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Geometric GEM Efficiency Study

Trigger to lower GEM extrapolation for top GEM matching

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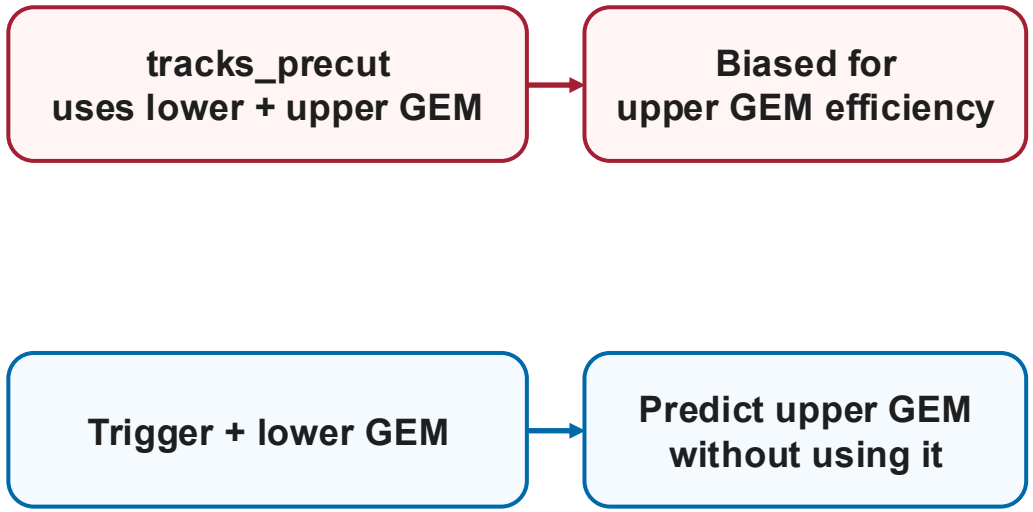
Motivation: avoid a biased denominator

Standard GEMTrack tracks use both lower and upper GEM hits.

That is circular if the upper GEM is the detector being tested.

The goal is a denominator based only on trigger plus lower GEM information.

The result should be interpreted as geometric matching efficiency.



Geometric method: trigger + lower GEM predict upper GEM

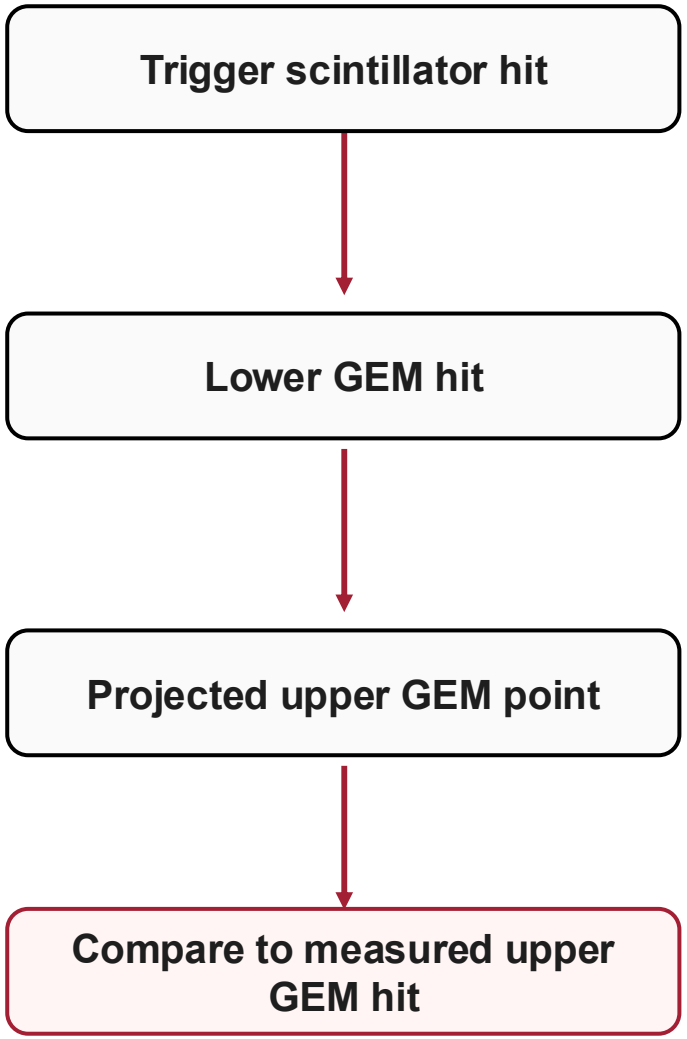
The method is event-by-event and treats left/right arms separately.

Upper GEM is excluded from the prediction stage.

Trigger-lower GEM candidates are first built within a shifted pairing window (expected separation is centered near dx ≈ 18 mm, dy ≈ 0 mm).

Candidates are ranked by distance from the expected trigger–lower offset.

Accepted trigger–lower candidates are selected with one-to-one protection.



A match is counted only if a measured upper hit is near the prediction.

The upper GEM matching also marks accepted upper hits as used, so the same upper hit is not counted multiple times in the fixed-window numerator.

Denominator: valid trigger to lower GEM projections.

Numerator: projections with an accepted upper GEM match.

Residual quality is evaluated from accepted matches.

