Neutron-Proton Pairing and Transfer Reactions

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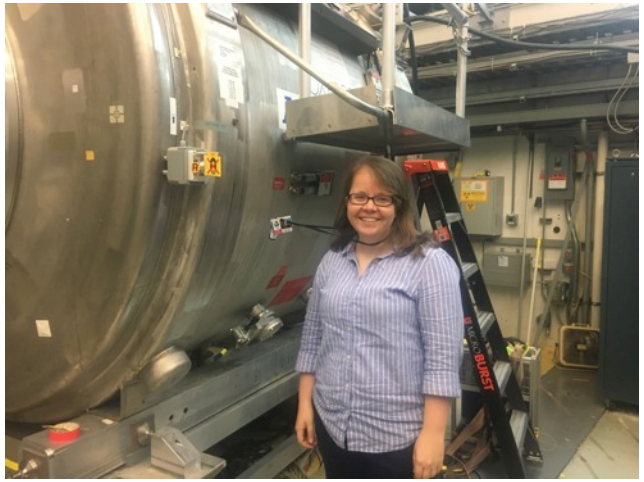
ReA Solenoidal Spectrometer Projects

Si arrays, active targets, and beyond

24 March 2017, Physics Division, Argonne National Laboratory

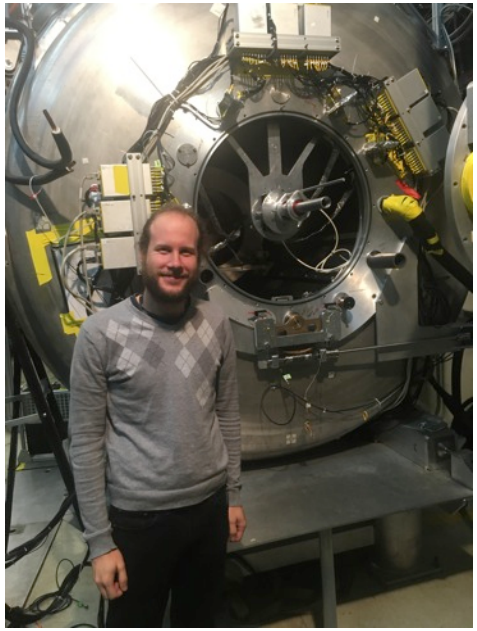
Work supported under contract number DE-AC02-05CH11231.

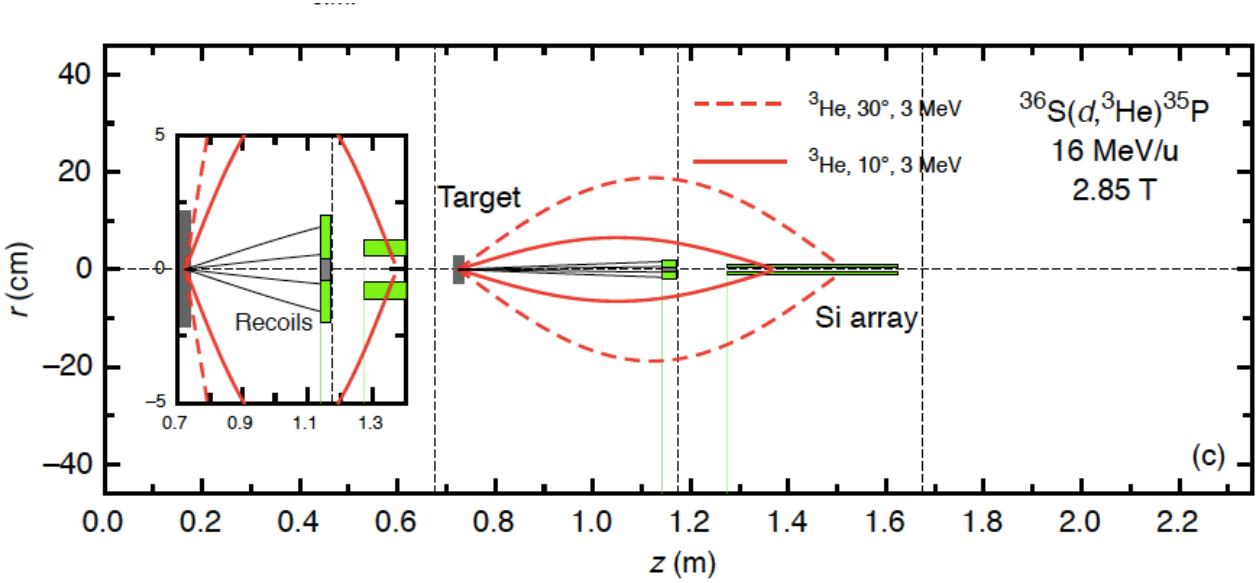
Our Credentials ☺



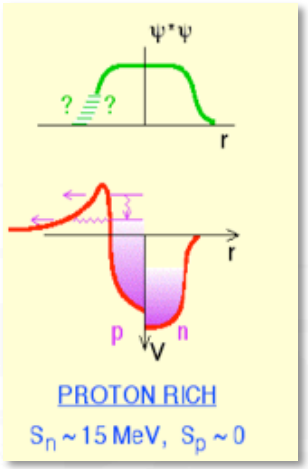
ATLAS-1673
Identification of the first-excited
$s_{1/2}$ x 2p2h configuration in ^{35}P

LBNL – **ANL** – iThemba - U. Conn.
Collaboration





The Nuclear Landscape



N=Z - line

Mirror symmetry

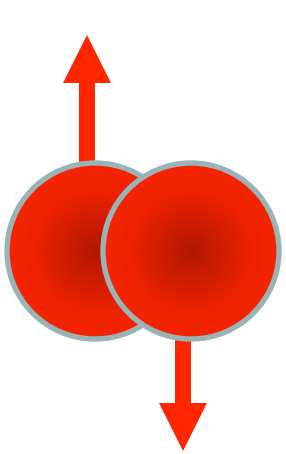
p and 2p tunneling

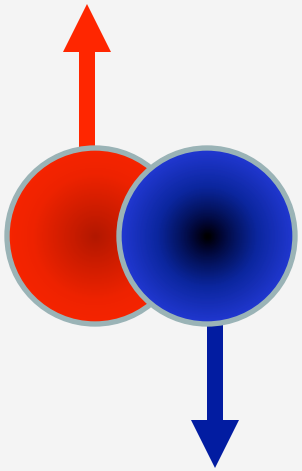
Spin triplet superconductivity (T=0 pairing)

