

Modeling Short-Range Nucleon Pair and Triplet Abundances in Atomic Nuclei

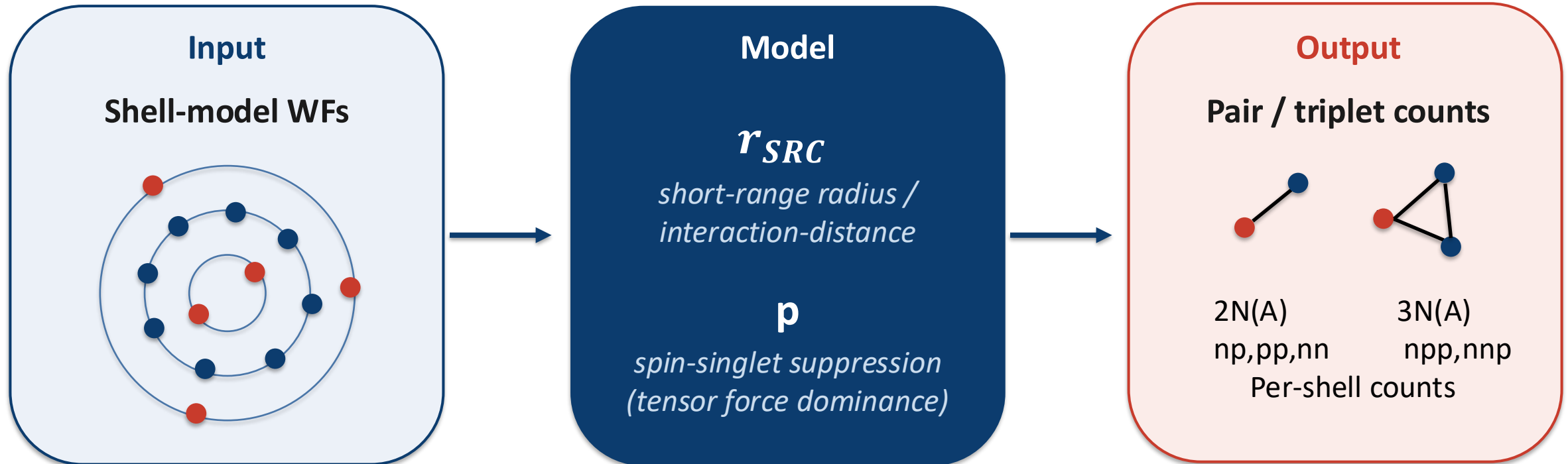
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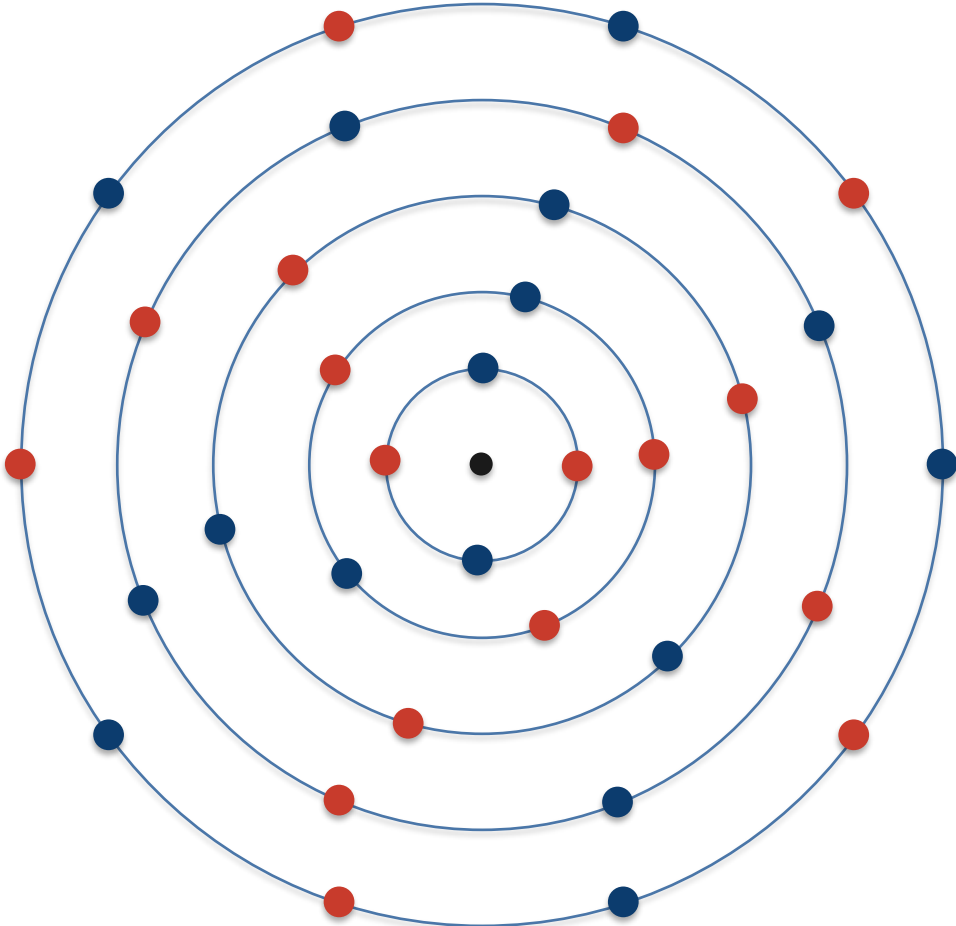
What this model does

