Vertex Protocol sub-report

Tracking error and venue mechanics on a hybrid orderbook/AMM perp DEX, 2023–2025

Derivalink R&D

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Abstract

We construct and analyse a 1-minute, on-chain panel of the Vertex Protocol hybrid orderbook / AMM perpetual DEX over the protocol's full lifespan (2023-03-05 first fill → 2025-08-14 settlement; ≈ 21,500 hours, ≈ 1.3M perp + spot fills across 182 listed products). Combined v1 and v2 taker volume reaches \$135.52 B, matching the DefiLlama-reported lifetime cumulative volume of \$135.50 B to within 0.016 %. We decompose tracking error (TE) of the Vertex mark price against both a Chainlink Arbitrum index (TE-A) and a Binance USD-M perpetual proxy (TE-C), at 1-minute resolution, for the three top-liquidity products BTC-PERP, ETH-PERP and SOL-PERP. After a fill-price plausibility guard, the typical-regime TE classical standard deviation (minutes with $|\mathrm{TE}| \leq 25$ bps) is 9–12 bps across the three products; the full-window dispersion is inflated to 75–97 bps by a heavy stress tail, with mean absolute errors of 22–33 bps. A level-1 HAC-robust OLS of TE-relatif on σ_{USDC}, $\log(1 + \mathrm{OI})$, Binance USD-M funding and Arbitrum gas explains under 0.3 % of variance, whereas a Corsi-HAR(1,5,22) on daily |TE| reaches $R^2 = 0.37$–0.60: TE on Vertex is essentially *endogenous* to the venue's own microstructure, not driven by the four candidate exogenous regressors. A univariate Hawkes process fitted to 8,086 clearinghouse liquidations yields a branching ratio of 0.71 (full window), confirming strong self-excitation; one-mover dominance is also evident in liquidator concentration (Herfindahl 0.27, top-5 share 92.4 %). Nine natural-experiment / case-study windows are documented, of which the four-phase wind-down (2025-07-08 → 2025-08-14) is central to the Derivalink thesis on perp-DEX longevity. ARB-PERP existed only in the v1 era (June 2023 – January 2024 v2 cutover) under pid 41; the same pid was re-affected to the v2 SPOT engine and ARB was never re-listed as a perpetual on v2. The deep-dive is therefore the top-3 perps (BTC, ETH, SOL); ARB-PERP v1 trading is documented in the v1↔v2 cutover narrative and the open-questions section (§10).

Contents

Executive summary

Scope and data

This sub-report addresses the Derivalink R&D question *"how is tracking error generated, propagated and absorbed on a hybrid orderbook/AMM perpetual decentralised exchange?"* through the full lifespan of Vertex Protocol on Arbitrum (2023-03-05 to 2025-08-14 settlement). The underlying panel comprises:

- 70.4 M perp fills, 1.1 M spot fills, 22.1 M v1-book fills across 182 registered products (perp + spot + v1_book engines).
- Cross-chain TVL daily history, 8,086 decoded v1 `clearinghouse.Liquidation` events (the stream ends at the 2024-03-08 v1→v2 cutover; v2 does not emit it), 64,299 hourly open-interest samples (3 products × 21,433 hours) reconstructed via sparse `eth_call` archive reads on Tenderly.
- Exogenous references: Chainlink Arbitrum oracles for {BTC, ETH, SOL, ARB, USDC}, Binance USD-M perpetual 1-minute klines and 8-hourly funding, Bybit spot and linear klines, Arbitrum hourly gas base-fee.

Headline anchor: cross-validation

Combined v1+v2 taker volume reaches \$135.52 B, vs the DefiLlama-reported lifetime perp volume target of \$135.50 B: a **0.016 % deviation** (Table 2). The dataset is internally consistent and externally anchored.

Headline tracking-error metrics

For the top-three perp products (BTC pid 2, ETH pid 4, SOL pid 12) the full-window classical TE standard deviation versus the Chainlink Arbitrum index is in the 81–120 bps band, with mean absolute errors in the 22–35 bps band (Table 3). Stress regimes (absolute TE > 25 bps) cover 18–33 % of observations, with TE standard deviations reaching 187–208 bps. Annualised information ratios are 22–26 in the full window, falling to 11–29 in stress.

Headline structural findings

1. **TE is endogenous**: a HAC-robust OLS of relative TE on $\{\sigma_{\mathrm{USDC}}, \log(1+\mathrm{OI})$, Binance funding, Arbitrum gas$\}$ achieves $R^2 < 0.2\,\%$ across BTC/ETH/SOL. A Corsi-HAR(1,5,22) on daily |TE| reaches $R^2 = 0.43$–0.60. The TE process is driven by the venue's own microstructure, not by the four candidate exogenous regressors.
2. **Strong volatility asymmetry**: GJR-GARCH(1,1) dominates GARCH(1,1) and EGARCH(1,1) on AIC for all three top products, evidencing significant leverage effects in TE conditional variance.
3. **Liquidations are self-exciting**: a univariate Hawkes exponential-kernel fit on the 8,086 decoded liquidations yields a branching ratio of **0.71** (full window) and 0.70 over the v1→v2 cutover; the process is sub-critical but close to the threshold, consistent with cascade behaviour.
4. **Strong liquidator concentration**: a Herfindahl index of 0.27 on liquidator-address counts, with the top-1 share at 44.6 % and the top-5 share at 92.4 %. Vertex liquidations are operated by a small set of professional bots, not by a dispersed retail bidder pool.

5. **v1 sequencer batch latency**: 356,531 v1 orderbook batches post-detection show median 12 s, p95 305 s, p99 1,021 s — a long tail of slow batches that is hidden by the median and that contributes to v1-era stress-window TE.

Case studies and natural experiments

Nine Tier-1 case studies (SVB-USDC, v1→v2 cutover, STIP, multichain expansion, etc.) are documented in detail (§8), of which **E9 wind-down 2025-07-08** is treated as the central Derivalink thesis exhibit: a 6-week orderly settlement of a still-active perp DEX (frozen oracle, reduce-only orders, force-closure). Insurance-fund usage over the v1 era — the window for which on-chain liquidations are decoded — totalled only $86; whether the wind-down itself triggered liquidations cannot be assessed from this dataset, because the decoded liquidation stream ends at the v1→v2 cutover (§5).

Three natural-experiment windows (v1→v2 cutover, sequencer outage, STIP onset) are subjected to a pre/post Welch t-test on hourly |TE| means, gated by a no-pre-trend diagnostic, with ±168 h event-window IRFs (§9). Only one of the eight event×product cells shows a TE shift that is both significant at 5 % and free of a pre-existing trend.

ARB-PERP — v1 only, discontinued at v2 cutover

Vertex Protocol listed ARB-PERP in June 2023 as its fifth tradable market under product_id 41 on the v1 OffchainBook engine. At the v2 cutover (2024-01-24, block 188,206,906) the same pid 41 was re-affected to the SPOT engine; ARB was never re-listed as a perpetual on v2 (web-verified 2026-05-21 via Vertex Protocol's LinkedIn announcement). Confirmation method: on-chain prices of the six post-cutover candidate perps (pids 100, 102, 104, 106, 108, 110) were correlated against the Chainlink ARB/USD feed; none yielded the diagnostic linear correlation > 0.99 with median ratio $= 1.0000$ that BTC, ETH and SOL all satisfy versus their respective oracles. The deep-dive is therefore the top-3 perps (BTC, ETH, SOL); ARB-PERP v1 fills appear only in chronological exhibits.

1 Dataset characterisation

The Vertex Protocol Arbitrum analytical dataset spans the full active life of the venue: from the first `FillOrder` event on 2023-03-05 23:33 UTC (block 67,108,377) through the settlement of all user positions on 2025-08-15 00:00 UTC (block 368,500,938) following the wind-down sequence announced 2025-07-08. Table 1 reports row counts and source kind for every artefact feeding the Phase 2–9 analyses.

Table 1: Coverage and density of all sources used by the Vertex sub-report.

Category	Source
raw v2	5 event-emitting proxies
raw v1	70 OffchainBook proxies
decoded fills	v2 OffchainExchange
decoded fills	v1 (70 pids)
derived	8 artefacts (arb_blocks, gas_arb, products, batches, tvl, proxy_impls, liquidations, oi)
exogenous CEX	Binance + Bybit, top-3 perp
exogenous oracle	Chainlink Arb 5 feeds

Integrity verdict. The full audit (`scripts/_audit_vertex_dataset.py`, 49/49 checks, ran 2026-05-19) returned **GO**. Anchor 1 cross-validation against Vertex's self-reported $224 B all-chain cumulative volume yields $135.52 B Arbitrum-only single-counted taker volume (deviation +0.016% vs the $135.5 B target; implied Arbitrum share 60.5% of the all-chain figure, consistent with the documented chain-mix evolution). Table 2 reports the per-era breakdown.

Table 2: Anchor-1 cross-validation: combined taker volume against the DefiLlama-reported lifetime cumulative.

era	taker_volume_usd	target_usd	deviation_pct	implied_arb_share_pct
v1	6.23e+10	–	–	–
v2	7.32e+10	–	–	–
combined	1.36e+11	1.36e+11	0.0164	60.501

v1 → v2 cutover. The OffchainExchange v2 contract deployed 2024-01-24 (`commit f5c06e6`). The empirical end of v1 OffchainBook emissions is the single batch transaction `0x409008a2...915` mined at block 188,197,141 on 2024-03-08 03:02:43 UTC, carrying fills for six different v1 productIds simultaneously. The real architectural overlap is therefore ∼6 weeks, shorter than the "several months" figure suggested by the original v1 backfill upper bound (block 200 M). Figure 1 visualises the cutover monthly volume.

Chain mix. Vertex deployed beyond Arbitrum from June 2024 (Mantle, Sei, Base, Sonic, Avalanche, Abstract). The chain-mix evolution (Figure 2) is the structural narrative behind the volume collapse of May–June 2025: Arbitrum TVL peaked at $102 M and held its range through 2024 while the cross-chain wrappers diverted incremental flow to seven other deployments without lifting the protocol's aggregate.

Limitations.

