Updated Tracking Configuration

Matthew Gignac & Elizabeth Berzin

2026/10/21

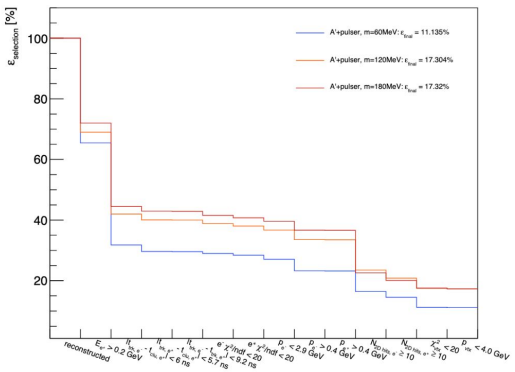
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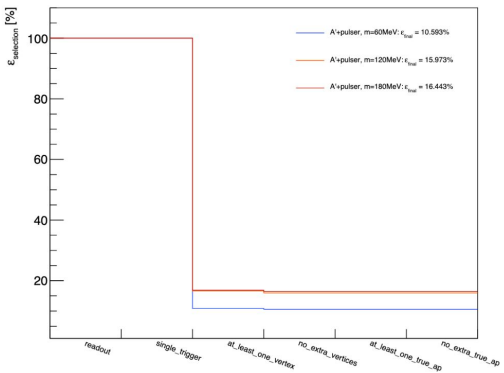
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$e^+\Delta_t(trk,clu) < 4$ns	2.15004e+07	0.809	7.7633e+06	0.964	30440	0.954	54293	0.97
$pe^- < 1.75$GeV	2.14217e+07	0.806	7.75548e+06	0.963	30379	0.952	54201	0.969
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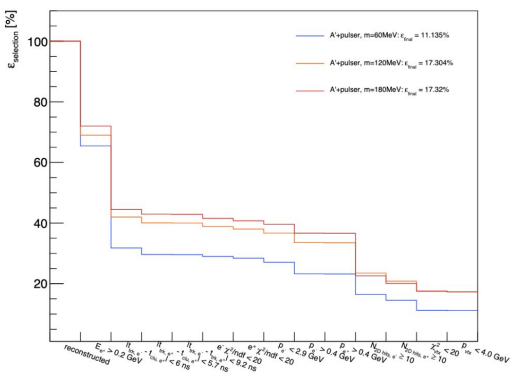
75% pre-selection efficiency?

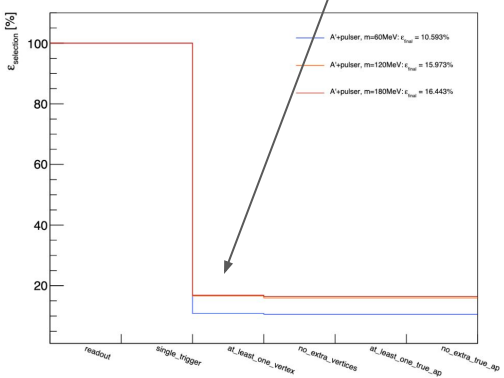
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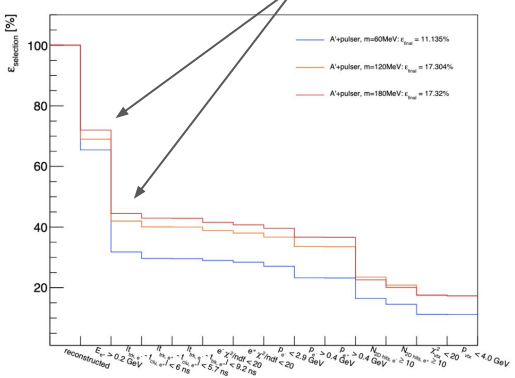
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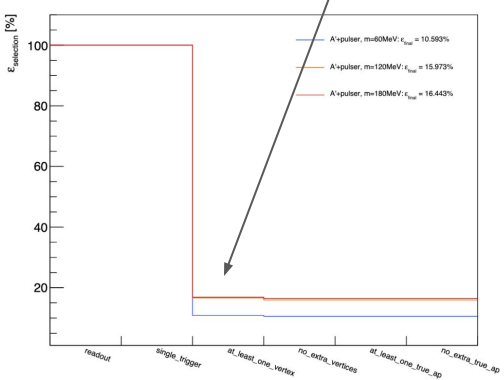
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2016

Positron cluster and electron timing cuts driving inefficiency



<20% pre- selection efficiency?



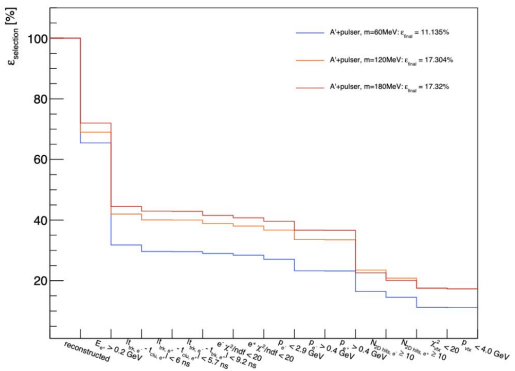
2021

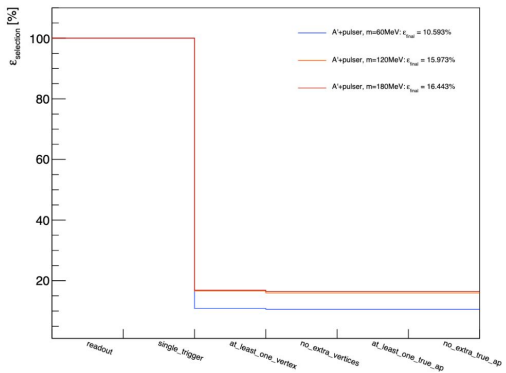
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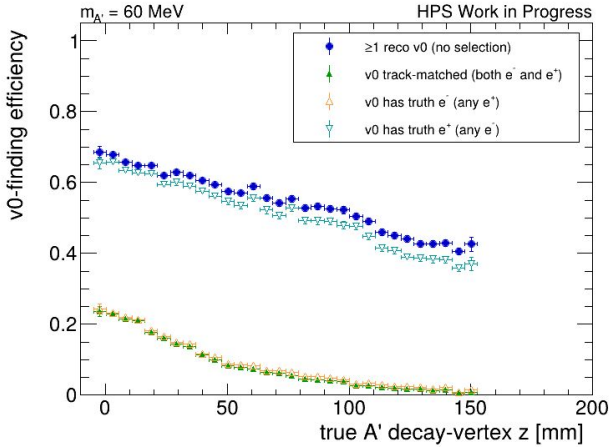
2016 *2021*

