Deviations from Hauser-Feshbach behaviour in evaporation chains in light heavy-ion collisions

Bologna–2018 European Nuclear Physics Conference

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NUCL-EX Collaboration

05 September 2018

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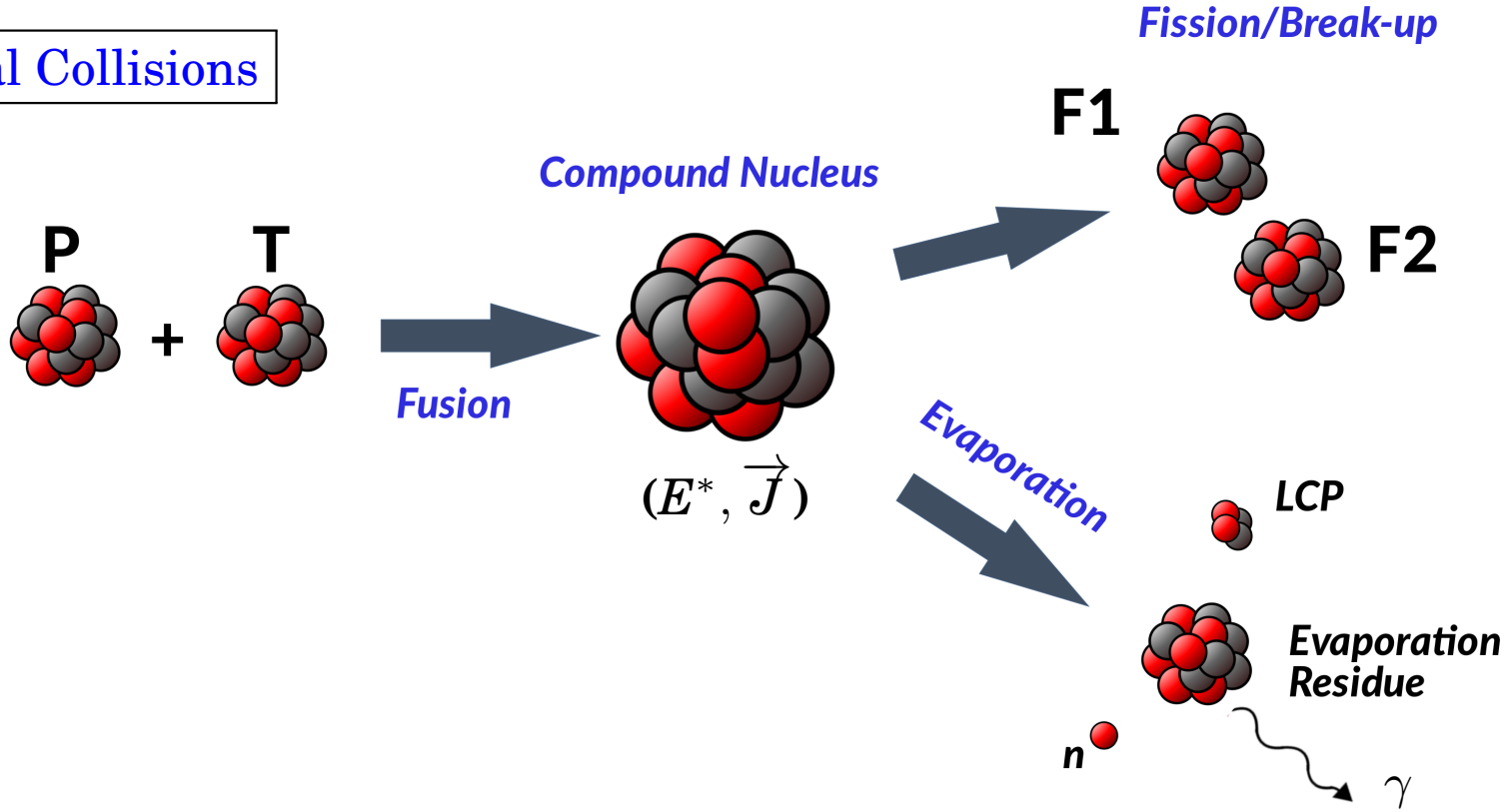
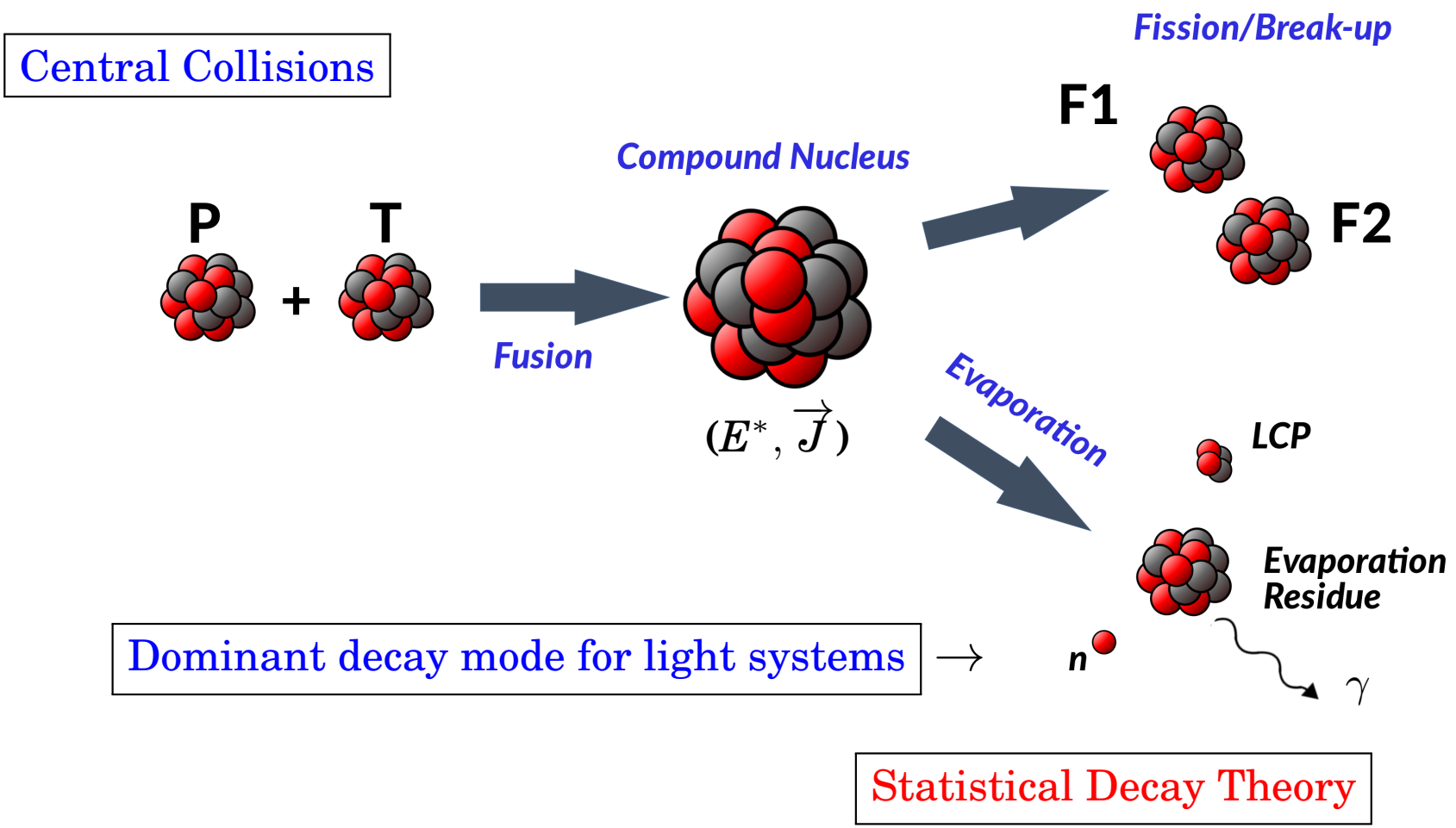
SEZIONE DI FIRENZE