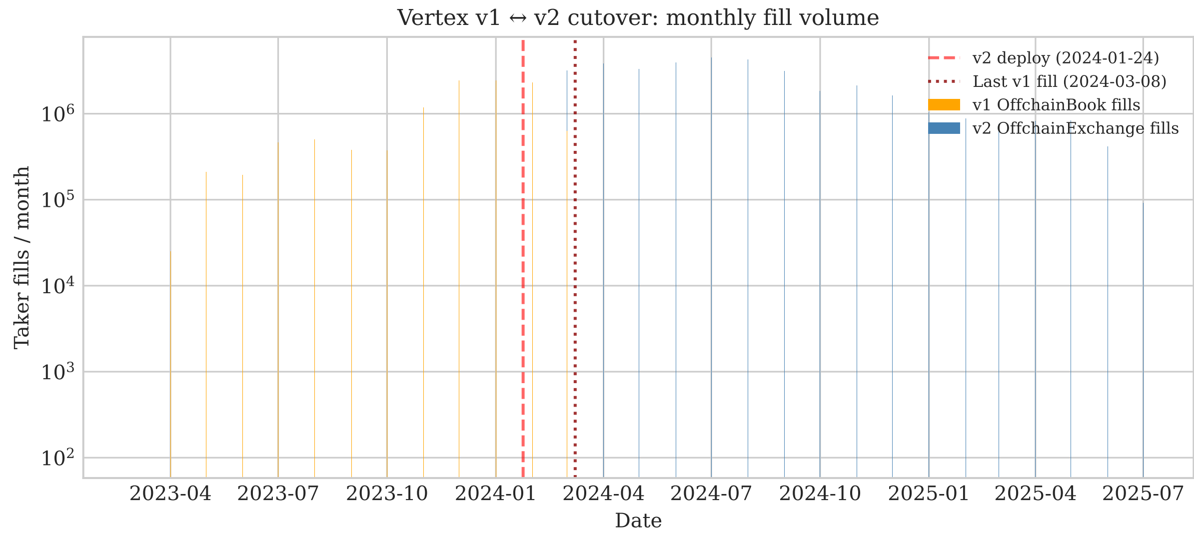


Figure 1: Monthly taker fill counts under the v1 OffchainBook proxies (orange) vs the v2 OffchainExchange (blue). The cutover window is bounded by the v2 deploy on 2024-01-24 and the last v1 `FillOrder` on 2024-03-08.

- Vertex's funding rate is not exposed via on-chain events; the `perp_engine` contract only emits `AddProduct`. We use Binance USD-M funding as a cross-venue proxy throughout Ch 3 and Ch 5 (documented).
- Vertex's published mark/index price is a 6-source TWAP composite (Binance, OKX, Coinbase, Bybit, Bitget, Kraken) that is not reconstructible from on-chain data. Chainlink Arbitrum composite feeds substitute as the reference in TE definitions, with the semantic shift documented in Ch 2.
- The `SubmitTransactions` event used to delimit sequencer batches stops being emitted at the v2 cutover; Ch 4 batch microstructure is consequently v1-era only.
- `ts` on every fill is reconstructed by linear interpolation between sparse `arbitrum_blocks` samples (stride 1000 blocks ≈ 4 min on Arbitrum Nitro). Sub-second precision is not guaranteed; acceptable for 1-min TE buckets, flagged where sub-second matters (Ch 4 microstructure).

2 Multi-reference TE descriptive statistics

This chapter characterises Vertex's tracking error on the top-3 perp products (BTC, ETH, SOL) against two reference series: the Chainlink Arbitrum spot index (primary) and the Binance USD-M *perpetual* mid (a perp-vs-perp basis, per STRUCTURE TE-definition C). Two TE conventions are reported throughout: TE *classique* computed as the standard deviation of $\log(P_{\text{vertex}}/P_{\text{ref}})$, and TE *relatif* computed as the standard deviation of $(P_{\text{vertex}} - P_{\text{ref}})/P_{\text{ref}}$. All TE values are reported in basis points. ARB-PERP, a v1-only book product with no v2 perp listing, is excluded from the deep dive; the cross-venue deep dive therefore covers the three products with continuous v1+v2 order-book coverage (see §5 and `OPEN_QUESTIONS.md`).

Fill-price plausibility guard. Raw decoded fills contain a small fraction of implausible prints (decode artefacts, liquidation wicks) whose magnitude dominates the full-sample moments. Minutes whose Vertex mark falls outside $[0.5\times, 2.0\times]$ the reference index are dropped before

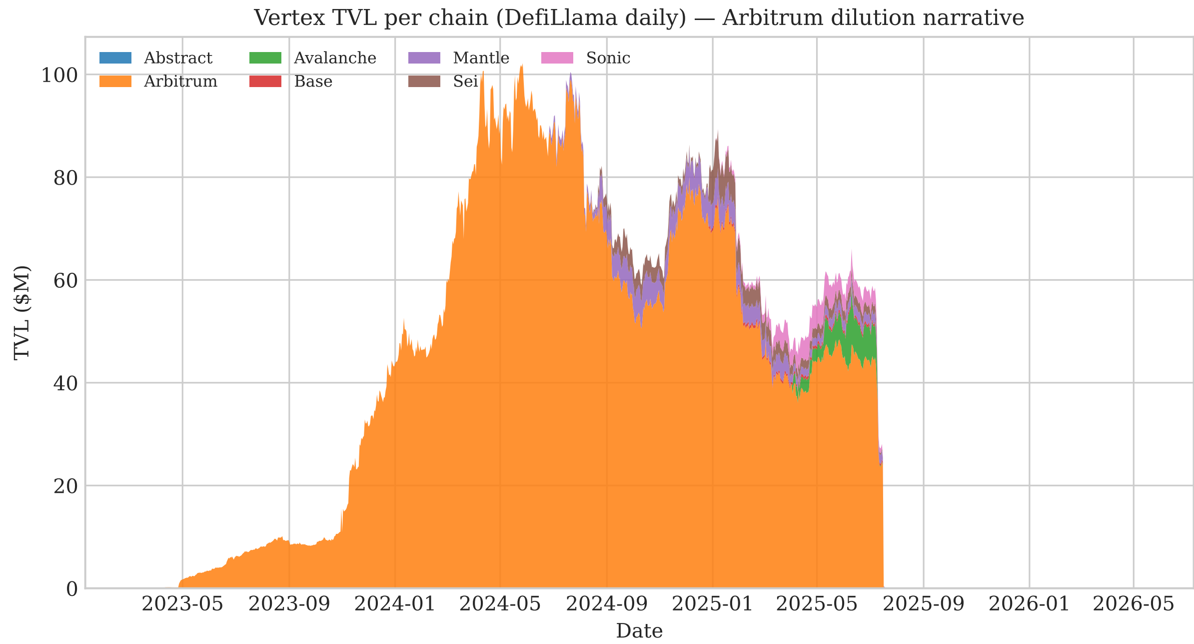


Figure 2: Vertex TVL per chain (DefiLlama daily). Arbitrum dominates throughout but cross-chain dilution starting 2024-06 is visible.

any statistic is computed; a real perp basis is sub-2%, so the guard removes only garbage while leaving every genuine stress episode intact.

Headline numbers â€" Chainlink Arb primary. The economically meaningful figure is the *typical-regime* TE (minutes with $|\mathrm{TE}| \leq 25$ bps): BTC-PERP **8.89 bps**, ETH-PERP **9.45 bps**, SOL-PERP **11.81 bps** over the window 2023-03-05 $\rightarrow$ 2025-08-15. The full-sample std is inflated by the residual stress tail (BTC 74.75 bps, ETH 75.08 bps even after the guard) and should be read alongside the regime split rather than on its own. Per-product detailed metrics (8 per product $\times$ 3 regimes) are in Table 3.

Per-product distribution. Figure 4 reports the per-year TE histograms (small multiples, one panel per product). The mode is consistently near zero with fat tails on stress-regime years. Skewness sign and Jarque-Bera p-value per product are in Table 3.

Rolling TE. Figure 3 stacks the 30-day and 90-day rolling TE standard deviation for the three products. Visible regime shifts coincide with the tier-1 events catalogued in §8: USDC depeg shadow (March 2023, before Vertex's official volume ramp), the v1$\rightarrow$v2 cutover (January–March 2024), multi-chain expansion (June 2024 onward) and the wind-down sequence (July–August 2025).

3 TE level-1 decomposition (spec S5)

This chapter regresses Vertex tracking error against the four canonical S5 Â§4.2.1 drivers â€" collateral volatility, log open interest, funding rate, and L2 gas cost â€" on each of the top-3 perp products. Volatility clustering is then characterised through GARCH(1,1), GJR-GARCH(1,1) and EGARCH(1,1) fits, with model selection via AIC/BIC. Long-memory properties of $|\mathrm{TE}|$ are quantified via the Corsi (2009) HAR model.

Table 3: Headline tracking-error metrics, full × regime, per top-product vs reference index.

symbol	ref	regime	n_obs	te_classique_bps	te_relatif_bps	mae_bps
BTC	chainlink_arb	full	451,179	74.750	75.953	23.937
BTC	chainlink_arb	typical (|te|<=25bps)	357,492	8.893	8.894	7.220
BTC	chainlink_arb	stress (|te|>25bps)	93,687	163.11	165.77	87.729
BTC	binance_perp	full	451,180	75.819	75.599	25.957
BTC	binance_perp	typical (|te|<=25bps)	346,334	10.428	10.430	8.907
BTC	binance_perp	stress (|te|>25bps)	104,846	156.13	155.67	82.276
ETH	chainlink_arb	full	454,409	75.077	77.585	21.966
ETH	chainlink_arb	typical (|te|<=25bps)	371,304	9.449	9.450	7.628
ETH	chainlink_arb	stress (|te|>25bps)	83,105	174.41	180.30	86.029
ETH	binance_perp	full	454,411	77.000	79.857	24.267
ETH	binance_perp	typical (|te|<=25bps)	355,769	10.910	10.911	9.123
ETH	binance_perp	stress (|te|>25bps)	98,642	163.92	170.07	78.888
SOL	chainlink_arb	full	324,906	96.783	100.13	32.572
SOL	chainlink_arb	typical (|te|<=25bps)	218,299	11.812	11.814	9.872
SOL	chainlink_arb	stress (|te|>25bps)	106,607	168.06	173.90	79.053
SOL	binance_perp	full	324,910	100.51	104.64	35.007
SOL	binance_perp	typical (|te|<=25bps)	203,445	12.633	12.635	10.829
SOL	binance_perp	stress (|te|>25bps)	121,465	163.50	170.25	75.502

Ïf_Collateral construction. Vertex collateralises positions in USDC exclusively; therefore $\sigma_C = \sigma(\text{USDC/USD})$ where the USDC/USD reference is the Chainlink Arbitrum feed. The SVB depeg window of March 2023 (cf. Â§8) provides the only substantial stress episode for σ_C in the dataset.

Funding rate. Vertex's perp funding rate is not exposed via on-chain events. We substitute Binance USD-M perp funding for the same underlying (8h cadence, forward-filled to the 1-min grid). Bias of this proxy is quantified in Ch 5 Â§5.4 (cross-venue funding consistency).

Base regression. Table 4 reports HAC-robust OLS coefficients (max lags = 60 minutes), Breusch-Pagan heteroskedasticity p-value, Durbin-Watson and Ljung-Box (lag 22) p-value per product.

