CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
IEM
Instituto de Estructura de la Materia

Testing the parity inversion in ${}^{11}_{3}Li$ at the upgraded SEC device

Grupo de Física Nuclear Experimental

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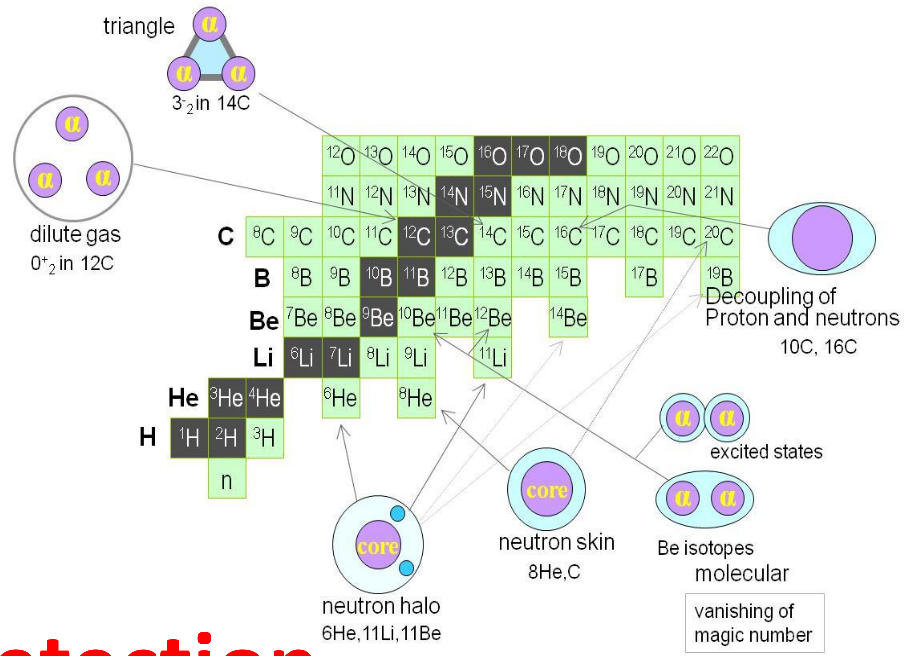
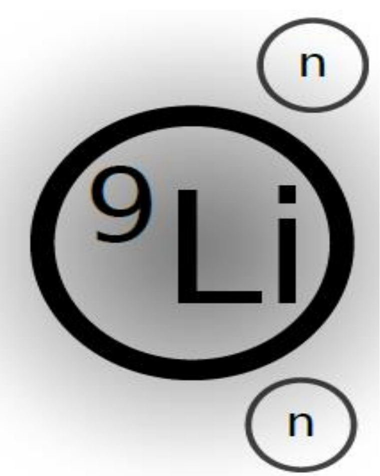
Halo Nuclei

- The low mass region of the Segre chart is home to multiple types of exotic nuclei.
- One of the exotic nuclei are the hallo nuclei.
- A hallo nucleus is a system where the W.F fulfils two main conditions.
  - A large probability *fc* for finding a cluster component in the total WF.
  - A large fraction *fh* of the probability must be in a region outside the cluster potentials.