Physics Case: Light-HIC at low energy (< 15 MeV/u)

Central Collisions



Physics Case: Light-HIC at low energy (< 15 MeV/u)



- NUCL-EX collaboration:
  1. $^{12}C+^{12}C$ @ 95 MeV and $^{14}N+^{10}B$ @ 80.7 MeV
  2. $^{12}C+^{13}C$ @ 95 MeV
  3. $^{16}O+^{12}C$ @ 90.5, 110 and 130 MeV
  4. $^{24}Mg+^{12,13}C$ @ 162 and 142 MeV
- Excited CN nuclei: $^{24,25}Mg$ [A.Camaiani's talk], ^{28}Si and $^{36,37}Ar$ [S.Barlini's talk] @ 2-3 MeV/u

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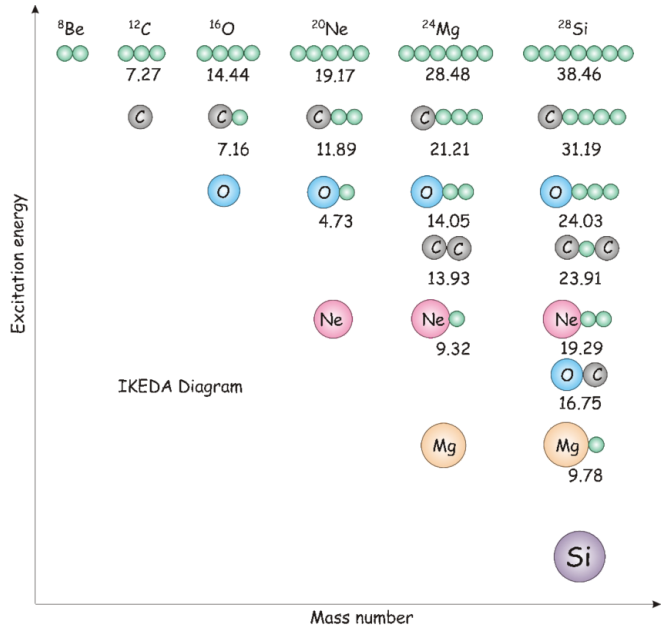
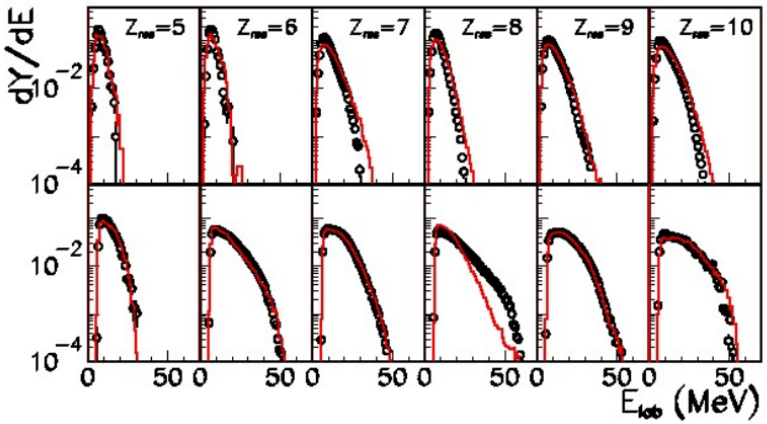
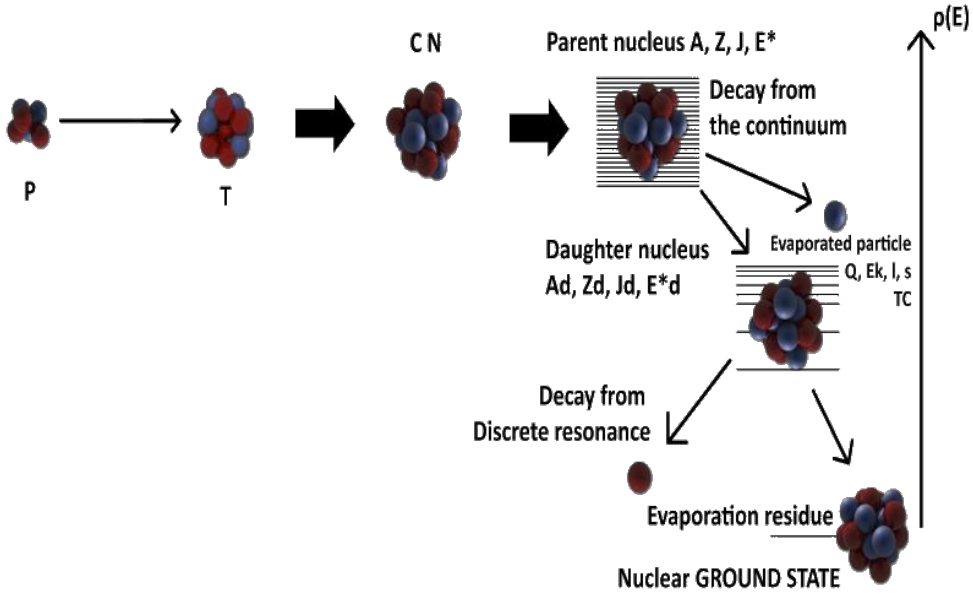
- *(L. Morelli et. al.,J. Phys. G: Nucl. Part. Phys. 41, 075107 & 075108, (2014))* $\rightarrow$ Predominance of α-particles emission in specific decay channels



K. Ikeda, Prog. Theor. Phys. 40, 277 (1968)



Statistical Decay Models



G.Baiocco, PhD Thesis (2012) & G.Baiocco et al., Phys. Rev.C87 054614 (2013)

- HFℓ: evaporation of LCP (n, p, d, t, ^{3}He, α) and ^{6}Li,^{7}Li is treated with the standard Hauser-Feshbach formalism of CN decay.
  $\rightarrow$ transmission coefficients and Level Densities (LD) optimized for A$<$40
  $\rightarrow$ information on measured excited levels from the NUDAT2
- Gemini++ *(R. J. Charity et. al.,J. Phys. Rev. C 82, 014610 (2010))*

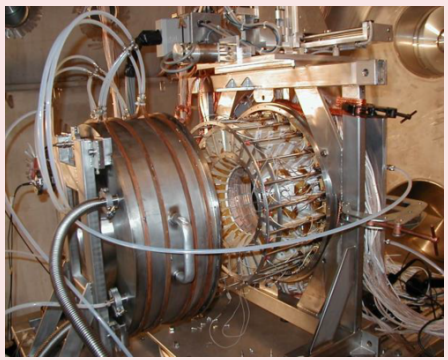
Experiment

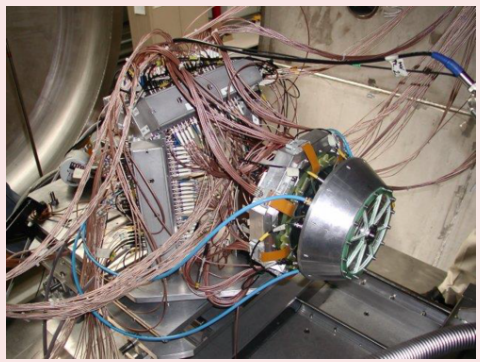
Formation of the ^{28}Si Compound Nucleus

- Pulsed (about 1 ns resolution, 400 ns repetition period) ^{16}O beam @ 90.5, 110 and 130 MeV with intesities of around 0.1 pnA on a ^{12}C target at LNL. The employed apparatus was Garfield + Ring Counter (RCo) detectors.

