Probing the ^{11}Li low-lying dipole strength via ^{9}Li(t,p) with the ISS INTC-P-582

Yassid Ayyad (NSCL/FRIB) and Enrico Vigezzi (INFN) for the ISS collaboration

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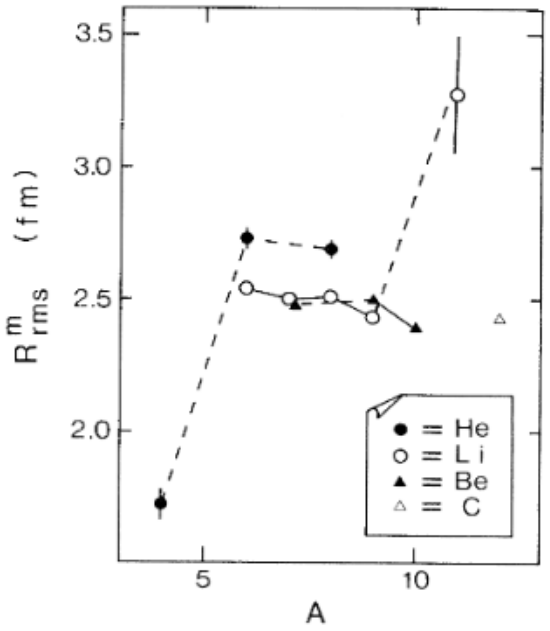
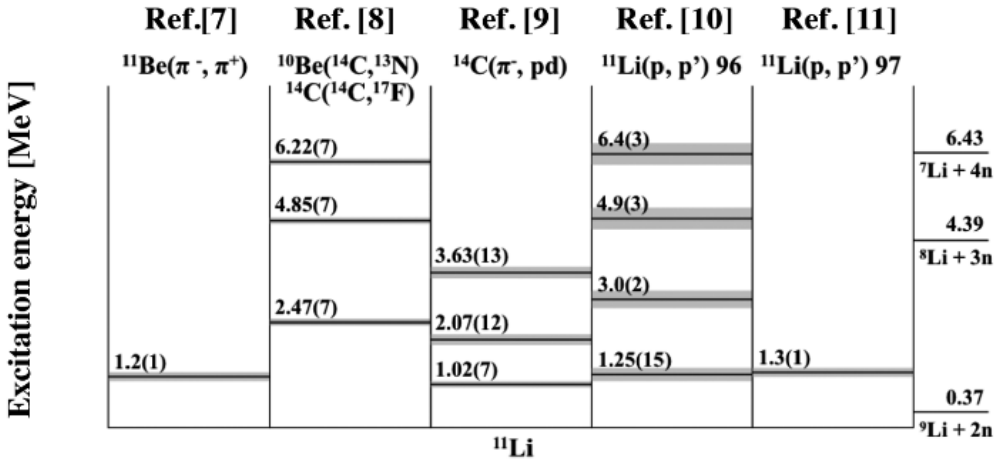
^{11}Li structure and binding energy



I. Tanihata et al., Phys. Rev. Lett. 55, 2676 (1985)

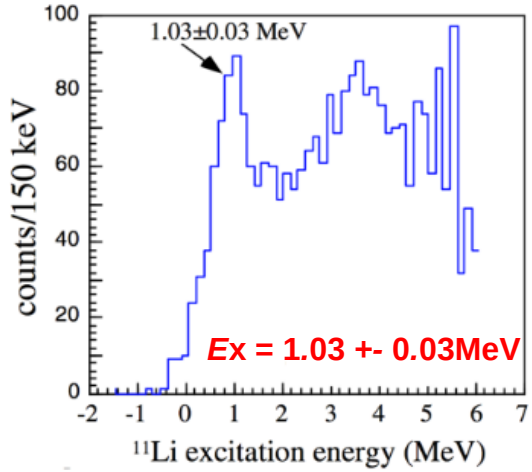


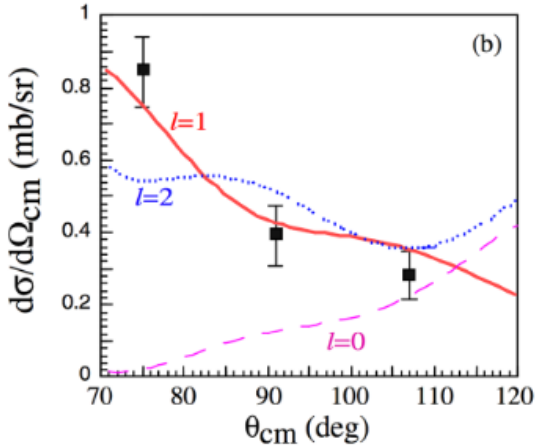
Reference (year)	S_{2n} [keV]
[17] (1975)	170 ± 80
[18] (1988)	320 ± 120
[19] (1991)	340 ± 50
[20] (1993)	295 ± 35
[21] (2005)	376 ± 5
[22] (2008)	369.15 ± 0.65
[23] (2009)	363 ± 22
mean	369.2 ± 0.6

