# Probing the dynamics of open quantum systems with low-energy elastic scattering of halo nuclei

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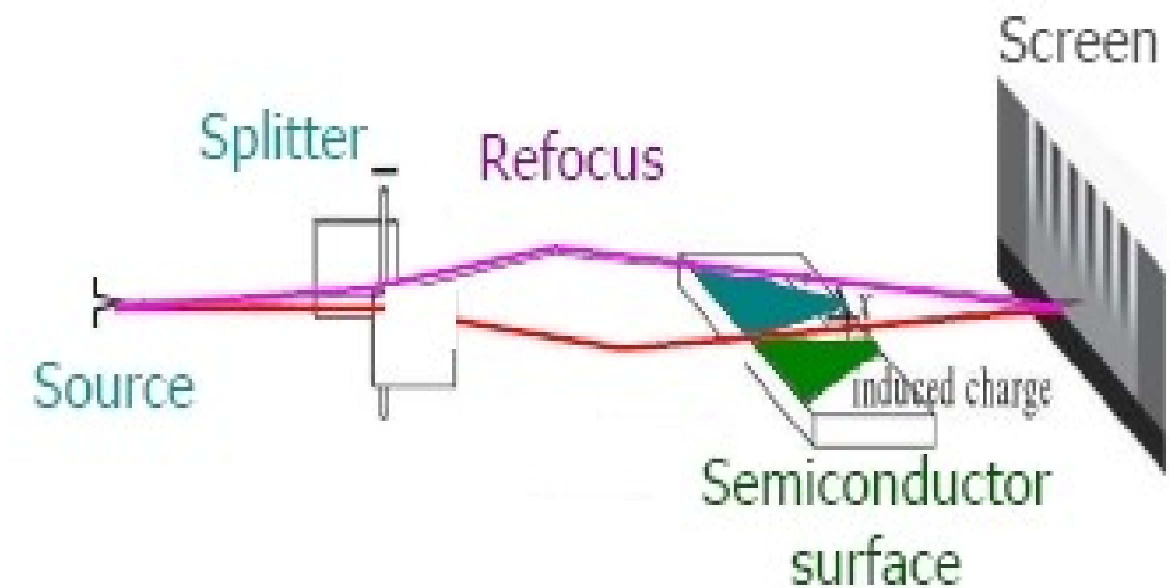
**What I will tell you**

- Motivation
- Near-barrier elastic scattering of $^{11}$**Be** + $^{64}$**Zn**
- Conclusions & Outlook