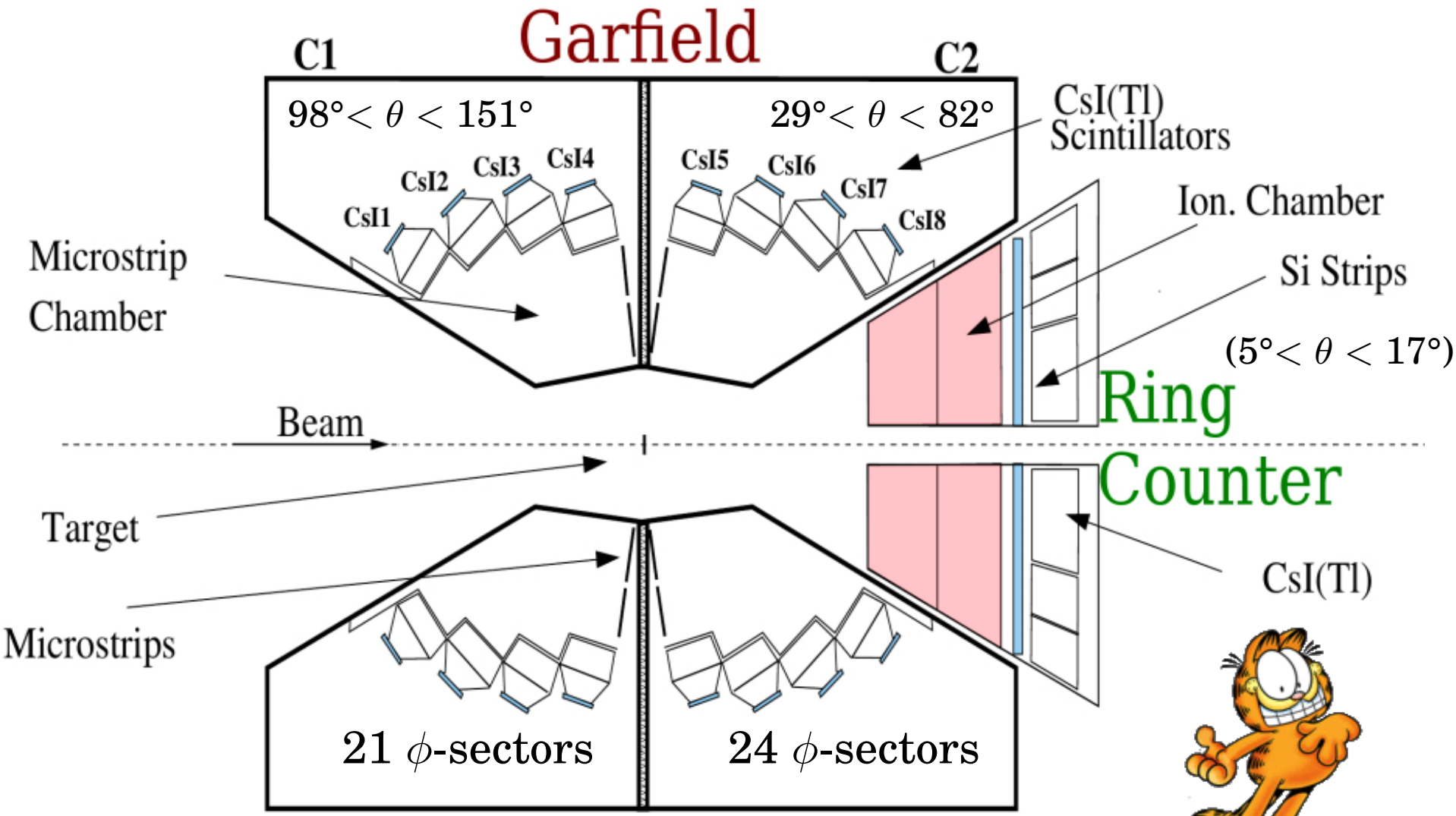
Reaction	$\mathbf{E}^*$ [MeV]	$\mathbf{J_{max}}$ [$\hbar$]	$\mathbf{V_{CN}}$ [cm/ns]	$\sigma_\mathbf{F}$ [mbarn]
^{16}O+^{12}C	55	14	1.88	886
^{16}O+^{12}C	63	16	2.08	841
^{16}O+^{12}C	72	18	2.26	809

Parameters calculated with PACE4 (cross-section from Bass model)