First Detection

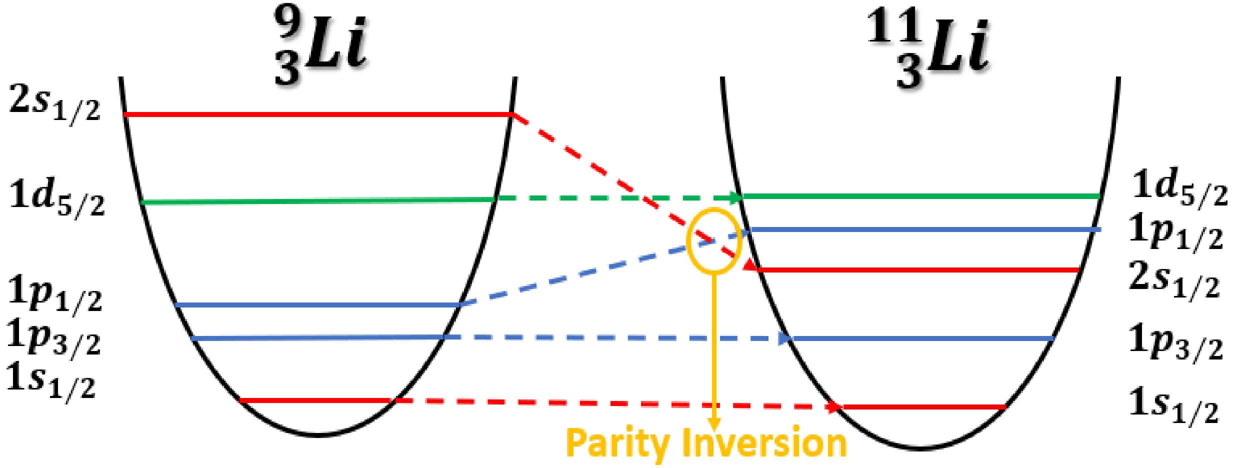


- ✓ The first empirical observation came from scattering experiments of Lithium isotopes, to measure the interaction cross-section of neutron-rich nuclei.
- ✓ The cross-section drastically increases with the jump from ${}^{9}_{3}Li$ to ${}^{11}_{3}Li$, pointing toward a nuclear radius larger than the theoretical prediction.
- ✓ This was interpreted as a system, formed by a compact core and an external set of nucleons (one neutron for ${}^{11}_{4}Be$ and two neutrons for ${}^{11}_{3}Li$).
- ✓ A few years later the ${}^{9}_{3}Li$ momentum distribution obtained from ${}^{11}_{3}Li$ break-up experiments confirmed this hypothesis.

Why should we study ^{11}Li

^{11}Li is the archetype of the two neutron halo and thus, can be used to study, among other things.

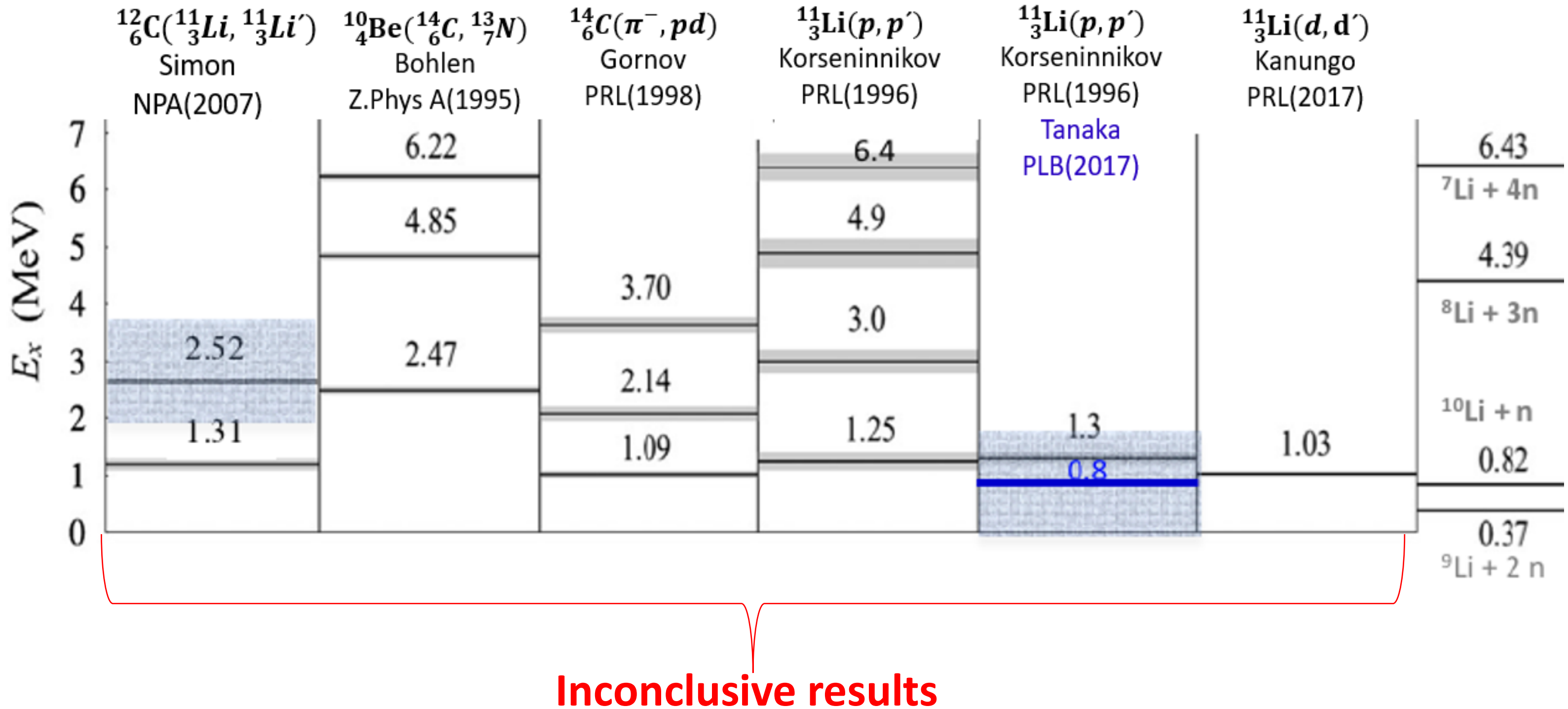
- **The structure of a three-body bound system** since the gs of ^{11}Li is well-established as a very **complex mixture of waves** (p(59(1)%) + s (35(4)%) + d(6(4)%).
- **Di-neutron correlations,** since ^{11}Li is a **Borromean nucleus** (a bound three-body system with all subsystems unbound).
- **Party inversion:** ^{11}Li is placed at the center of the **first island of inversion**, its stability and the observed γ form its deacy is explained through an intruder 2s state yet to **be observed.**



