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Search for near-threshold multi-neutron resonances with neutron rich nuclei at R^3B

Nikhil Mozumdar

T. Aumann, A. Barriere, M. Duer, I. Gasparic, C. Hang Qi, J. Kahlbow, T Kröll, A. Lagni, E. Lorenz, V. Panin, A. Revel, D. Rossi, J.L. Rodriguez, O. Sorlin, M. Xarepe & the R^3B collaboration

Overview

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- **Motivation**
- **2- Neutron reconstruction**
- **nn - Interaction**
- **$^{18}C(p,2p)^{17}B$**

Summary

Motivation

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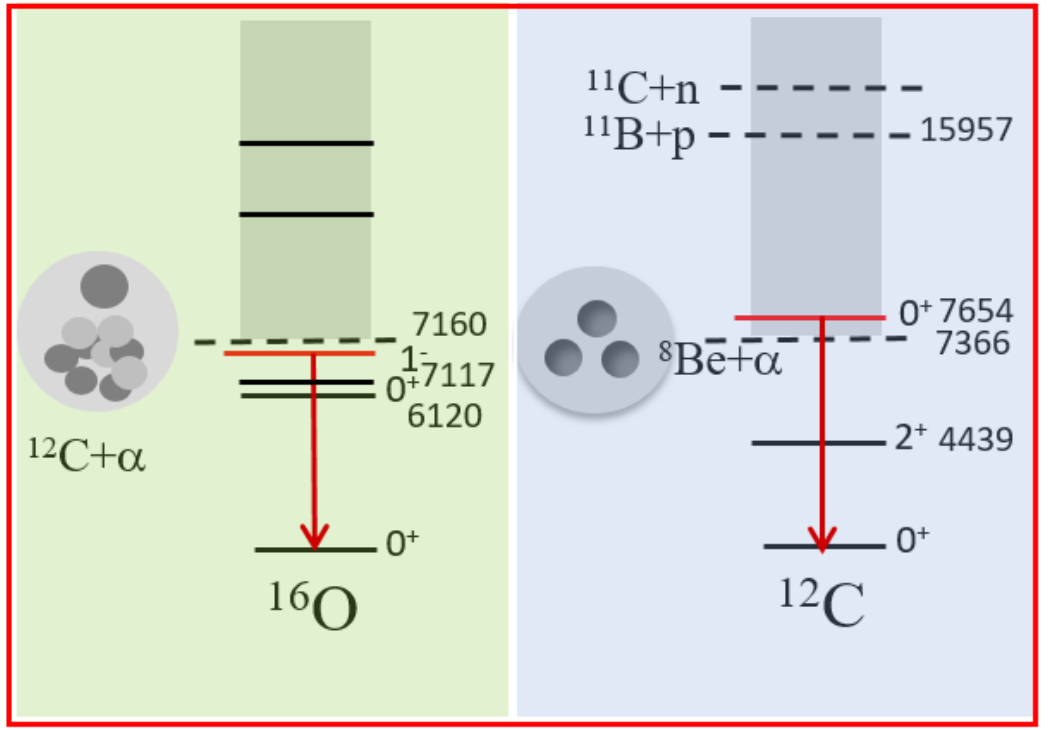
- Near threshold states are of special interest in nuclear physics: 3-α Hoyle state in ^{12}C. The **Ikeda conjecture**
- A Generalization of the conjecture proposed for states near all particle removal thresholds
- Recent progress shows multiple examples of such near threshold states
- The objective is to study and characterize the nn-interactions for such narrow near threshold 2n resonances



Kiyomi Ikeda, Noboru Takigawa, and Hisashi Horiuchi. *Progress of Theoretical Physics Supplement*, E68:464–475, 1968.

Motivation

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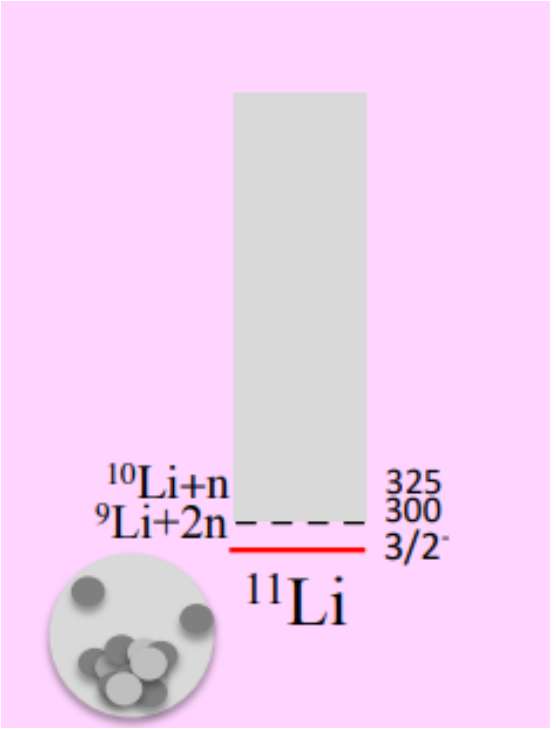

J. Okolowicz, et al. Prog. Th. Phys. Supp. 196 (2012)

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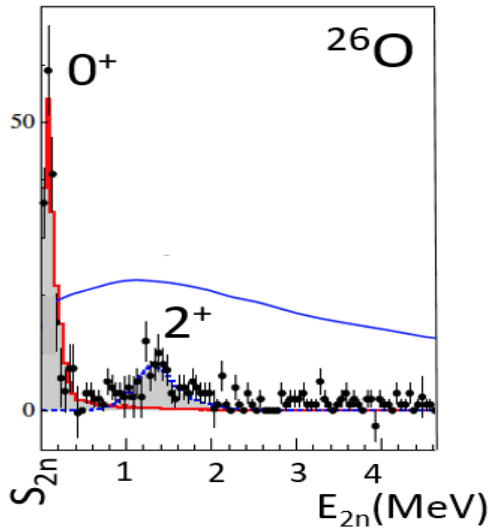
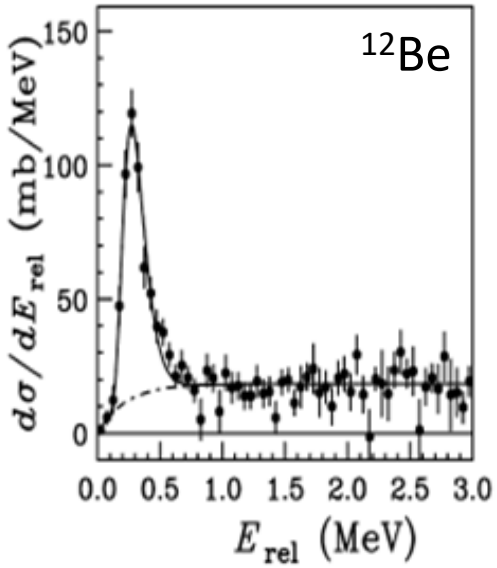
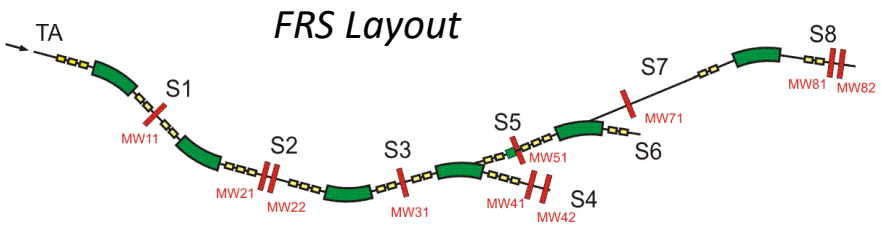


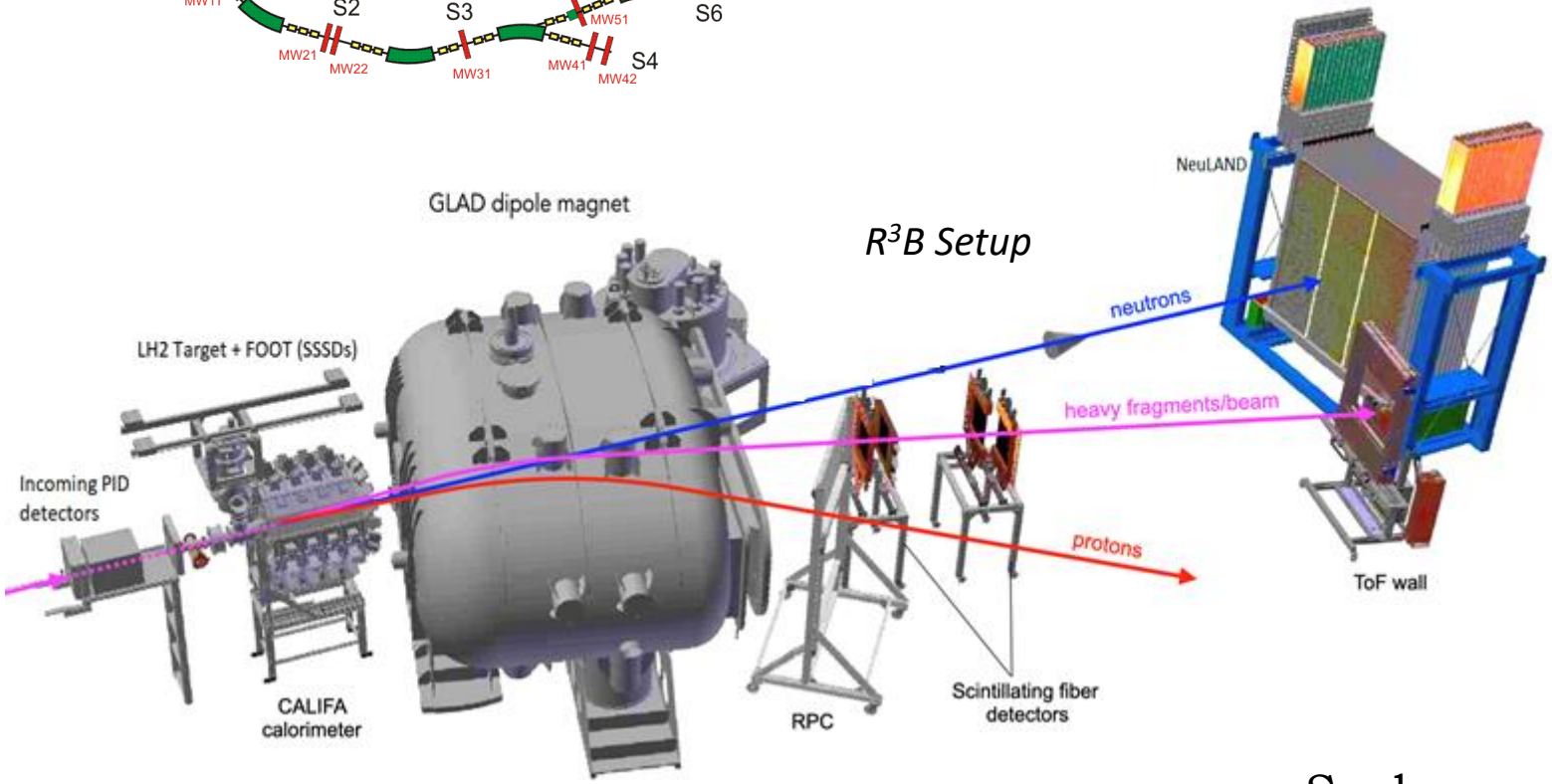
Y. Kondo et al. PRL 116 (2016)



