Investigation of Resonance States in ^{11}Li

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TRIUMF

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Introduction

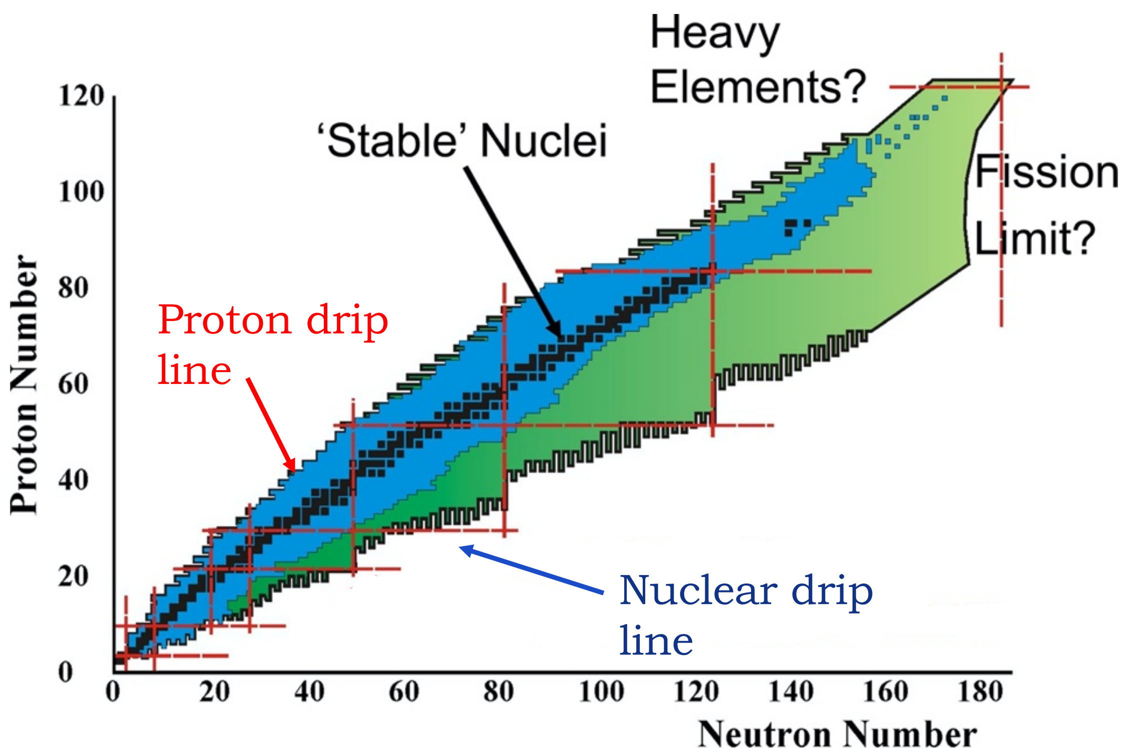


Chart of nuclide

- Moving away from stability (towards driplines) limits our knowledge of nuclear structure
- Study of exotic nuclei discovers new features and phenomena that appears in n-p asymmetric systems
- Evidences of new magic numbers
- Observation of new phenomena like **halo nuclei.**

Introduction

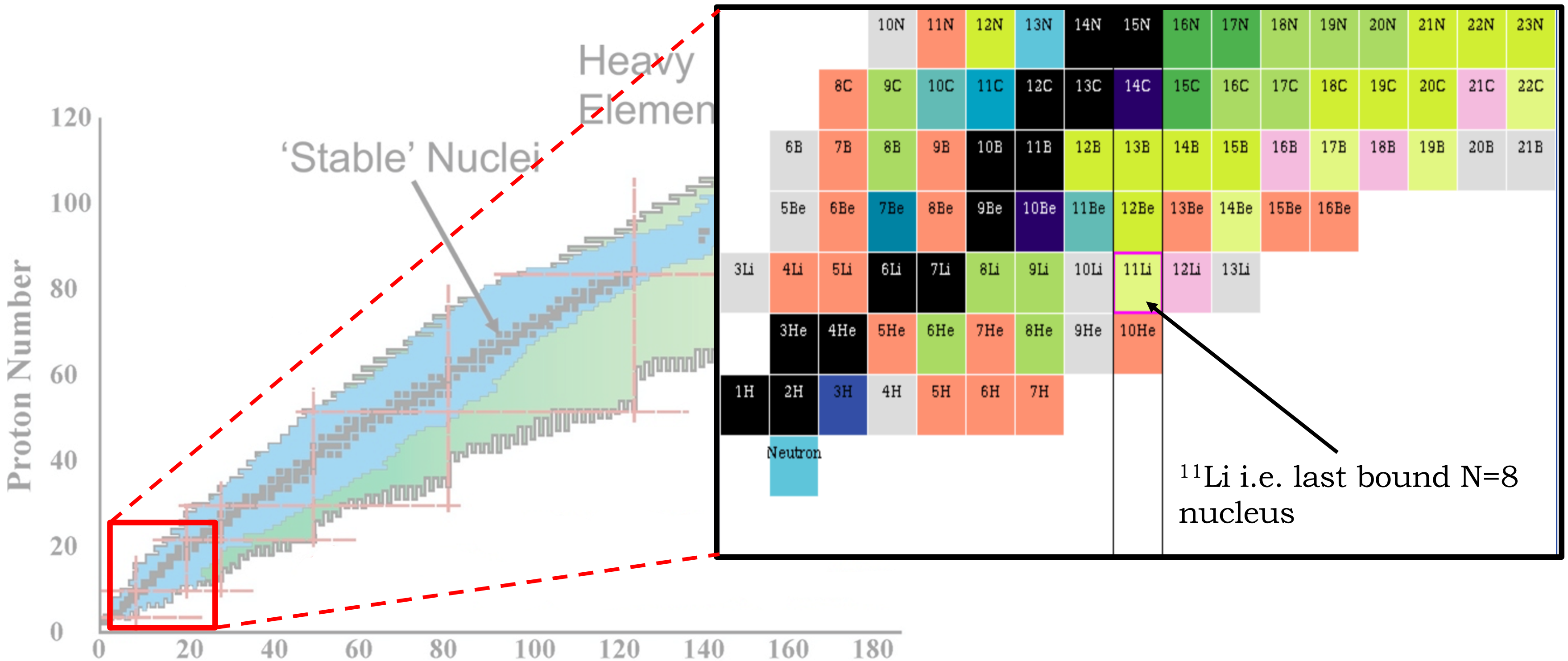


Chart of nuclide

Halo nuclei

VOLUME 55, NUMBER 24 PHYSICAL REVIEW LETTERS 9 DECEMBER 1985

Measurements of Interaction Cross Sections and Nuclear Radii in the Light *p*-Shell Region

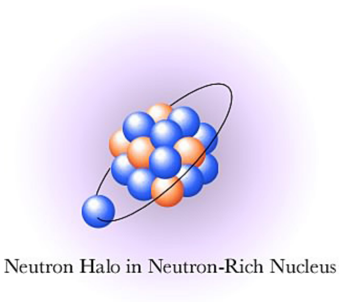
I. Tanihata,[a] H. Hamagaki, O. Hashimoto, Y. Shida, and N. Yoshikawa
Institute for Nuclear Study, University of Tokyo, Tanashi, Tokyo 188, Japan

K. Sugimoto,[b] O. Yamakawa, and T. Kobayashi
Nuclear Science Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

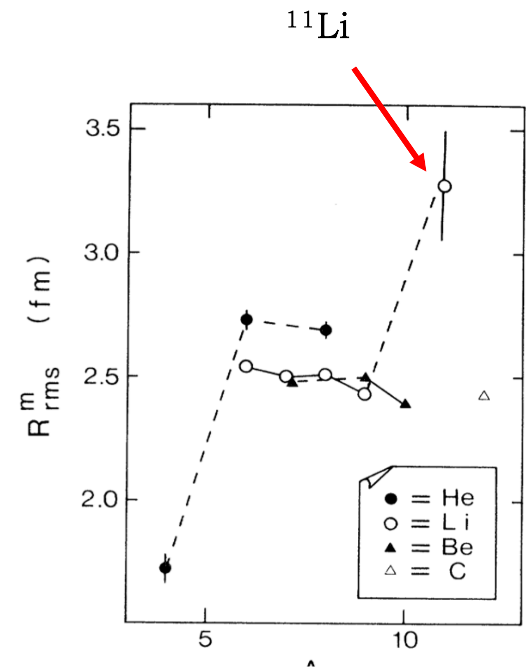
and

N. Takahashi
College of General Education, Osaka University, Toyonaka, Osaka 560, Japan
(Received 11 July 1985; revised manuscript received 17 September 1985)

- First observed in 1985
- Large matter radius of ^{11}Li



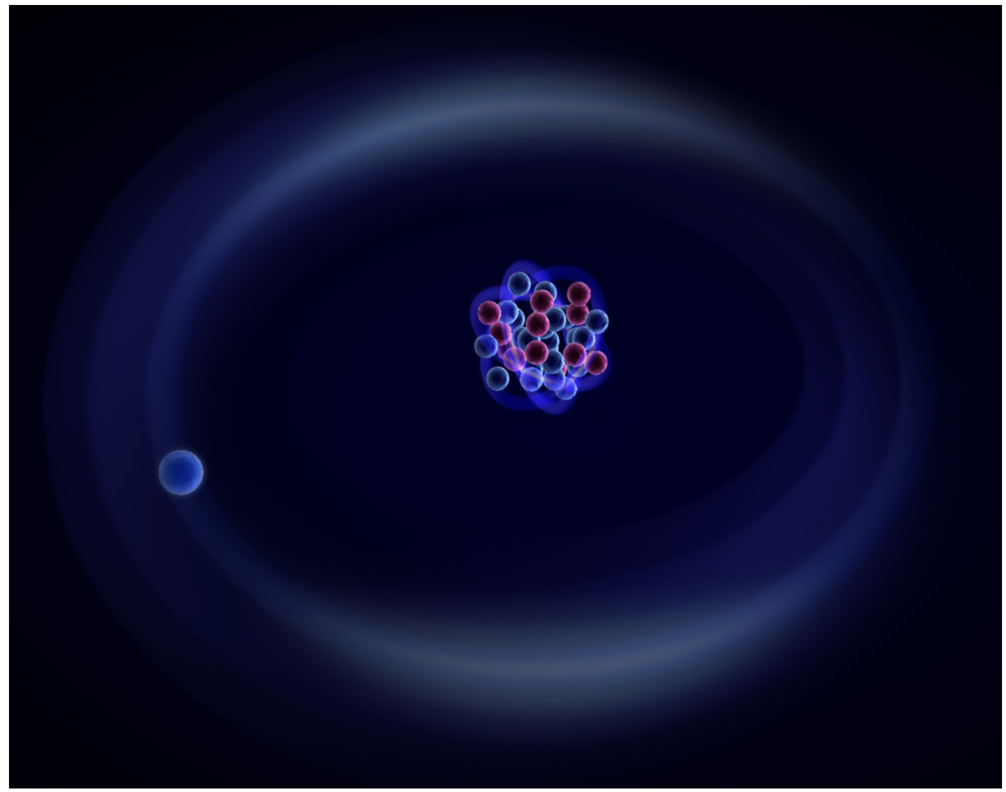
Moon Halo



Matter r.m.s radius of isotopes of He, Li, Be and C

Halo nuclei

- Lie near dripline
- Long tail in matter distribution
- Low nucleon separation energy
- Known neutron halo : ^{6}He, $\mathbf{^{11}Li}$, ^{11}Be, ^{14}Be, ^{17}B, ^{15}C, ^{19}C, ^{22}C and ^{37}Mg.

