Anomalous Neutron Pairing Vibrations in Xe Nuclei beyond N=82

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CSIC, LBNL, ANL, and (Hopefully) ISS friends Collaboration

ISOLDE Solenoidal Spectrometer

ISOLDE Solenoidal Spectrometer Workshop 2020

20-21 July 2020

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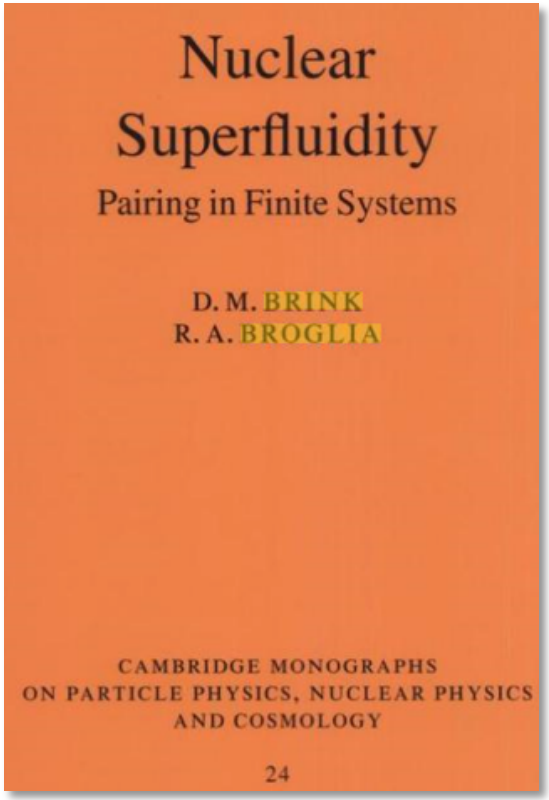
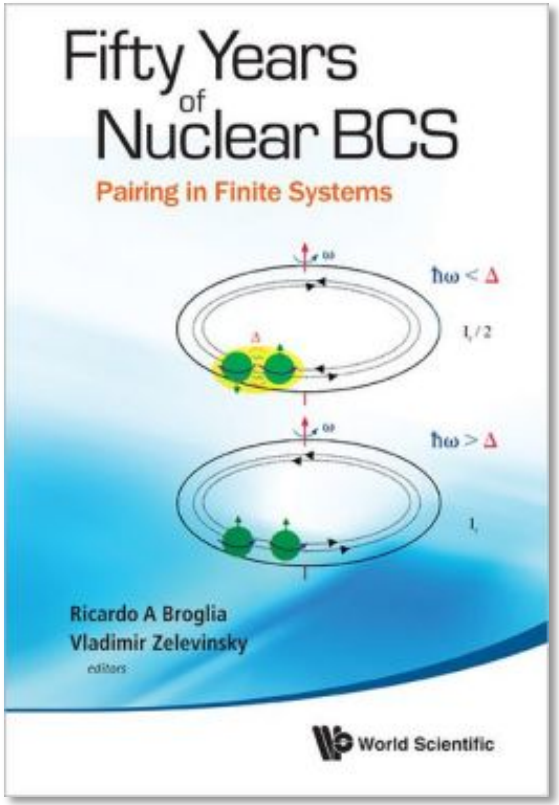
Pair correlations provided a key to understanding

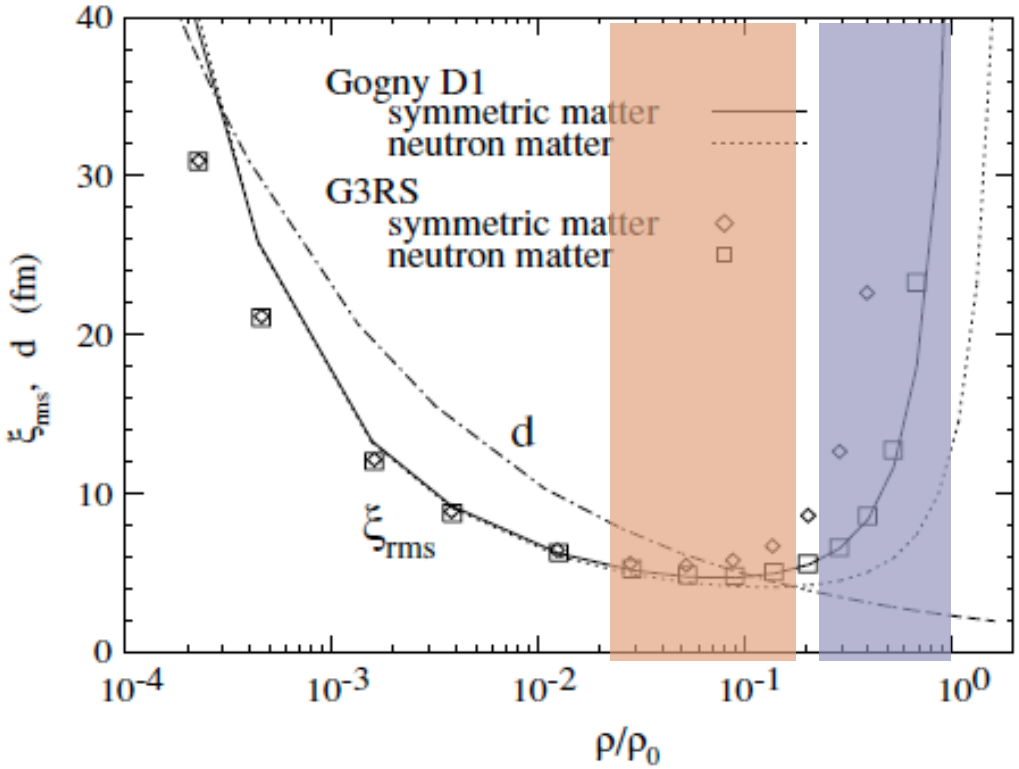
- the excitation spectra of even-A nuclei,
- odd-even mass differences,
- rotational moments of inertia,
- … and a variety of other phenomena