T. Sugimoto et al. PLB 654, 160 (2007)

Experiment at R³B





- R³B (**R**eaction with **R**elativistic **R**adioactive **B**eams) setup designed to measure the full reaction kinematics
- Radioactive ion "cocktail" beam from fragmentation of ^{40}Ar primary beam (3.10^{10}pps) @ 600 AMeV on a Be production target at FRS

Spokesperson: O.Sorlin

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2- Neutron reconstruction

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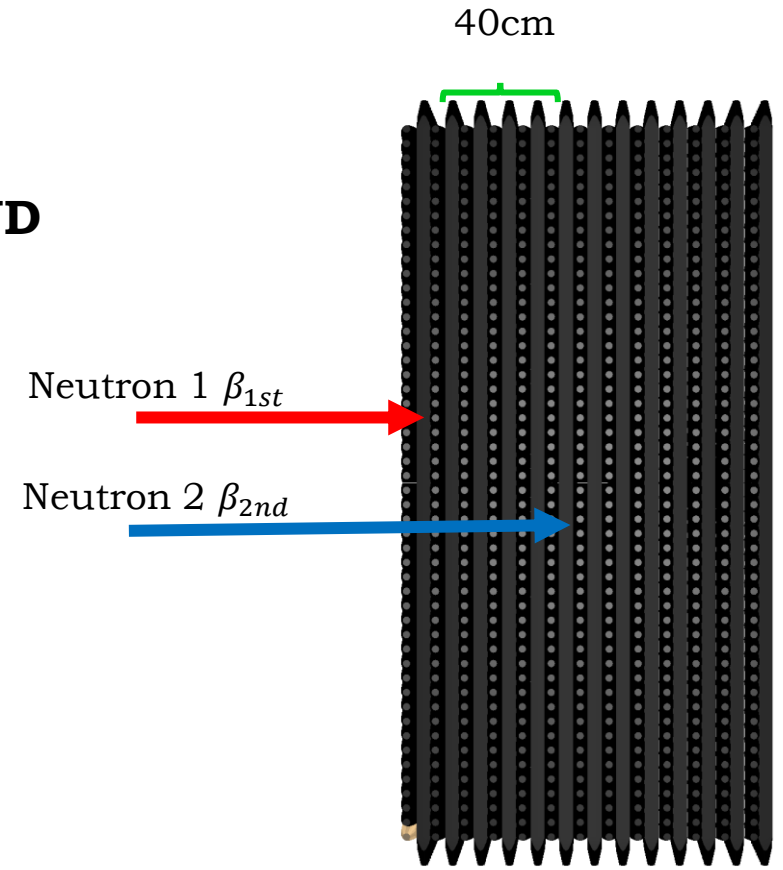
- Multiple methods developed
- Current reconstruction method based on dividing **NeuLAND** in two walls and detecting one neutron in each
- E_{dep} > 30 MeV
- First hit in time → First Neutron
- Second Hit selection after spatial separation of Z =40cm
- $\beta_{2nd} > \beta_{1st}$



2- Neutron analysis

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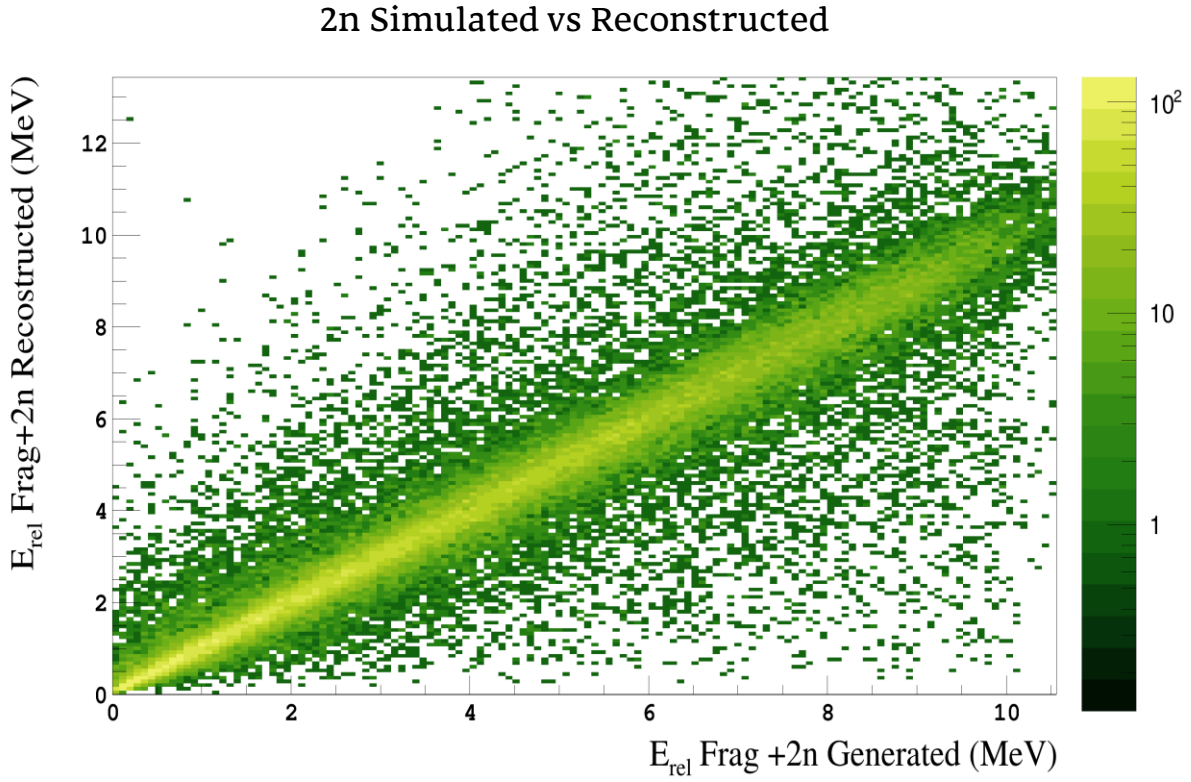
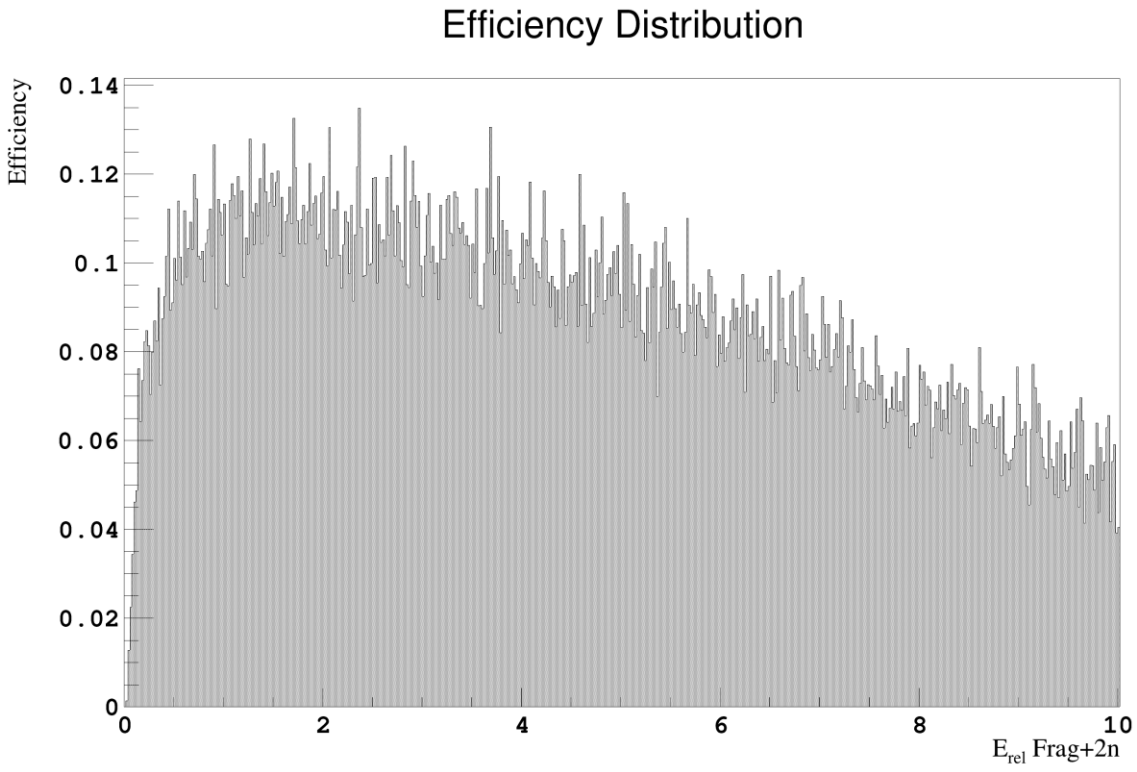
Simulation verification of reconstruction procedure





- Correlation between simulation and reconstruction.
- Maximum efficiency ~10%
- Cross talk contribution ~11%