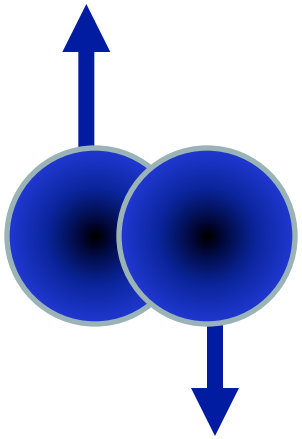
rp-process

Novae, X-ray bursts

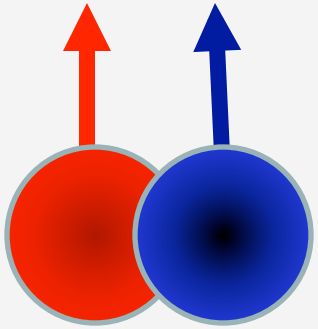
S. Frauendorf and A.O.Macchiavelli, Progress in Particle and Nuclear Physics, 78, 24 (2014)







T=1, S=0



T=0, S=1

$T_z=0$

N=Z nuclei, unique systems to study *np* correlations

As you move out of N=Z, T=1 *nn* and *pp* pairs will start to dominate. T=0 excited states.

Role of isoscalar (T=0) and isovector (T=1) pairing

Large spatial overlap of *n* and *p*

Pairing vibrations (normal system)

Pairing rotations (superfluid system)

Does isoscalar pairing give rise to collective modes?

Possible signals

Binding energy differences

Low-lying states of odd-odd self-conjugate nuclei

Rotational properties: moments of inertia, alignments

Beta decay

Direct reactions

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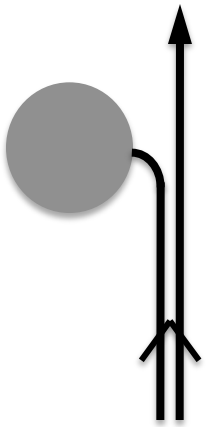
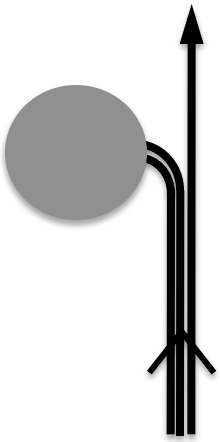




$$< A+1 \mid a^{+} \mid A >$$

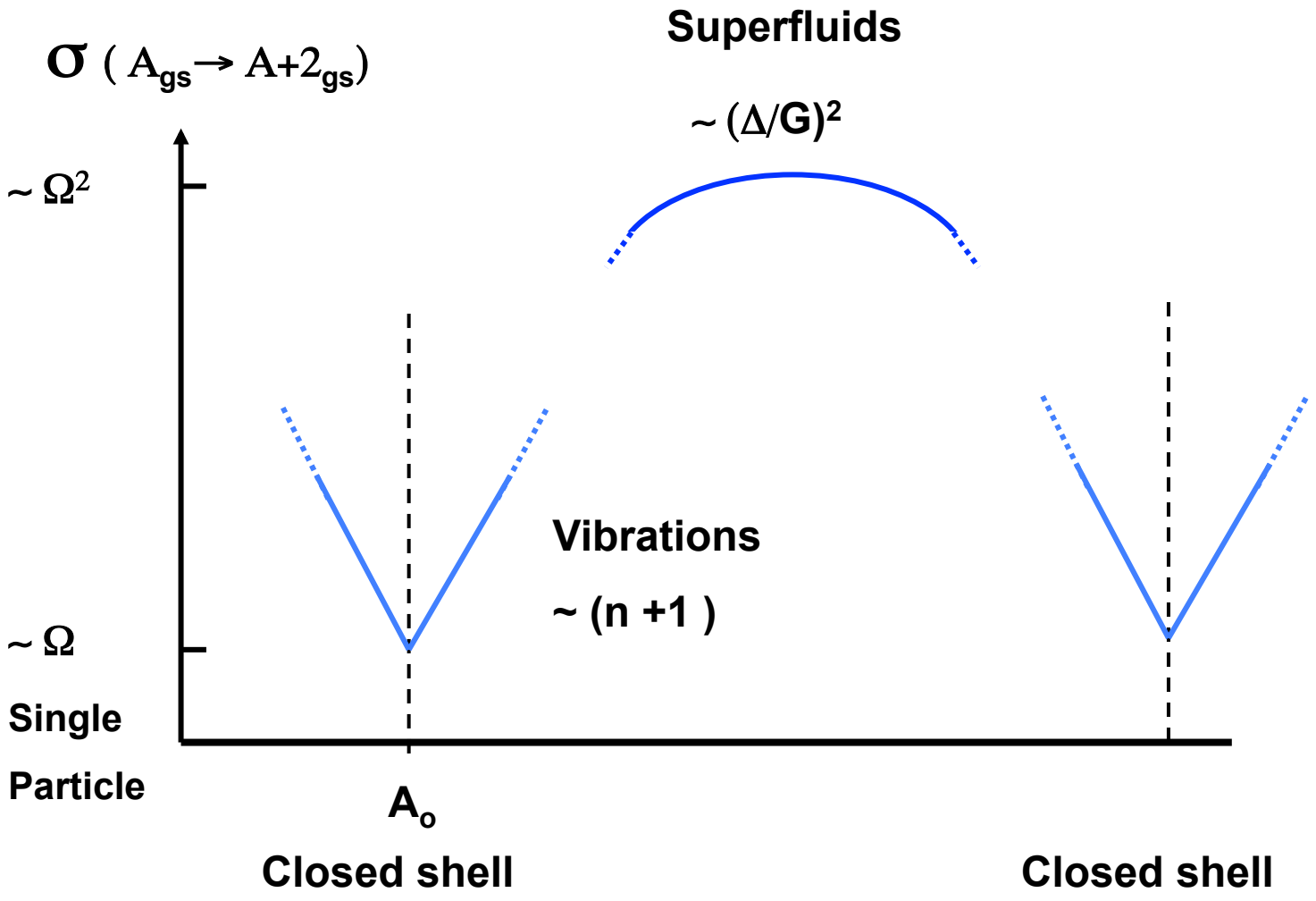
Spectroscopic (U, V) Factors

$$< A+2 \mid a^{+}a^{+} \mid A >$$

Constructive interference

Two particle transfer reactions like (t,p) or (p,t), where 2 nucleons are deposited or picked up at the same point in space provide an specific tool to probe the amplitude of this collective motion.