Introduction

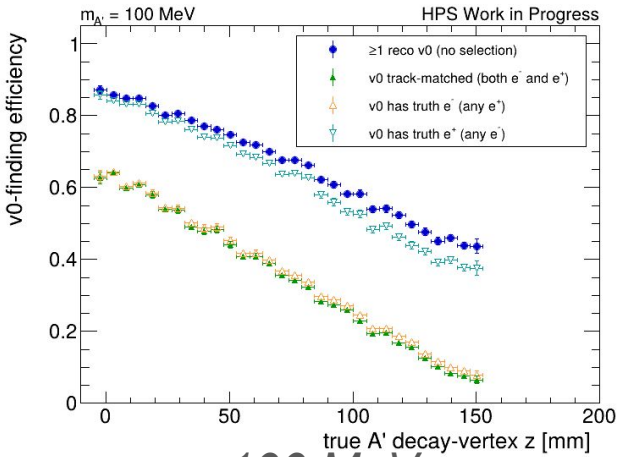
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- *Short story:* these two analyses cannot be compared on equal footing: different trigger strategy → different events preselected prior to cut-flow!
- Explored the 2021 yields at various levels:
  - From **HPSTR level**:
    - Rate at which events form a v0 (singles triggered event)
    - Signal (truth) kinematics of events that have a v0 and those that do not
  - From **EVIO level**,
    - Explored what efficiency could be recovered by extending tracking
    - Studied CPU cost of extended tracking

Basic reconstruction rates

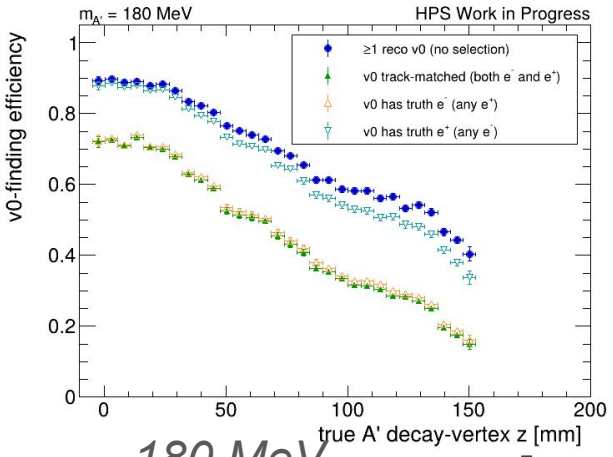
- From having a truth vertex, study rates we have:
  a. Reconstructed *any* vertex in the event
  b. Independently truth matched positron, positron+electron associated to vertex
- Issue is clear: driving inefficiency is the presence of an electron!
- Significant losses at low mass; seems to be largely geometric acceptance



60 MeV



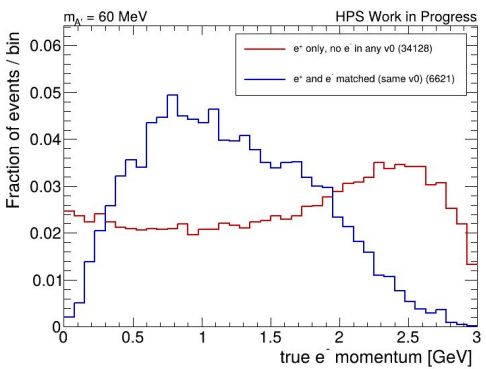
100 MeV



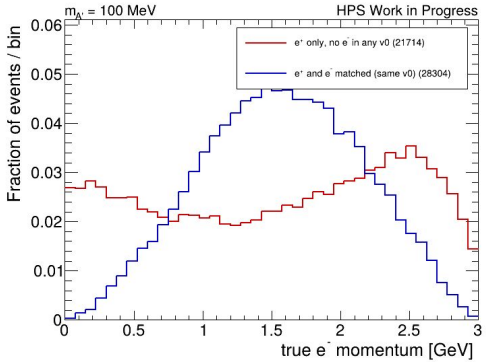
180 MeV

Signal kinematics

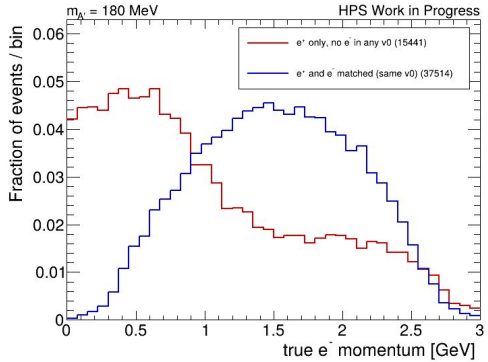
- Understand the phase-space in scenarios with and without the truth electron reconstructed and associated to the vertex
  - Low A' masses → significant contribution from *high* momentum electrons
  - Higher A' masses → mostly a *low* momentum electron issue
- High masses → larger opening angles, improved acceptance of the high momentum electrons. Lower masses, smaller angles, geometric origin



60 MeV

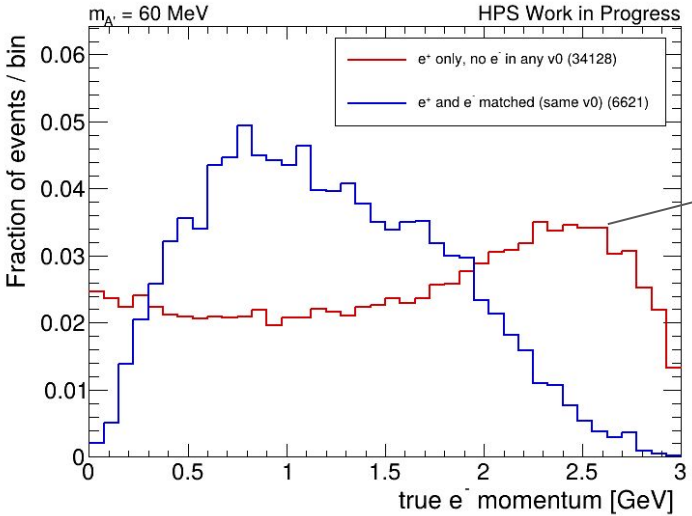


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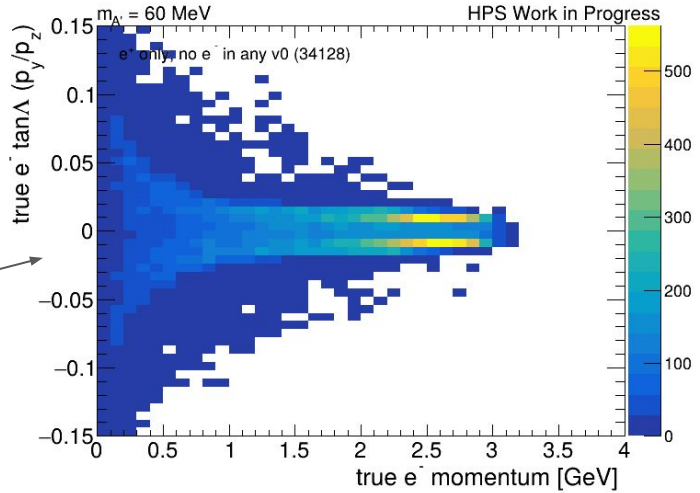