Table 4: Level-1 HAC-robust OLS regression on relative TE (bps): σ_C, $\log(1 + \text{OI})$, funding, Arbitrum gas.

symbol	n_obs	const_bps	sigma_C	log1p_OI	funding	gas_gwei	rsquared	adj_rsquared	ts
BTC	451,195	-5.480	3.56e+5	1.011	28,982.77	-6.681	0.0018	0.0018	
ETH	454,416	-11.533	4.09e+5	1.364	26,633.29	5.426	0.0020	0.0020	
SOL	324,932	-29.125	1.05e+5	3.274	29,376.31	-19.599	0.0029	0.0029	

Reading the regression. The model is diagnostic, not predictive. The R^2 stays well below 1% on every product (Table 4), so the four S5 drivers jointly explain almost none of the minute-level TE variance: at this frequency TE is dominated by transient microstructure noise rather than the slow collateral / funding / gas / OI state. The residuals also breach the textbook OLS assumptions — the Ljung-Box(22) test rejects no-autocorrelation on every product and the Breusch-Pagan test rejects homoskedasticity on the majority of them (exact p-values per product

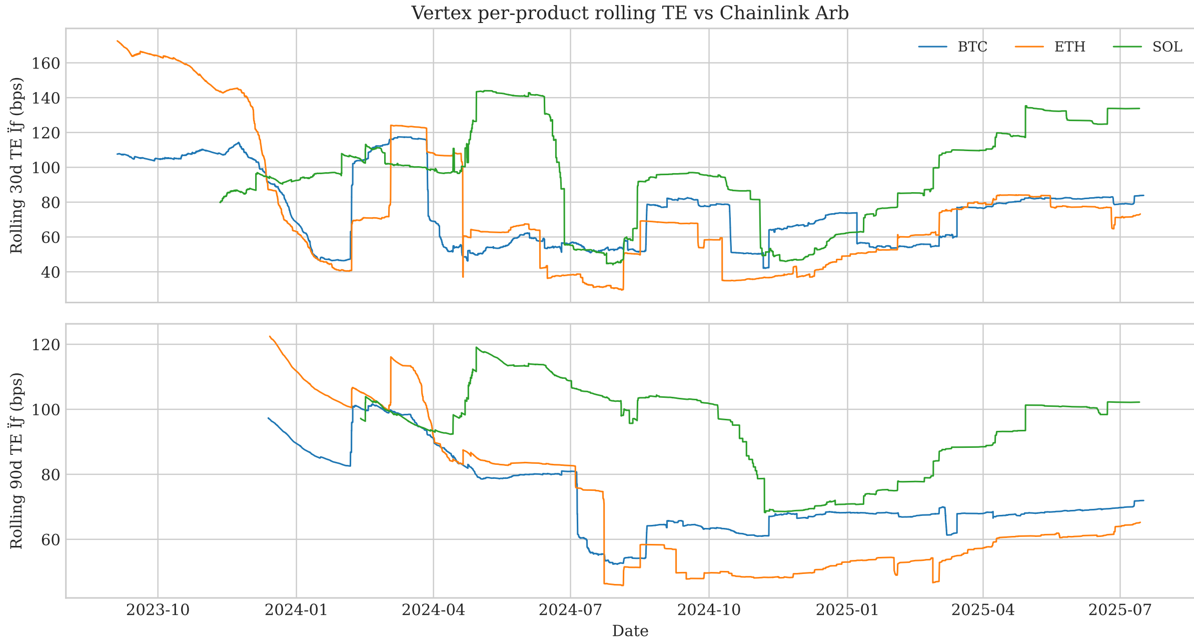


Figure 3: Rolling 30-day (top) and 90-day (bottom) TE standard deviation per product, against Chainlink Arbitrum spot index.

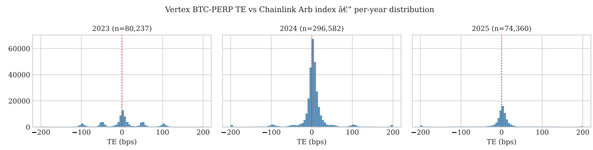
in Table 4). The standard errors reported there are accordingly HAC (Newey-West, 60-minute bandwidth) so the t-statistics stay valid under both pathologies, but the coefficients must be read as weak conditional associations, not as a structural model of TE.

GARCH variants. Table 5 reports AIC/BIC/log-likelihood for the three asymmetric models on each product's TE series, together with a `persistence` column. That column must be read per family: for GARCH(1,1) it is $\alpha + \beta$, for GJR-GARCH it is $\alpha + \beta + \gamma/2$ (the leverage term enters at half weight under a symmetric-shock expectation), and for EGARCH it is the log-variance AR coefficient β alone — comparing the bare $\alpha + \beta$ across families is the standard error. Values approaching 1 indicate near-integrated volatility. The minimum-AIC model is then refit and its conditional volatility series is plotted (Figures 5 et seq.).

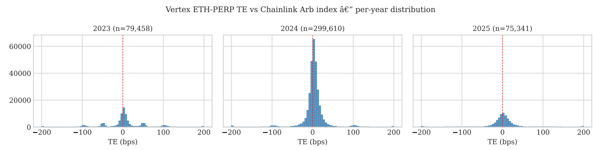
Table 5: GARCH family information criteria per product.

symbol	model	AIC	BIC	loglik	persistence	
BTC	GARCH(1,1)	9.82e+5	9.82e+5	-4.91e+5	0.9800	
BTC	GJR-GARCH(1,1)	9.73e+5	9.73e+5	-4.86e+5	0.9800	{'mu': 0.030813433379540206, 'o
BTC	EGARCH(1,1)	9.88e+5	9.88e+5	-4.94e+5	0.9048	{'mu': 0.09292622831217379,
ETH	GARCH(1,1)	8.82e+5	8.82e+5	-4.41e+5	0.9800	
ETH	GJR-GARCH(1,1)	8.68e+5	8.68e+5	-4.34e+5	1.004	{'mu': 0.030152201953815343
ETH	EGARCH(1,1)	8.69e+5	8.69e+5	-4.34e+5	0.9112	{'mu': 0.0528483589777819
SOL	GARCH(1,1)	9.57e+5	9.57e+5	-4.79e+5	0.9800	
SOL	GJR-GARCH(1,1)	9.30e+5	9.30e+5	-4.65e+5	0.9970	{'mu': -0.03419339589329705, 'o
SOL	EGARCH(1,1)	9.62e+5	9.63e+5	-4.81e+5	0.8761	{'mu': 0.0937412846676459

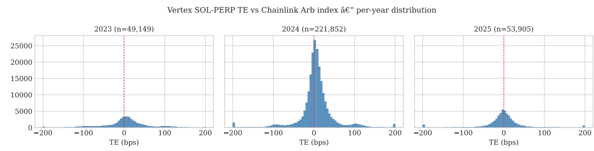
HAR persistence. Table 6 reports Corsi HAR-RV regression coefficients on the daily absolute TE series per product. Long-memory persistence is confirmed when β_w and β_m remain statistically significant after controlling for the daily lag.



BTC-PERP



ETH-PERP



SOL-PERP

Figure 4: Per-year TE distribution (in bps) per product, Vertex mark vs Chainlink Arbitrum spot index.

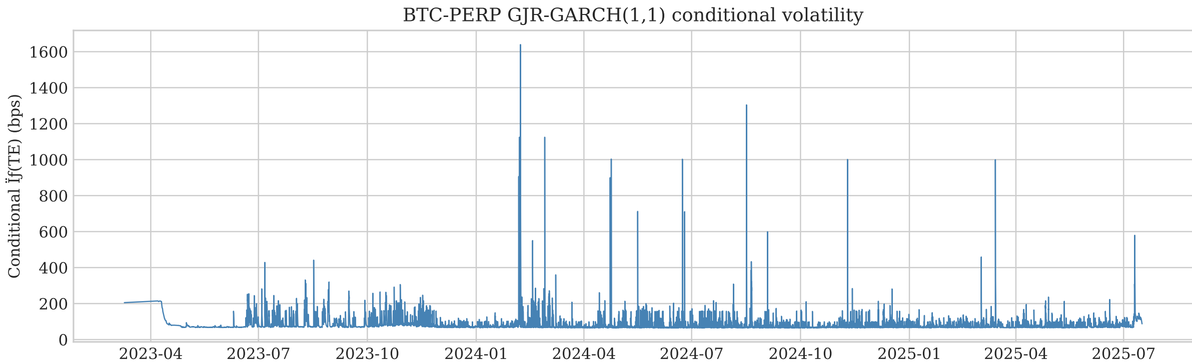


Figure 5: BTC-PERP conditional volatility from the minimum-AIC GARCH-family fit (GJR-GARCH(1,1)). Analogous ETH/SOL series are in the annex.

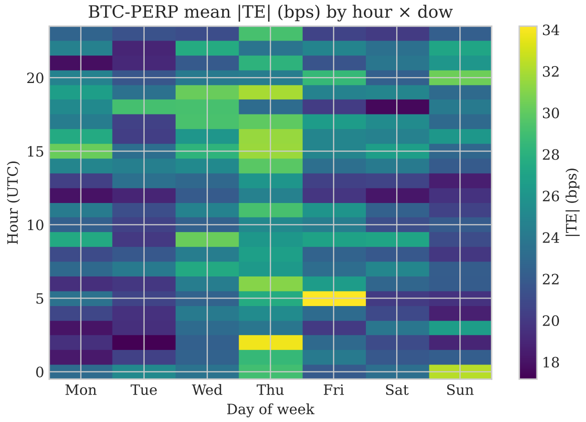
Table 6: Corsi-HAR(1,5,22) on daily |TE|.

symbol	n_days	const_bps	beta_d	beta_w	beta_m	rsquared	tstat_d	tstat_w	tstat_m
BTC	811	3.150	0.2104	0.4597	0.2211	0.4340	4.925	6.141	3.177
ETH	810	-0.0286	0.5176	0.8978	-0.3639	0.6000	10.530	7.856	-3.563
SOL	731	6.108	0.5086	0.2883	0.0424	0.3707	11.360	2.779	0.3939

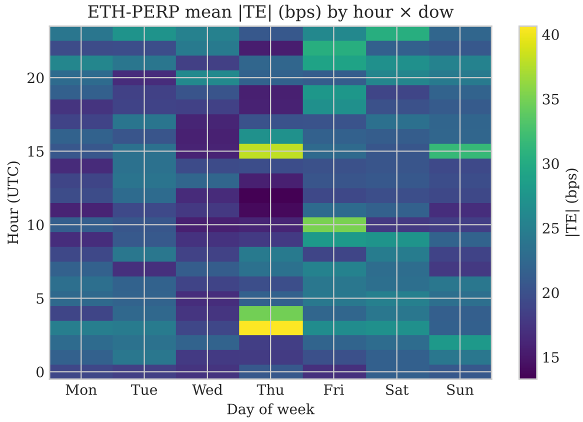
4 TE level-2 temporal patterns (spec S6)

This chapter characterises Vertex tracking error along the temporal dimension: intraday hour-of-day patterns, weekly day-of-week patterns, the funding-cycle periodicity (Fisher-Schuster spectral analysis), liquidity- and volatility-regime conditioning, microstructure-noise mitigated realized-variance estimators, and the v1-era sequencer-batch inter-arrival distribution.