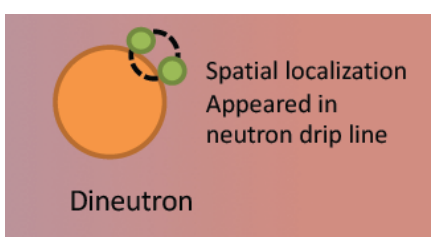


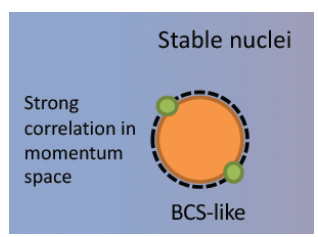


Motivation

The evolution of pairing correlations in exotic nuclei is a topic of great interest in nuclear structure, in particular pairing in neutron-rich isotopes and the role of weak binding.







d Separation

ζ_{rms} Correlation Length

Matsuo *et al.* PRC 73 (2006) 044309
Pillet *et al.* PRC 76 (2007) 024310

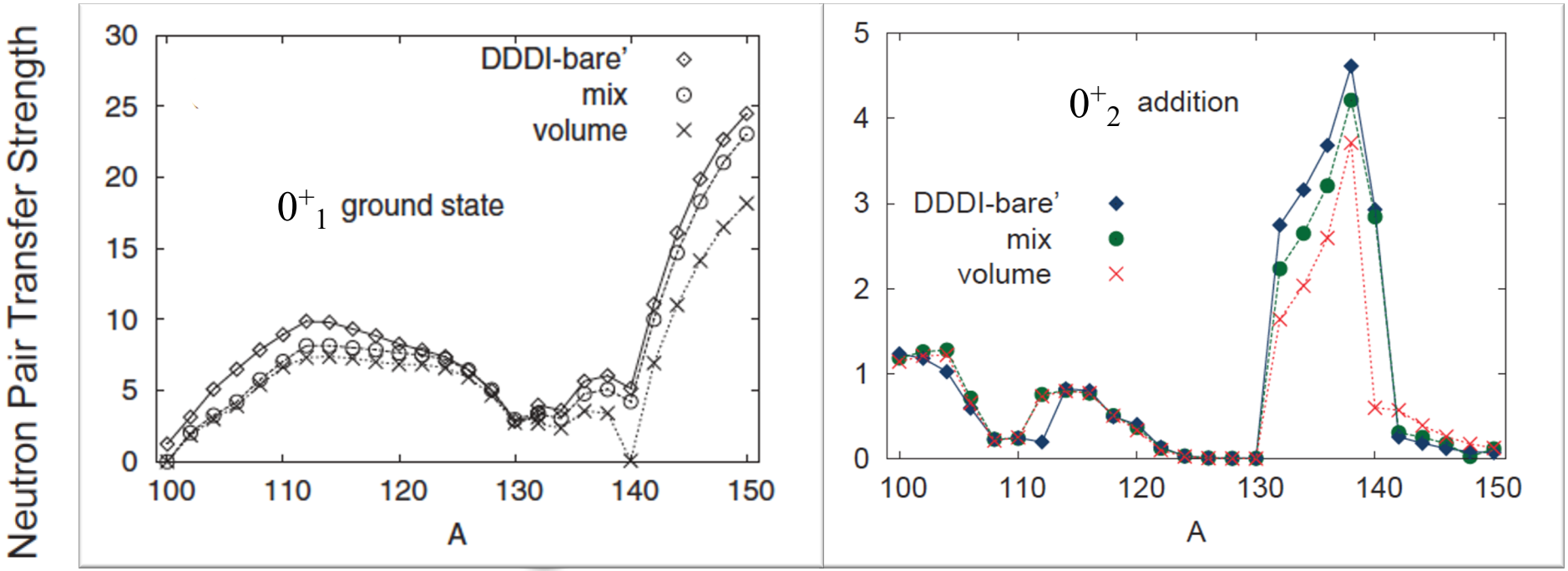
Key observable → (t,p) Two-neutron transfer reactions

