

EXPAND

“EXPLORATIONS ACROSS THE NEUTRON DRIPLINE”

LPC-CAEN, IRFU/CEA-SACLAY, IPN-ORSAY

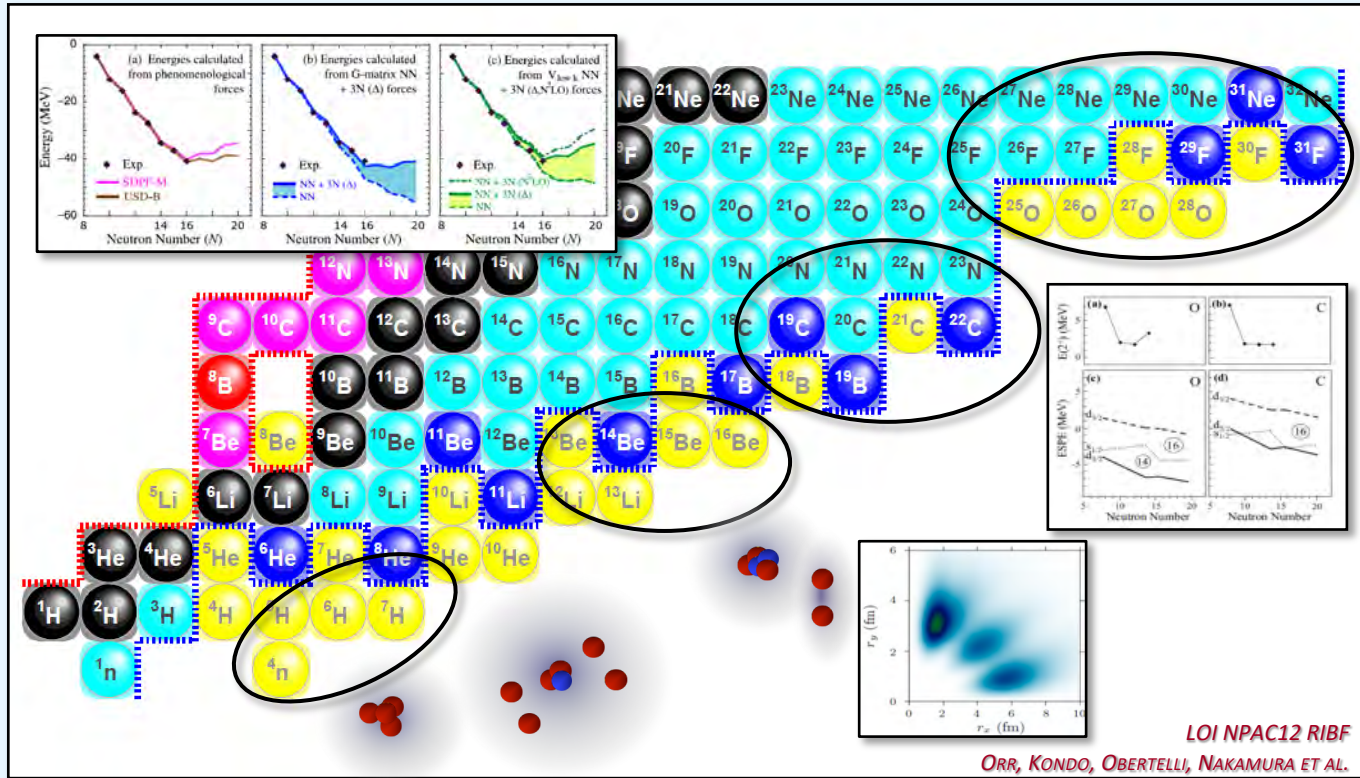
TOKYO INSTITUTE OF TECHNOLOGY, RIKEN NISHINA CENTER



AND THE “SAMURAI COLLABORATION”



