

Multi-neutron analysis with NeuLAND

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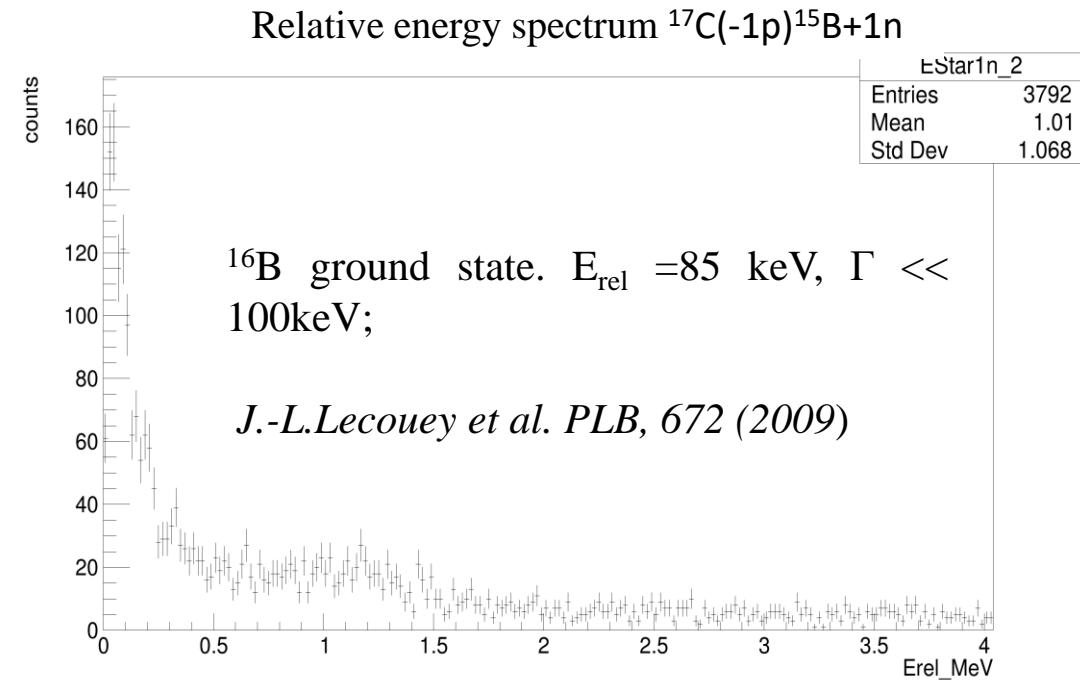
Helmholtz Forschungsakademie Hessen für FAIR



Recap ...



- 1n Reconstruction shown in Budapest,
 - Sorting and selecting *fastest hit in time*
 - Align Fragment velocity to neutron velocity
- To confirm with simulation if the approach is correct
- Extract efficiency
- 2n Relative energy reconstruction



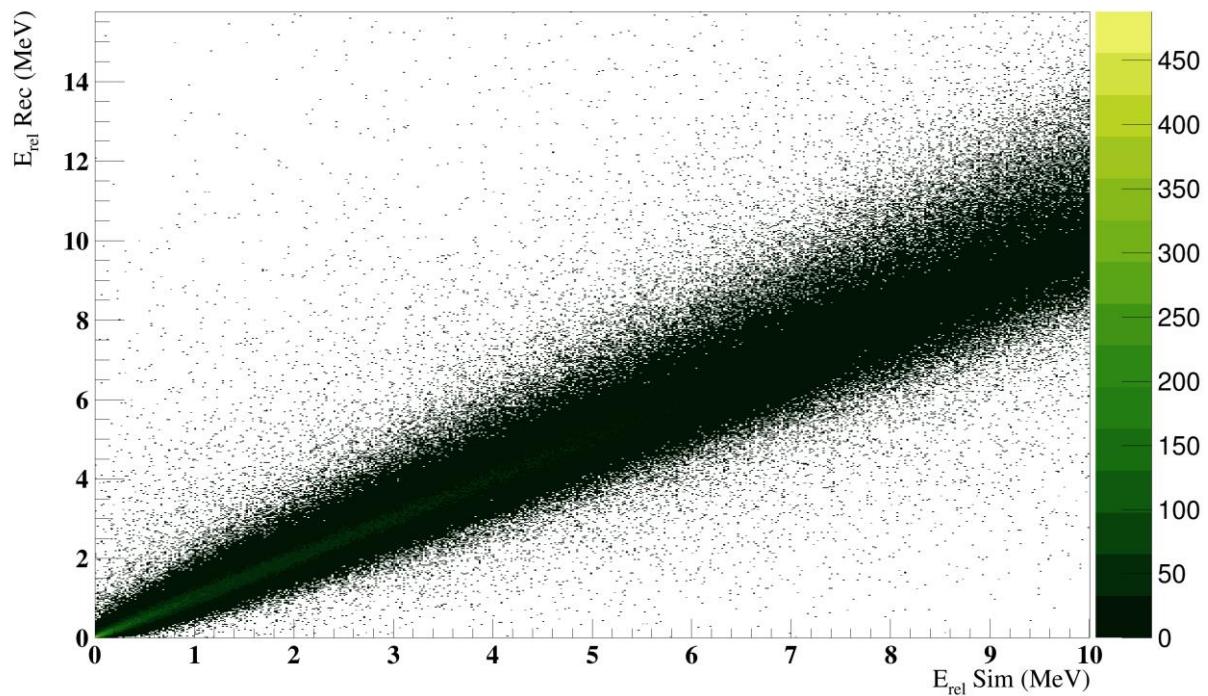
* Simulations shown based on QGSP INCLXX physics list

1 - Neutron simulations

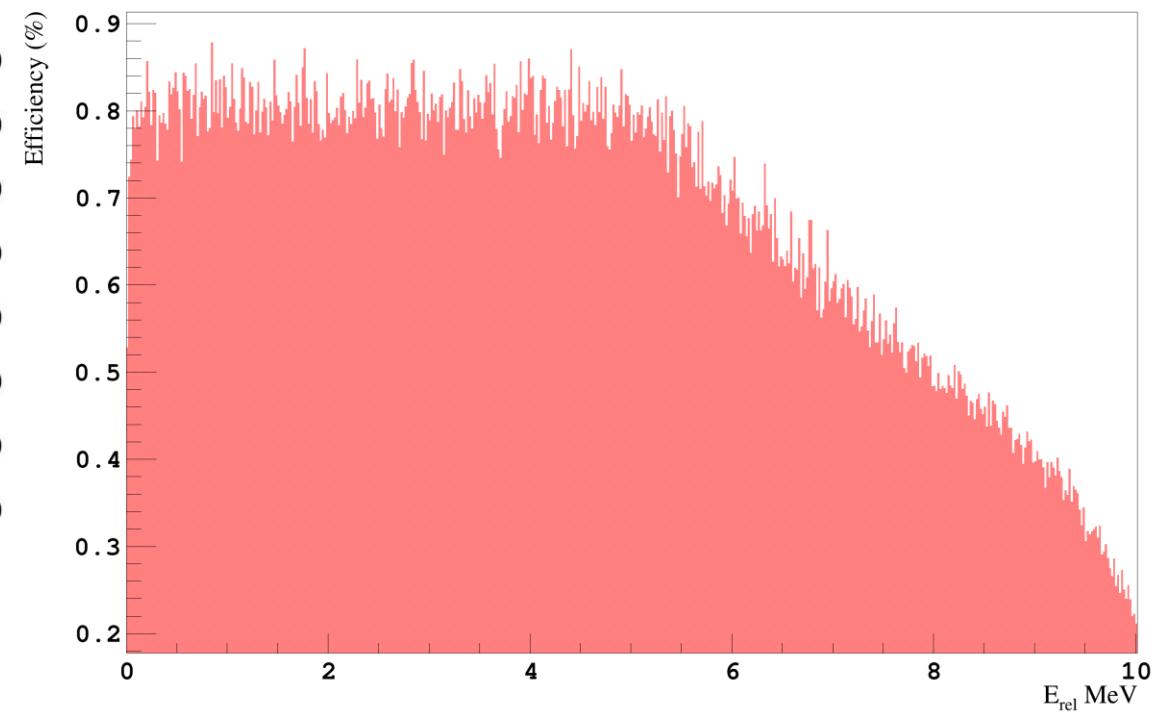


From uniform E_{rel} distribution 0-10 MeV simulation :

1n Simulated vs Reconstructed



Efficiency Distribution



- Good correlation between simulation and reconstruction using *first hit in time* approach
- Efficiency with acceptance distribution

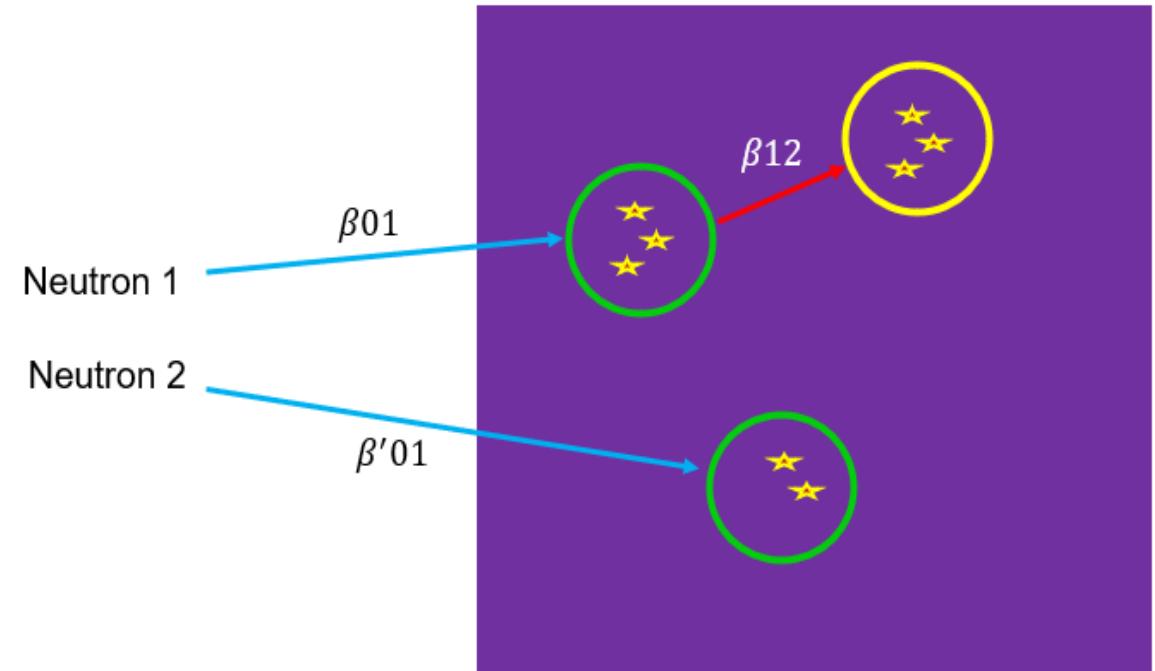
2 - Neutron reconstruction

- Based on method adopted from *PhD thesis of Christopher Lehr and Kondo et al. NIM 463 (2020)*
- Method Based on **clustering** and **causality** condition
- First hints from 1-n reconstruction plots