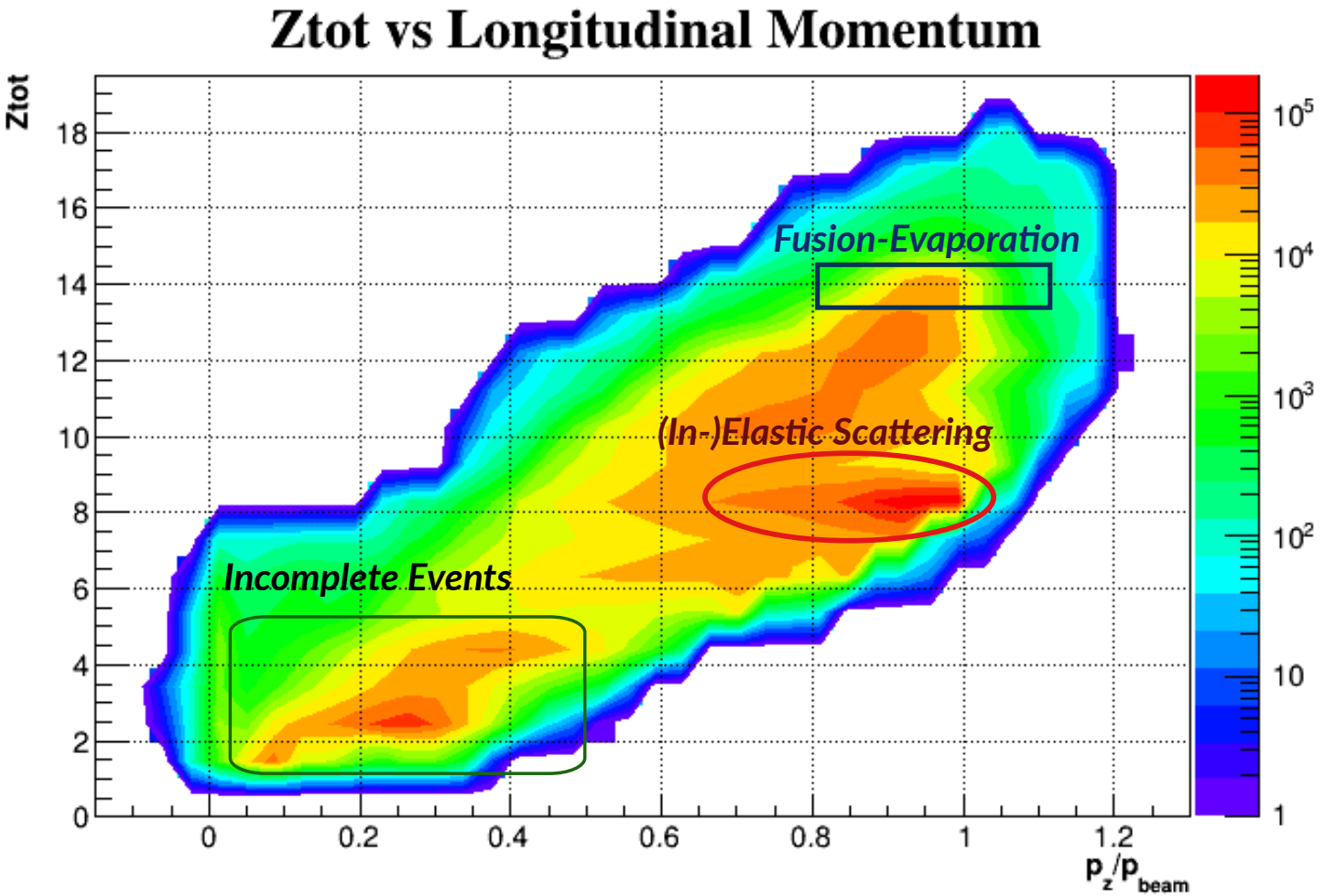
Experimental Apparatus



M.Bruno et al., Eur. Phys. J. A 49, 2013

Event Selection

^{16}O+^{12}C @ 130 MeV



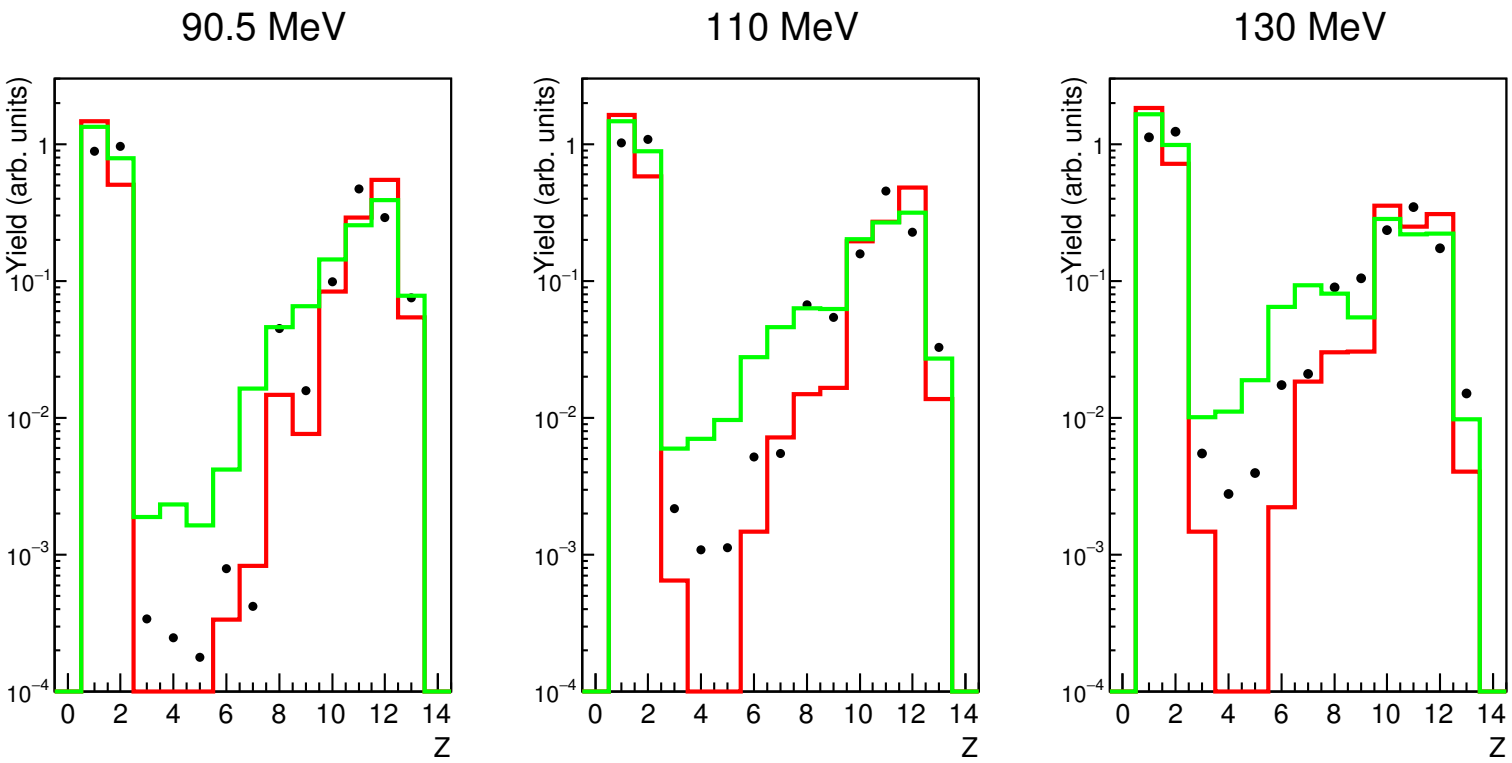
The results in the next slides are obtained with the Fusion-Evaporation selection

($Z_{tot} = 14$ & $0.8 < p_z/p_{beam} < 1.1$)

Charge Distribution

Distributions normalized to the number of events (≡evaporation residue number)