Shell-model input \rightarrow number of SRC pairs and triplets across A



Calibrated once to ^{12}C : SRC/A , $pp/np \rightarrow r_{SRC} \approx 0.9 \text{ fm}$, $p \approx 0.15$

Shell-model wavefunctions

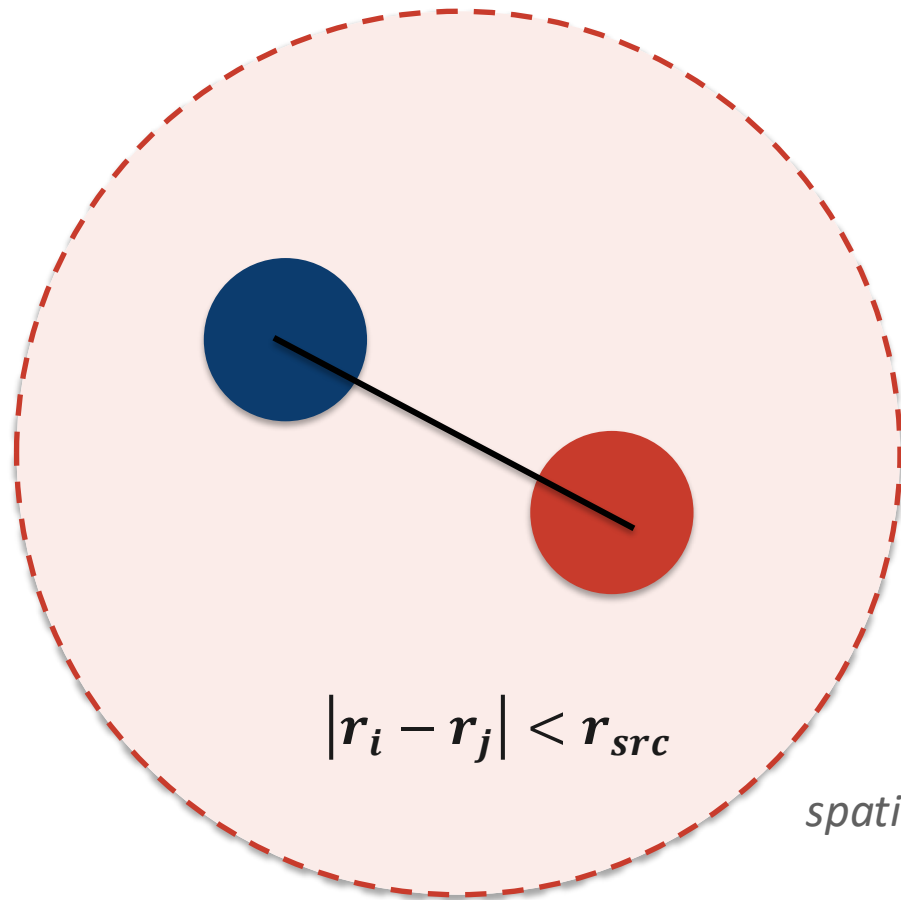


$$R_{n,l}(r)Y_{lm}(\theta, \phi)$$

single-particle WF in 3D HO basis

shell model occupations

Spatial Overlap and Symmetry



- Baseline assumption: spatial WF overlap \Rightarrow SRCs
