Cluster structure in ^{14}C

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and the AT-TPC collaboration

XVI CPAN Days

20/11/24

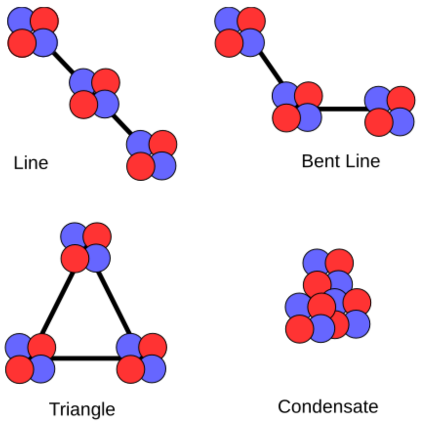
CLUSTERING IN ATOMIC NUCLEI

Nucleus made up of clusters of nucleons **(α particles)**, not individual protons or neutrons

More common in **lighter nuclei**: ^{12}C, ^{16}O, ^{24}Mg...

Proximity to **cluster emission threshold** and **deformation** favor clustering

Geometric arrangement is crucial for understanding nuclear properties



Example arrangements of three α clusters [1]

[1] L. Carpenter PhD Thesis

THE LINEAR-CHAIN CLUSTER STATE (LCCS)

Three α particles arranged in a **linear, one-dimensional structure** [2]

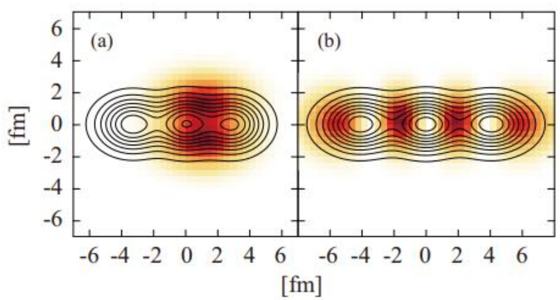
No evidence supporting LCCS in ^{12}**C**

Experimentally confirmed in ^{16}**C** [3]

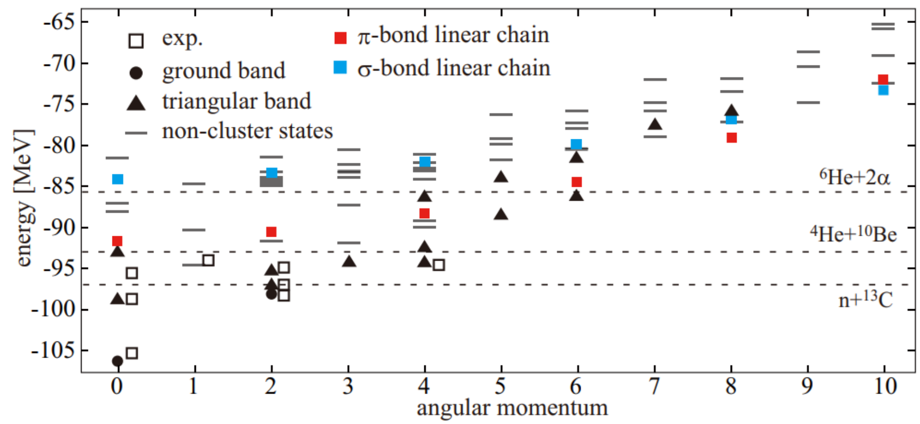
Neutron excess is important in the stabilization of this configuration

Does ^{14}C have sufficient number of neutrons to stabilize it?

AMD calculations predicts LCCS in ^{14}C with two rotational bands: π-bond and σ-bond [4]



Density distribution of the two LCCS configurations in ^{14}C [5]



^{14}C energy levels [6]

[2] H. Morinaga, *et al.* Phys. Rev. **101** (1956) 254-258.