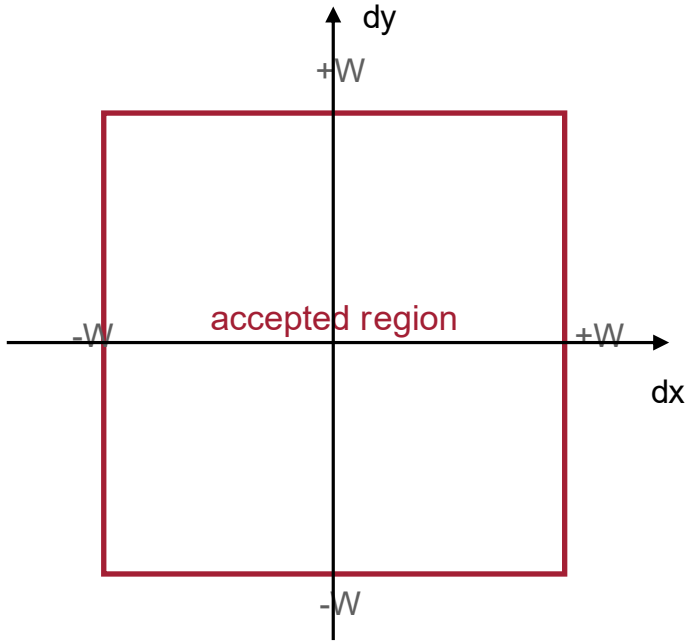
Matching window and residual definition

Residual (dx, dy) are evaluated in the lower GEM local frame.

dx and dy compare the predicted top point with the measured upper GEM hit.

The matching cut is rectangular: |dx| < W and |dy| < W.

W is the half-width. For example, W = 10 mm means +/-10 mm.



Run samples and current scope

Cosmic runs used

4583, 4585, 4586, 4587

4594, 4595, 4602

Excluded from clean set: 4581, 4584, 4588

Elastic runs used

2666, 2668, 3160

3513, 3515, 3516

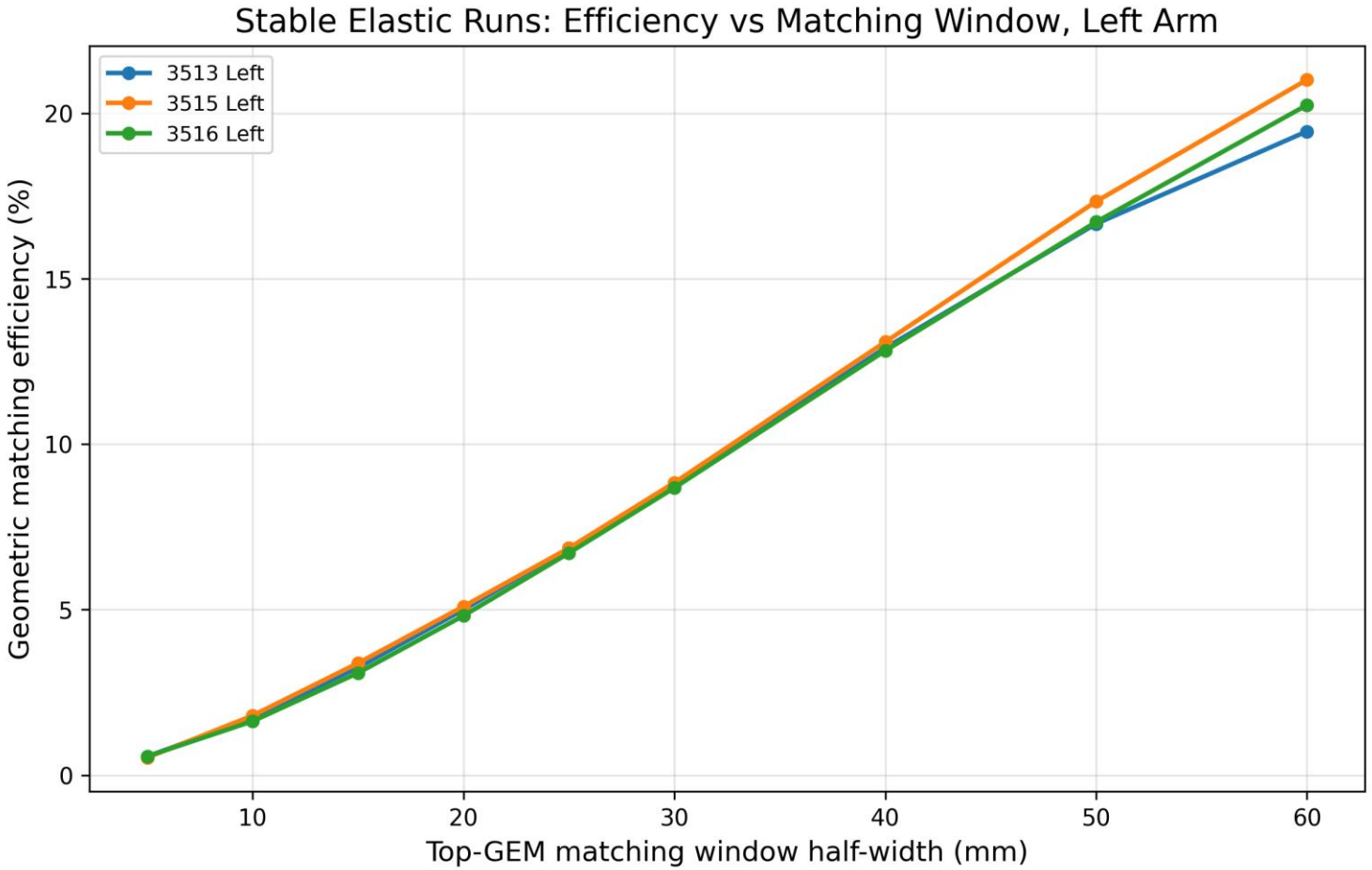
4024, 4397, 4398, 4399

Excluded from clean set: 3237, 3512

Current results use spatial matching only.