- At close range, spatially anti-symmetric part goes to zero

$$\Psi_S^{ij} = N_{ij} [\psi_i(\mathbf{r}_i) \psi_j(\mathbf{r}_j) + \psi_i(\mathbf{r}_j) \psi_j(\mathbf{r}_i)]$$

$$S^{ij} \times \int_{|\mathbf{r}_i - \mathbf{r}_j| < r_{src}} |\Psi_S^{ij}(\mathbf{r}_i, \mathbf{r}_j)|^2 d^3r_i d^3r_j$$

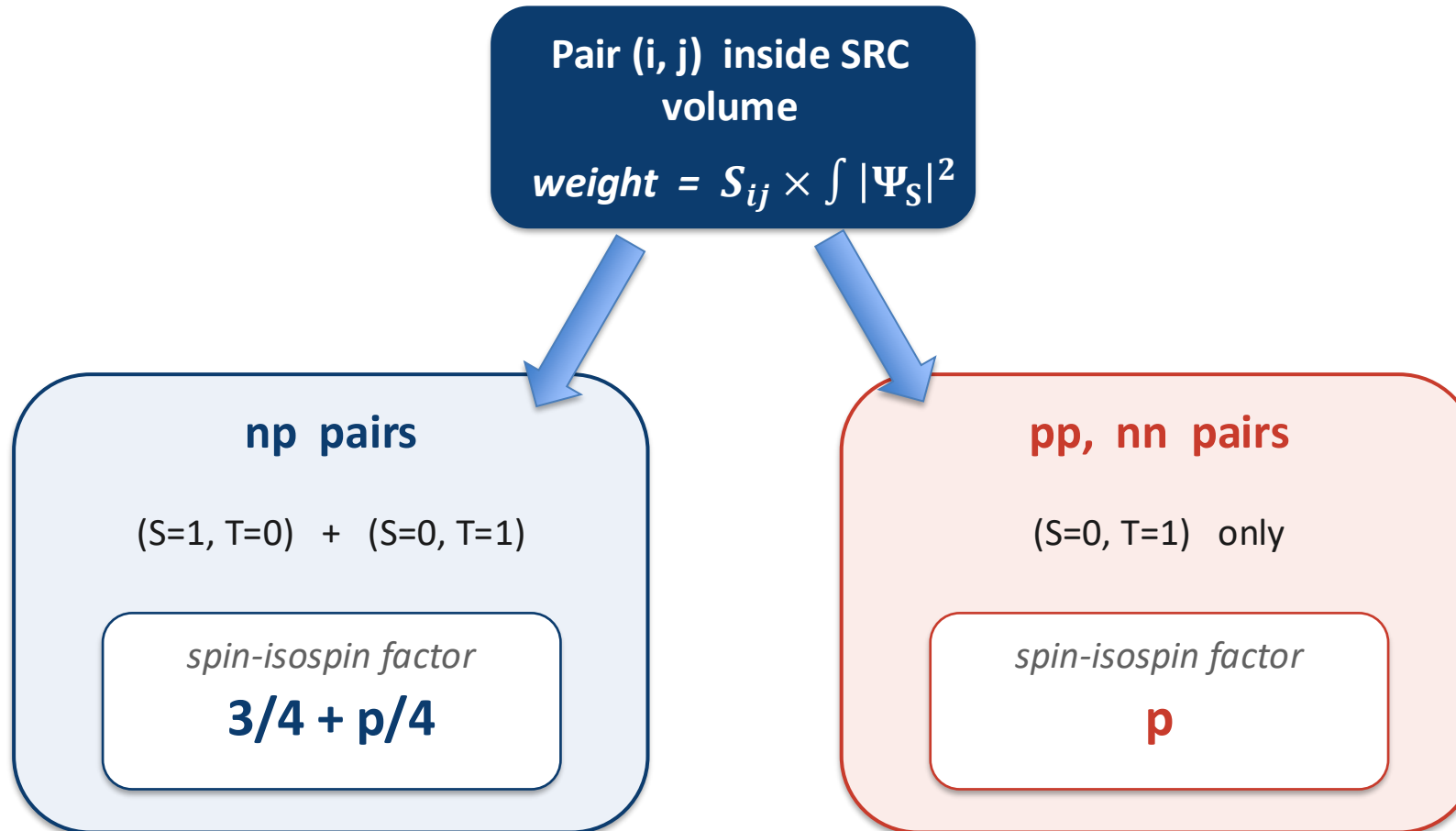
spatially symmetric fraction inside SRC vol.