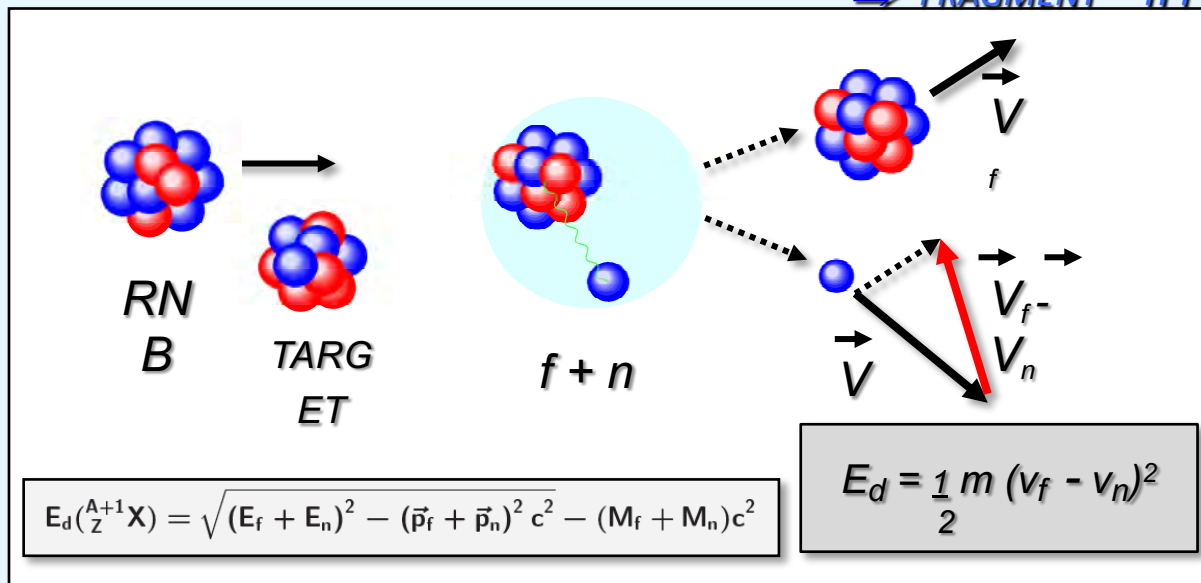
EXPAND - PHYSICS: STRUCTURE & CORRELATIONS AT AND BEYOND THE NEUTRON DRIPLINE ($A < 50$)



INVARIANT MASS SPECTROSCOPY OF UNBOUND STATES / SYSTEMS ...

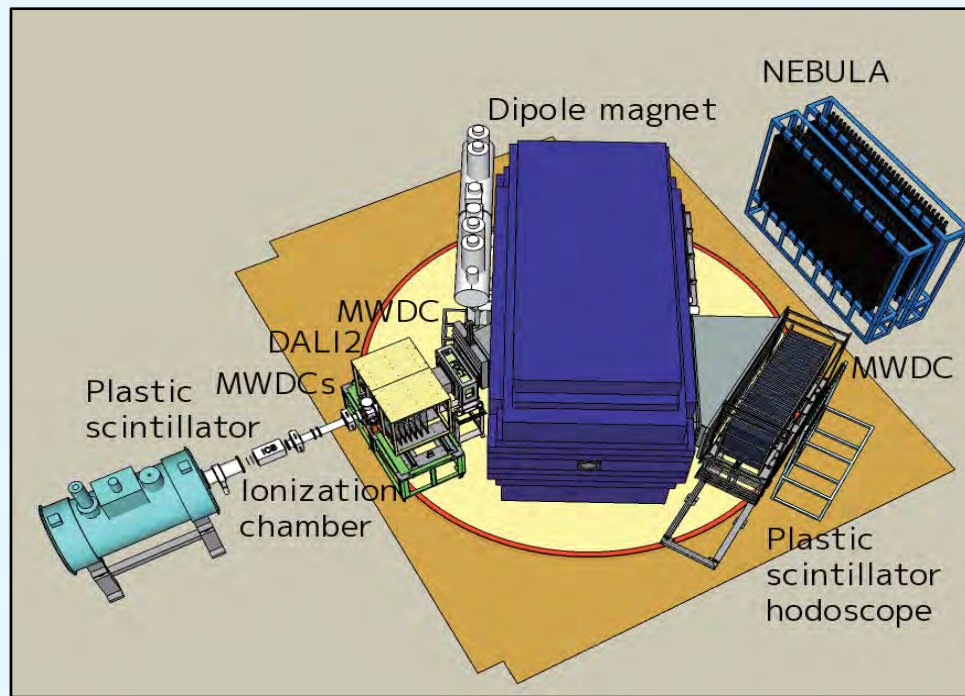
... NUCLEON "KNOCKOUT", BREAKUP ($\beta \approx 0.6$) + IN-FLIGHT DECAY

\Rightarrow FRAGMENT - n FSI



NOTE: VERY THICK TARGET ($\sim 1 \text{ g/cm}^2$) AND VERY FORWARD FOCUSING OF REACTION PRODUCTS

SAMURAI + NEBULA @ RIBF-RIKEN ...



BigRIPS + ^{48}Ca @ 345 MeV/nucleon ($\sim 800^* \text{ pA}$) \Rightarrow "INTENSE" LIGHT NEUTRON DRIPLINE BEAMS