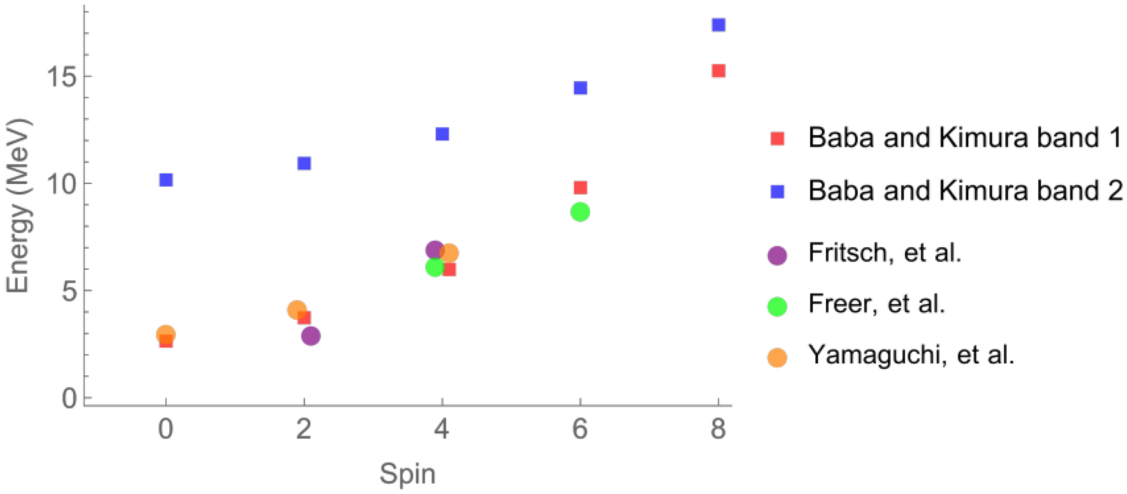
[3] N. Itagaki, *et al.* Phys. Rev. C **64** (2001) 014301.

[4] T. Suhara, Y. Kanada-En'yo, Phys.Rev. C **82** (2010) 044301

[5] T. Baba, *et al.* Phys. Rev. C **95** (2017) 064318

[6] T. Baba, *et al.* Phys. Rev. C **94** (2016) 044303

EXPERIMENTAL EVIDENCES



^{10}Be + α resonant scattering with two different techniques:

- Thick target experiments
  Freer [7] and Yamaguchi [8]

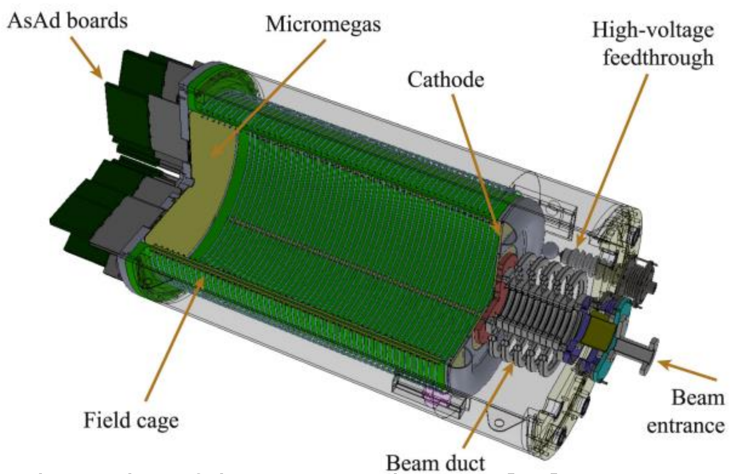
- AT-TPC experiments
  Fritsch [9]

[7] M. Freer, *et al*. Phys. Rev. C **90** (2014) 054324

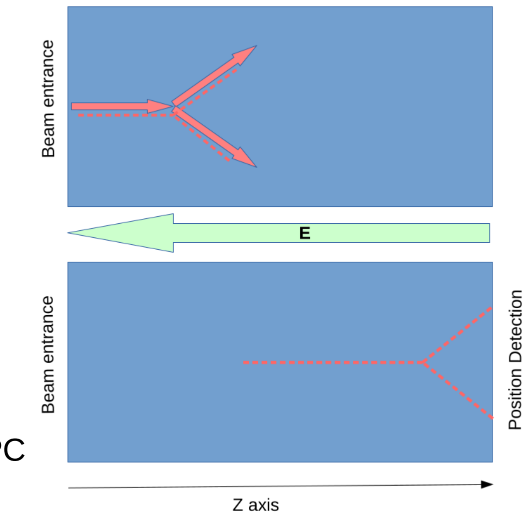
[8] H. Yamaguchi, *et al.* Phys. Lett. B **766** (2017) 11-16