$$\Psi^{ij} = \Psi_S^{ij} \chi_A^{ij} + \Psi_A^{ij} \chi_S^{ij}$$

$$\left(\lim_{|\mathbf{r}_i - \mathbf{r}_j| \rightarrow 0} S_{ij} = 1 \right)$$

gives ZRA

Spin-isospin Dependence



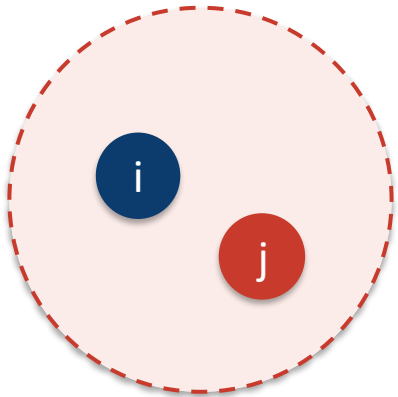
T=1,S=0 pairs are less likely to form SRC pairs by a factor **p**.

Model Description

Spatial overlap × spatial symmetry × spin-isospin

1 Spatial overlap

$$\int_{|\mathbf{r}_i - \mathbf{r}_j| < r_{src}} |\Psi_S^{ij}(\mathbf{r}_i, \mathbf{r}_j)|^2 d^3r_i d^3r_j$$



$$|r_i - r_j| < r_{src}$$

Probability two nucleons sit in close proximity.

2 Spatial symmetry

S_{ij} = spatially symmetric fraction inside SRC vol.

$$\Psi^{ij} = \Psi_S^{ij} \chi_A^{ij} + \Psi_A^{ij} \chi_S^{ij}$$

Of the WF inside that sphere, how much is spatially symmetric?