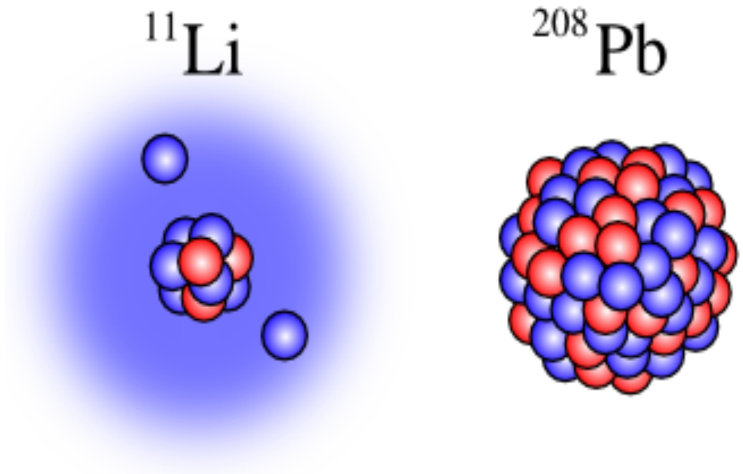


One neutron halo with core

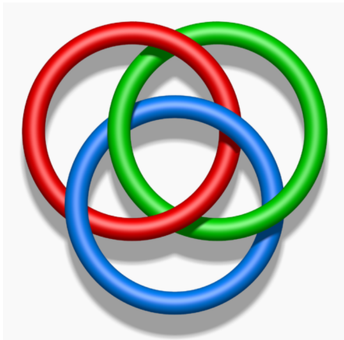
Background for ^{11}Li

- ^{9}Li core with 2 halo neutrons
- Borromean system
- Half life : 8.2 ms decay by β decay
- Radius ~3.27 ± 0.24 fm
- Two neutron separation energy ~369(65) keV

^{11}Li is one of the most studied halo nucleus but still there is much more to explore

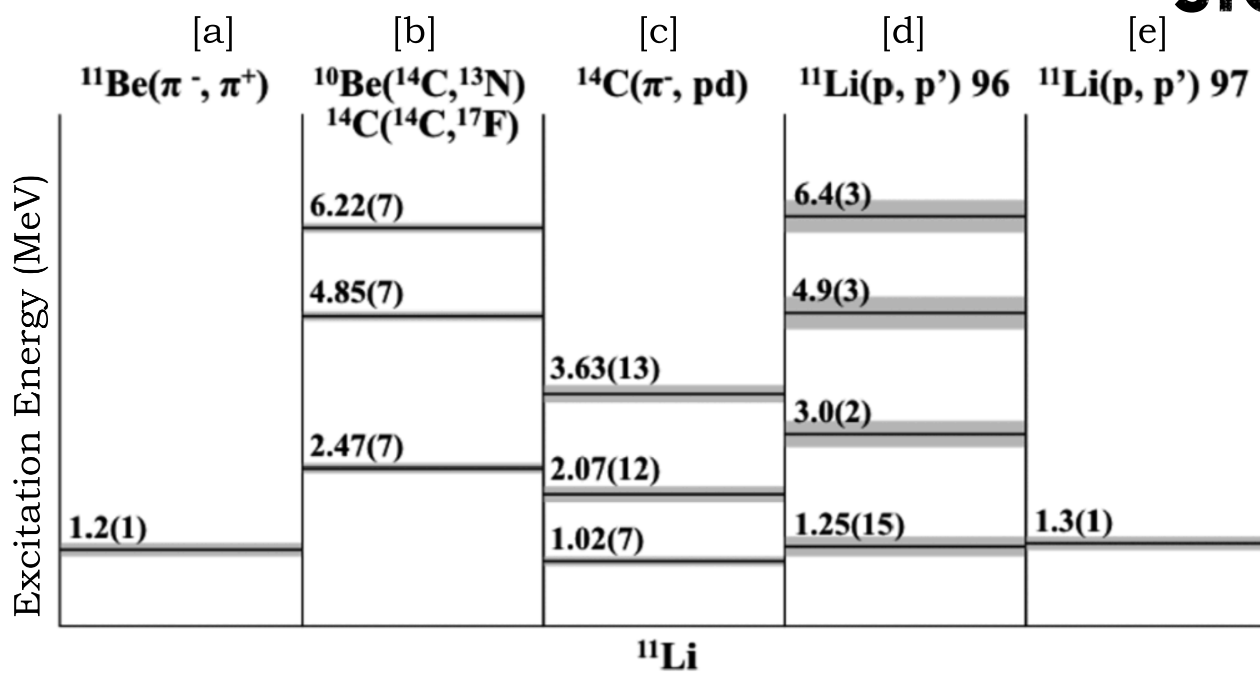


Comparable sizes of ^{11}Li and ^{208}Pb



Borromean rings

Previous measurements of Excited states in ^{11}Li



a. T. Kobayashi et al., Nucl. Phys. A 538, 343c (1992)
b. H.G. Bohlen et al., Z. Phys. A 351, 7 (1995).
c. M.G. Gornov et al., Phys. Rev. Lett. 81, 4325 (1998).
d. A.A. Korsheninnikov et al., Phys. Rev. C 53, R537 (1996).
e. A.A. Korsheninnikov et al., Phys. Rev. Lett. 12, 2317 (1997).

Previous measurements of ^{11}Li resonances at IRIS

PRL **114,** 192502 (2015) PHYSICAL REVIEW LETTERS week ending 15 MAY 2015

Evidence of Soft Dipole Resonance in ^{11}Li with Isoscalar Character

R. Kanungo,[1] A. Sanetullaev,[1,2] J. Tanaka,[3] S. Ishimoto,[4] G. Hagen,[5,6] T. Myo,[7] T. Suzuki,[8] C. Andreoiu,[9] P. Bender,[2] A. A. Chen,[10] B. Davids,[2] J. Fallis,[2] J. P. Fortin,[1,11] N. Galinski,[2] A. T. Gallant,[2] P. E. Garrett,[12] G. Hackman,[2] B. Hadinia,[12] G. Jansen,[5,6] M. Keefe,[1] R. Krücken,[2,13] J. Lighthall,[2] E. McNeice,[10] D. Miller,[2] T. Otsuka,[14] J. Purcell,[1] J. S. Randhawa,[1] T. Roger,[15] A. Rojas,[2] H. Savajols,[15] A. Shotter,[16] I. Tanihata,[3,17] I. J. Thompson,[18] C. Unsworth,[2] P. Voss,[9] and Z. Wang[2,9]

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The first conclusive evidence of a dipole resonance in ^{11}Li having isoscalar character observed from inelastic scattering with a novel solid deuteron target is reported. The experiment was performed at the newly commissioned IRIS facility at TRIUMF. The results show a resonance peak at an excitation energy of 1.03 ± 0.03 MeV with a width of 0.51 ± 0.11 MeV (FWHM). The angular distribution is consistent

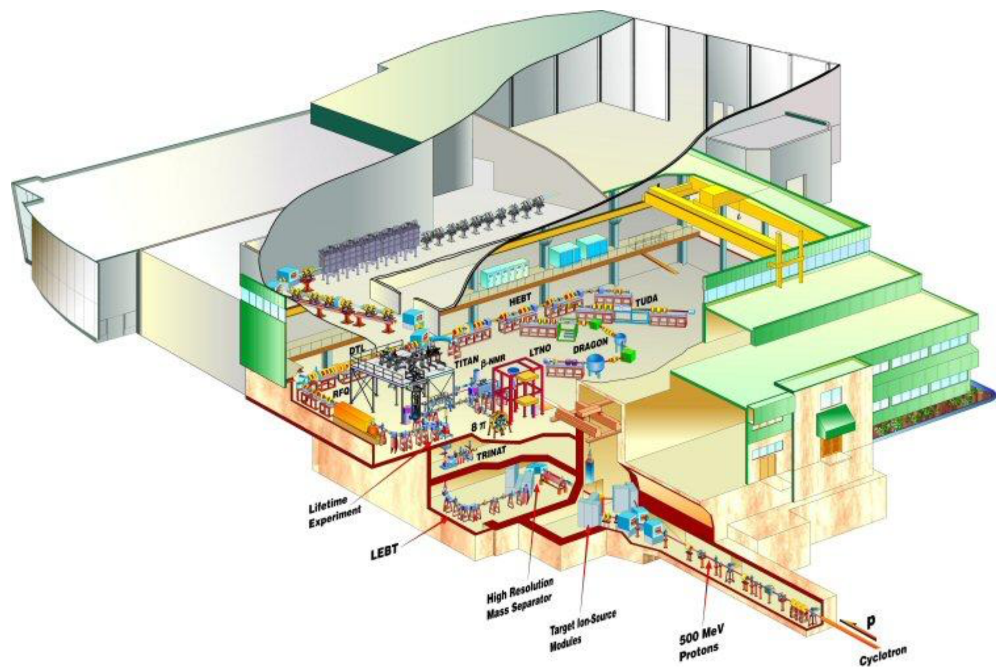
- Confirmed state at 1.03± 0.03 MeV
- Beam energy was 5.5*A* MeV

Reaction of interest *^{11}Li(d,d')*
Beam energy 7.3A MeV

Experimental setup

IRIS (ISAC Rare Isotope Spectroscopy)