The transition operators <f|$a^{+}a^{+}$|i>, <f|aa|i> are the analogous to the transition probabilities BE2's on the quadrupole case.



Systematic relative measurements and within a given nucleus.

(p, ^{3}He), (^{3}He,p)	$\Delta T=0,1$
(d,α), (α,d)	$\Delta T=0$
(α, ^{6}Li), (^{6}Li,α)	$\Delta T=0$

Volume 37B, number 4 PHYSICS LETTERS 13 December 197

ENHANCEMENT OF DEUTERON TRANSFER REACTIONS BY NEUTRON-PROTON PAIRING CORRELATIONS*

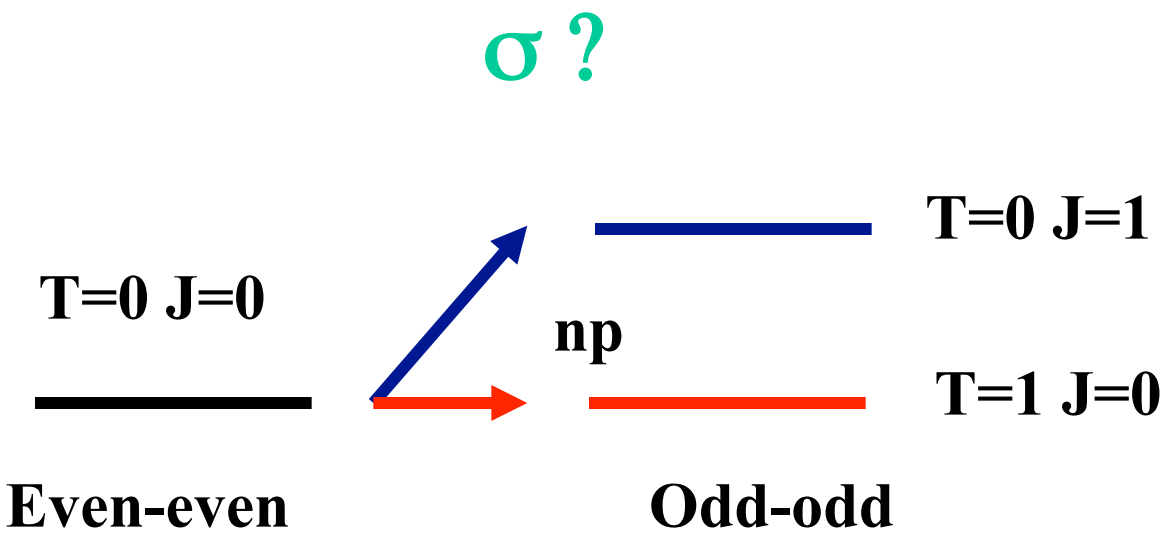
P. FRÖBRICH
Physik-Department der Technischen Universität München, Teilinstitut Theorie, München, Germany

Received 7 October 1971

It is shown for ^{36}Ar (p,^{3}He)^{34}Cl that the transfer of a neutron-proton pair is enhanced as compared to the shell model if one takes into account $T = 0$ and $T = 1$ neutron-proton pairing correlations in the description of target and residual nucleus.

