Preliminary Event Validation for ~Six Nuclear Model Configurations in $^{40}_{18}Ar$ within the *Legacy* GENIEv3.02 $n \rightarrow \bar{n}$ Module and Comparison with Two of E. S. Golubeva's MCs

Part of Work under GENIE Incubator: "nnbar_upgrade"

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TUESDAY, MARCH 20TH, 2018

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists, Office of Science Graduate Student Research (SCGSR) program. The SCGSR program is administered by the Oak Ridge Institute for Science and Education for the DOE under contract number DE-SC0014664.

Work to do and done thus far

Working with Steven Gardiner and Marco Roda

- Will complete conversion of new radial annihilation distribution to XML or vector format
- Will make two "tunes" of the NNBarOsc module
    1. A "Legacy" tune, with all original assumptions in play
    2. A "Modern" tune, with all *best* assumptions available to GENIE v3+ (including new radial annihilation distribution)

I have completed production of ~six 10,000 event samples for study with Yeon-Jae Jwa and Georgia Karagiorgi

- Actually *eight* models (*but the default is a Bodek-Ritchie*):

$$\{\mathrm{hN_{INC}}, \mathrm{hA_{INC}}\} \otimes \{\mathrm{Default}, \mathrm{Bodek-Ritchie}, \mathrm{Local\ Fermi\ Gas}, \mathrm{Effective\ Spectral\ Function}\}$$

    - All use original radial annihilation distribution
    - Same eight model combinations will also be run for new annihilation distribution
- Once completely validated, I will update this presentation in full on the group meeting's Indico page
    - Can also make a DUNE DocDB entry if you like
- Will then do full LArSoft reconstruction, and hand off all events to Yeon-Jae for CNN (**?*and*** BDT**?**) analysis
    - Aaron Higuera will not be available to render BDT analysis
    - All this work will go into the final uncertainty/signal stability assessment

An interesting consequence…

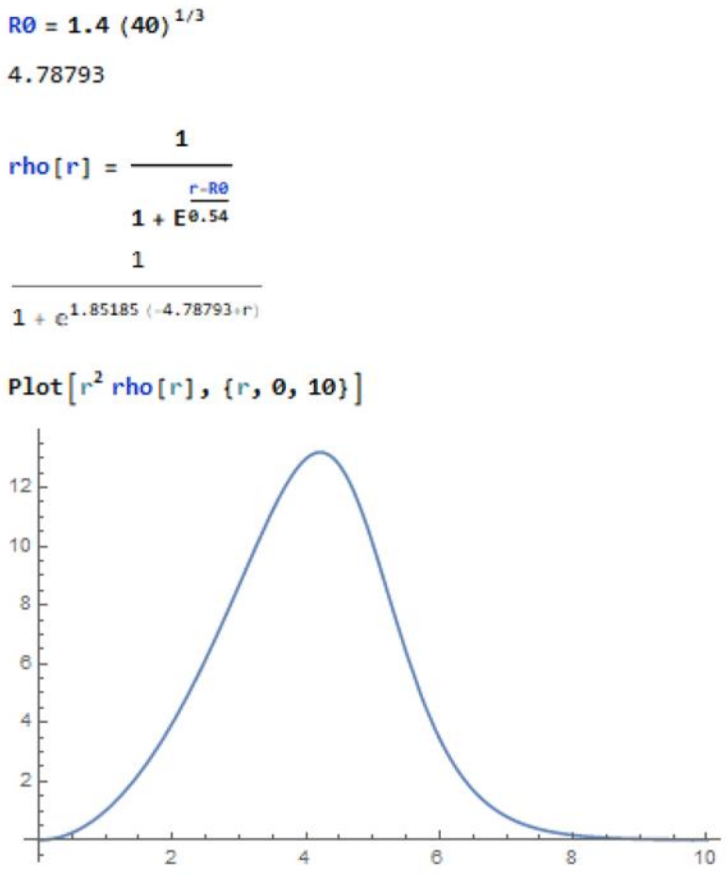
It turns out that the annihilation position *as a probability distribution* is *not* actually a Woods-Saxon within the original GENIE NNBarOsc module

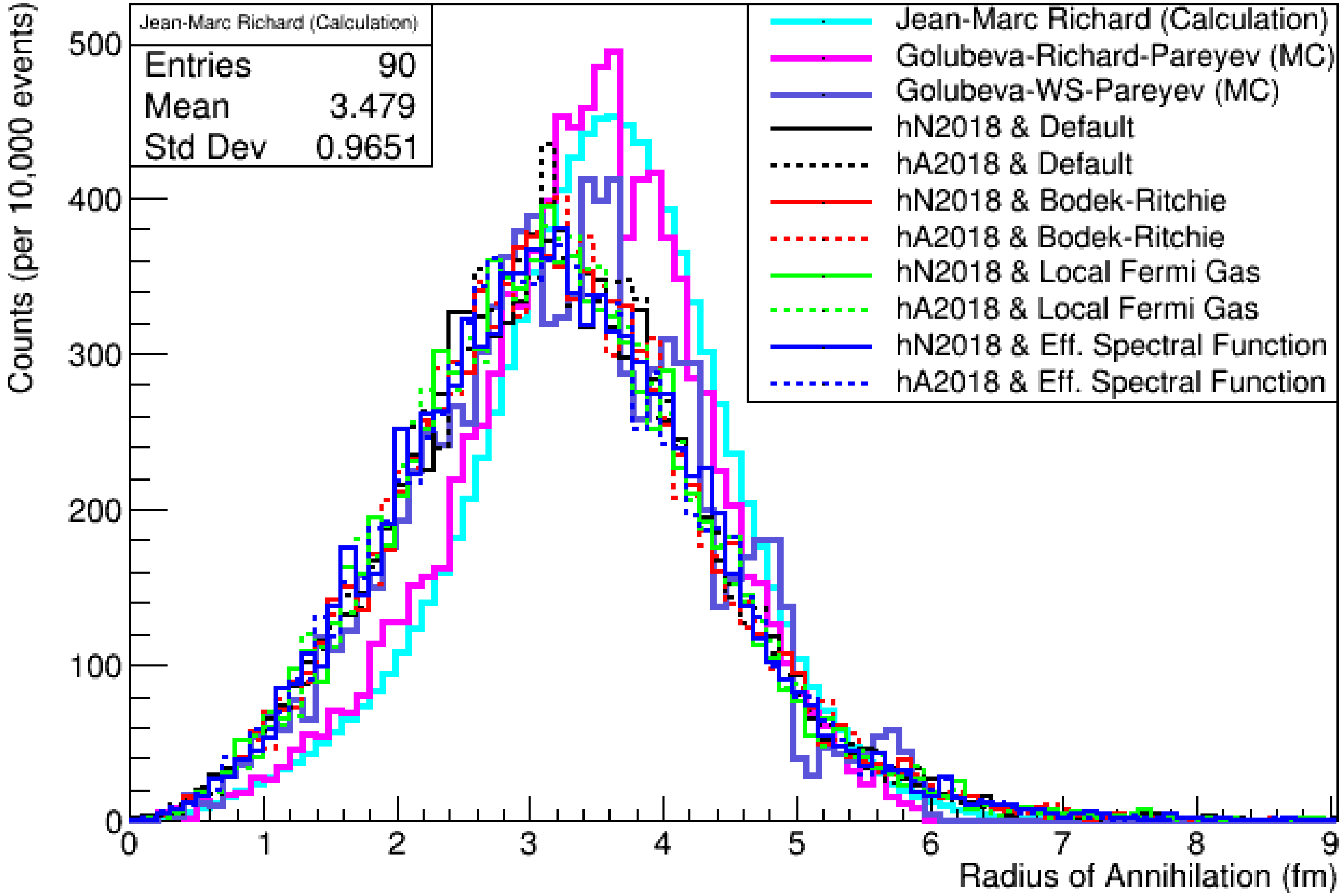
- Instead, the unity-normalized function is $P(r){\sim}\rho(r)r^2$:

$$V \sim \int P(r)dr \sim \int \rho(r)r^2 dr$$

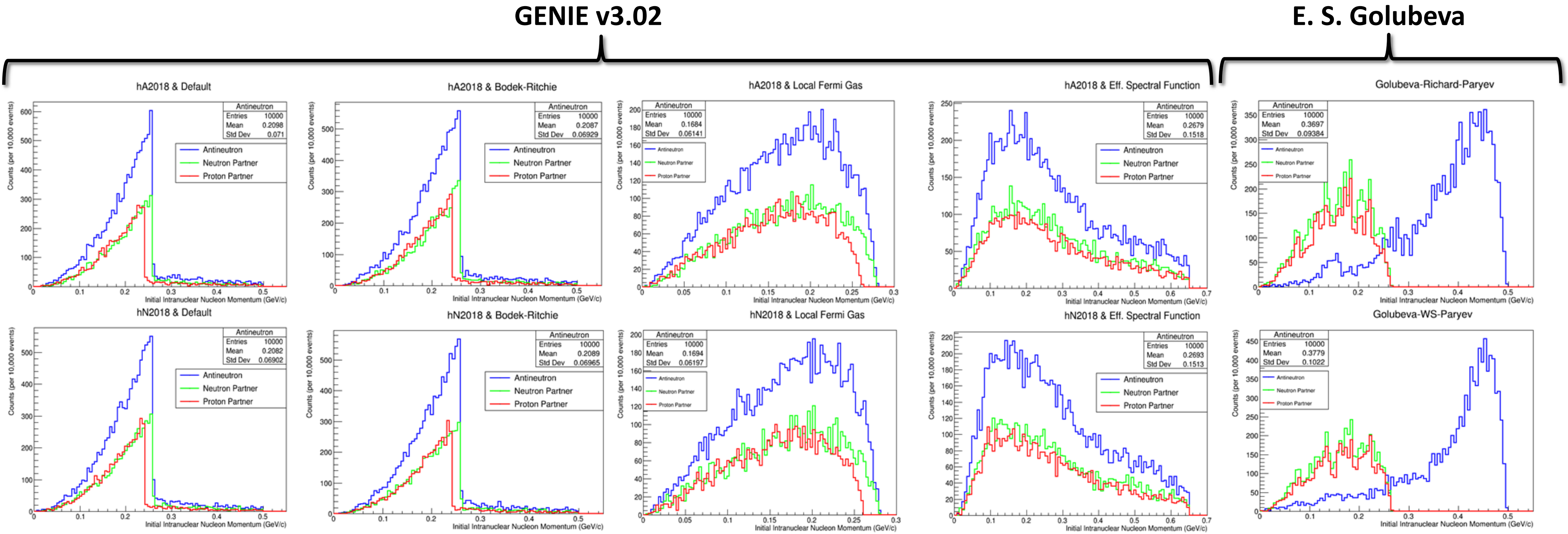
Thus, one must consider the behavior not of $\rho(r)$, but its convolution with r^2

- This does not look like a Woods-Saxon much at all…
- Indeed, it looks a lot like the *new* radial annihilation position distribution created by Jean-Marc Richard (see next slide)
- Thus, I actually don't expect much change in the model from the inclusion of the new annihilation position distribution
- However, the inclusion of correlations between r and the momentum of the nucleons may have more consequential effects
  - Present in the Local Fermi Gas and Effective Spectral Function nuclear models