I. Tanihata and K. Ogata Eur. Phys. J. A (2019)55: 239

Soft isoscalar resonance in ^{11}Li

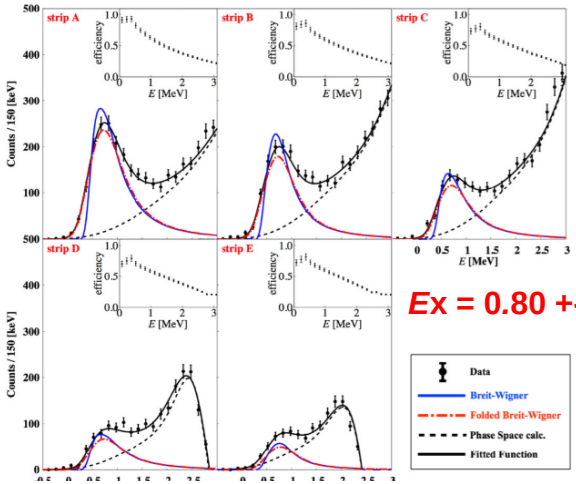
^{11}Li(d,d') isoscalar probe



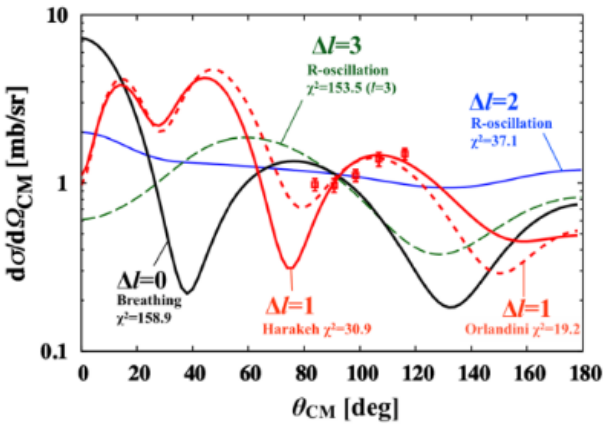


R. Kanungo et al., Phys. Rev. Lett.114, 192502 (2015).

^{11}Li(p,p') isoscalar and isovector probe



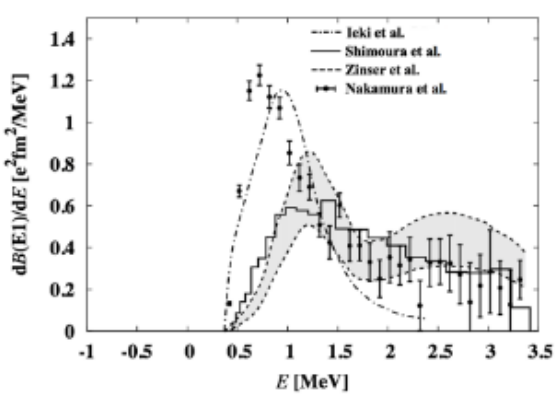
Ex = 0.80 +- 0.04MeV

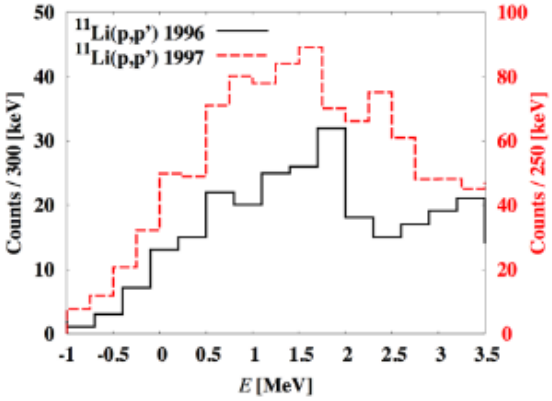


J. Tanaka et al., Phys. Lett. B774, 268 (2017)

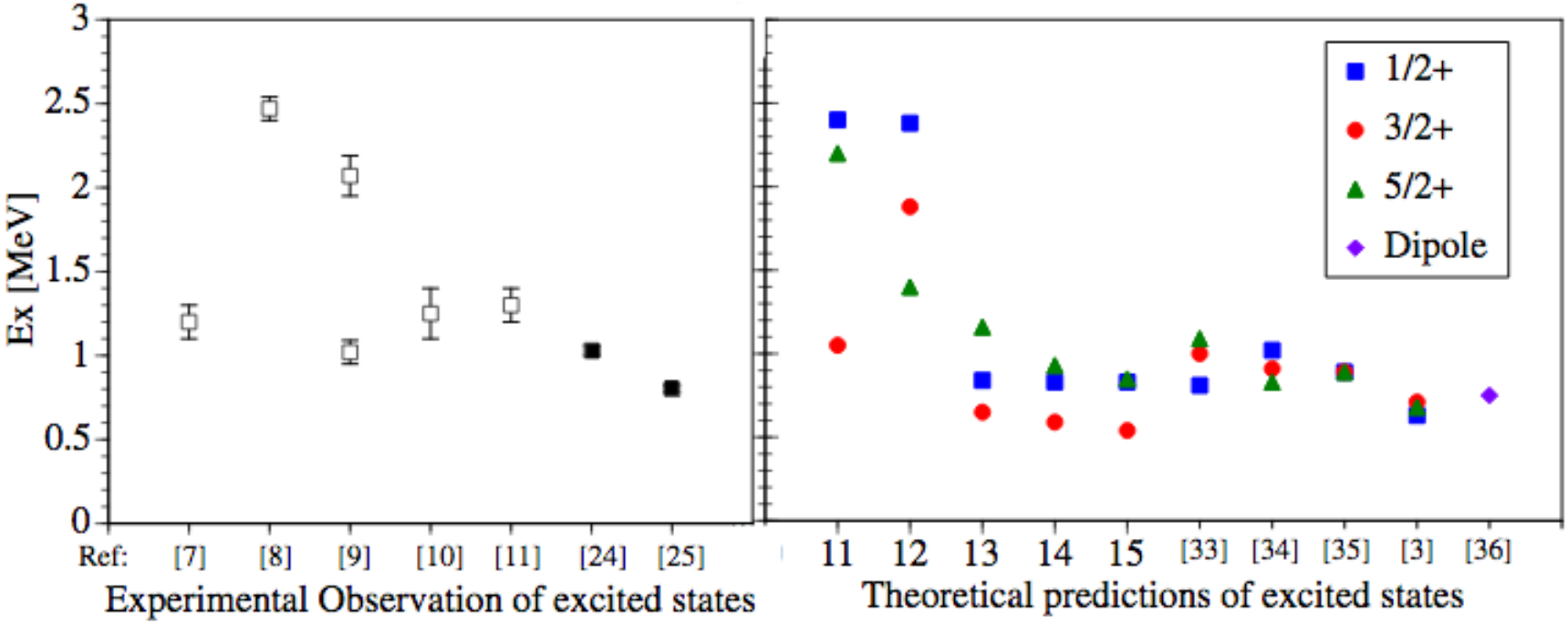
Differences between probes and experiments

- Difference in excitation energy and width with both reactions. Strong isoscalar E1 strength. Lack of proper calibration for the (d,d') reaction.