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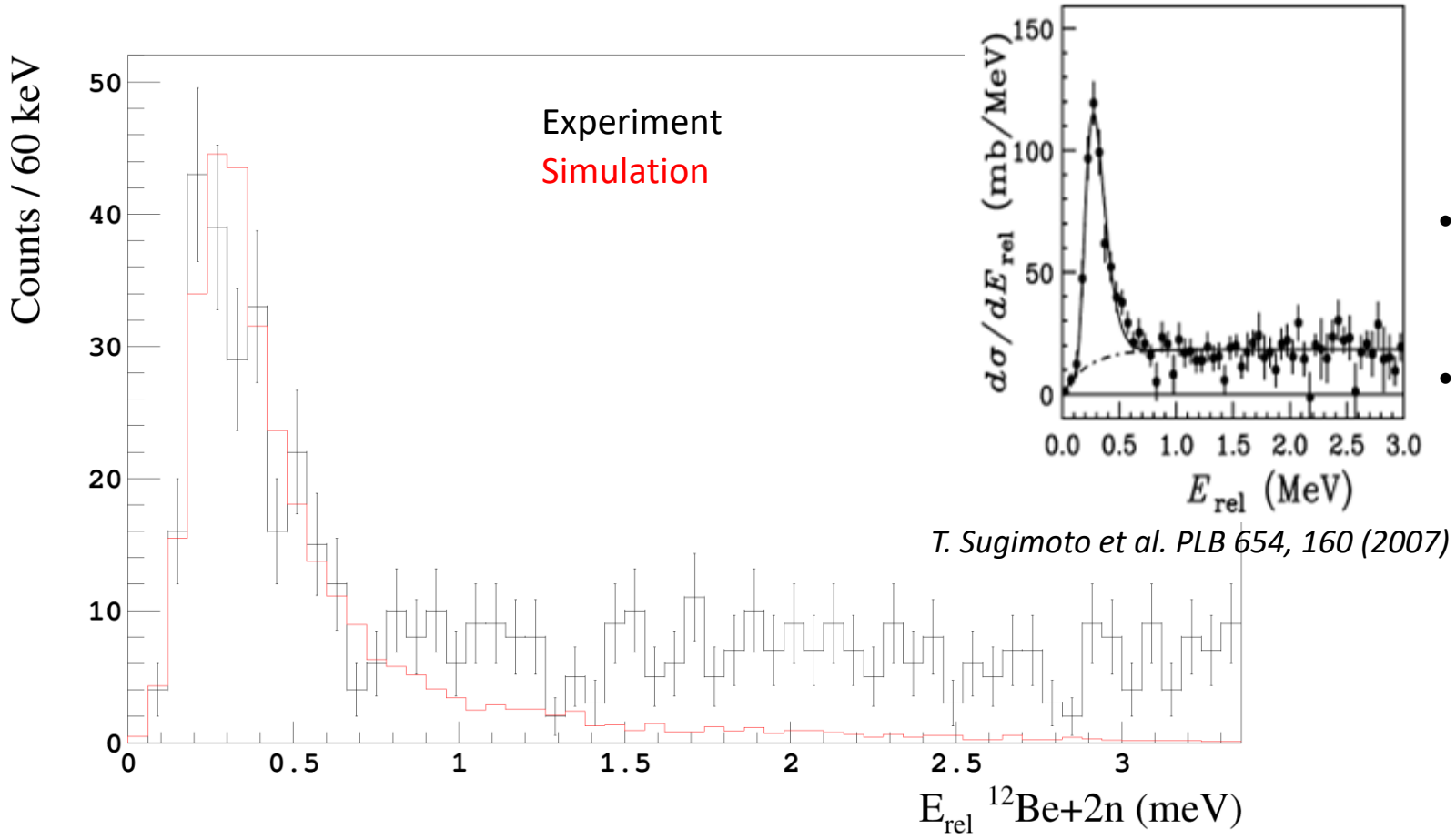
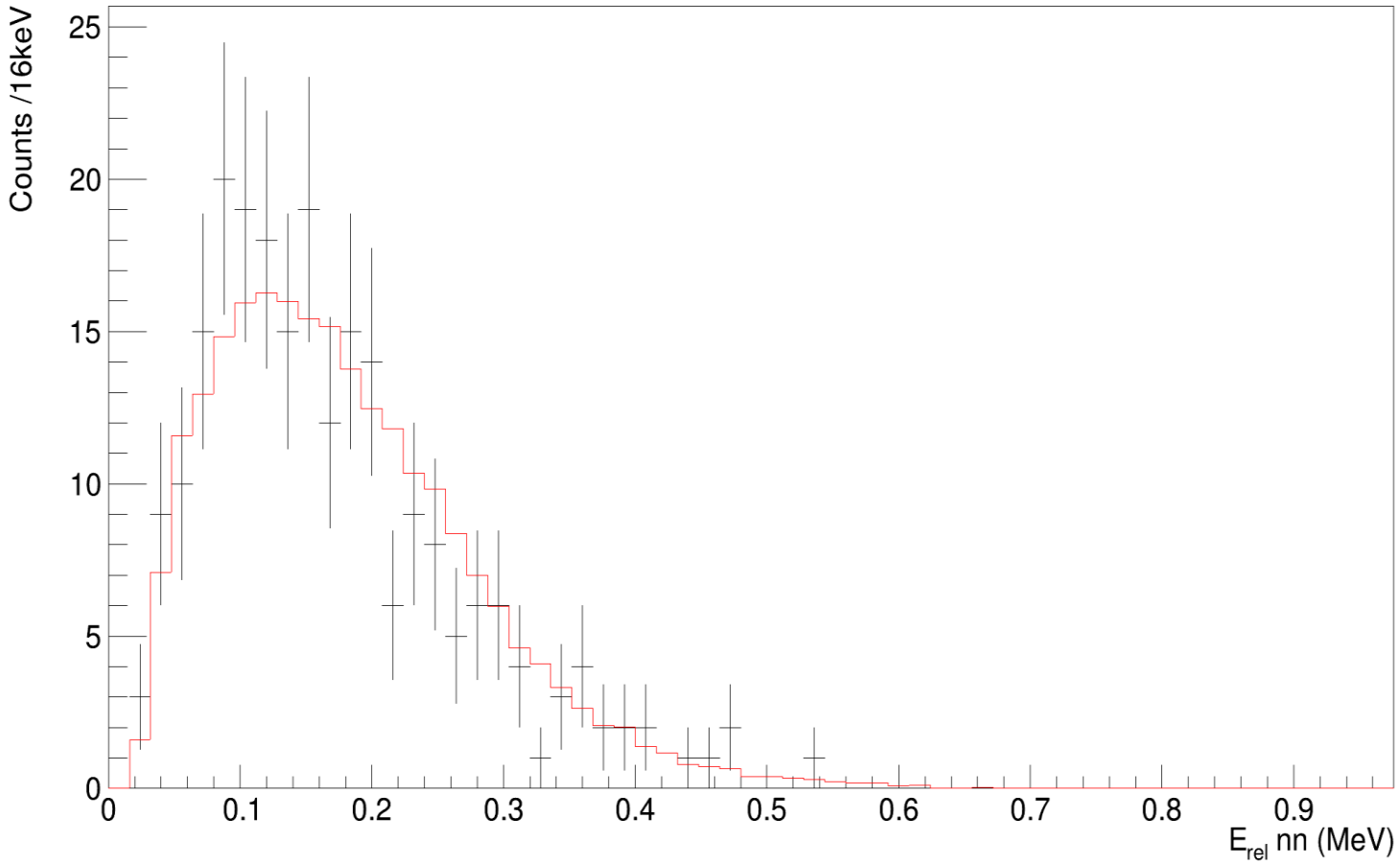
nn - Interaction: ^{15}B(-1p)^{12}Be+2n



T. Sugimoto et al. PLB 654, 160 (2007)

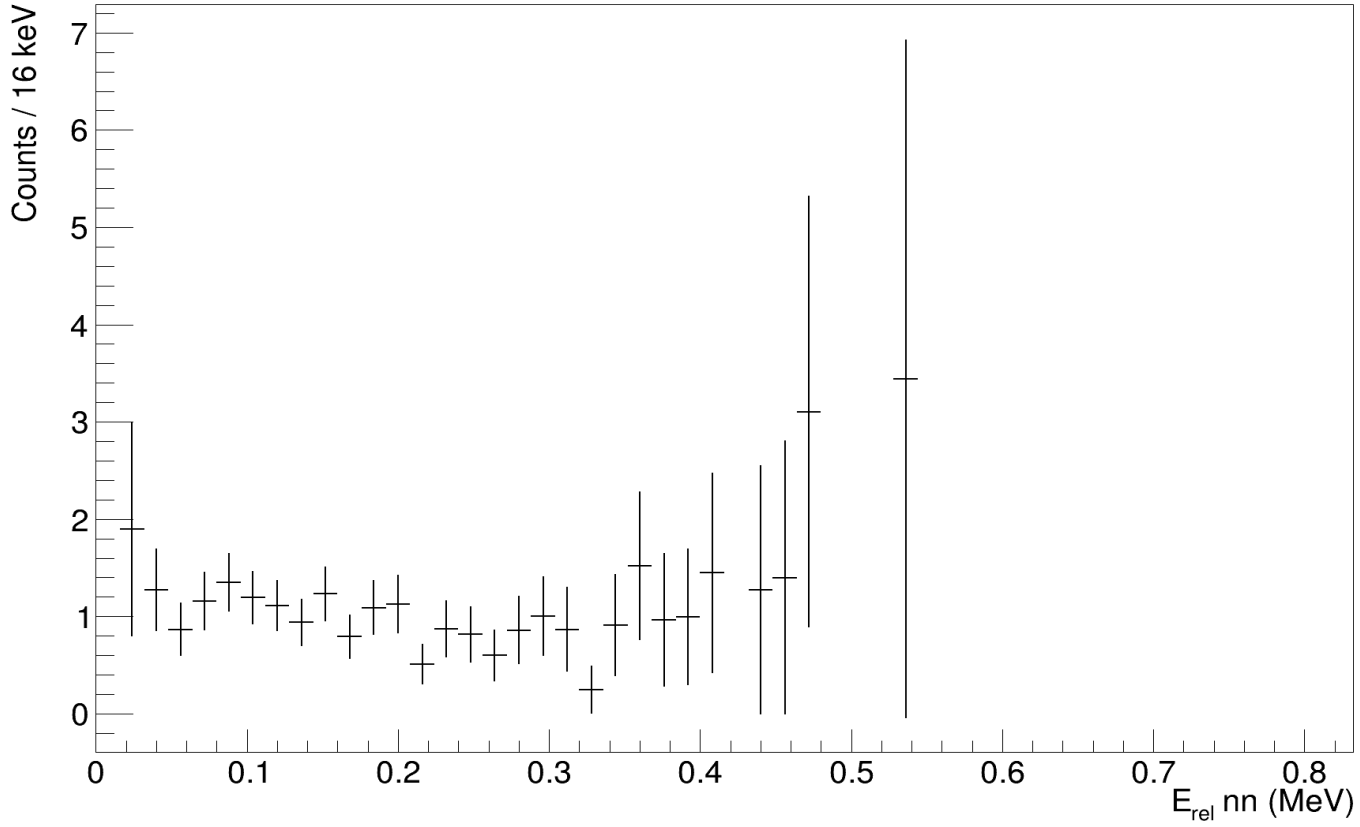
- ^{12}Be + 2n Relative energy distribution
- 2_1^+ state identified at ~250 keV

