Search for Cluster Structure Using Radioactive Beams and Active Targets

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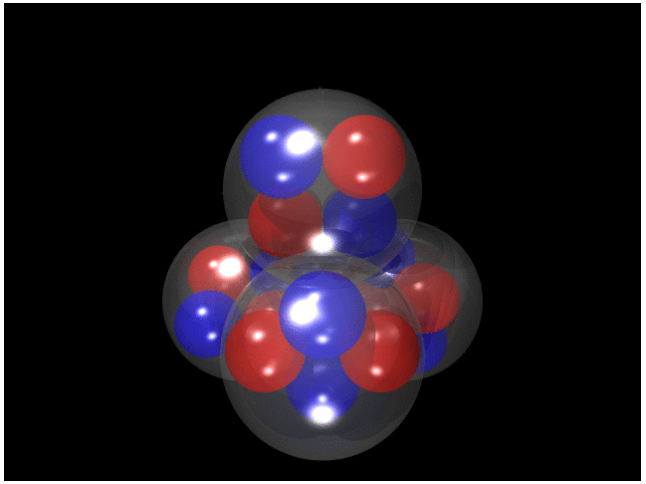
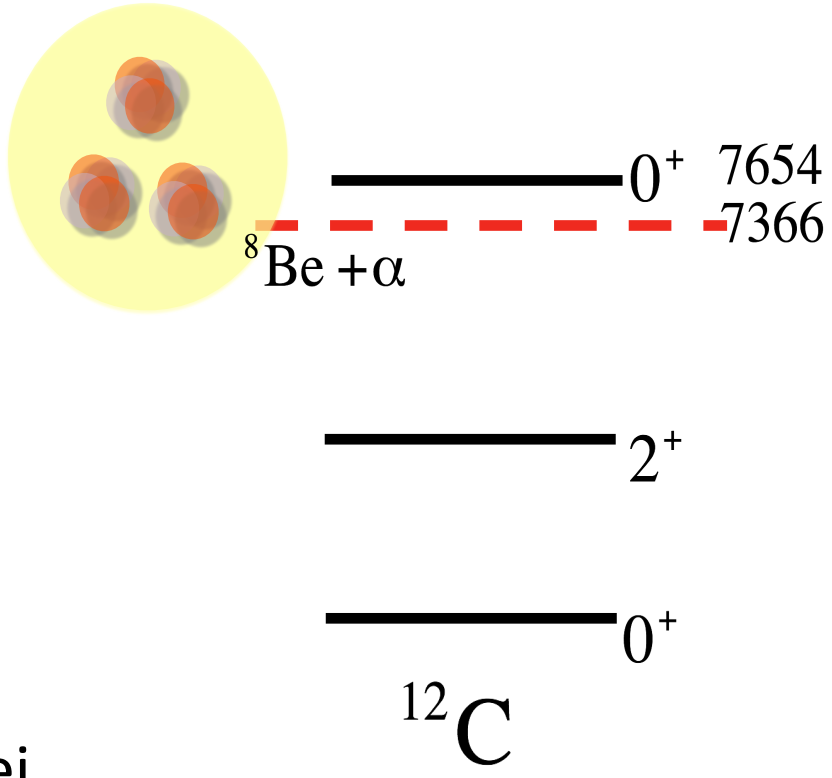
University of Notre Dame

INT Worshop

March 13, 207

Clusters in Nuclei

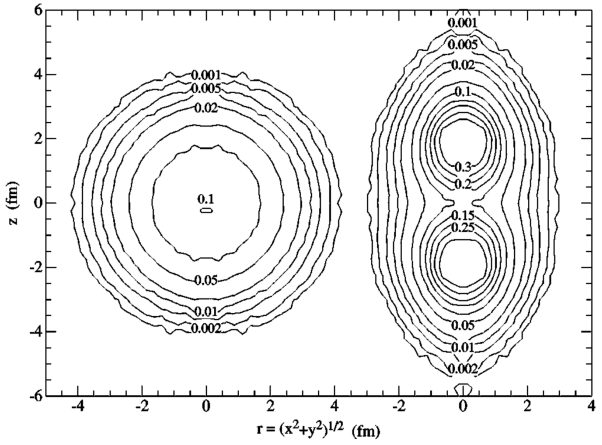




- Emergent structure in nuclei
  - What causes nuclei to cluster?
- Nucleosynthesis in stars and explosive environments
- Nuclear theory