^{22}C @ $\sim 60 \text{ pps}$, ^{31}Ne @

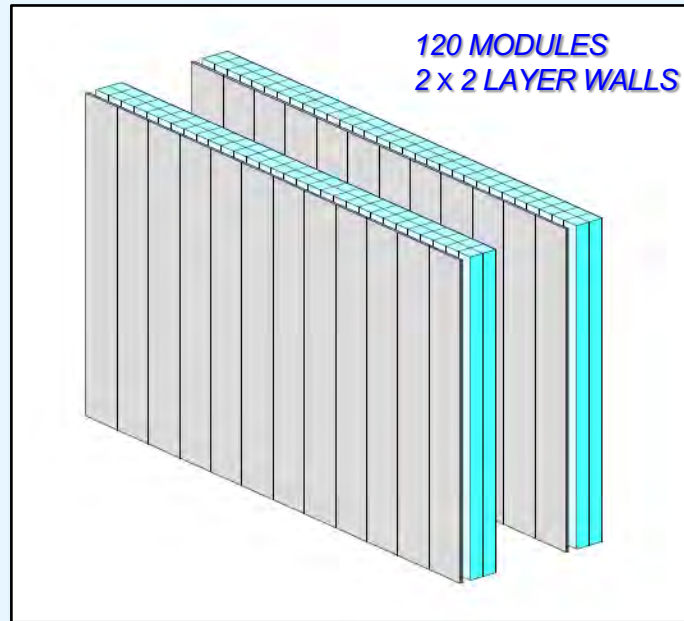
$\sim 1500 \text{ pps}$...

* "DayOne" 2012 $\sim 80 \text{ pA}$... 2016/17 $\sim 600 \text{ pA}$

SAMURAI+NEBULA Commissioning - 2012

EXPAND – Explorations Across the Neutron Dripline

NEBULA ...

