Summary on RJMCMC progress in CIDeR workshop

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CIDeR-ML meeting

April 18, 2025

Original plan vs actual achieved

Original plan: Carried out as planned; Postponed; ~~Cancelled~~.

Adjusted plan: New plan, achieved; New plan, not achieved yet.

- 4.11 Run `skdetsim`, shooting N 0.1-1 GeV electron/muon; check chain fidelity
- 4.14 Calculate confusion matrix of `RJMCMC-fiTQun` to see the ring counting capabilities. Low energy fake rings issue found.
- 4.14 Record proposed steps and acceptance information: chain fidelity checked, birth/death low acceptance issue found.
- 4.15 ~~Change initial state from `fiTQun` 1R to MR~~ Record birth/death separately, found unbalanced birth/death issue;

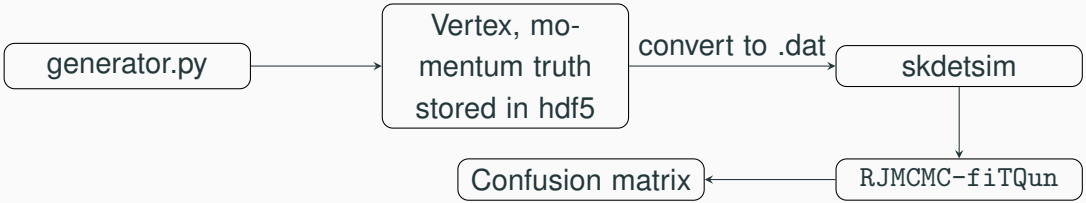
Original plan vs actual achieved

Original plan: Carried out as planned; Postponed; ~~Cancelled~~.

Adjusted plan: New plan, achieved; New plan, not achieved yet.

- 4.15 Adjust the smearing width of 4-hit new ring proposal, resolves unbalanced birth/death issue, but low acceptance remains;
- 4.16-17 Tune prior and estimate chain convergence using Gelman-Rubin method
- 4.15-16 Study the `fiTQun` multi-ring algorithm
- 4.17 record `fiTQun` searched new ring as proposal

4.11-4.14: Simulation and reconstruction pipeline



4.15: fake rings with low energy

$E_{\mathrm{vis}} > 130$ MeV cut on reconstructed rings can make confusion matrix more diagonal.

Truth \ Recon	1	2	3	4	5	6
1	67	32	0	0	0	1
2	0	4	0	0	0	96
3	0	0	0	0	0	100
4	0	0	0	0	0	100
5	2	0	0	0	0	98
6	0	0	0	0	0	100

$\Rightarrow$

Truth \ Recon	1	2	3	4	5	6
1	92	7	0	0	0	0
2	12	73	10	3	1	0
3	1	16	45	31	7	0
4	0	2	16	35	35	12
5	0	0	8	28	45	19
6	0	0	2	14	44	39

4.15-16: Acceptance rate of new ring proposal

The program now records the proposals and acceptance probability.

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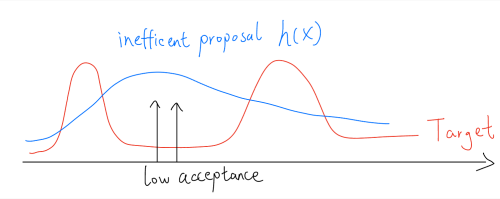
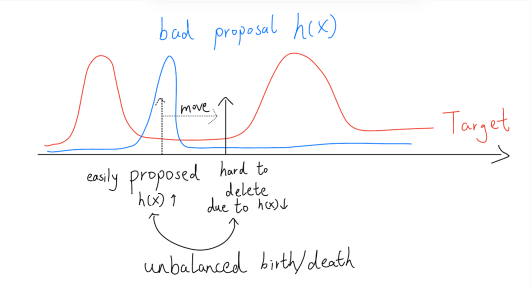
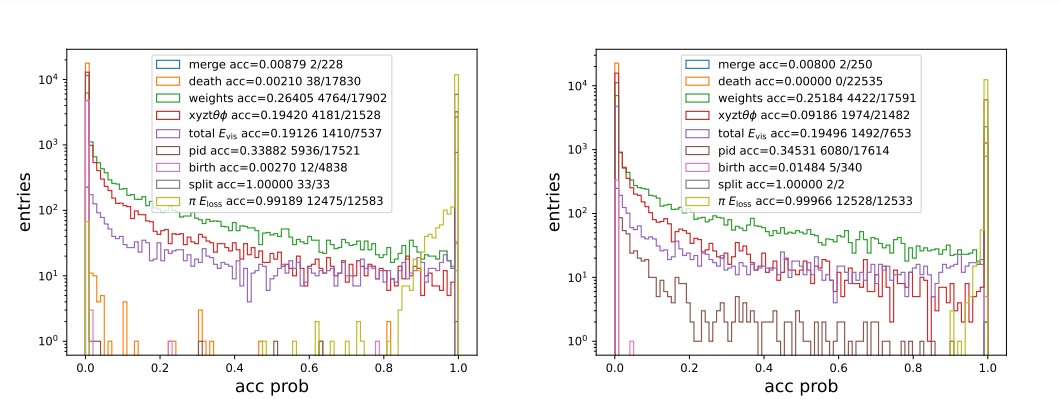