STRONGLY DEBATED!!!

The study of these phenomena is linked to a precise understanding of the structure of ^{11}Li

Despite the efforts the excited structure of ^{11}Li remains unknown



The current knowledge of the structure of ^{11}Li can be summarized as:

- **Diversity in energy of excited structure of ^{11}Li. No firm spin assignments.**
- **Identification of resonances without incorporating reaction dynamics.**
- **Very narrow states suggested at high energies and continuum at low.**
- **The influence of the reaction mechanism is not resolved.**

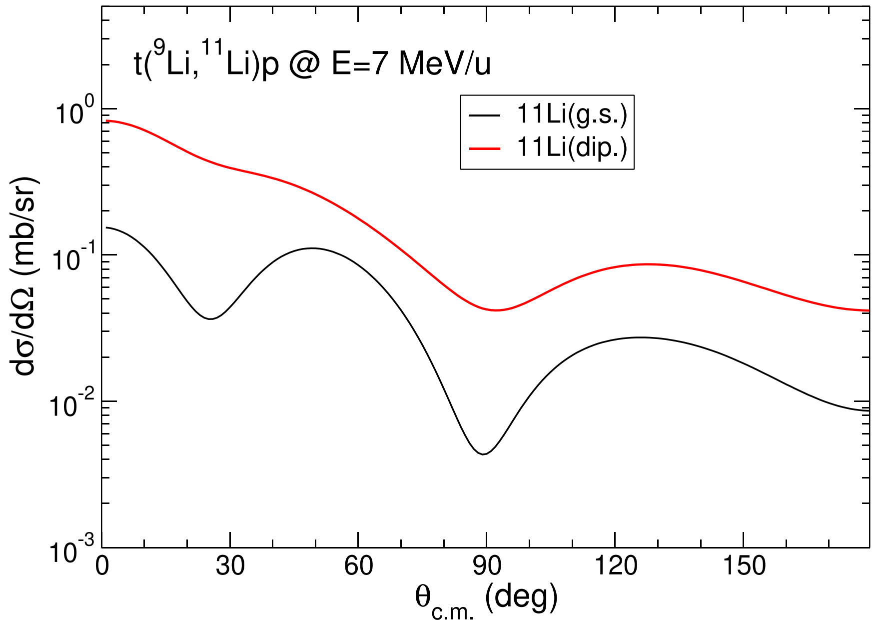
Most experiments try to populate the excited states of $^{11}_{3}Li$ by exciting the very complex g.s.

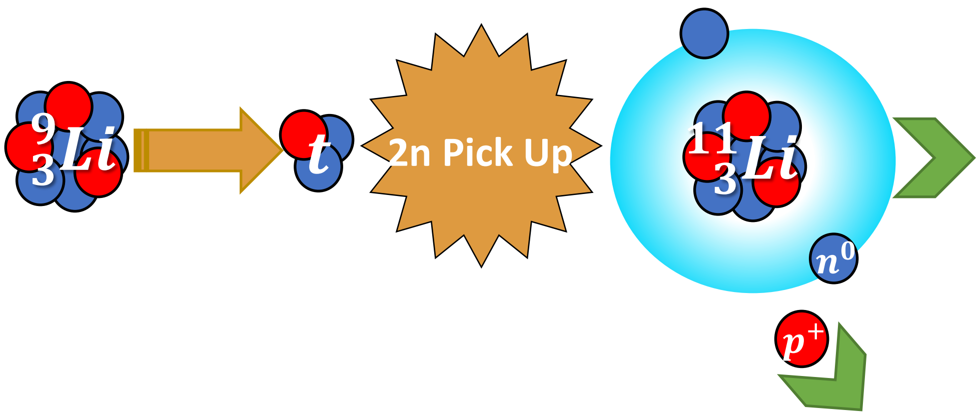
We propose a different approach starting from the simpler g.s. of $^{9}_{3}Li$ using the $^{9}_{3}Li(t,p)^{11}_{3}Li^*$ reaction in inverse kinematics.