→ *Data points (Black Dots), HFℓ(red line) and Gemini++ (green line)*



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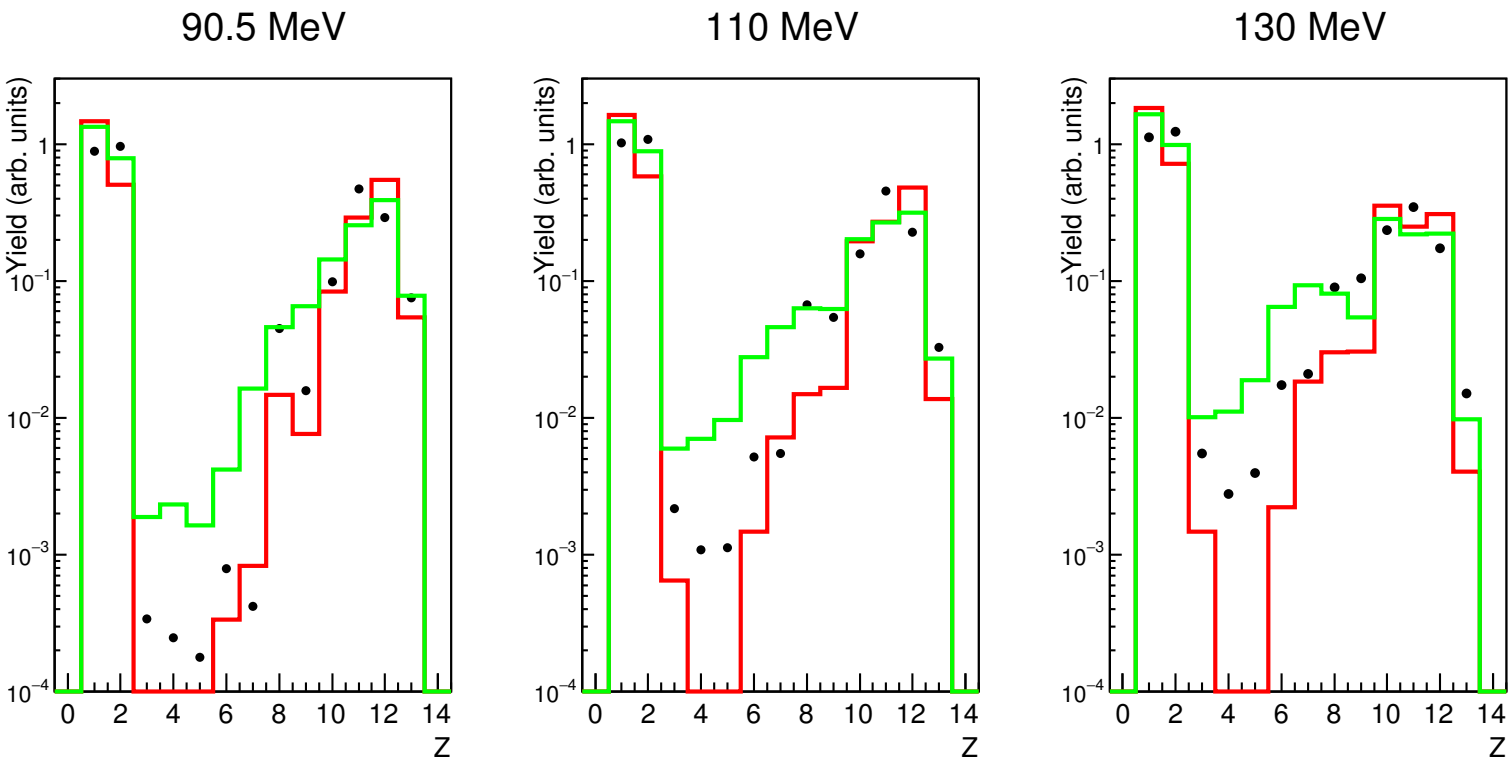
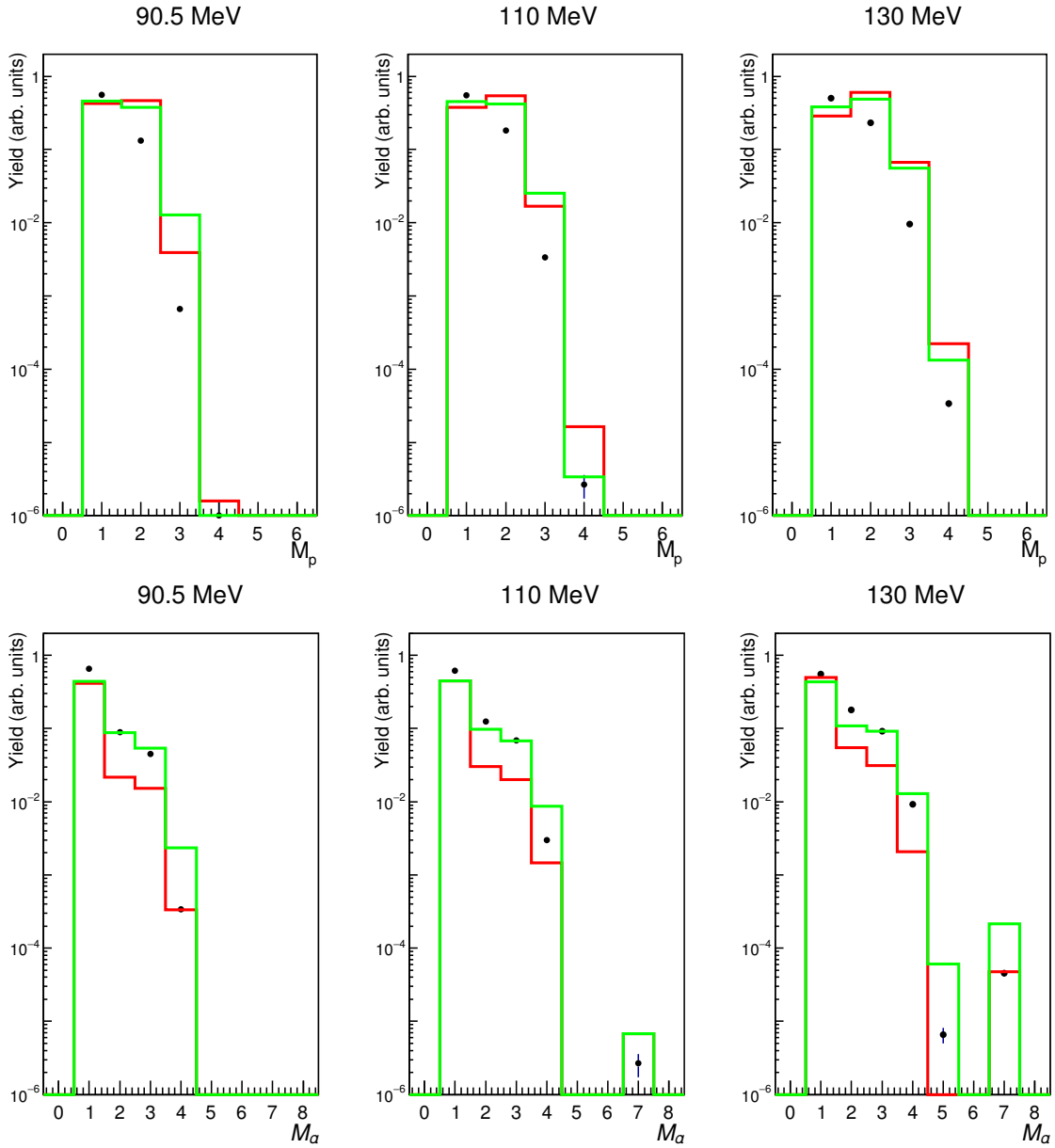


- Underestimation (HFℓ) and overestimation (Gemini) of the yield for the IMF region
  → For Gemini IMF (Z>3) emission is included: break-up contribution
- For some $Z \approx Z_{projectile}$ → direct reaction contamination ?

Multiplicity Distribution

(event nr. normalized spectra)