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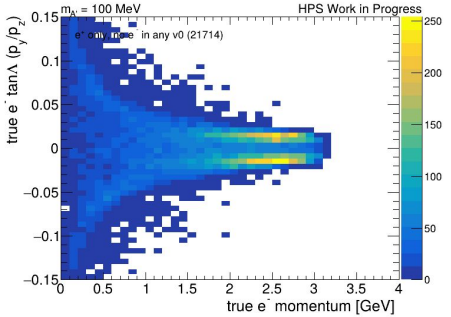
Signal kinematics



High p(e-) at very small tanL – edge of acceptance

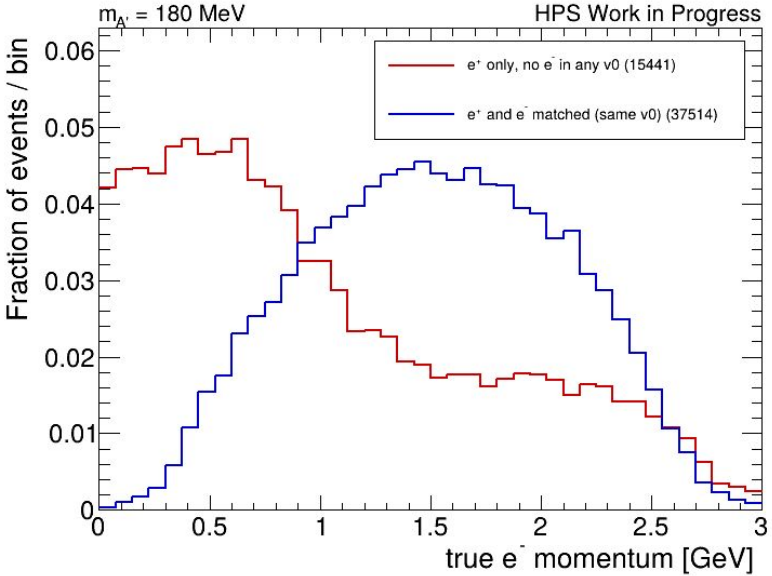


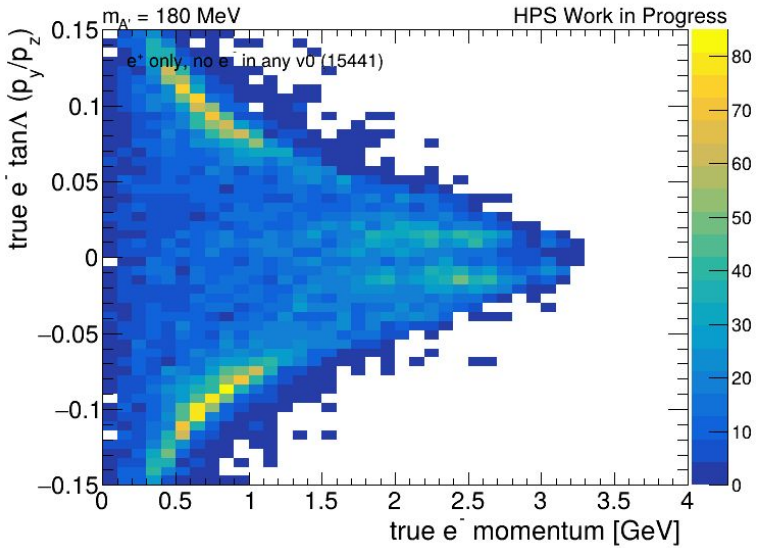
Similar story for the 100 MeV sample



Signal kinematics

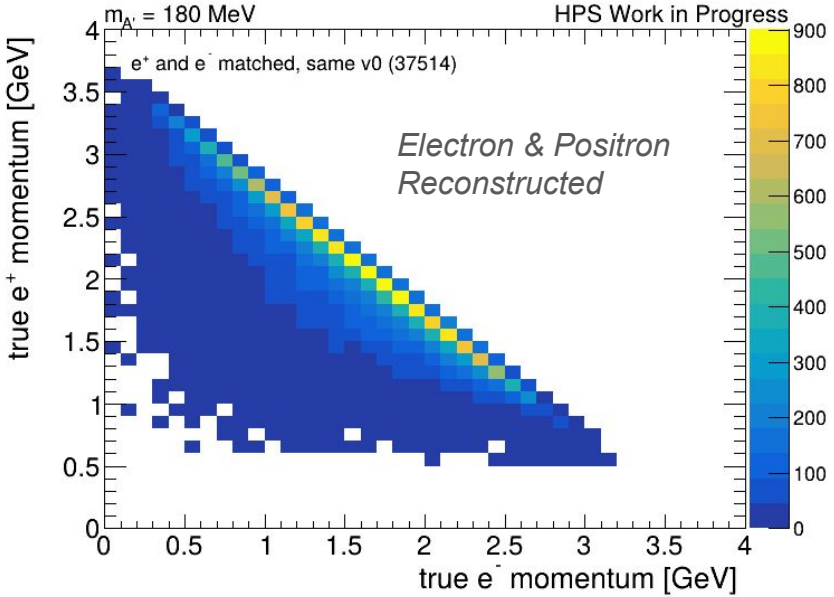
180 MeV sample quite different story
Focus of my investigation!

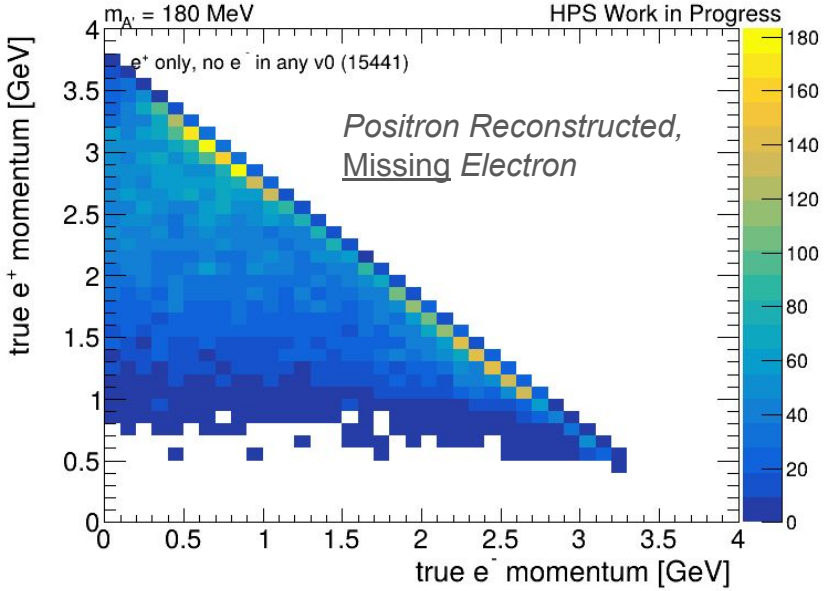




Kinematics of 180 MeV signal sample

- Improving low electron p reconstruction opens more asymmetric events with a hard positron and soft-ish electron (~0.5-1 GeV)