The 2nd-order DWBA calculation using (FRESCO) gives three reactions channels

- **t + ^{9}Li: Xi. Li et al, Phys. A789 (2007)1**
- **d + ^{10}Li : H. An and Ch. Cai, PRC 73, 054605(2006)**
- **p + ^{11}Li: A.J. Koning & J.P. Delaroche NPA 713, 231 (2003)**

The excitated states of can be populated throug this reaction





The excited states of $^{9-11}_{3}Li$ can be studied via the emitted tritons, deuterons and protons.

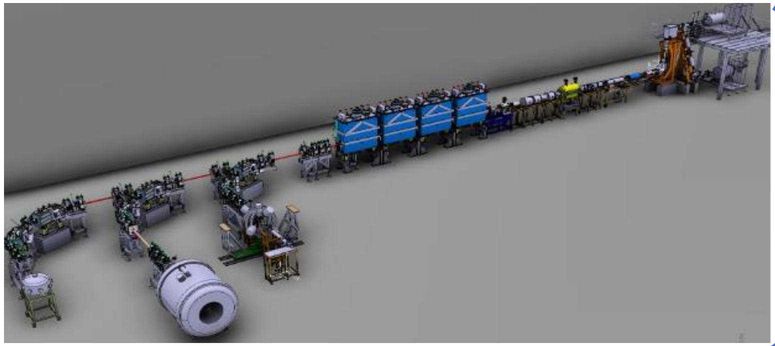
To confirm the party inversion of ^{11}Li we need to probe its excited states.

To achieve this through the $^{9}Li(t,p)^{11}Li^{*}$ reaction we need the following:

A system to produce a ^{9}Li beam and accelerate it up to 7 MeV/u

↓

ISOLDE+HIE-ISOLDE pos accelerator



A reaction chamber to place the detectors, capable of achieving high vacuum and (ideally) previously tested.

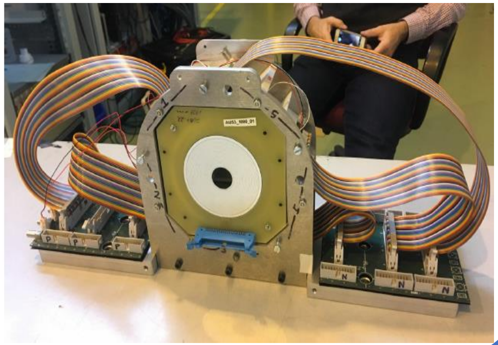
↓

ISOLDE -Scattering Experiments Chamber (SEC)

A particle detection system capable off distinguishing particles with with very similar mases (p, d, t).

↓

The PENTAGON



The pentagon is a particle + gamma detection system developed by the IEM experimental nuclear physics group.