Motivation

PHYSICAL REVIEW C **84**, 044317 (2011)

Anomalous pairing vibration in neutron-rich Sn isotopes beyond the $N = 82$ magic number

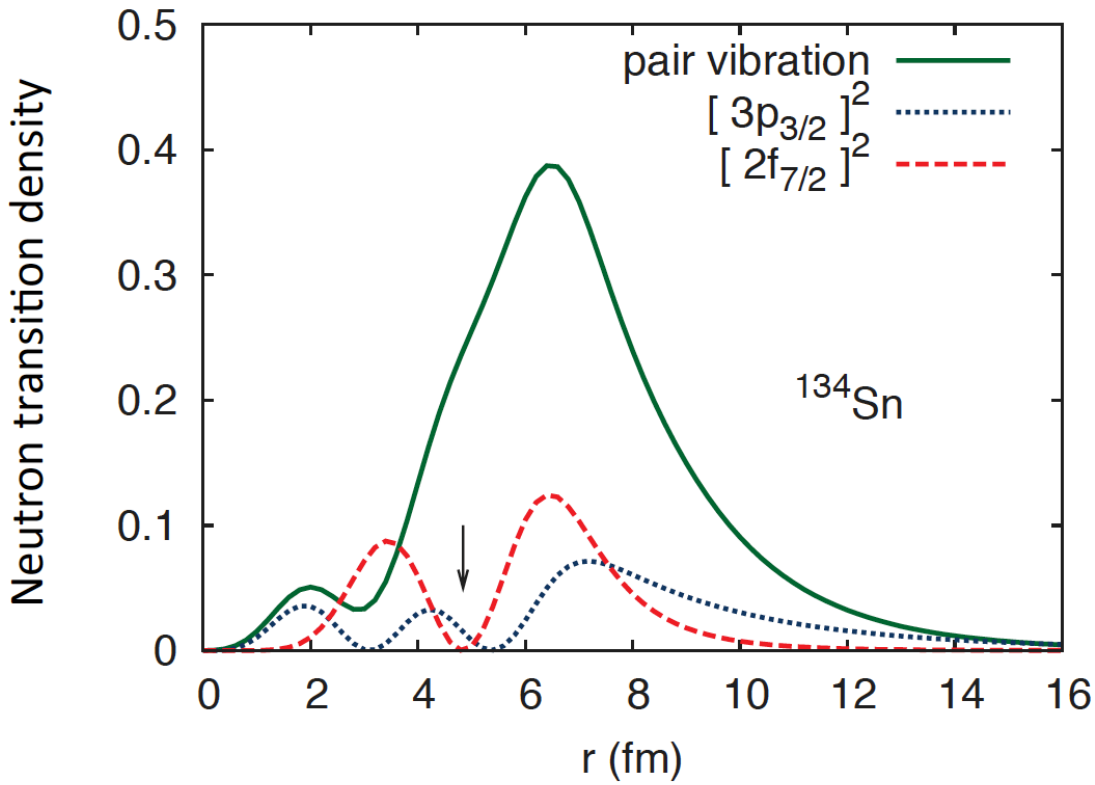
Hirotaka Shimoyama and Masayuki Matsuo



Motivation

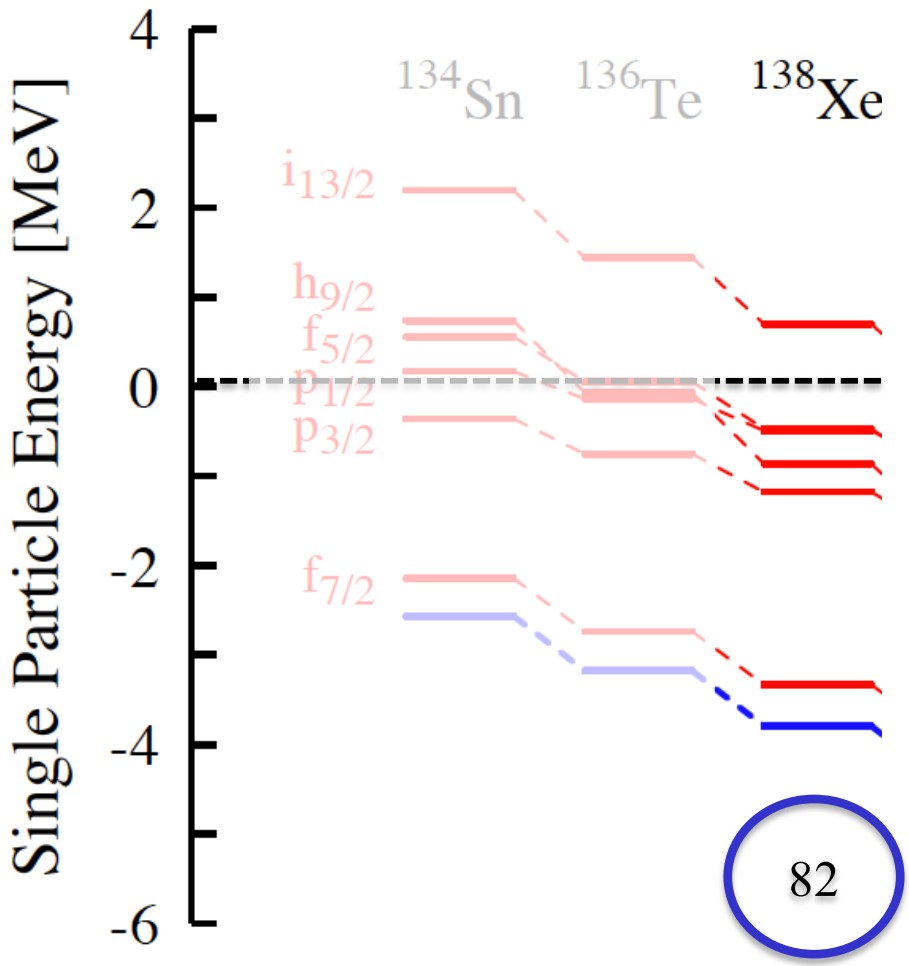
Currently it is not possible to study Sn nuclei with A > 140. However, the region 132 < A < 140 where strong transitions to an excited pairing vibrational 