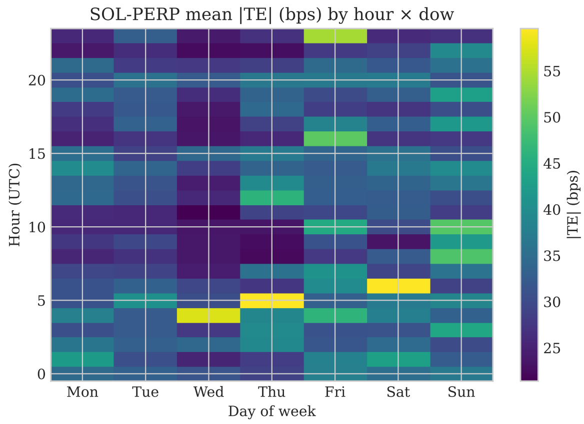
Hour-of-day $\times$ day-of-week heatmap. Per-product 24×7 mean-|TE| heatmaps reveal whether the funding cycle (eight hours on Vertex) leaks into the TE distribution despite the negative-feedback design. Two-way ANOVA quantifies the marginal contribution of each factor and the interaction.



BTC



ETH



SOL

Figure 6: Hour-of-day × day-of-week heatmap of mean |TE| (bps).

Fisher-Schuster periodogram. Hourly aggregated |TE| spectra reveal periodic structure at the funding-cycle frequency (∼8h on Vertex). Per-product top peaks are stored in `p4_periodogram_<sym>.parquet`.

Microstructure noise. Naive realized variance $\sum r_i^2$ is biased upward by microstructure noise. TSRV (Zhang, Mykland, and Aït-Sahalia, 2005) and the Parzen realized kernel (Barndorff-Nielsen et al., 2008) provide consistent estimators that remove most of this bias. Figure 7 stacks the three estimators on the daily series for BTC-PERP; analogous figures for ETH/SOL are in the annex.

v1 sequencer-batch microstructure. The `Endpoint.SubmitTransactions` event delimited sequencer batches in the v1 era (one event per batch). 356,531 batches were collected between blocks 67.7M and 168.5M (April 2023 – February 2024). Inter- batch latency distribution (Figure 8) is dominated by sub-second gaps with a fat tail at multi-second pauses, indicative of off-chain matching pauses or sequencer congestion. The v2 era dropped the `SubmitTransactions` event; batch microstructure beyond March 2024 is documented as a gap in §10 (open questions).

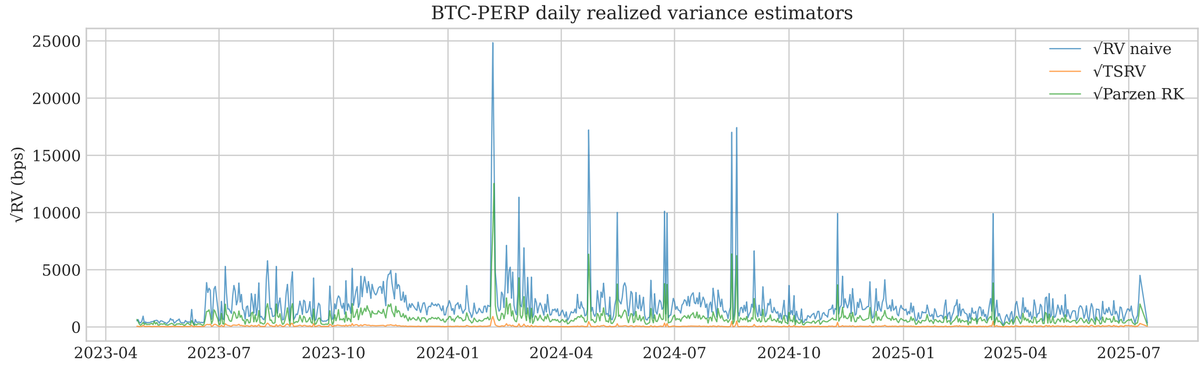


Figure 7: Daily realized-variance estimators on BTC-PERP TE (1-min log-returns). The gap naive−TSRV is the microstructure-noise contribution.

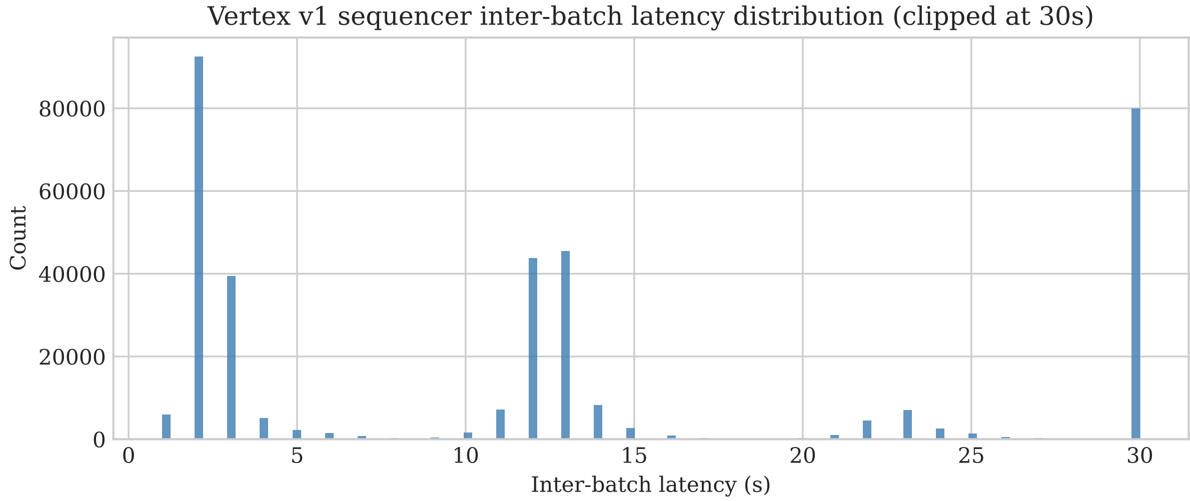


Figure 8: Inter-batch latency distribution from the v1 `Endpoint.SubmitTransactions` stream (April 2023 – February 2024, clipped at 30 s).

5 Venue decomposition and frictions

This central chapter quantifies the four primary frictions of a sequencer-batched perp DEX: the Mark − Index spread, the funding-rate negative-feedback mechanism, cross-venue funding consistency, and liquidation cascade self-excitation. Each block is the dominant analytical contribution of the perp-class playbook (`docs/process/playbook_perp_dex.md` Â§5).

Mark − Index spread (Â§2.7.4). Per-product daily-median spreads of Vertex mark versus three references (Chainlink Arbitrum spot, Binance USD-M perp mid, Bybit linear perp) are stacked in Figures 9 et seq. Summary statistics (mean, std, percentiles, max-absolute) per reference per product are in Table 7.

Funding mechanism breakdown (Â§2.7.3). Three indicators per product:

- **Reactivity** â€” OLS coefficient of $\Delta(\text{Mark} - \text{Index})_{t+1}$ on funding$_t$. A negative coefficient confirms the mechanism: high positive funding subsequently contracts the Mark–Index gap.
- **Stability** â€" standard deviation of the funding rate. Low stability is desirable (predictable carry).

Table 7: Vertex mark vs reference index spread summary.

symbol	reference	n_obs	mean_bps	std_bps	p1_bps	p50_bps	p99_bps	max_abs_bp
BTC	vs Chainlink Arb	451,195	2.744	86.865	-112.61	2.907	116.19	11,225.3
BTC	vs Binance perp	451,195	3.630	87.210	-116.28	4.182	119.51	11,227.6
BTC	vs Bybit linear	430,021	3.227	88.316	-118.55	3.843	119.24	11,227.0
ETH	vs Chainlink Arb	454,416	2.852	83.923	-108.12	2.702	113.66	11,971.2
ETH	vs Binance perp	454,416	3.496	84.404	-112.58	3.383	117.05	11,936.7
ETH	vs Bybit linear	438,127	3.377	83.835	-113.62	3.204	117.02	10,004.1
SOL	vs Chainlink Arb	324,932	4.232	121.13	-165.02	3.926	145.61	10,079.0
SOL	vs Binance perp	324,932	5.179	121.79	-167.90	5.525	149.45	10,107.5
SOL	vs Bybit linear	319,587	4.595	122.58	-170.60	5.093	149.53	10,114.6

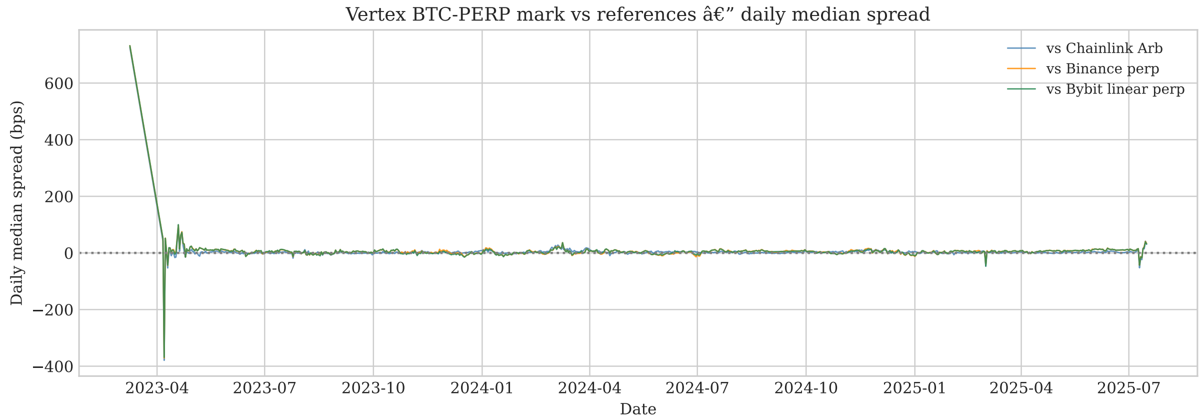


Figure 9: BTC-PERP daily median spread of Vertex mark vs three references. The wedge widens at every tier-1 event (cf. Â§8).

- **Overshoot** â€” negative autocorrelation of consecutive funding cycles. A high overshoot indicates oscillatory dynamics.