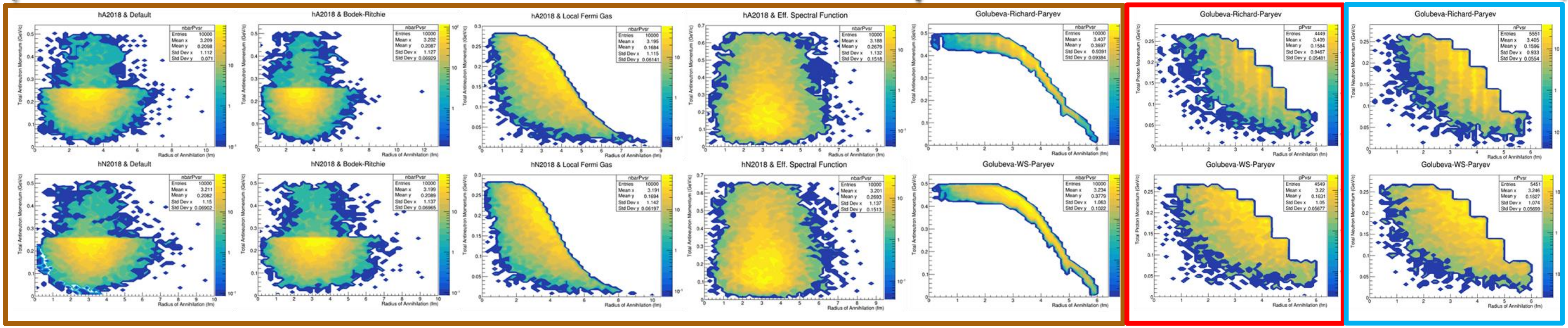


Radial Annihilation Probability Distribution



Total Initial Intranuclear Nucleon Momentum

GENIE v3.02 **E. S. Golubeva**

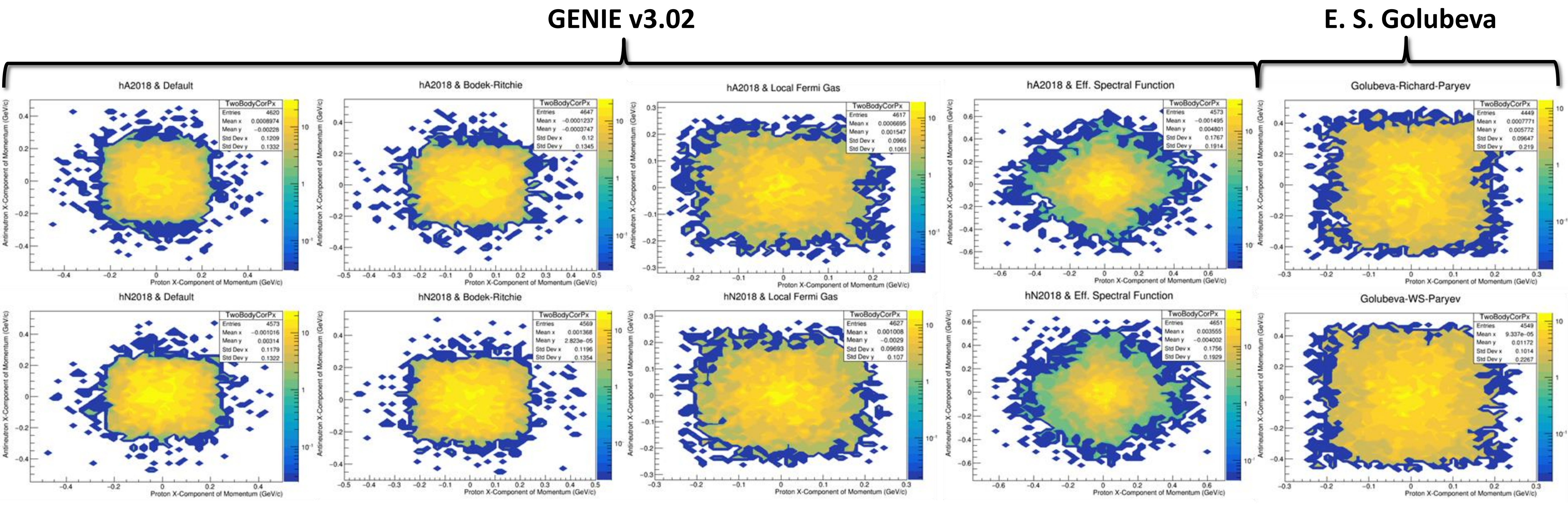


$\bar{n}$ p n

$\bar{n}$, p and n distributions are identical **$\bar{n}$ and $\{p, n\}$ distributions are different**

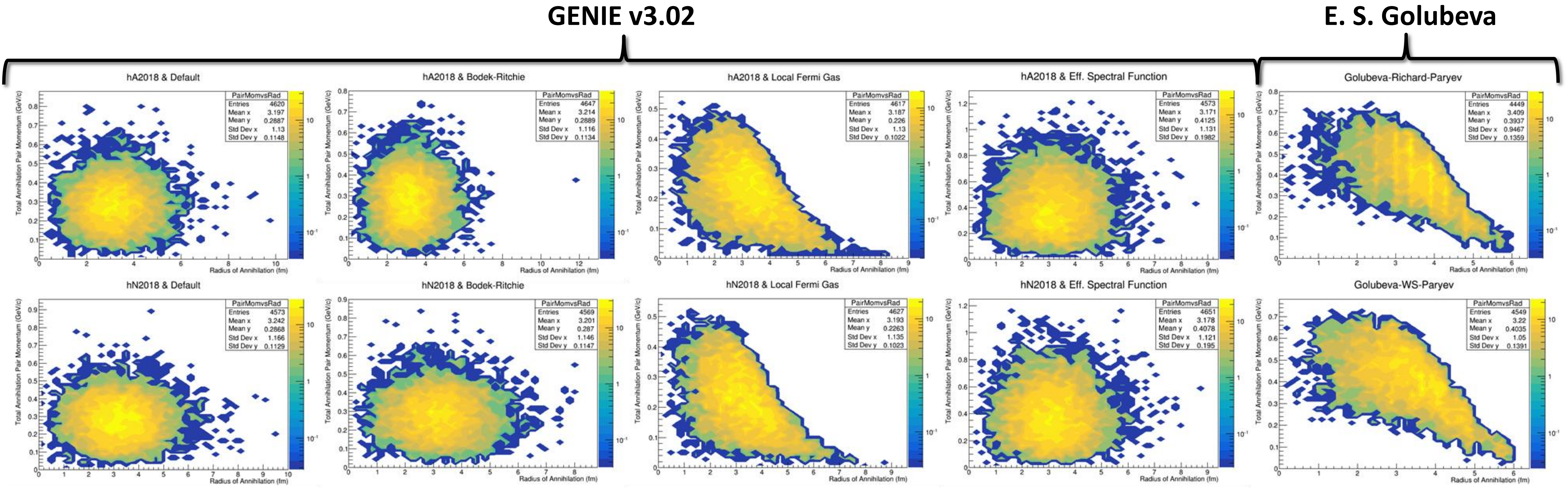
Initial Intranuclear Radius:Momentum Correlations (r: $P_{\bar{n}}$; $P_{p,n}$)

All non-LFG GENIE distributions look rather similar for $\bar{n}$, p and n, but are quite different for Golubeva's due to a *zoned* local Fermi gas and an antineutron potential



Initial Intranuclear $\bar{n}p$ Correlations ($P_x^{\bar{n}}: P_x^{p}$)