0^+_2 state are predicted is within reach of present accelerator facilities.

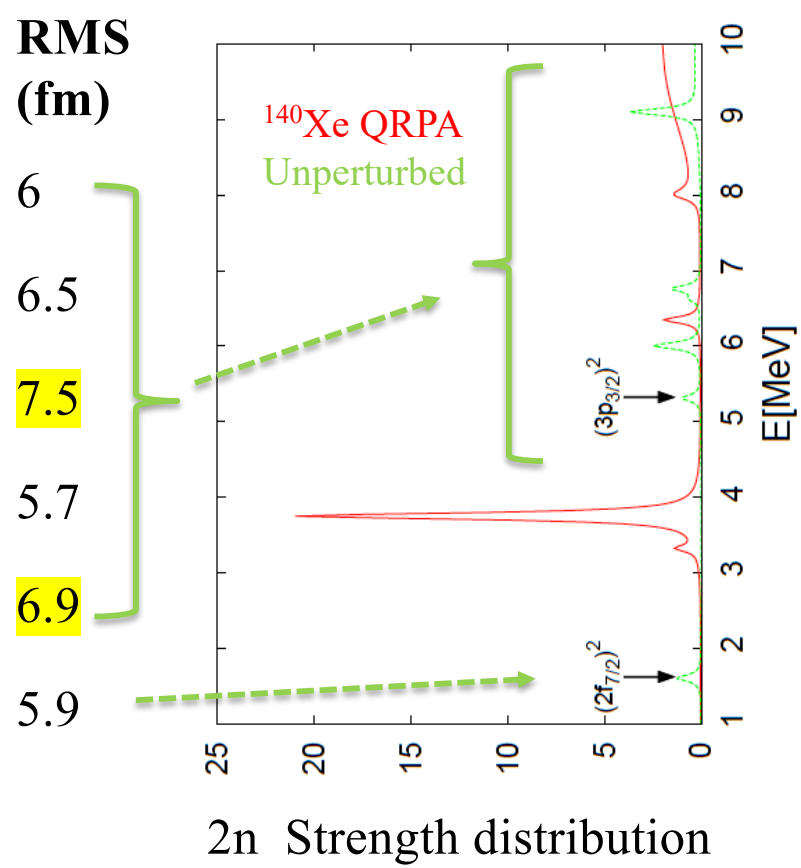
The first excited 0^+ state can be regarded as a pairing vibrational mode built on the weakly bound $p_{3/2}$ and $p_{1/2}$ orbits, which show a rather long tail in the transition density extending beyond the nuclear surface, resulting in a large strength, comparable to that populating the ground state.



