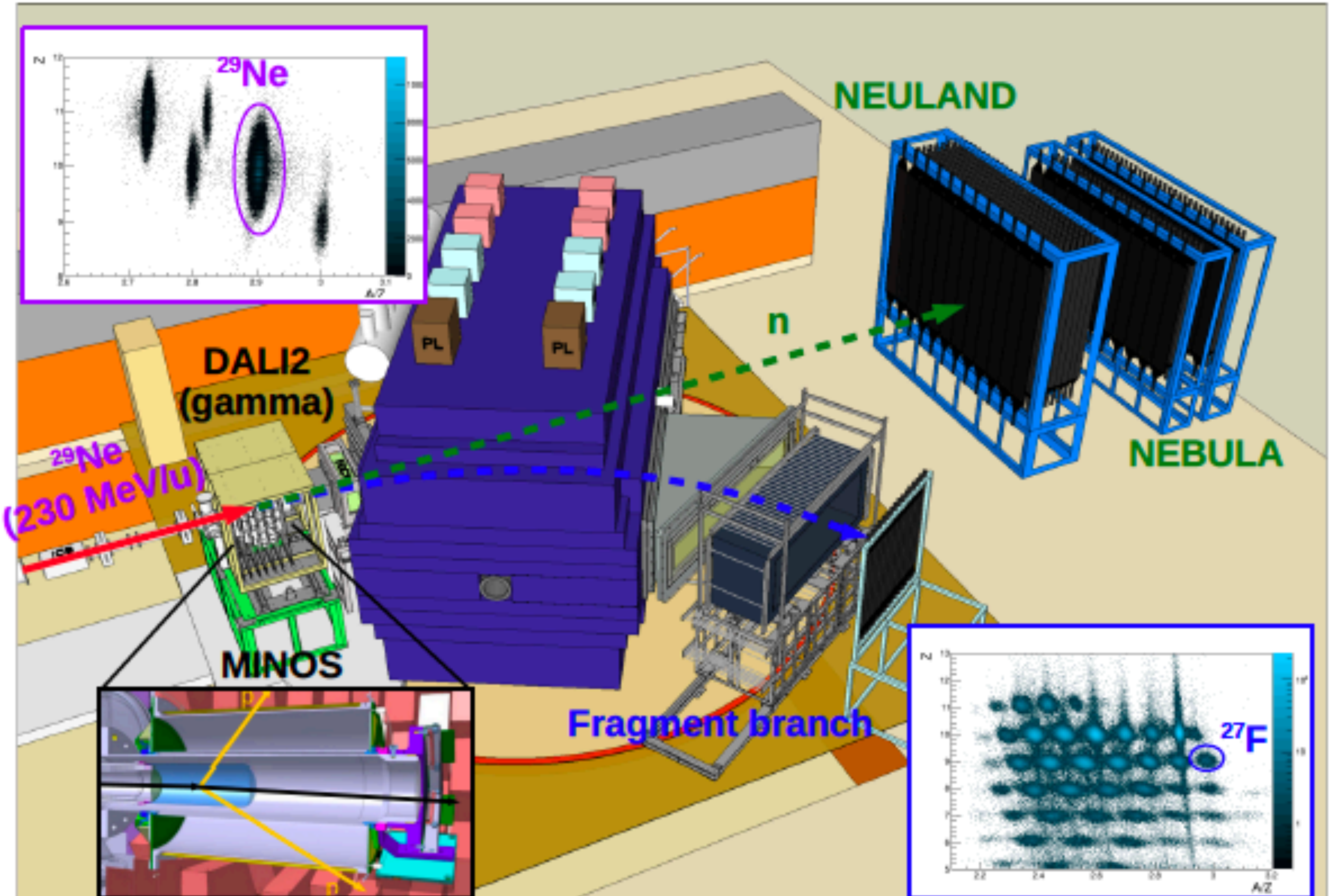
Is ^{28}F lying inside or outside of the Island Of Inversion ?

How do neutron correlations look like at the drip line ?