$$d\sigma/d\Omega \approx 2.5 d\sigma/d\Omega_{sp}$$

(^{3}He,p) Transfer Reactions

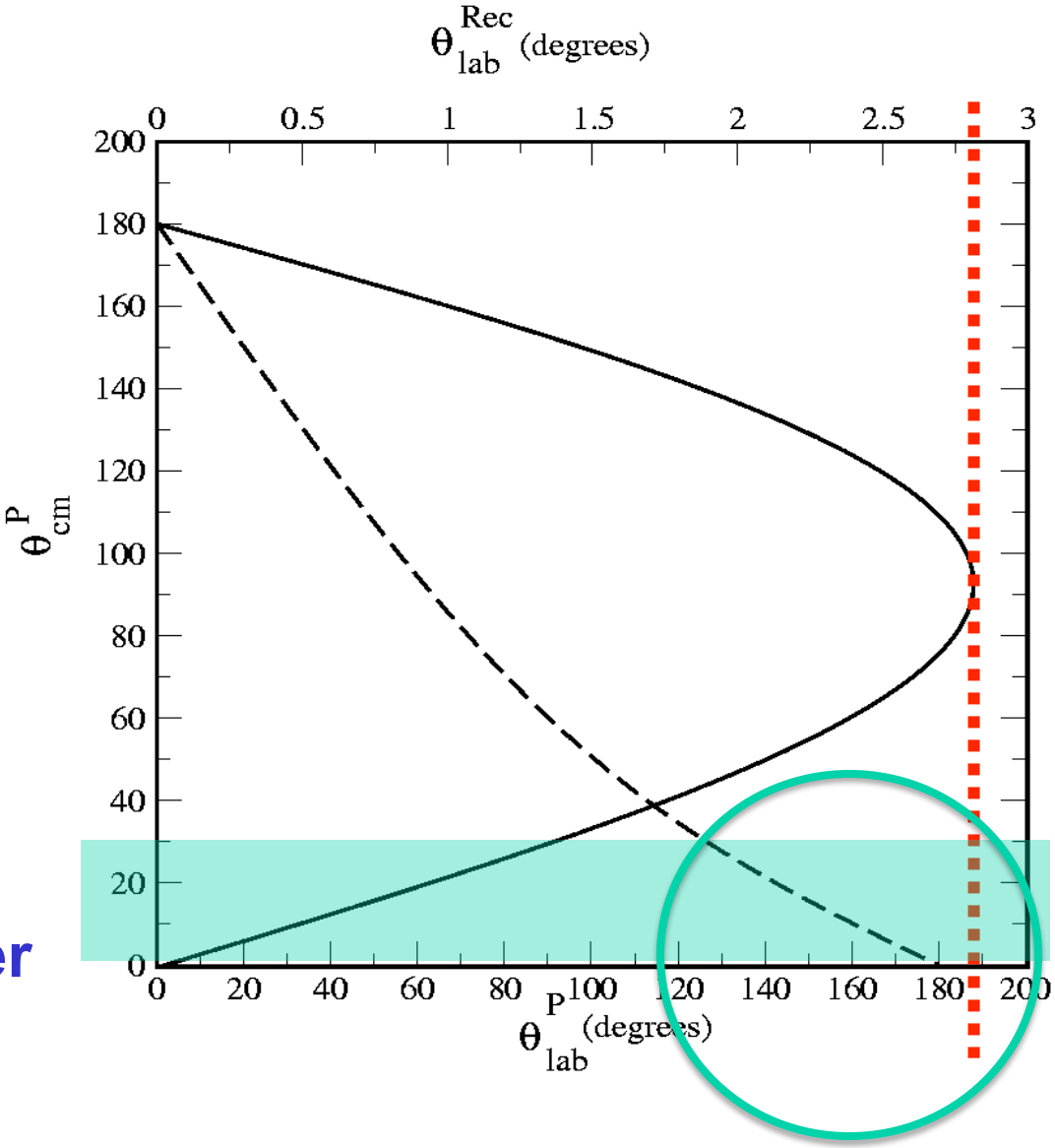


(^{3}He,p) - L=0 transfer

Measure the *np* transfer cross section to T=1 and T=0 states

Both absolute σ(T=0) and σ(T=1) and relative σ(T=0) / σ(T=1) tell us about the character and strength of the correlations