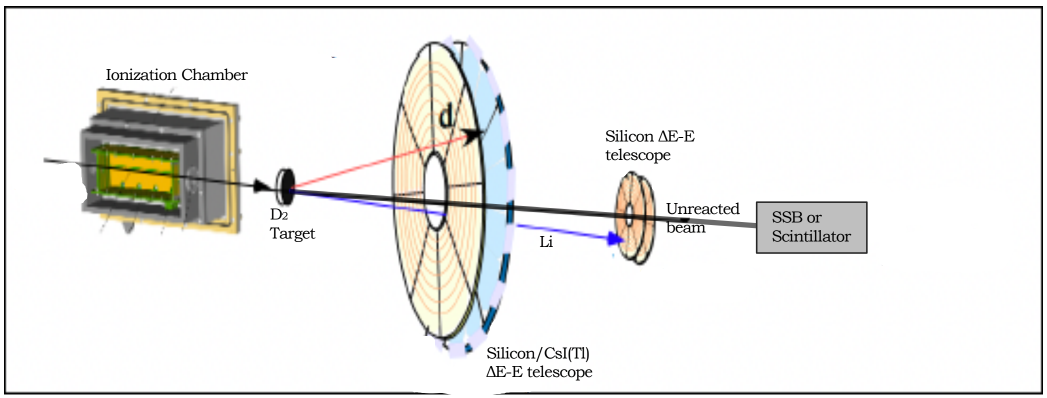
- ISAC-II facility, TRIUMF, Canada
- Study Direct reactions
  - Elastic, inelastic and transfer



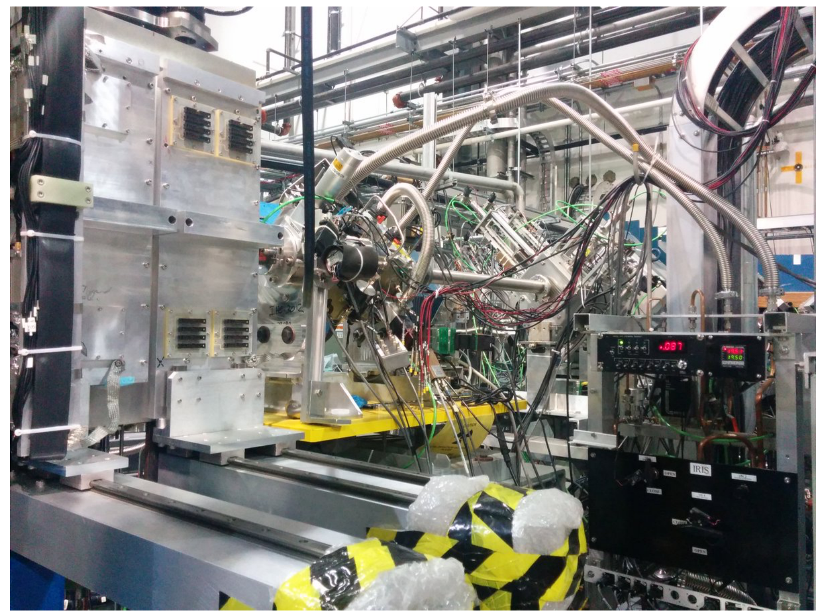
Layout of ISAC, TRIUMF

Key Components of IRIS setup

- Ionization chamber
- Charged particle Detectors
- Solid deuteron target
- SSB and Scintillator



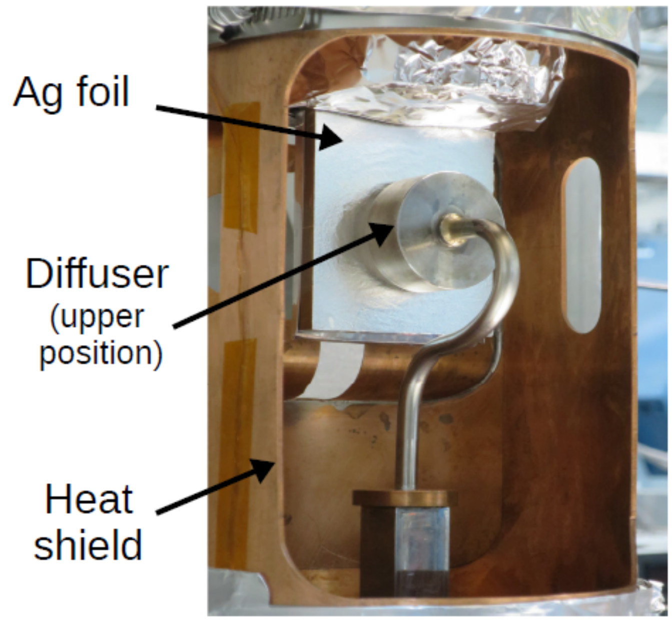
Schematic view of IRIS setup



IRIS setup

Solid deuteron target

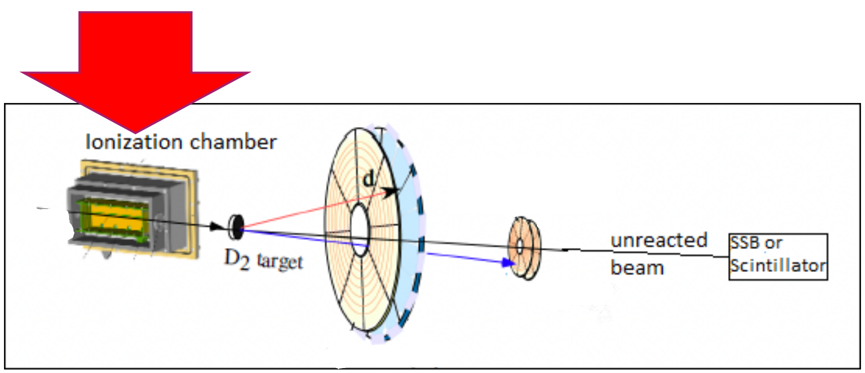
- High density of deuterons than gas or liquid
- Windowless
- Backed with Silver foil
- Copper heat shield
- Temperature ~4K using cryocooler with helium compressor
- Target thickness can be control throughout the experiment
- Online measurement of target thickness

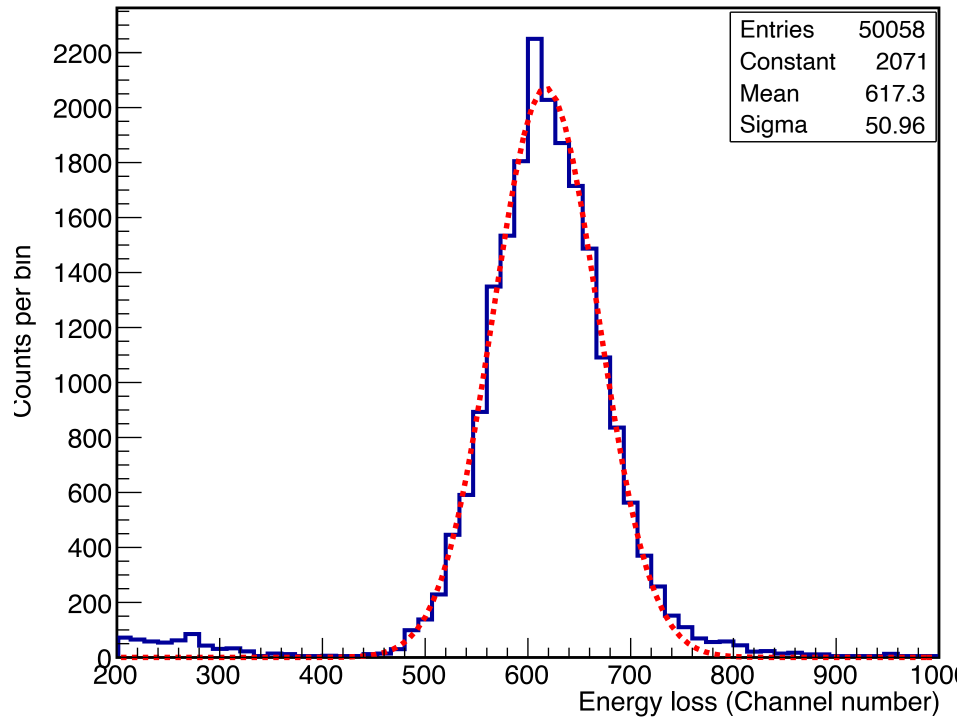


IRIS target assembly

Ionization Chamber (IC)

- Gas filled detector (Isobutane)
- Counts the beam particles
- Identifies the beam particles
- IC pressure ~19.5 torr
- Only one species i.e. ^{11}Li

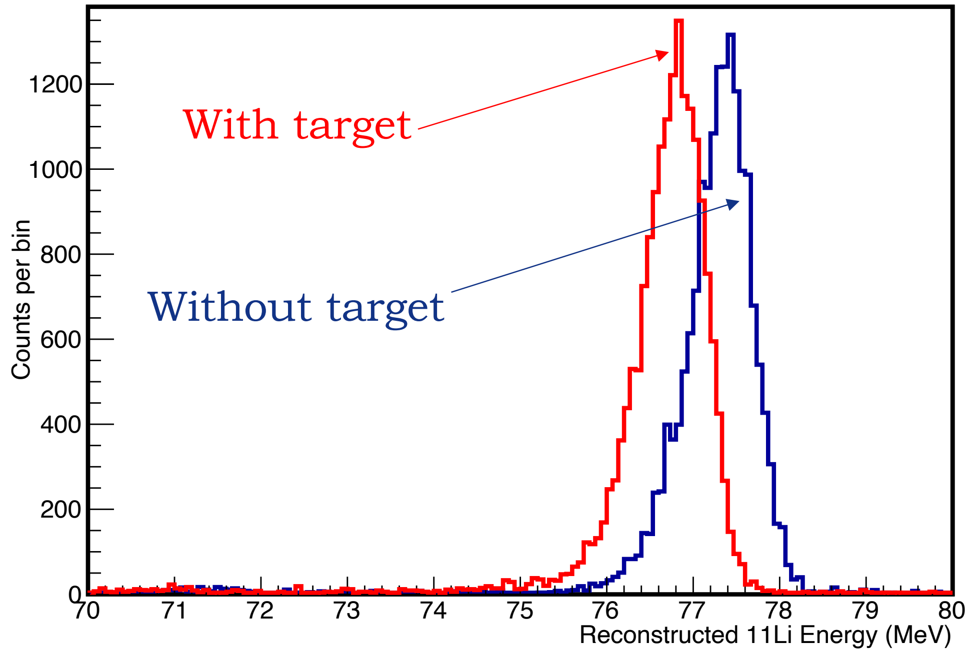




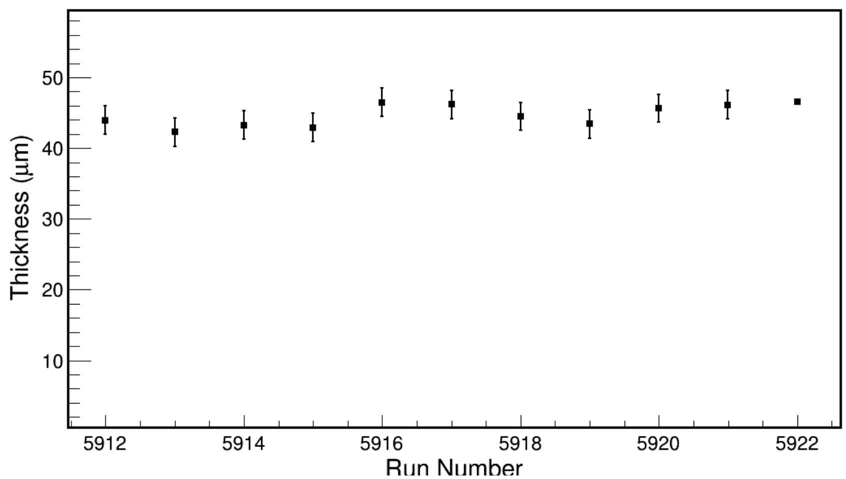
^{11}Li peak in Ionization Chamber ADC channels fitted with gaussian