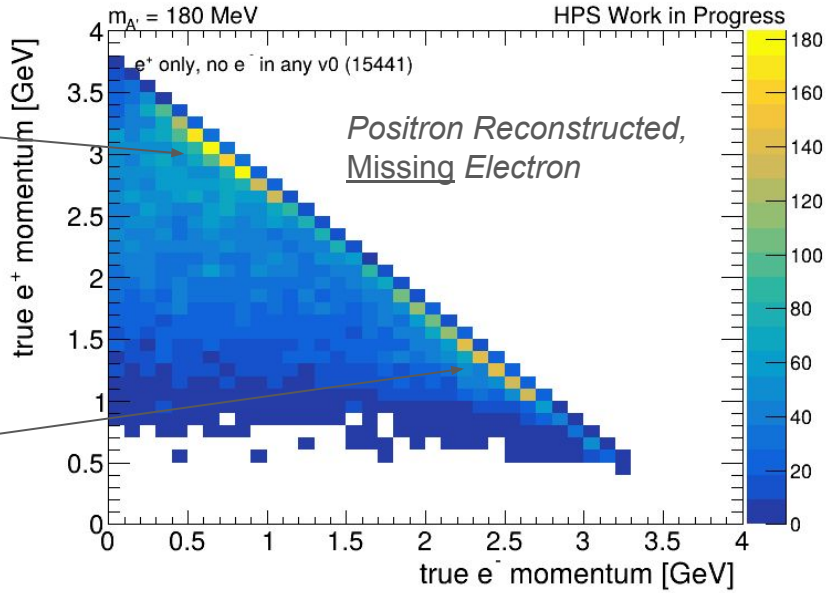


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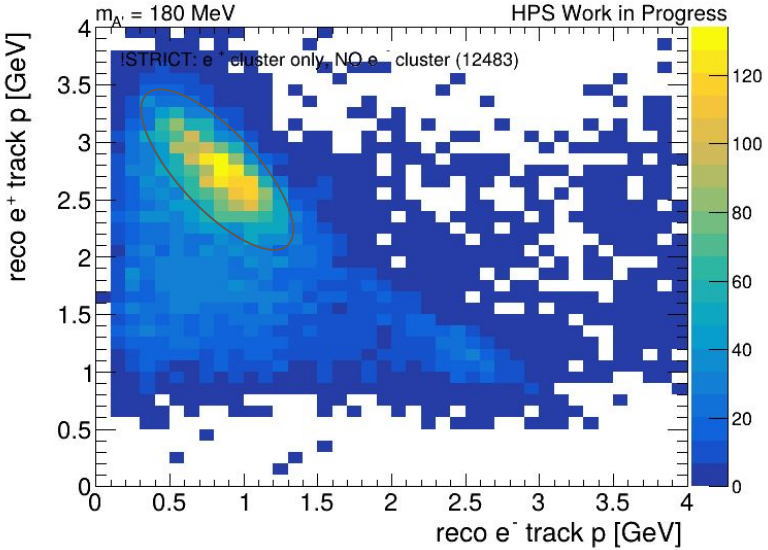
Low momentum electrons → some recoverable, requires work on low momentum tracking

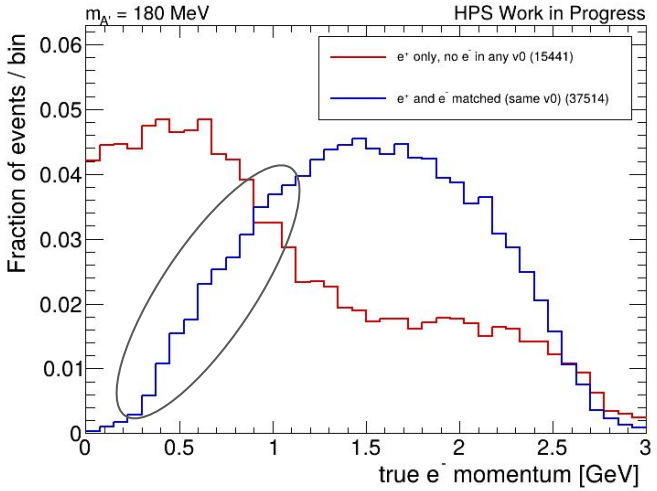
High momentum electrons → mostly unrecoverable, low tanL; geometrically out of acceptance



What do we gain without clusters?

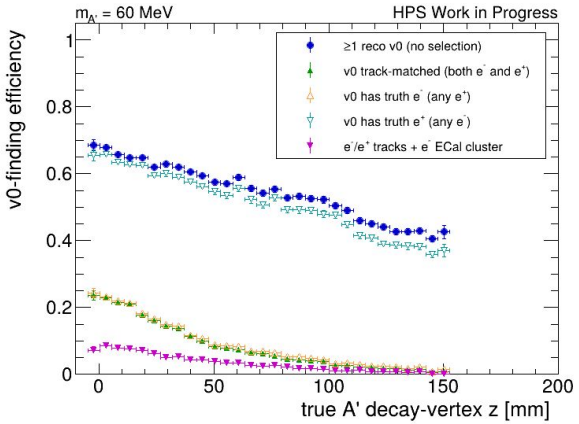
- Events without an electron cluster correspond to low momentum tracks
- Same momentum regime where efficiency is turning on slowly → significant loss of events opened by the singles trigger / lost by pairs

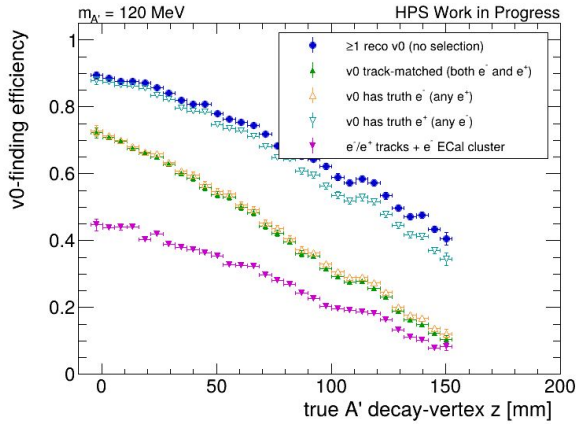


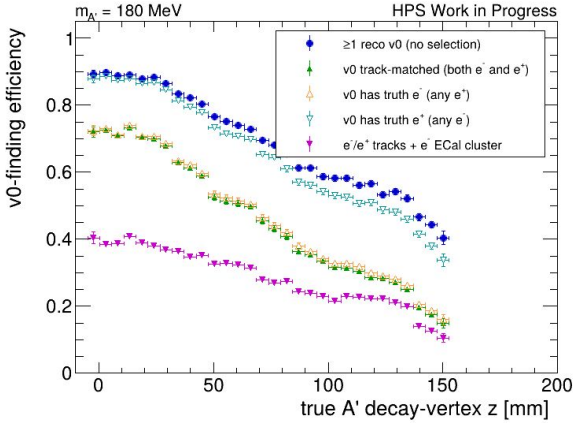


V0 finding efficiency: with ECal electrons

- Comparing acceptance between events with electron cluster to track only
  - Large gains especially at high mass, where the losses are mostly due to low momentum electrons (that don't hit the ECal)
  - Improvements to low momentum electron tracking could buy us even more signal acceptance! Worth checking…