- Electromagnetic dissociation experiments (i.e. Coulex) E1 strength is explained consistently by a transition to the continuum without resonance. Observed excitation energy is around 0.67 MeV.
- (p,p') should show isoscalar and isovector components almost equally*. No experimental evidence has been given yet.
- No spin-parity determination from experiment.





Experimental observation and theoretical predictions



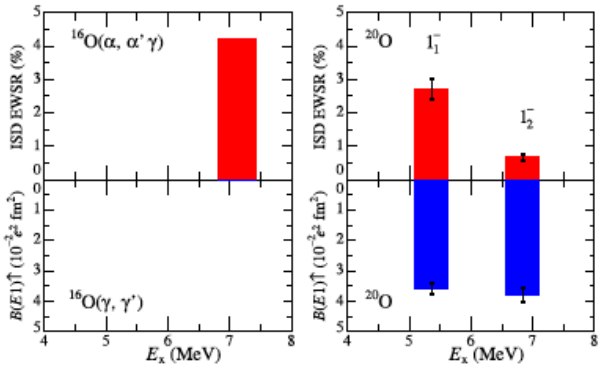
^{9}Li(t,p)^{11}Li as novel probe for Pygmy Dipole Resonance (PDR)

Is the PDR a bona fide collective mode, distinct from GDR?

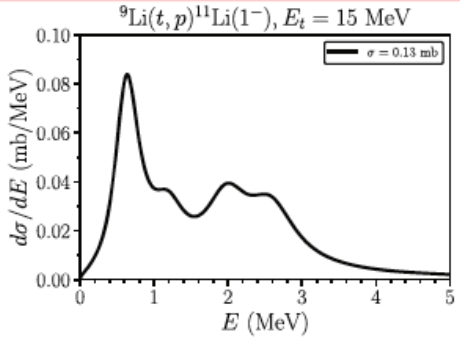
multi-messenger approach
in order to characterize PDR

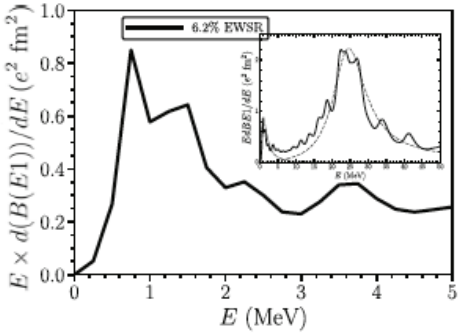
↓

standard probes: (α,α'), (p,p')
(γ,γ')