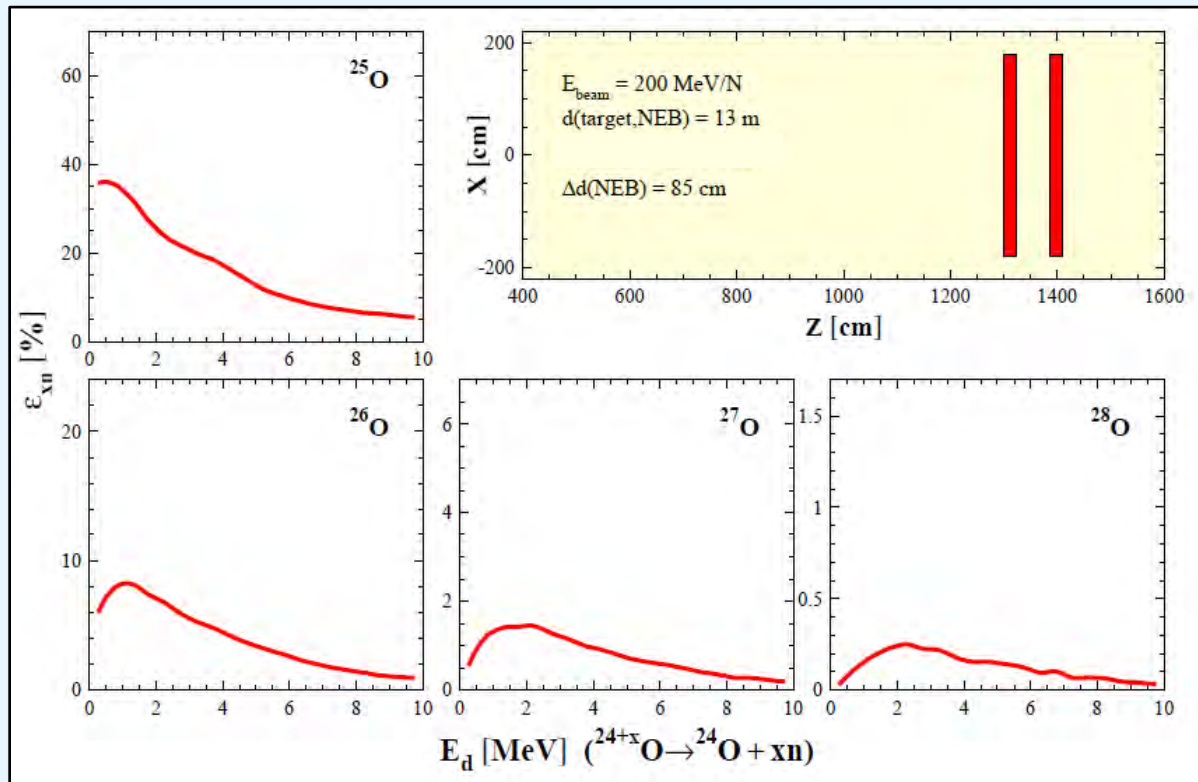


MODULE

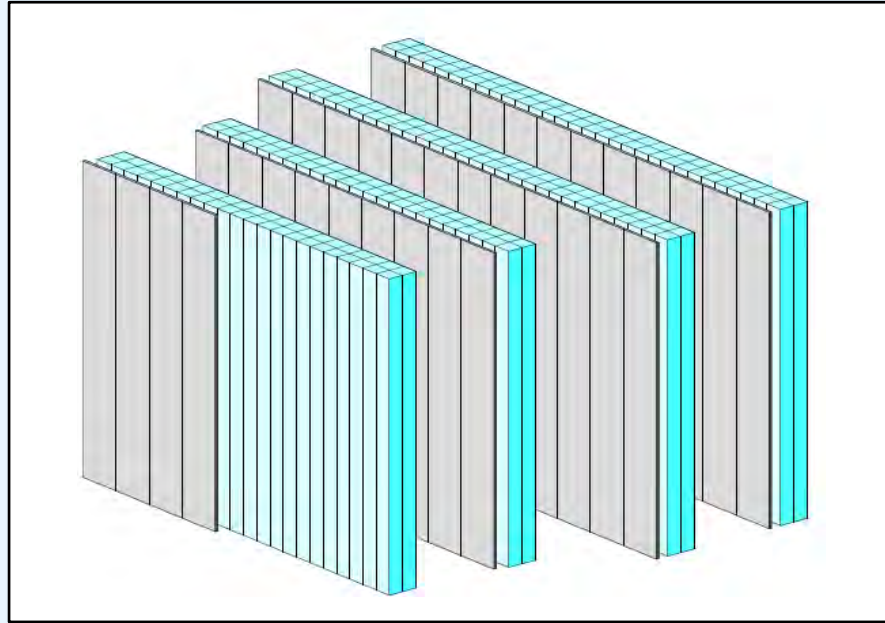


VETO
PADDLE

NEBULA DETECTION EFFICIENCY @ 200 MeV/nucleon ...



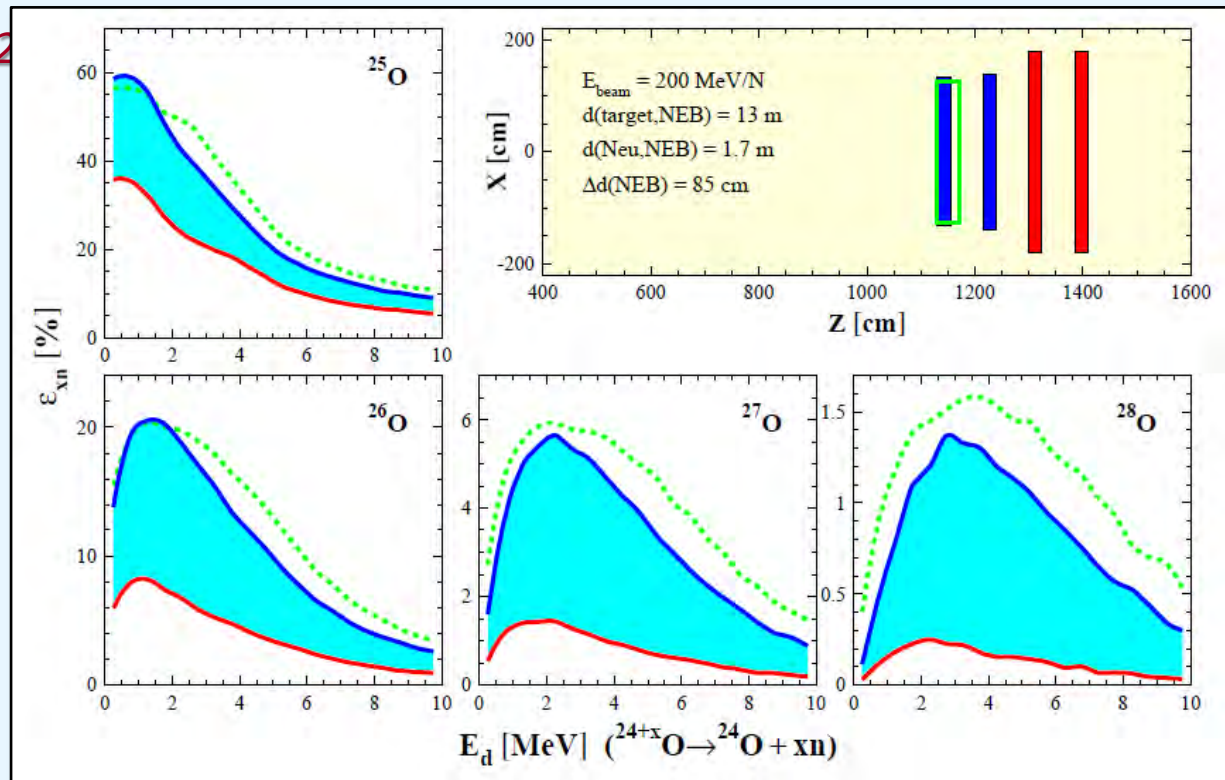
"NEBULA-PLUS" ...