Definitions:

Crosstalk : Multiple hits coming from same neutron but identified as hits coming from different neutrons

Causality : Hits originating in a second point from the same neutron after an initial scattering from a different point



NeuLAND

2 - Neutron reconstruction



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Some initial processing:

- Sort hits based on time
- Align fragment velocity similar to 1n case
- Select only hits > 6 MeVee
- Perform clustering to remove proton crosstalk
 - multiple approaches available in current work a square cut was used in space time: $\Delta X = 25\text{cm}$, $\Delta Y = 25\text{cm}$, $\Delta Z = 25\text{cm}$, $\Delta T = 3\text{ns}$

Delta T = 3ns? Why? delta position = 5 bars

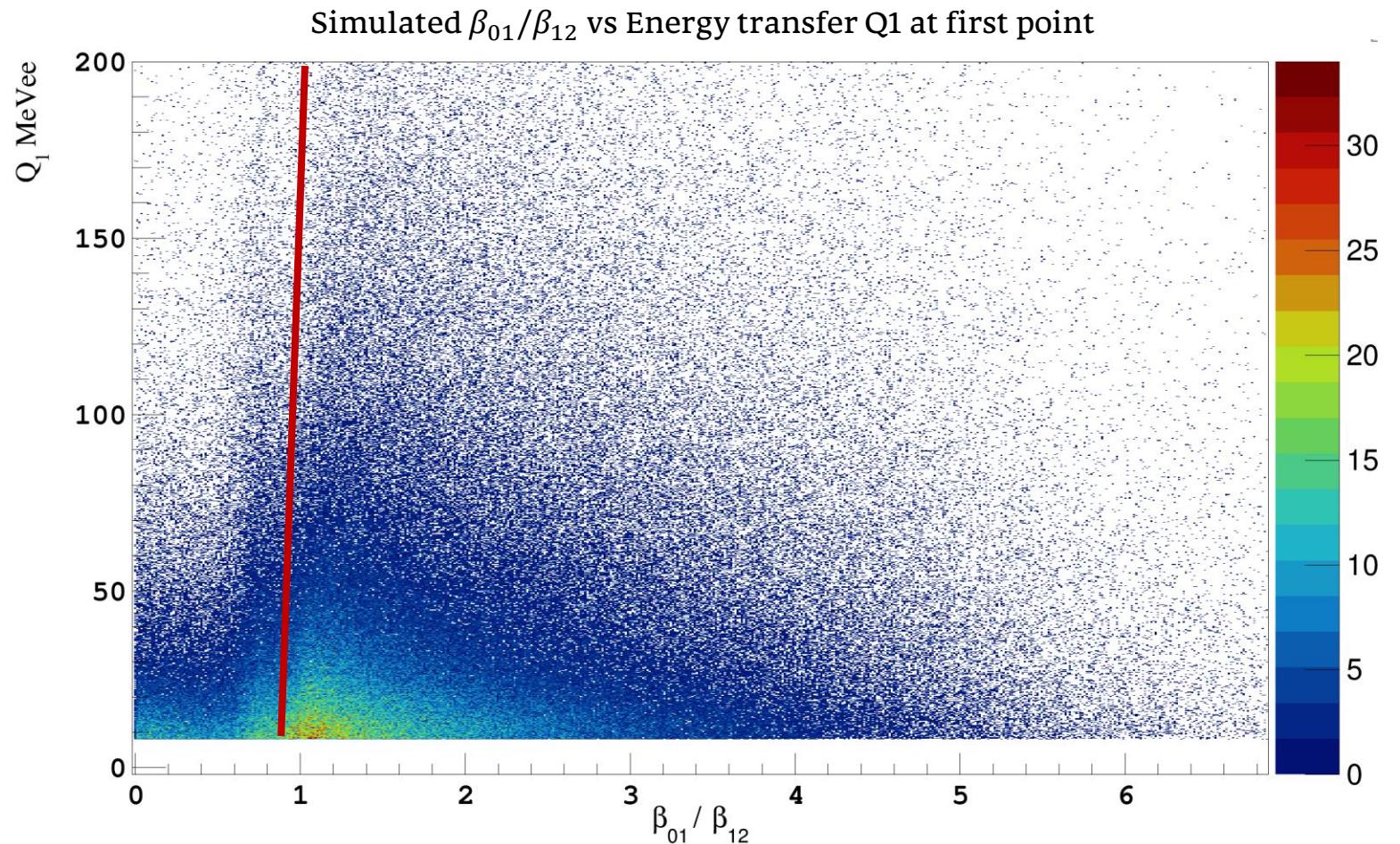
Look at 1-neutron case first

Hints from 1 - Neutron simulations



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- Causality cut for $\beta_{12} < \beta_{01}$
- Allowance for time resolution of NeuLAND

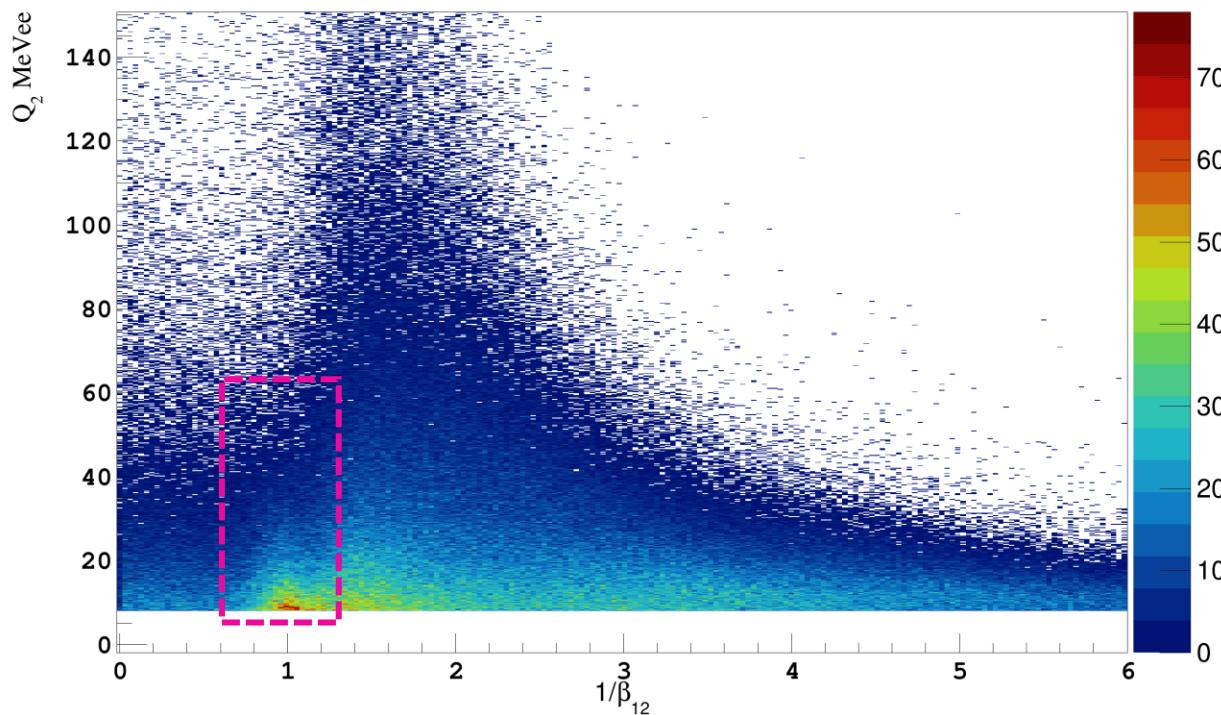


Hints from 1 - Neutron simulations

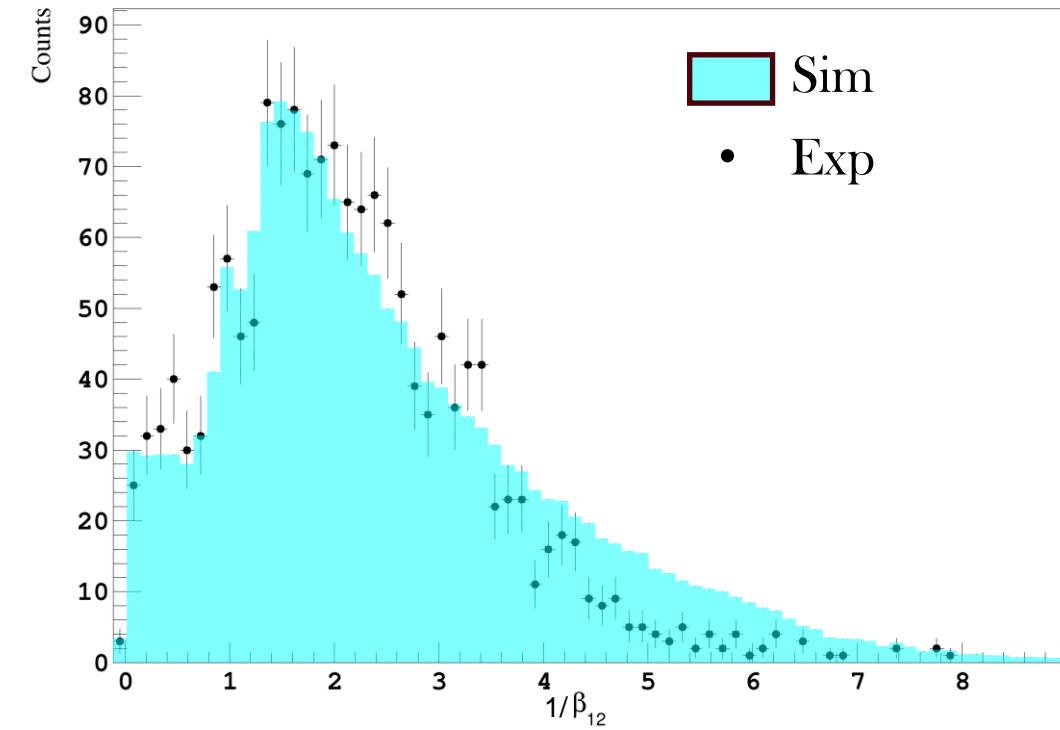


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Simulated $1/\beta_{12}$ vs Energy transfer Q_2 at second point