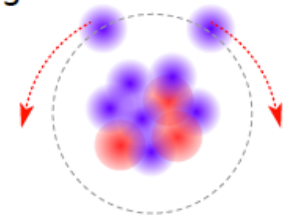


N. Nakatsuka et al.
Physics Letters B
768 (2017) 387





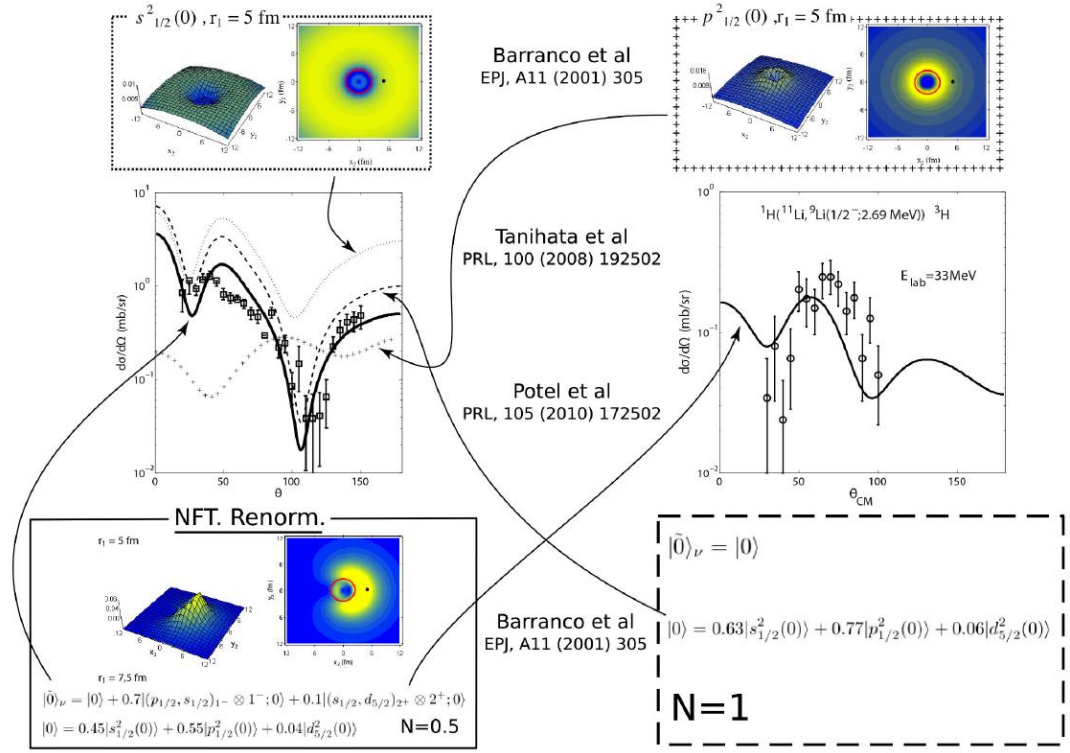
populating the ^{11}Li PDR
with (*t,p*)



Broglia *et al.* Eur. Phys. J. A
(2019) **55**: 243

particle-particle correlations might be a distinctive feature of PDRs!!!