3 Spin–isospin

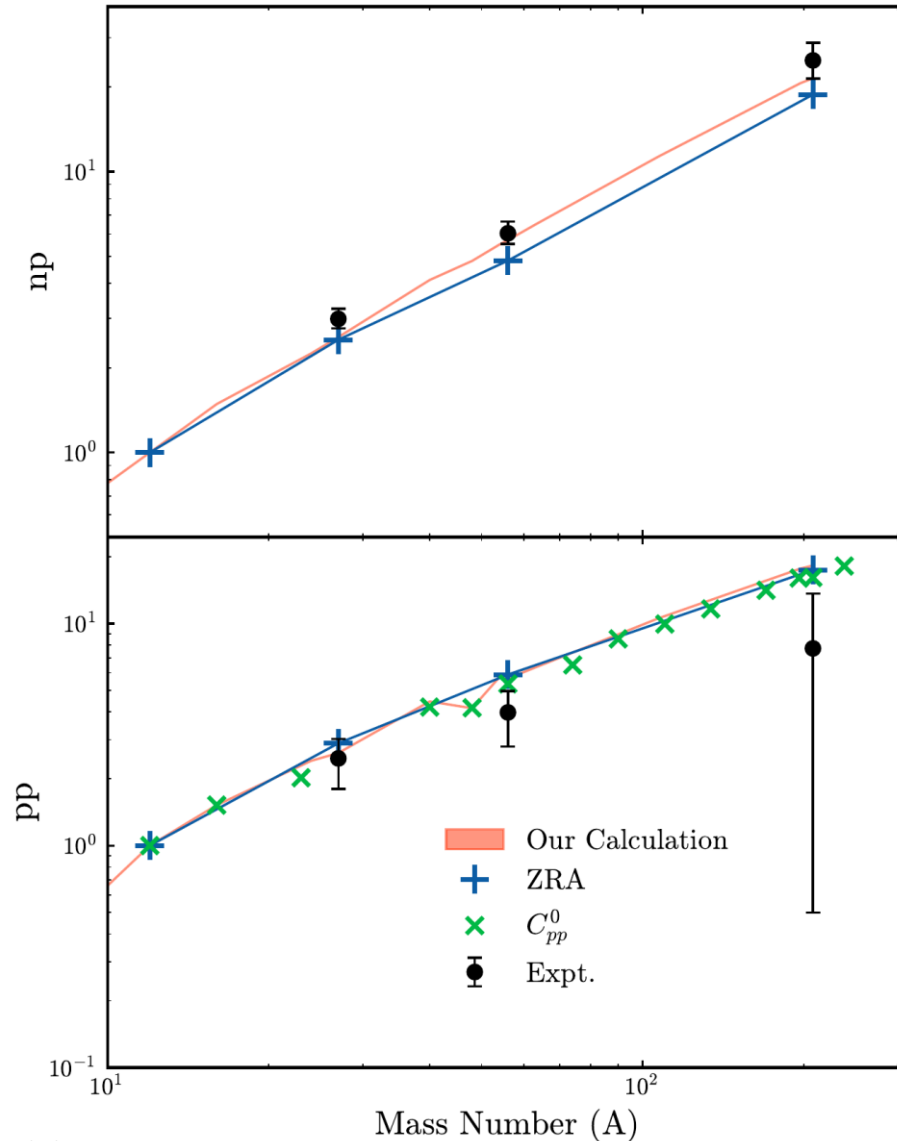
$np \rightarrow (S=1, T=0) + (S=0, T=1)$