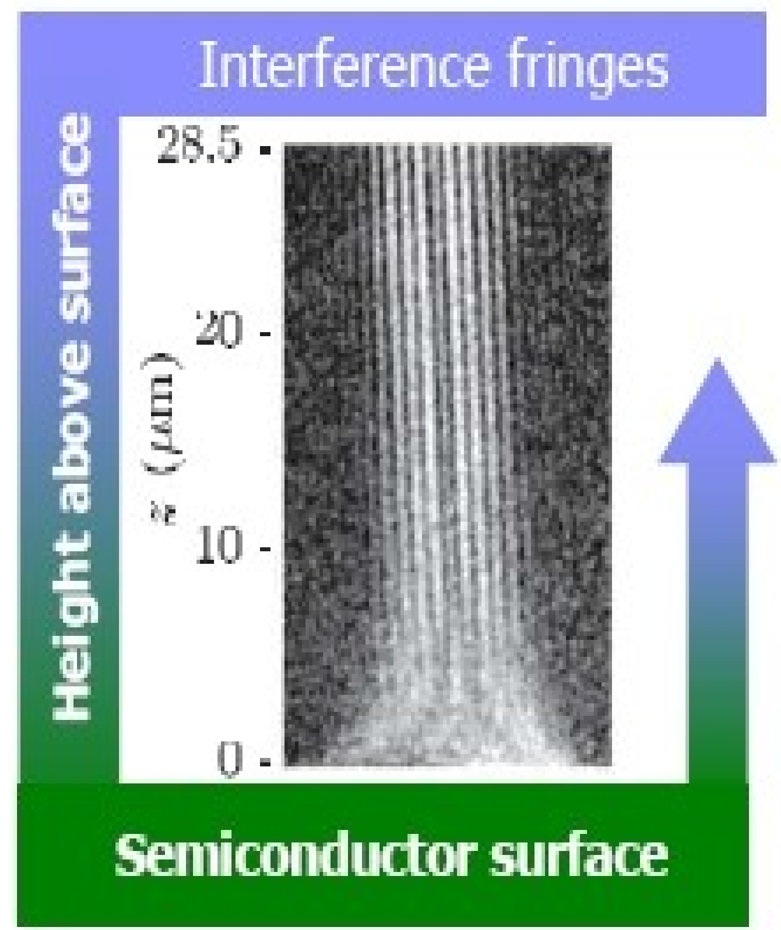
# Loss of Quantum Coherence

## Electron entanglement with a surface

Double-slit type experiment with single electrons




Sonnentag & Hasselbach, PRL **98** (2007) 200402

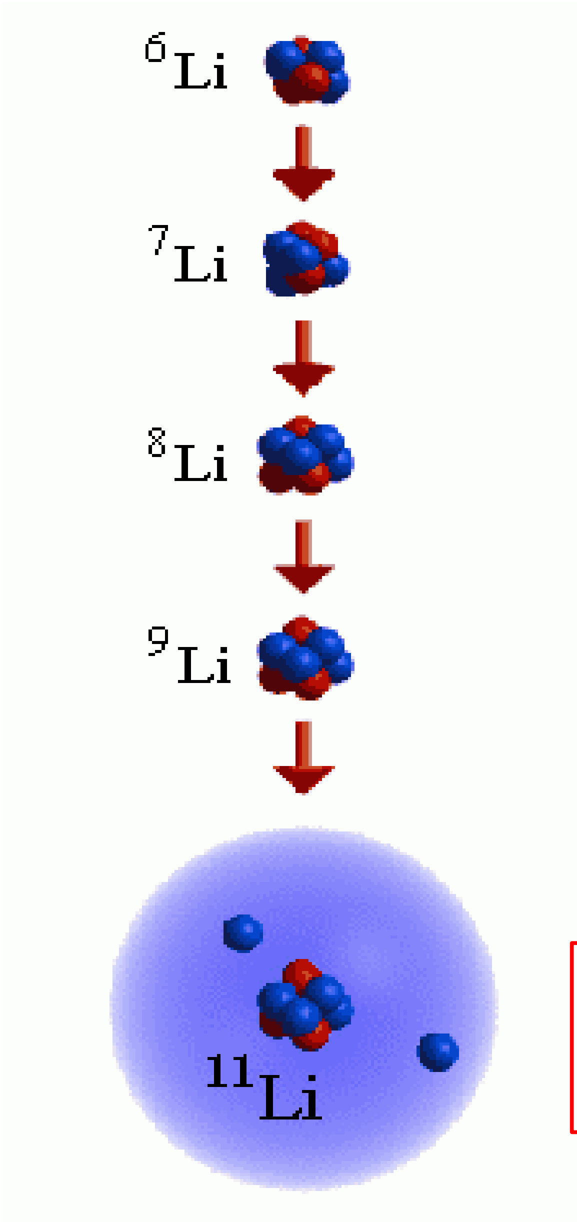