Benchmarking model calculations: ^{11}Li(p,t)^{9}Li

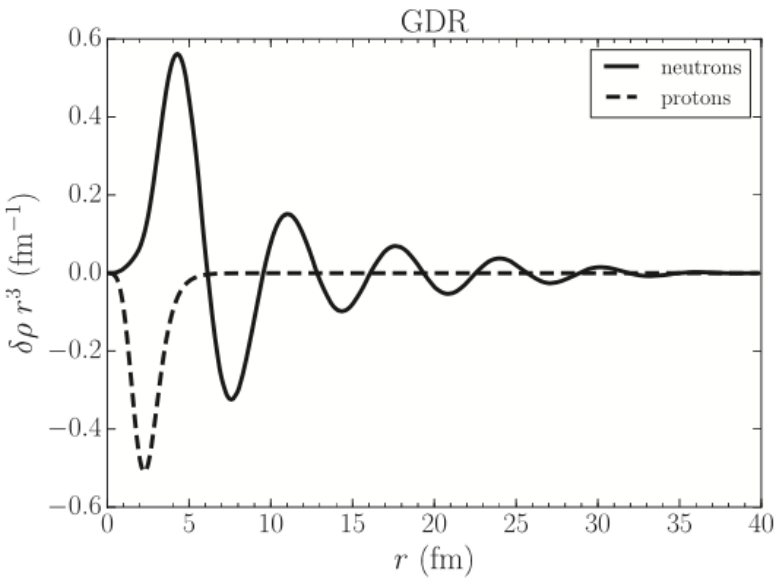


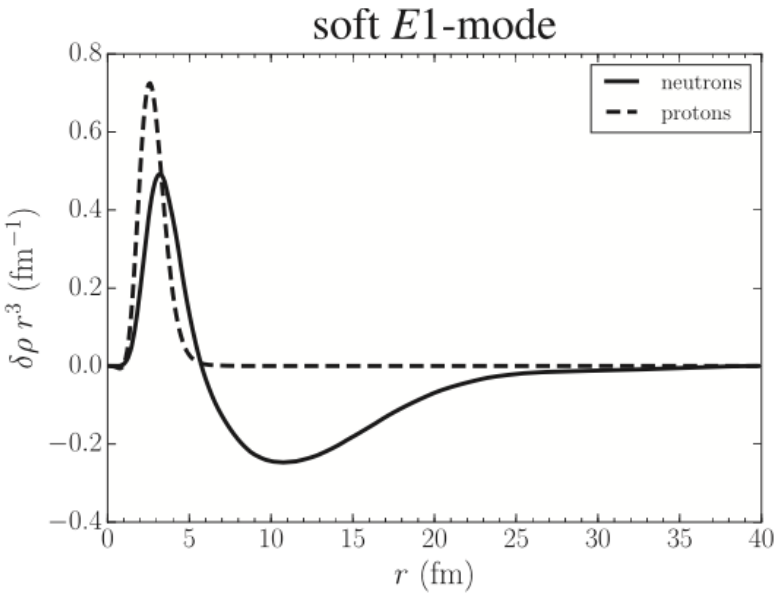
- Absolute differential cross sections: two-neutron transfer on second order DWBA (G. Potel).
- Reproduces: ground state, binding energy and radius of ^{11}Li including the dipole resonance in the g.s.
- Good agreement with ^{11}Li(p,t)^{9}Li and ^{9}Li(d,p)^{10}Li.
- 1^- dipole low excitation energy mixed with the g.s.
- Dipole and quadrupole (core excitation) resonances with 0.7 and 0.1, respectively.

$$|gs(^{11}Li)\rangle = 0.55|p^2_{1/2}\rangle + 0.45|s^2_{1/2}\rangle + 0.7|(s_{1/2}, p_{1/2})_{1^-} \otimes 1^-; 0^+\rangle + 0.1|(s_{1/2}, d_{5/2})_{2^+} \otimes 2^+; 0\rangle,$$

Isoscalar and isovector nature of the 1-

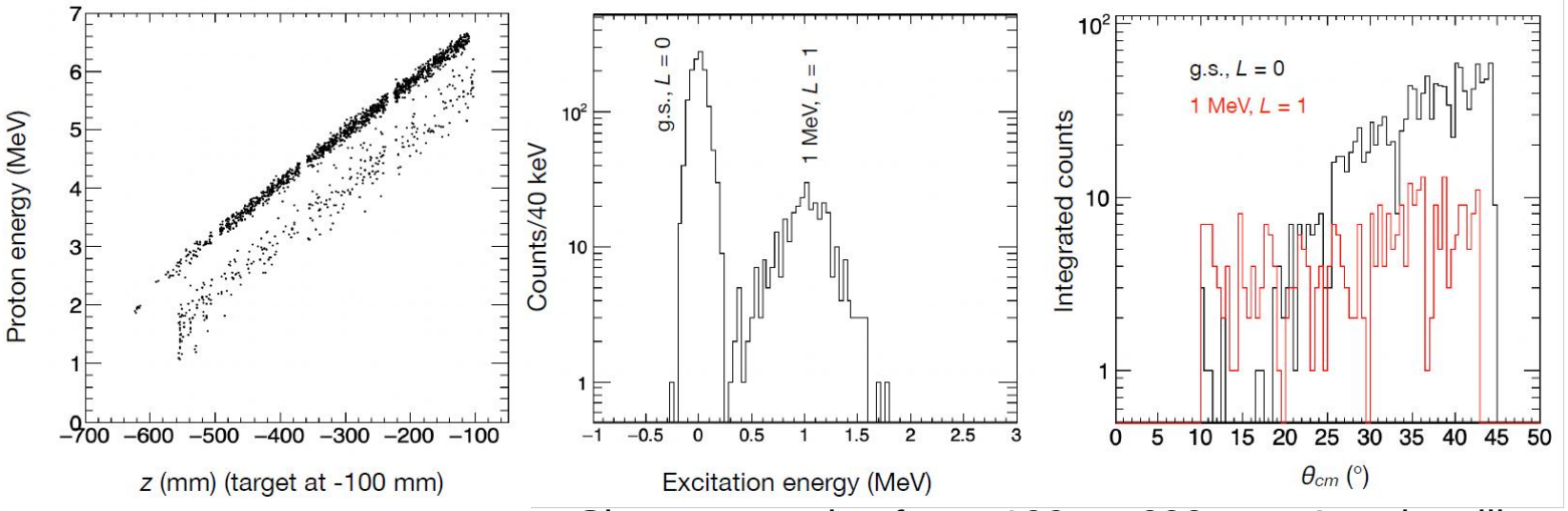
- Transition densities for GDR and PDR in the 1-
- PDR: isoscalar character in interior and neutron excitation on the outer part.
- GDR: isovector in the interior.