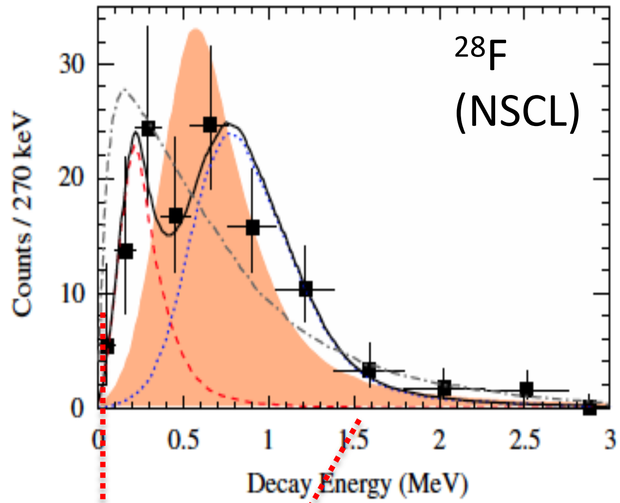
^{28}F Binding energy agrees with USDA,B predictions
-> out of island of inversion (*Christian PRL 108 (2012))*

No L assignment of the states, Low statistics and poor energy resolution
Drop of neutron efficiency above 1.5 MeV , No gamma detection
-> Study of ^{28}F at RIKEN using ^{29}Ne(-1p) and ^{29}F(-1n) knockout reactions.

Study of ^{28}F using knockout reactions in LH target at SAMURAI/RIKEN



Spectrum of ^{28}F populated by the $^{29}Ne(-1p)^{28}F$ reaction



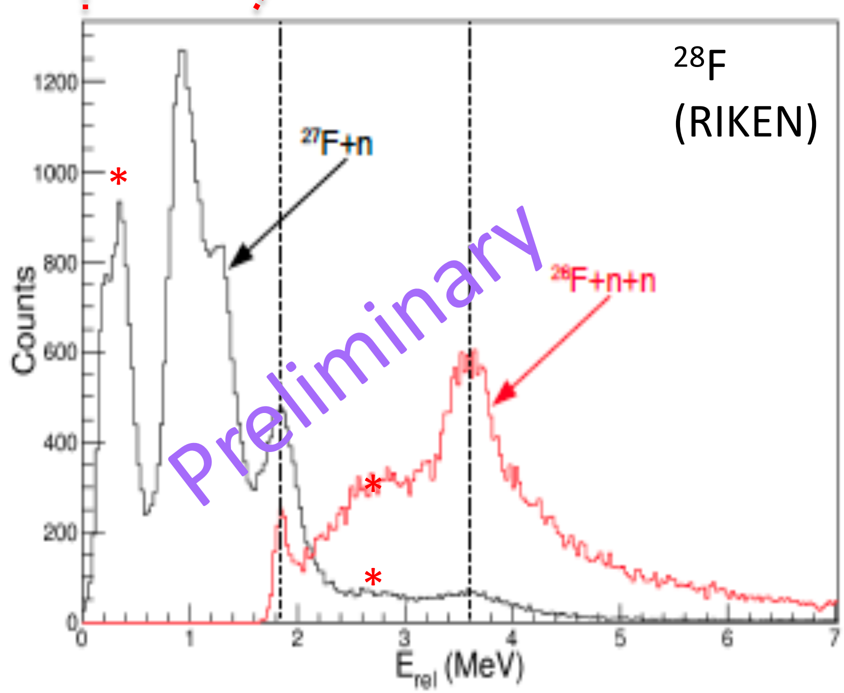
Larger statistics (x1500)

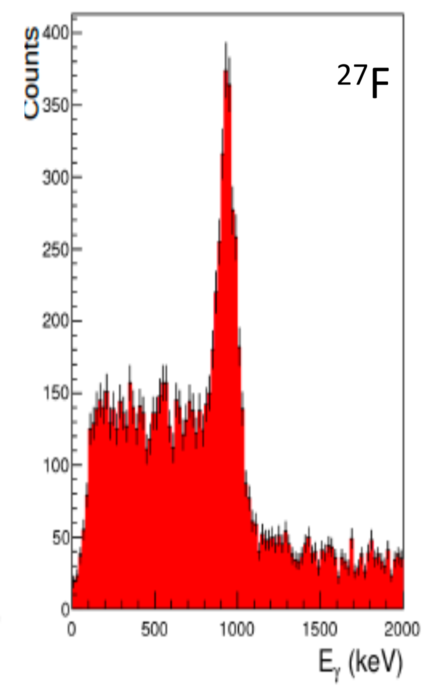
Better energy resolution

γ-ray detection in ^{27}F *

Larger acceptance
-> 2n detection

$S_n(^{27}F)$ = 1600 (50) keV
1270 (410) keV (Tabulated)