Courtesy of David Hinde

- Decoherence – “dynamical dislocalization of quantum mechanical superpositions”

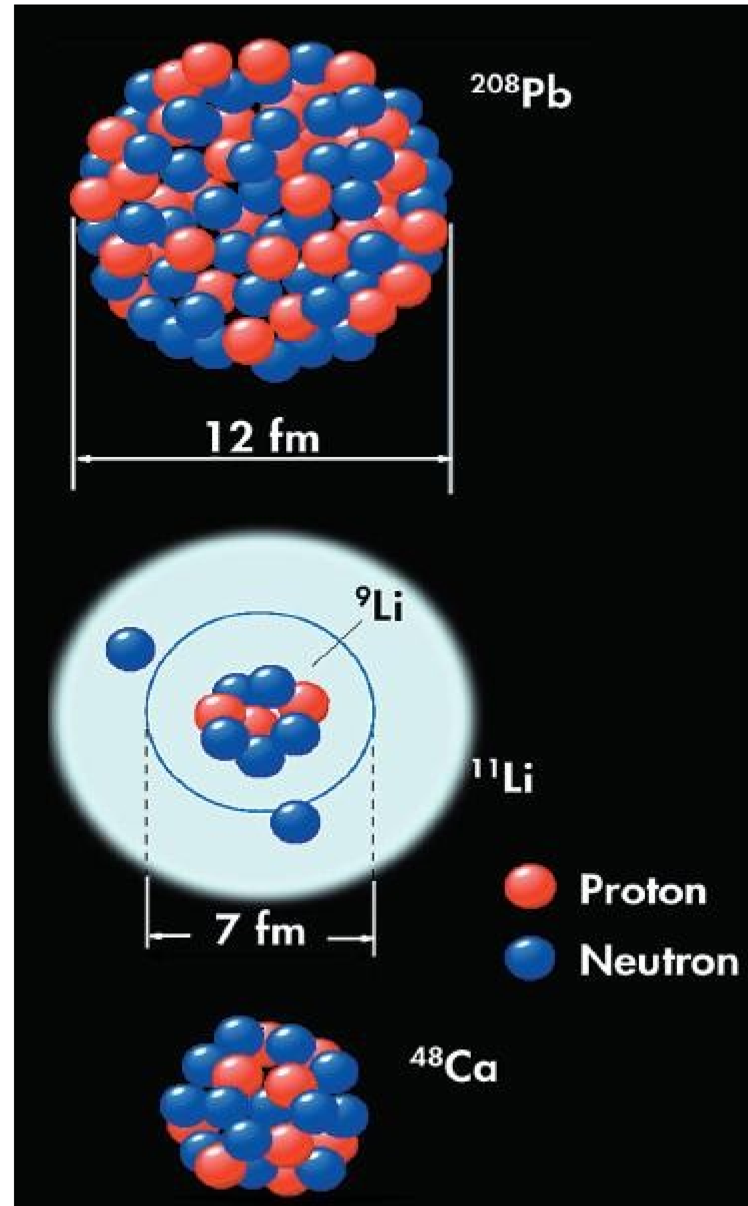
(H.D. Zeh arXiv:quant-ph/0512078 v2) coherence shared with (lost in) environment