Timing cuts were investigated but disabled for the present summary because trigger timing treatment is still under review.

Stable elastic runs: efficiency grows reproducibly



Runs 3513, 3515, and 3516 nearly overlap.

Efficiency increases smoothly as W increases.

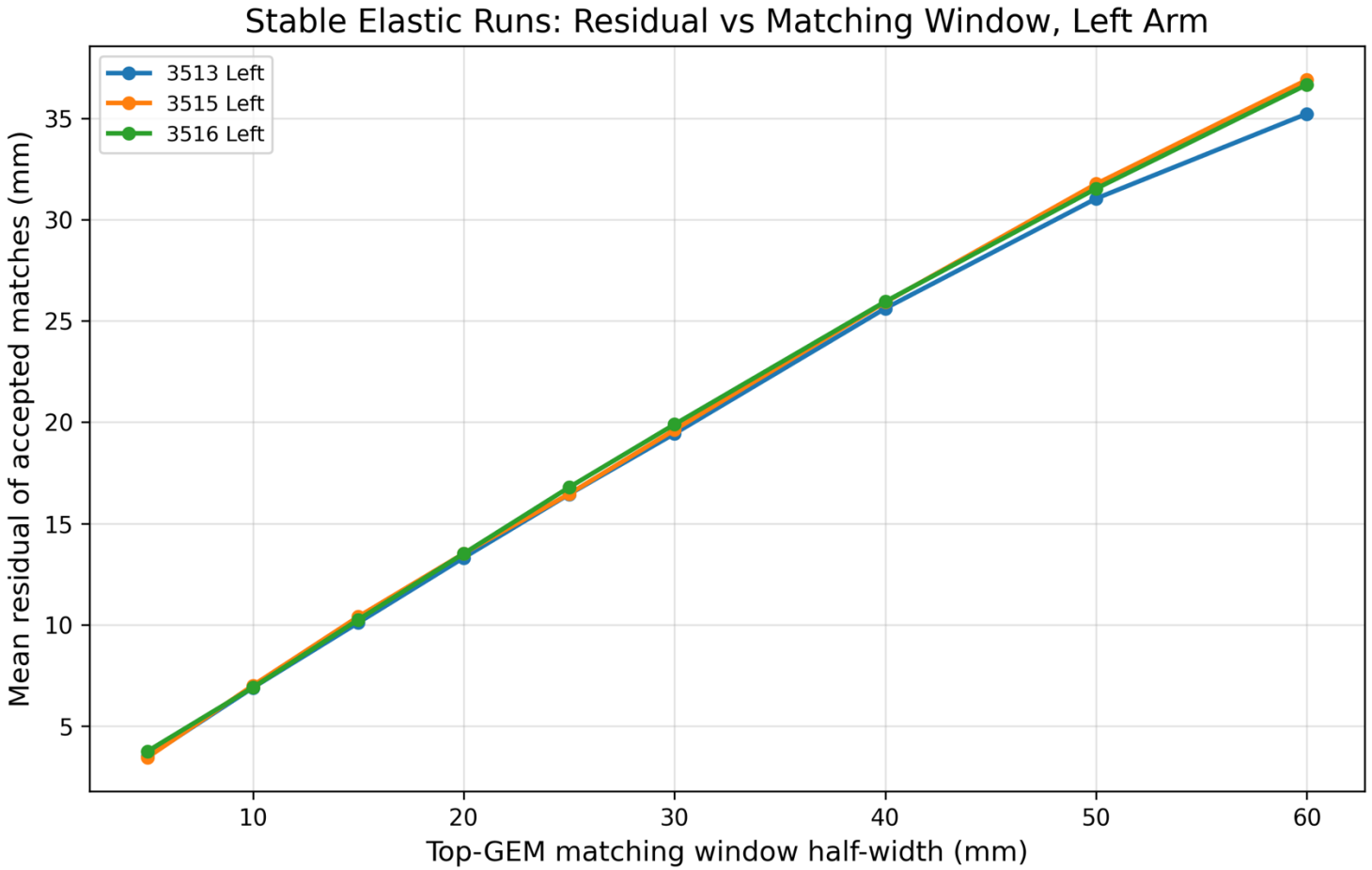
This supports stable geometric matching behavior.

Interpretation

The method is reproducible across the clean elastic sample.

The absolute values are geometric matching efficiencies, not final intrinsic detector efficiencies.

Stable elastic runs: residual cost of looser cuts



Mean residual rises with the matching window.