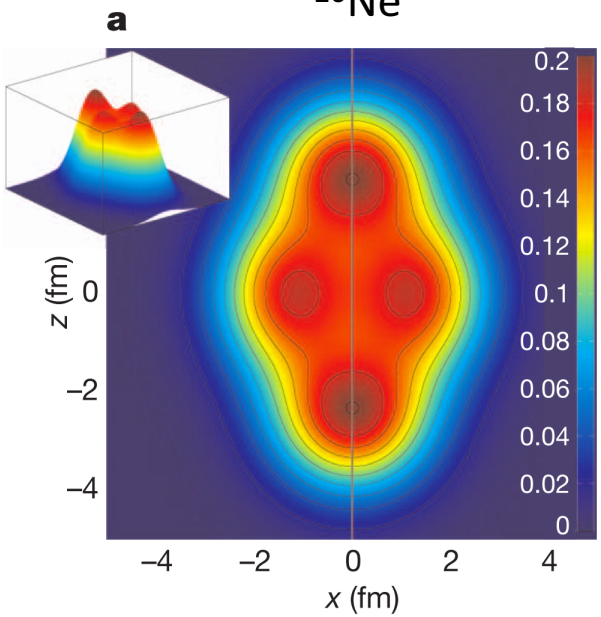
http://www.scholarpedia.org/article/Clusters_in_nuclei

Calculation of clusters from Ab-initio theory



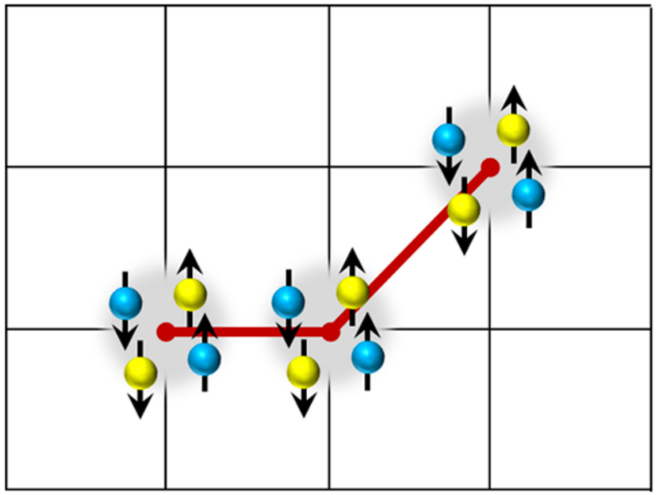
^{8}Be

^{20}Ne

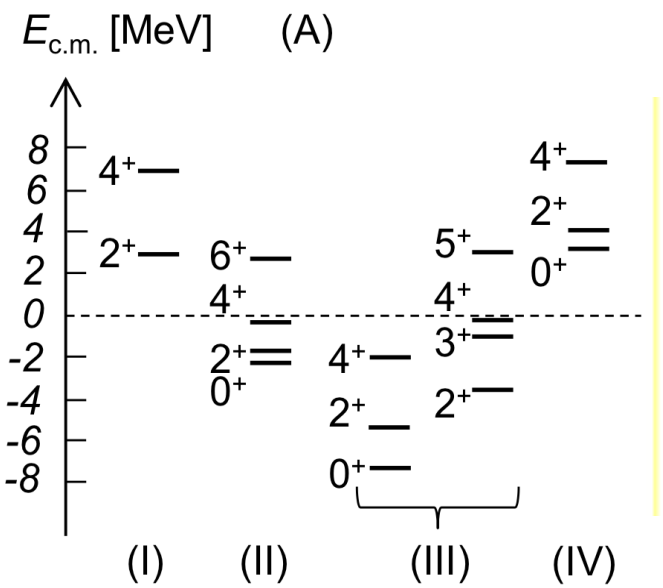


^{12}C(0^{+}_{2})

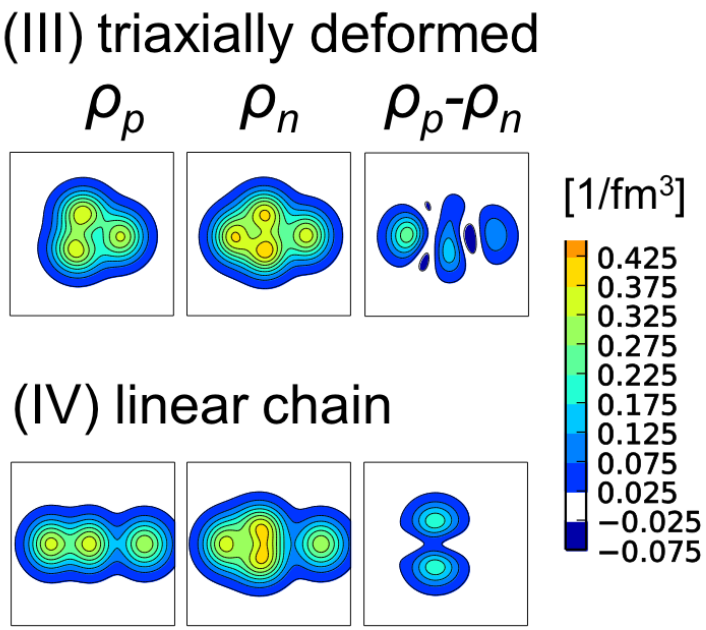
- Green's function Monte Carlo
  - R. B. Wiringa, S. C. Pieper et al., PRC 62 014001 (2000)
- Relativistic Mean-field Theory
  - J. Ebran et al., Nature 487, 341 (2012)
- Lattice EFT
  - Epelbaum et al., PRL 109, 252501 (2012)
- Can we paint a coherent picture?
- Connection to scattering observables?