Target thickness

- Used elastic scattering of ^{11}Li from Ag foil
- Energy was measured with and without target
- Energy difference was used to find thickness
  - $t = \int_{E_i}^{E_f} \frac{1}{S(E)} dE$

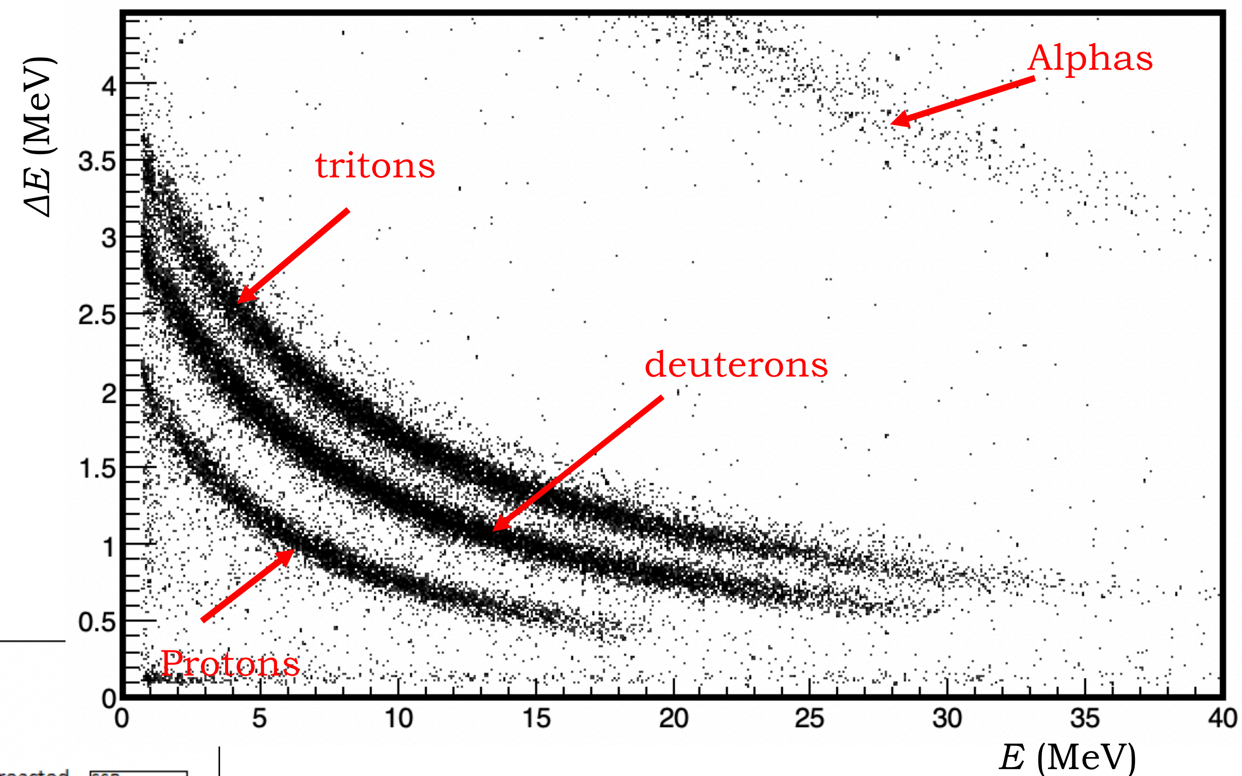


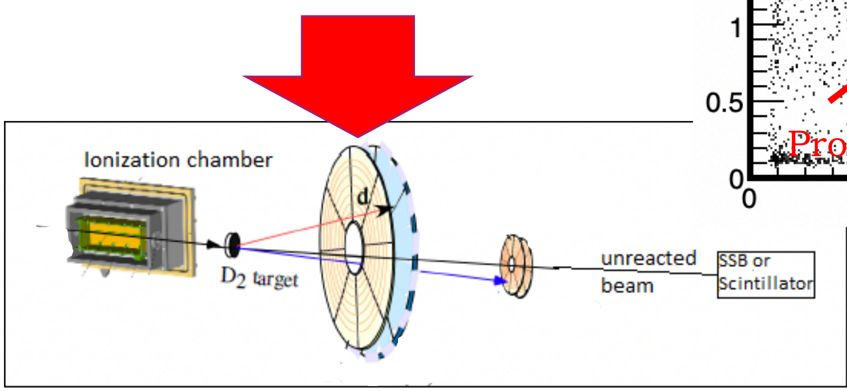
Reconstructed ^{11}Li energy with (red) and without (blue) D_2 target.



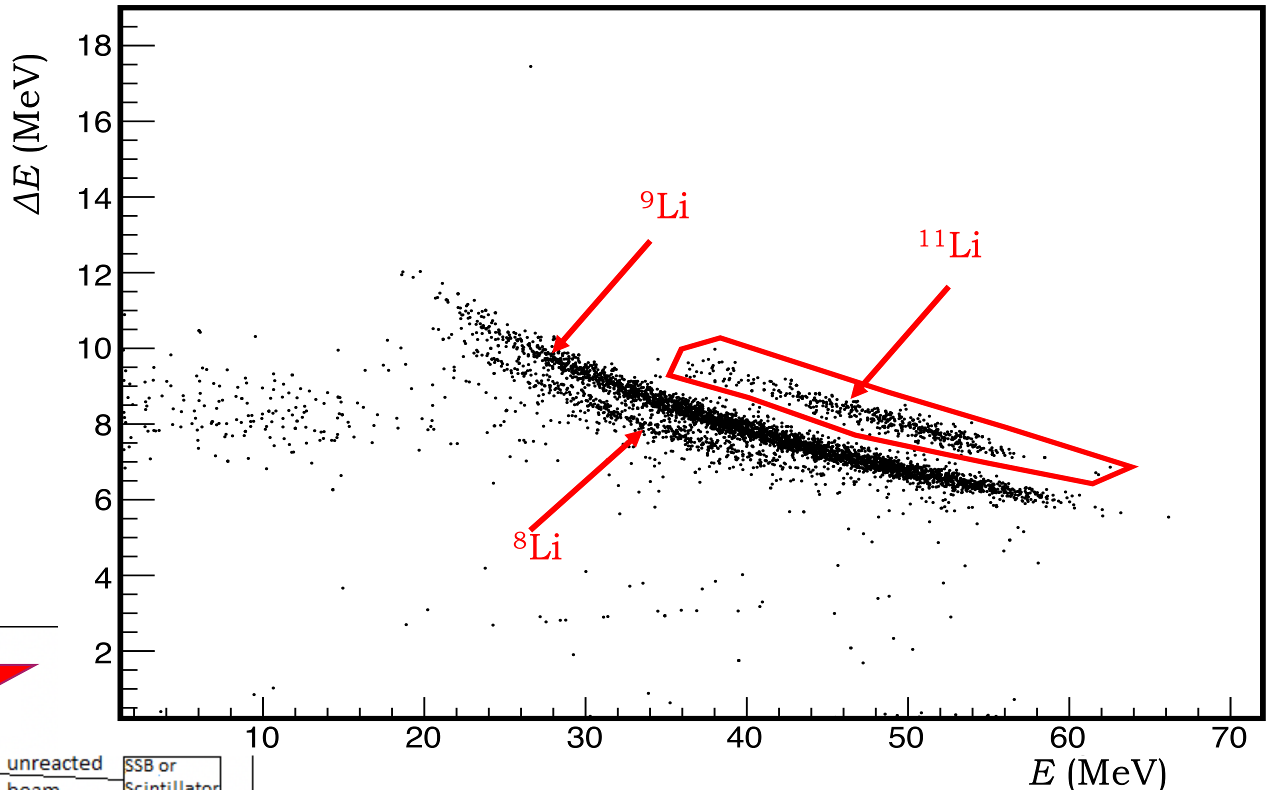
Thickness of deuteron target during experiment