Exp vs Sim $1/\beta_{12}$

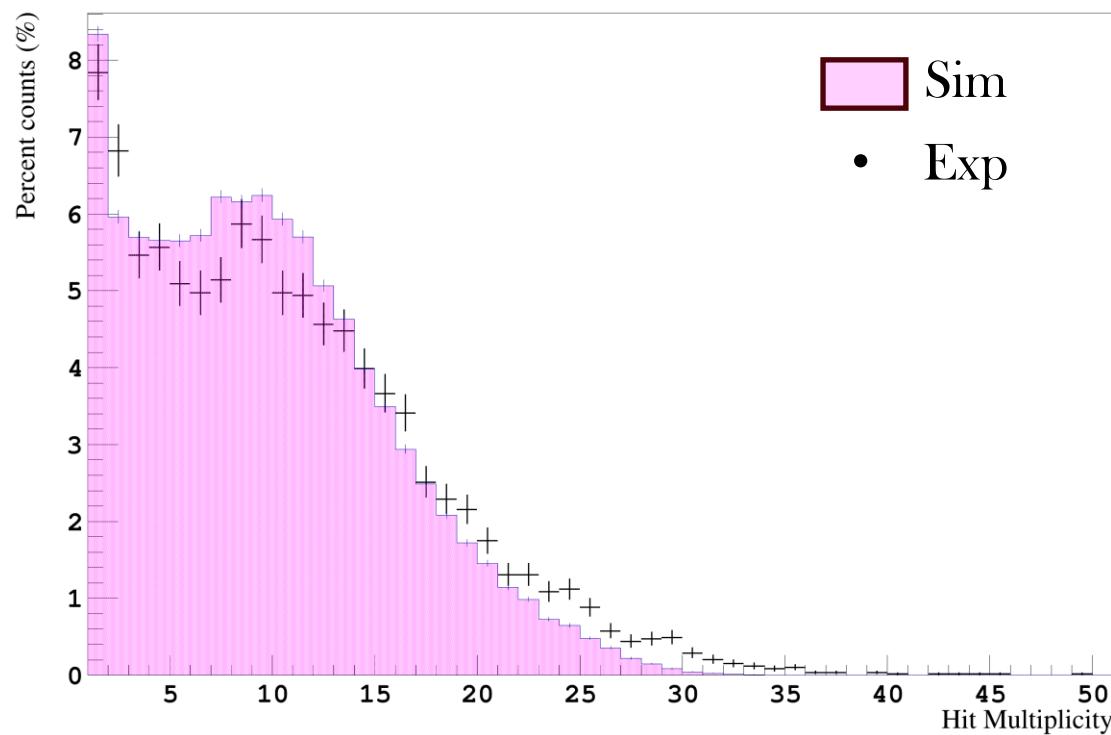


why $1/\beta_{12}$?

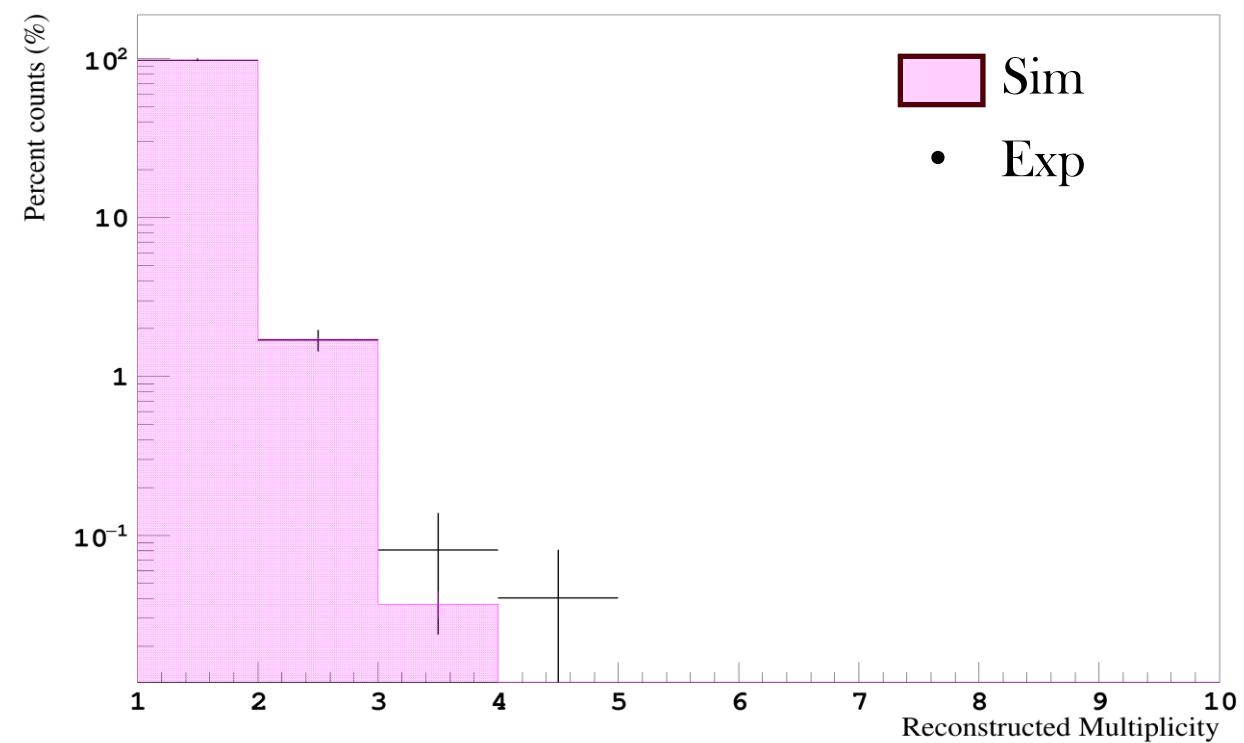
- Cut for $1/\beta_{12} = 1$ for secondary gamma
- Allowance for time resolution

Hints from 1 - Neutron simulations

Sim vs Exp hit multiplicity (before reconstruction)



Sim vs Exp multiplicity after reconstruction



2 - Neutron simulations



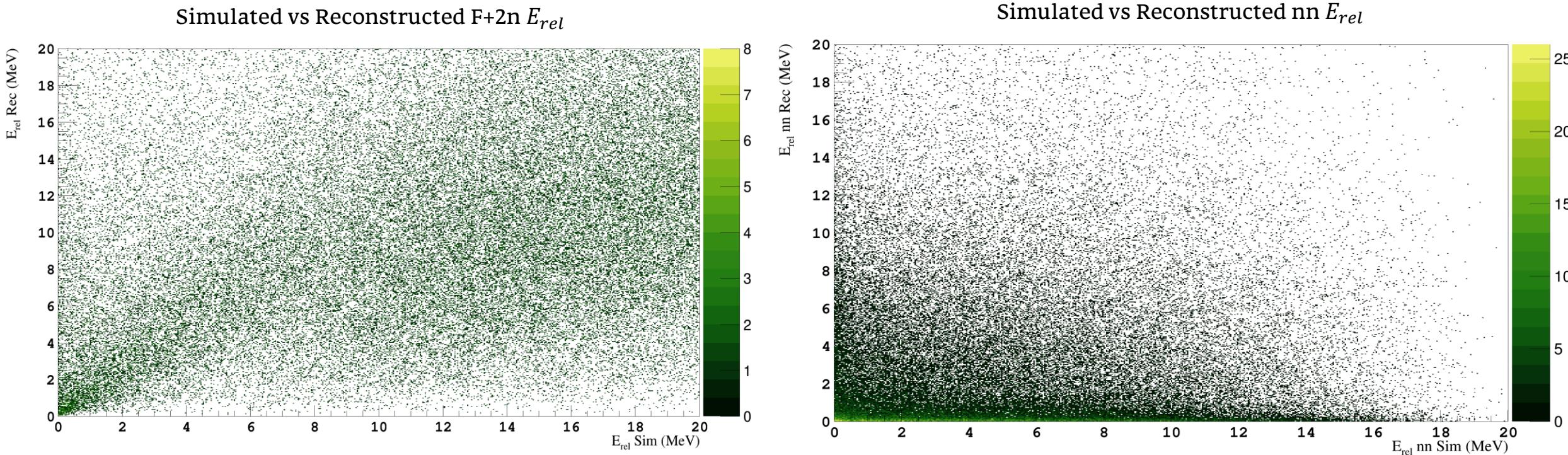
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What does crosstalk look like in terms of relative energy?

2 - Neutron simulations

What does crosstalk actually look like in relative energy terms?