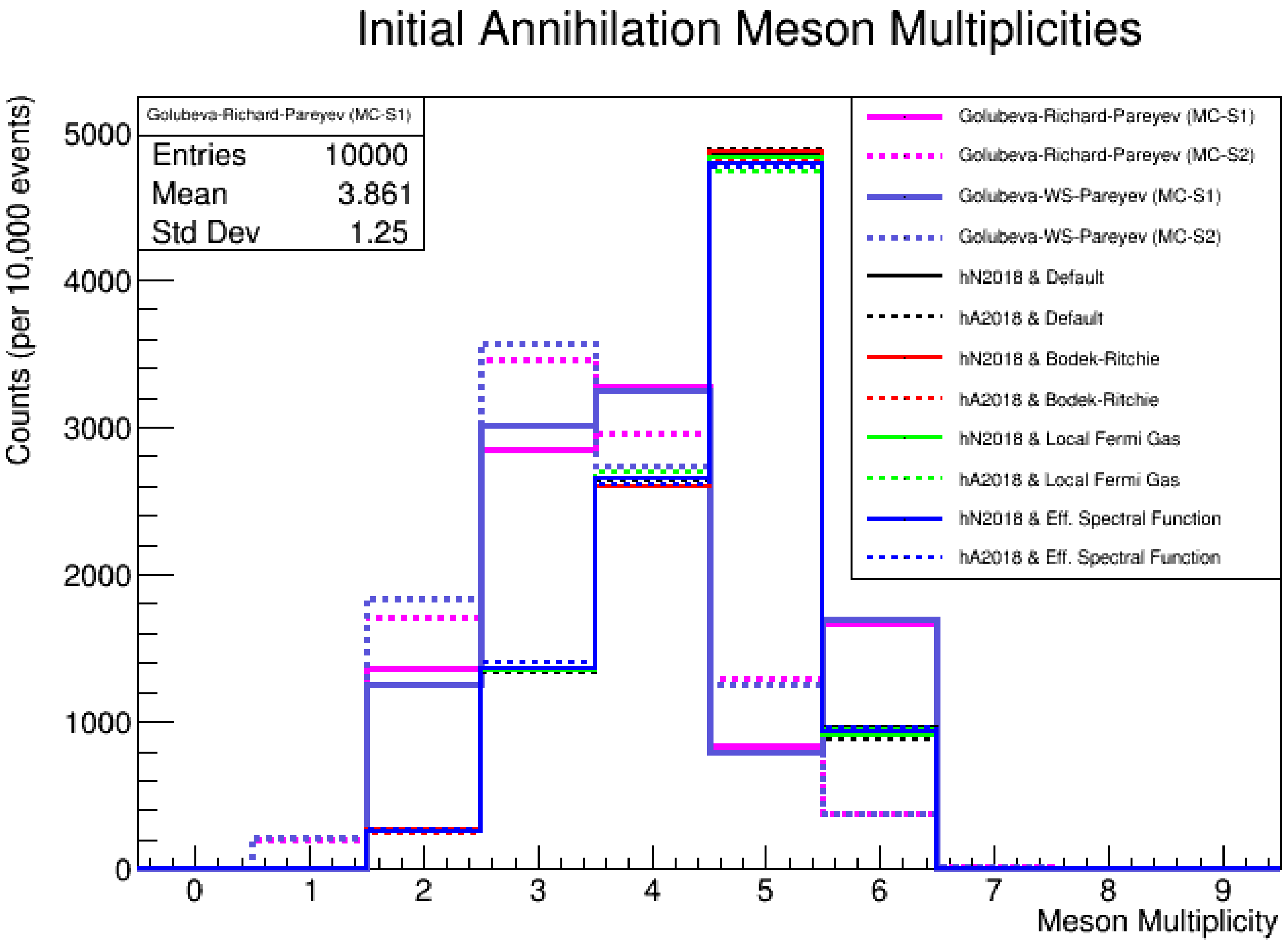
The eff. spectral function does show some two-body correlations; I will review this code soon; GENIE's and Golubeva's Local Fermi Gas models seem consistent and do not show two-body correlations



Initial Intranuclear Radius:Total Pair Momentum Correlations ($\sqrt{\sum_{i=1}^{3}\left(P_{\bar{n}}^{i} + P_{p}^{i}\right)^{2}}$)

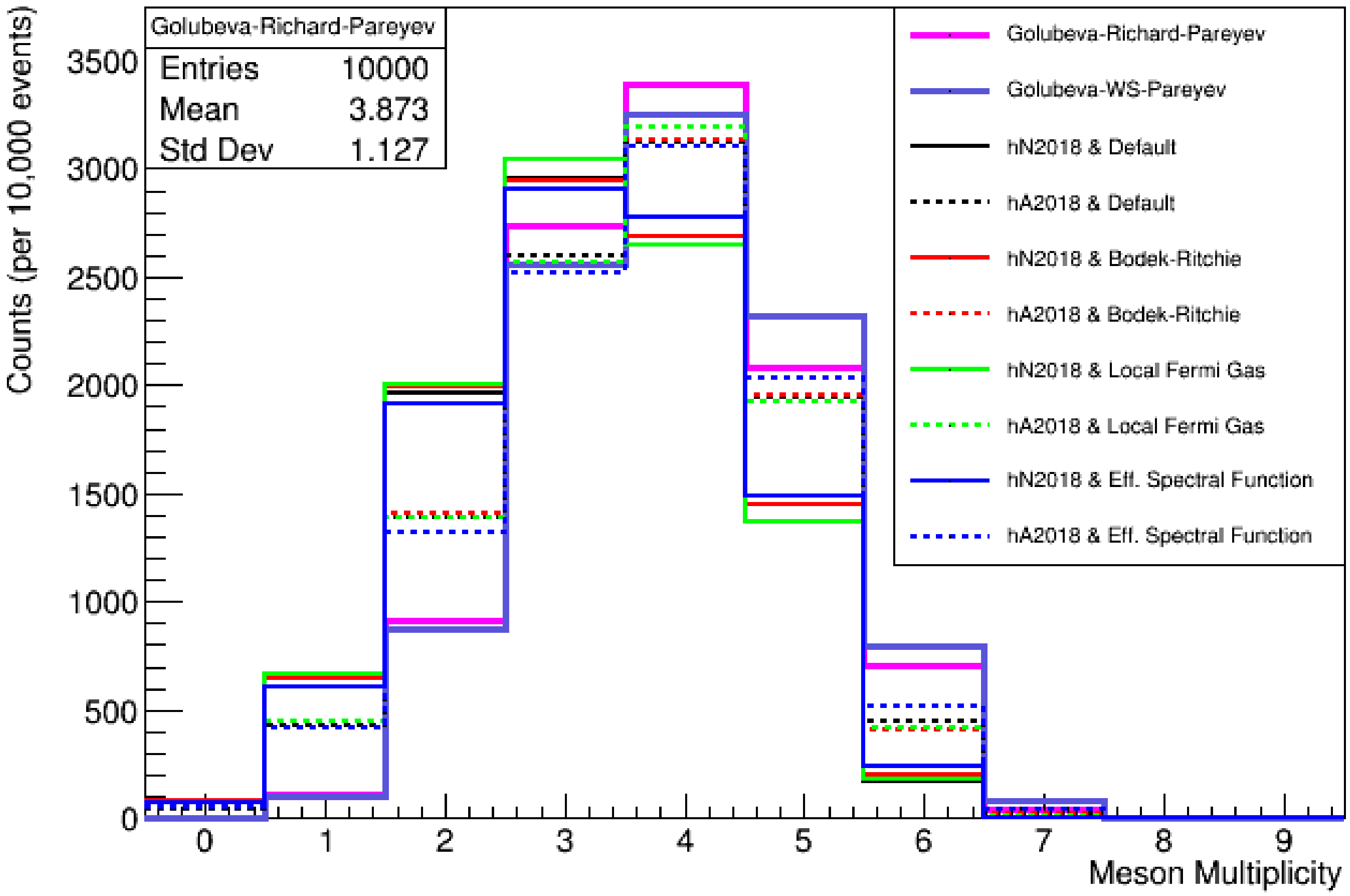
No highly apparent correlations exist outside of LFGs, although *some* diagonals *might* be visible in the ESF plots…