^{44}Ti(^{3}He,p) at 242MeV



L=0 transfer

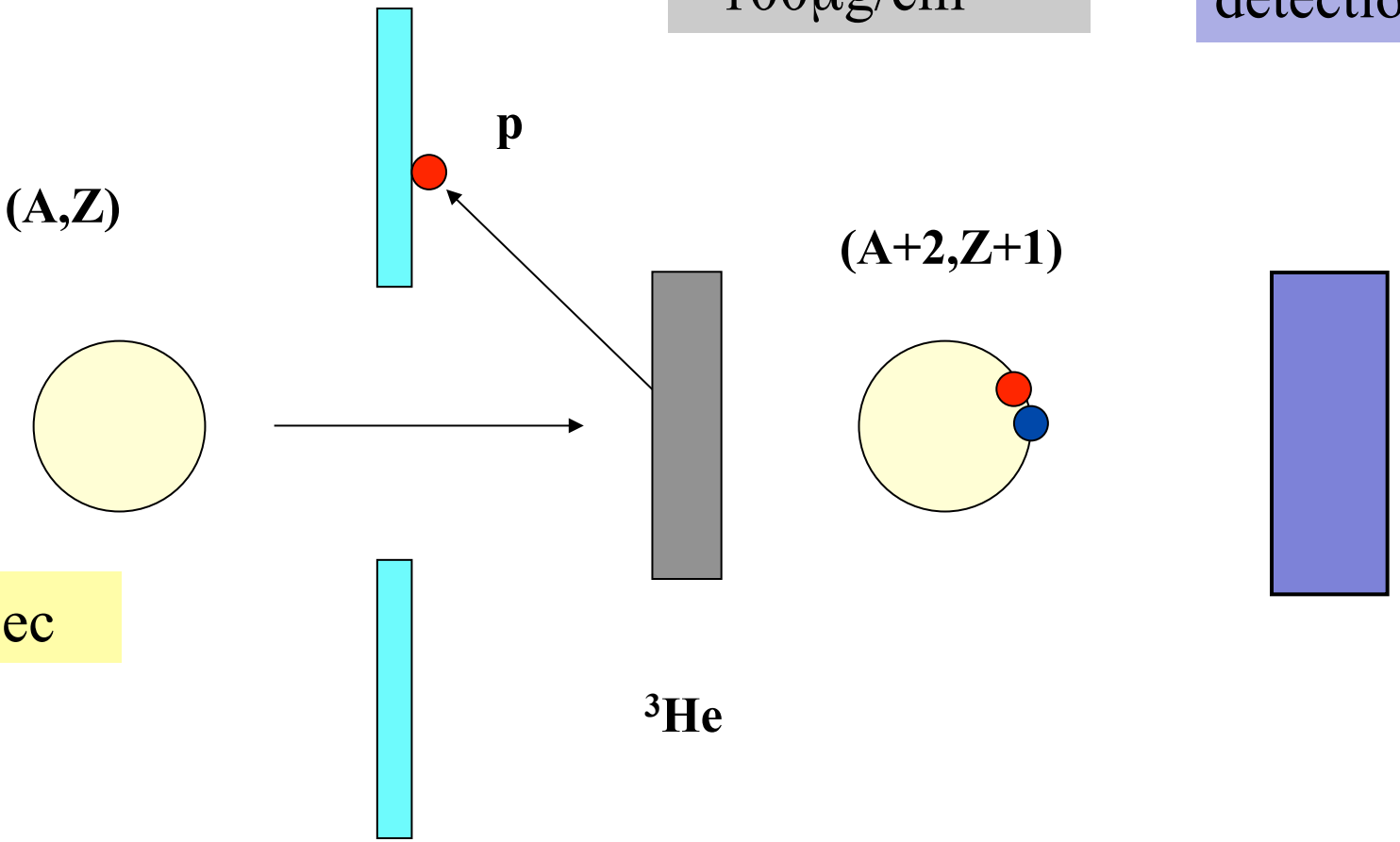
Backward protons

E ~ 5-6MeV

Si detector 500μ
16x16 ~1sr

Gas cell
~100μg/cm^2

Recoil
detection



~10^6 /sec

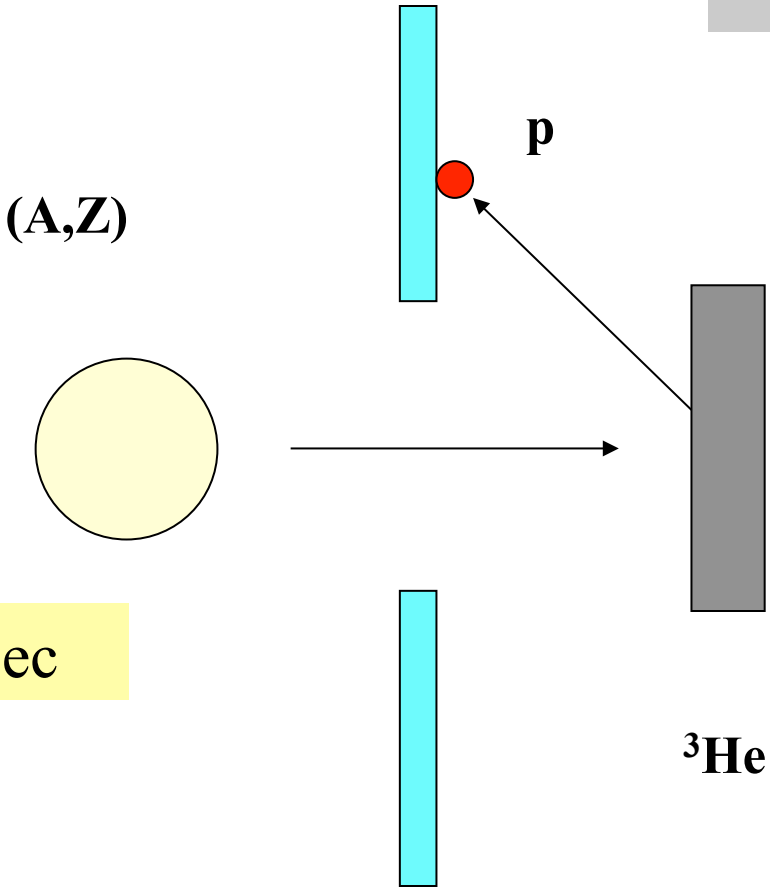
Measure E(Θ), dσ/dΩ (Θ), σ

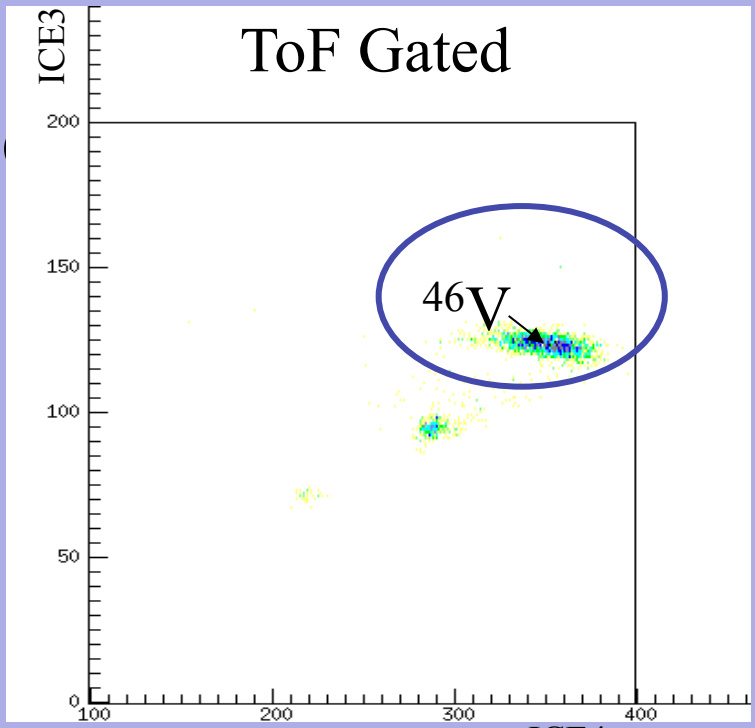
~ 20 counts/day

Si detector 500μ
16x16 ~1sr

Gas cell
~100μg/cm^2

Recoil detection



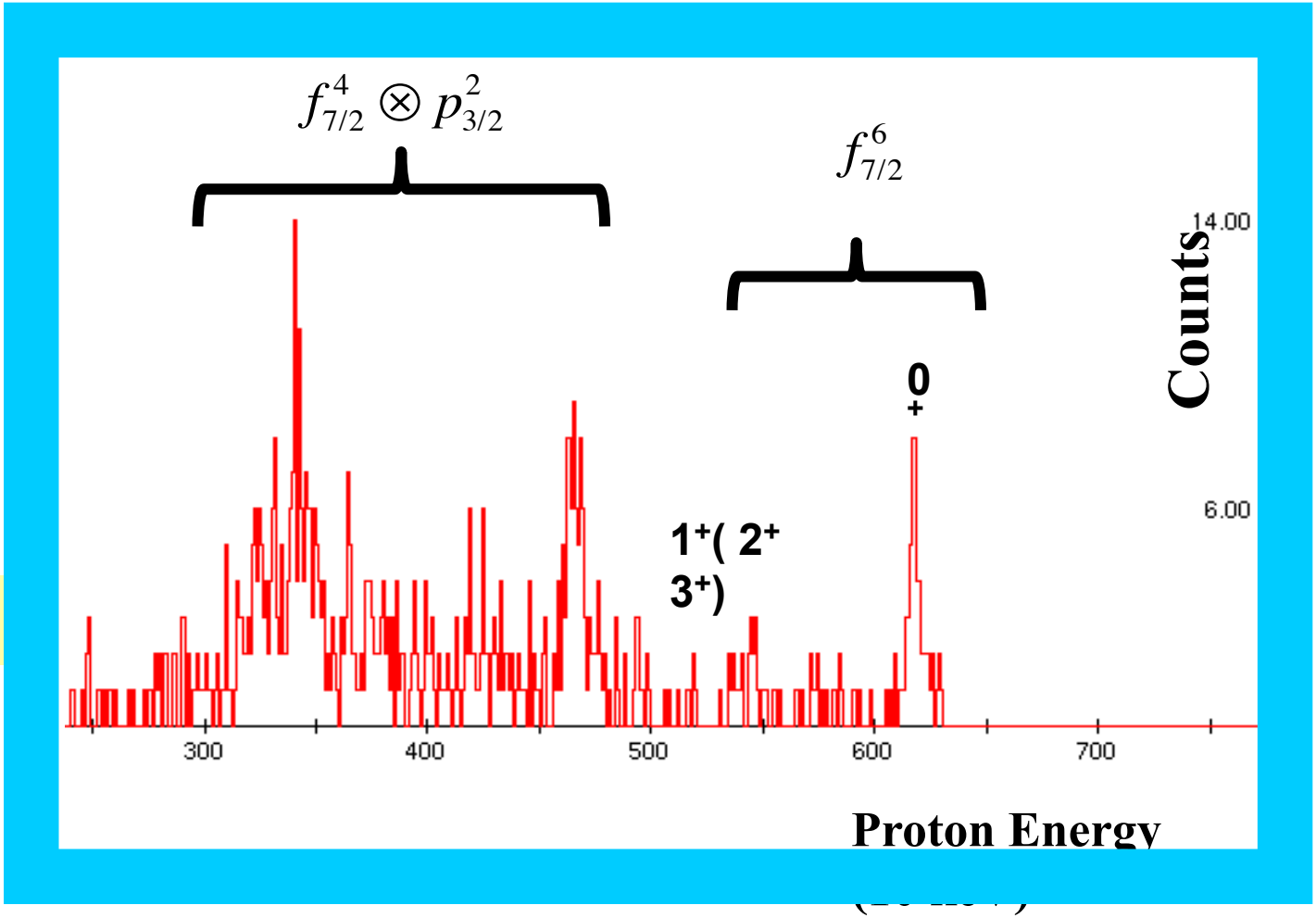


~10^6 /sec

Measure E(Θ), dσ/dΩ (Θ), σ