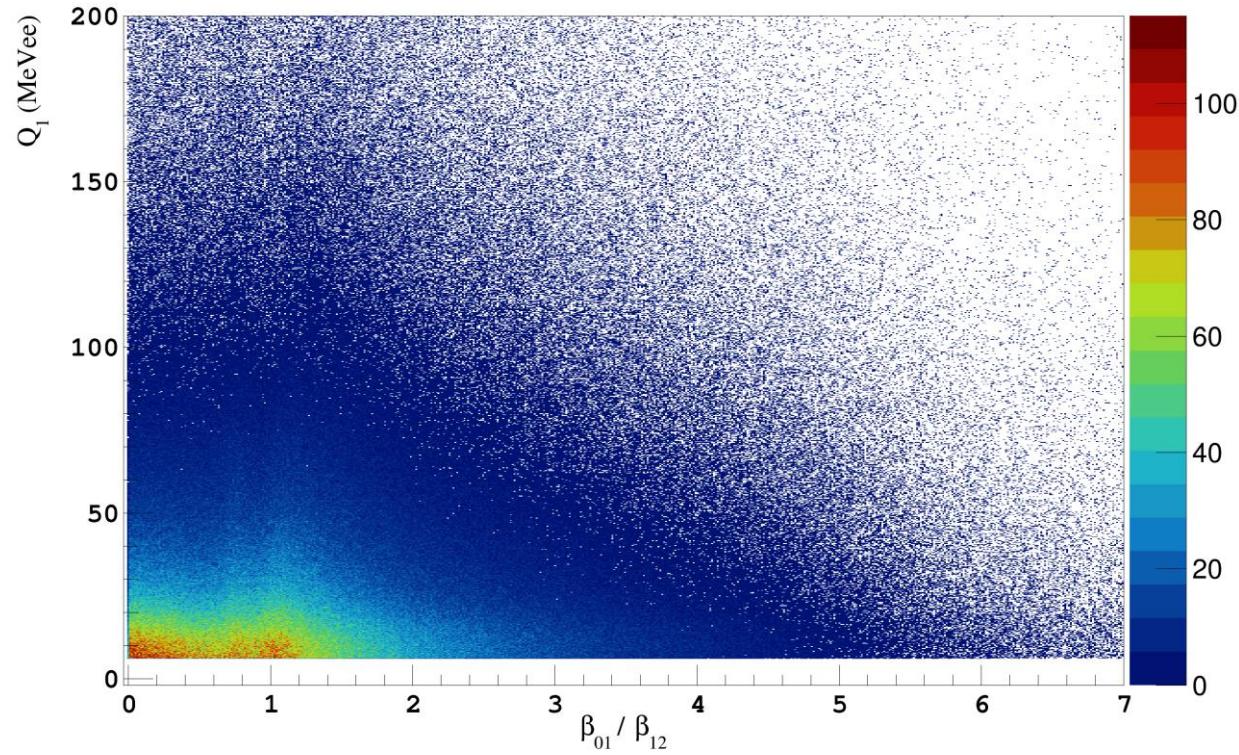
From uniform E_{rel} F + 2n distribution 0-20 MeV simulation :



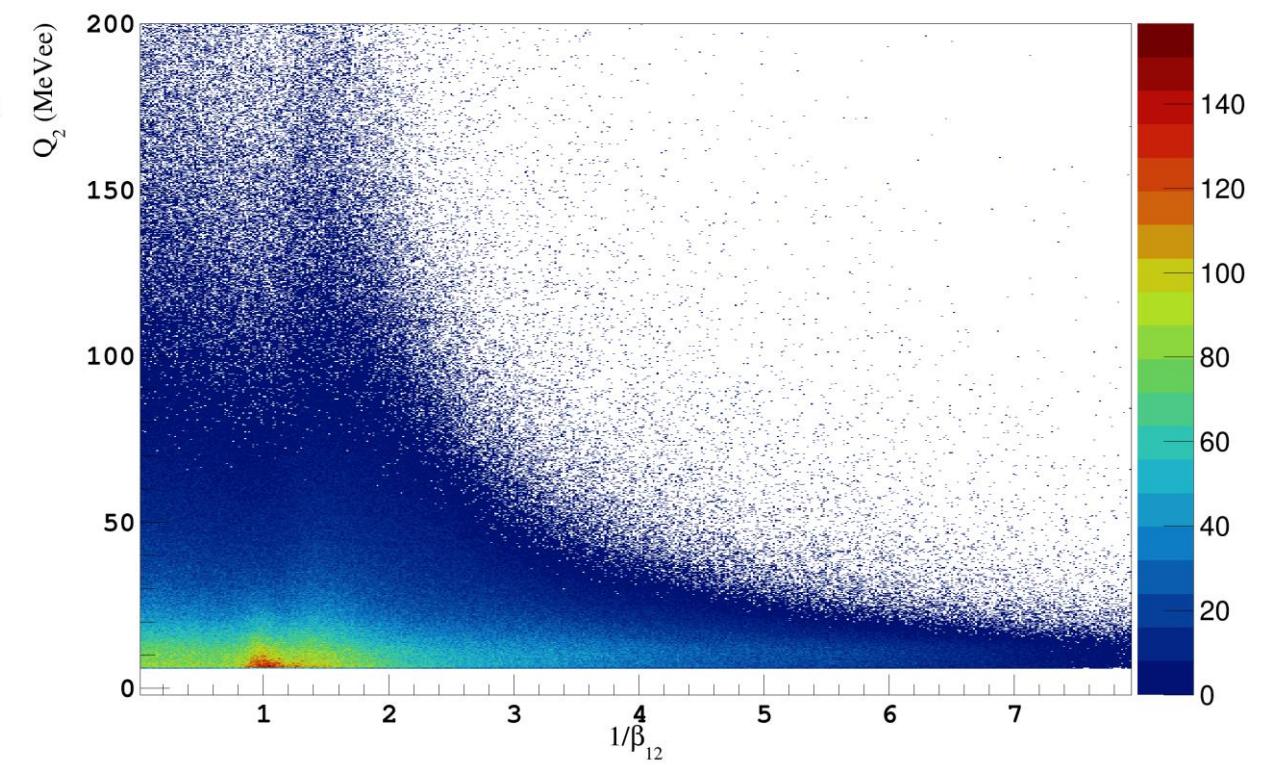
2 - Neutron simulations

Velocity distribution plots

Simulated β_{01}/β_{12} vs Energy transfer Q1 at first point



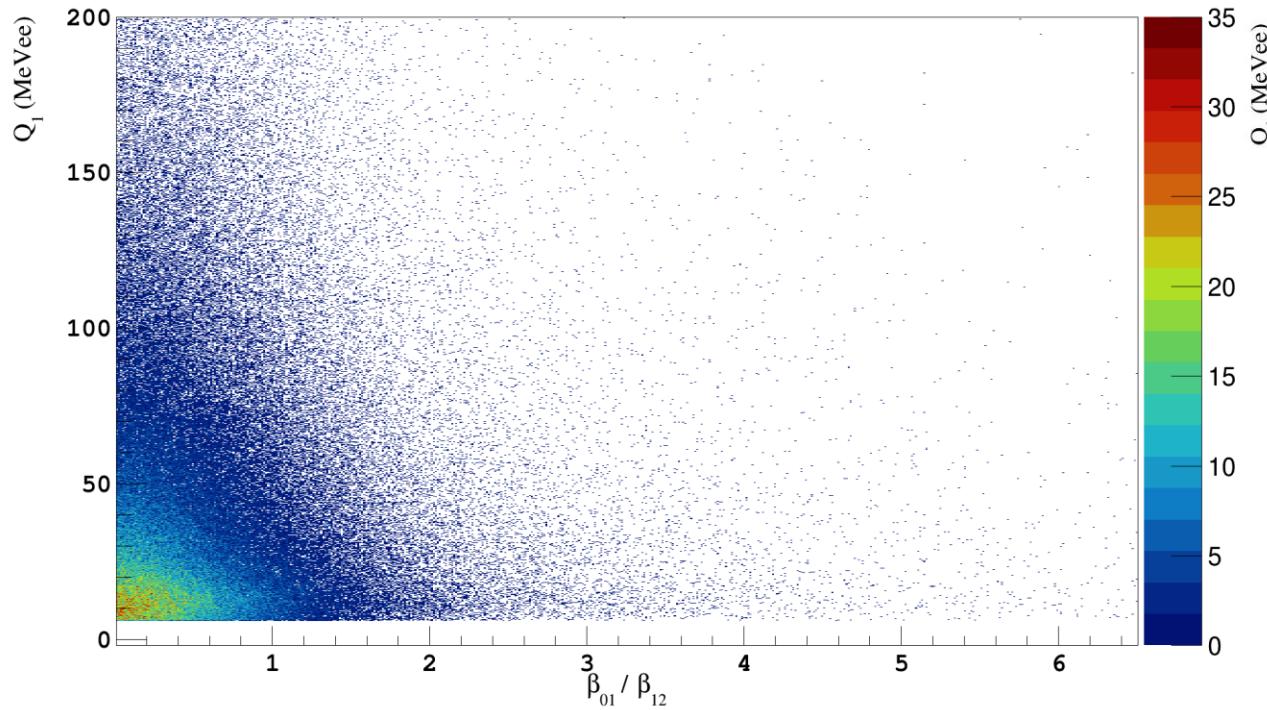
Simulated $1/\beta_{12}$ vs Energy transfer Q2 at second point



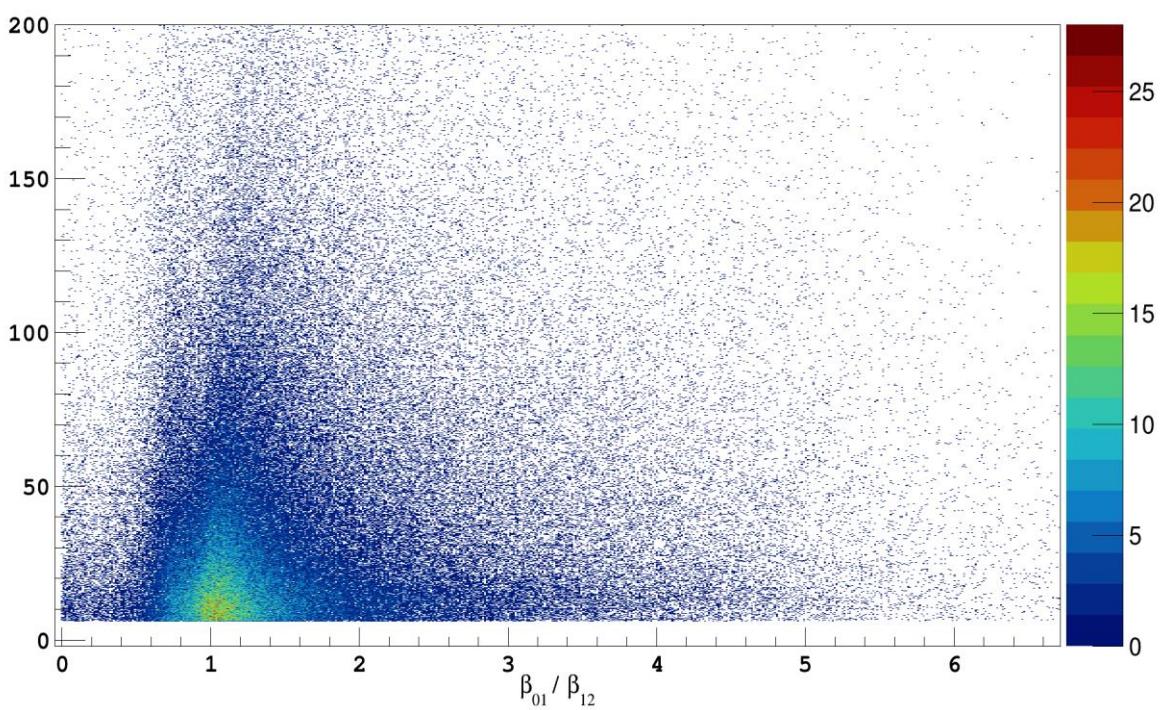
2 - Neutron simulations

Velocity distribution plots

Simulated β_{01}/β_{12} vs Energy transfer Q1 at first point
for two well identified neutrons