…but I could see this just being a momentum cutoff effect

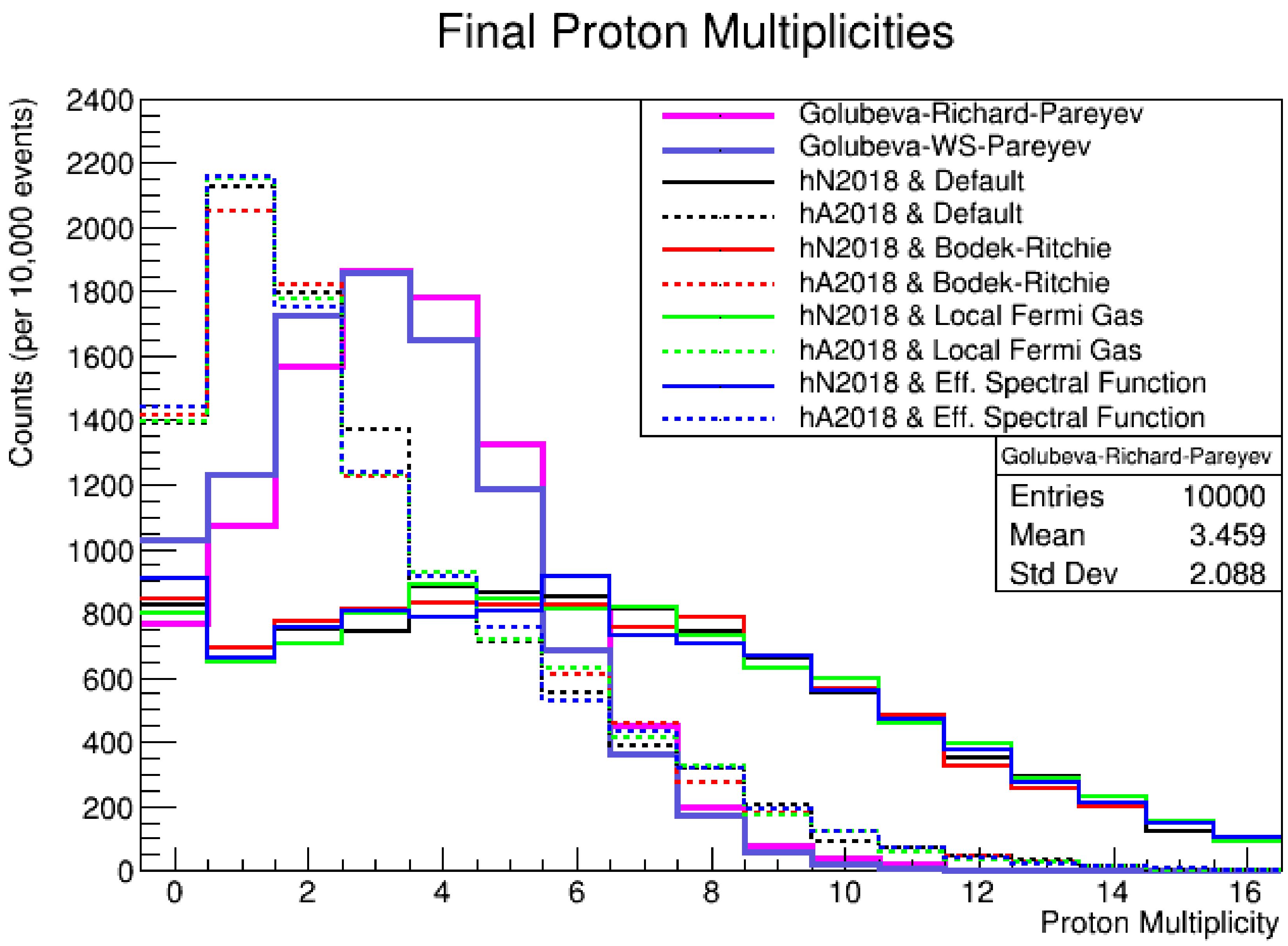


Initial Annihilation Meson Multiplicities

Initial meson multiplicities are not directly comparable at all due to very different branching channels (~ 10 vs. ~ 100) and associated fractions