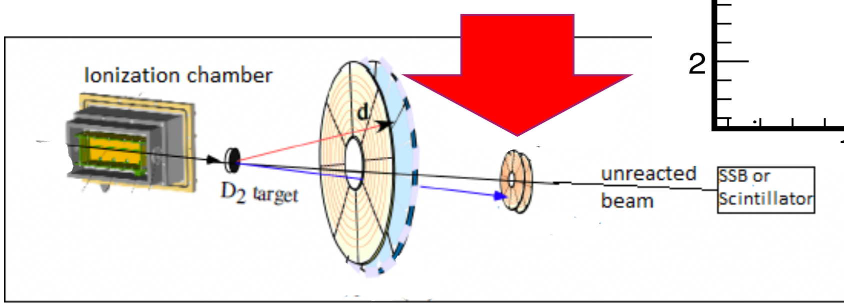
Light particle identification





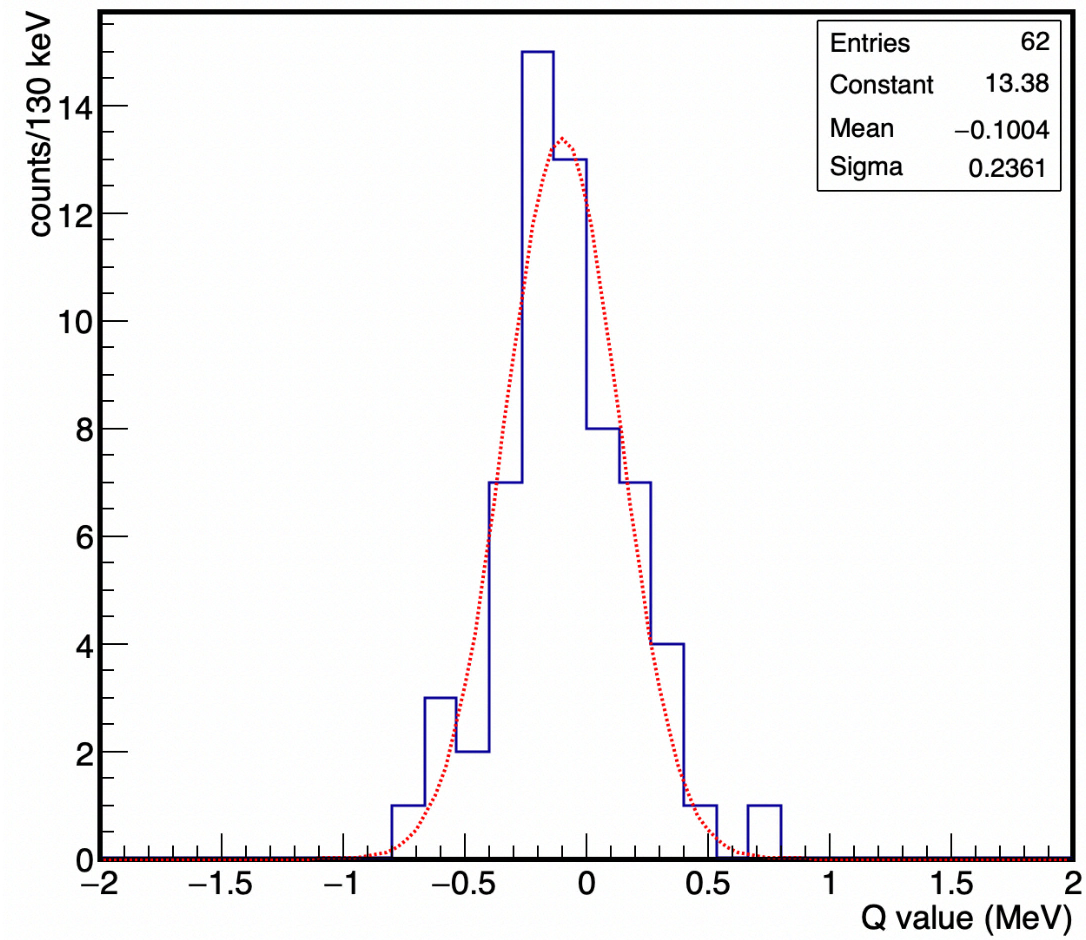
Beam like particle identification





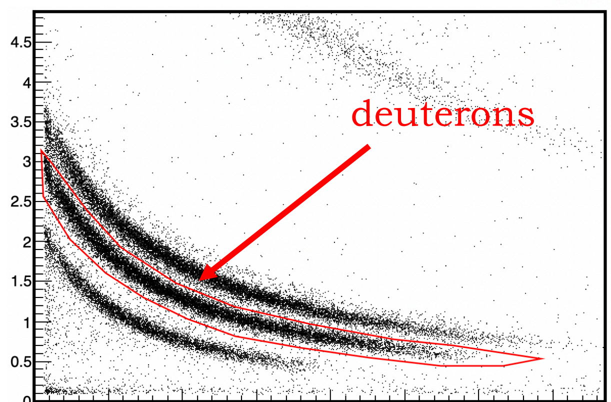
Elastic spectrum for $^{11}Li(d,d)^{11}Li$

- Ground state peak was obtained with missing mass technique

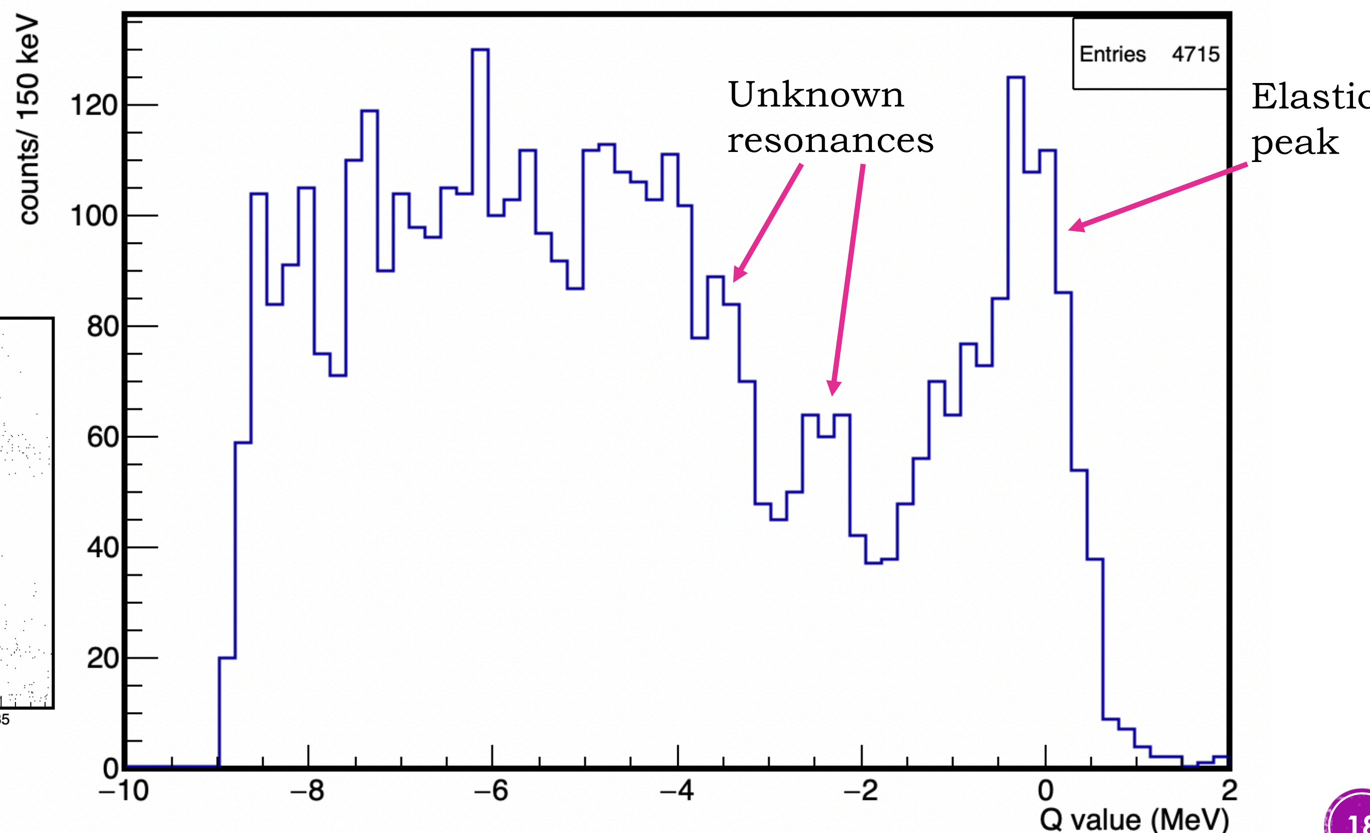


Ground state peak fitted with gaussian

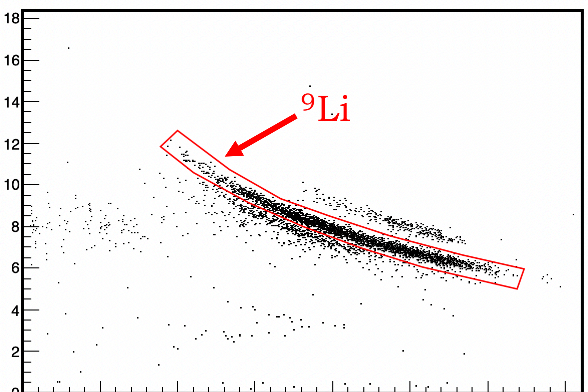
Q value spectrum for $^{11}Li(d,d')$



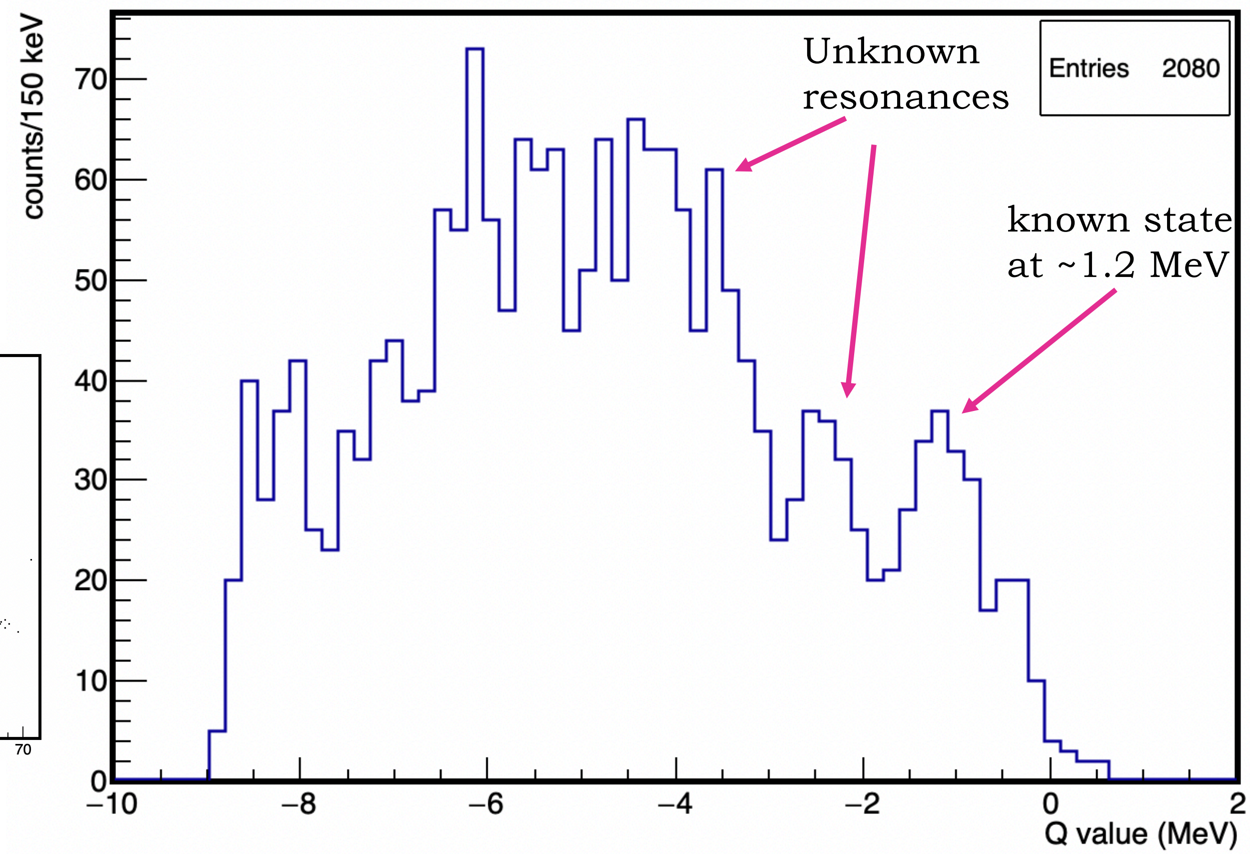
Light particle identification with red polygon on deuterons