$pp, nn \rightarrow (S=0, T=1)$ only

*tensor enhances (1,0)
suppress (0,1) by p*

Finally, sum over pairs $\sum_{i < j}$

2N results: np and pp pair counts vs A



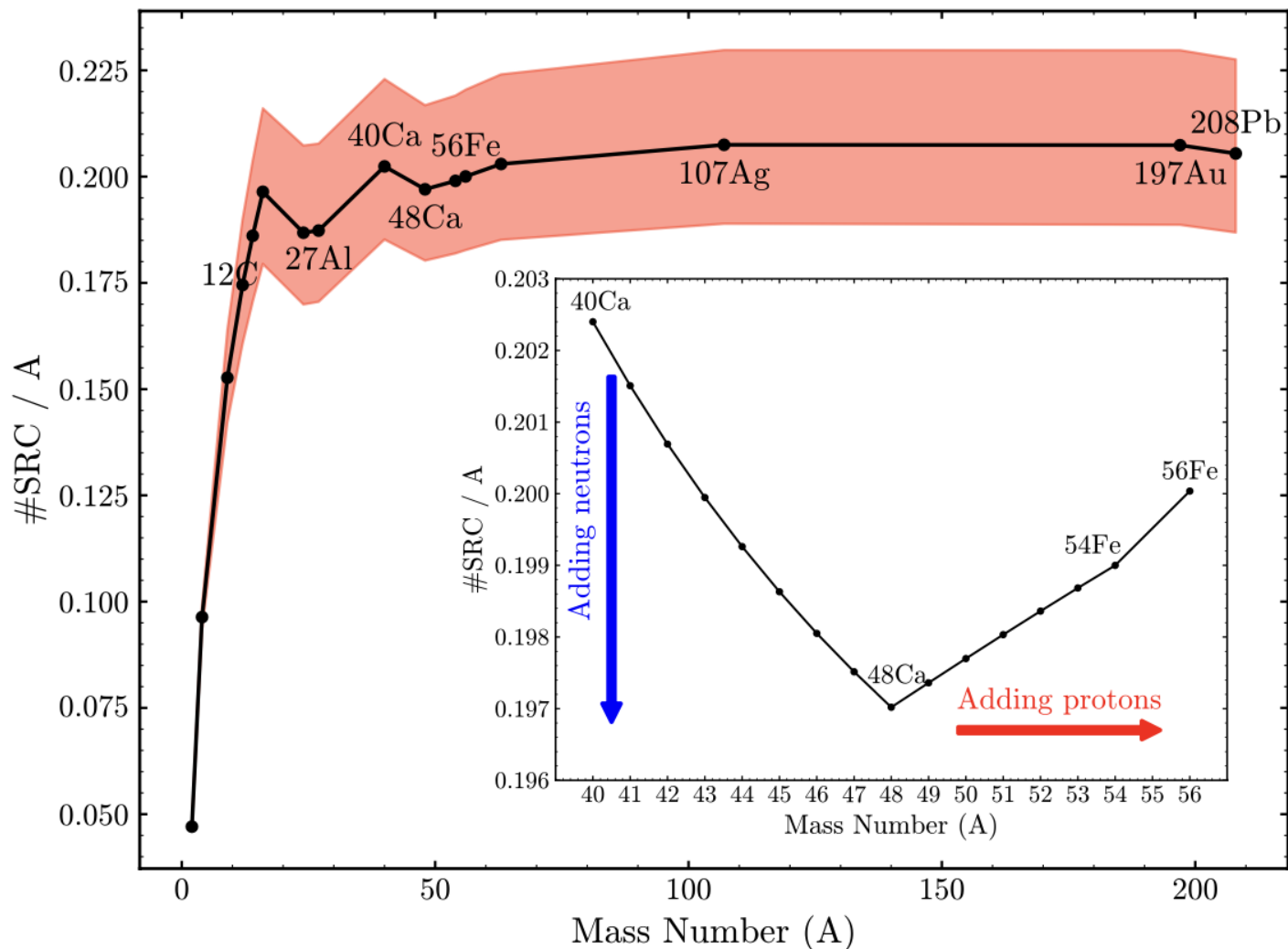
np

Matches ZRA + CLAS
extractions

pp

Matches Woods–Saxon C⁰pp
result

SRC / A vs A — and the CaFe systematics



Plateau

SRC/A flattens at large A

CaFe