Neutron configurations from reactions and momentum distributions

$^{29}Ne_{19}$ ($3/2^-$)

Kobayashi et al. PRC (2016)

(-1p) sd shell

↓

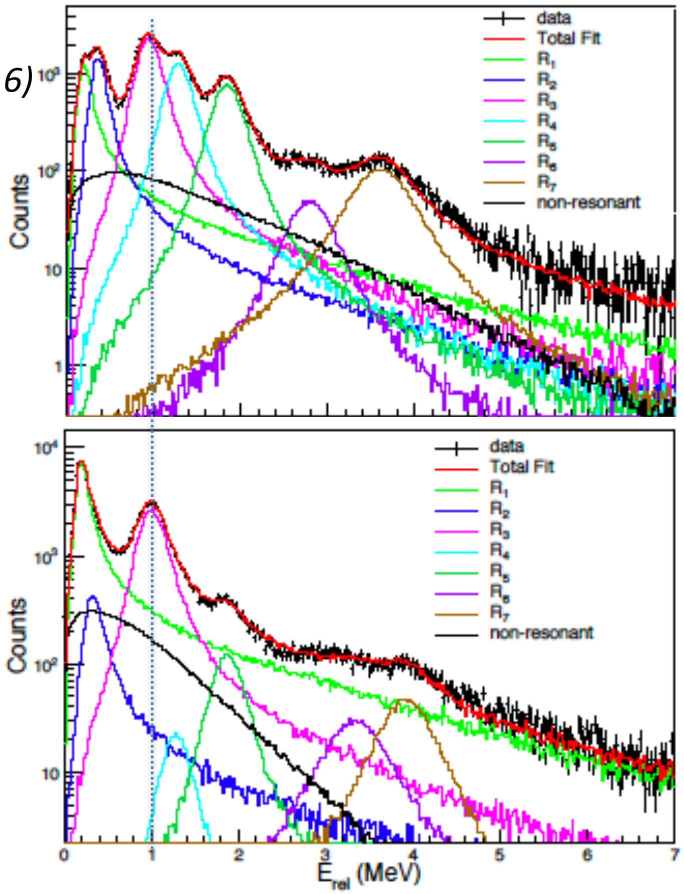
^{28}F (π=-)

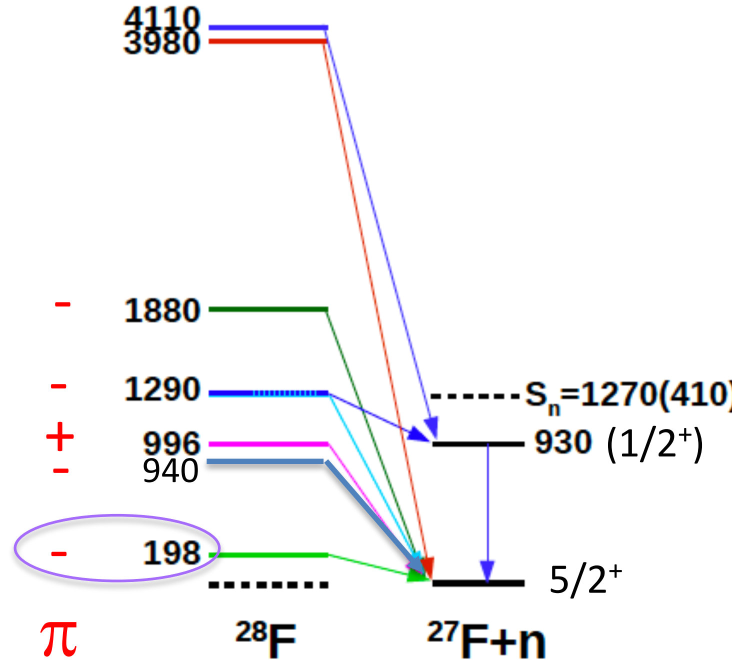
$^{29}F_{20}$ ($5/2^+$)

(-1n) sd-fp?