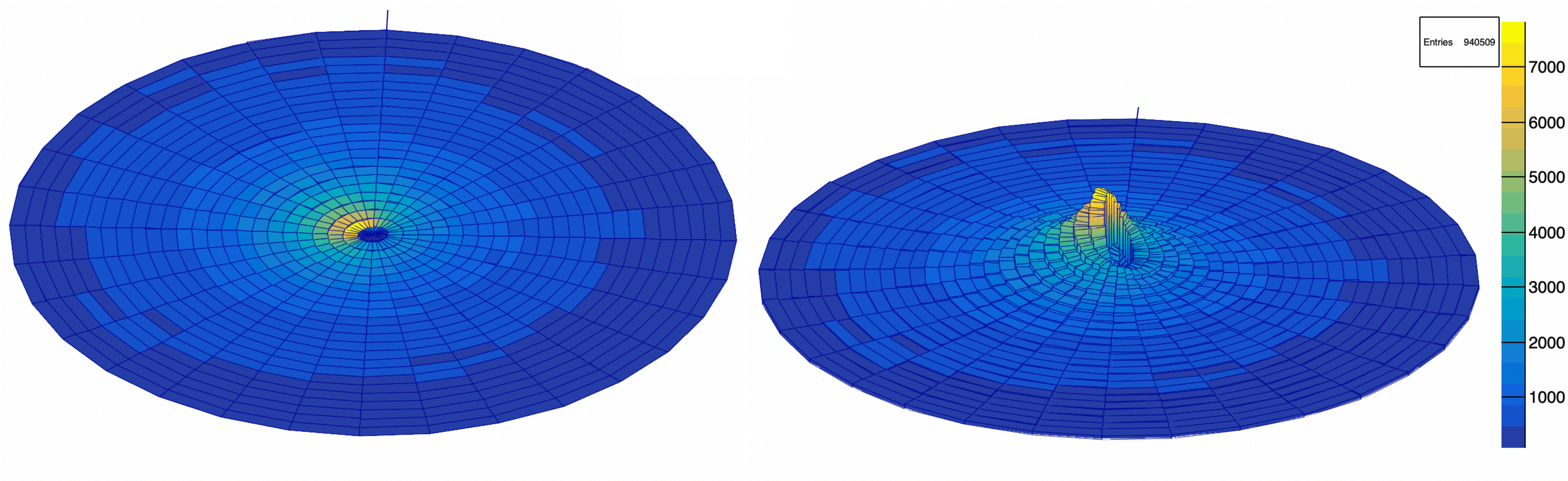
Inelastic spectrum for $^{11}Li(d,nnd')^9Li$



Heavy particle identification with red polygon on ^{9}Li



Further corrections



Beam symmetry plot shows the interaction point was not at the center

Summary and Future work

- Study of nuclear limits is important to understand nuclear structure
- Experiment was performed at IRIS (Triumf) to study ^{11}Li(d,d’) reaction
- Spectrum shows the evidence for multiple resonance states
- Will be corrected for any background noise from silver foil.
- These states will be analyzed with theoretical calculations to assign relative spin-parity values

Acknowledgements

- Supervisor Dr. Rituparna Kanungo
- M.Singh ,M.Holl ,L.Atar ,M.Alcorta , S. Bhattacharjee , S. V. Burbano , C. Burbadge , M. Cavenaile , B. Davids , R. Dunlop , N. Esker , S. Gillespie , B. Greaves , G. Hackman , P. Jassal , R. Kruecken , A. Maclean , B. Olaizola , A. Radich , J. Refsgaard , J. Randhawa , P. Subramaniyam , C. Svensson , D. Walter
- Astronomy and Physics Department, SMU
- NSERC ,CINP and SMU for funding

NSERC CRSNG

CINP ICPN Canadian Institute of Nuclear Physics Institut canadien de physique nucléaire

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One University. One World. Yours.

Charge particle detectors

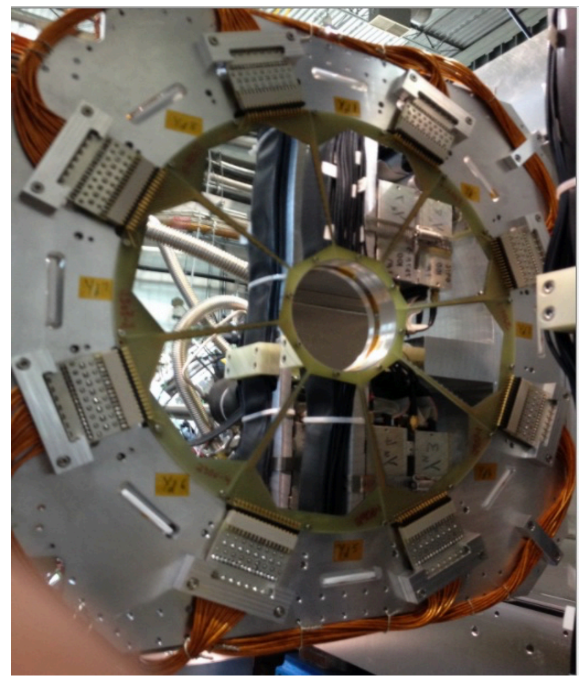
- **YY1- Silicon strip detector**

  8 sectors and 16 rings
- CsI(Tl) – Cesium Iodide thallium doped

  16 sectors in coincidence with YY1
- S3 – Double sided strip detector

  S3d1 and S3d2

  32 sectors and 24 rings



YY1 detector

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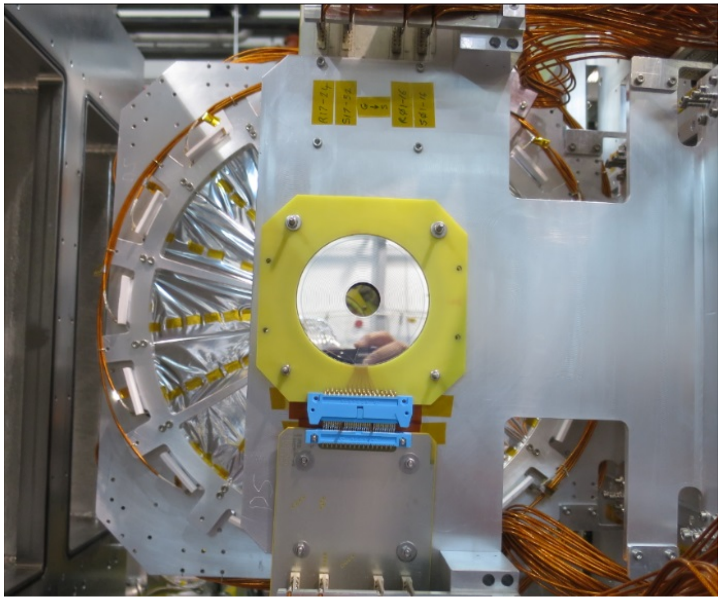
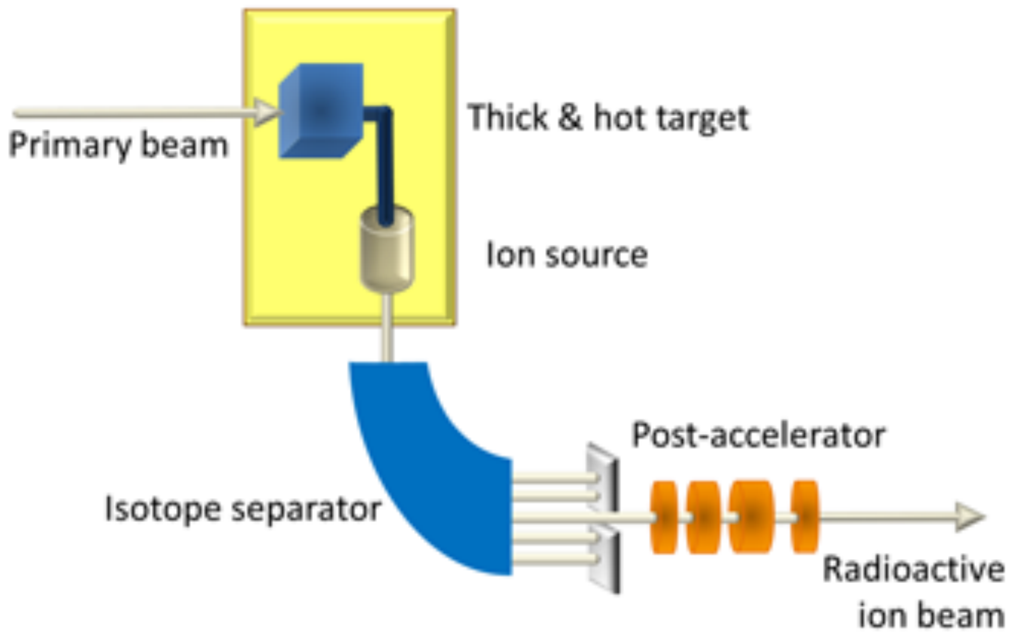


S3 detector

ISOL – Isotope separation on-line



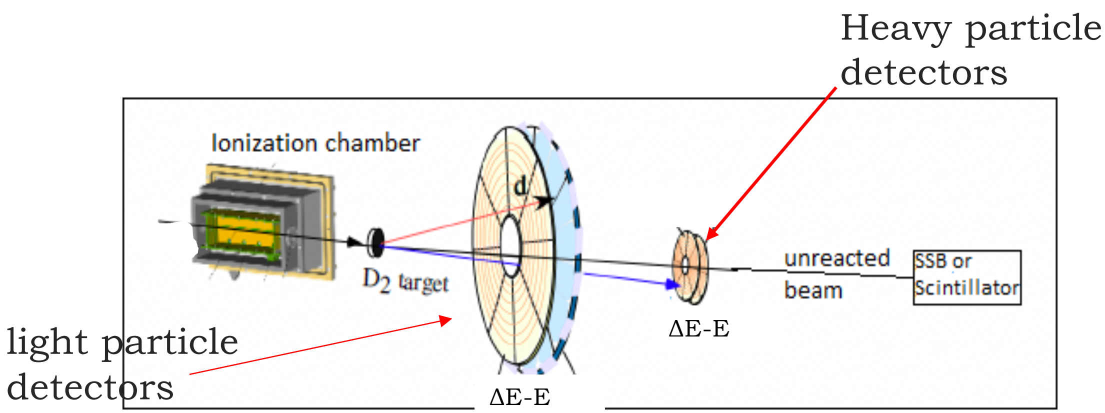
Calibration

- Conversion of ADC channel to Physical quantity, i.e. energy
- Equation for calibration $E = g \times (c - p)$