~ 20 counts/day

Si detector 500μ
16x16 ~1sr

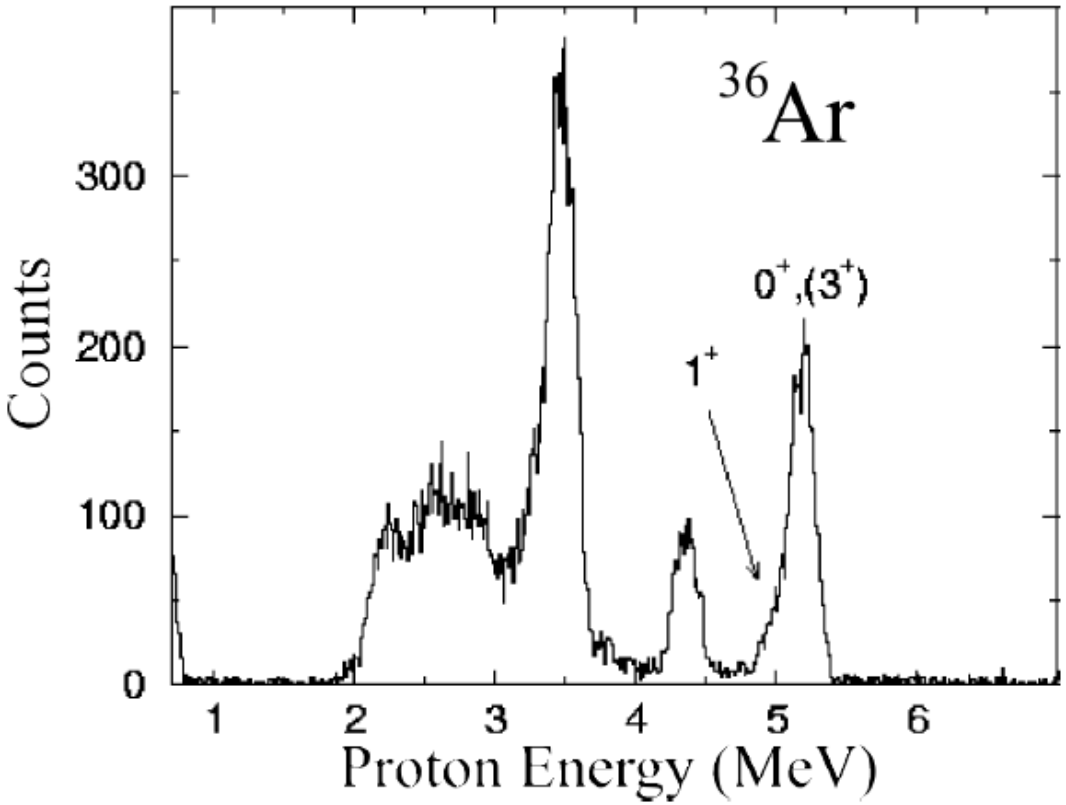


~10^6 /sec

Measure E(Θ), dσ/dΩ (Θ), σ

~ 20 counts/day

^{36}Ti(^{3}He,p) at 180 MeV



Investigation of np pairing using the ^{36}Ar(^{3}He,p)^{38}K

A. M. Rogers,[1,*] B. Back,[2] H. L. Crawford,[3] C. M. Deibel,[4] P. Fallon,[3]
C. R. Hoffman,[2] B. P. Kay,[2] J. Lee,[5] C. J. Lister,[1] A. O. Macchiavelli,[3]
K. E. Rehm,[2] D. Santiago-Gonzalez,[6] J. P. Schiffer,[2] and A. H. Wuosmaa[7]