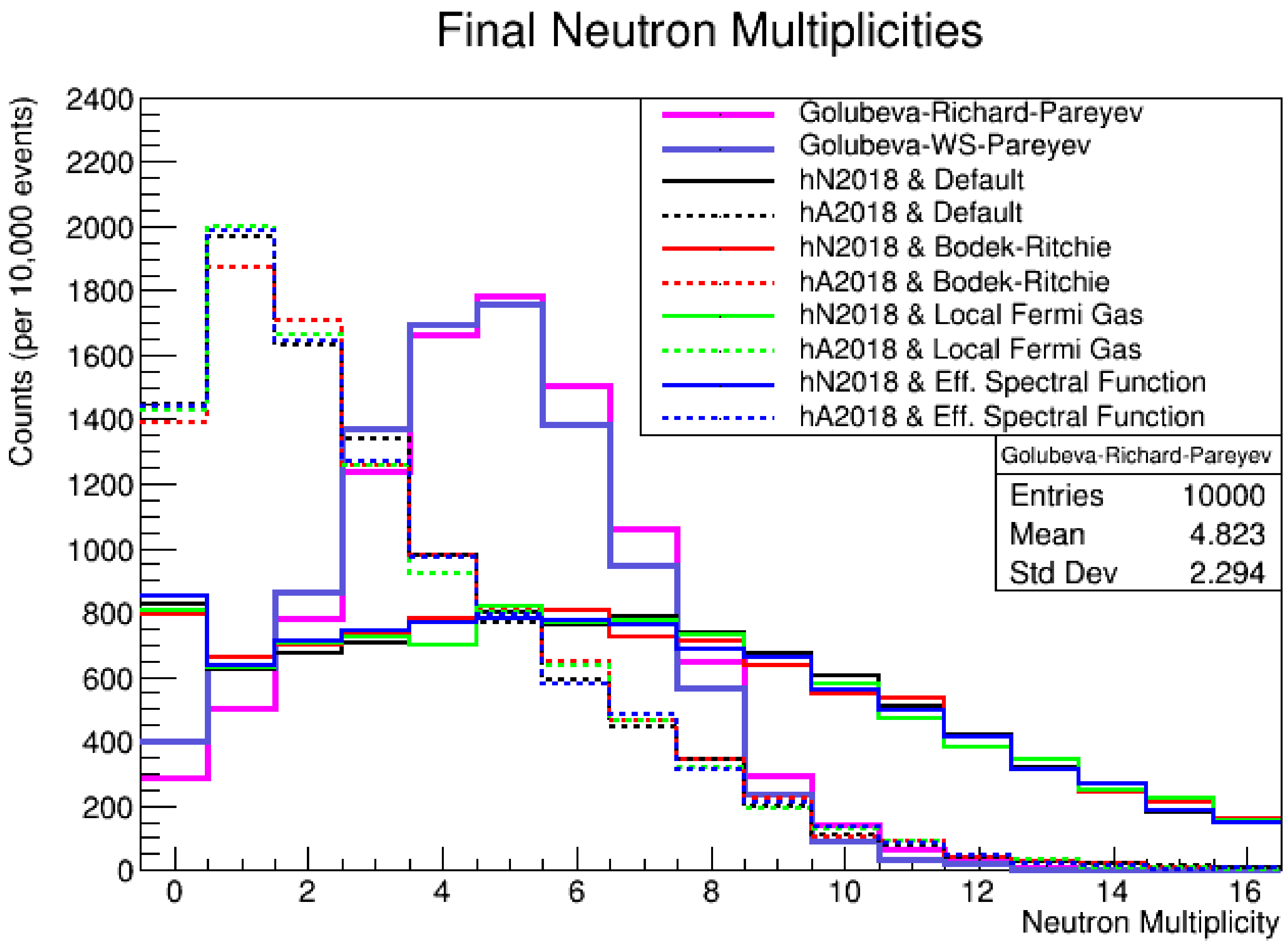
Outgoing Pion Multiplicities



Outgoing Proton Multiplicities

Large discrepancies in hN INC vs. our Golubeva's INC caused by

- No local decrease in nuclear density upon annihilation
- No nucleon evaporation model



Outgoing Neutron Multiplicities

Large discrepancies in hN INC vs. our Golubeva's INC caused by

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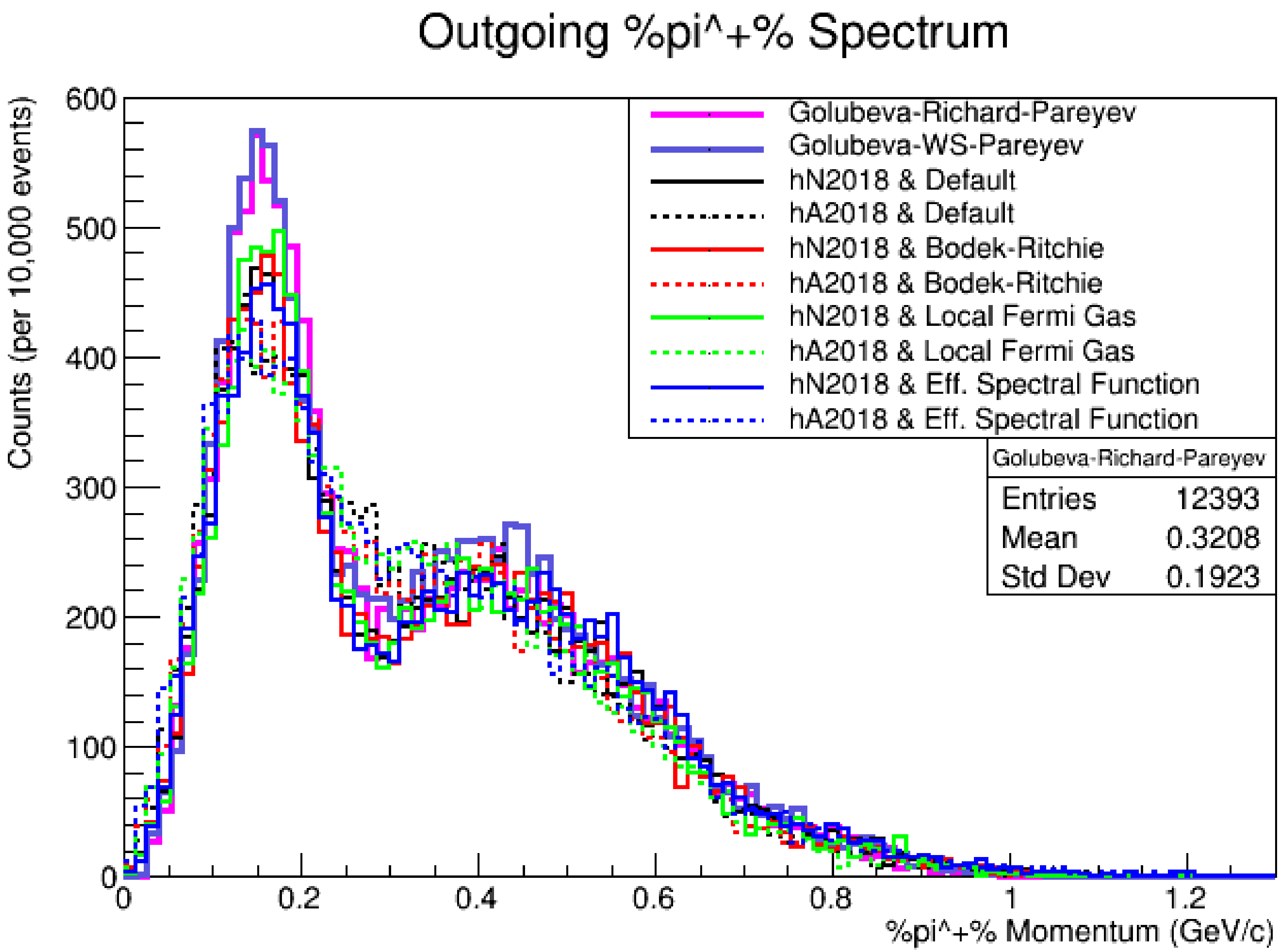
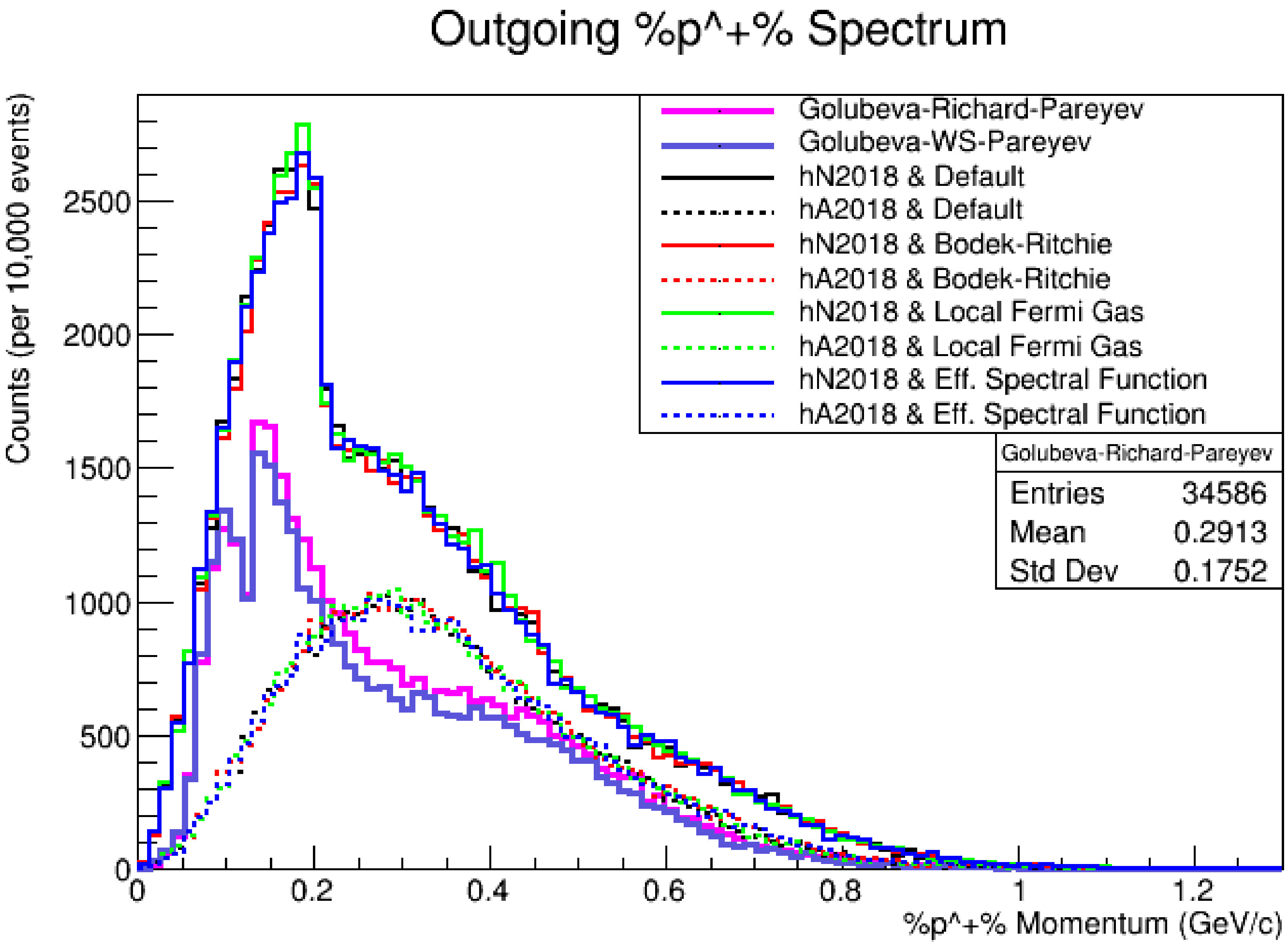
Outgoing π^+ Spectrum