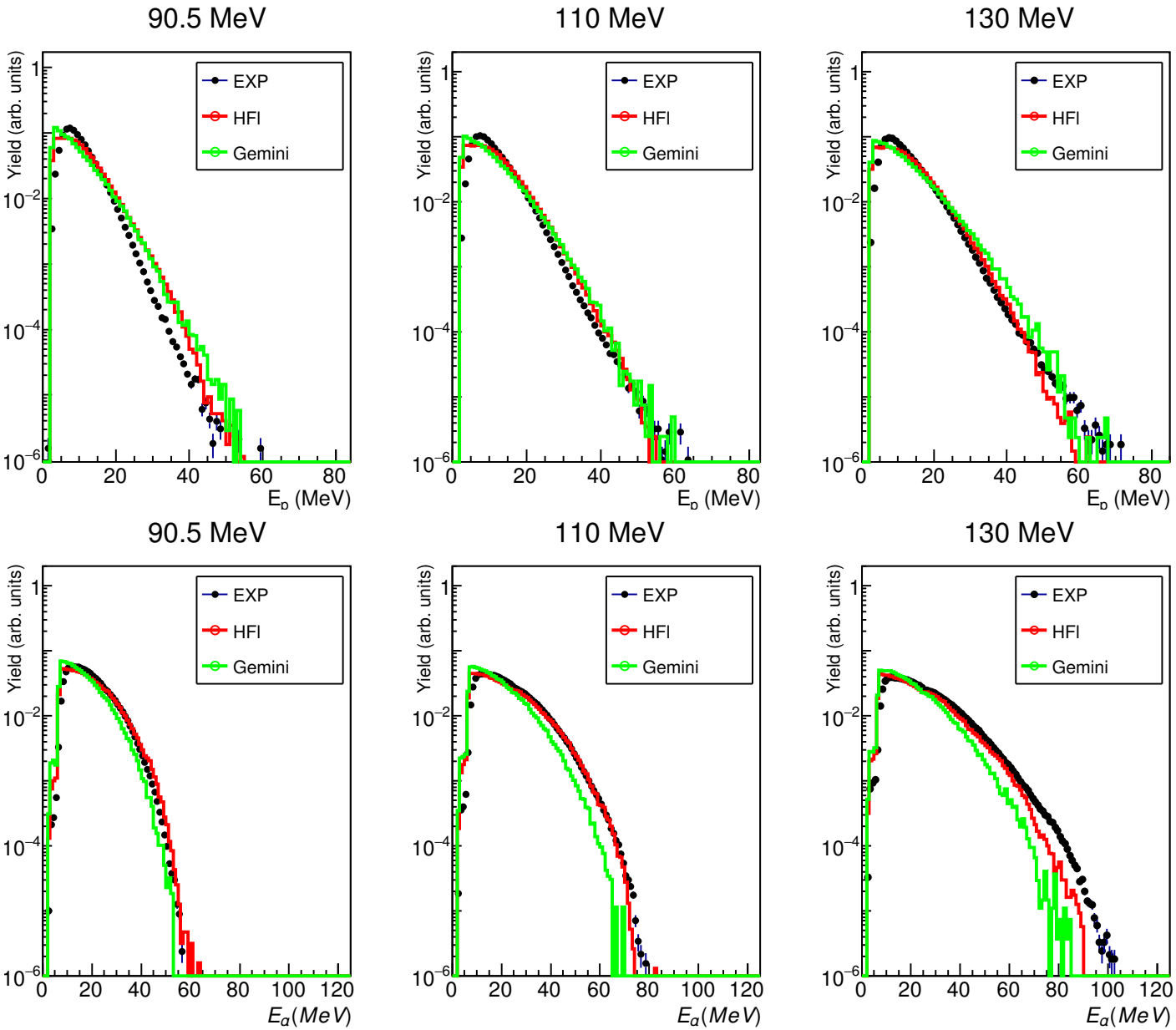
Protons

Integrated over the entire apparatus (Garf+RCo)

α-particles

Lab Energy Distribution

(shape normalized spectra)



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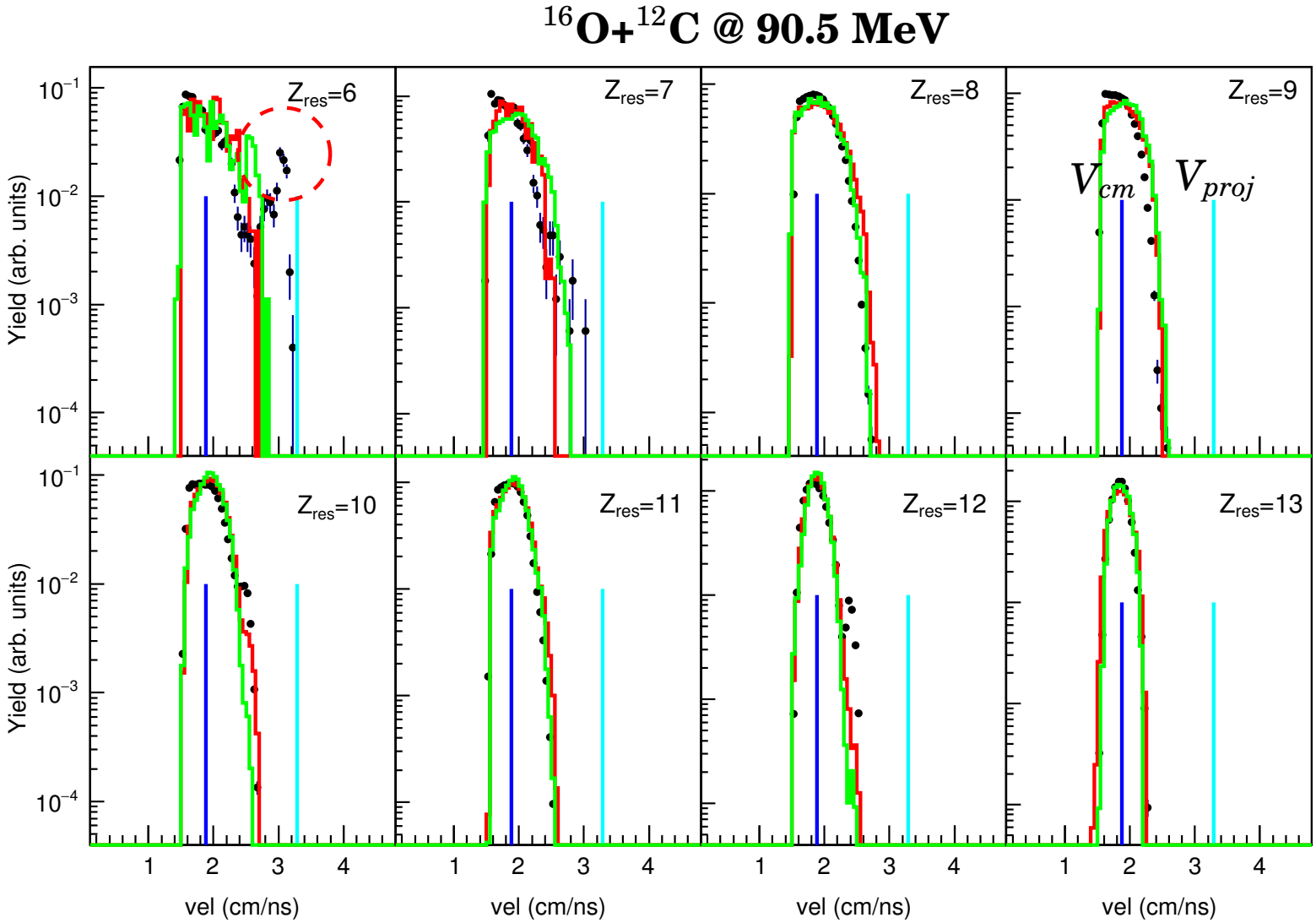
Selection of decay channels

Residue Velocity

(shape normalized spectra)



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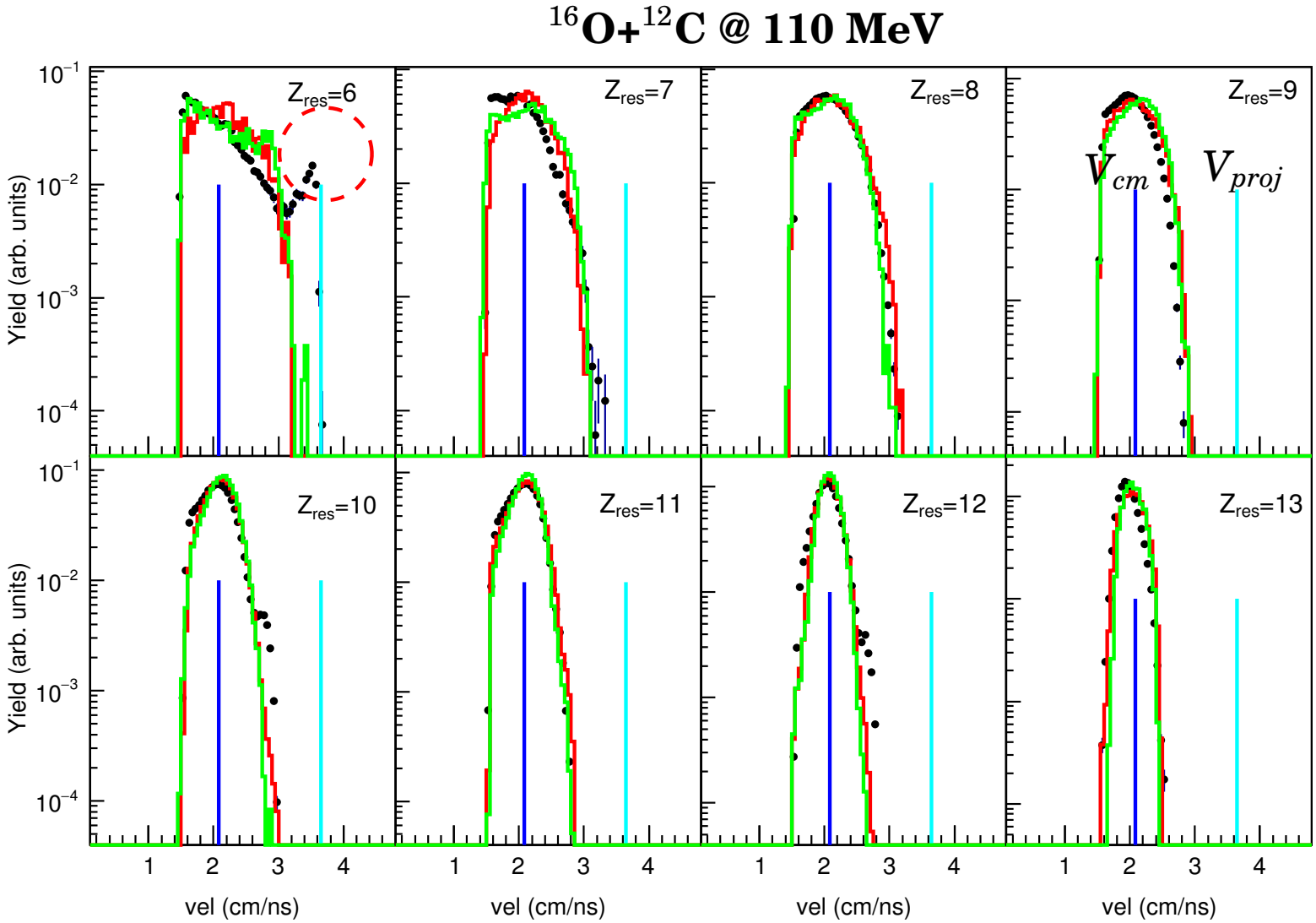