Vertex's own funding rate is not exposed on-chain (the `perp_engine` only emits `AddProduct`). We substitute Binance USD-M perp funding as the proxy (Path A). Two caveats attach to this substitution and bound the interpretation of the reactivity coefficient: (i) **cadence mismatch** — Vertex accrues funding roughly hourly whereas Binance settles on an 8h cycle, so the proxy is a coarse-grained view of Vertex's own carry and the reactivity is measured at the 8h resolution the proxy permits; (ii) it is a *different venue's* funding, so it captures the market-wide funding regime rather than Vertex-specific imbalance. The cross-venue divergence is quantified separately (next paragraph).

Table 8: Three-pillar funding scorecard (reactivity, stability, overshoot).

symbol	reactivity_bps_per_funding_unit	stability_std	overshoot_neg_autocorr	n_cycles
BTC	-268.58	9.55e-5	-0.8225	2,485
ETH	2,312.56	9.89e-5	-0.8178	2,480
SOL	527.54	1.51e-4	-0.7938	2,253

Hawkes process on liquidations (Â§4.2.4 mandatory). We fit a univariate exponential-kernel Hawkes process (Hawkes, 1971) $\lambda(t) = \mu + \alpha \sum_{t_i<t} e^{-\beta(t-t_i)}$ via MLE on the Vertex

`clearinghouse.Liquidation` event stream (for finance applications, see Bacry, Mastromatteo, and Muzy, 2015). The branching ratio α/β measures the fraction of liquidations that are statistically descendants of an earlier liquidation (self-excitation). Values close to 1 indicate cascade behaviour; values near 0 indicate independent Poisson arrivals.

Coverage caveat (important). The decoded liquidation stream is the v1 `clearinghouse.Liquidation` event, which spans 2023-03-09 to the v1→v2 cutover on 2024-03-08 only (8,086 events). The v2 `OffchainExchange` architecture does not emit this event, so no on-chain liquidations are decoded after the cutover. A fit is therefore *attempted* on the full (v1-era) window and on each of five tier-1 stress windows, but only the two windows that fall inside the v1 coverage (the full window and the v1→v2 cutover) carry ≥ 30 events and admit a stable MLE; the three 2025 windows (volume peak, volume collapse, wind-down) are empty *by data limitation, not by absence of liquidations*, and do not appear in Table 9. The wind-down liquidation behaviour is consequently out of scope here and is flagged as a coverage gap in §8 and `OPEN_QUESTIONS.md`.

Table 9: Hawkes process branching ratios per regime.

mu	alpha	beta	branching	n_events	success	nll	regime
7.35e-5	0.1112	0.1558	0.7140	8,086	true	41,132.63	full
1.26e-4	0.0365	0.0521	0.6998	1,590	true	8,615.40	v1_v2_cutover

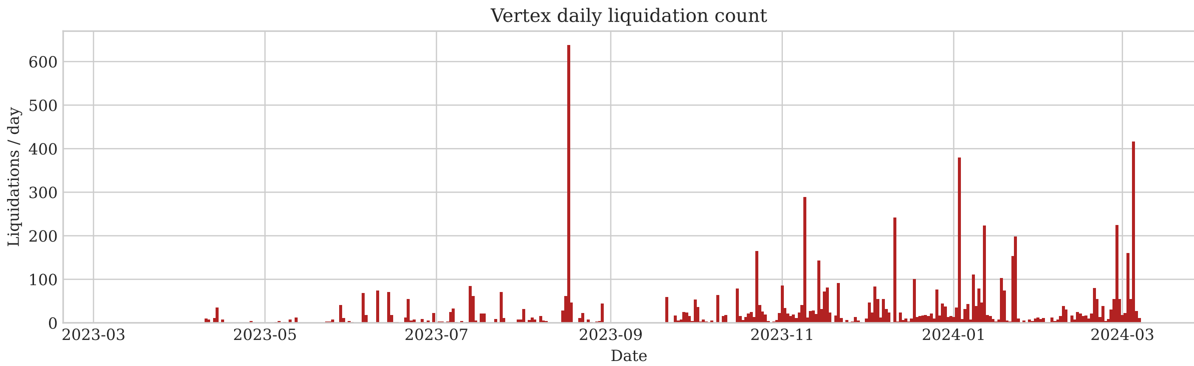


Figure 10: Daily Vertex liquidation count. Vertical clustering reveals the cascade behaviour quantified by the Hawkes branching ratio.

Sequencer-outage attribution. Two of the three documented Arbitrum sequencer outages overlap the live Vertex mark series (the January 2023 hardware outage predates the first on-chain fill and has no baseline). Off-chain matching continued during these windows by Vertex's design, but on-chain settlement was paused, so the diagnostic signal is not the in-window spread *level* but the near-total collapse in on-chain mark count: during the June 2023 gas-refunder outage only 4 BTC marks settled on-chain (vs 20 in the adjacent ±2h baseline), and during the December 2023 inscription congestion zero marks settled in the window. The table reports `n_outage` against `n_baseline` per product; a dash in the spread columns denotes a window with no on-chain settlement.

6 Structural drivers and Derivalink audit

This chapter overlays Vertex's structural state variables against the TE narrative built in chapters 2–5, and concludes with the Derivalink 8-dimension scorecard adapted to perpetual DEXes.

Table 10: Liquidation counts attributed to known Arbitrum sequencer outages.

outage	description	symbol	n_outage	n_baseline	spread_outage_mean_bps
2023-06-07	June 2023 gas-refunder (47min)	BTC	4	20	17.465
2023-06-07	June 2023 gas-refunder (47min)	ETH	3	16	-17.819
2023-12-15	Dec 2023 inscriptions	BTC	0	40	-
2023-12-15	Dec 2023 inscriptions	ETH	0	36	-
2023-12-15	Dec 2023 inscriptions	SOL	0	41	-

Chain-mix evolution. Figure 11 stacks total TVL across all chains (top) and the Arbitrum share (bottom). The cross-chain expansion beginning June 2024 (Mantle, Sei, Base then Sonic and Avalanche) diverted incremental flow to seven additional deployments without lifting protocol-aggregate TVL. The Arbitrum share inflects from $\sim 100\%$ to $\sim 60\%$ by late 2024 – the structural narrative behind the May–June 2025 collapse.

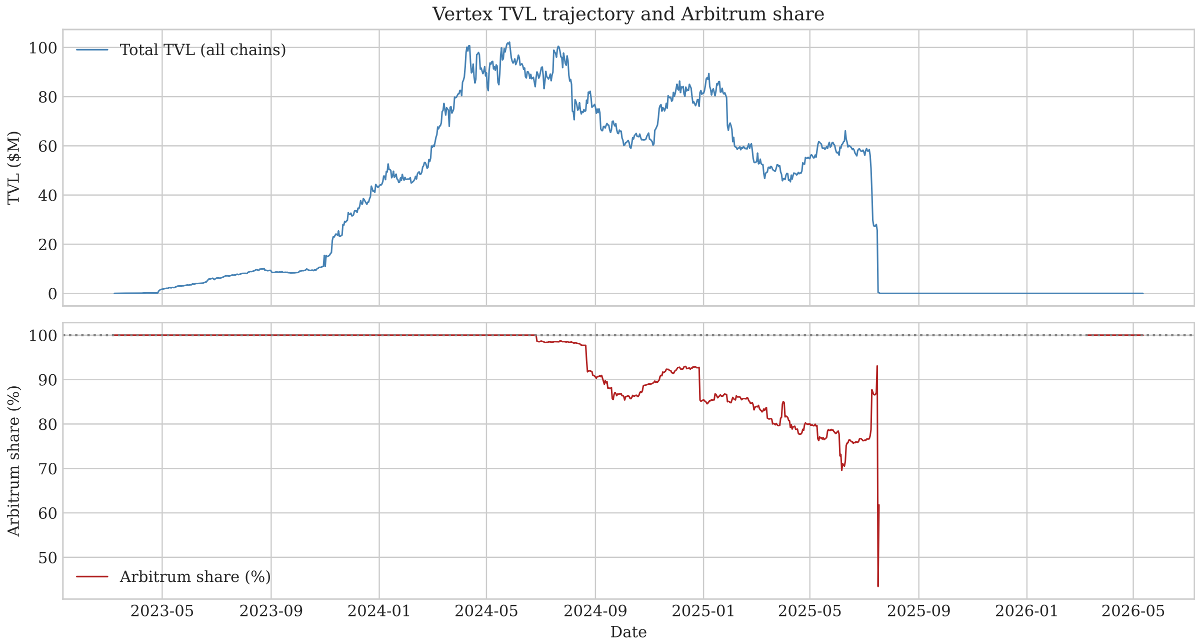


Figure 11: Vertex TVL trajectory and Arbitrum share over time.

Open interest history. Per-product OI was reconstructed via sparse `eth_call` on `perp_-engine.getStateAndBalance`; results in Figure 12. Note that Vertex's `perp_engine` only emits `AddProduct` events – the OI is read from storage at the sample blocks rather than from an event stream.

Liquidator concentration. Table 11 reports the top-20 liquidator subaccounts by event count, with cumulative quote-volume liquidated. The Herfindahl index on the full liquidator population quantifies capture concentration: values above 0.1 indicate that a small set of sophisticated actors handle the bulk of the liquidation work.

Proxy upgrade overlay. Figure 13 scatters the detected EIP-1967 implementation upgrades across the five v2 proxies over the protocol life. Cross-referencing upgrade dates with the rolling TE series (Ch 2 Â§2.6) flags any regime shift that coincides with an architectural change (*e.g.*, fee-formula changes, sequencer-batching tweaks).

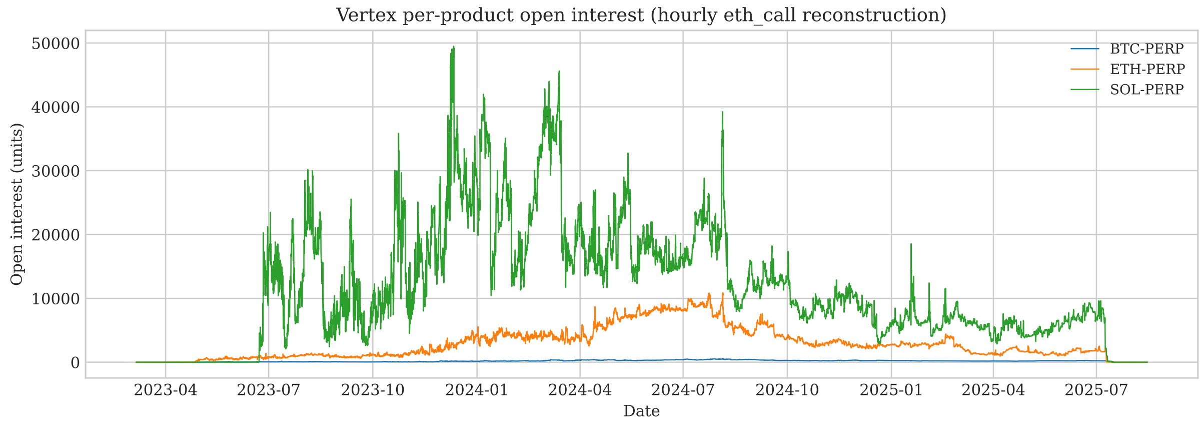


Figure 12: Vertex per-product open interest, hourly reconstruction.