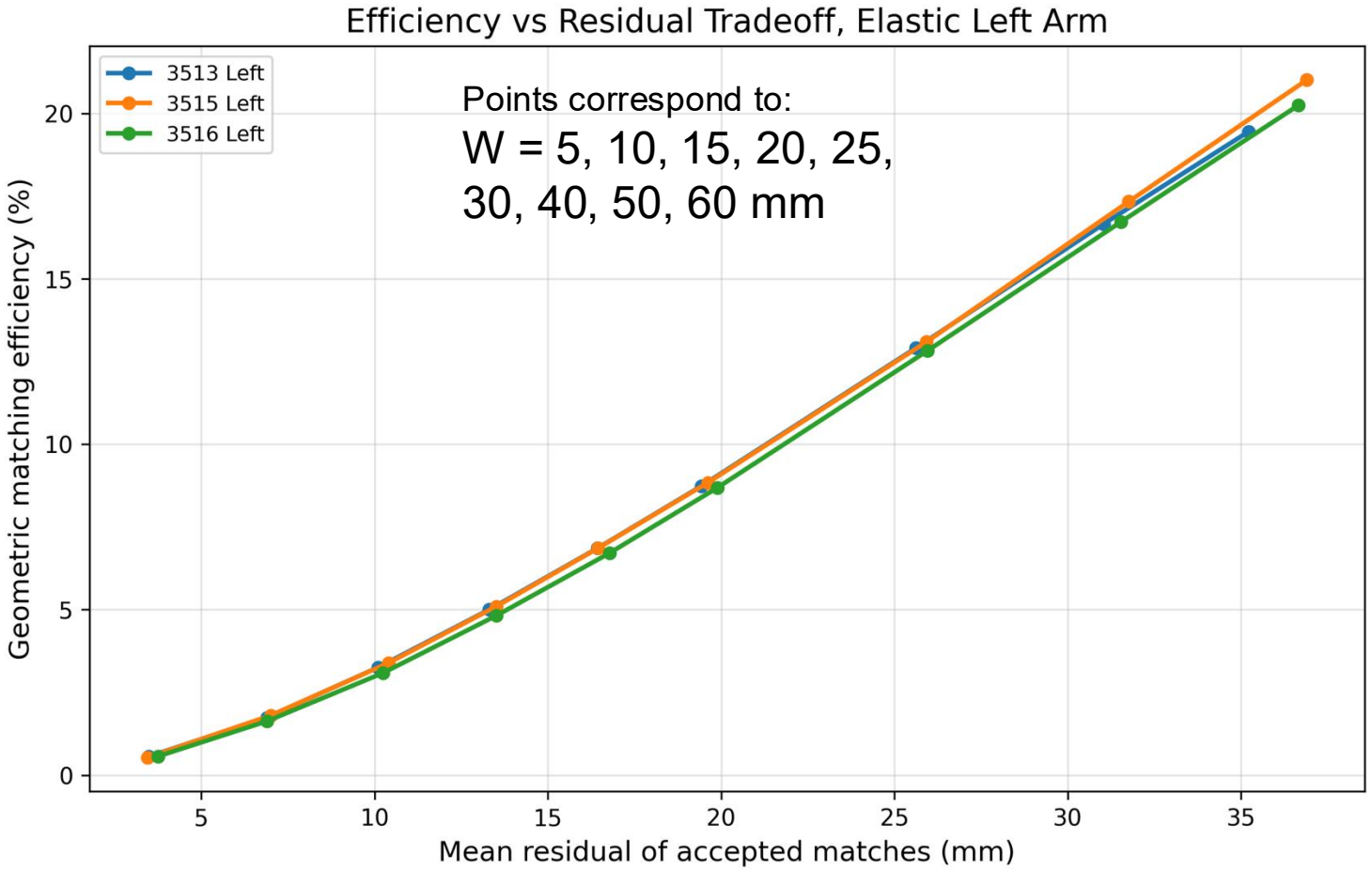
The trend is nearly identical across the same three runs.

Large windows admit increasingly distant associations.

Key point

Higher apparent efficiency must be balanced against lower matching quality.

Efficiency and residual quality form a tradeoff curve



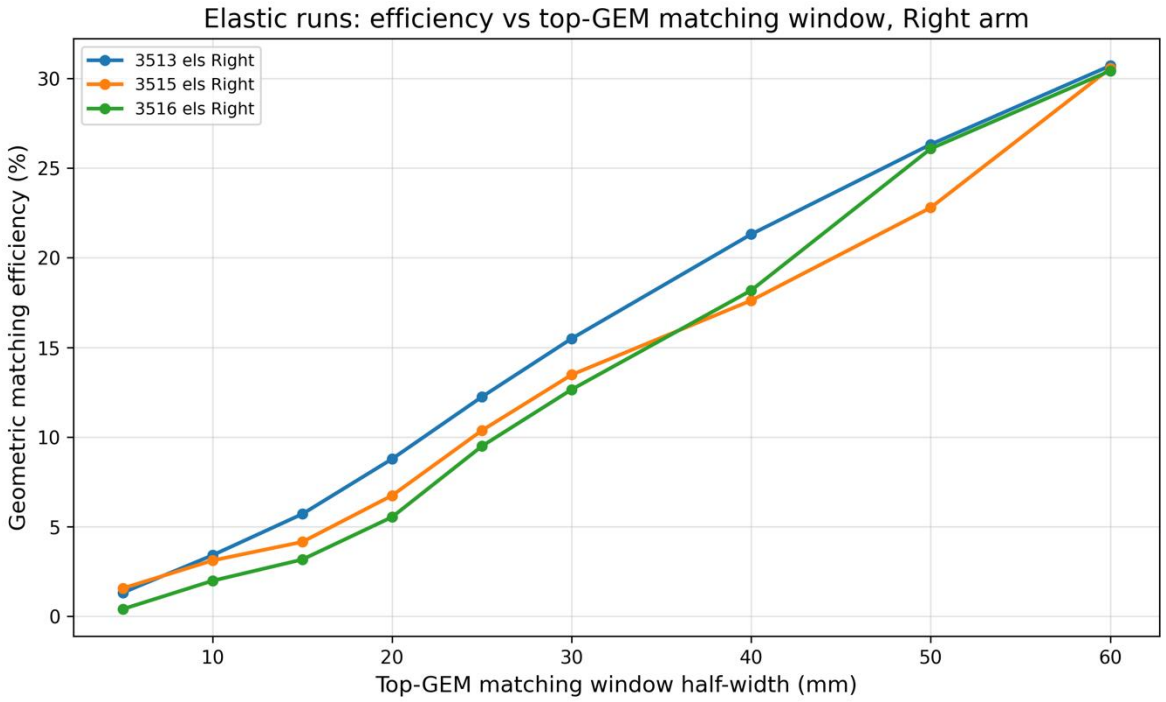
Each point corresponds to one matching half-width W.