Clusters with “Valence” Particles



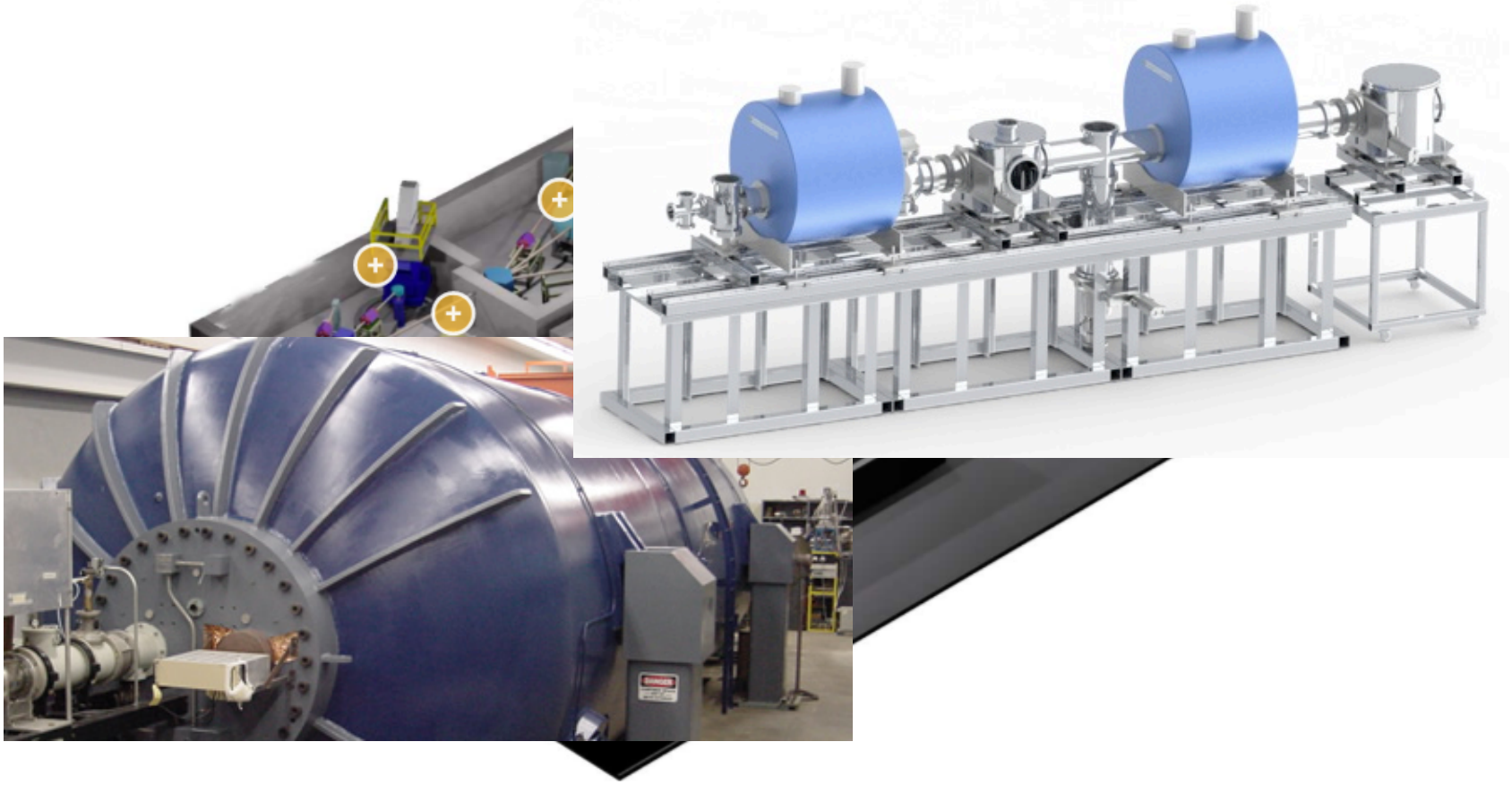
^{14}C



- ”Nuclear Molecules”
- Anti-symmetrized Molecular Dynamics
- Suhara and Kanada-Enyo PRC 82, 044301 (2010)