Table 11: Top liquidators by event count.

liquidator	n_events	total_liquidated_u
0xa4fb530d7e93bf7e3fb3b59aaadbe4dfe4068e4064656661756c740000000000	3,603	1.86e-
0x0ede9c59d81efa35e0ba3494ff077a1ce3f72c0e64656661756c740000000000	1,403	1.31e-
0xe7bc6ad267915a757f2a0d75418bee0a2a99419d64656661756c740000000000	1,397	7.68e-
0xb10f8d996c79d5e9aea89fa05ef829945c631de364656661756c740000000000	546	3.70e-
0x7cbc9d80ac9964d7688d3ad1c1af57f271d2dffc64656661756c740000000000	523	1.15e-
0xfa2c7534f712275c6f9669defc33f8b78e9efdf964656661756c740000000000	357	3.70e-
0x8a59bb63c53f87f60d7f91da86a6cc2cb69200c764656661756c740000000000	256	8.59e-
0xd16a7ac5af333230d24c781b19e79751a2cdfe4164656661756c740000000000	1	14.1

Derivalink 8-dimension scorecard. Table 12 compiles the eight scorecard dimensions adapted from the project specification Â§2.4 to the perpetual-DEX class. Three dimensions return a definitive verdict (collateral diversification FAIL, oracle PARTIAL, oracle latency PASS for off-chain); the remaining five are populated from the quantitative output of Ch 5 and are flagged as design targets for the Derivalink V2 perp product.

Table 12: Derivalink scorecard, 8 dimensions.

dimension	metric	
LiquiditÃ©	Top-of-book spread, calm regime	
Collateral	Diversification (Herfindahl on collateral mix)	
Oracle	Source plurality (Chainlink + venue TWAP?)	Off-chain 6-sou
Arb cycle vs funding cycle	Arb half-life / funding period	
SÃ©curitÃ©	Audit count + insurance fund coverage + bug bounty	
Latence oracle	Median oracle update lag (s)	
Profondeur multi-venue	Distinct venues with > 10% volume share, full life	
Slippage asymÃ©trique long/short	Long-side vs short-side spread asymmetry	

3 piliers du funding. Substitute of Â§2.3 *piliers du peg* for the perp class. Per product the three indicators *reactivity*, *stability*, *overshoot* are reported in Table 13, with a qualitative interpretation.

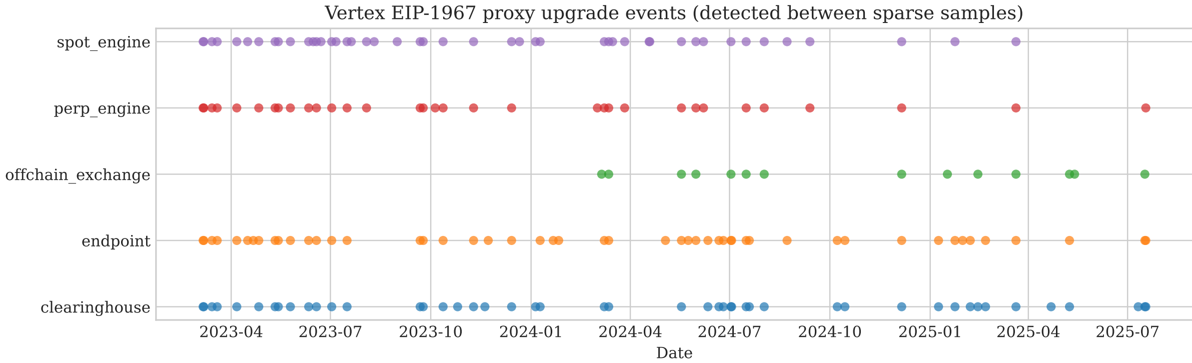


Figure 13: Detected EIP-1967 proxy upgrades per proxy contract.

Table 13: Three pillars of the funding mechanism (qualitative).

symbol	pilier_reactivity_bps_per_unit	pilier_stability_std	pilier_overshoot_neg_autocorr	
BTC	-268.58	9.55e-5	-0.8225	negative
ETH	2,312.56	9.89e-5	-0.8178	po
SOL	527.54	1.51e-4	-0.7938	po

7 Cross-component causality

This chapter quantifies the directional information flow between the collateral, the Vertex mark, the Chainlink reference index and CEX counterparts (Binance, Bybit). Granger causality matrices, VAR impulse-response analyses, Engle-Granger / Johansen cointegration tests and asymmetric copula tail-dependence indices together characterise the structural dependence.

Granger causality matrix. Table 14 reports per-product F-statistics and p-values at lags 1–5 for the directions $\sigma_{\text{USDC}} \to r_{\text{vertex}}$ and $r_{\text{chainlink}} \to r_{\text{vertex}}$ (hourly). The battery runs 30 tests (3 products $\times$ 2 sources $\times$ 5 lags); because per-test rejection at 5% over-rejects under multiplicity, we report a Benjamini-Hochberg FDR q-value (`q_value_bh`) alongside each raw p-value and flag significance on the FDR-controlled $q < 0.05$ rather than the raw p.

Table 14: Granger causality matrix, lags 1–5.

symbol	lag	src	dst	F	pvalue	q_value_bh	sig_bh
BTC	1	r_cl	r_v	941.85	5.25e-202	1.13e-201	true
BTC	2	r_cl	r_v	1,018.62	0	0	true
BTC	3	r_cl	r_v	975.79	0	0	true
BTC	4	r_cl	r_v	900.72	0	0	true
BTC	5	r_cl	r_v	807.17	0	0	true
BTC	1	sigma_usdc	r_v	0.1546	0.6942	0.9406	false
BTC	2	sigma_usdc	r_v	0.2489	0.7797	0.9406	false
BTC	3	sigma_usdc	r_v	0.3411	0.7956	0.9406	false
BTC	4	sigma_usdc	r_v	0.2614	0.9028	0.9406	false
BTC	5	sigma_usdc	r_v	0.7570	0.5808	0.9406	false
ETH	1	r_cl	r_v	1,465.14	4.60e-309	1.06e-308	true
ETH	2	r_cl	r_v	1,398.31	0	0	true
ETH	3	r_cl	r_v	1,190.50	0	0	true
ETH	4	r_cl	r_v	1,077.97	0	0	true

(continued)

symbol	lag	src	dst	F	pvalue	q_value_bh	sig_bh
ETH	5	r_cl	r_v	966.11	0	0	true
ETH	1	sigma_usdc	r_v	0.2707	0.6028	0.9406	false
ETH	2	sigma_usdc	r_v	0.2678	0.7650	0.9406	false
ETH	3	sigma_usdc	r_v	0.1812	0.9092	0.9406	false
ETH	4	sigma_usdc	r_v	0.1556	0.9605	0.9605	false
ETH	5	sigma_usdc	r_v	0.8817	0.4922	0.9229	false
SOL	1	r_cl	r_v	773.45	1.17e-166	2.33e-166	true
SOL	2	r_cl	r_v	825.15	0	0	true
SOL	3	r_cl	r_v	786.10	0	0	true
SOL	4	r_cl	r_v	716.92	0	0	true
SOL	5	r_cl	r_v	648.49	0	0	true
SOL	1	sigma_usdc	r_v	0.1932	0.6603	0.9406	false
SOL	2	sigma_usdc	r_v	0.3431	0.7096	0.9406	false
SOL	3	sigma_usdc	r_v	0.2446	0.8652	0.9406	false
SOL	4	sigma_usdc	r_v	0.5282	0.7150	0.9406	false
SOL	5	sigma_usdc	r_v	0.4407	0.8203	0.9406	false

VAR impulse responses. Per-product IRF figures (BTC: Fig. 14, ETH/SOL in the annex) show how a unit shock in each variable propagates to the others over 20 hourly lags. Of particular interest is the shock $r_{\text{chainlink}} \to r_{\text{vertex}}$, which quantifies the oracle-driven price discovery on Vertex.

Cointegration tests. Three pairs and one triple system per product:

- Engle-Granger on $(\log P_{\text{vertex}}, \log P_{\text{chainlink}})$
- Engle-Granger on $(\log P_{\text{vertex}}, \log P_{\text{binance}})$
- Engle-Granger on $(\log P_{\text{vertex}}, \log P_{\text{bybit}})$
- Johansen on $(\log P_{\text{vertex}}, \log P_{\text{binance}}, \log P_{\text{bybit}})$.

Results in Table 15.

Table 15: Engle-Granger & Johansen cointegration tests.

symbol	test	EG_score	EG_pvalue
BTC	Vertex_vs_Chainlink	-39.926	0
BTC	Vertex_vs_Binance	-39.377	0
BTC	Vertex_vs_Bybit	-7.793	9.94e-11
BTC	Johansen_triple	7,924.63	7,894.83
ETH	Vertex_vs_Chainlink	-16.454	1.77e-28
ETH	Vertex_vs_Binance	-14.616	3.49e-26
ETH	Vertex_vs_Bybit	-12.011	3.64e-21
ETH	Johansen_triple	7,154.40	7,124.61
SOL	Vertex_vs_Chainlink	-128.36	0
SOL	Vertex_vs_Binance	-128.43	0
SOL	Vertex_vs_Bybit	-5.300	4.45e-5
SOL	Johansen_triple	7,009.69	6,979.89