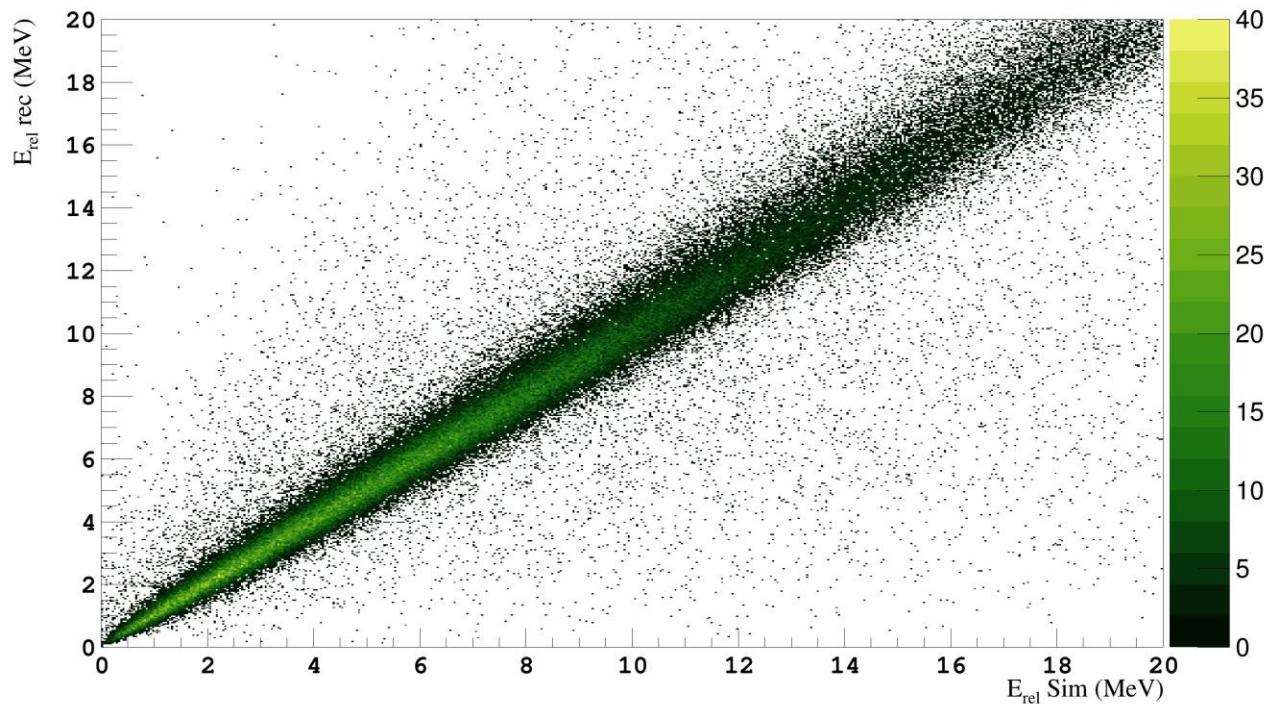
Simulated β_{01}/β_{12} vs Energy transfer Q1 at first point
for cross talk



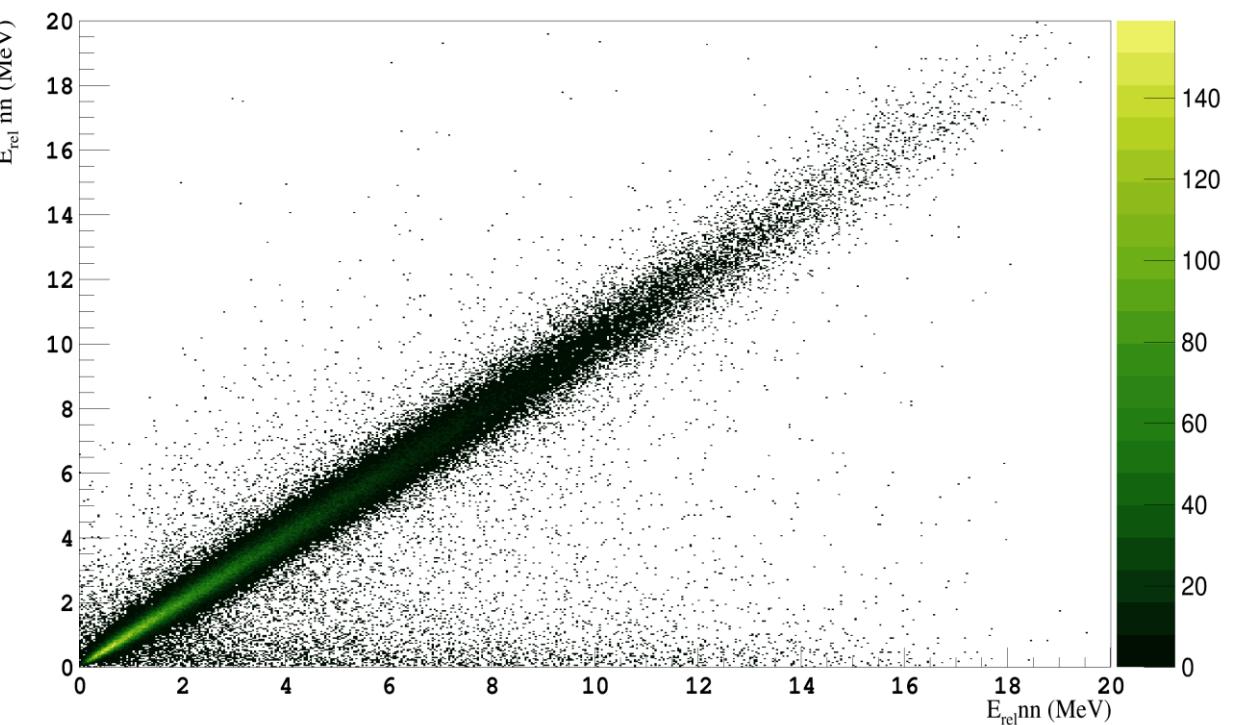
2 - Neutron simulations

After reconstruction...

Simulated vs Reconstructed F+2n E_{rel}



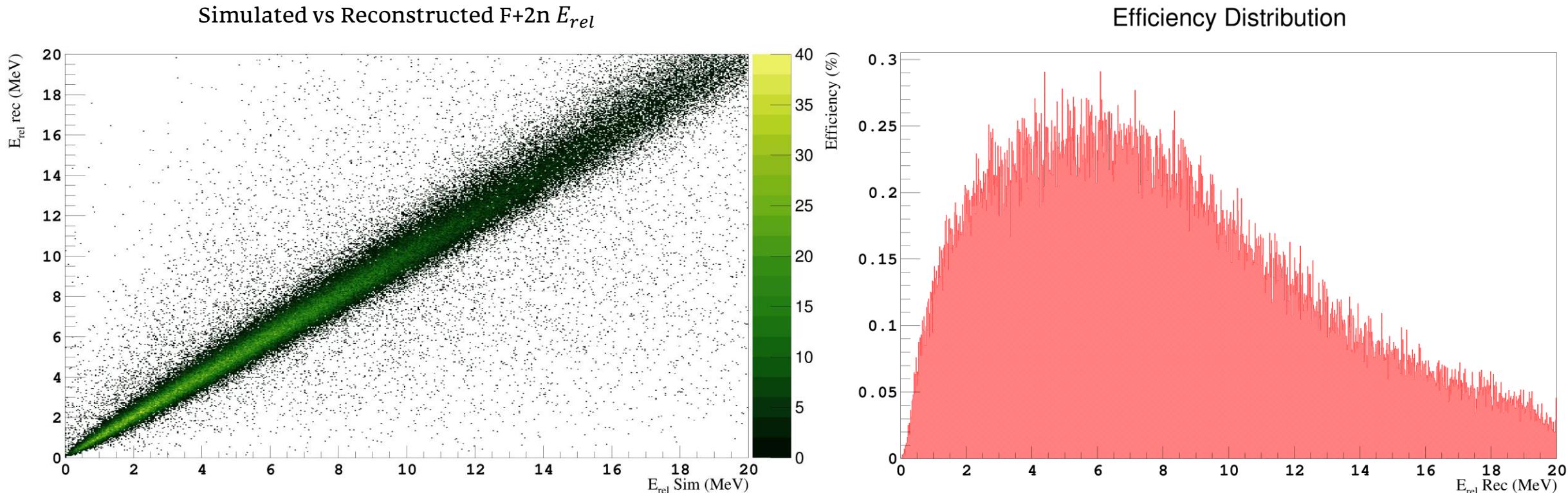
Simulated vs Reconstructed nn E_{rel}



- Good correlation between simulation and reconstruction for both F+2n and nn E_{rel}
- Small amount of crosstalk remain $\sim 4\%$

2 - Neutron simulations

After reconstruction...