# Open Quantum Systems: Halo Nuclei



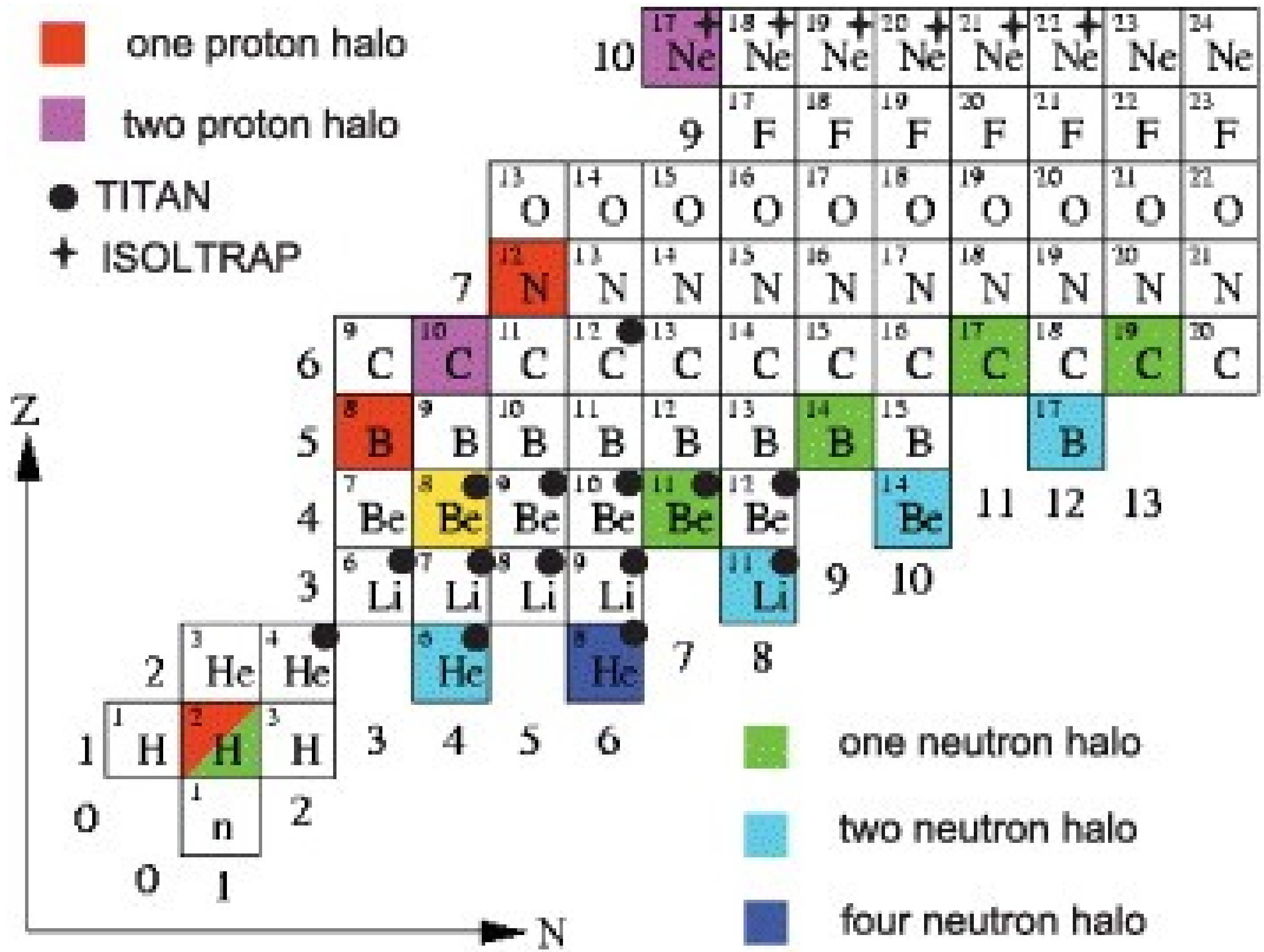

$S_n = 4.06$ MeV

$\mathbf{S_n = 0.32}$ **MeV**




A.S. Jansen et al, RMP **76** (2004) 215

# Table of Light Nuclei

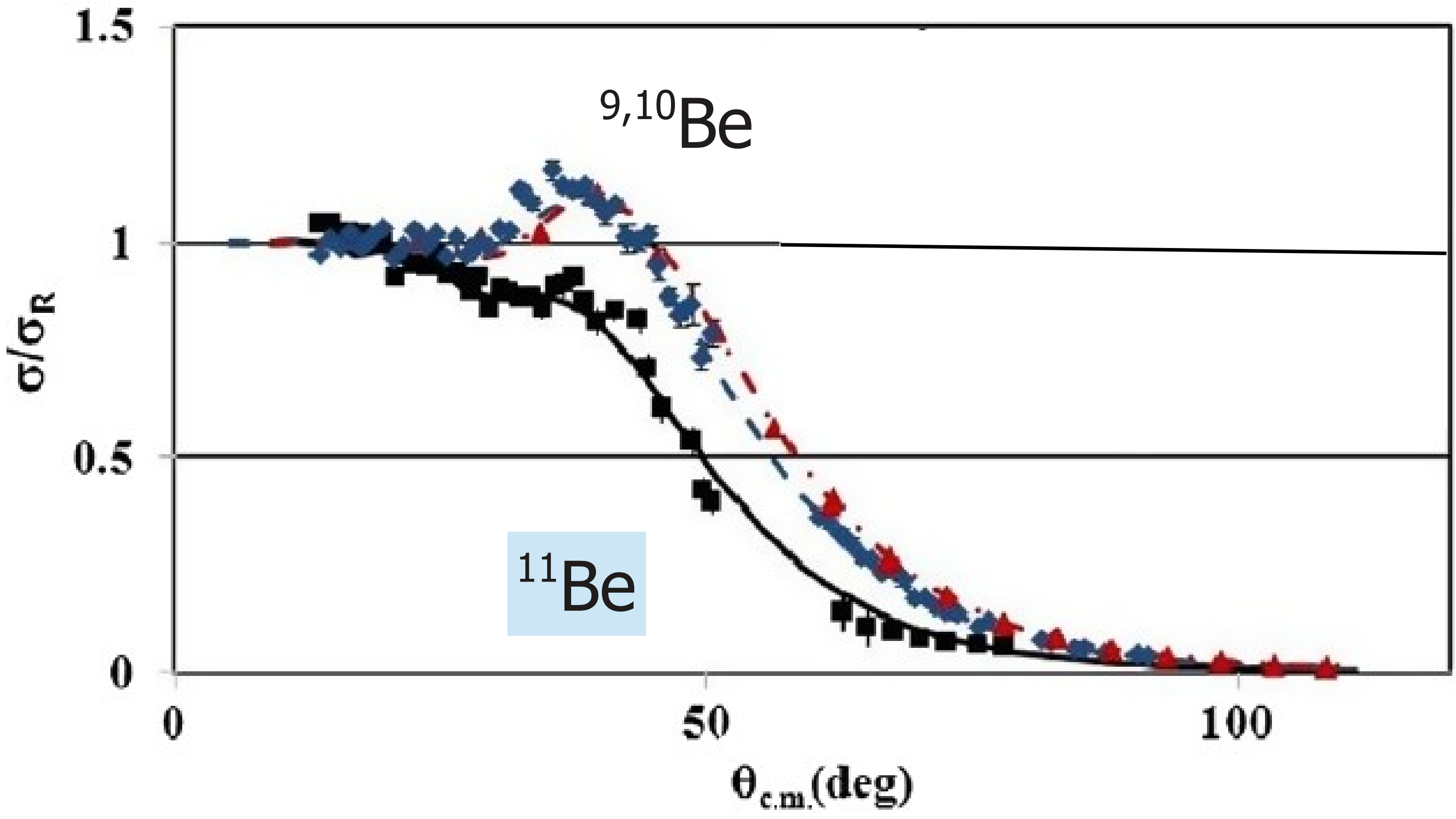