[9] A. Fritsch, *et al.* Phys. Rev. C **93** (2016) 014321

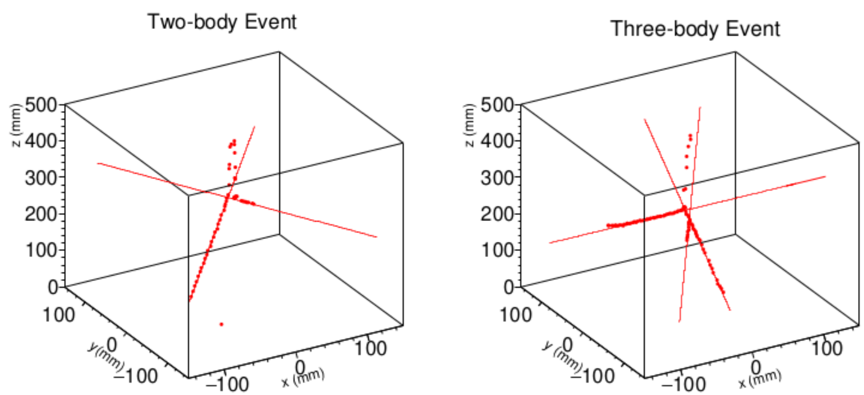
THE AT-TPC



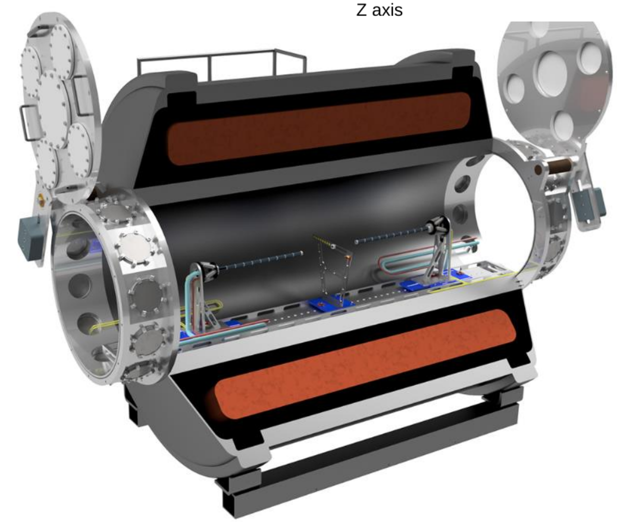
Schematics of the AT-TPC detector [10]



Operation of the AT-TPC



Example of track reconstruction [1]



Schematics of the SOLARIS solenoidal spectrometer [11]

[1] L. Carpenter PhD Thesis

[10] Y. Ayyad, *et al.* Nucl. Instrum. Methods Phys. Res. A **954** (2020) 161341

[11] https://www.anl.gov/phy/solaris.

PREVIOUS EXPERIMENT WITH THE AT-TPC [1]

- University of Notre Dame
- pAT-TPC
- ^{10}Be beam at **20 MeV** and **38 MeV**
- pAT-TPC filled with 90:10 He:CO_2 at **720 torr**
- No magnetic field

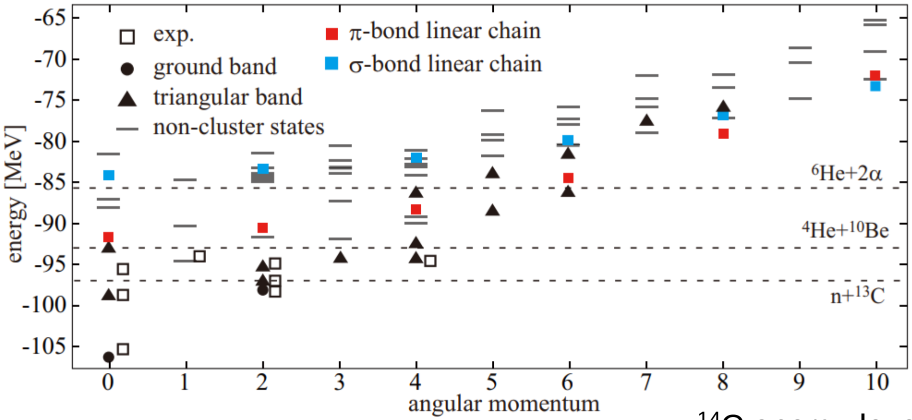
20 MeV dataset (low energy)

- Elastic scattering two-body events

38 MeV dataset (high energy)

- Elastic and inelastic scattering two-body events
- Three-body events: ^{6}He + 2α

Setup of the experiment [1]