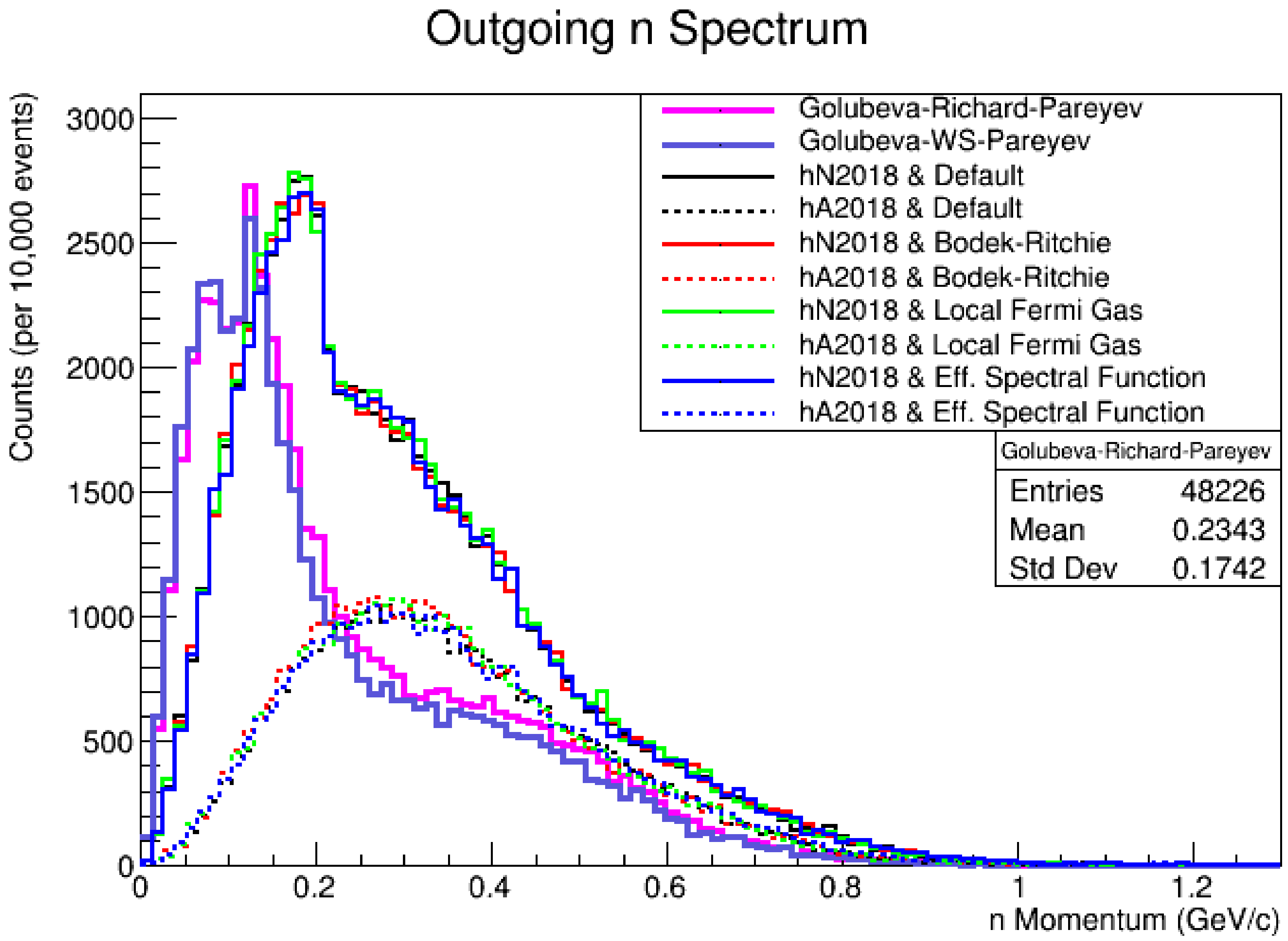


Model	Count (per 10,000 events)
ESG-JMR-EP LFG	1.2393
ESG-WS-EP LFG	1.2808
hN’18 and Default	1.1825
hA’18 and Default	1.1587
hN’18 and BR	1.1811
hA’18 and BR	1.1552
hN’18 and LFG	1.1725
hA’18 and LFG	1.1547
hN’18 and ESF	1.2116
hA’18 and ESF	1.1770