nn - Interaction: $^{15}B(-1p)^{12}Be+2n$



- **In black** Experimental Erel nn distribution for 12Be+2n with cut on 280 keV resonance
- In Red Simulated nn distribution for 280 keV direct phase space decay
- Maxima at ~100 keV

nn - Interaction: $^{15}B(-1p)^{12}Be+2n$



- Experiment / Simulation divided spectrum
- Phase space like?
- Need other examples to study change in nn E_{rel}

nn - Interaction: ^{19}N(-1p)^{16}C+2n Revisited

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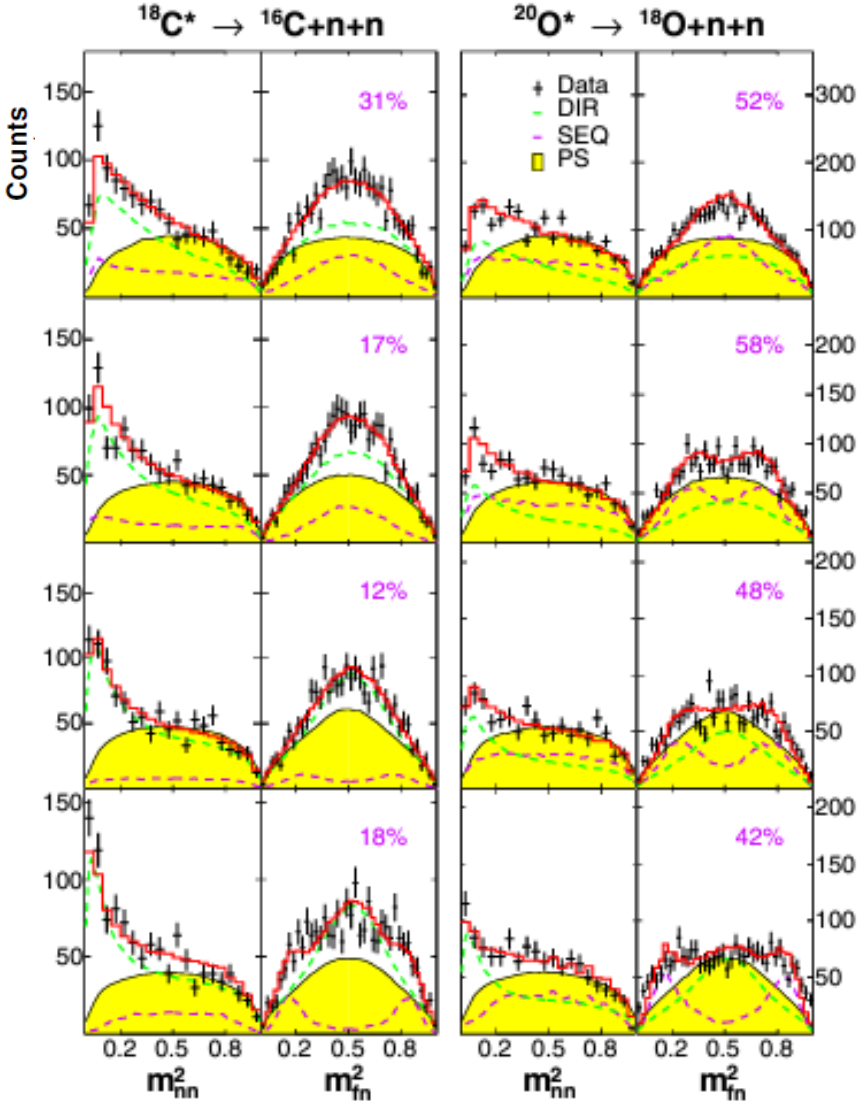
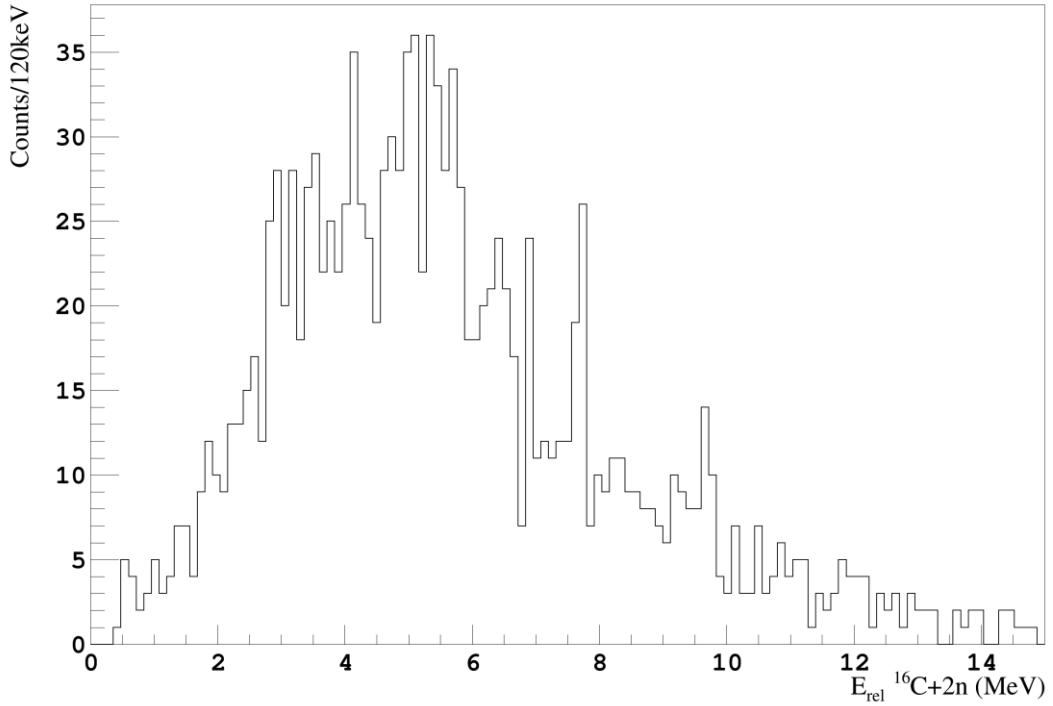
R. Aldric et al. PRL 120, 152504 (2018)

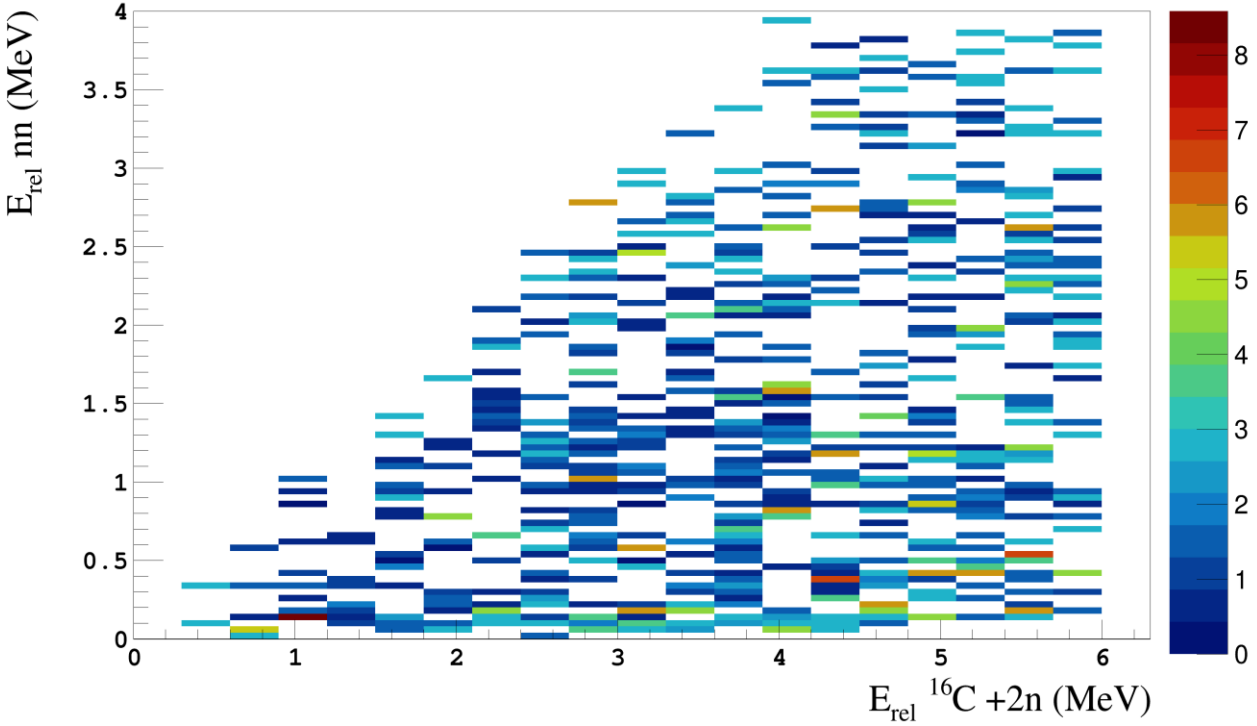
- Strong pairing correlation in Core +4n Nuclei
- Signature from m^2_{nn} ($\sim {}^{E_{rel}\,nn}/_{E_{rel}\,total}$) distribution
- Strong direct decay component
- Look for change in nn Relative energy with total energy for same channel