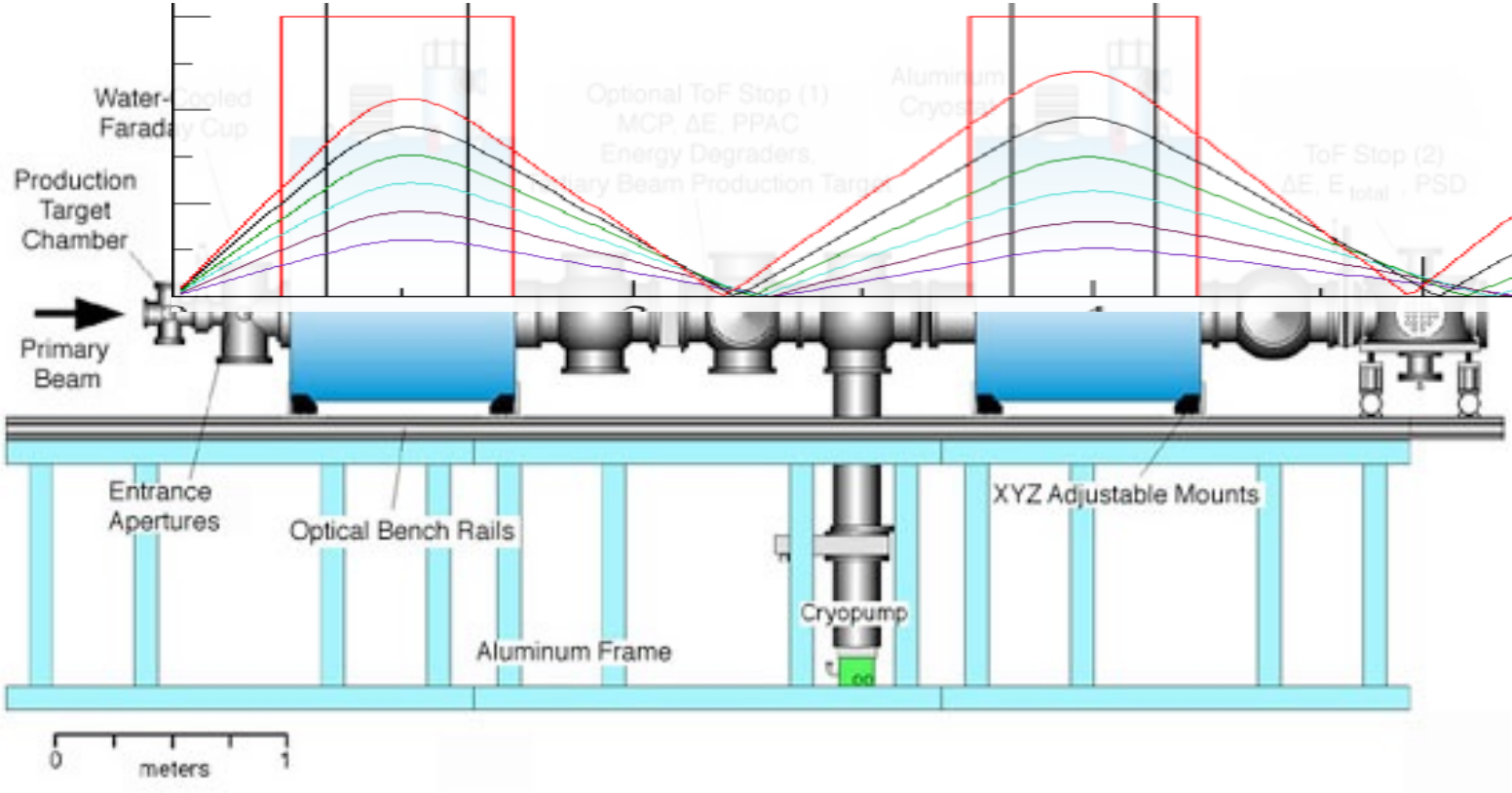
- Resonant alpha scattering: radioactive beam

Institute for Nuclear Structure and Astrophysics at Notre Dame



- 10 MV FN Tandem Van de Graaff Accelerator
- TwinSol – dual superconducting magnets