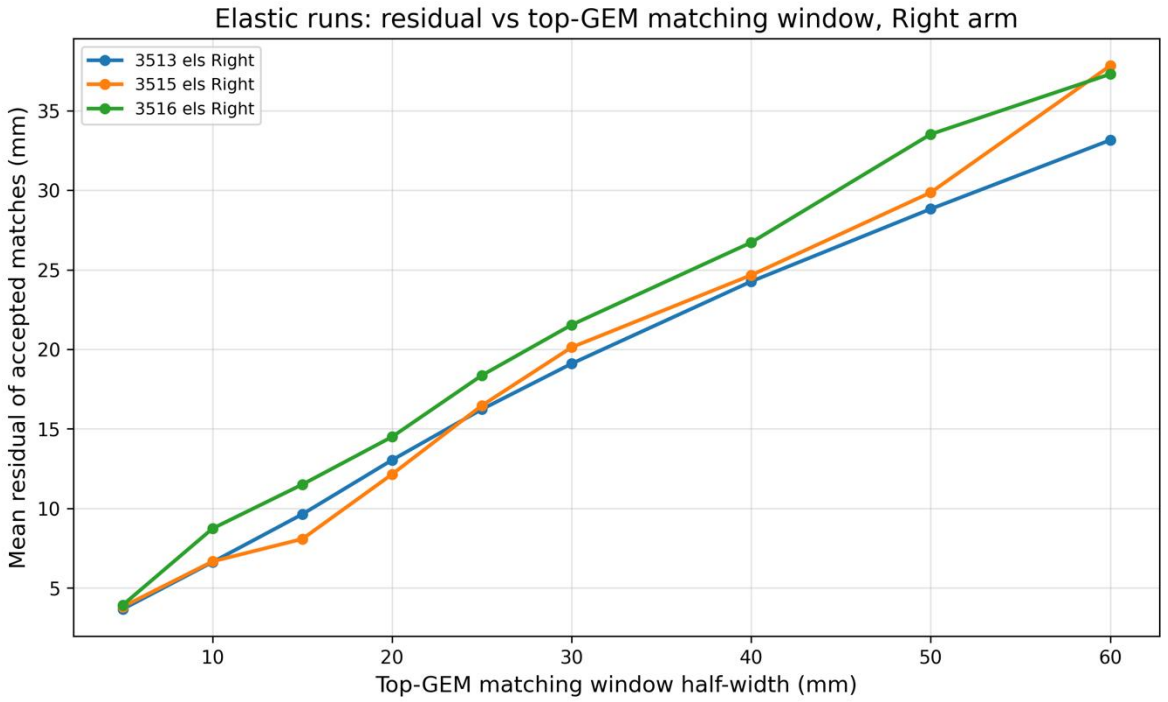
Intermediate W values give a more balanced working region.

Possible working region

W around 10 to 20 mm appears physically reasonable, pending further validation.