Motivation

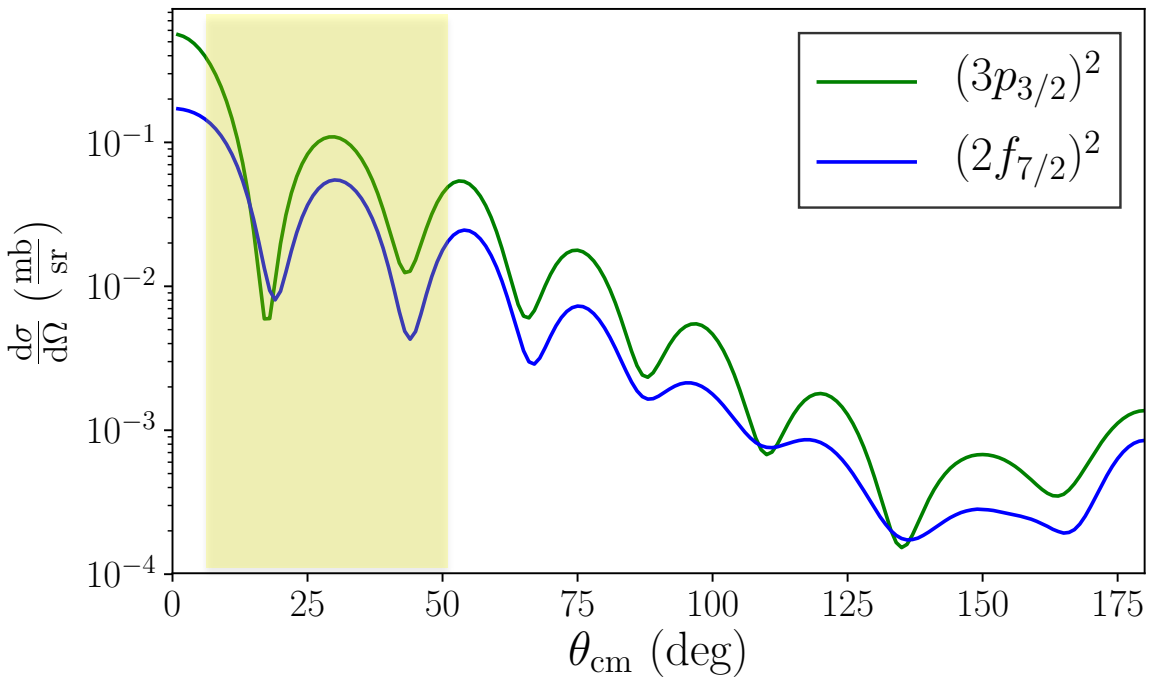
Similar effects are expected in the PV mode in ^{138}Xe [S. Tamaki. Master thesis, Niigata University, 2016]





ISS Experiment

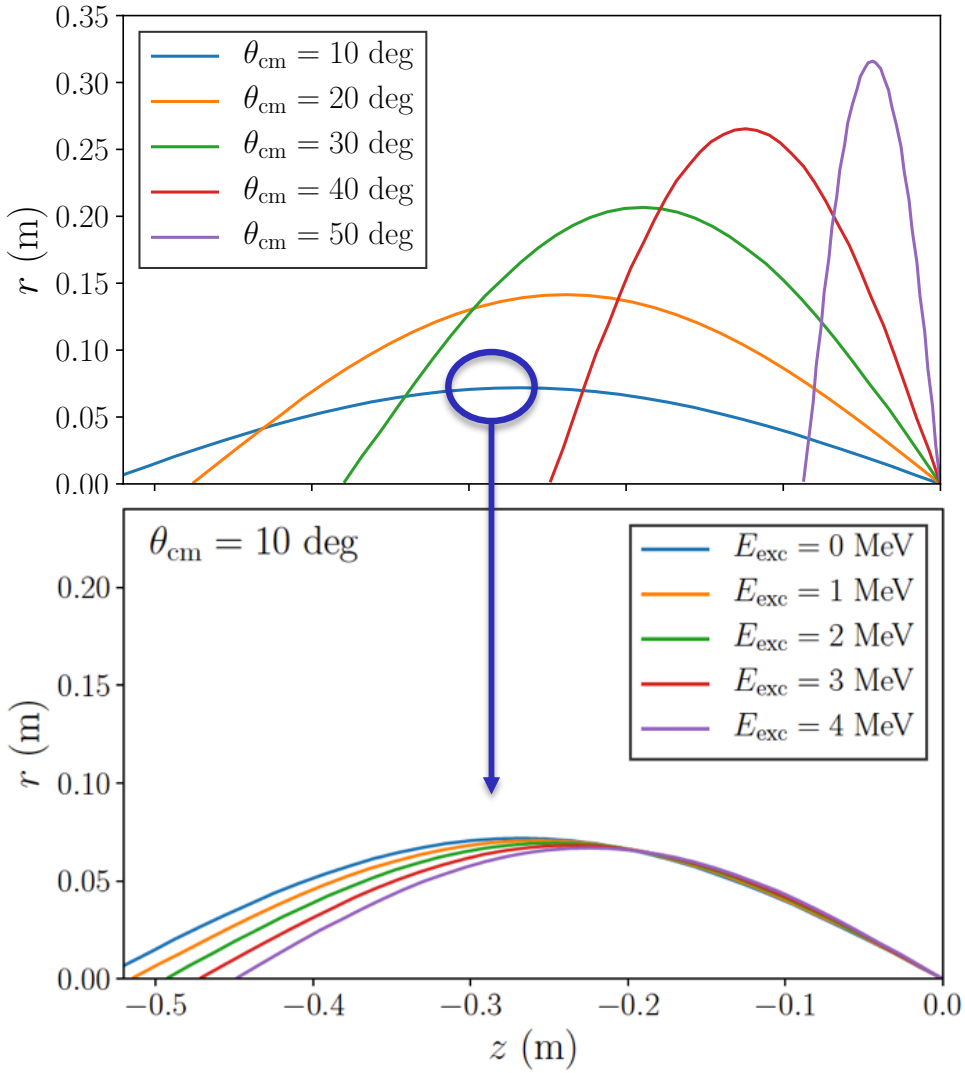
^{138}Xe(t,p)^{140}Xe at 10 MeV/A focus on L=0 transfers to PV → forward CM angles