Detectors

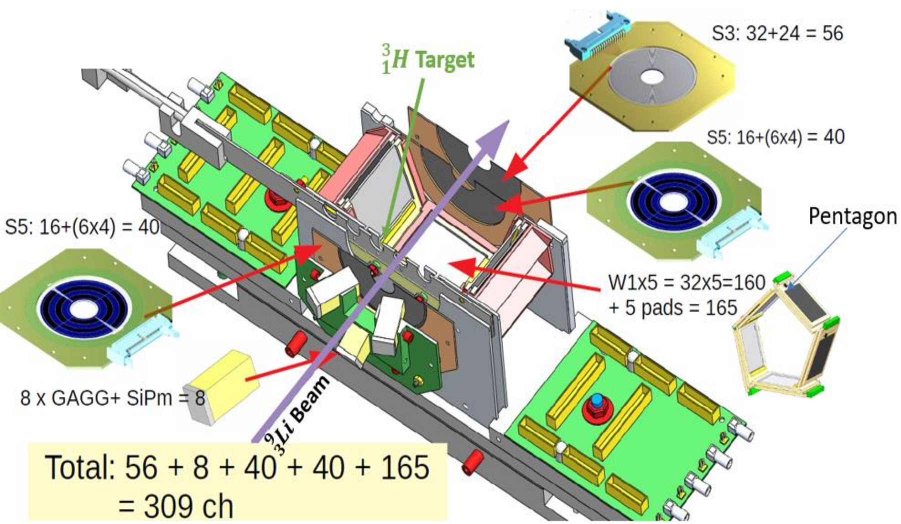
DAQ

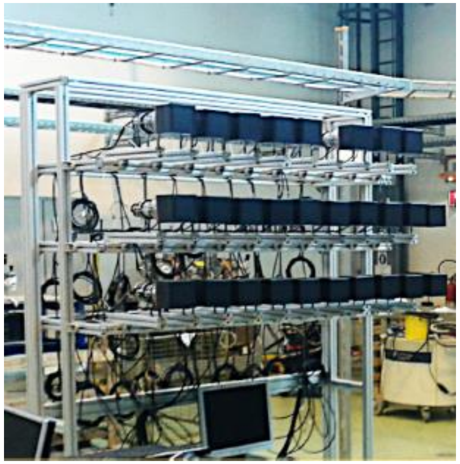
Particle Identification
→ **Silicium detectors**
- **5 DSSD+PAD (Central Body)**
- **3 CD (Caps)**

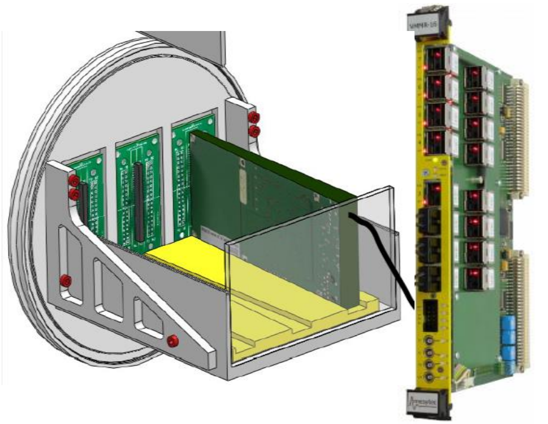
Photon Detection
→ **Scintillator detectors**
- **8 GAGG Array**

Neutron Detection
→ **SAND detectors**

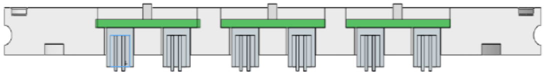
DAQ:
- ✓ MVLC (Controler)
- ✓ 6 x MMR-64 (DSSD+CD)
- ✓ VMMR-8 (Optical link)
- ✓ 3xMPP16-QDC (GAGG+SAND)
- ✓ MDPP 32 (PAD)