Add $1f_{7/2}$ n/p



SRC/A drops/rises

Baseline

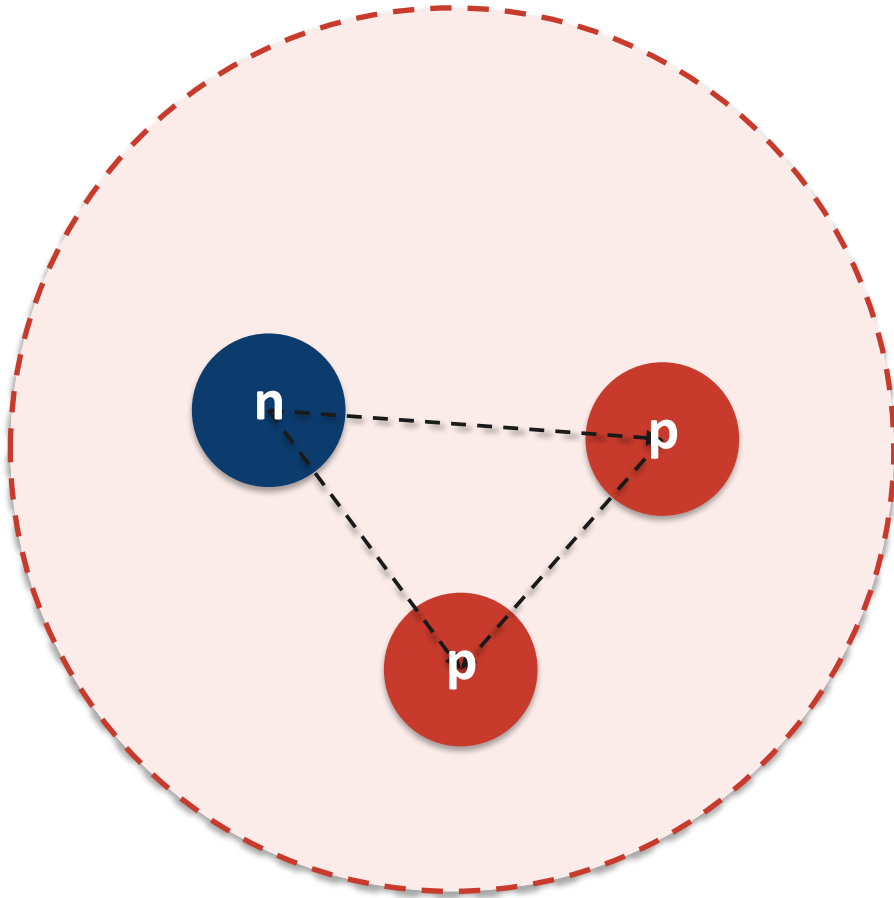
Experimental deviation



not just spatial overlap.

Extension to 3N-SRC

all three pairwise distances $< r_{SRC}$



– S^{ijk} Spatially symmetric fraction

$$\Psi^{ijk} = \Psi_S^{ijk} \chi_A^{ijk} + \Psi_A^{ijk} \chi_S^{ijk} + \Psi_{\text{mixed}}^{ijk} \chi_{\text{mixed}}^{ijk}$$