Summary of observations

- Hard electron, soft-positron: issue at low mass (<100 MeV)
  - Events are triggered, so the positron is not the problem here, since those triggered events will require large-ish tanL to hit the calorimeter.
  - This results in a hard low angle electron that misses silicon – no tracking
  - **Mostly unrecoverable in singles (positron) trigger strategy**
- Hard positron, soft electron**:** most noticeable at higher masses
  - Minimum number of hits during tracking could be relaxed.
  - Spent some time searches for ways to boost low momentum tracking yield (next slides)
- Relaxing ECal requirements increases signal yield 30-40%
  - Limitation becomes on the tracking side – so far, our tracking is not quite optimized for low momentum, so we are not benefiting from the singles trigger as much as we could. Tracking improvements could improve yield to the asymmetric A’ decays

HPS Tracking Changes

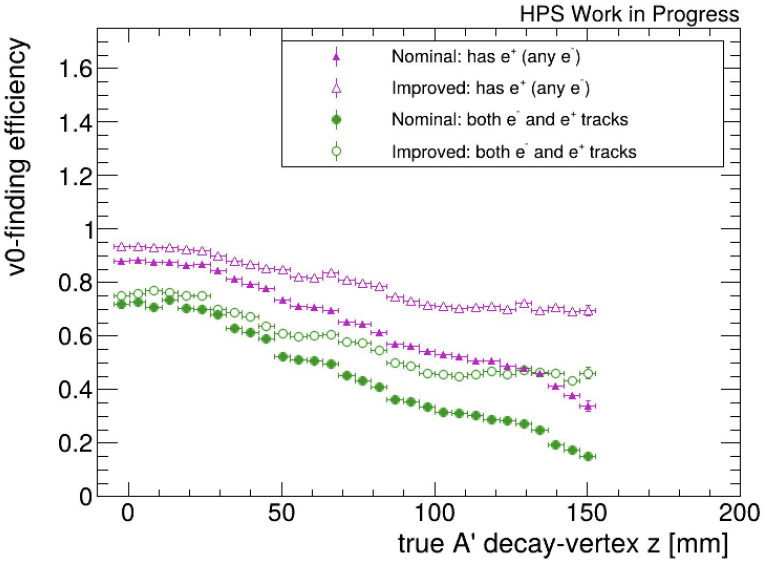
- Deep dive into the tracking configuration: relaxed several parameters and extended the seeding strategies in iteration 2

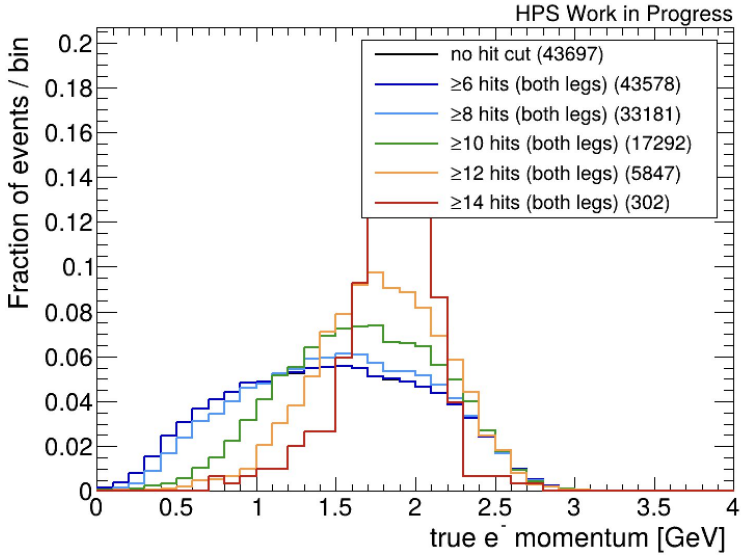
Group	Parameter	Production	T1 (adopted)
Seed p_T floor	$1/p_T$ max [GeV^{-1}] (p_T floor 113→83 MeV)	8.88	12.0
Seed pointing† (at target plane)	iter-2 bend-plane $d\rho$ (d_0) [mm]	39.25	55.0
	iter-2 vertical dz (z_0) [mm]	8.38	20.0
	iter-1 bend-plane $d\rho$ (d_0) [mm]	15, hardcoded	15, steerable
	iter-1 vertical dz (z_0) [mm]	3, hardcoded	3, steerable
Hit content	min. hits, iter-2 (top/bot)	8	6
Hit sharing	max. shared hits	2	3
	max. χ^2 incr. to share	5.86	8.0
Seeding	seed strategies (See table)	20	23
	strategies used in iter-1	17	17

Seed code	Layer-pairs used	Hit content
BBS0000	1, 2, 3	pairs 1–2 axial+stereo; pair 3 stereo
BSB0000	1, 2, 3	pairs 1 & 3 axial+stereo; pair 2 sterec
0BSB000	2, 3, 4	pairs 2 & 4 axial+stereo; pair 3 sterec

Updated tracking configuration

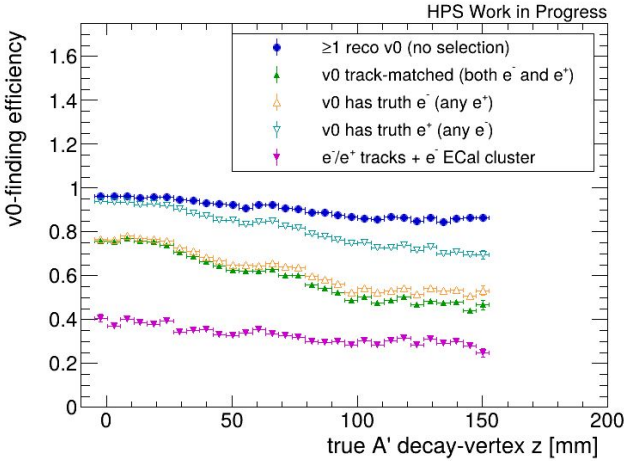
- Notable improvements for highly displaced vertices!
  - Around a factor of x3 at 150mm!
- Improvements likely related to seeding strategies and relaxed IP cuts
  - Still need to characterize efficiency changes parameter-by-parameter