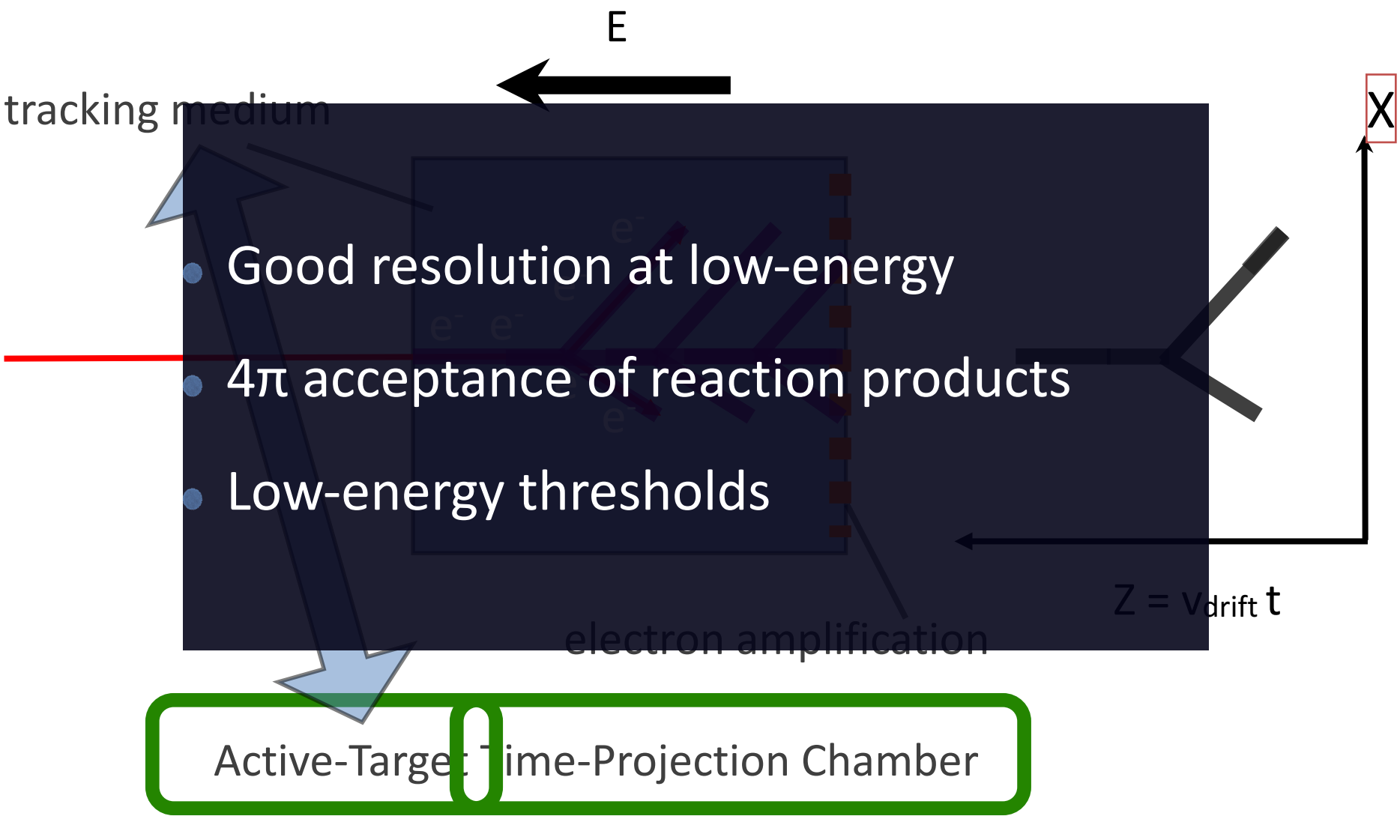
Radioactive Beams at Notre Dame



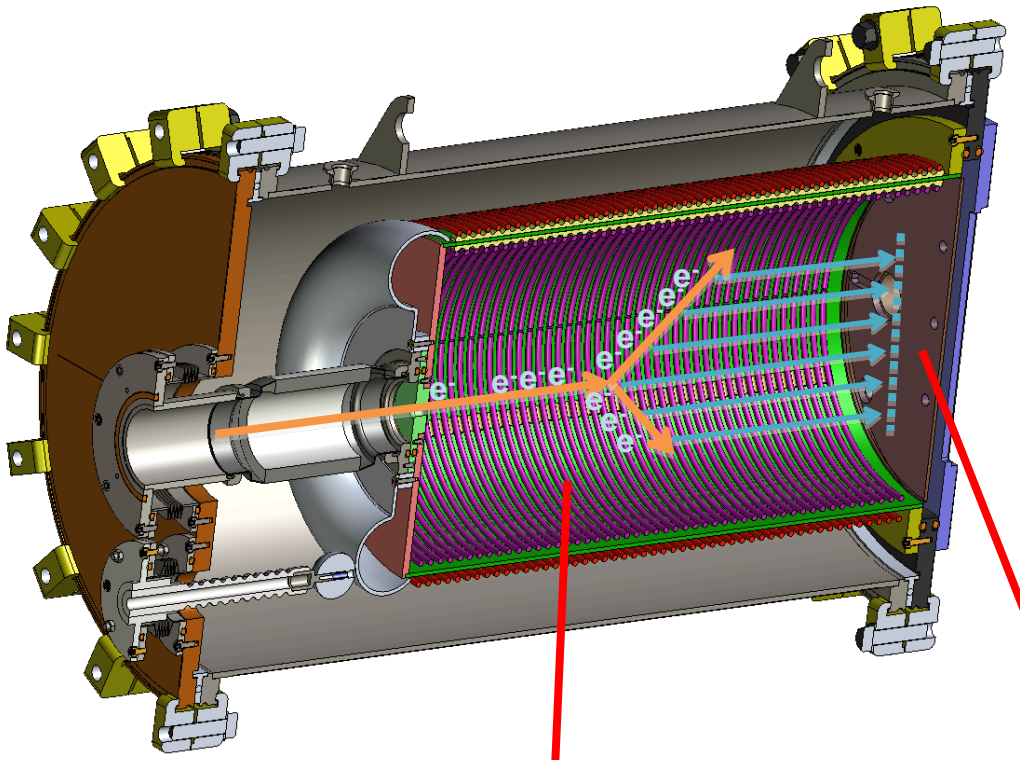
- Light radioactive-ion beams produced in flight
- Transfer reactions
- Prototype Active-Target Time-Projection Chamber