nn - Interaction: ^{19}N(-1p)^{16}C+2n Revisited



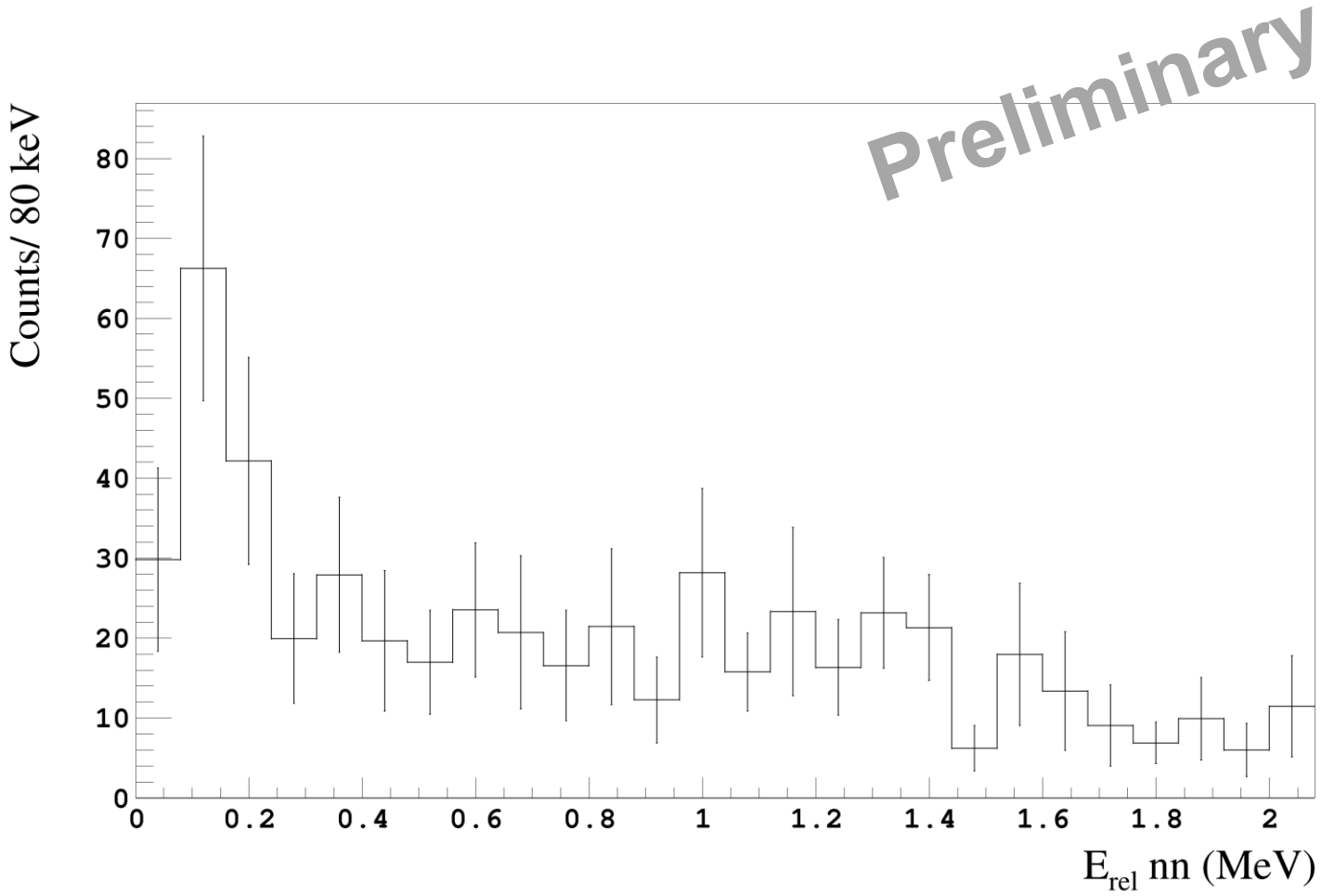
^{16}C+2n E_{rel} spectrum



^{16}C+2n E_{rel} vs nn E_{rel} normalized by simulated phase space

- Increase in intensity in low nn E_{rel} over entire E_{rel}
- Low stats to see clearly
- Check nn E_{rel} projection

nn - Interaction: ^{19}N(-1p)^{16}C+2n Revisited



- nn E_{rel} distribution Normalized by phase space
- Clear Peak at ~100keV
- nn - FSI signature maintained at high Frag + 2n E_{rel}
- Check for other nuclei with strong direct decay contribution, underway

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$^{18}C(p,2p)^{17}B$

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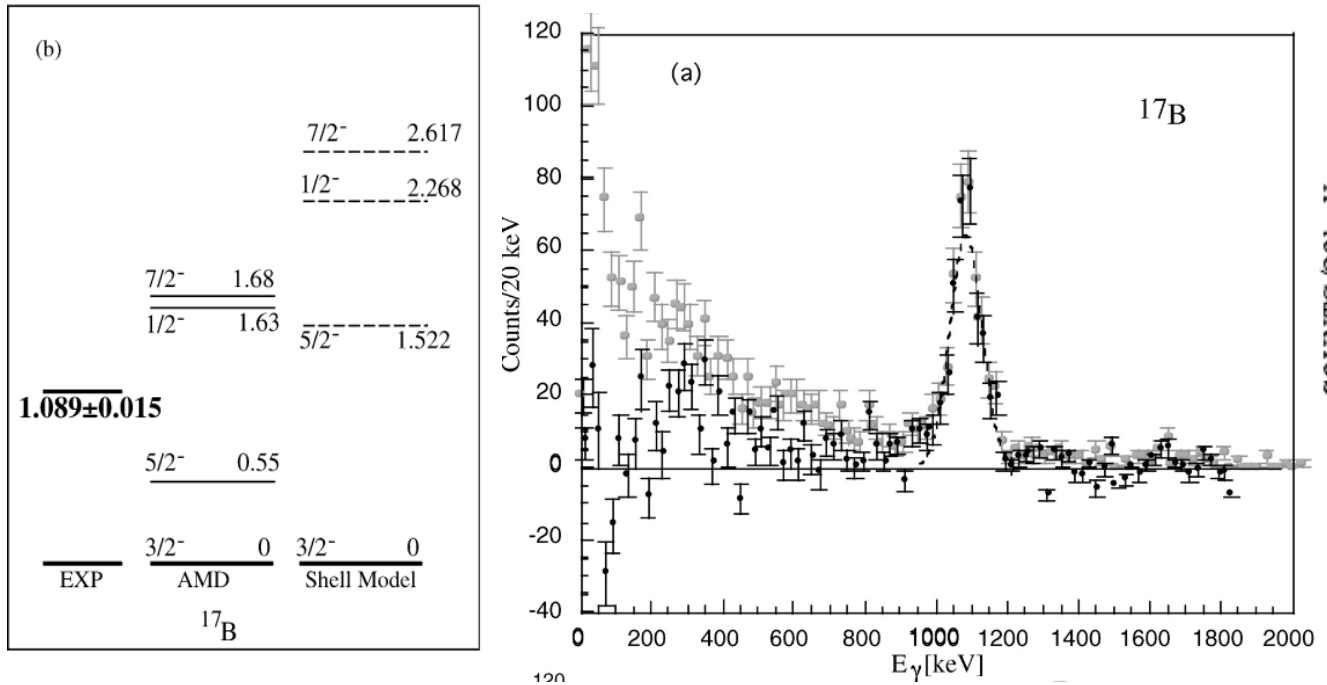
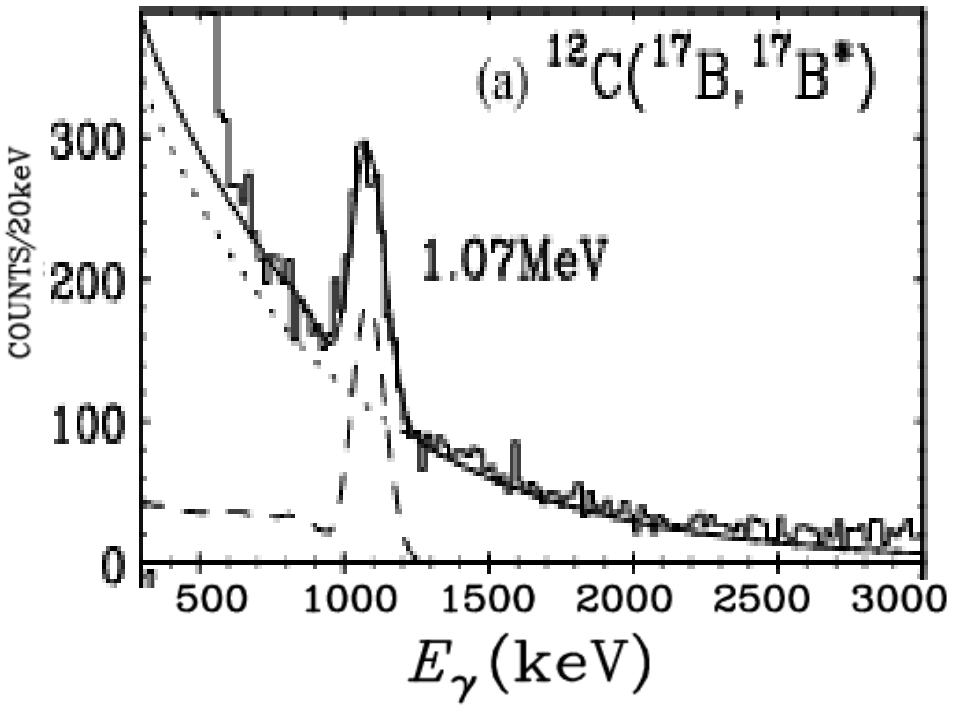
^{17}B Previous studies: via inelastic scattering

Kanungo et al. (PLB 608 2005)

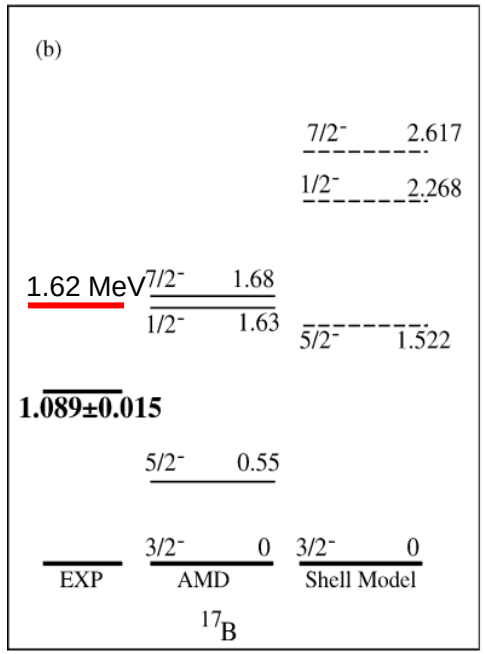


Kondo et al. (PRC 71 044611 2005)