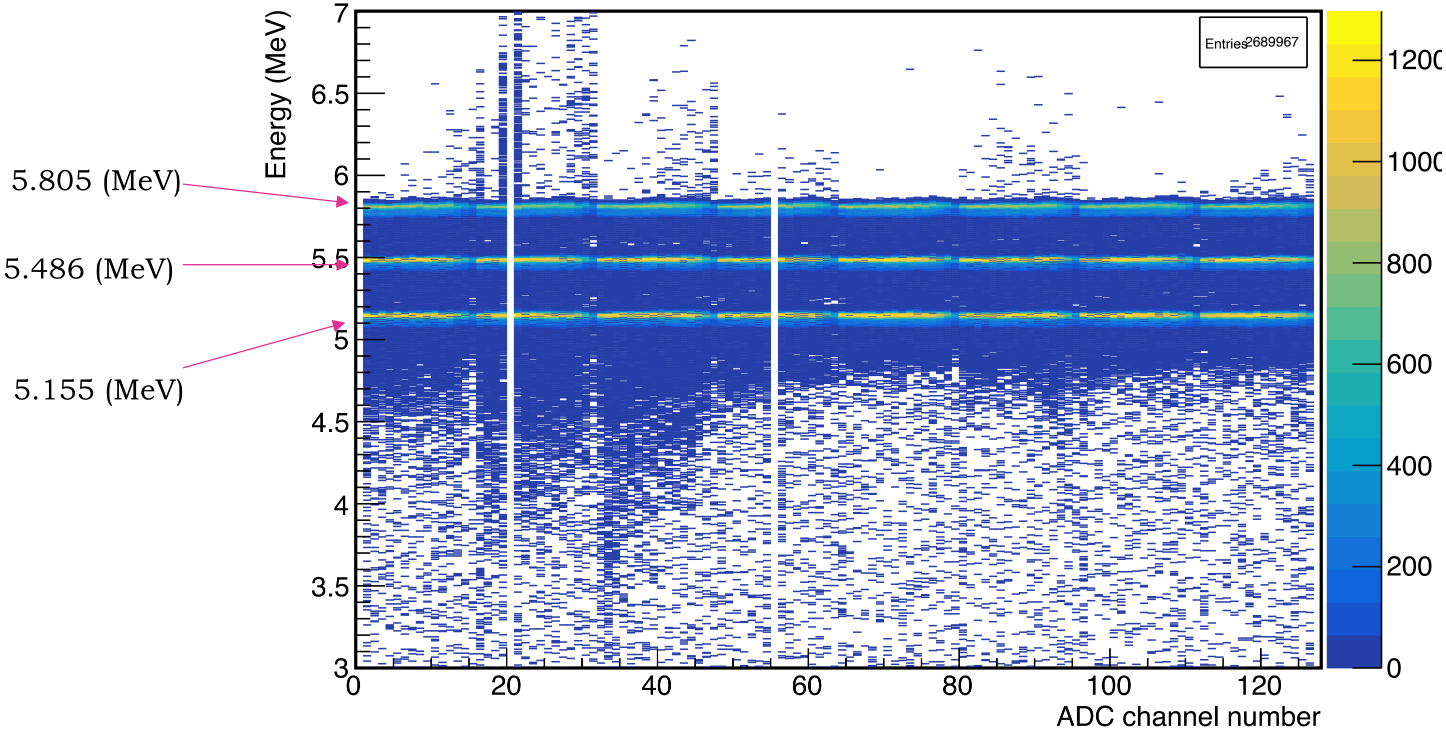
  where E = Energy, g = gain , c = Channel number and p = pedestal, is the offset corresponds to zero energy. Pedestals were collected without the beam.

Calibration of detectors

- Calibration of heavy particle silicon detectors (S-3 type) was done with elastic scattering of ^{11}Li with silver foil
- Calibration of light particle detectors (silicon and CsI(Tl) was done with elastic scattering of 11Li with deuteron target
- All the calibrations were verified with the known states of stable beam of ^{22}Ne

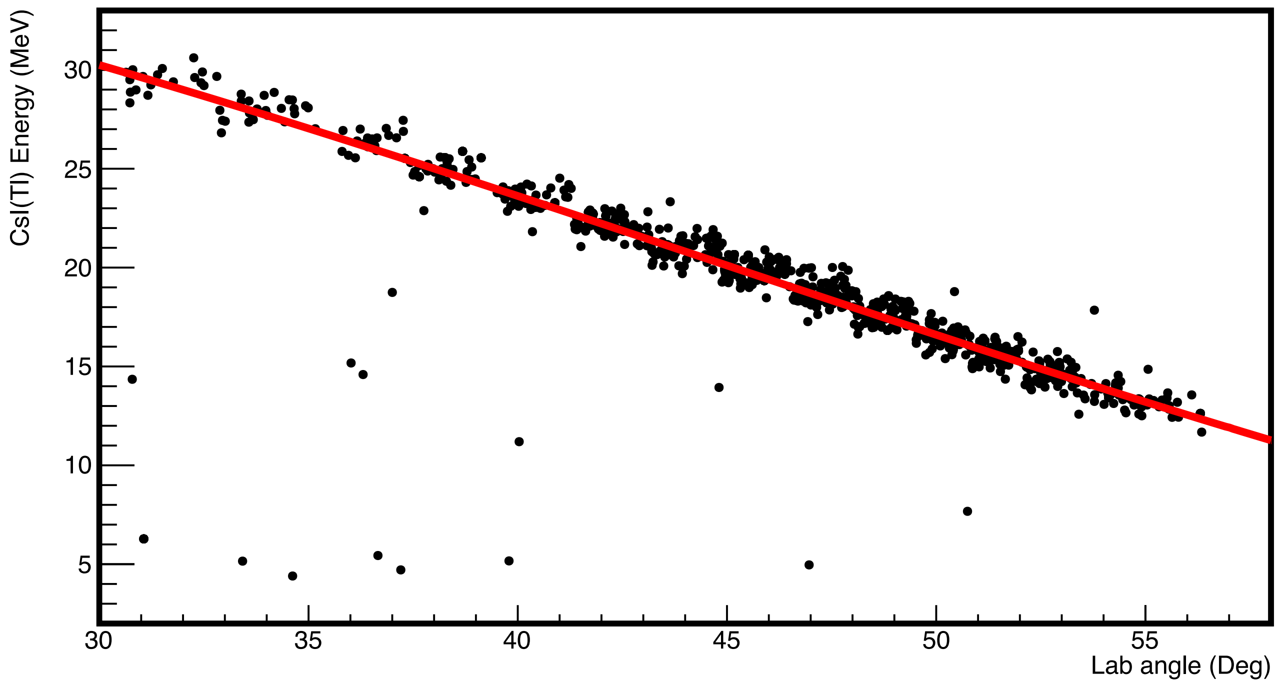


YY1 calibration



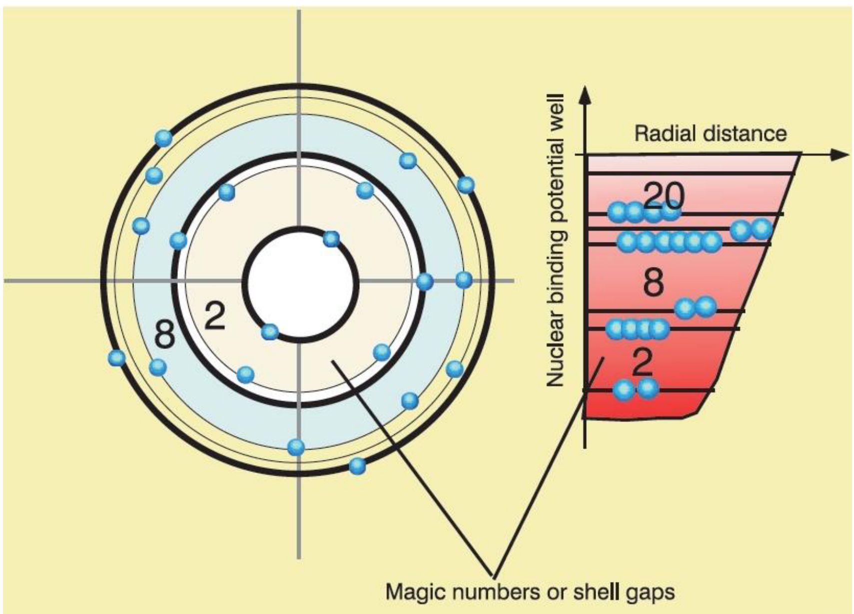
Calibrated YY1 detector with triple alpha source.

CsI(Tl) detector

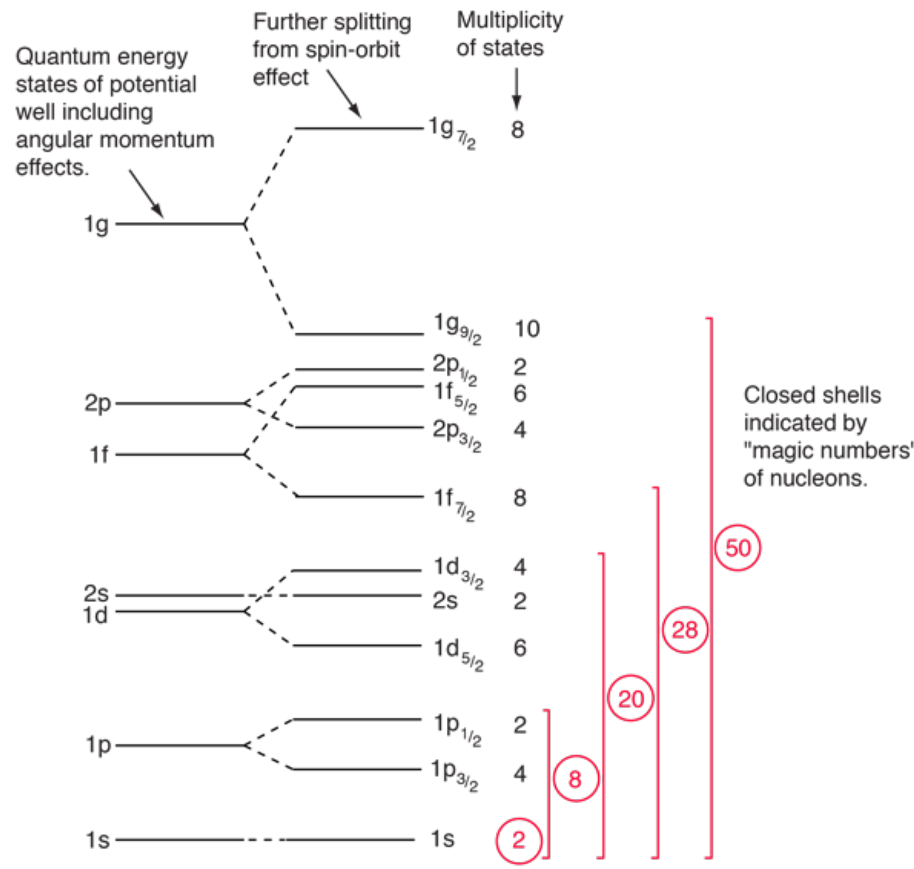


Calibrated YY1 detector. Elastic scattered ^{11}Li simulated (Red) overlaid on data (black)