F. Bechetti et al., NIM A 505, 377-380 (2003)

Active-target Concept



Prototype AT-TPC

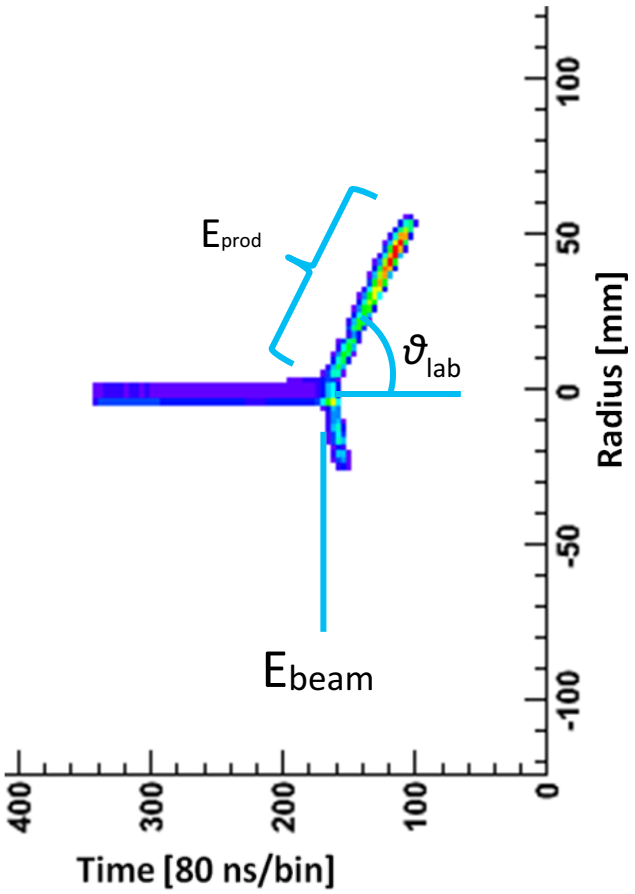


- Target gases
  - He:CO2 – alpha
  - Isobutane, methane, H2 - proton

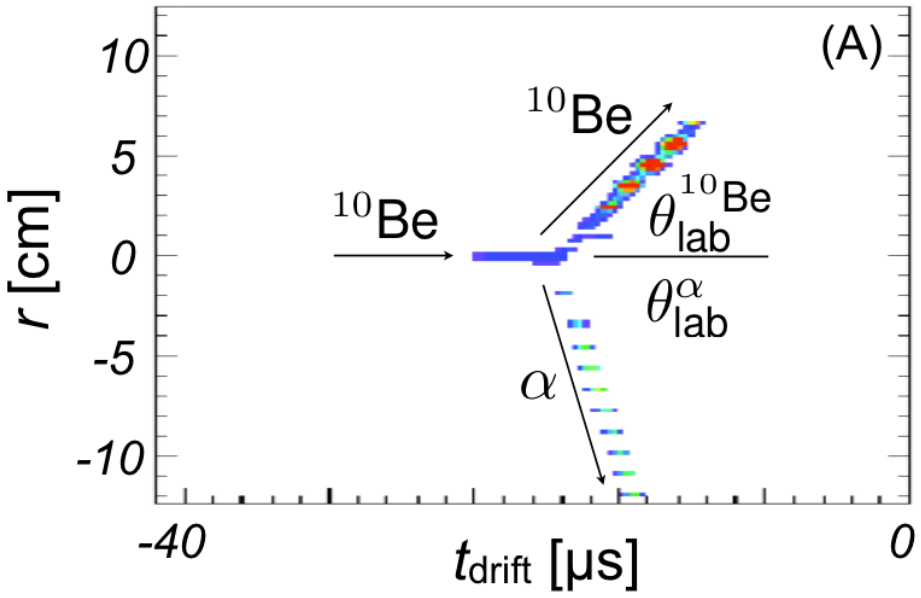
D. Suzuki et al., NIM A, 691 39 (2012)