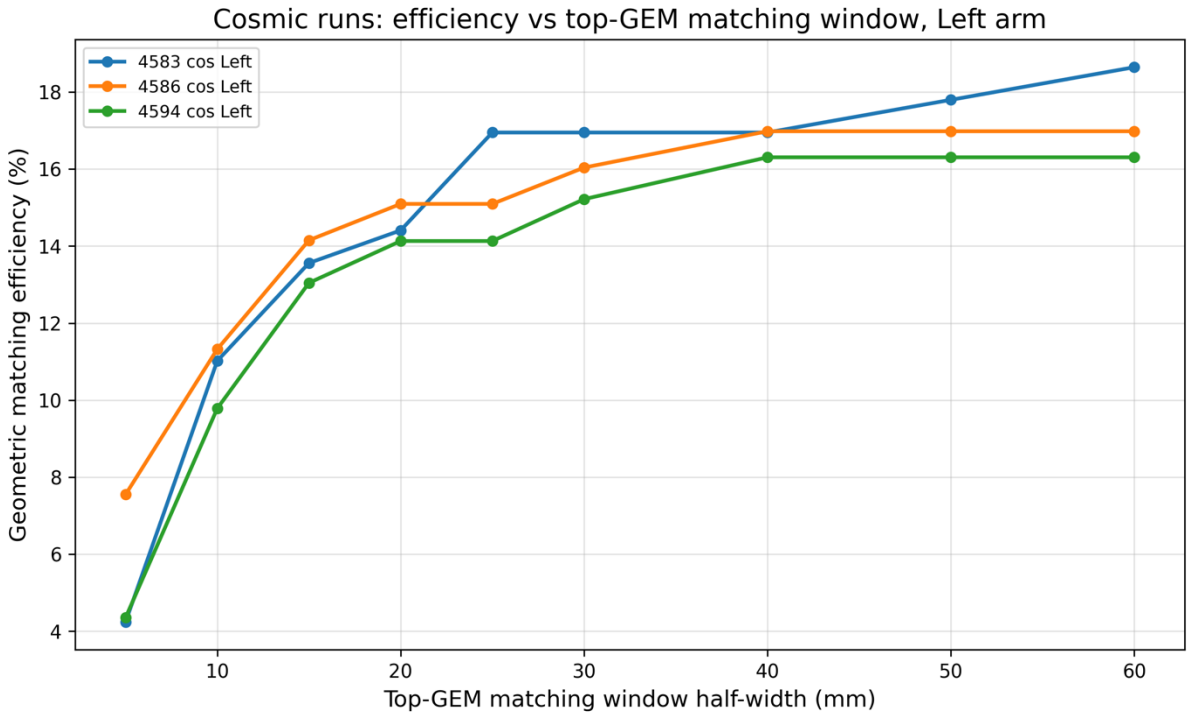
Right arm elastic behavior is more variable

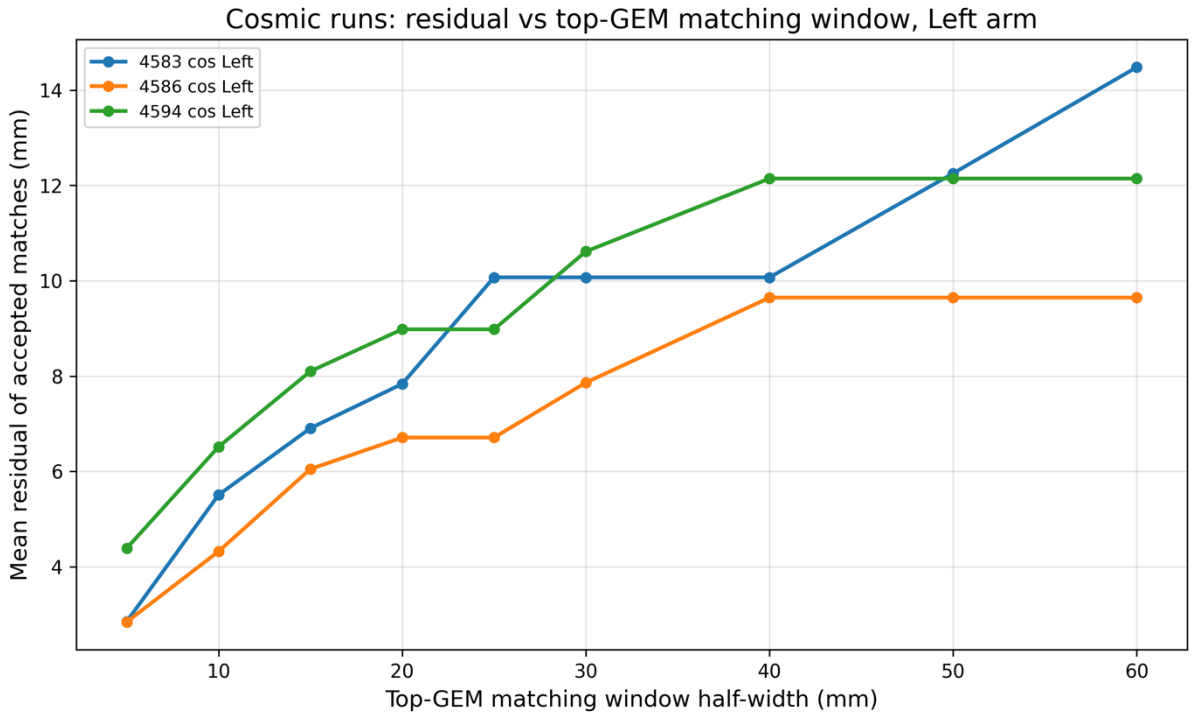




Observation: right-arm elastic scans seem to be less stable than left-arm scans.