- Good correlation between simulation and reconstruction for both F+2n and nn E_{rel}
- Small amount of crosstalk remain $\sim 4\%$
- Efficiency distribution



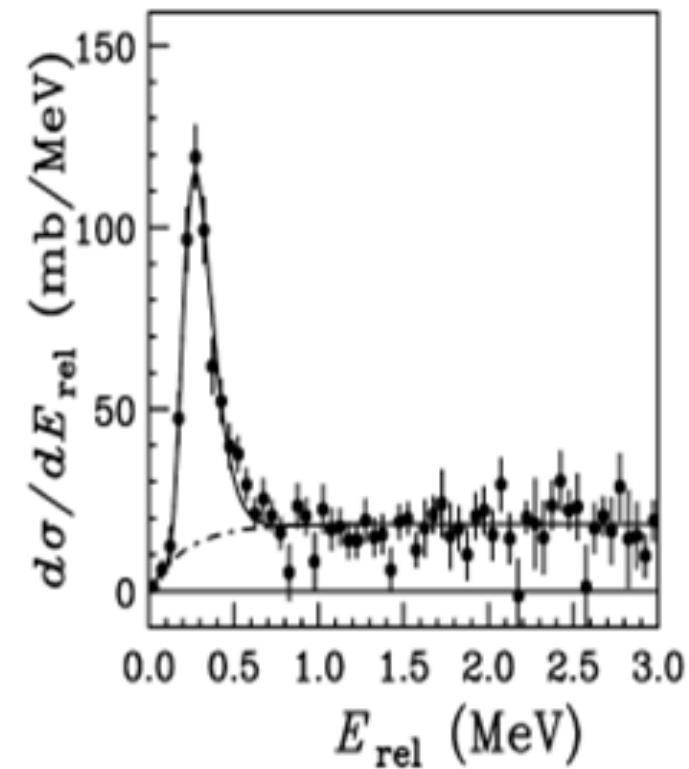
So what about Experiment?

So what about Experiment?



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- We take the case for ^{15}B (-1p) $^{12}\text{Be} + 2\text{n}$
- Narrow resonance at ~ 280 keV below 1n threshold
- Previously only published with inelastic scattering