Residue Velocity

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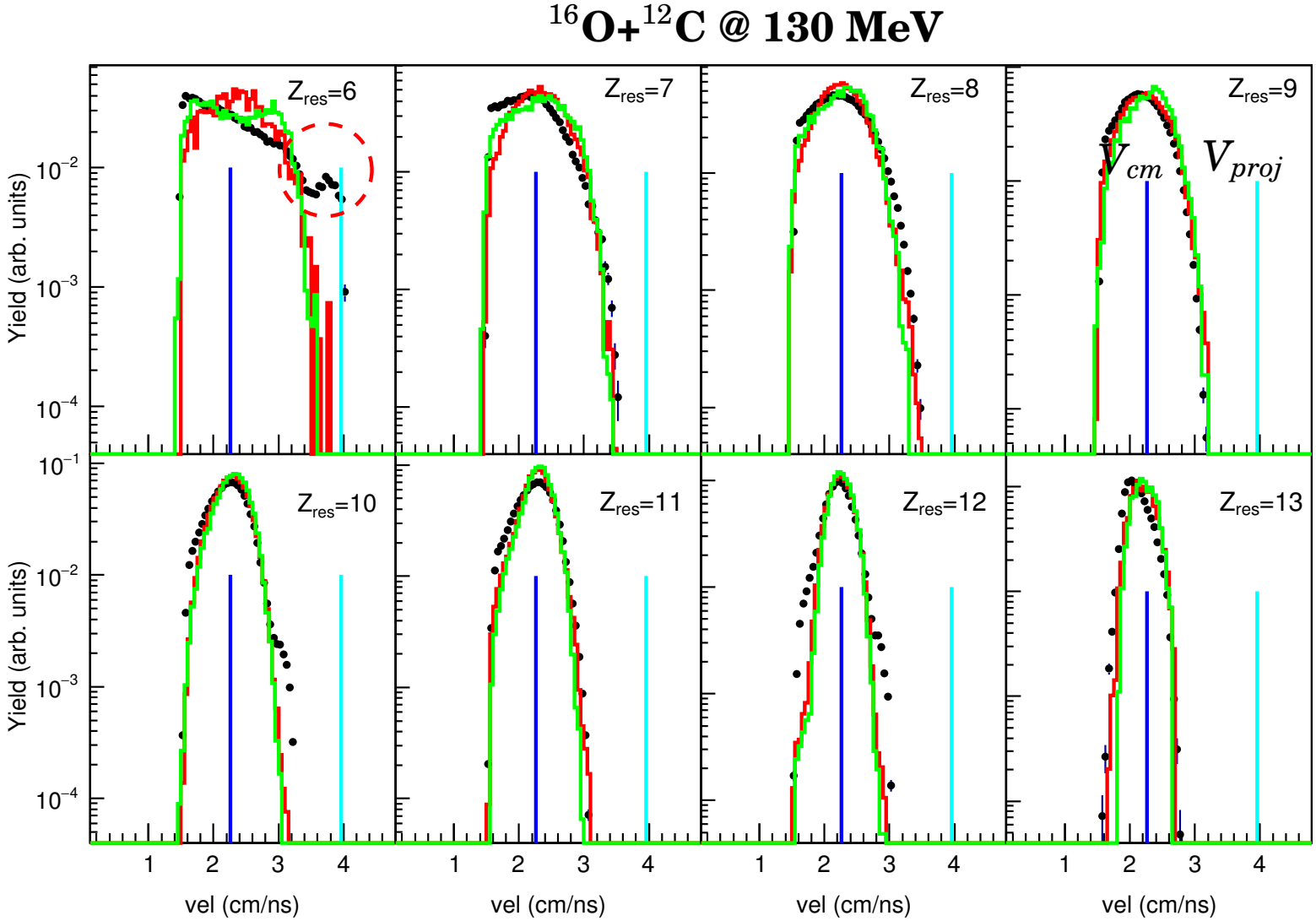
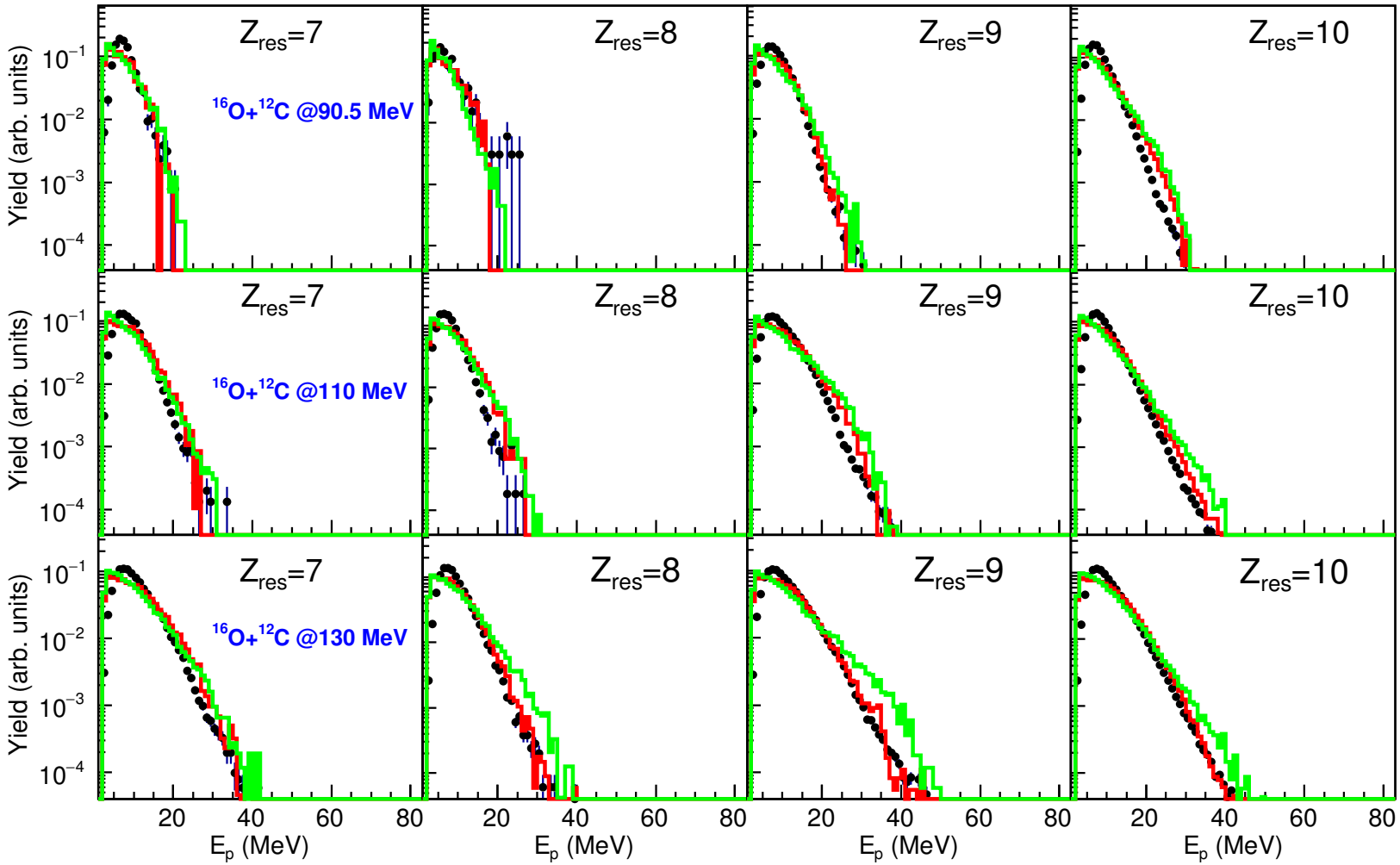