Hypothesis:

- Uninformative proposal are not efficient, causing chain hard to converge
- Bad proposal (mismatch target distribution) may cause imbalanced birth/death rate when chain not converged

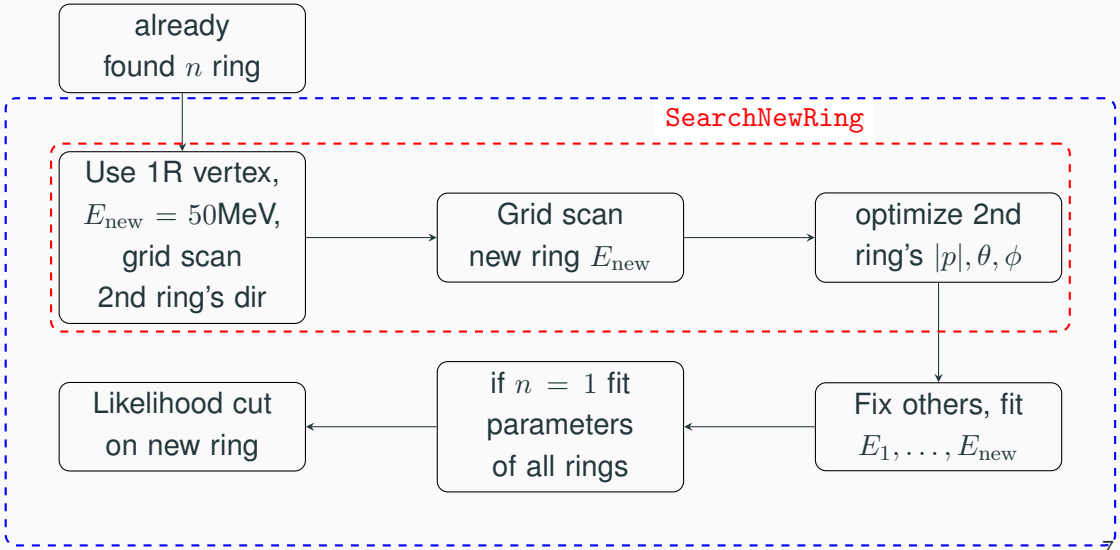
4.15-16: Acceptance rate of new ring proposal



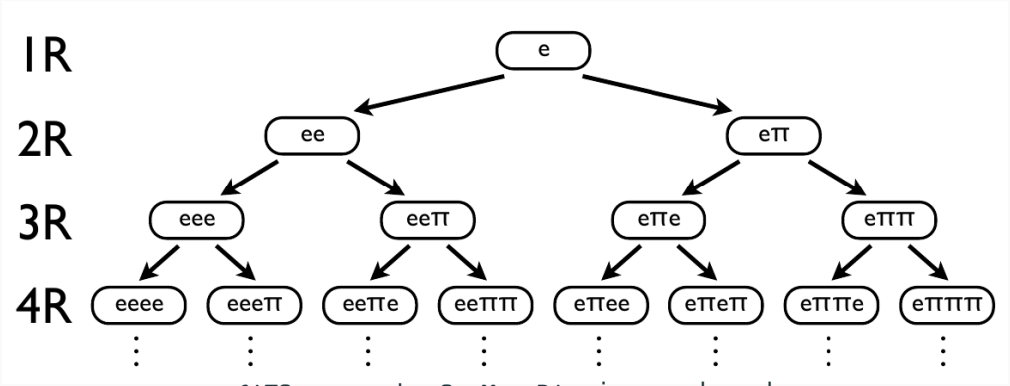
Enlarge the smearing of 4-hit proposal: from a mismatch proposal to a uninformative proposal

Both lead to low acceptance in ring jump; former one has unbalanced birth/death acceptance.

4.15-16 Study `fiTQun` multi-ring fitter



4.16-17 Try `fiTQun::SearchNewRing` based RJMCMC new ring proposal



`fiTQun` executes `OneMoreRing` in every branch

Our goal: hook into `SearchNewRing` as a good-enough new ring proposals; let RJMCMC stochastically explore PID space and other parameters. Still needs

Conclusion and outlook

- Set up the simulation-reconstruction pipeline.
- Obtained the confusion matrix and acceptance history.
- Identified the problems with 4-hit new ring proposal algorithm.
- Studied `fiTQun` multi-ring algorithm to obtain better proposal algorithm.
- Ongoing work on `fiTQun::SearchNewRing` as RJMCMC proposal.

Future: simulated annealing (to avoid zero gradient when ring mismatch) + gradient guided MCMC (RJHMC)