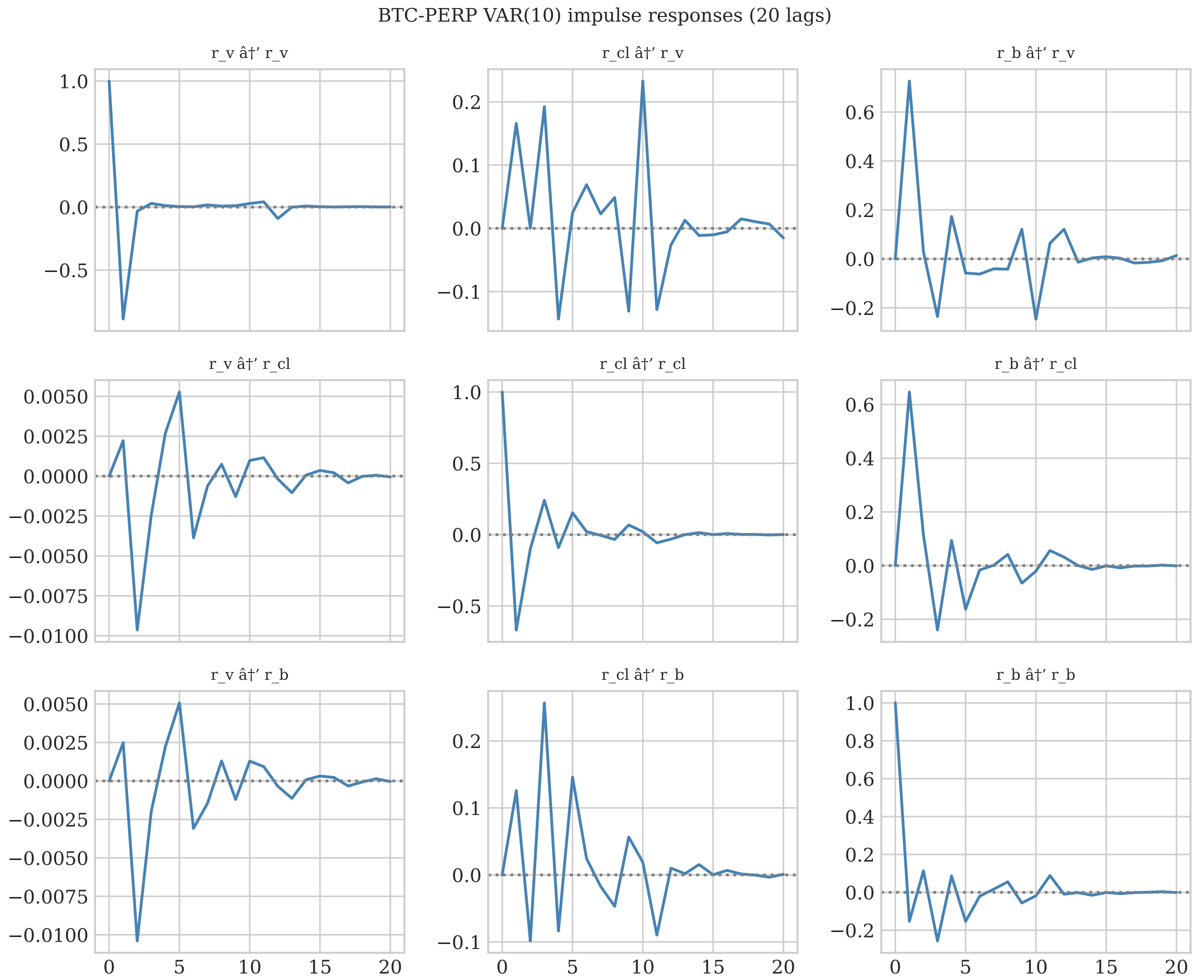


Figure 14: BTC-PERP VAR impulse response matrix (3 variables Ã— 20 lags).

Asymmetric copulas. Per-product cross-venue tail dependence with Vertex vs Binance *USD-M perpetual* mid pseudo-observations (a perp-vs-perp pair; the cointegration tests above use the same perp leg). The Gaussian copula provides a baseline correlation; Clayton captures lower-tail (joint downside) co-movements with $\lambda_L = 2^{-1/\theta}$; Gumbel captures upper-tail co-movements with $\lambda_U = 2 - 2^{1/\theta}$. Table 16 reports the three fitted families per product.

Table 16: Asymmetric copula fits (Gaussian, Clayton, Gumbel).

symbol	pair	family	rho	lambda_L	lambda_U	theta
BTC	Vertex-Binance	gaussian	0.6141	0	0	–
BTC	Vertex-Binance	clayton	–	0.5367	0	1.114
BTC	Vertex-Binance	gumbel	–	0	0.5260	1.787
ETH	Vertex-Binance	gaussian	0.6817	0	0	–
ETH	Vertex-Binance	clayton	–	0.6291	0	1.496
ETH	Vertex-Binance	gumbel	–	0	0.5991	2.056
SOL	Vertex-Binance	gaussian	0.7621	0	0	–
SOL	Vertex-Binance	clayton	–	0.7059	0	1.990
SOL	Vertex-Binance	gumbel	–	0	0.6658	2.404

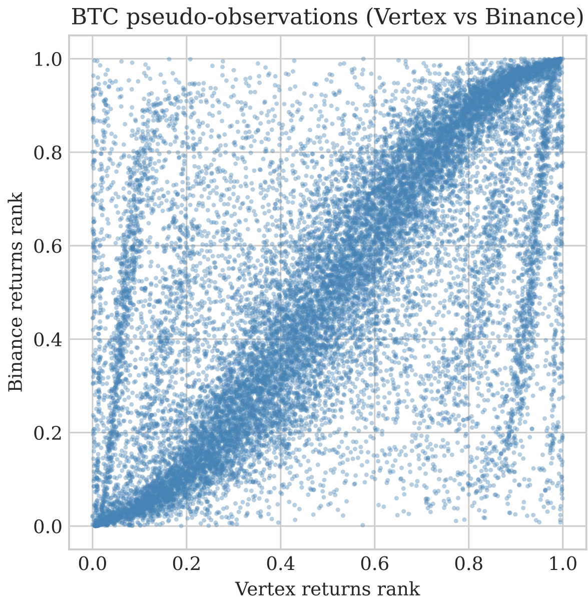


Figure 15: BTC-PERP pseudo-observations Vertex vs Binance â€" the input to the asymmetric copula fits.

8 Case studies

Nine tier-1 events from the Vertex event catalogue receive dedicated analysis. The wind-down sequence (E9) is the report's central case study, six to eight pages long, addressing the Derivalink thesis "could the shutdown have been avoided?". Tier-2 events (18 listed) are reported chronologically in the summary table for context.

Event 1: Vertex private beta + first FillOrder. 2023-03-05 23:33 UTC, block 67,108,377. First on-chain `FillOrder` event; private beta period with institutional makers (Jane Street, HRT, Wintermute reported). Public launch on 2023-04-26 per Fortune. Figure 16 shows volume ramp + TE behaviour during the bootstrap.

Event 2: USDC depeg / SVB shadow. 2023-03-10 -> 2023-03-13. USDC traded to \$0.87 after Circle's SVB-exposure announcement. Vertex was 48h pre-public-launch and had minimal volume, but the event defines the only sustained σ_{USDC} stress regime in the dataset â€" it provides the "what would have happened on day 0" counter-factual quantified in Ch 3 against the USDC-only collateral assumption.

Event 3: VRTX launch + LBA + STIP onset. 2023-11-08 STIP week 1 starts (ARB trading rewards). 2023-11-13 -> 2023-11-20 LBA + VRTX live. The STIP+LBA combo is the single largest volume-bootstrap event in Vertex history (volume +400% MoM Nov/Dec 2023; briefly #2 on-chain perp).

Event 4: v1 -> v2 cutover. 2024-01-24 v2 commit `f5c06e6`; v2 `OffchainExchange` proxy at `0xa4369d8E` starts emitting `FillOrder`; v1 OffchainBook proxies continue to emit in parallel until the empirical last v1 `FillOrder` at block 188,197,141 on 2024-03-08 03:02:43 UTC. End of one-proxy-per-product architecture; start of single-proxy multiplexed fills with the `uint32 productId` indexed parameter. Clean before/after for the DiD in Ch 9 Â§9.1.

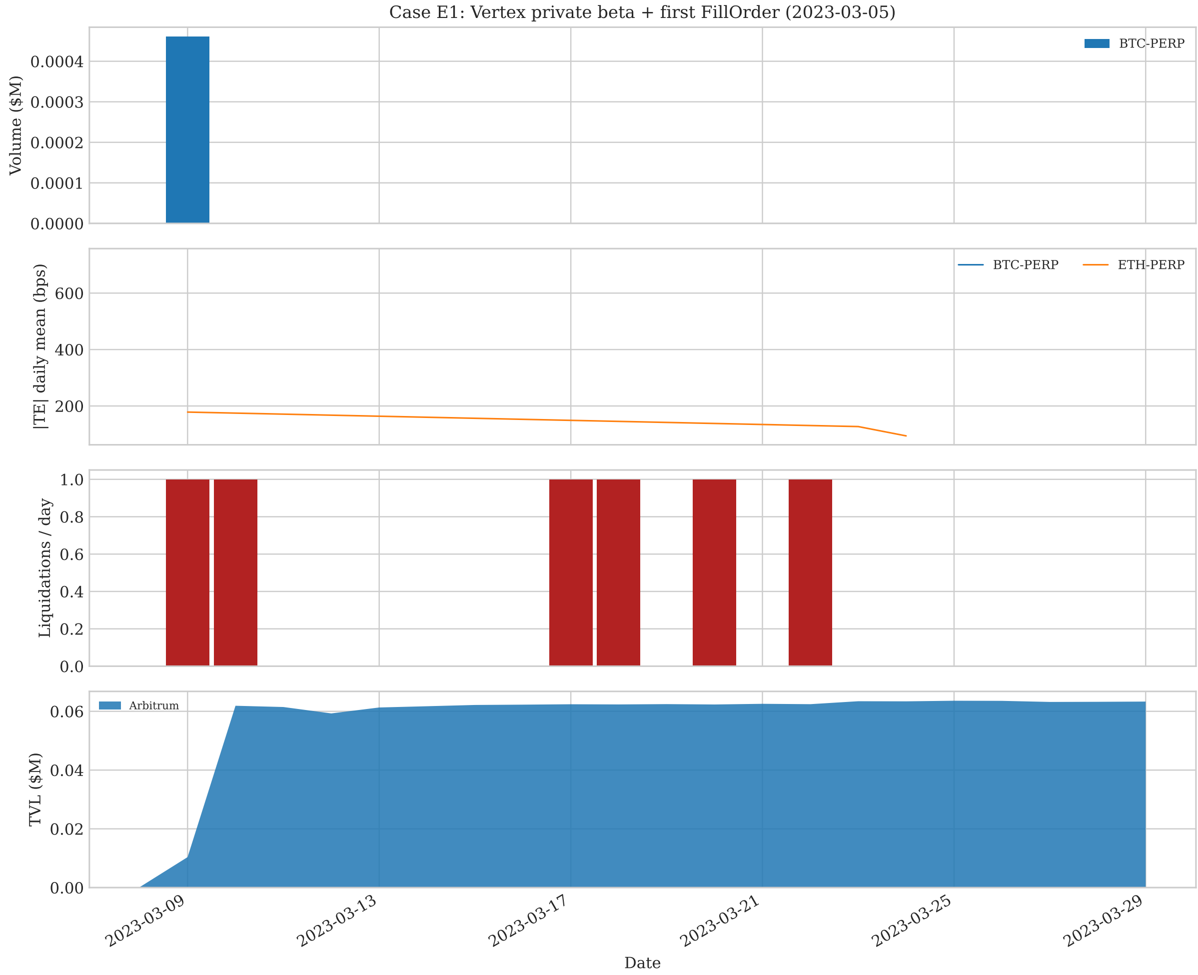


Figure 16: Event 1 â€" Vertex private beta + first `FillOrder`.