# Rare-Isotope Beam Facilities


**Nuclear Reactions are the primary probe of the New Physics**

Elastic scattering of Beryllium isotopes by the $^{64}$Zn target

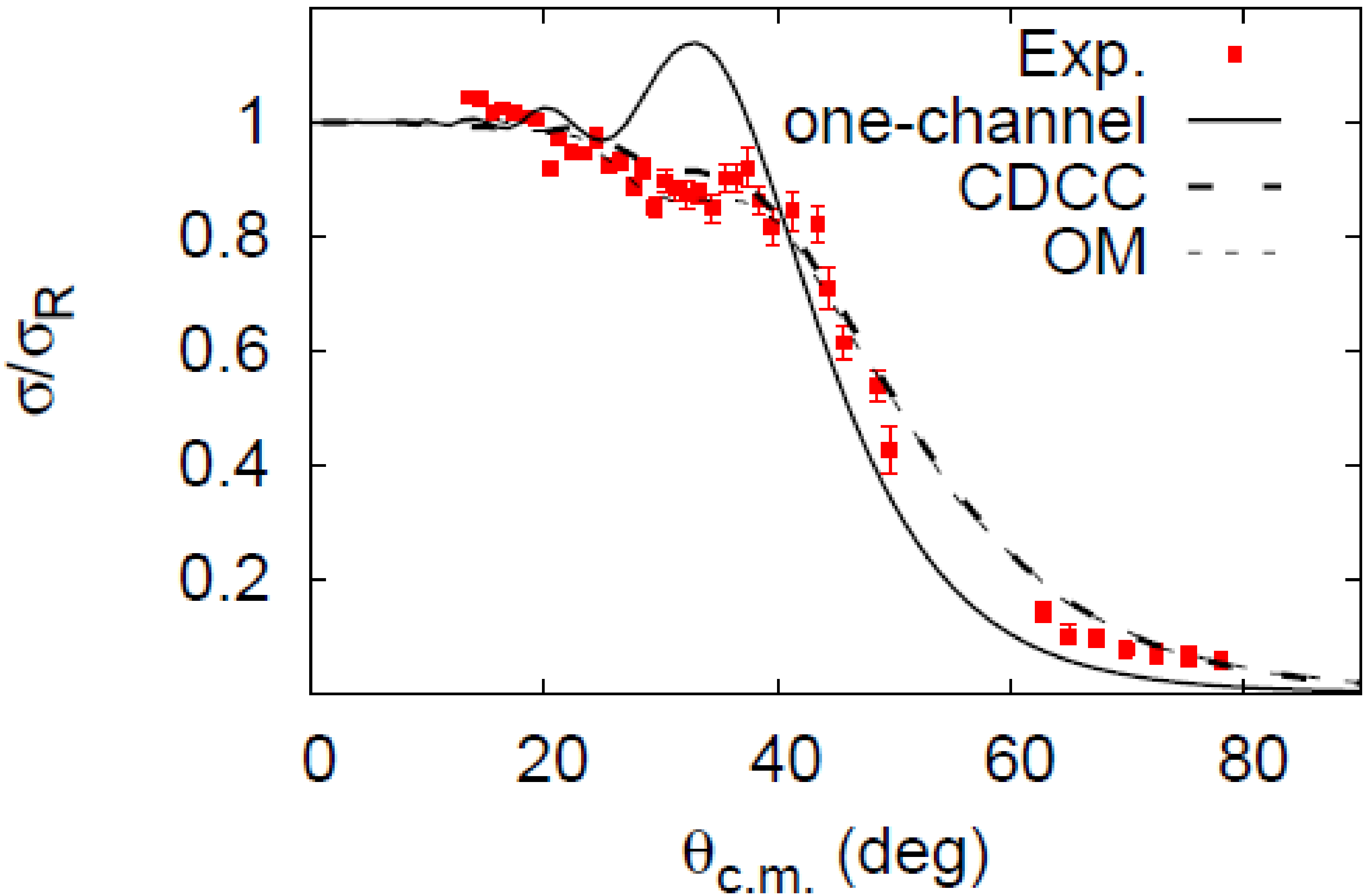
A. Di Pietro et al, PRL **105** (2010) 022701