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of Physics & Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA
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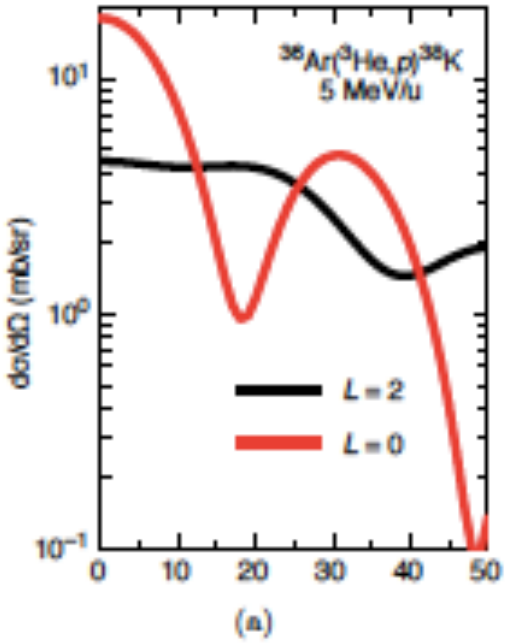
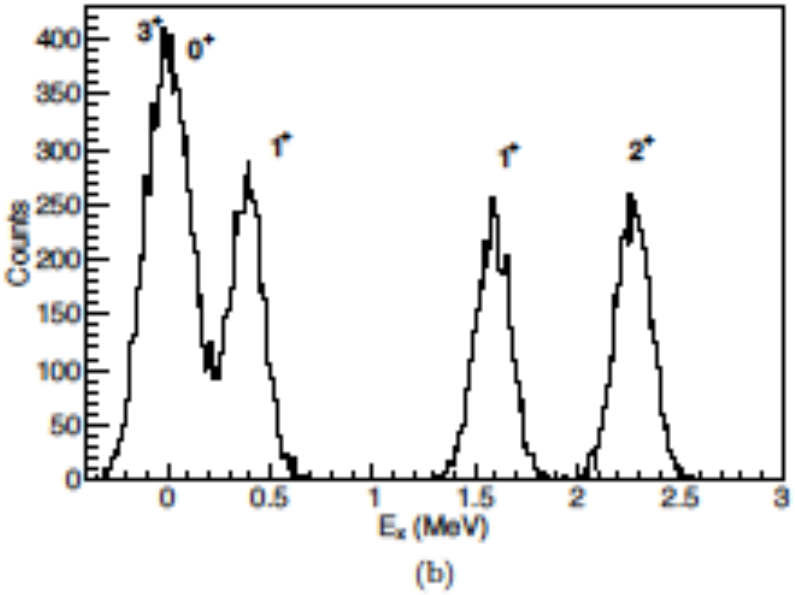
HELIOS





National Superconducting Cyclotron Laboratory
Proposal Form - PAC 41

By submitting this proposal, the spokesperson certifies that all collaborators listed have read the Description of Experiment and have agreed to participate in the experiment.

Title

Studying np pairing in N=Z nuclei: The 52Fe(3He,p) reaction at ReA3 with the AT-TPC

Spokespeople

	Primary Spokesperson	Backup Spokesperson
Name	Yassid Ayyad	Augusto O. Macchiavelli
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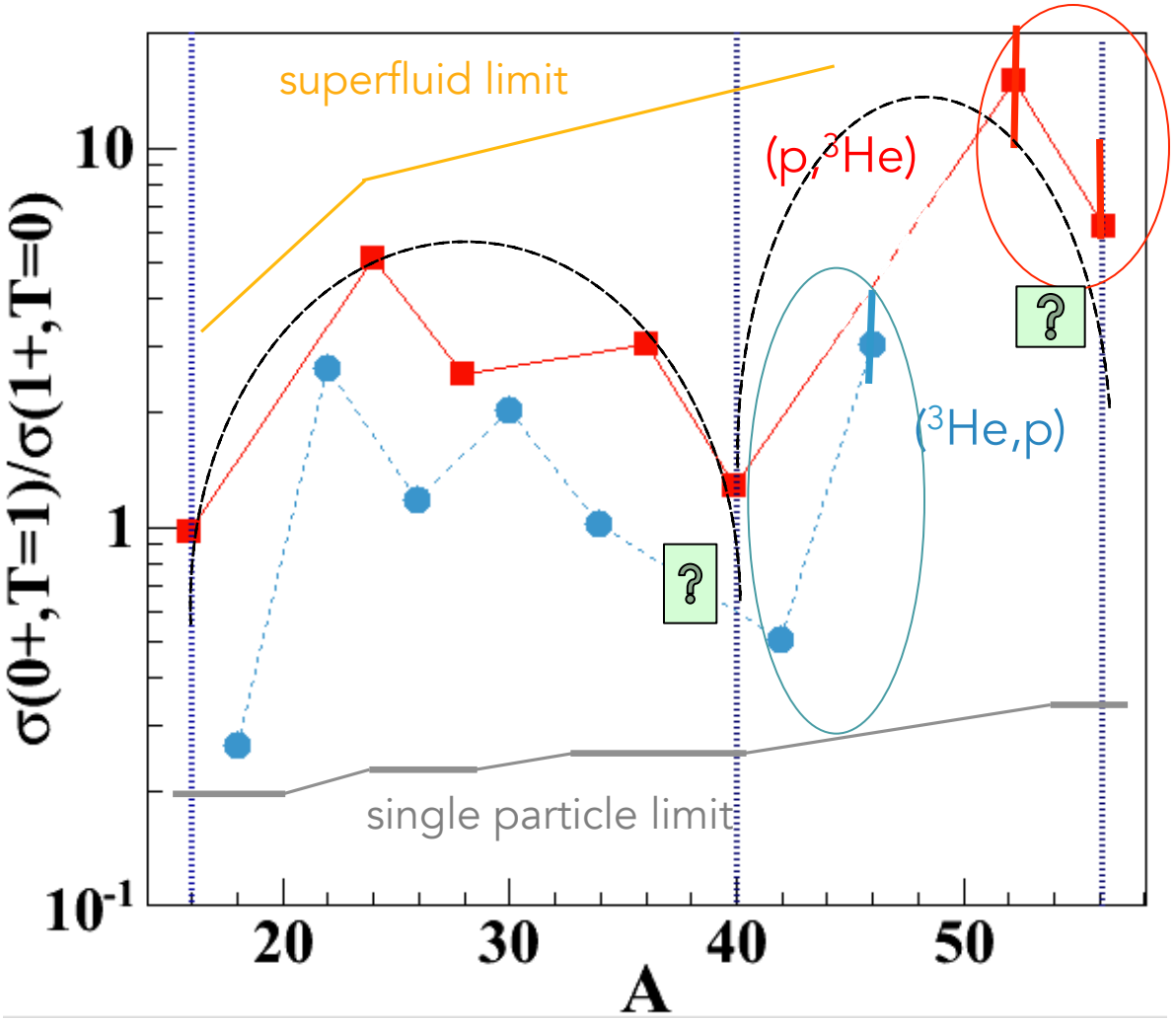
Organization	LBNL	LBNL
Position	Senior Researcher	Senior Researcher