Cosmic samples show different topology-dependent behavior

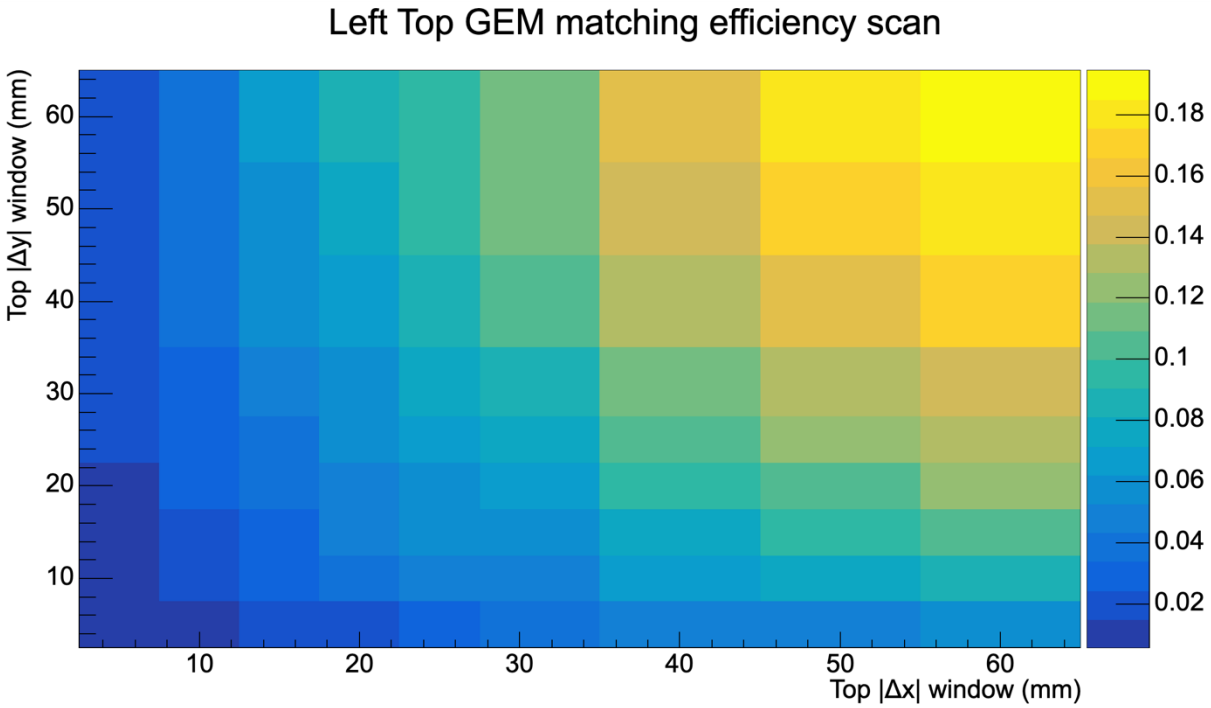


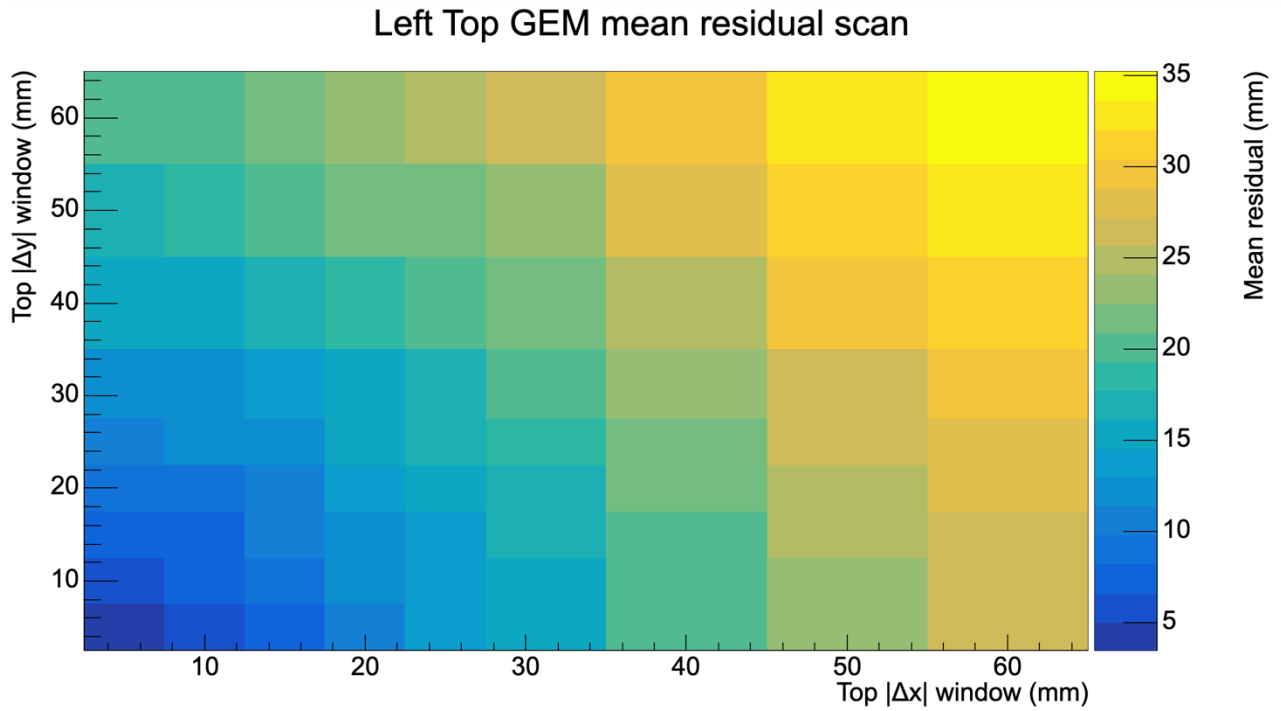


Cosmic tracks mostly come from above and are not bent by the beamline magnetic geometry.
This may naturally produce closer lower-to-upper GEM associations than elastic beamline trajectories.
This can explain earlier saturation and smaller residual growth compared with elastic events.