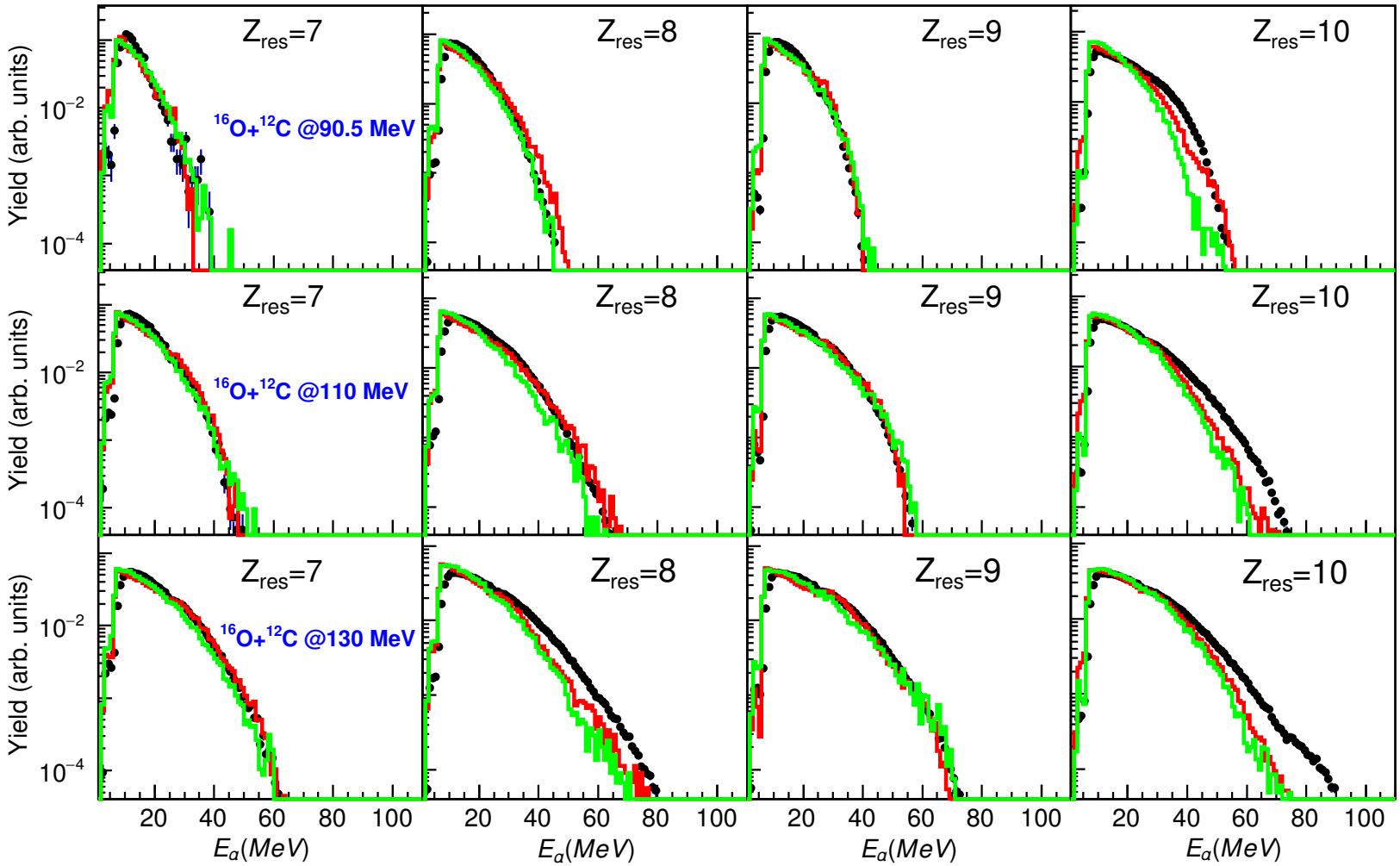
Proton Lab Energy

(shape normalized spectra)



Alpha Lab Energy

(shape normalized spectra)



Branching ratios of α-channels

		90.5 MeV(%)			110 MeV(%)			130 MeV(%)		
Zres	**Channels**	Exp	HFℓ	Gem	Exp	HFℓ	Gem	Exp	HFℓ	Gem
6	$^{12-xn}$C+xn+4α	100	100	100	100	100	94	99	92	72
7	$^{15-xn}$N+xn+p+3α	100	100	94	98	99	96	95	97	95
8	$^{16-xn}$O+xn+3α	100	99	91	99	87	63	88	43	31
9	$^{19-xn}$F+xn+p+2α	99	99	99	93	93	96	88	89	83
10	$^{20-xn}$Ne+xn+2α	74	17	13	45	6	9	29	2	4
11	$^{23-xn}$Na+xn+p+α	95	95	91	93	87	85	88	55	61
12	$^{24-xn}$Mg+xn+α	53	11	18	35	5	8	28	3	3

- Major error contribution from bad identification (p-d-t and ^3He-α) - around 5% for each channel.
- For many even-Z_{res} we found clear deviations from HFℓ and Gemini (rather similar results for both codes).
- BR differences change with energy: e.g Oxygen (Z_{res}=8).

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Conclusions

Summary

- F-E in the ^{16}O+^{12}C reaction @ 90.5, 110 and 130 MeV.
- Comparison with two statistical decay models:
  1. HFℓ and Gemini++ show rather similar results
  2. Overall good reproduction of the shape of inclusive observables (e.g. proton and α energy distributions)
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What comes next?

- Study of channels of particular interest: investigate the nature of the observed differences (α-clustering or dynamical effects) and their energy dependence