Shell model

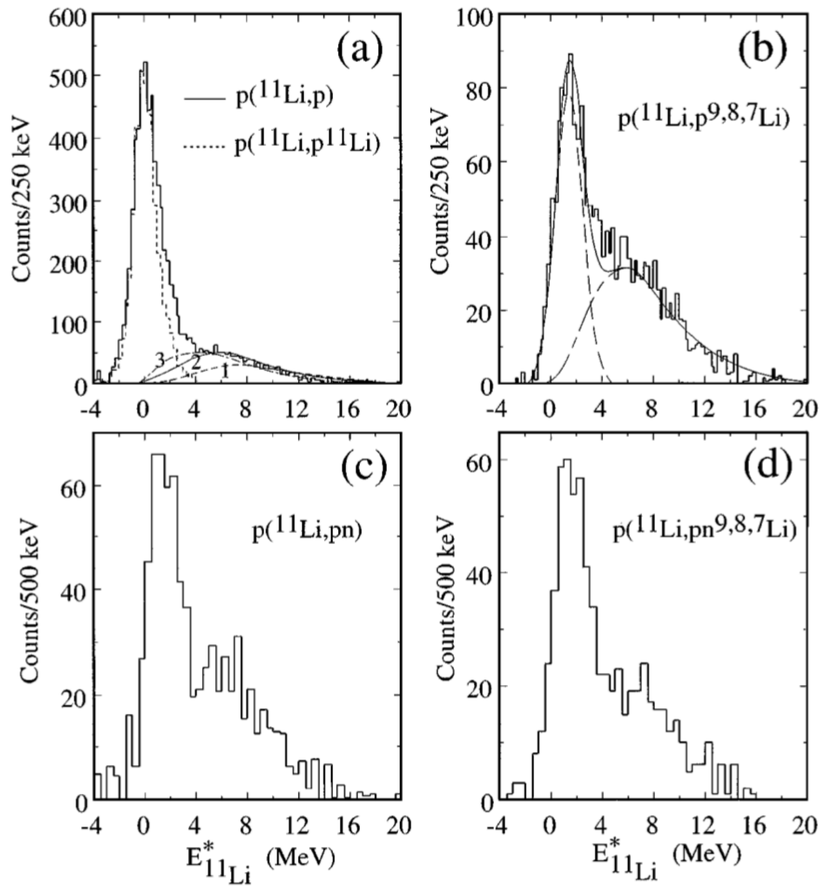


Planetary model of nucleus



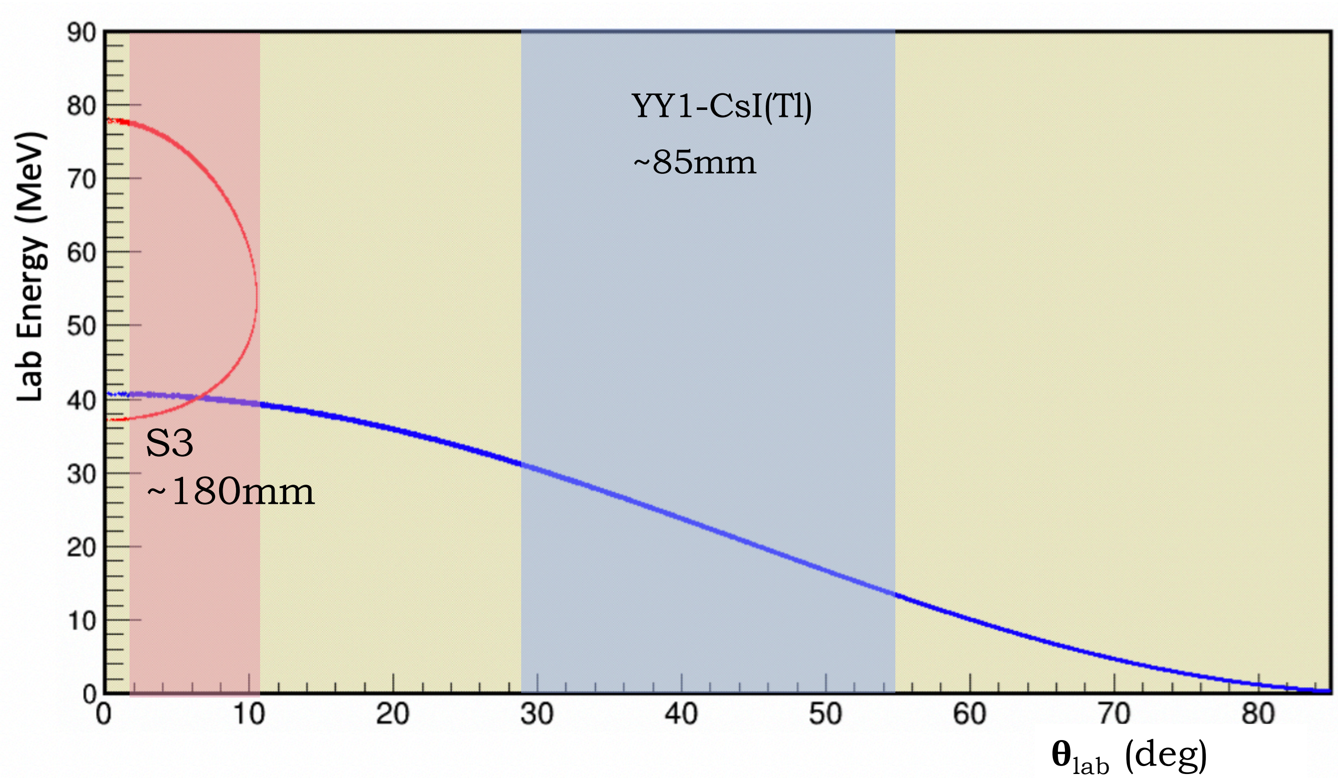
Shell structure in nuclei

Previous measurements of Excited states in ^{11}Li



A.A. Korsheninnikov et al., Phys. Rev. Lett. 12, 2317 (1997).

Simulations



Kinematic plots of elastic scattering of ^{11}Li with deuterons. Red curve for scattered ^{11}Li and blue represents the deuterons

Q value spectrum

- Missing mass technique
- Consider A+B->C+D , then Q value is

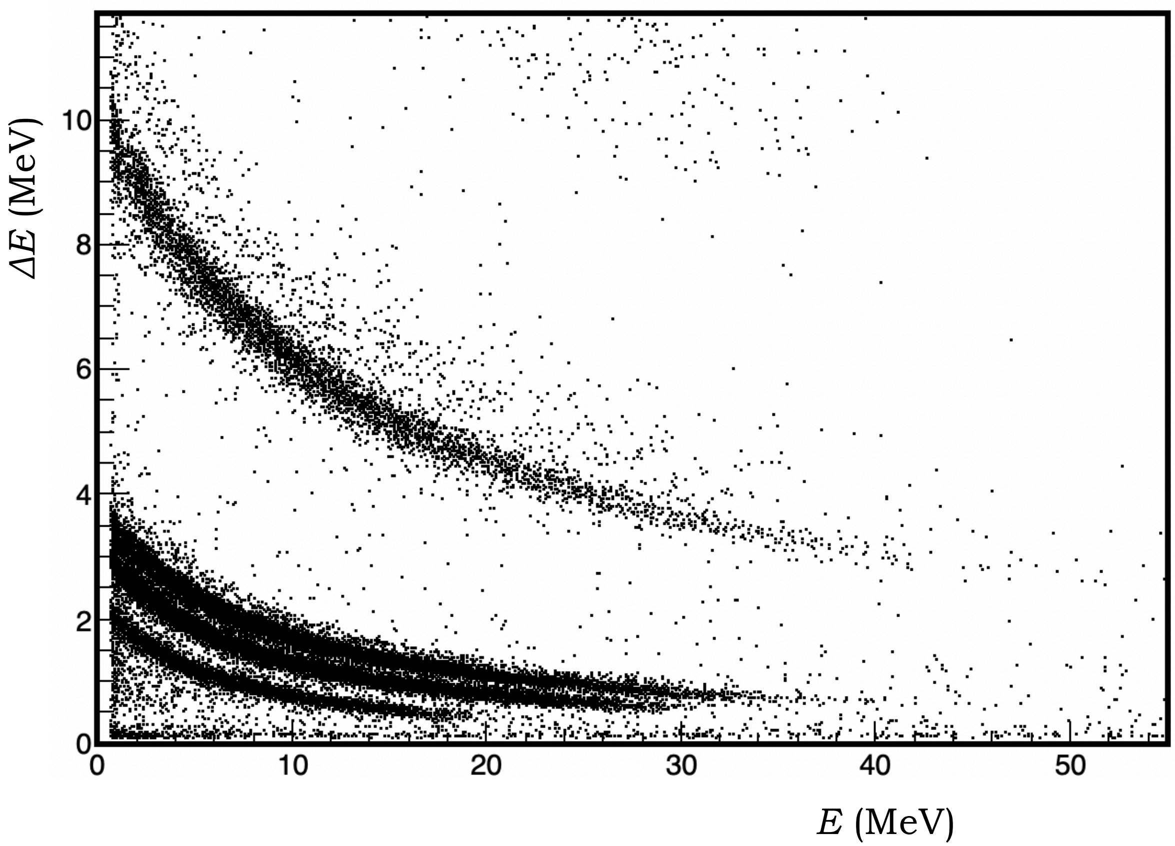
$$Q = m_A + m_B - m_C - m_D$$

Where m_A, m_B, m_C and m_D are masses of the particles.

- If D is in excited state, then

$$m_D = (\sqrt{m_A{}^2 - m_B{}^2 + m_C{}^2 + 2mB(TA + mA) - 2(TA + mA + mB)(T_C + m_C) + 2P_C P_A \times cos(\theta_C)}$$

Light particle identification



Heavy particle detection