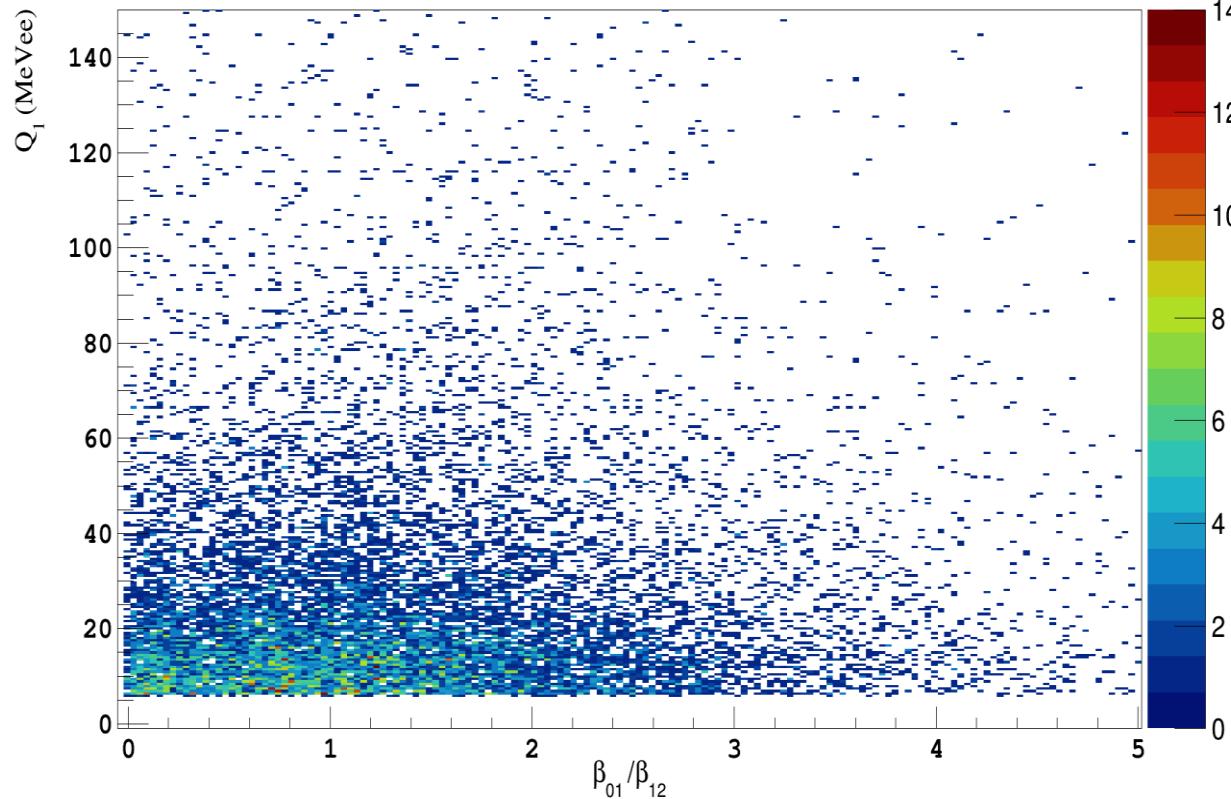


T. Sugimoto et al. PLB 654, 160 (2007)

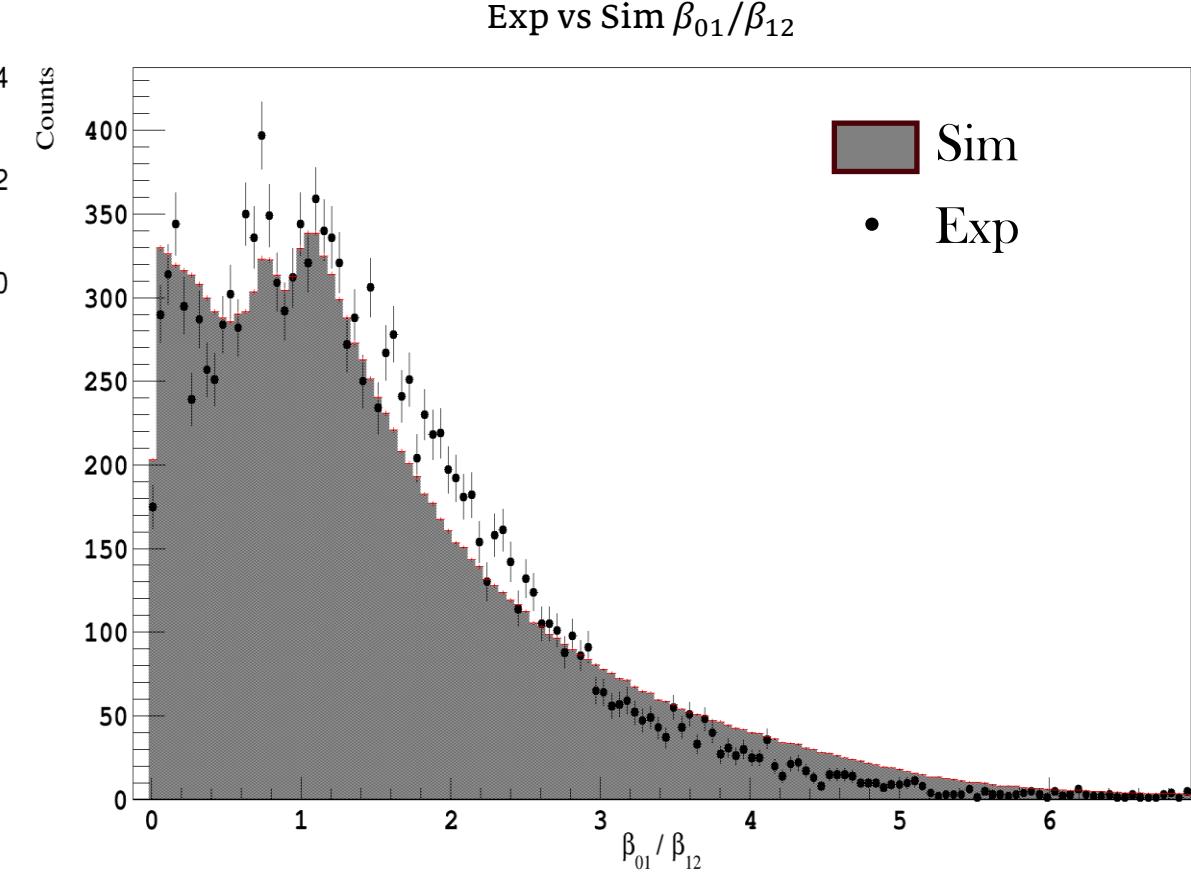
2 - Neutron reconstruction

Velocity distribution plots

Experimental β_{01}/β_{12} vs Energy transfer Q1 at first point



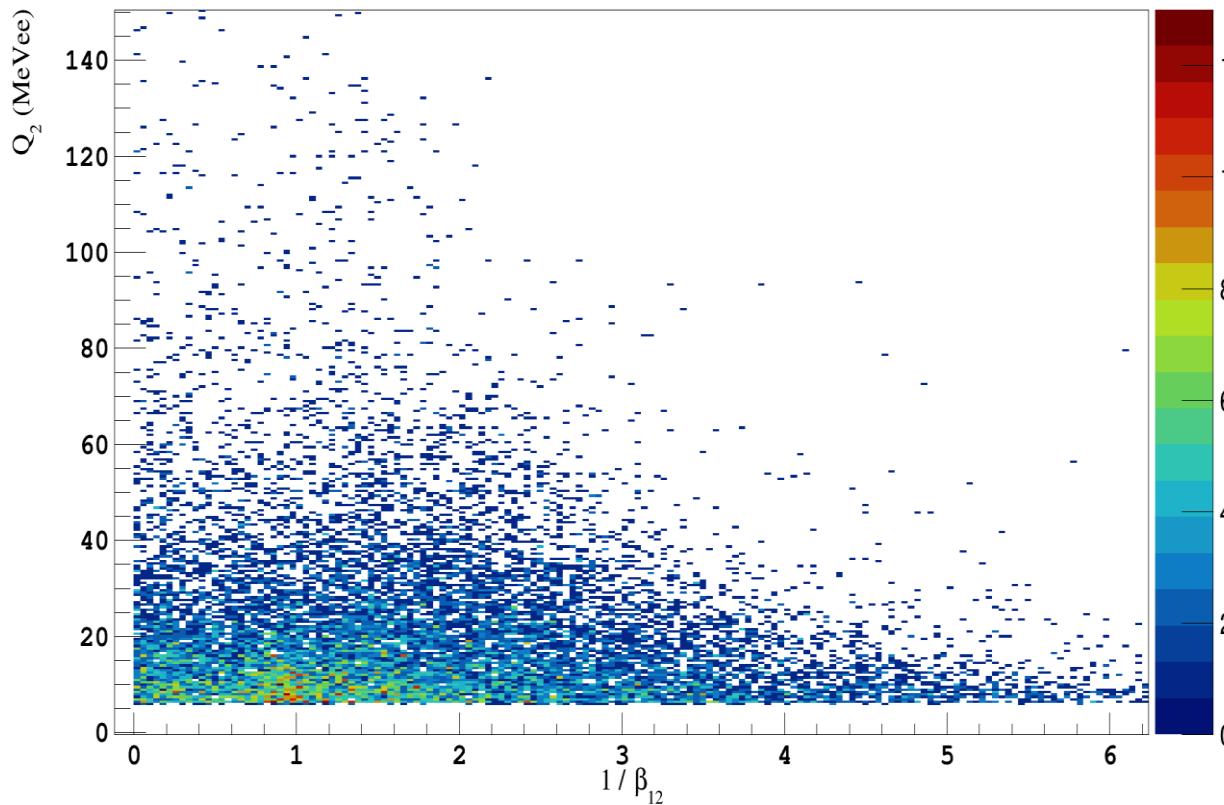
Exp vs Sim β_{01}/β_{12}



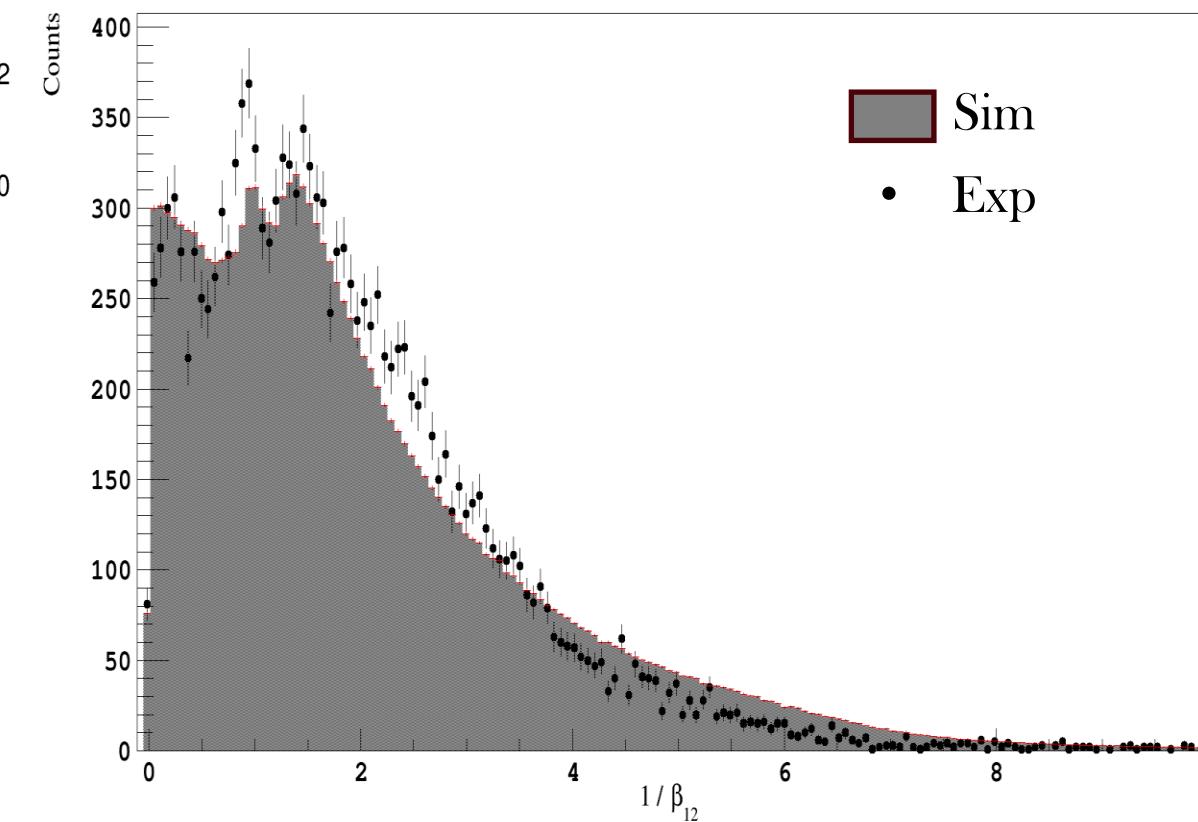
2 - Neutron reconstruction

Velocity distribution plots

Experimental $1/\beta_{12}$ vs Energy transfer Q_1 at first point



Exp vs Sim $1/\beta_{12}$

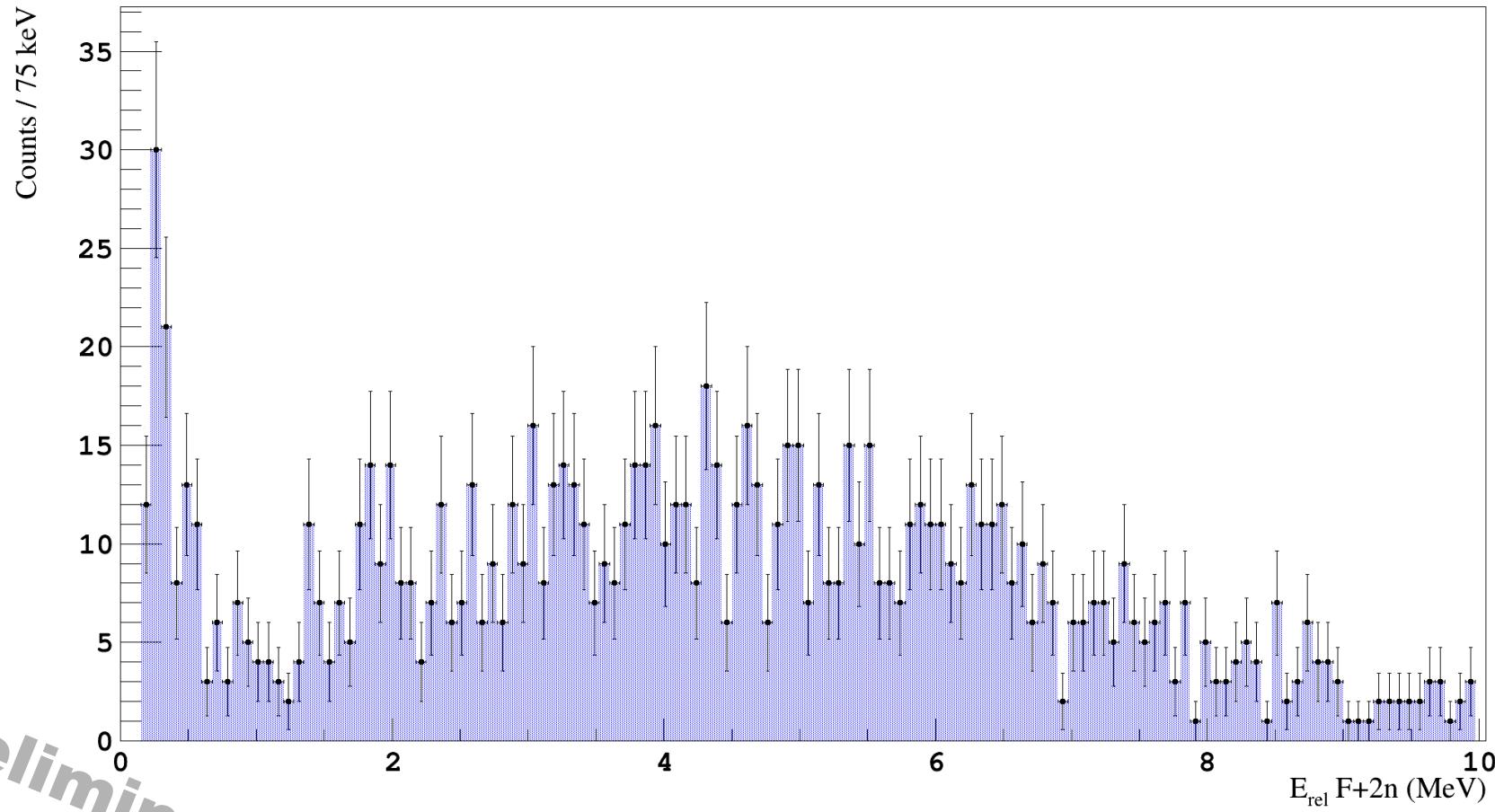


$^{15}\text{B} (-1\text{p}) \ ^{12}\text{Be} + 2\text{n}$



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Reconstructed Frag + 2n E_{rel} distribution