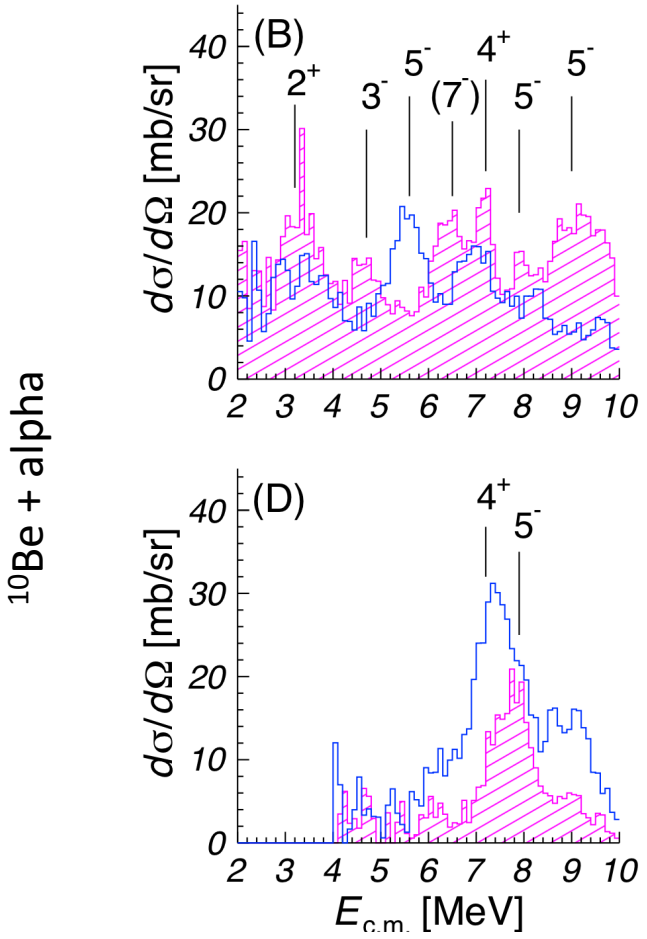
What we measure

- Energy of beam, E_{beam}
  - position
- Angle, θ_{lab}
- Energy of recoil, E_{prod}
  - Bragg curve/range
- Cross Sections: $d\sigma/d\Omega(E,\theta)$



Cluster Structure in ^{14}C

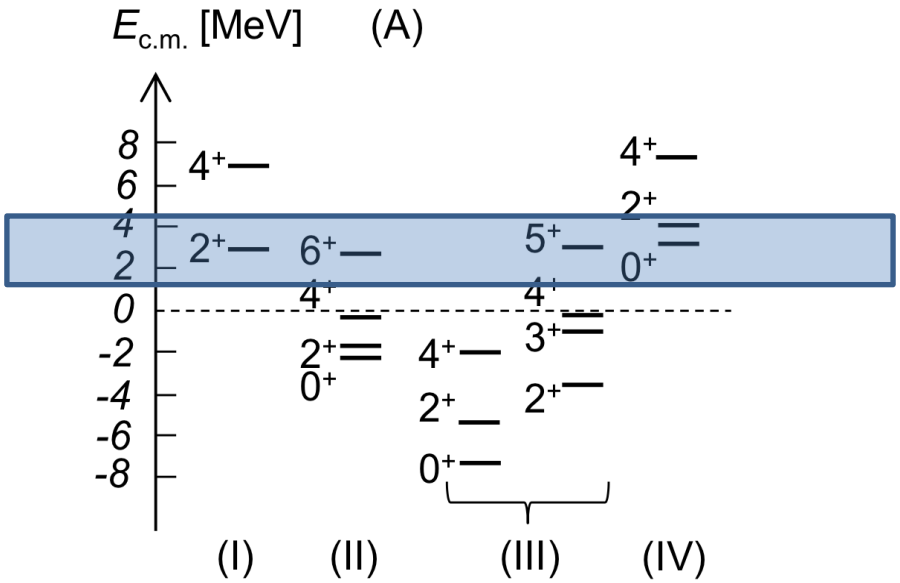


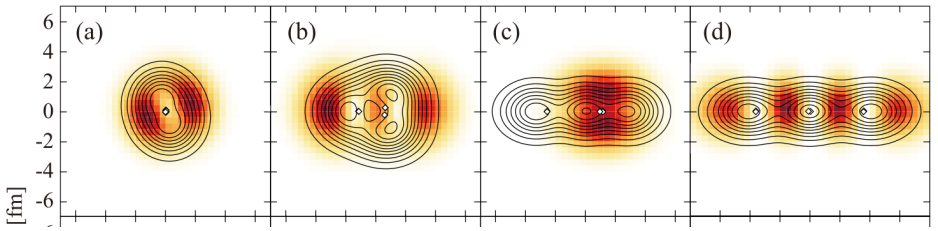


A. Fritsch et al. PRC 93, 014321 (2016)

- Resonant alpha scattering to study structure of ^{10}Be, ^{14}C, ^{14}O
  - Used TwinSol beams of ^{6}He, ^{10}Be, ^{10}C
  - Cross sections and angular distributions
  - Ability to measure inelastic scattering directly: angles, energy