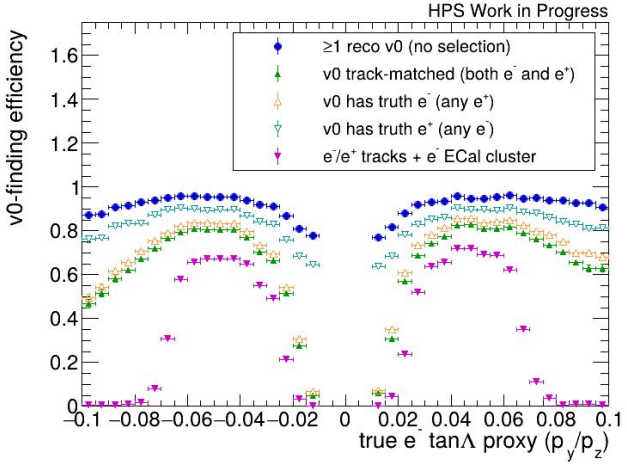


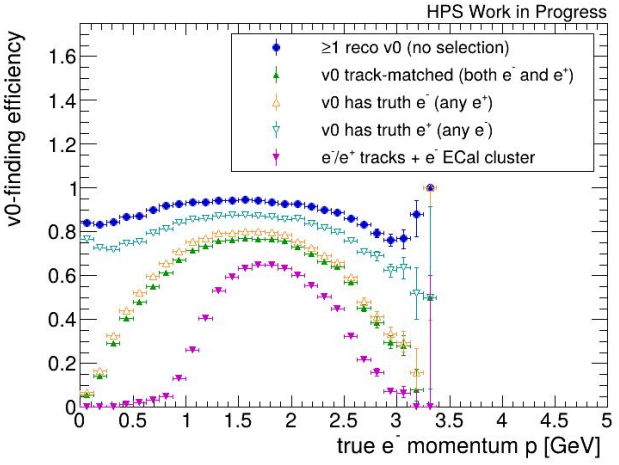


Comparing v0 finding efficiency: updated tracking

- Instructive to see gains above events where both electron and positron are within acceptance (poorman pairs trigger – we don't simulate it)
- Extends to higher tanL and lower momentum – makes sense…



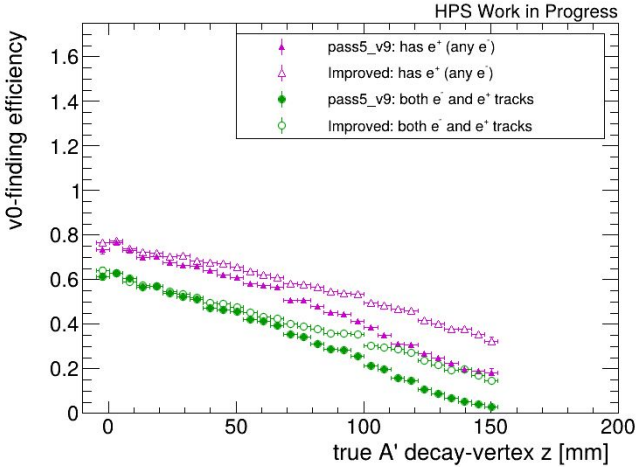


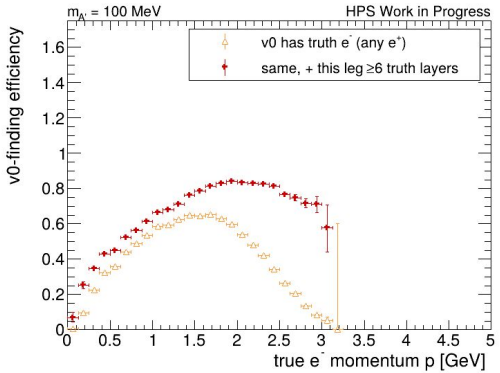


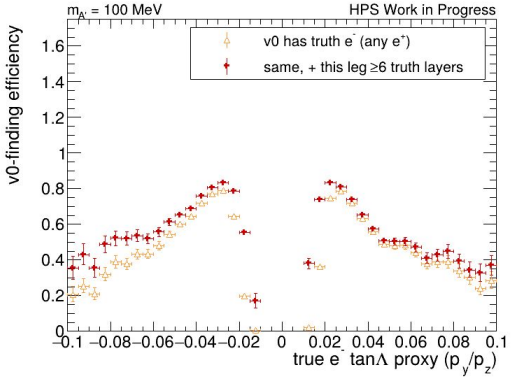
180 MeV sample

Effect of improved tracking at low mass (100 MeV)

- Recall that efficiency losses for low mass samples was mostly due to high momentum electrons with small tanL – these are ~not recoverable
- Some notable improvements with updated tracking, but not as a dramatic improvement as the high mass sample

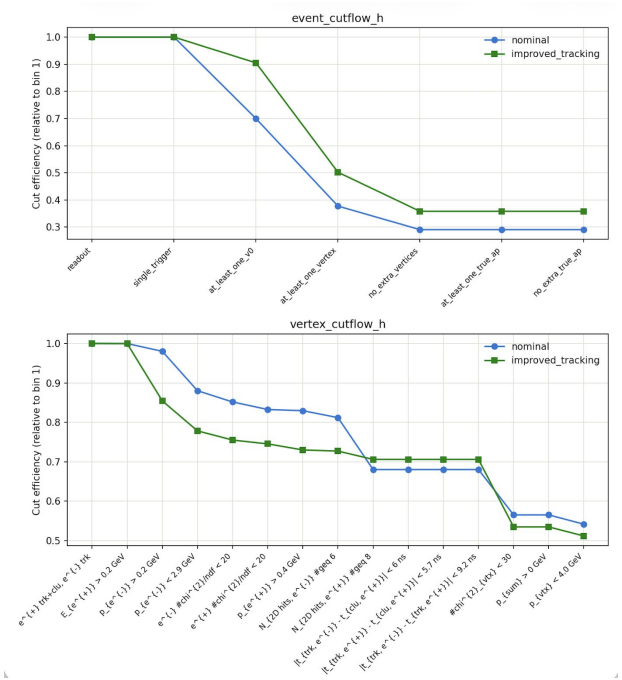






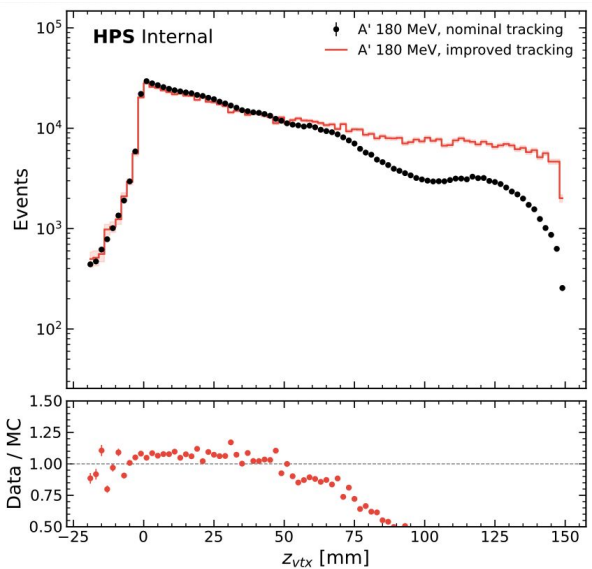
Effect on preselection cutflow efficiencies (180 MeV)