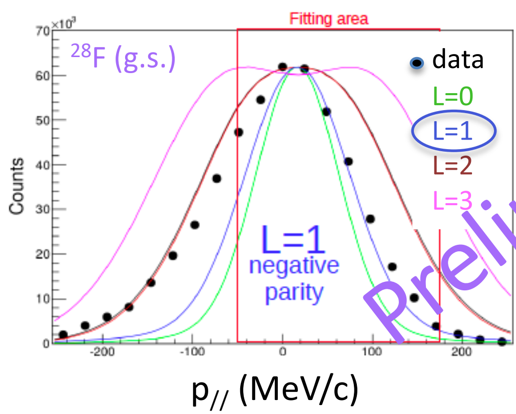
↓

^{28}F (π=+,-)

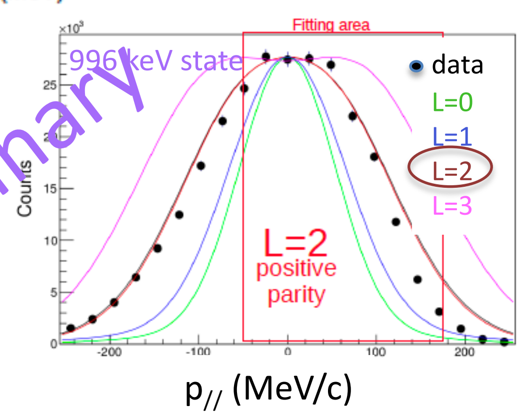




^{28}F sits the island of inversion

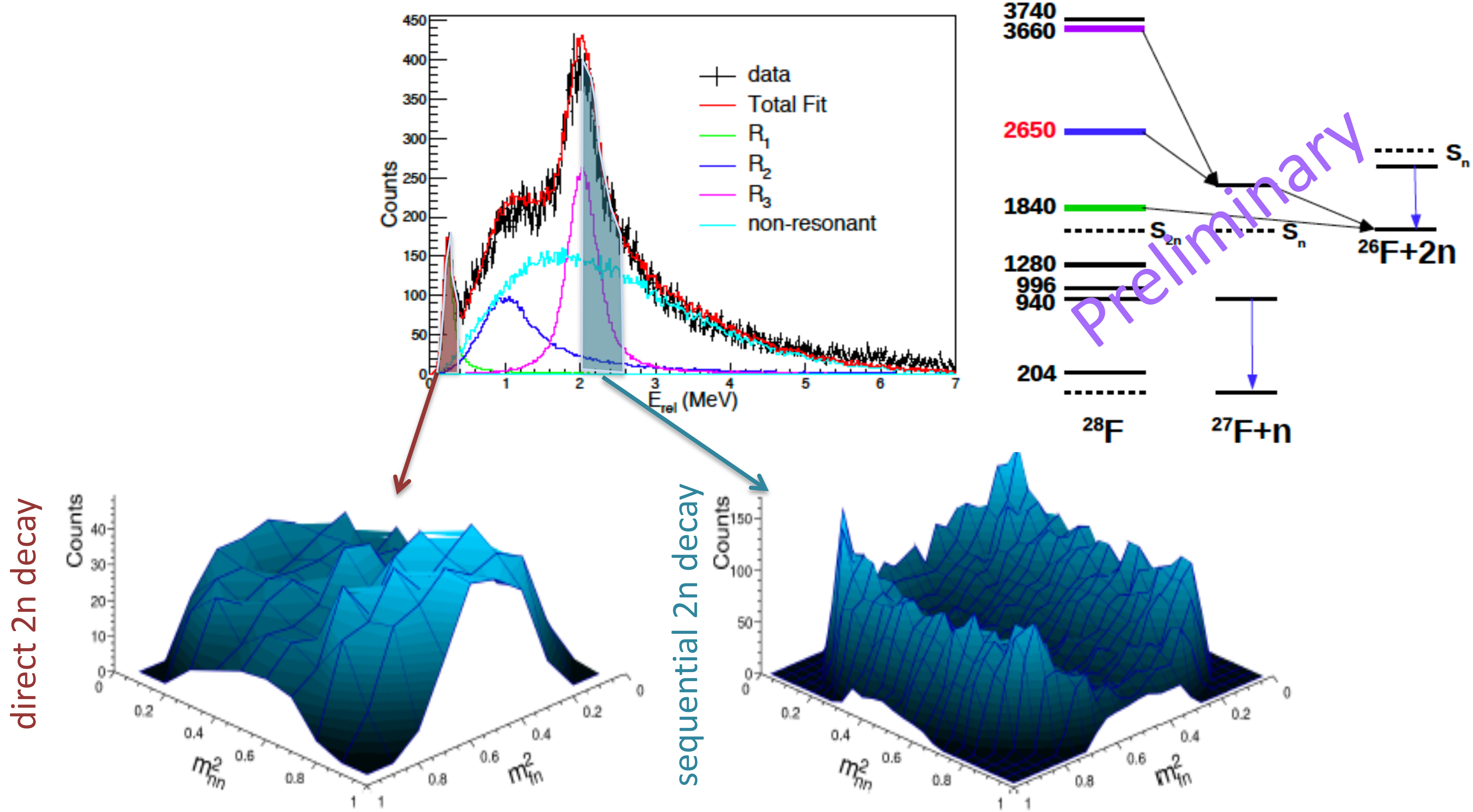


Preliminary

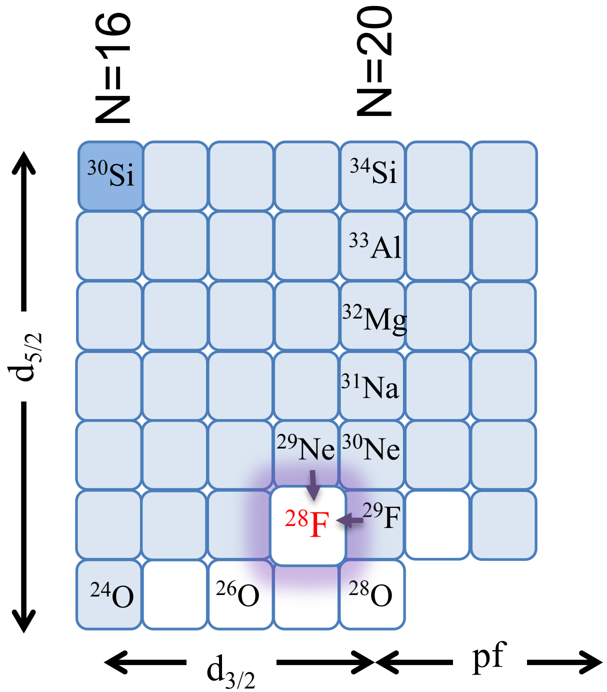


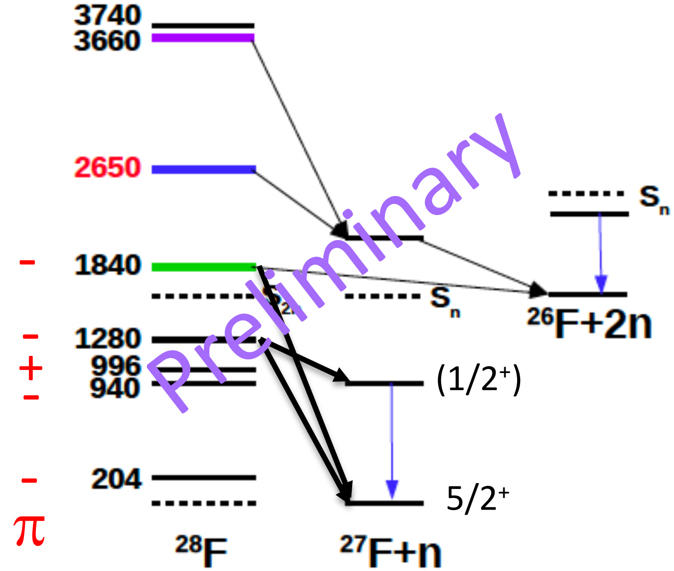
Preliminary calc. J. Tostevin

Hints of 2n decay patterns of ^{28}F



Conclusions on ^{28}F study





Spectroscopy and decay of ^{28}F produced by (-1p) and (-1n) reactions.

^{28}F ground state likely has a negative parity state -> in the Island of inversion

^{28}F spectroscopy and decay modes will be compared to models including continuum

Neutron neutron correlations strongly depend on the states -> config of state at 1840 keV?

All these analysis / conclusions are preliminary yet.