Example output: maps and residual diagnostics

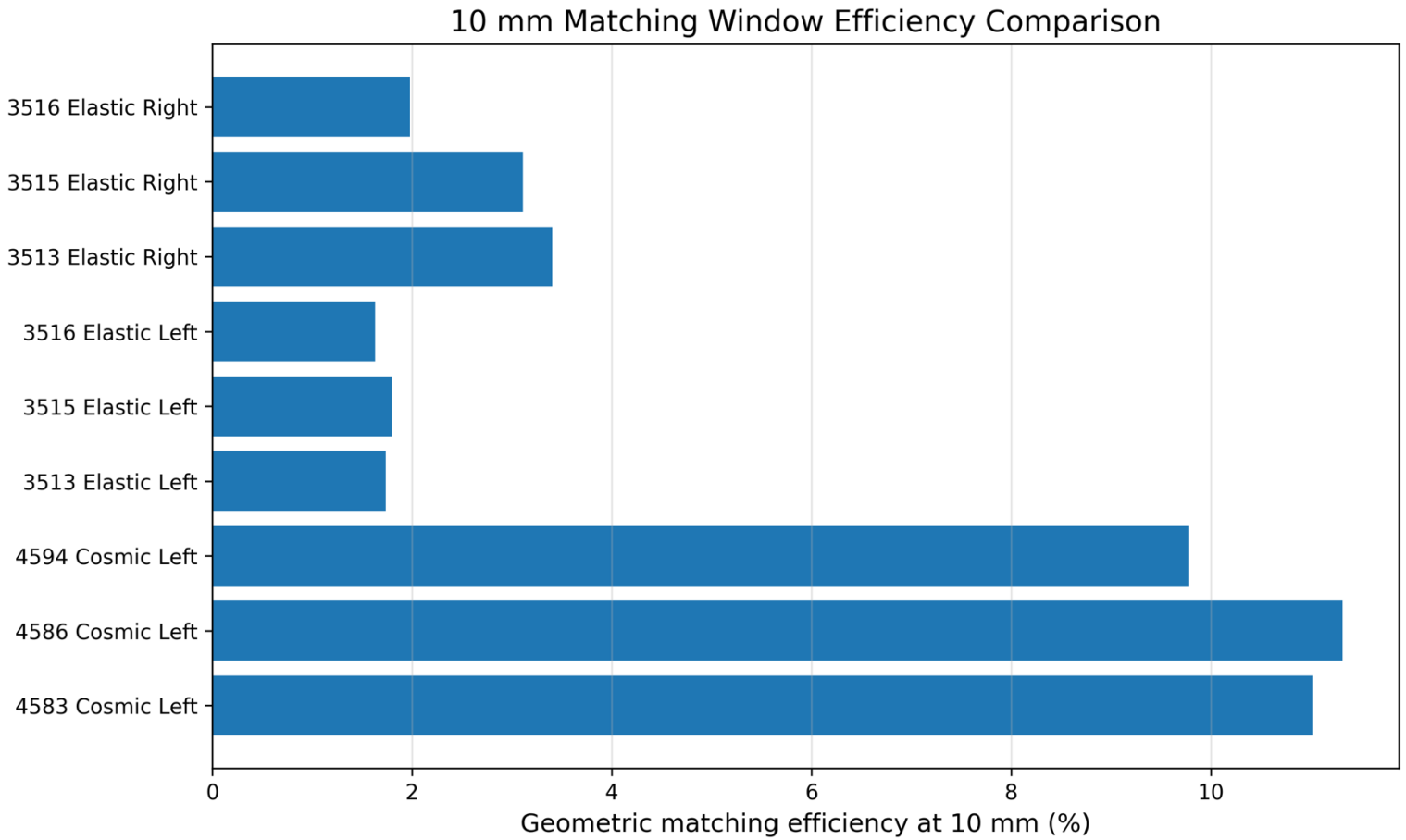
- **Elastic run 3513**
- **Left arm**





The scan behavior appears more stable along the non-dispersive direction than along the dispersive direction.
Qualitatively consistent with the expected beamline geometry and magnetic bending.

Fixed W =10 mm comparison across representative runs



10 mm is a useful intermediate reference point.

Cosmic left-arm efficiencies are larger than elastic values.

Right-arm cosmic are not shown here and require slow-control checks.

Timing diagnostic: not ready for current results

Tried USE_IN_TIME_TRIGGER_ONLY = true in the geometric loop.

Numerator and denominator collapsed to zero for run 3513.

Diagnostics showed trigHit.in_time = 0 for all candidates entering the loop.

Follow-up with Win and Ethan suggested a trigger reference-time subtraction change may explain the zero in-time candidates.

Advised not to use in-time cuts for detector efficiency until GEM timing analysis is ready.
Trigger timing treatment remains under discussion with detector experts.

Current decision: keep the present study spatial-only and treat timing as follow-up work.

Conclusions and near-term next steps

What is established now

Unbiased geometric method implemented.

Stable elastic runs show reproducible efficiency-window behavior.

Efficiency increases with looser windows, but residual quality degrades.

Open next steps

Reproduce the same study for Bottom GEM efficiency.

Understand trigger reference-time handling.

Check right-arm cosmic high-voltage history.

Main takeaway: the spatial geometric framework is stable enough for systematic study, but timing and detector-state checks are needed.