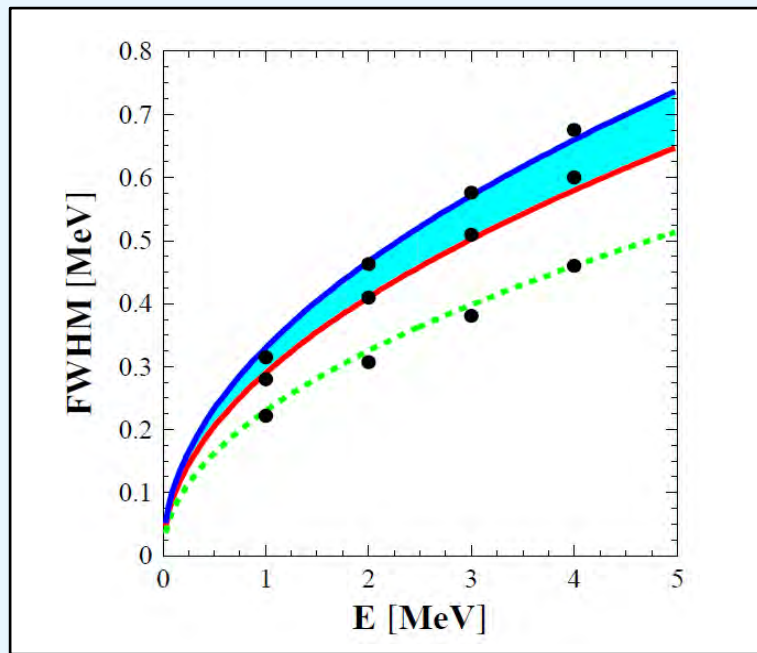
UPGRADE NEBULA WITH ADDITION OF 90 NEW MODULES + ELECTRONICS + HV
⇒ 4 WALLS EACH OF 44 / 46 / 60 / 60 MODULES

NEBULA-PLUS vs NEBULA vs NEULAND-NEBULA DETECTION EFFICIENCY

@



NEBULA-PLUS RESOLUTION @ 200 MeV/nucleon ...



- **NEBULA-PLUS** RESOLUTION SLIGHTLY DEGRADED COMPARED TO **NEBULA**
OWING TO SHORTER DISTANCE TO NEW WALLS.
- **NEULAND+NEBULA** – CONTRIBUTION OF SUPERIOR NEULAND GRANULARITY.

NEBULA-PLUS ...

- ORIGINAL GOAL TO DOUBLE NUMBER OF NEBULA MODULES / WALLS ...

... DEEMED TOO COSTLY BY ANR.

- RESUBMISSION ACCEPTED FOR 90 MODULES ...

HOWEVER ... GRANT AWARDED 100 K€ LESS THAN REQUESTED + \$ VS € EXCHANGE RATE DROP + AT

TENDERING PRICE SCINT.

MODULES [ST GOBAIN] x1.5

- NEULAND-TYPE WALL(S) INVESTIGATED: TOO COSTLY + ELECTRONICS-DAQ ISSUE

... DEMONSTRATOR USED (2015-2017) FOR PART OF PHYSICS

PROGRAMME.

- STRATEGY: ACQUIRE 90 SCINTILLATOR MODULES (NEBULA DESIGN, INCLUDING LIGHT GUIDES + PMTS) & EQUIP AS MANY AS POSSIBLE (60)

WITH READOUT ELECTRONICS & HV.

- AFTER INSTALLATION & COMMISSIONING UPGRADE TO EQUIP REMAINING 30 SCINT. MODULES –

SUPPLEMENTARY FINANCING

* ESSENTIALLY OWING TO INCREASED COST OF SCINTILLATOR MODULES

REQUIRED ~60 K€*

EXPAND – Explorations Across the Neutron Dripline

NEBULA-PLUS ...

STATUS & CALENDER:

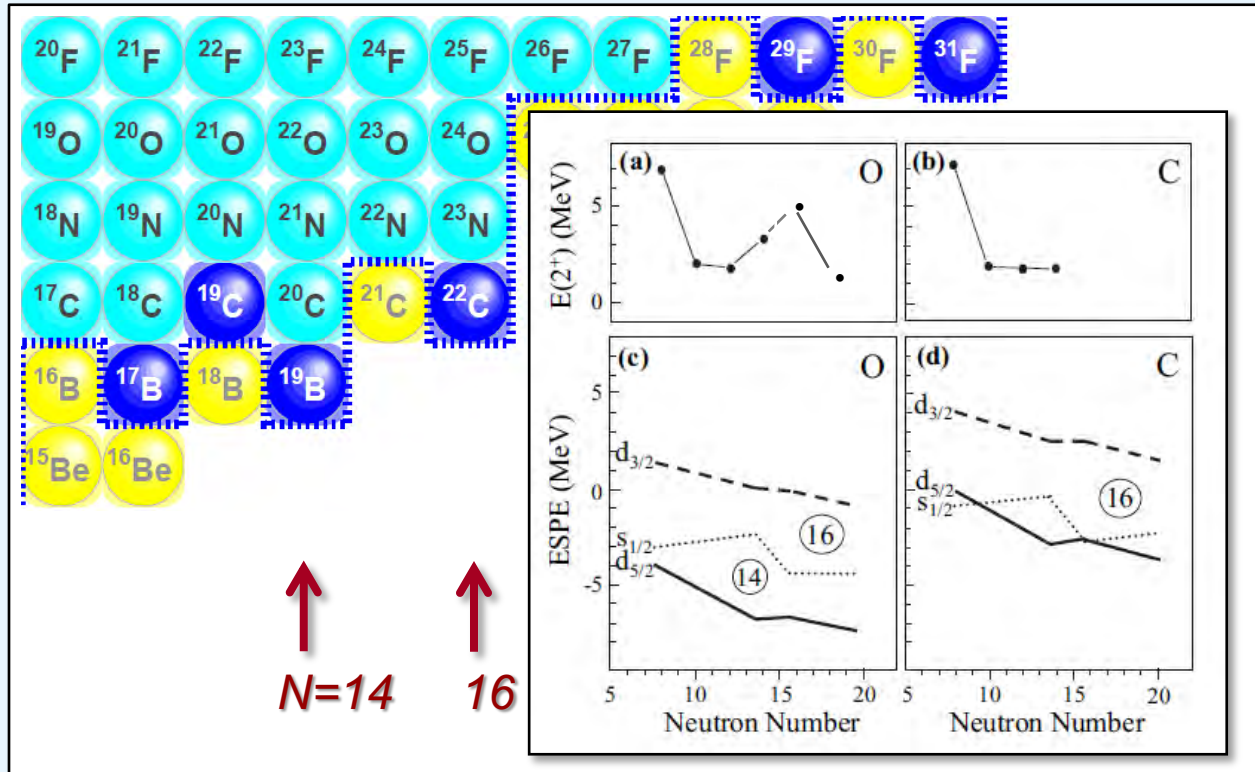
- *SCINTILLATOR BARS (90) + LIGHT GUIDES: ELJEN (USA) – FINAL BATCH DELIVERED MID-MAY*
- *PMTS : H22184 HAMAMATSU – 80 DELIVERED (40 TESTED), REMAINING 100 BY EARLY-SEPT*
- *ACCEPTANCE TESTING OF SCINT. MODULES COSMIC RAYS + SOURCES (90 TESTED) – APRIL-JUNE 2019*
- *FASTER READOUT ELECTRONICS & 180 CHANNEL HV SYSTEM – OCT-NOV 2019*
- *SHIP NEBULA-PLUS TO JAPAN – NOV-DEC 2019 [VAT~50-60k€]*
- *INSTALLATION & SOURCE + COSMIC RAY TESTS – JAN-APRIL 2020*
- *COMMISSIONING (BEAM) – MAY-JULY 2020 ... TO BE CONFIRMED*
- *FIRST EXPERIMENT – OCT-NOV 2020 ... TO BE CONFIRMED*
- *COMPLETE READOUT ELECTRONICS INSTRUMENTATION (30 SCINT. MODULES) – 2020-21*

SELECTED HIGHLIGHTS PHYSICS PROGRAMME (2012-18) * ...

- Spectroscopic study of the unbound systems (Z=5 & 6) in the region of N=14-16
- Determination of the total interaction cross section of ^{22}C
- First observation of $^{20,21}\text{B}$ (N=15,16)
- First observation of $^{24,25}\text{N}$ (N=17, 18) and the spectroscopy of ^{23}N (N=16)
- Investigation of two-neutron unbound system ^{26}O
- Search for $^{27,28}\text{O}$ and the investigation of the very neutron rich F isotopes near N=20 [analyses in final stages]
- An investigation of the two-neutron unbound system ^{16}Be [analyses being finalised]
- A search for the ^4n system and the investigation of ^7H [analyses in progress]
- Investigation of clustering in the neutron-rich Be isotopes: $^{10,12,14}\text{Be}(p,p\alpha)$ quasi-free knockout [analyses in progress]