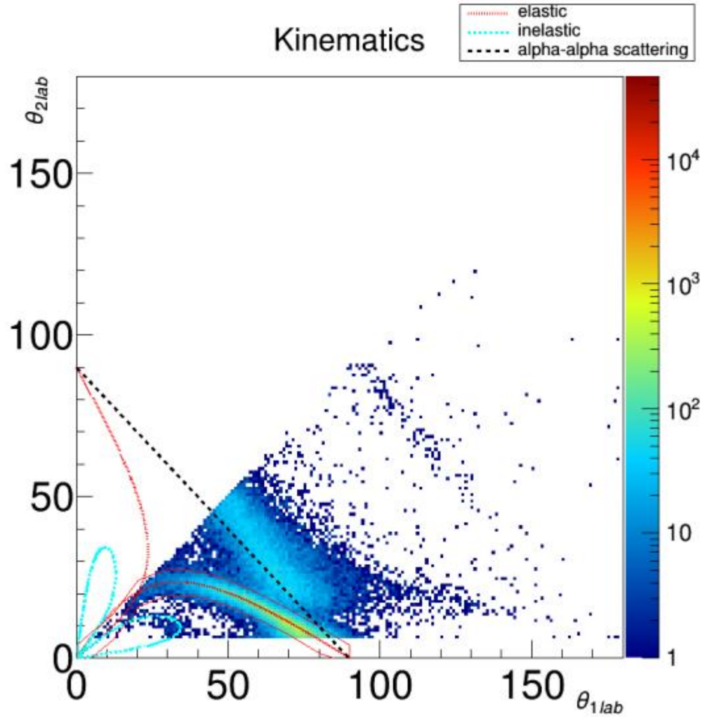
^{14}C energy levels [6]

[1] L. Carpenter PhD Thesis

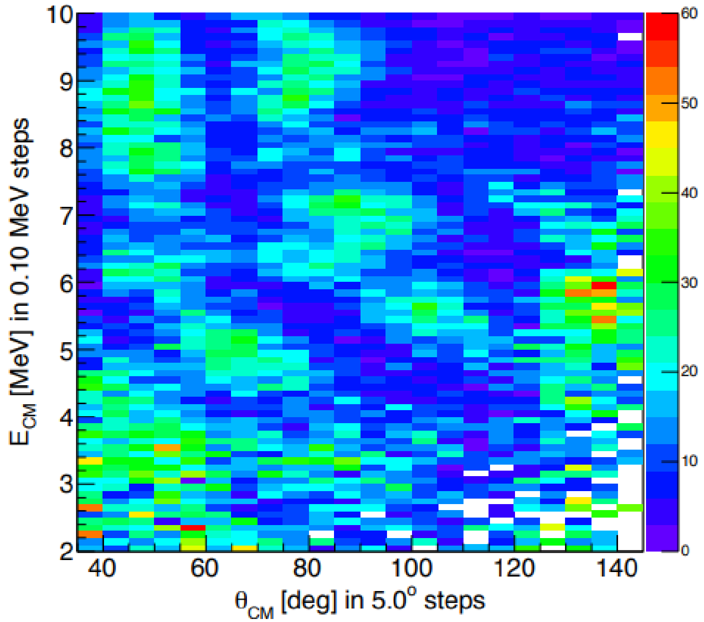
[6] T. Baba, *et al.* Phys. Rev. C **94** (2016) 044303

PREVIOUS EXPERIMENT WITH THE AT-TPC [1]

- Track reconstruction
- Vertex reconstruction ⟶ Excitation energy function
- Obtaining the angle and the energy of the tracks



Angular correlation between the two scattered particles [1]

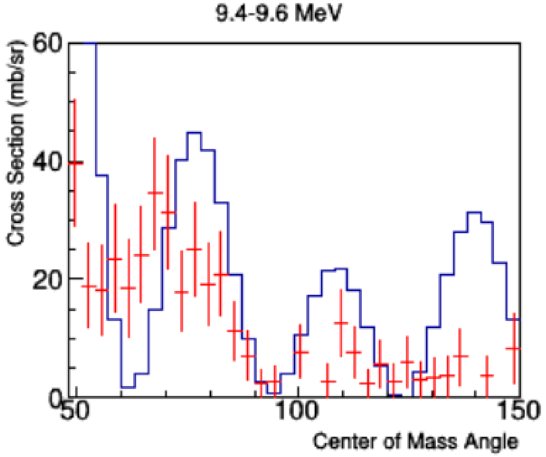


E_{cm} as a function of θ_{CM} for the low energy dataset [9]