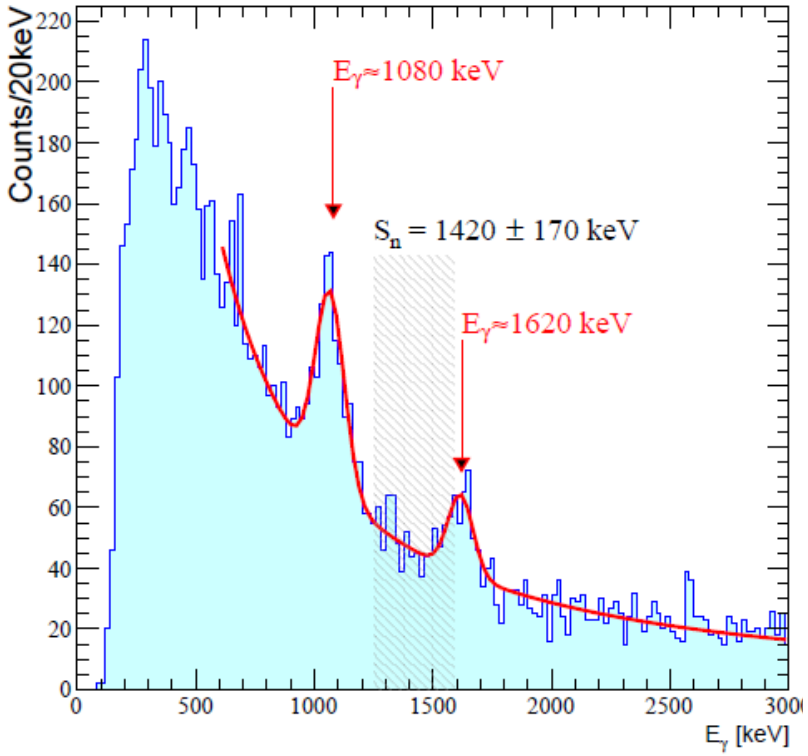


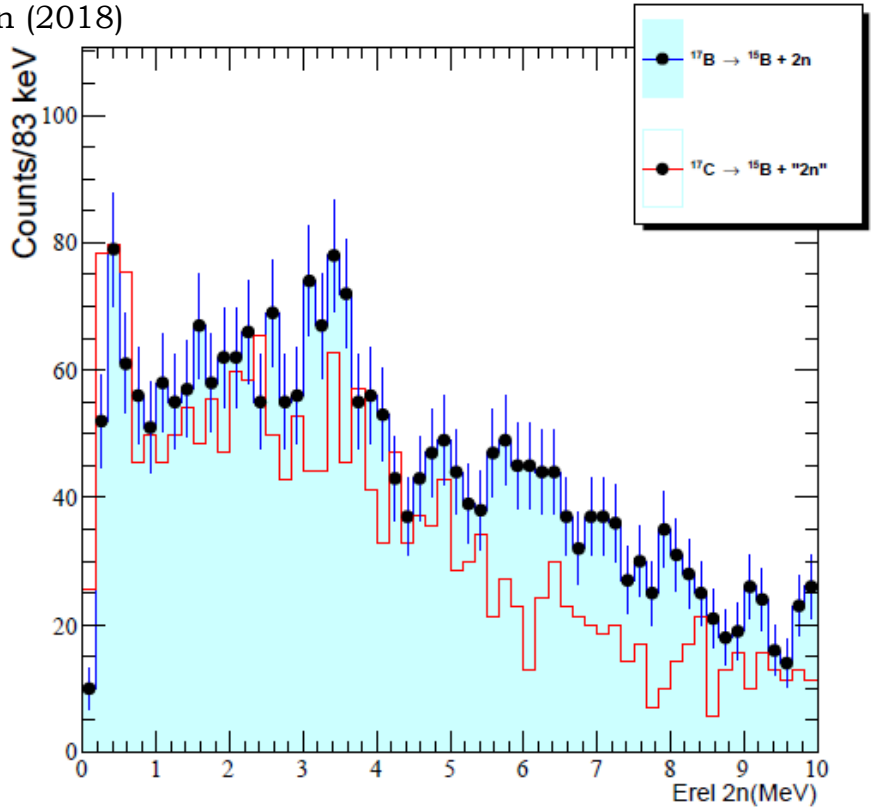
$^{18}C(p,2p)^{17}B$

^{17}B previous studies: via $^{19}C \rightarrow ^{17}B$

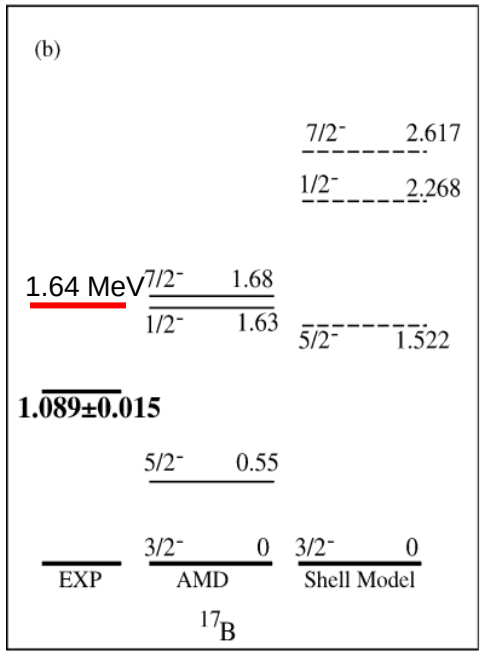


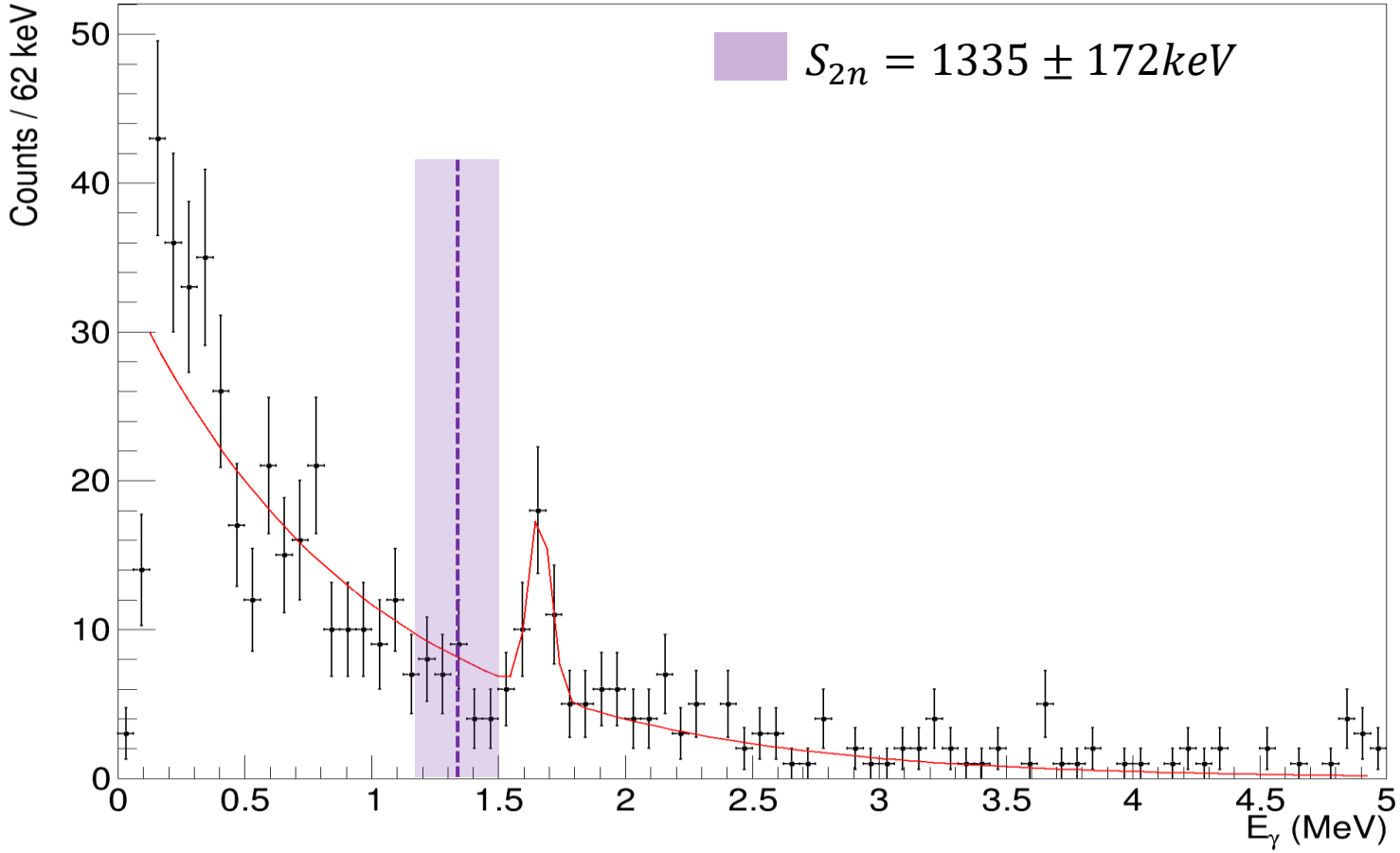
HDR J. Gibelin (2018)