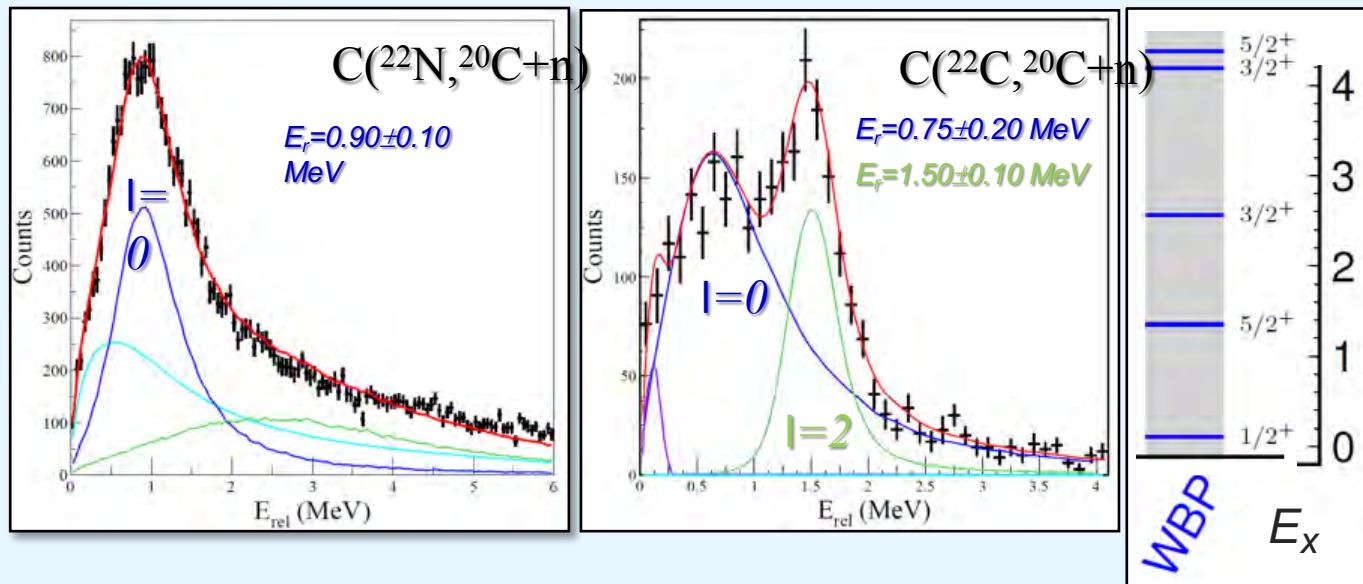
* IN2P3 SPOKESPERSONS/GROUPS PLAYED MAJOR/KEY ROLE

Z=6: STRUCTURE IN THE REGION OF $N \sim 14 - 16$ ($\nu 2s_{1/2} - \nu 1d_{5/2}$) ...



FIRST OBSERVATION & SPECTROSCOPY OF ^{21}C :

$\text{C}(^{22}\text{N}/^{22}\text{C}, ^{20}\text{C}+n)$ @ ~ 250 MeV/nucleon

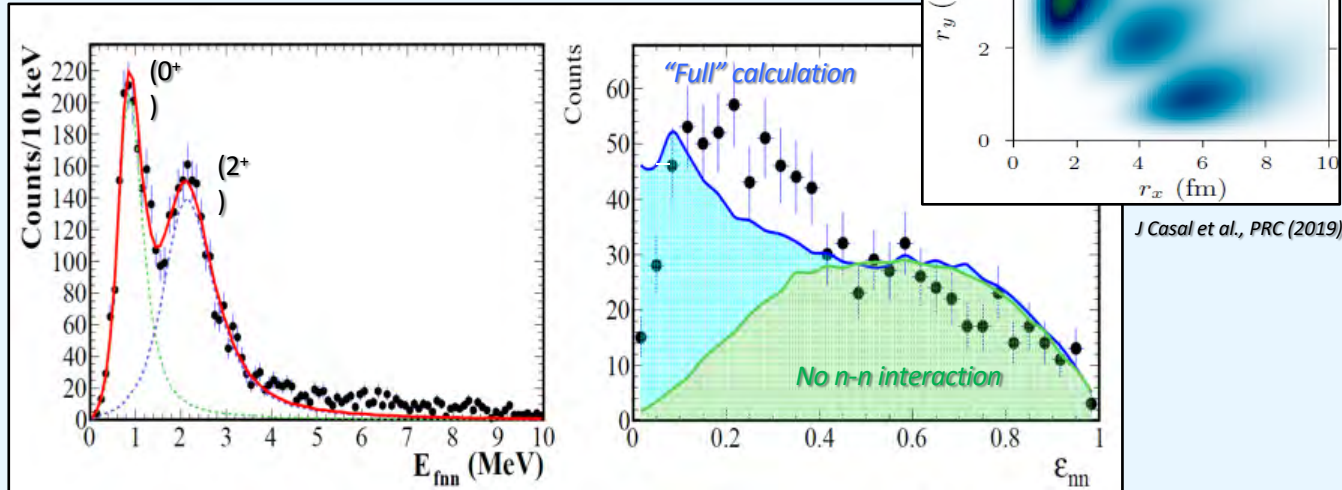


	E_x (MeV)	J^π	ℓ	σ_{sp} (mb)	C^2S	$\sigma_{-1n(e)}^{\text{th}}$ (mb)
$[^{22}\text{C}(0^+), ^{21}\text{C}(J^\pi)]$	0.000	$1/2_1^+$	0	89.35	1.403	137.55
	1.109	$5/2_1^+$	2	29.39	4.212	135.87
Eikonal + shell model C^2S	2.191	$3/2_1^+$	2	25.44	0.342	9.55
JA Tostevin						

SPECTROSCOPY & NEUTRON-NEUTRON CORRELATIONS IN ^{16}Be :