- Comparing nominal reconstruction to improved version:
- Significant improvements possible:
  - Increased efficiency to pass hit cuts at >=6
  - 50% events retained with at least one good vtx
- If we relax second vertex veto:
  - 50% compared to ~30% previously
    - 1.7x more signal!
  - Worth understanding recoil contribution



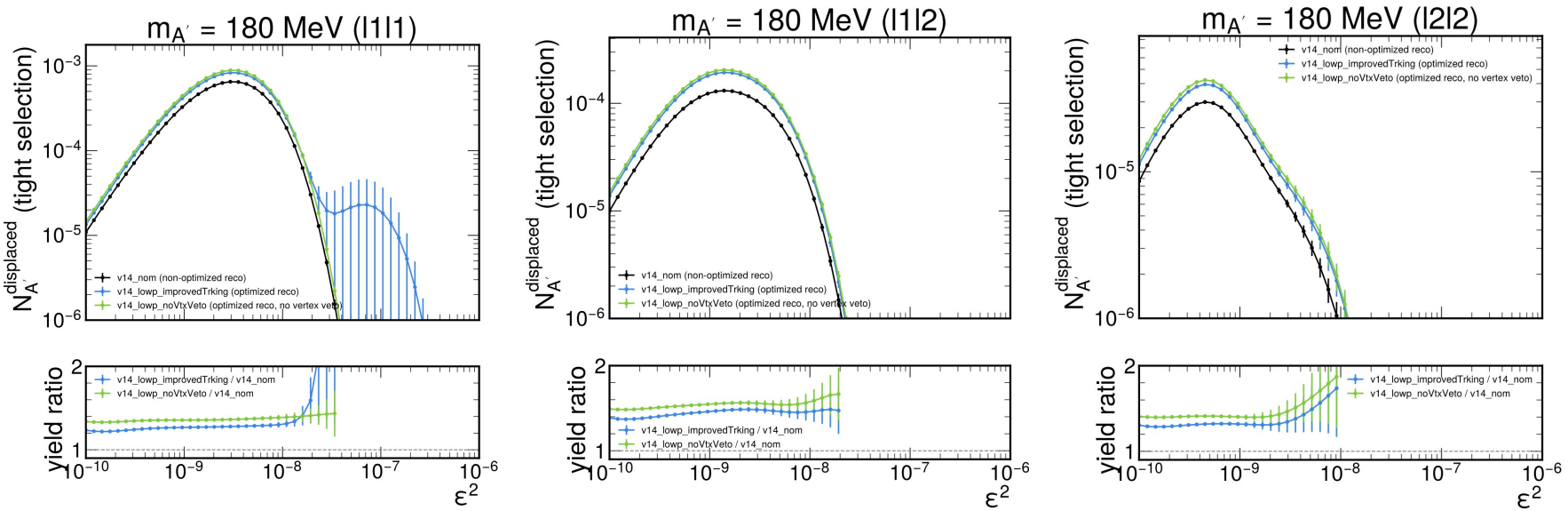
Effect on preselection cutflow efficiencies (180 MeV)

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- If we relax second vertex veto:
  - 50% compared to ~30% previously
    - 1.7x more signal!
  - Worth understanding recoil contribution
- Note: flat lifetime distribution!
  - Majority of signal increase for highly displaced vertices
  - Expect most improvement in the L2 and beyond



Signal yields

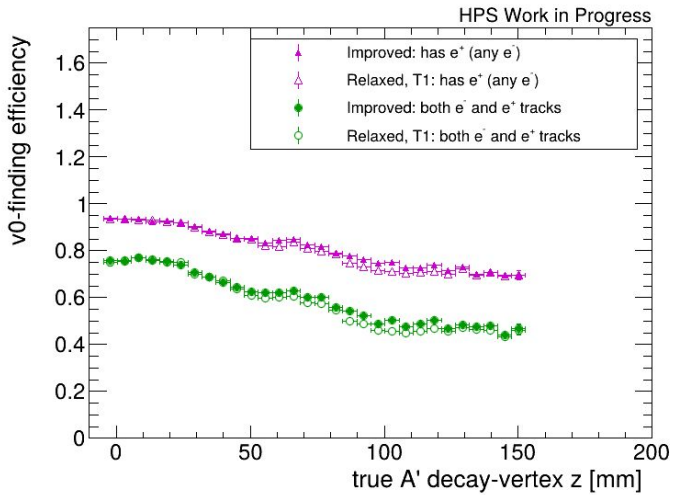
- Re-ran 180 MeV signal point & single run (14185) with updated tracking
- Elizabeth kindly re-computed signal yields using complete formalism
- Approximately ***40-50% increase in signal yield (*)*** across hit categories