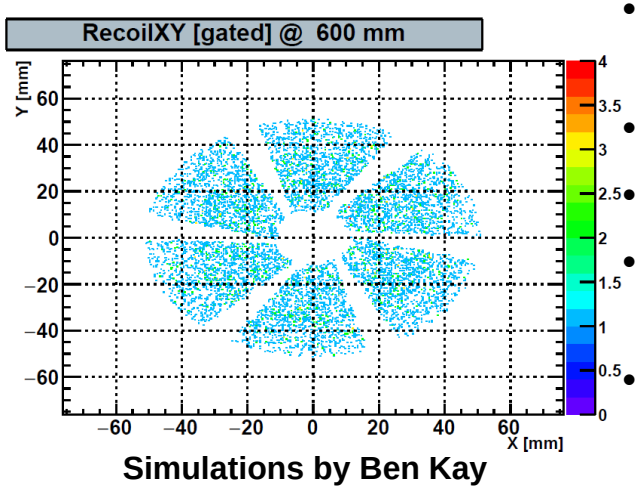




E. Vigezzi and
F. Barranco

^{9}Li(t,p)^{11}Li with the ISS





Simulations by Ben Kay

- Si array covering from -100 to -600 mm. Annular silicon detectors for recoil detection.
- 1.6 T of magnetic field. 9.5 MeV/u beam energy.
- 45 μg/cm^2 of tritium.
- Q-value resolution: 150 and 500 keV for the g.s. and the 1$^-$, respectively.
- Angular coverage of 10° <$\theta_{c.m.}$<30°, with a 70% efficiency in the azimuthal angle and 94% efficiency in the theta angle.

Estimated rates

Isotope	Half life	Driver	Yield / μC	Target
^{8}Li	838 ms 6	PSB	5.80e+8	Ta foil thin
^{9}Li	178.3 ms 4	PSB	1.70e+7	Ta foil thin
^{11}Li	8.5 ms 2	PSB	5.00e+2	Ta foil rolls
^{11}Li	8.5 ms 2	PSB	2.50e+3	Ta foil discs
^{11}Li	8.5 ms 2	PSB	7.00e+3	Ta foil thin

Expected intensity around 10^6 pps. 2 uA and 5% of transmission **(Beam development needed prior to the experiment P-568).**

Tritium target 45 μg/cm^2 **(Modified to comply with the 10 GBq limit).** Target degradation is minimal with low A beam.

Cross section to the 1^- around 1.0 mb

300 counts in 5 day (15 shifts) on the PDR region

Summary

- Probing the particle-particle nature of the ^{11}Li soft dipole resonance with the ISS.
- Population of the 1^- dipole resonance enhanced by two-particle transfer.
- ISS offers unprecedented capabilities for transfer reactions in inverse kinematics.
- A strong theoretical support founded the main goal of this experiment with state-of-the-art reaction calculations and with a comprehensive ^{11}Li g.s. structure.
- This experiment represents a gateway to perform high-resolution transfer reactions with tritium targets.