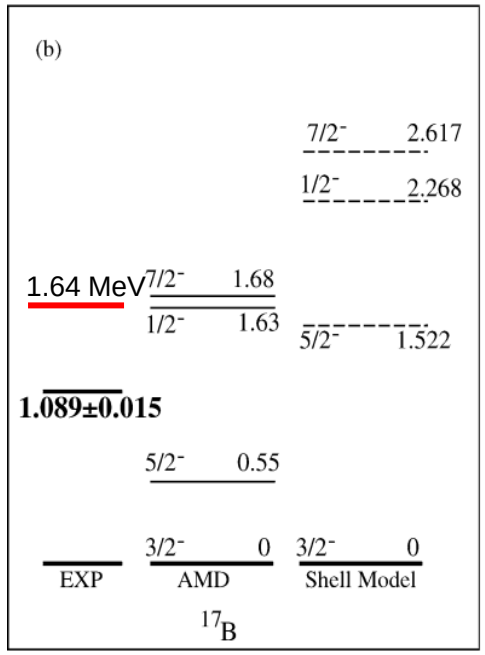
$^{18}C(-1p)^{17}B+\gamma$

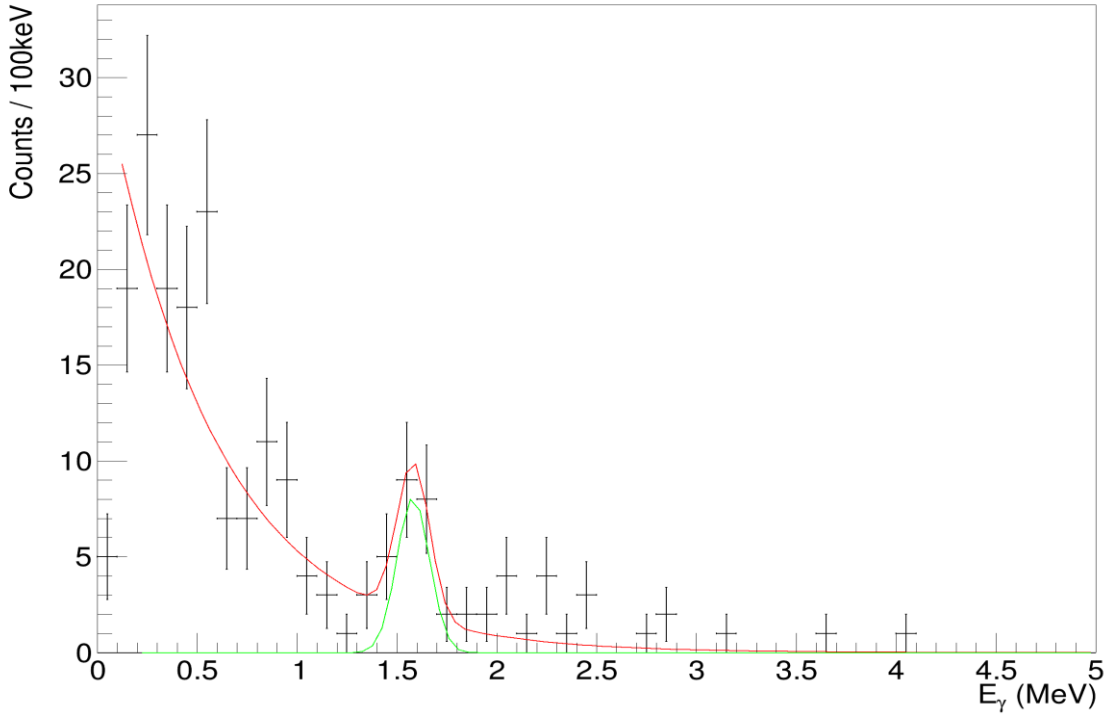




- Peak seen at ~1.64 MeV
- Very large uncertainty in S2n → peak under threshold within 2σ
- No peak at ~1.08 MeV

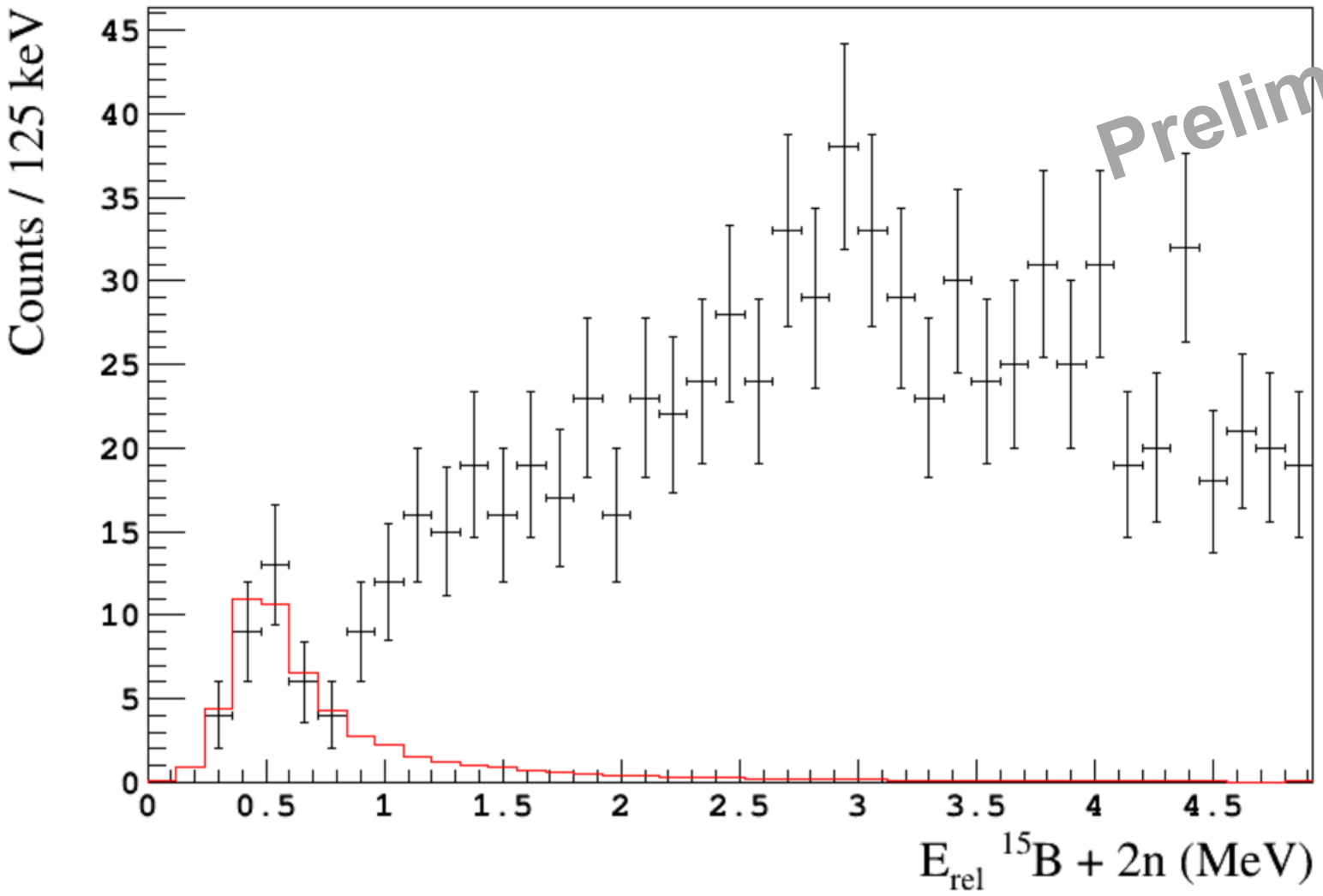
$^{18}C(p,2p)^{17}B+\gamma$





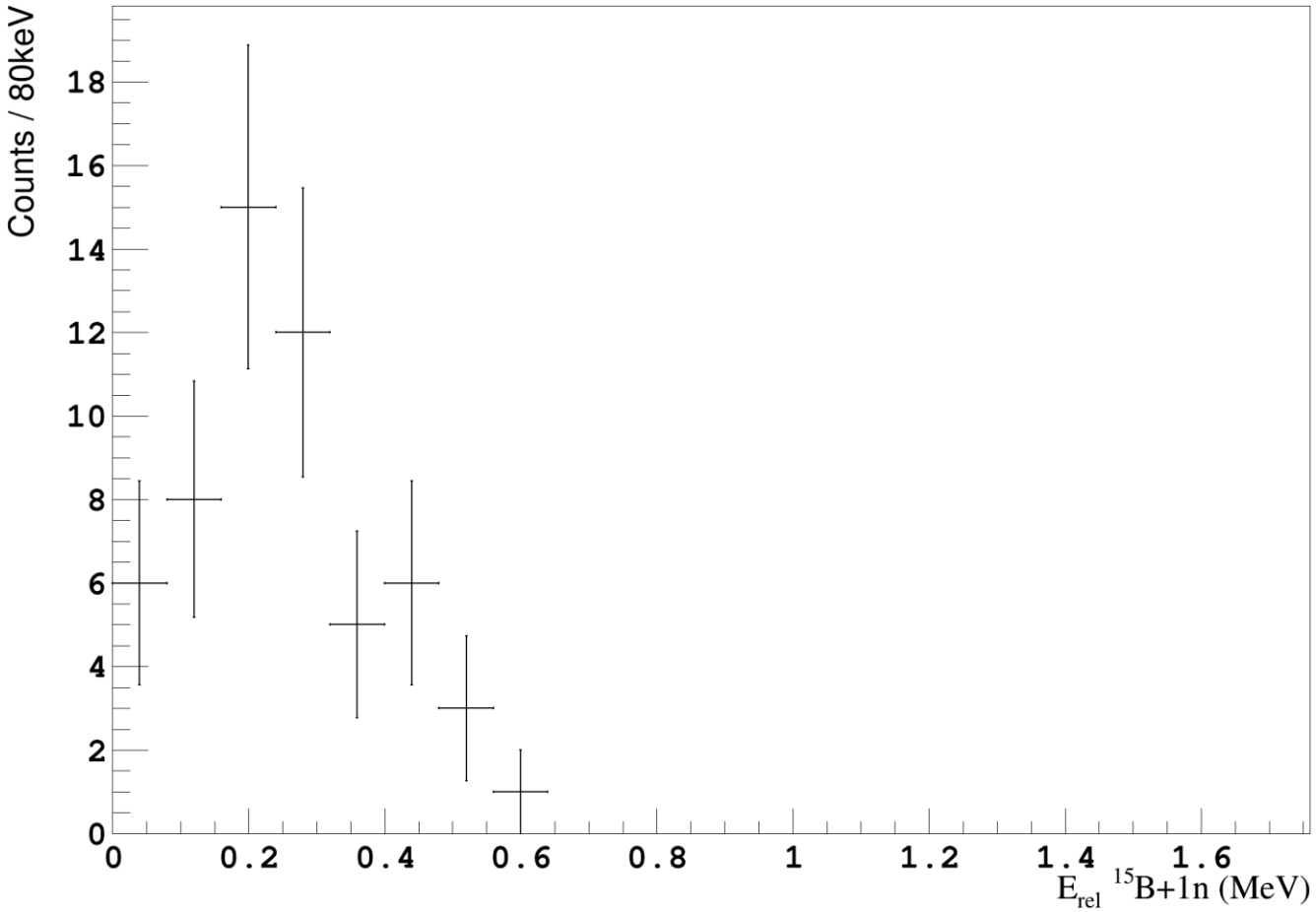
- If $^{1}/_{2}^{-}$ only 35%(9) of the strength in the gamma branch compared to YSOX SM (C.Yuan)
- Possibility of $^{3}/_{2}^{-}$ state
- Check $^{15}B+2n$ spectrum