A pure $(1p_{3/2})^2$ configuration yields an integrated cross section of around 0.25 mb, a conservative estimate for the population the pairing vibrational state in ^{140}Xe.

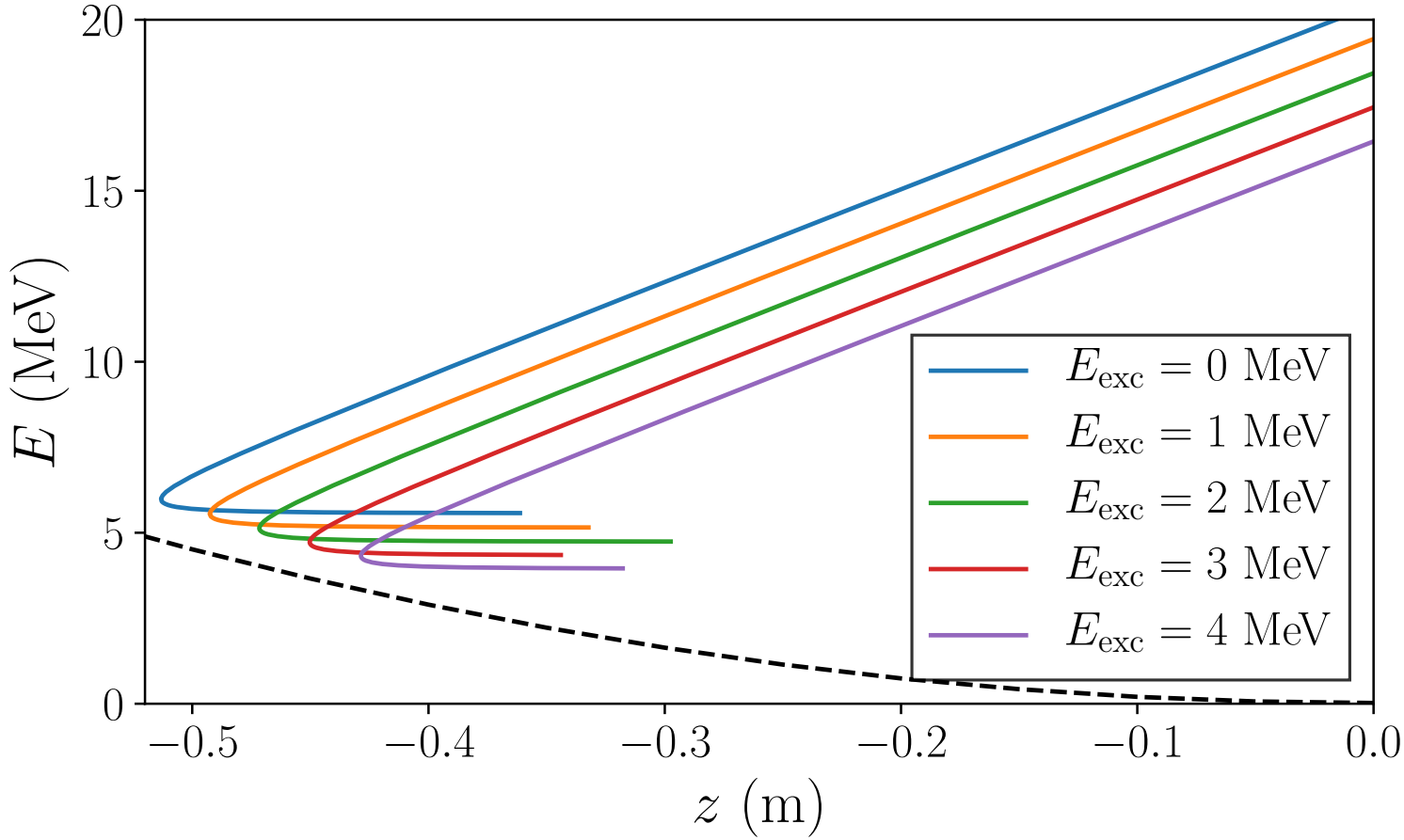
ISS Experiment: Kinematics considerations