Suppression of the Coulomb-nuclear interference peak for $^{11}$**Be**

# Elastic scattering of $^{11}Be + ^{64}Zn$ at Ecm = 24.5 MeV

A. Di Pietro et al, PRC **85** (2012) 054607

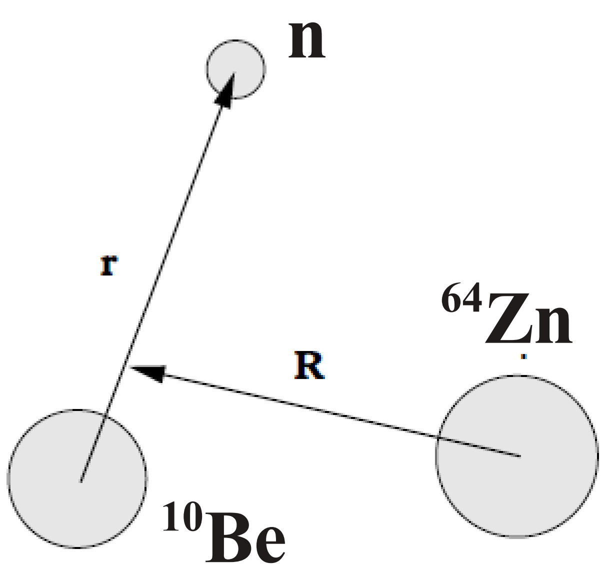


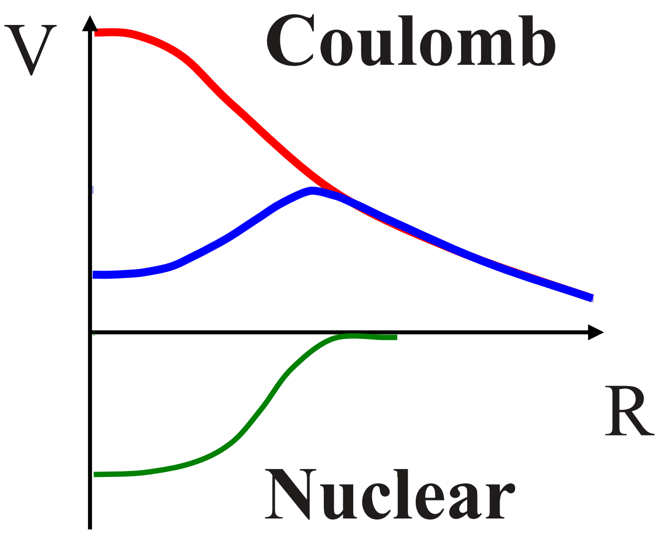
# Some Formulae

G.R. Satchler, Direct Nuclear Reactions (Clarendon Press, Oxford, 1983)

$$\sigma/\sigma_R = 1 + \frac{|f_N(\theta)|^2}{|f_C(\theta)|^2} + \frac{2\,Re\left[f_C^*(\theta) f_N(\theta)\right]}{|f_C(\theta)|^2}$$

**Nuclear** **Coulomb-nuclear interference**



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**Nuclear** **Coulomb-nuclear interference**

$$f_C(\theta) = -\frac{\eta}{2k\sin^2(\theta/2)}\, e^{-i\eta \ln \sin^2(\theta/2) + 2i\sigma_0}$$

$$\mathrm{g}(\theta) = f_C(\theta) + \frac{i}{2k}\sum_L \left[(2L+1) - (L+1)S_L^+ - LS_L^-\right] e^{2i\sigma_L} P_L(\cos\theta)$$

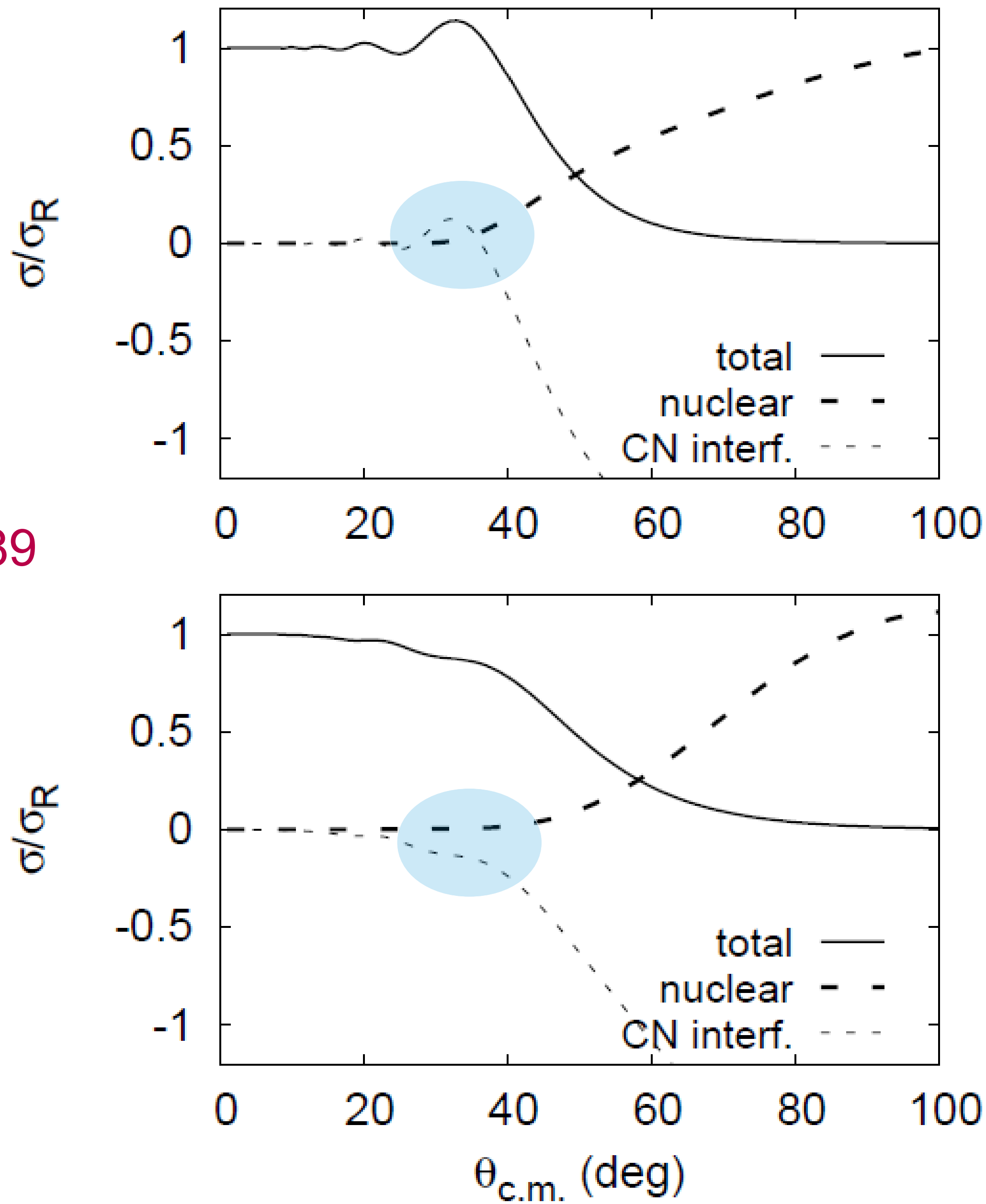
$$\mathrm{h}(\theta) = \frac{i}{2k}\sum_L \left(S_L^- - S_L^+\right) e^{2i\sigma_L} P_L^1(\cos\theta)$$