$^{18}C(p,2p)^{15}B+2n$



- Possible peak at ~450keV in $^{15}B+2n$ spectrum
- Compatible with above threshold gamma?
- Heavily biased by efficiency distribution and crosstalk

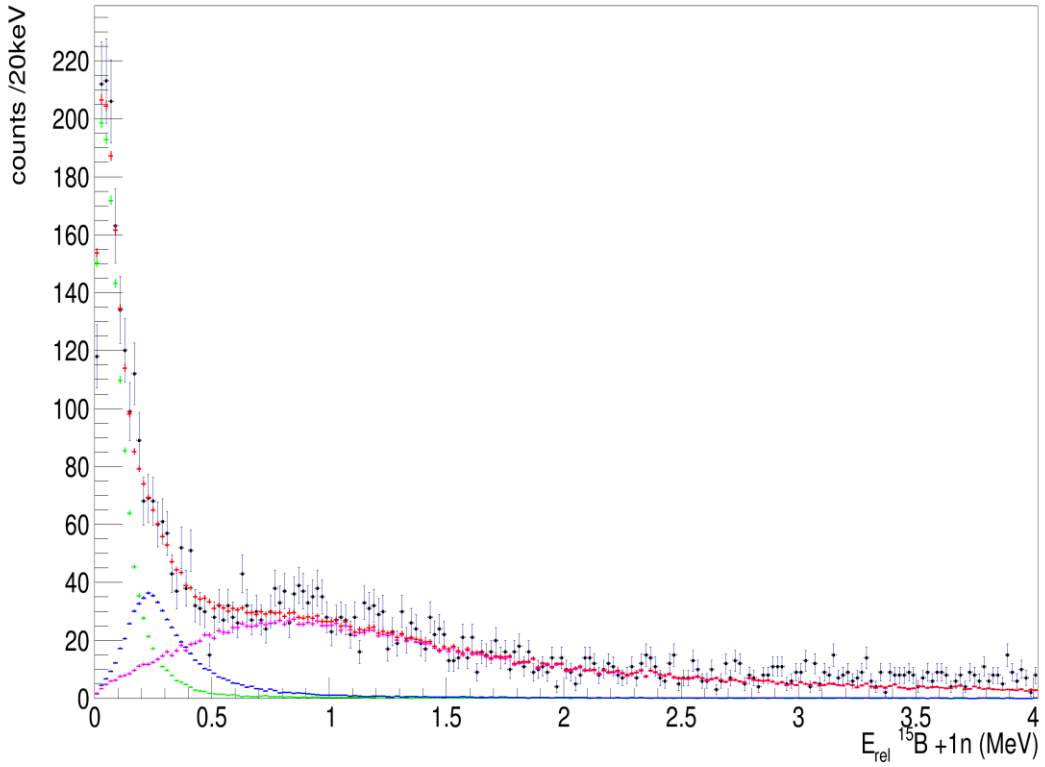
$^{18}C(p,2p)^{15}B+2n$



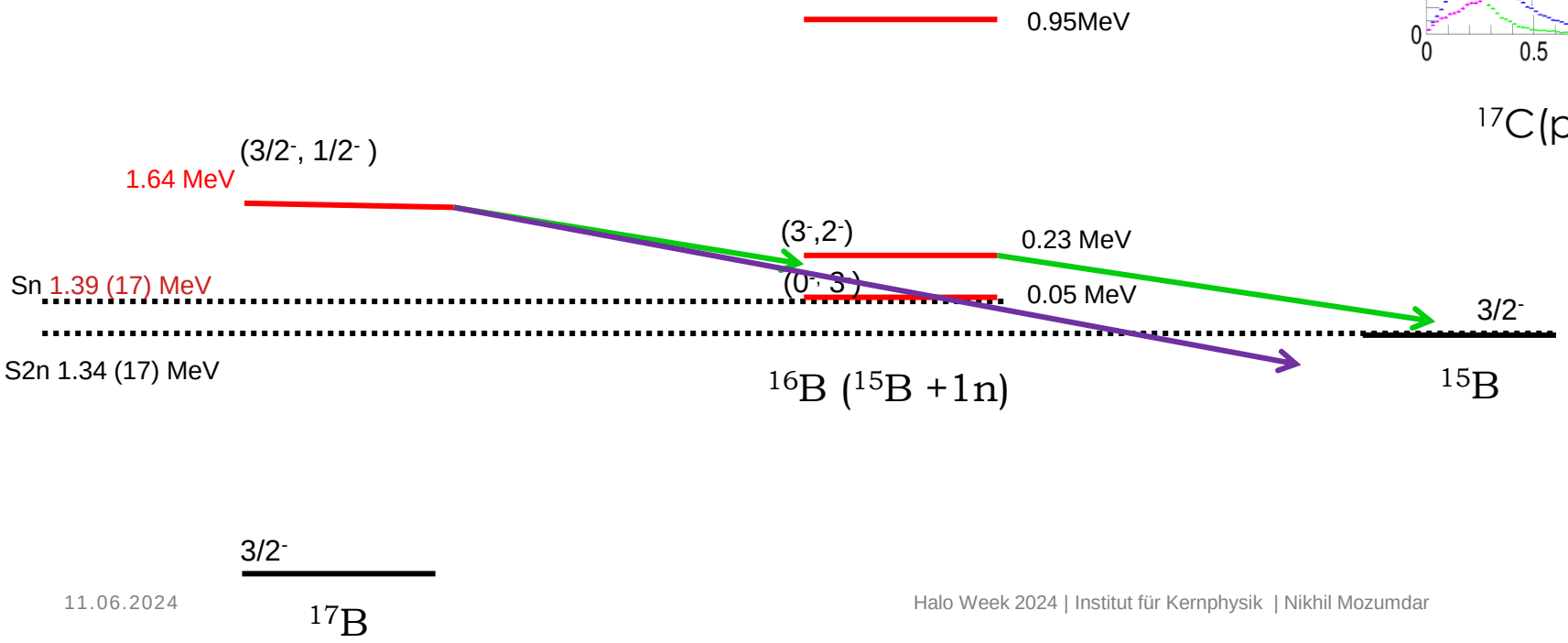
- Gate on ~450 keV Peak
- $^{15}B+1^{st}$ Neutron + $^{15}B+2^{nd}$ Neutron E_{rel}
- Very likely equal sharing of energy

$^{18}C(p,2p)^{15}B+2n$

- **<u>Same state as gamma?</u>**
- Two Possible modes of decay: Sequential or direct→Very difficult to resolve same energy sharing
- If $^{3}/_{2}^{-}$, direct decay likely. Overlap with ^{15}B G.S?



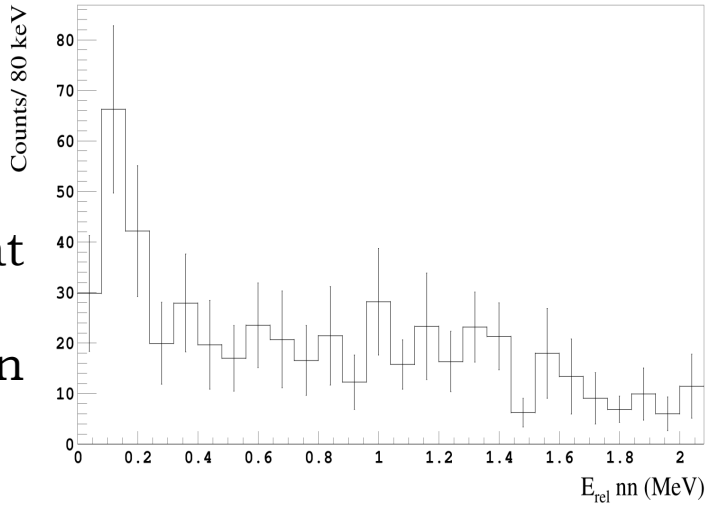
$^{17}C(p,2p)^{15}B+1n$ fit from current experiment

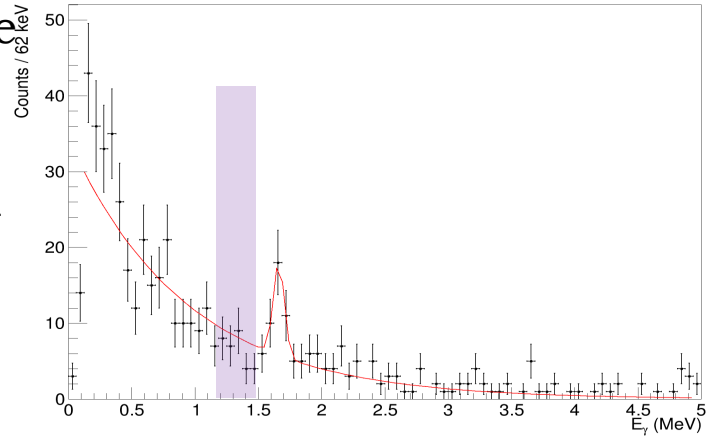


Preliminary

Summary

- ^{12}Be+2n nn Erel corresponding to 250keV 2^+ state shows peak at ~100keV. Comparable to phase space
  - Need another resonance at different energy to check change in nn E_{rel}
  - Is total E_{rel} dominated by the nn E_{rel}?
- nn-FSI signature at high Frag +2n E_{rel}
- ^{18}C(p,2p)^{17}B gamma observed above S_{2n} threshold. Though large uncertainty in threshold. Need precise estimation.
- Possible candidate of compatible neutron state in ^{15}B+2n spectrum
  - Estimate C^2S from single particle cross sections and compare
  - Such competitive decay possible?





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R3B

FAIR Phase 0 Research Program

GSI

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