Orbits at 3.85 Tesla,
to cover angular
range of interest
10 - 50 deg in CM



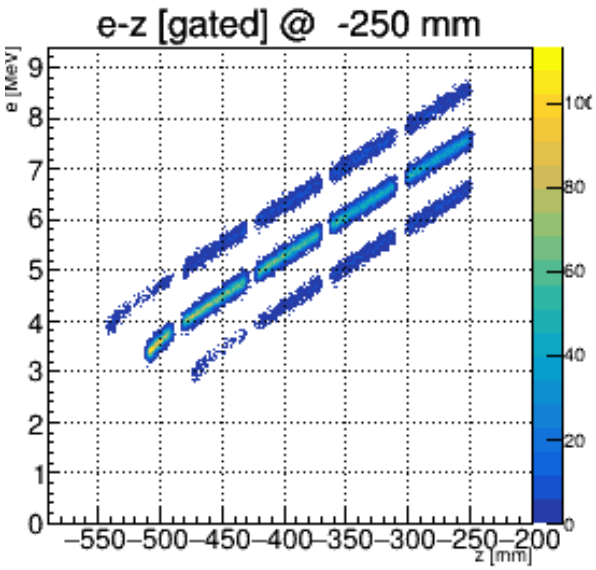
Ben Kay's HELIOMATIC

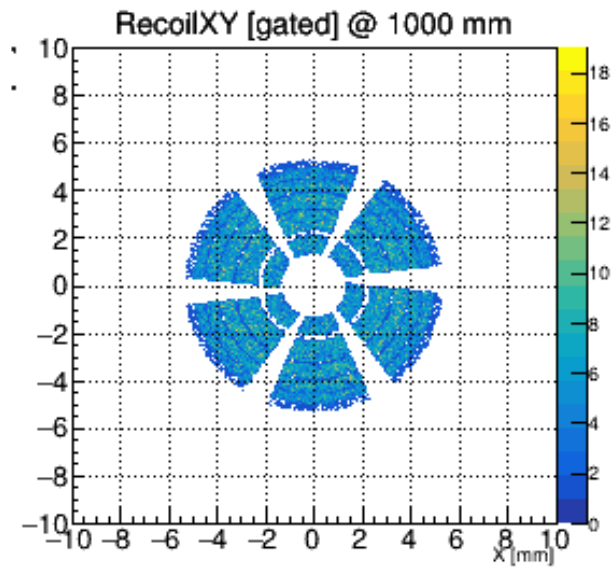
ISS Experiment: Kinematics considerations