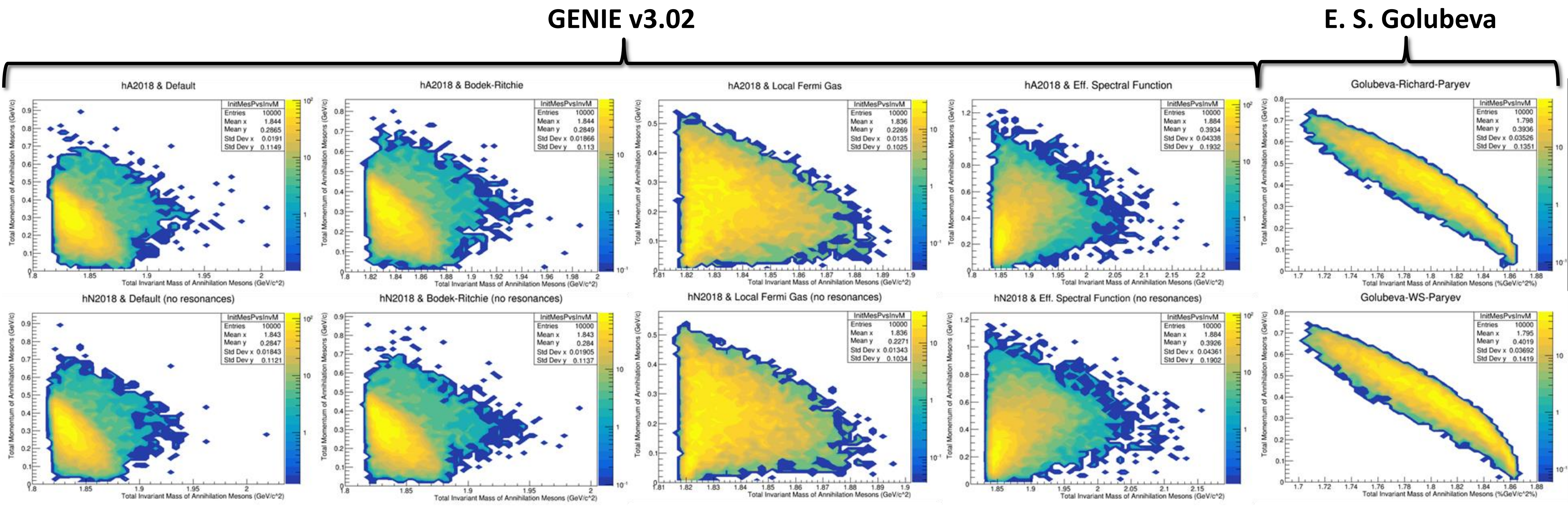
Model	Count (per 10,000 events)
ESG-JMR-EP LFG	3.4586
ESG-WS-EP LFG	3.1702
hN’18 and Default	6.1923
hA’18 and Default	3.0213
hN’18 and BR	6.1502
hA’18 and BR	3.0731
hN’18 and LFG	6.2689
hA’18 and LFG	3.0452
hN’18 and ESF	6.1745
hA’18 and ESF	3.0306

Outgoing Proton Spectrum



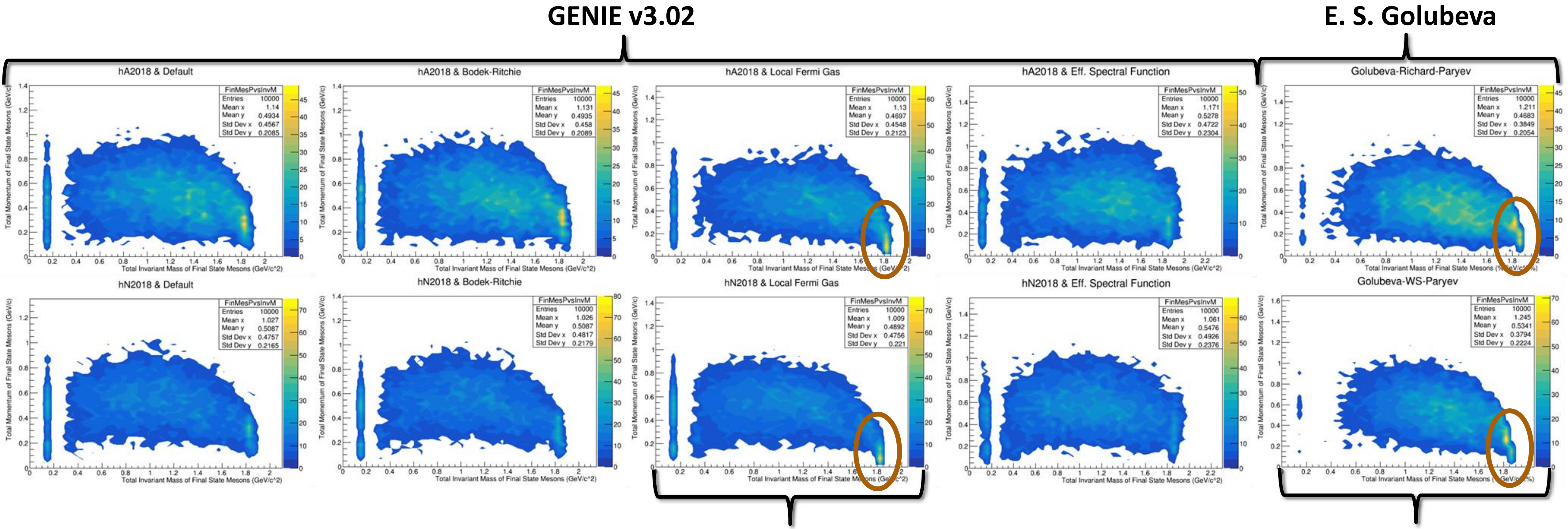
Model	Count (per 10,000 events)
ESG-JMR-EP LFG	4.8226
ESG-WS-EP LFG	4.5242
hN’18 and Default	6.6535
hA’18 and Default	3.1509
hN’18 and BR	6.6573
hA’18 and BR	3.2344
hN’18 and LFG	6.7182
hA’18 and LFG	3.1743
hN’18 and ESF	6.6032
hA’18 and ESF	3.1652

Outgoing Neutron Spectrum



~Total Initial Mesonic Parameter Space

(No photons included in GENIE *currently*)



Highly localized signal regions due to LFG modeling—*could* make separation from background *better*

~Total Final Mesonic Parameter Space

(No photons included in GENIE *currently*)