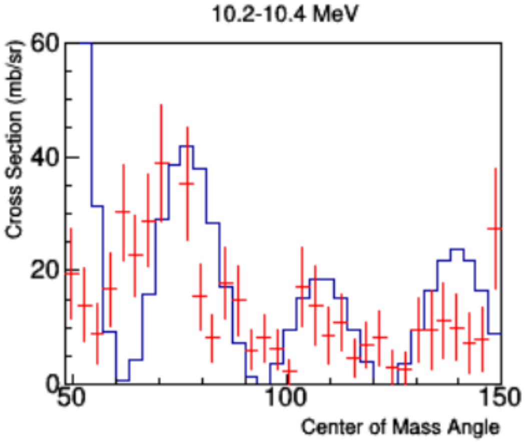
[1] L. Carpenter PhD Thesis

[9] A. Fritsch, *et al.* Phys. Rev. C **93** (2016) 014321

TWO NEW HIGHER-LYING CLUSTER STATES

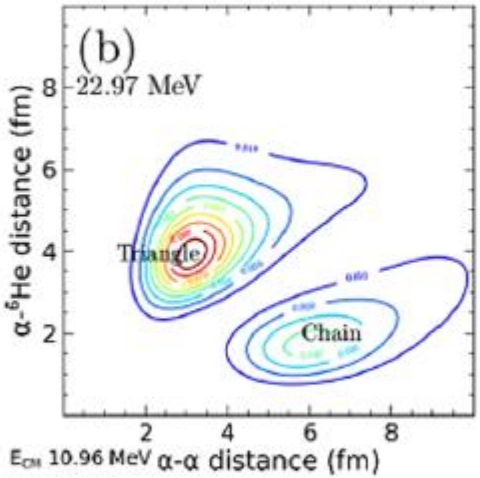


Comparison of calculation (blue line) and experimental data (red points) of the new 9.5 MeV state [1]



Comparison of calculation (blue line) and experimental data (red points) of the new 10.3 MeV state [1]

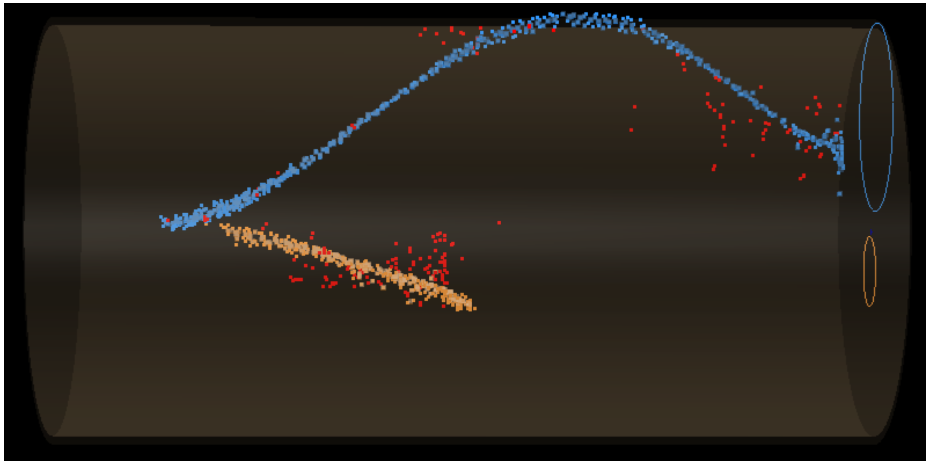
Comparison to Gamow coupled-channel calculation reveals that these states are a **superposition of triangular and LCCS configurations**



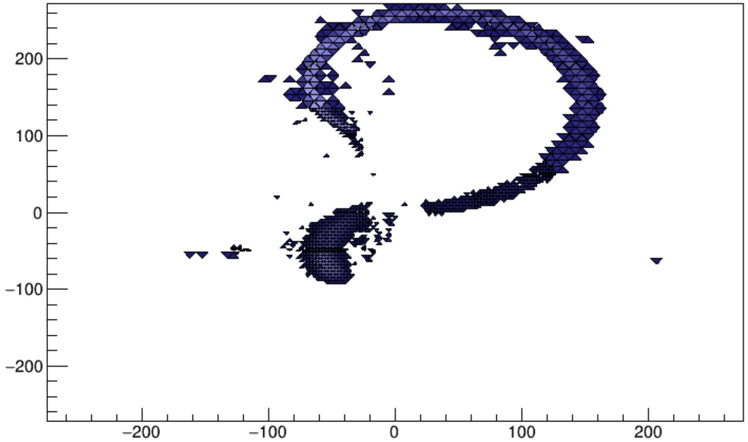
[1] L. Carpenter PhD Thesis

A NEW ^{10}Be + α EXPERIMENT

- Performed at **FRIB**
- ^{10}Be standalone beam at **30 MeV** and **48.5 MeV**
- AT-TPC filled with pure Helium at **300 torr** and **600 torr**
- SOLARIS magnetic field at **2T** → **Bends trajectories and allows obtaining all the information**