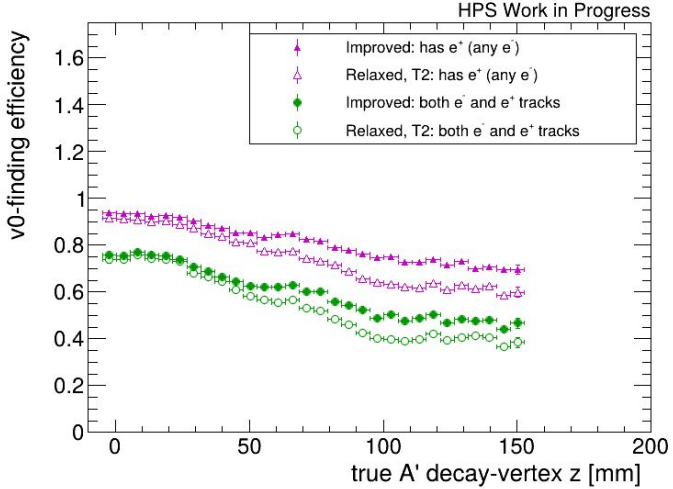


(*) assuming same radiation fraction – checked and confirmed to not change

CPU time in data

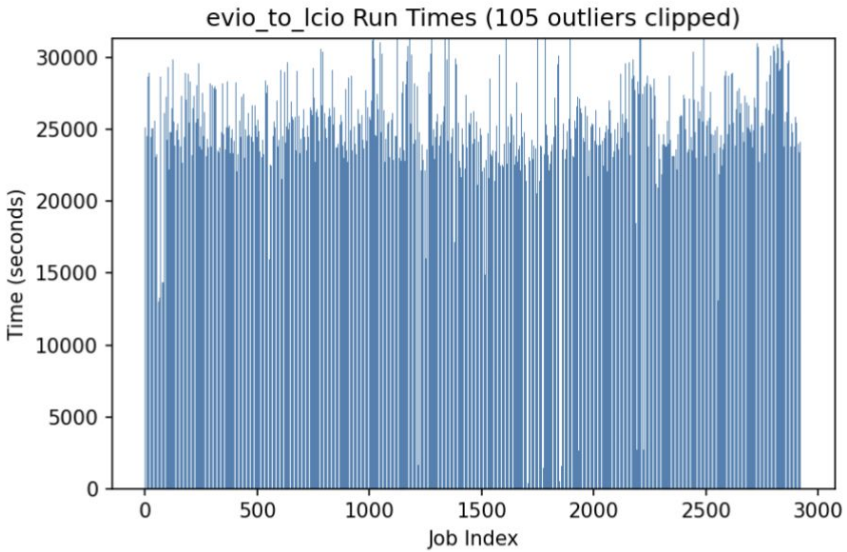
- As expected, significant impact on the CPU time
  - T2: Loosening requirements on second pass tracking → 2.6x increase
  - T1: Adding 6-hit tracks with loosened hit sharing → not much more than T2
  - L4: Loosening requirements on first pass tracking → >2x increase compared to T1
- Next step: check signal efficiency from L4 to T1 and T2
  - T1 adds real gains → best option at the moment



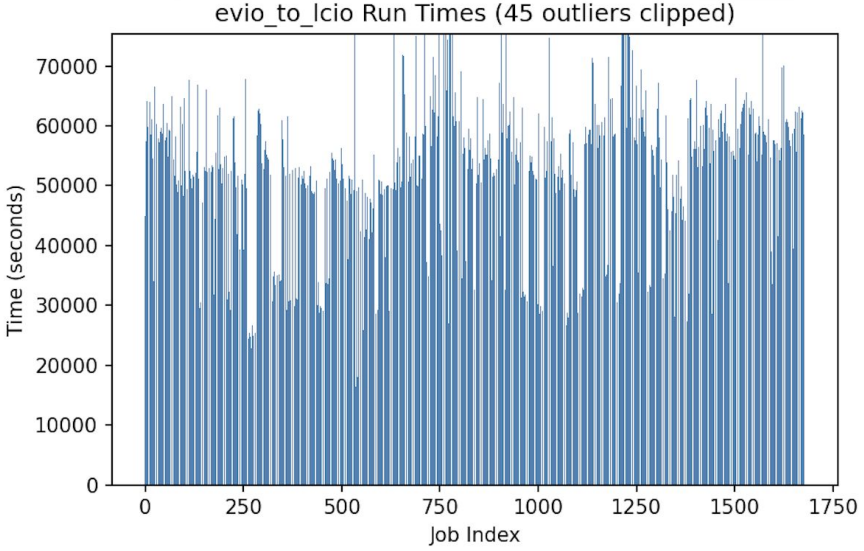


Small dev pass at JLab

- Small production run at JLab (55 runs, v0+fee skimming, all collections):
  - ***JLab**: /volatile/hallb/hps/test/prod/pass6dev-unskimmed*
  - ***SLAC**: /sdf/data/hps/physics2021/data/recon/pass6dev_v10/unskimmed*



pass5_v9



pass6_v10 (dev)

Conclusions

- Started to investigate the large-ish differences between the 2016 and 2021 cut flow efficiencies: largely trigger related
- Prompted a study of how to recover acceptance to asymmetric A’ decays where the positron is hard and electron is relatively soft; these are triggered events retained with the singles trigger that did not exist with pairs trigger in 2016
- Explored a low momentum KF tracking configuration; roughly factor of 2-3 increase in CPU for seemingly 40-50% more signal yield. Additional cross checks performed, confirming radiative fraction unchanged and data quality is as good or better than prior reconstruction passes
- Planning full 1% pass to be used to repeat analysis sensitivity

Backup slides

CPU Breakdown tests

- Relaxing tracking parameters has an expected large impact on CPU
- Looking at ways to reduce CPU footprint

Group	Change	pass5 → pass5b	Efficiency evidence	Expected CPU cost
A. Iteration-1 opening (patched code)	maxPtInverseIter1	4.0 → 12	untested alone	**HIGH** – iter-1 cuts are what kill seed candidates early;
	maxZ0Iter1 / maxD0Iter1	3 → 15 / 15 → 40 mm	part of loosetgt jump (+0.14 at z=150)	loosening them multiplies surviving combinatorics
	maxTanLambdaIter1	0.104 → 0.20		in the *first* pass, which sees **all** hits
B. Strategy promotion	numStrategyIter1	17 → 23 (all, incl. inner-layer)	never isolated; gain at z=0 was ~0, so likely small	**HIGH** – inner-layer strategies seed in the highest-occupancy layers, now on the full hit set
	+3 inner strategies (BBS0000 etc.)	20 → 23 total	part of lowp step	moderate
C. Iteration-2 opening	maxPtInverse	8.88 → 12	core of lowp step (0.15→0.28)	moderate (more candidates reach fitting, but on leftover hits)
	minHitsIter2	8 → 6	part of lowp/loosetgt	moderate
	maxZ0 / maxD0 (iter 2)	8.38 → 20 / 39.2 → 55 mm	part of loosetgt jump	moderate
D. Hit competition	maxSharedHits / maxChi2IncShare	2 → 3 / 5.86 → 8	never isolated; z=0 gain ~0 suggests small	low-moderate
E. Event admission	siHitsLimit	400 → 1000	recovers only skipped-event tracks	**HIGH on data, as a tail** – cost per event grows super-linearly with hits, and pass5's 400 cap was implicitly a CPU governor
–	removed dead lowPhThresh	no-op	none	none

CPU time in data

- As expected, significant impact on the CPU time
  - T2: Loosening requirements on second pass tracking → 2.6x increase
  - T1: Adding 6-hit tracks with loosened hit sharing → not much more than T2
  - L4: Loosening requirements on first pass tracking → >2x increase compared to T1
- Next step: check signal efficiency from L4 to T1 and T2

Configuration	$\langle t \rangle$/event [ms]	Tracks/event	$\langle t \rangle$/track [ms]	Max event [s]
L0: pass5 (production)	68.2	2.33	29.4	5.8
T2: + iteration-2 openings	174.8	3.07	57.0	34.2
T1: + 6-hit tracks, loose sharing	179.4	4.13	43.5	35.6
L4: + iteration-1 openings	403.5	4.12	97.8	45.5

Where does inefficiency arise?

- Low tanL mostly – Competition with the recoil electron?
- Effect at high tanL in bottom-, L5 is dead (not accounted for in truth hits)