$H(^{17}\text{B}, ^{14}\text{Be}+n+n)2p$ @ 250

MeV/nucleon

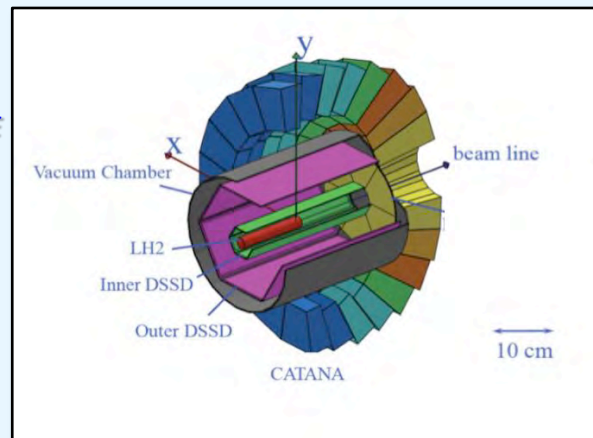


PHYSICS PROGRAMME WITH NEBULA-PLUS: NEAR FUTURE (2020-23) ...

- *SEARCH FOR EXCITED (CONTINUUM) STATES OF $^{22}\text{C} - 2^+$ (N=16 SUB-SHELL CLOSURE)*
- *INVESTIGATE TWO-NEUTRON DECAY OF ^{21}B & SEARCH FOR $^{21}\text{B}^*$ (N=16) & 3-NEUTRON DECAY OF ^{20}B*
- *SEARCH FOR ^{23}C (N=17) – POSSIBLE APPLICATION OF ($^{12}\text{C}, ^{12}\text{N}$)*
- *SPECTROSCOPY OF ^{39}Mg (N~28)*

*PROJET STRASSE * (~2020-22) ...*

- *IMPROVED VERTEX DETECTION FOR MINOS-TYPE THICK LIQUID H_2 TARGET – (p,xp), ...*
- *SI MICROSTIP DETS FOR TRACKING PROTONS*
- *LPC ~150K€ VIA NORMANDY REGION [CHAIRE D'EXCELLENCE - F FLAVIGNY]*



FINANCIAL RESOURCES (IN2P3) ...

- 2012-2018: AP IN2P3 ~20K€/YEAR + LIA ~3-6 K€/YEAR - ESSENTIALLY TRAVEL (JAPAN)

INCREASED COMMITMENT TO SAMURAI [NEBULA-PLUS & STRASSE] & FTE + ~1.5

- REQUEST (TRAVEL) 2020-2023: AP IN2P3 ~30K€/YEAR + LIA ~5 K€/YEAR
- REQUEST (EQUIPMENT-ELECTRONICS NEBULA-PLUS) 2020-2021: AP IN2P3 15K€/YEAR

MATCHING FUNDS – LPC (UNDER DISCUSSION)

MANPOWER (IN2P3) ...

- 2012-2018: ~5-6 FTE[‡] [PHYSICISTS]
- LPC - MARIAN PARLOG - RETIRED (JAN 2018), FRANCK DELAUNAY - SABBATICAL (2018-19)
- IN2P3/CNRS FUNDED POSTDOC - OCT 2019 (LPC)
- “CHAIRE D’EXCELLENCE” NORMANDY REGION – FREDDY FLAVIGNY* (OCT 2019)
- 2020-23: ~6-7 FTE[‡] [PHYSICISTS] + ~0.2 - 0.5 FTE [IR/IT] IN2P3

* Research project: RIBF (Strabe - EXPAND) & GRIT

‡ Including graduate students

SWOT ANALYSIS ...

STRENGTHS

- *RIBF's unequalled secondary beam intensities for light ($A < 50$) neutron-rich beams.*
- *State of the art setup and instrumentation.*
- *Collaboration very experienced in the simulation and analysis of complex experiments, including multi-neutron detection and cross talk analyses.*
- *French collaborators play key role in collaboration – reinforced with NEBULA-Plus.*

WEAKNESSES

- *Shortfall in ANR funding.*
- *SAMURAI electronics and DAQ not state of the art.*
- *Limited beam time at RIBF (maximum of 4 months/year).*
- *Recent difficulties in procuring ^{48}Ca source material (Nishina Centre/RIBF).*
- *Very limited theory support (France).*
- *Travel funds.*

OPPORTUNITIES

- *With successful commissioning of NEBULA-Plus the SAMURAI collaboration will be ideally positioned to play a leading role in neutron dripline physics for the next decade.*
- *Improvements possible with the Straße active target.*

THREATS

- *FRIB (>2022) and to a lesser extent FAIR (>2025) – but long lead times in ramping up primary beam power.*

LA CANICULE ...



- *I heard the Prime Minister speaking to the Queen...*

... *"It's hot enough to boil a monkey's bum, your Majesty"*
he said and she smiled quietly to herself.

- *She's a good Sheila, Bruce, and not at all stuck up.*