$$\frac{d\sigma(\theta)}{d\Omega} = |g(\theta)|^2 + |h(\theta)|^2$$

**Particles with spin 1/2**

# Decomposition of the elastic-scattering angular distribution

**$^{11}Be + ^{64}Zn$ @ Ecm = 24.5 MeV**




**one-channel**

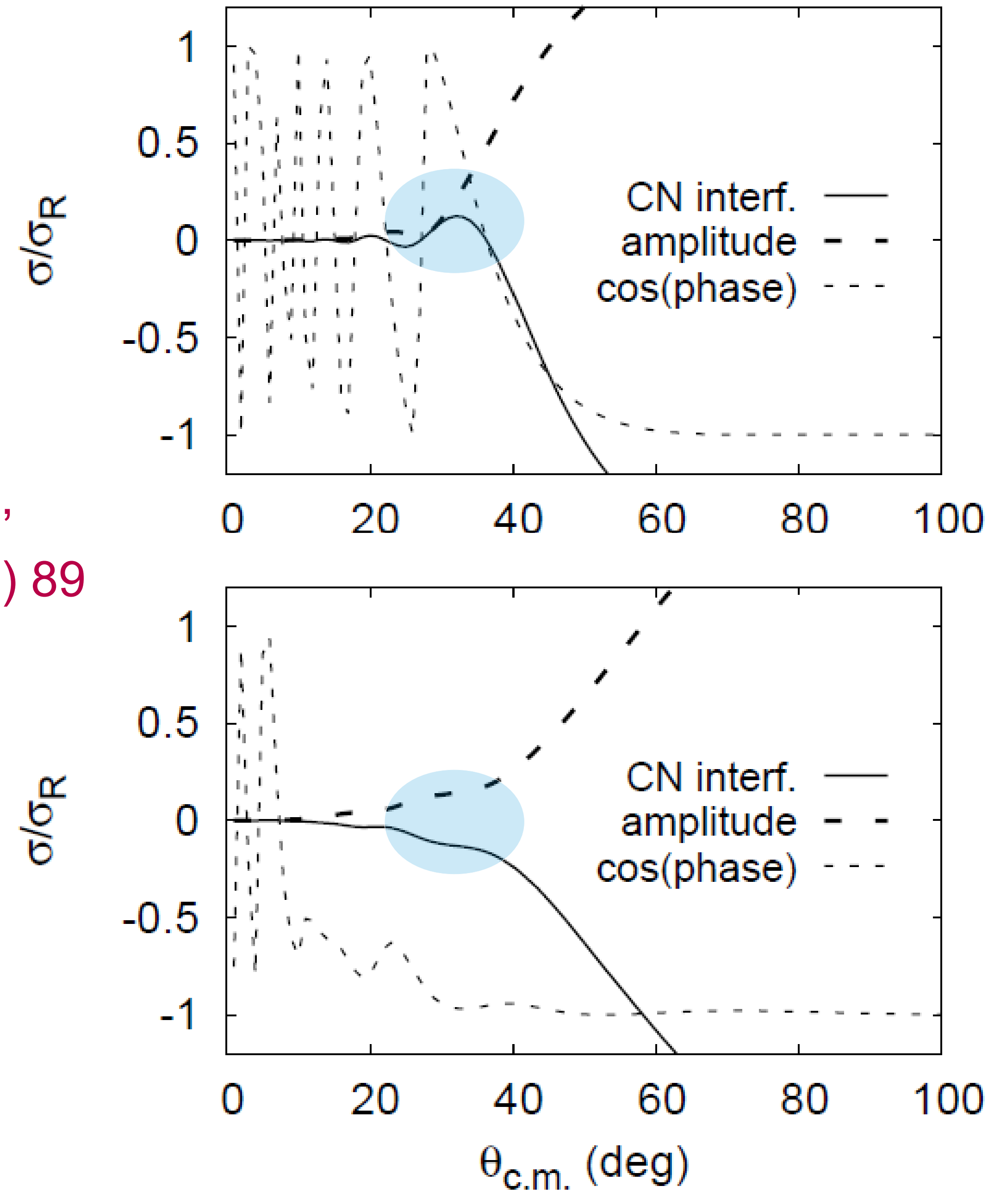
**CDCC**

ADT & Moro,

PLB **733** (2014) 89

# Decomposition of the Coulomb-nuclear interference term

**$^{11}$Be + $^{64}$Zn @ Ecm = 24.5 MeV**




**one-channel**

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ADT & Moro,

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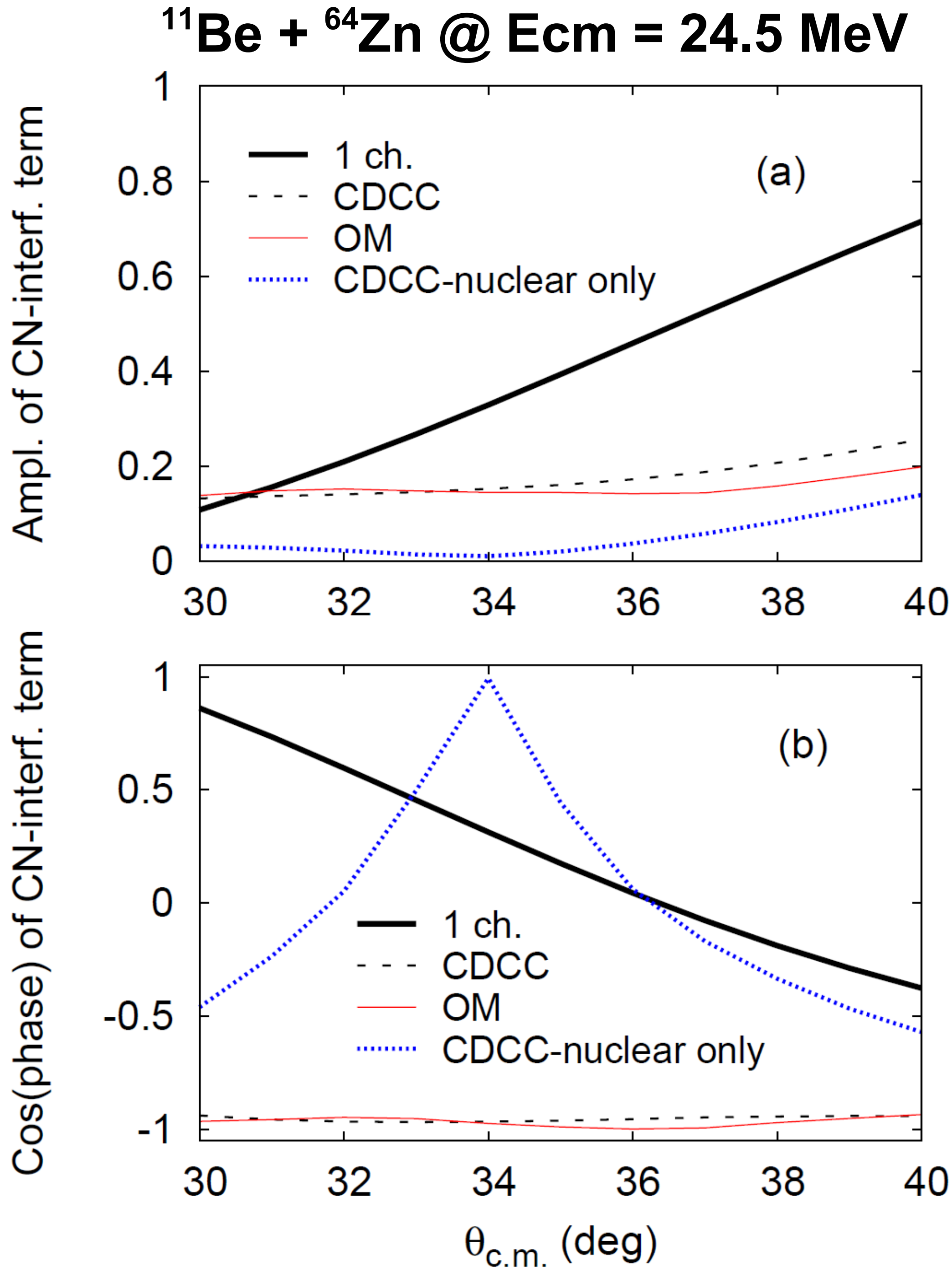
# Amplitude & Phase of the Coulomb-nuclear interference




**Amplitude**

**Cosine of the Phase**

ADT & Moro,

PLB **733** (2014) 89

# What I told you

- The **Coulomb-nuclear interference** is **critical** for the elastic-scattering angular distribution.

- The Coulomb-nuclear interference **declines** and becomes **destructive** due to **continuum couplings**.

- **Could the elastic scattering of halo nuclei be a tool for investigating the dynamics of open quantum systems in nuclear physics?**

| | | |
|---|---|---|
| **Halo Projectile** | ➔ | **Breakup Threshold** |
| **Target Nucleus** | ➔ | **Breakup Couplings** |
| **Incident Energy** | ➔ | **Control Variable** |