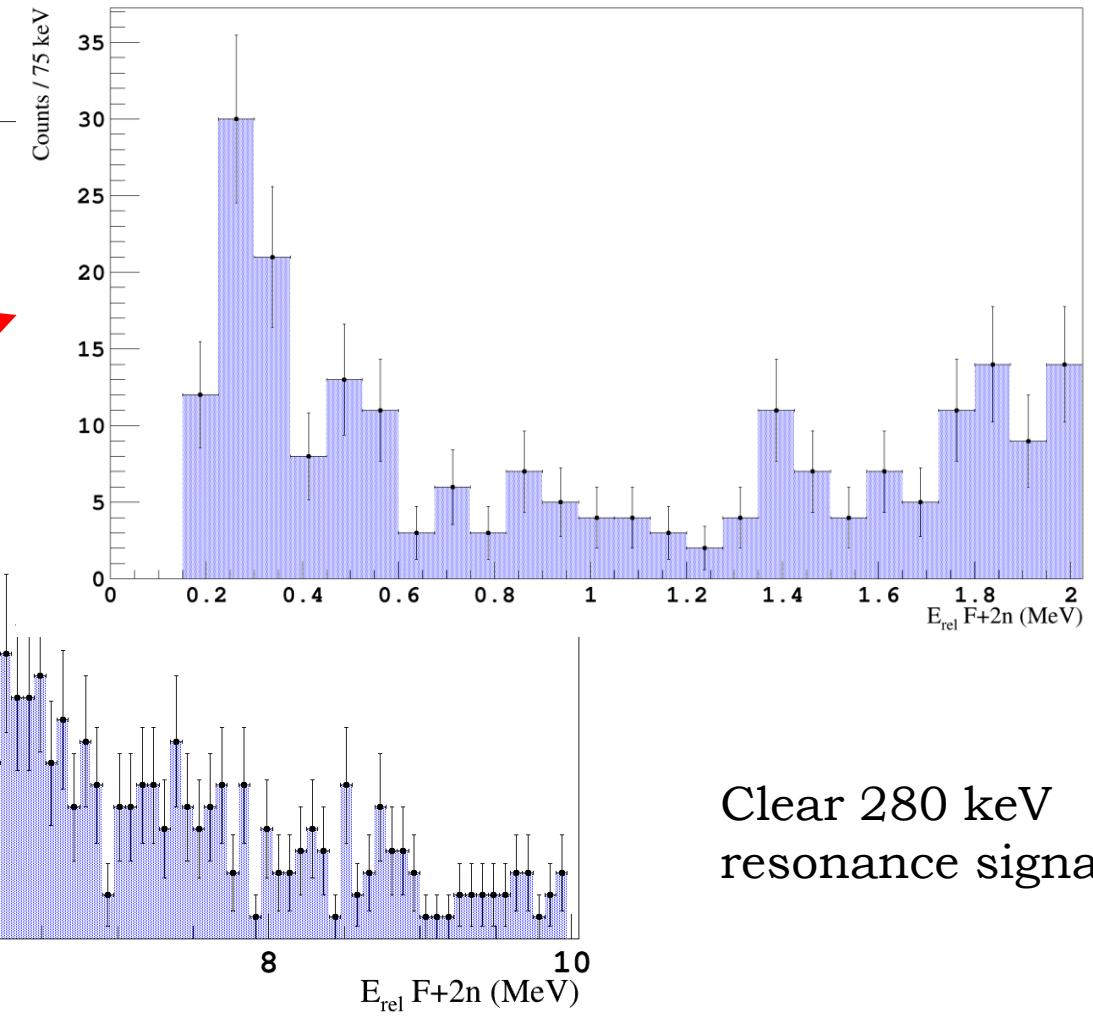
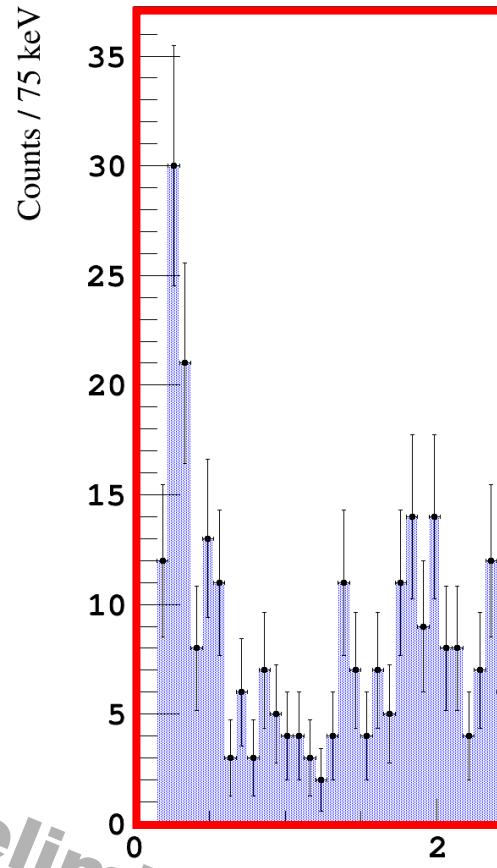
Preliminary!!!

$^{15}\text{B} (-1\text{p}) \ ^{12}\text{Be} + 2\text{n}$



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Reconstructed Frag + 2n E_{rel} distribution

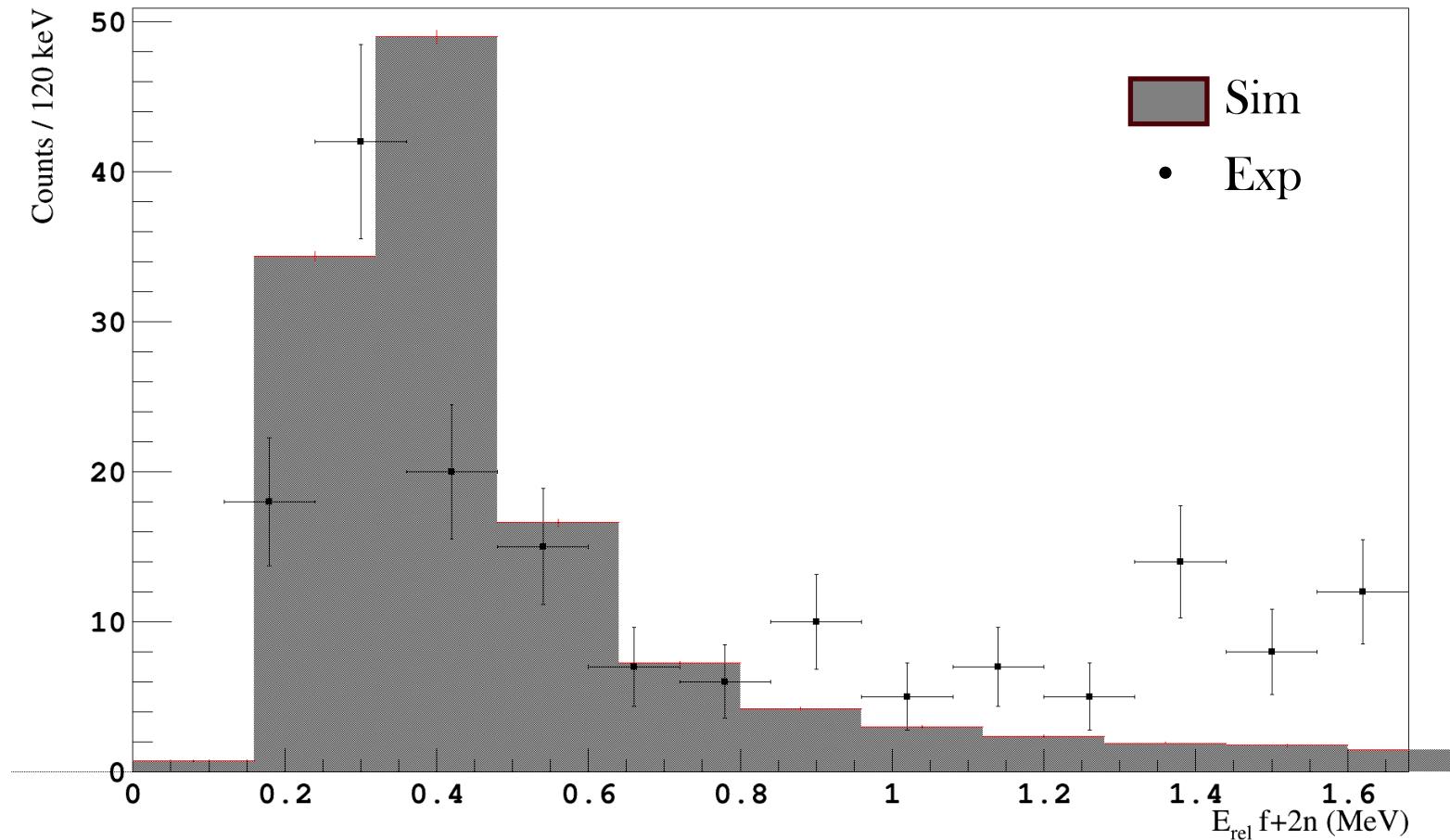


Preliminary!!!

$^{15}\text{B} (-1\text{p}) \ ^{12}\text{Be} + 2\text{n}$

1st test comparison of simulated and experimental data

Experimental vs Simulated $E_{rel} = 280$ keV resonance

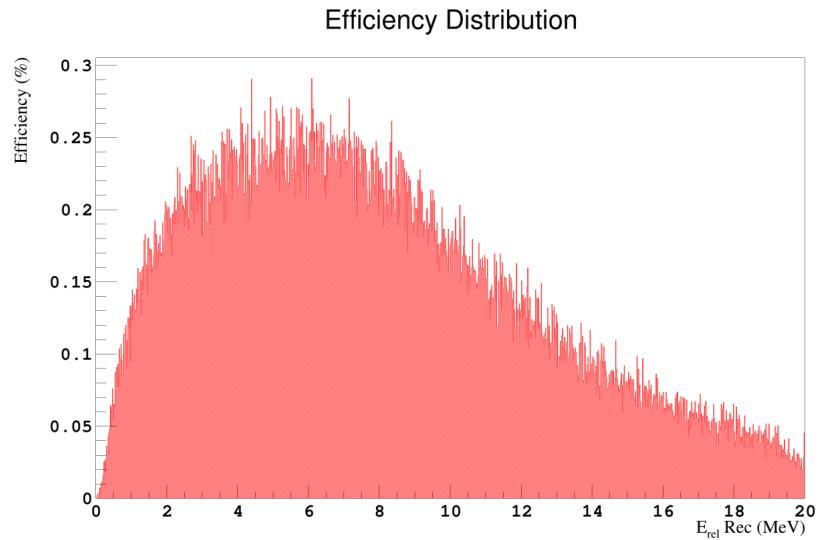


Preliminary!!!

OutLook



- ❑ First Frag + $2n$ Erel reconstruction
- ❑ Need to further refine method
- ❑ Use proper simulation parameters, time/energy resolution etc.
- ❑ Problems
 - Discrepancy in energy distribution between simulation and experiment
 - Low efficiency and large crosstalk at low relative energies
- ❑ Test alternative methods: TDR?



Thank you