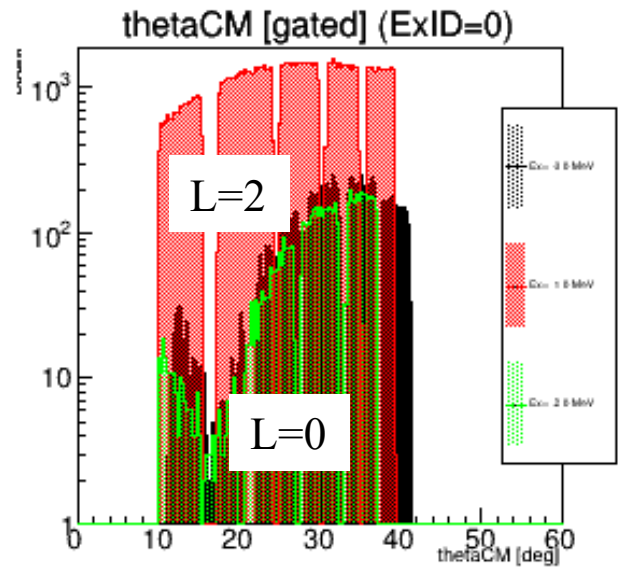


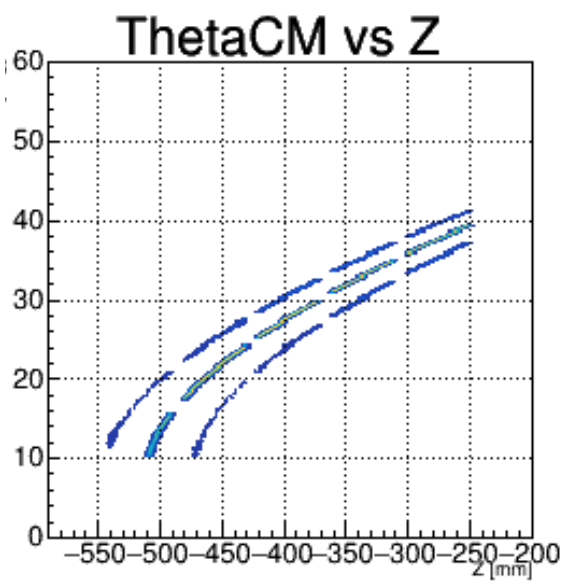
Ben Kay's HELIOMATIC

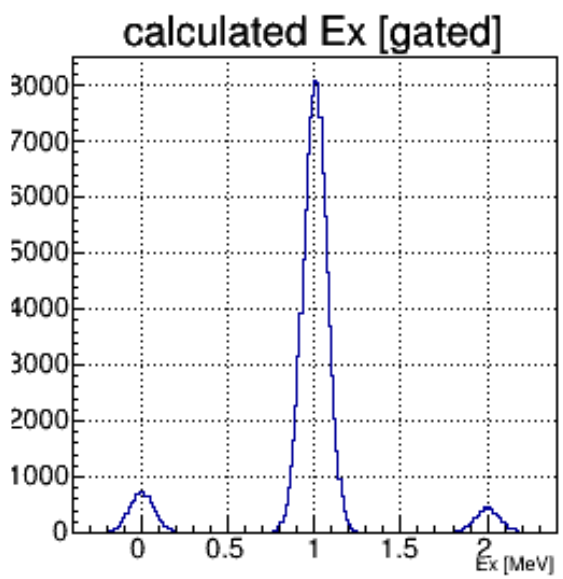
ISS Experiment: Realistic simulations











L=0 L=2 L=0

$^{138}Xe(t,p)^{140}Xe$ @ 6 MeV/A

2.85 T field

Ryan Leung and Ben Kay

ISS Experiment: Estimated Rates

Beam intensity → https://test-isoyields2-dev1.web.cern.ch/Yield_Home.aspx

^{138}Xe	14.08 m 8	PSB	5.70e+8	U Carbide
^{138}Xe	14.08 m 8	PSB	4.80e+8	Th Carbide
^{139}Xe	39.68 s 14	PSB	5.50e+8	Th Carbide
^{139}Xe	39.68 s 14	PSB	5.00e+8	U Carbide
^{140}Xe	13.60 s 10	PSB	3.50e+8	U Carbide
^{140}Xe	13.60 s 10	PSB	3.40e+8	Th Carbide

With 2μA proton beam and 1% extraction/reacceleration efficiency, take ~ 5×10^6 pps ^{138,140}Xe

Target: tritium loaded titanium foil effective thickness of 0.03 mg/cm^2 of tritium*

Beam	Intensity (pps)	PV reactions (per day)
^{138,140}Xe	~ 5×10^6	~ 650

Keep stable beams at < 10^7 pps to protect the tritium target

* K. Wimmer, *et al.* , Phys. Rev. Lett. 105 252501 (2010)

Summary

We propose to study pairing correlations in neutron-rich Xe isotopes, by systematically comparing the 2n transfer cross sections as a function of the projectile mass using beams of ^{134,136,138,140}Xe. Theoretical predictions suggest an enhancement of the two-neutron transfer strength going to excited 0^+ states beyond N=82, both in Sn's and Xe's isotopes.

The experiment will be performed at HIE ISOLDE, using 10 MeV/A Xe beams impinging on a radioactive tritium target. ISS, operating at 3.85 T, will identify the outgoing protons with a resolving power much improved over that of conventional setups.

Angular distributions in the angular range of 10-50^0 CM and integrated cross-sections (preferably absolute) will be measured for L assignment and to assess the anticipated enhancement of the cross-section with respect to a single-particle transition.

Preliminary estimates indicate that a week-long (2 days SIB, 4 days RIB, 1 day debugging) run will be adequate.

Thus, the proposed experiment appears quite feasible, and will provide important first data on neutron pairing properties beyond the N=82 magic number.

Thank you !