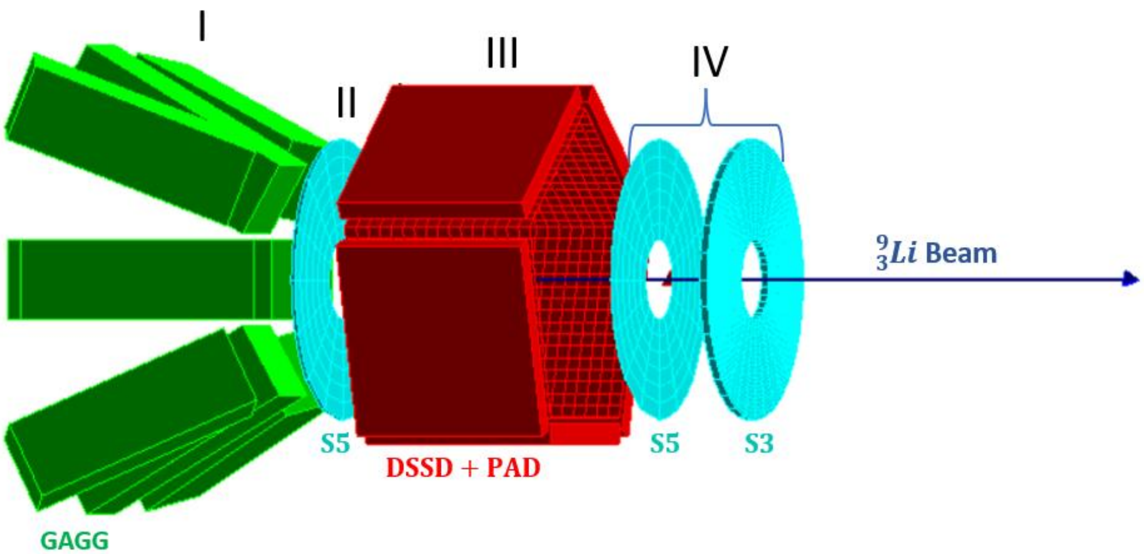


Outside

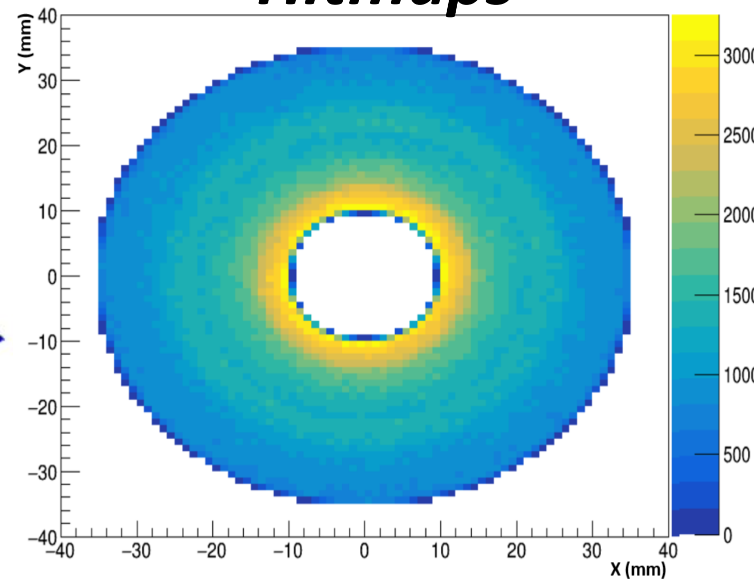


Chamber

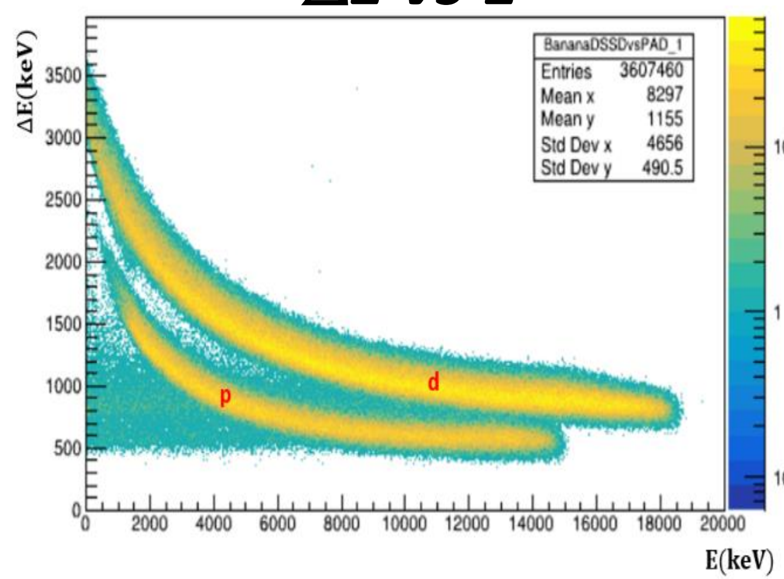
Geant 4 simualtions have been used to fine tune the tectror set up and model the bkg chanels



Hitmaps



ΔE vs E



I: **GAGG scintillators**

II: **DSSD annular detector** **,300 μm S5 (100^{o} – 145^{o})**

III: **5 particle telescopes** **(60 μm DSSD + 1500 μm Si-PAD)** **<u>forming a pentagon</u> covering** **44^{o} – 104^{o}**

IV: **2 annular DSSDs** **(60 μm S5 + 1000 μm S3) forming a particle telescope covering (6^{o} – 32^{o})**

- ✓ ${}^{11}_{3}Li$ is a halo nucleus located at the first island of inversion
- ✓ The excited states of ${}^{11}_{3}Li$ are still poorly known, with multiple experimental and theoretical works (several starting from ${}^{11}_{3}Li$ gs) producing inconclusive results.
- ✓ We will probe the excited states of ${}^{11}_{3}Li$ starting form the ${}^{9}_{3}Li$ nucleus and using a two-neutron pickup reaction in inverse kinematics (IS690).
- ✓ An improved detection set up capable off distinguishing particles of very similar mass is almost completed.
- ✓ Geant4 simulations have been used to fine tune the set up
- ✓ The experiment IS690 will be carried out at the HIE-ISOLDE facility.

Thank you for your attention !!

Any Questions?