LBNL – NSCL - Hong Kong – Seville Collaboration

Systematic of (^{3}He,p) and (p,^{3}He) N=Z nuclei



GANIL
M. Assie et al.

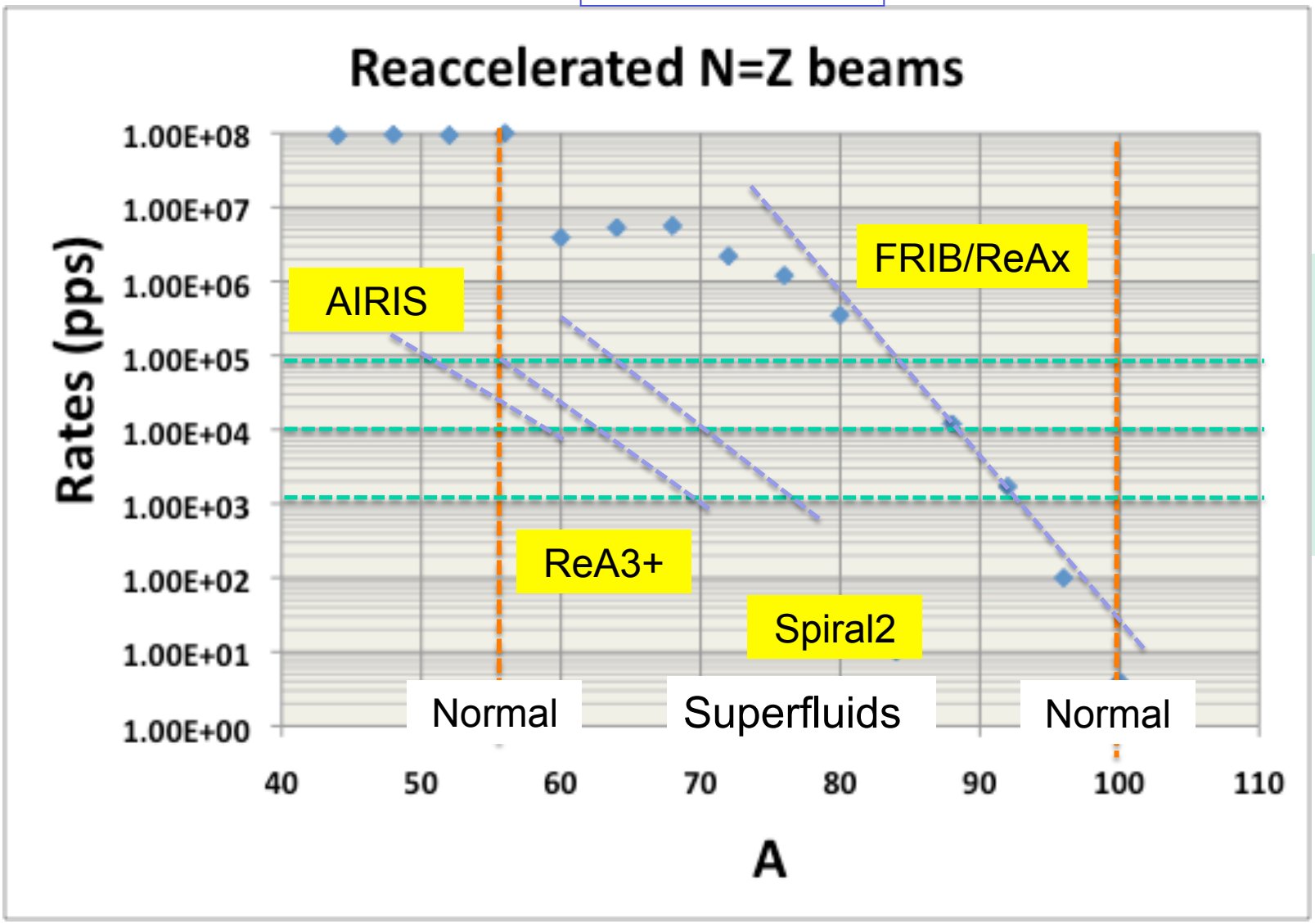
MUST2 and EXOGAM

ATLAS

NSCL

Adapted from Marlene Assie (IPN—Orsay)

Coming up



Simple Setup

HELIOS

AT-TPC

Summary

Although simple arguments may suggest that isoscalar pairing should be important, it is still not clear if it gives rise to collective modes.

Spin-orbit -- J=1 pairs P-wave contribution to matrix-elements -- Core polarization

Direct reactions are unique tools in our experimental study of exotic nuclei.

Two particle transfers provide probes of the amplitude of pairing collective modes.

(p,^{3}He), (^{3}He,p), (d,α), and (α,d) reactions can be used to firmly elucidate this question, particularly in the region from ^{56}Ni to ^{100}Sn

We need:

ReA Beams

????? (HELIOS-like spectrometer)

AT-TPC

gamma-particle coincidences

NP-Pairing and Quartetting ? More generally alpha-clustering
→ ECT* Workshop http://www.ectstar.eu/node/1664

Reactions: (d,^{6}Li) - Forward Lab angles - and (^{6}Li,d) – Backward Lab angles


Thank You !