– Spatial overlap $\int_{\Omega} |\Psi_S(r_i, r_j, r_k)|^2 d^3r_i d^3r_j d^3r_k$

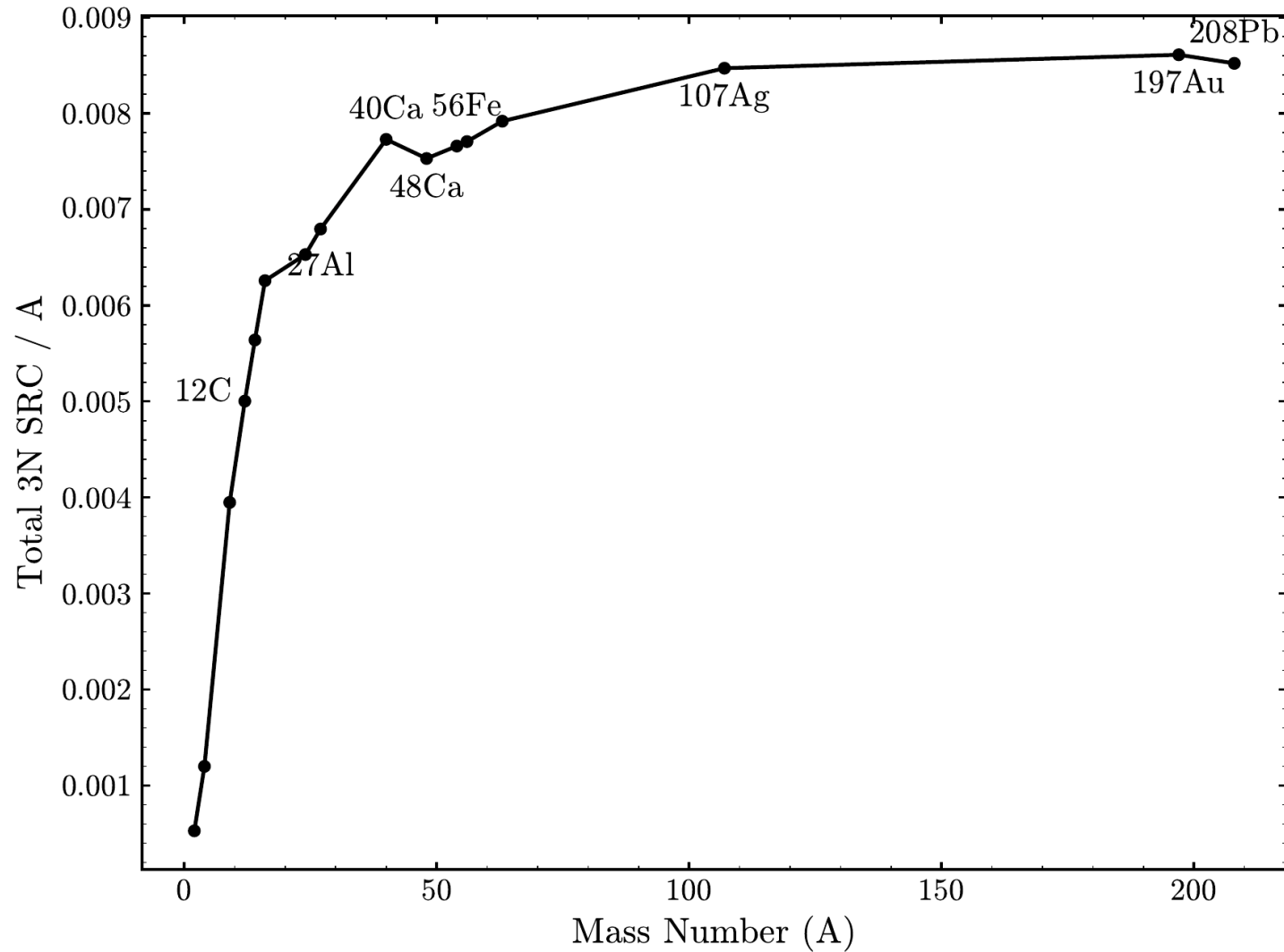
$$\Omega = \{\text{pairwise distances} < r_{src}\}$$

– Spin-isospin factor (suppress S=0): treat as 3 pairs (i.e only 2-body forces)

p and rsrc values remain the same.

Only npp, nnp (nnn and ppp suppressed by Pauli)

3N results: universal 3N / 2N \approx 5%



Flat

Universal across medium / heavy nuclei

$3N\text{-SRC} / 2N\text{-SRC}$

$\approx 5\%$

Summary

2 parameter model

Spatial overlap, rSRC, p

Calibrated once on ^{12}C

CaFe systematics

1f7/2 shell-opening predicted

Experimental deviation would point to pairing rules/different physics

2N abundances

np / pp / nn vs A

Agrees with ZRA, WS, CLAS

3N baseline

3N / 2N \approx 5 %

Universal across medium / heavy nuclei