Example of a scattering event inside the AT-TPC. The two tracks have been successfully reconstructed

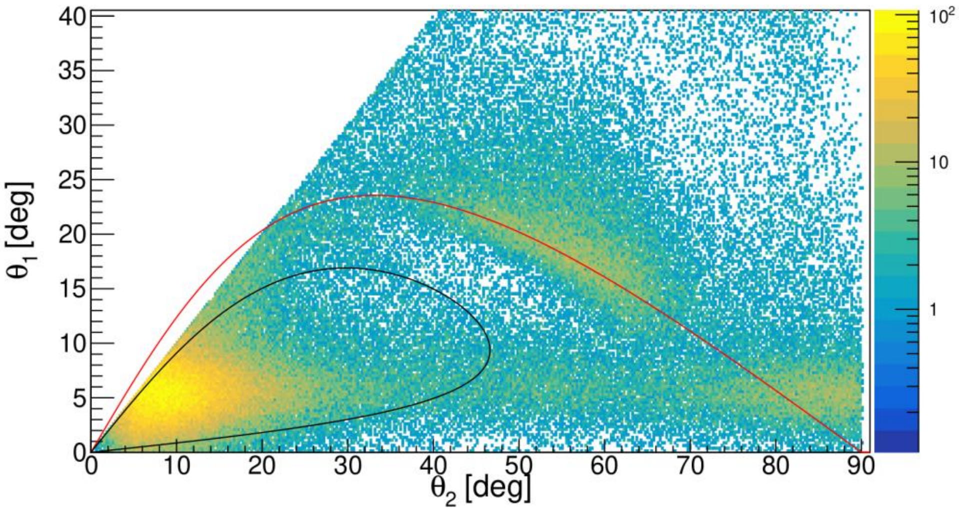


Signal of the padplane after a scattering event

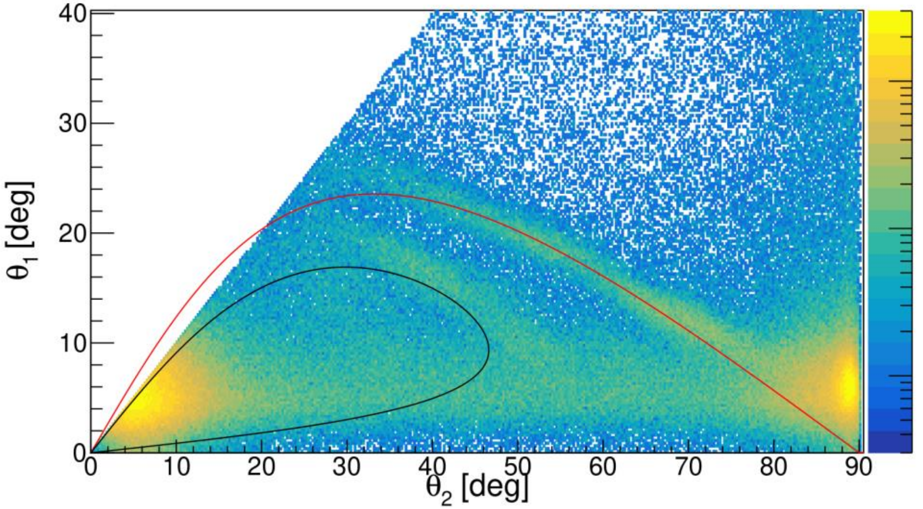
PRELIMINARY RESULTS

Angular correlations of the two scattered particles

Low energy (30 MeV)



High energy (48.5 MeV)



FUTURE WORK

- Improvement of the track clusterization in order to get better and cleaner tracks
- Obtaining the kinematic lines of low- and high-energy data
- Getting the excitation energy function
- Determination of the π-bond and σ-bond states with high precision

THANK YOU!

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