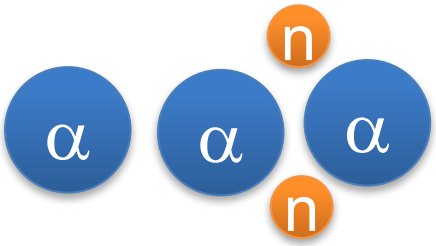
Cluster Structure in ^{14}C



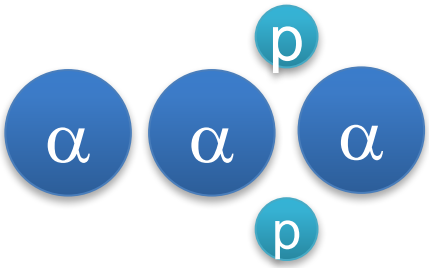


- Suhara, Kanada-Enyo PRC 82, 044301 (2010)
  - Triaxial and linear chain rotational bands (III) + (IV)
- Freer et al. PRC 90, 054324 (2014), Fristch et al. PRC 93, 014321 (2016), Yamaguchi et al. Phys. Lett. B 766, 11 (2017)
- Baba et al., PRC 94, 044303 (2016)
  - Pi-bond rotational band agree with experiment
  - Large cross section in inelastic channel

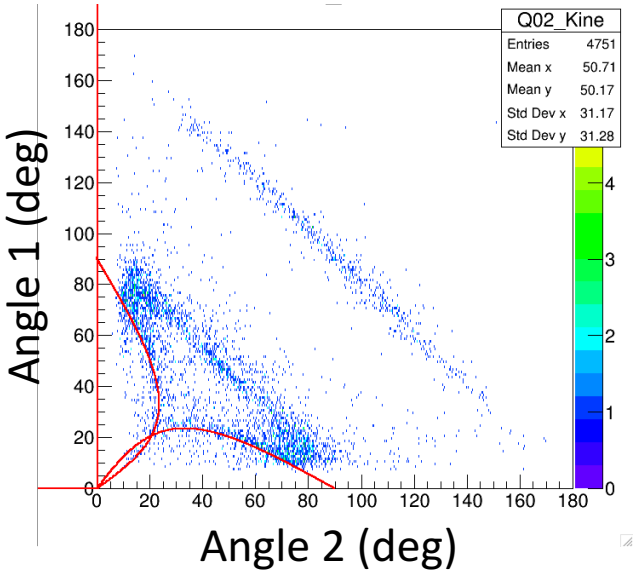
Search for Clusters in Isospin Mirror ^{14}O



?

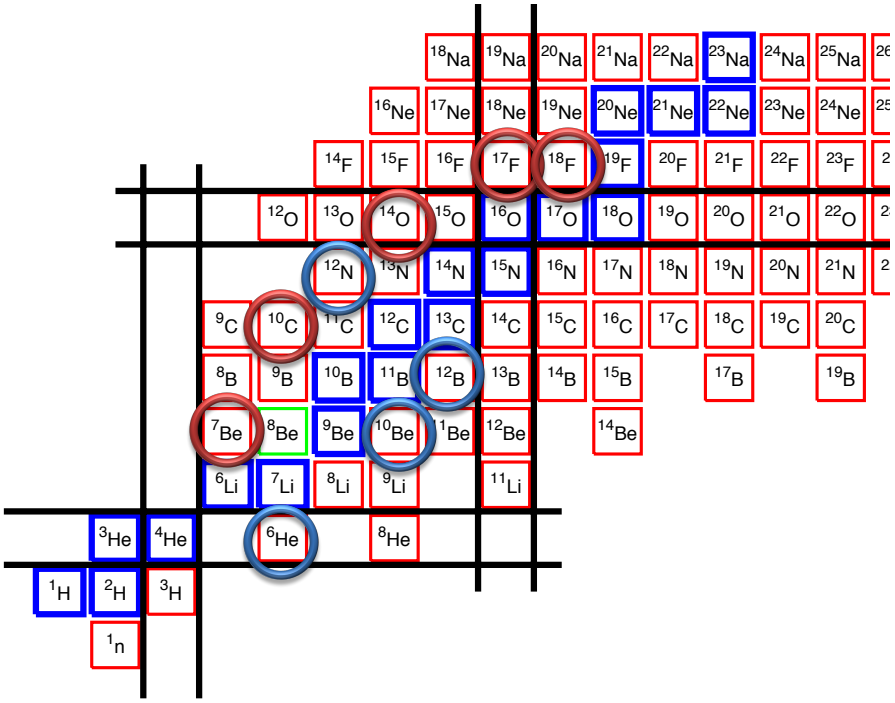


- ^{10}C + alpha scattering
- Isospin symmetric or isospin-breaking?
- Nuclear models?
- ^{22}Mg and ^{22}Ne



^{10}C + alpha elastic

Present and Future TwinSol Beams



- 10^2- 10^5 pps
- Scattering and light-ion reactions

Summary and Outlook

- Search for cluster structure in unstable nuclei
  - TwinSol and PAT-TPC at Notre Dame
  - Measure precisely cross sections
- Linking Clusters, Scattering observables, and Theory
- Any ideas for measurements are welcome

Acknowledgements

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Thank you!