Collaboration

Probing the ^{11}Li low-lying dipole strength via ^{9}Li(t,p) with the ISS

November 3, 2020

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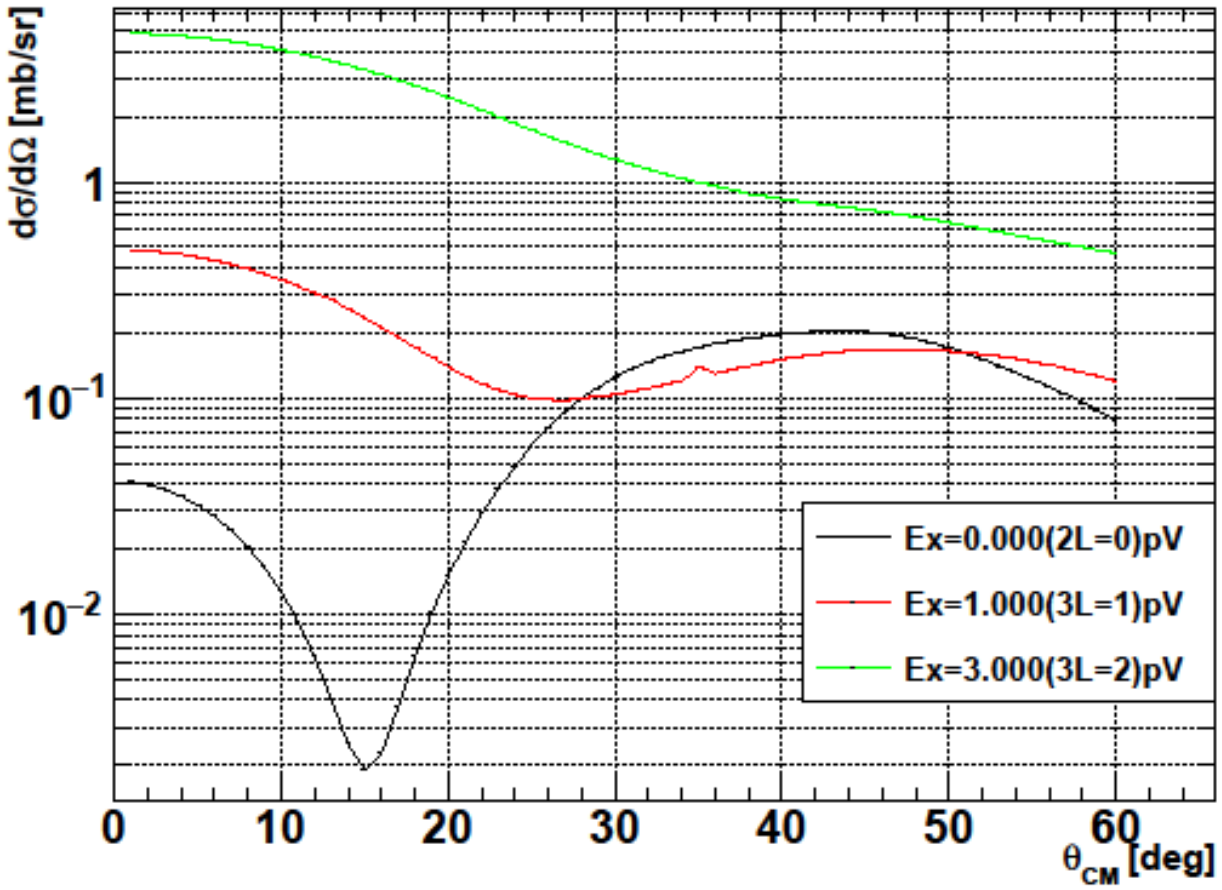
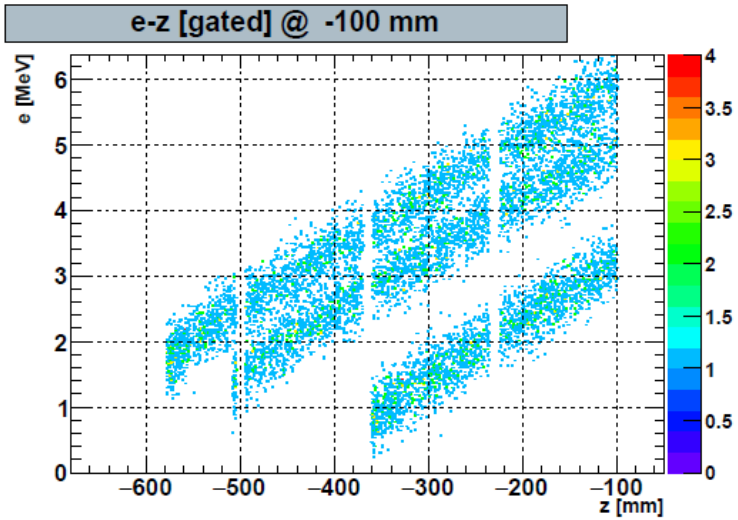
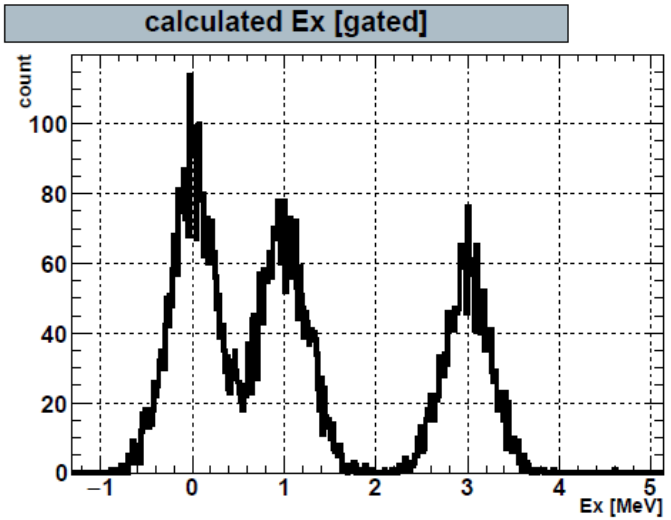
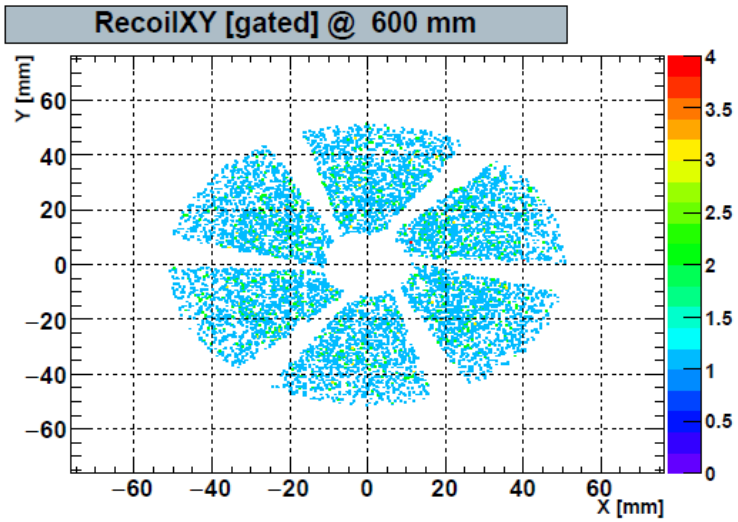
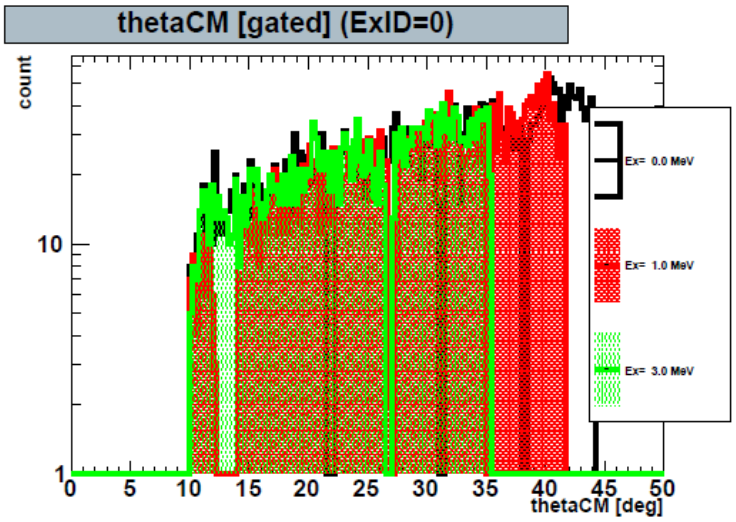
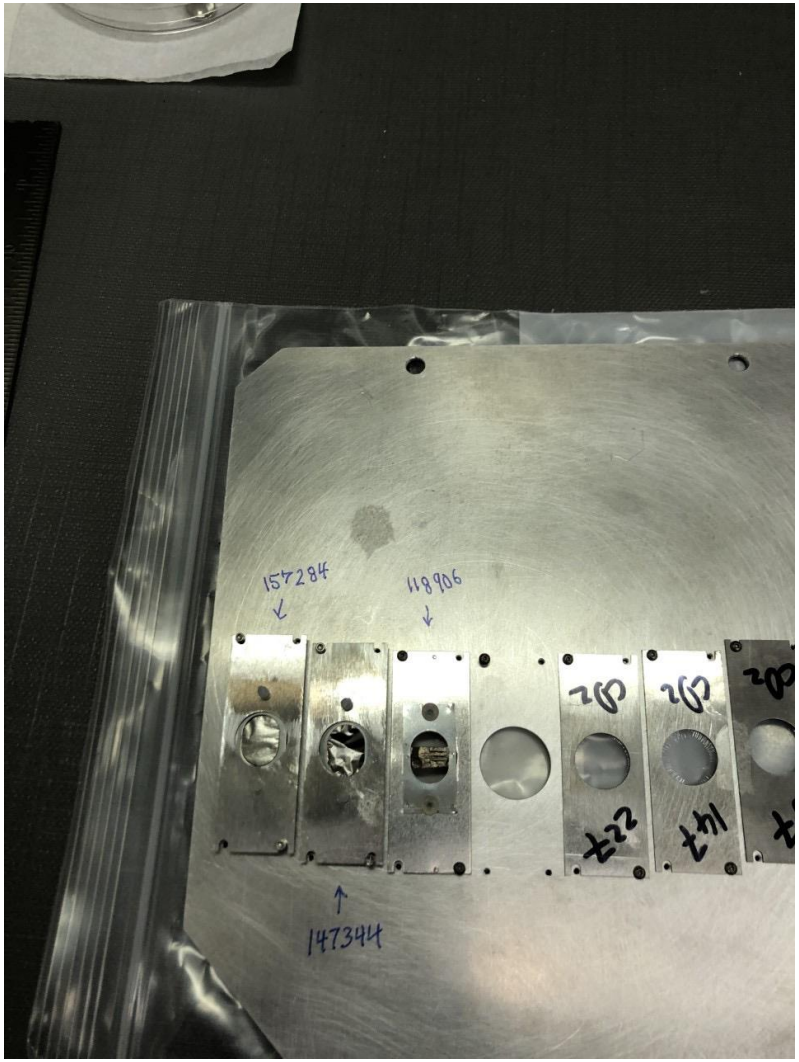

dσ/dΩ [mb/sr]
1
10^{-1}
10^{-2}
0
10
20
30
40
50
60
θ_{CM} [deg]
Ex=0.000(2L=0)pV
Ex=1.000(3L=1)pV
Ex=3.000(3L=2)pV


e-z [gated] @ -100 mm
e [MeV]
z [mm]


calculated Ex [gated]
count
Ex [MeV]


RecoilXY [gated] @ 600 mm
Y [mm]
X [mm]


thetaCM [gated] (ExID=0)
count
thetaCM [deg]
Ex= 0.0 MeV
Ex= 1.0 MeV
Ex= 3.0 MeV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118906
147344