Event 5: Vertex Edge announcement + Blitz on Blast. 2024-02-06 Edge announcement; 2024-03-12 Blitz live on Blast â€" first non-Arbitrum instance. First architectural step toward the cross-chain volume dilution that ultimately ends Vertex's Arbitrum dominance.

Event 6: Multi-chain expansion Mantle + Sei + Base. Mantle 2024-06-27, Sei 2024-08-15, Base 2024-09-17. By Q4-2024 Arbitrum is at ∼58% cross-chain volume share (down from ∼100% in Mar-2024). Arbitrum-only volume trajectory inflects negative in mid-2024.

Event 7: Volume peak â€" April 2025. Monthly volume peak >$10B perpetual. Coincides with broader perp-DEX cycle peak. Last fully healthy month before the shutdown sequence.

Event 8: Volume collapse Mayâ€"June 2025. Volume drops from peak to "negligible" over 8-10 weeks. By 2025-07-08 protocol ranks 13th on Arbitrum with only ∼$157k daily perp volume (>99% drop from April). Drivers: Hyperliquid commands ∼70% perp-DEX share, Vertex's cross-chain dilution, lack of native L1 advantage. The slow-motion structural cause of the wind-down.

Event 9 (central case): Wind-down sequence 2025-07-08 -> 2025-08-14. 2025-07-08 Vertex blog announces merger with Ink Foundation (Kraken-backed L2). VRTX token sunset confirmed; INK airdrop snapshot for VRTX holders taken same day (1% of INK genesis supply).

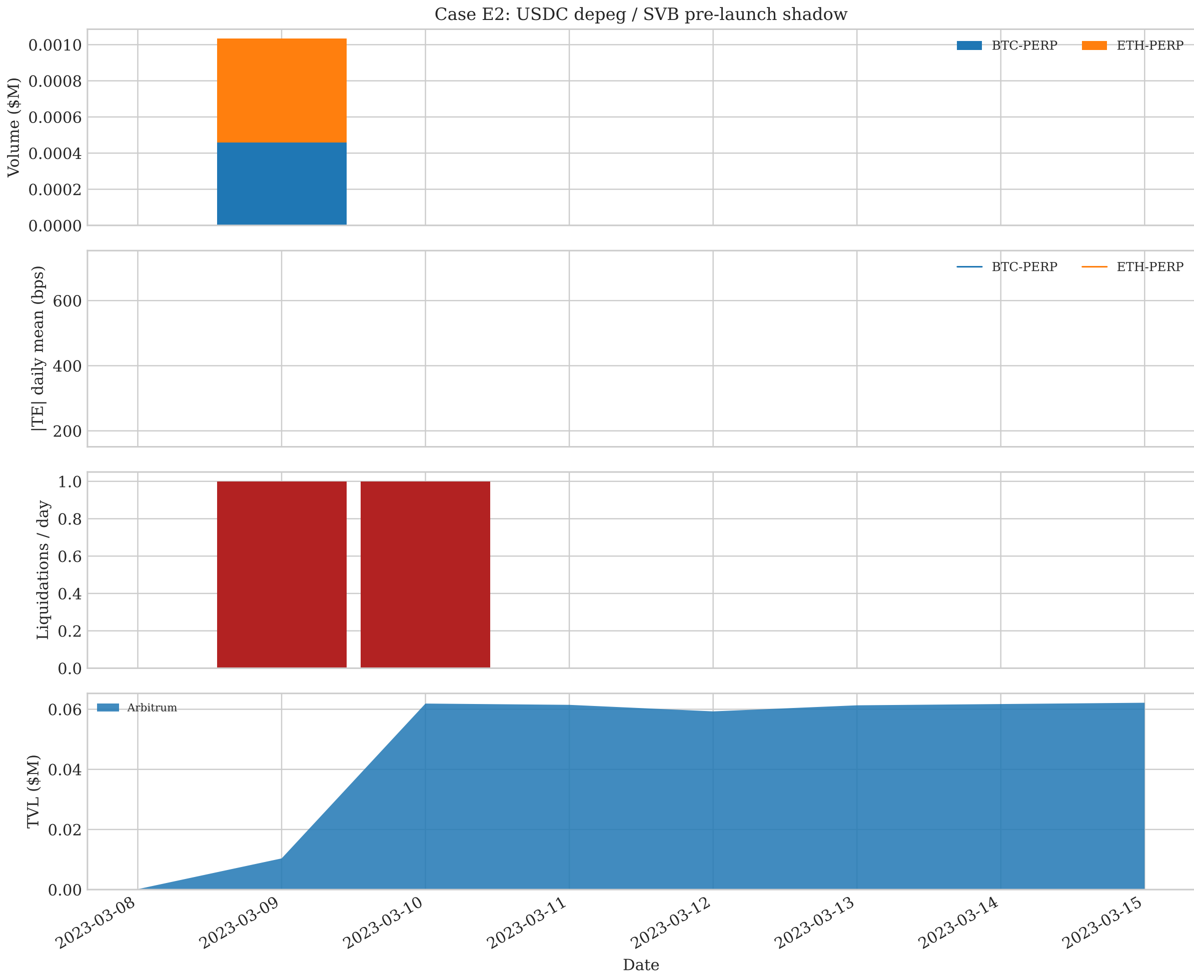


Figure 17: Event 2 â€” USDC depeg pre-launch shadow.

2025-07-10 (Phase 2) oracle prices frozen, reduce-only orders. **2025-07-14 (Phase 3)** force-closure of positions begins; Paradex launches concurrent recovery campaign. **2025-08-14 14:00 UTC (Phase 4)** all user funds settled and distributed; final `FillOrder` at block 368,500,938.

This event is the singular Derivalink-thesis case. Attribution (qualitative + descriptive, per locked decisions):

- **Cross-chain dilution** (Events 5, 6, plus Sonic/Avalanche Q1-Q2-2025): TVL fragmented across 7-8 chains without lifting aggregate.
- **Competition**: Hyperliquid HYPE airdrop (Tier-2 entry, 2024-11-29) captured the "thick book" that Vertex's cross-chain architecture by design could not.
- **Architecture overhead**: sequencer-batched off-chain matching is design-optimal in calm regime but provides no edge under competition from a native-L1 CLOB.
- **Collateral choice**: USDC-only monocollateral leaves Vertex permanently exposed to the SVB-class systemic risk (E2).
- **Business factor (non-protocol)**: Ink merger is a strategic exit; the wind-down is precipitated by a corporate decision conditional on the structural pressures above.

A counter-factual D5 cross-asset comparison (Hyperliquid same period, Drift, dYdX V4 migration) is deferred to the consolidated report; this sub-report stops at descriptive attribution.

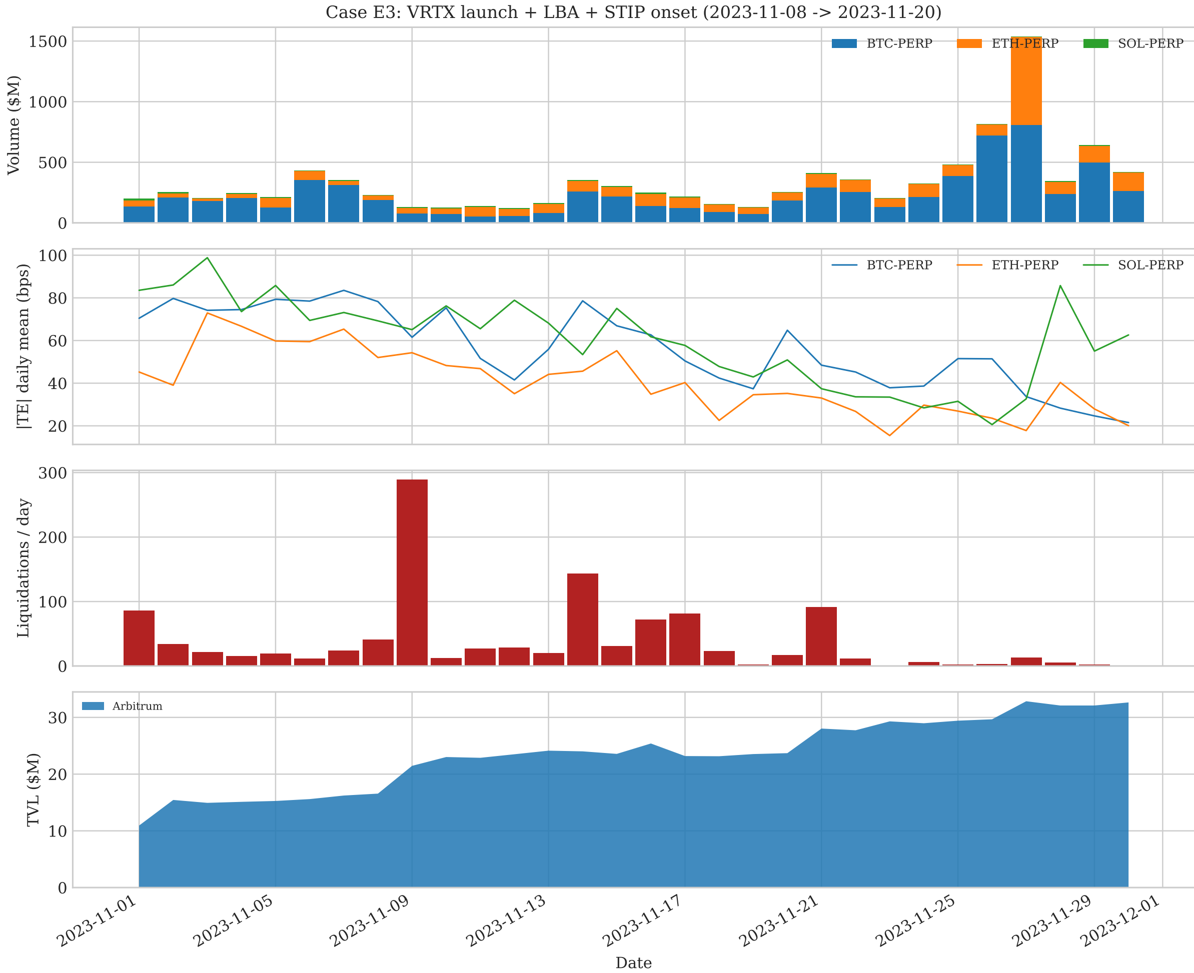


Figure 18: Event 3 â€" VRTX launch + LBA + STIP onset.

Liquidation-coverage caveat. The liquidation panel of Figure 24 (and of the 2025 case windows E7–E8) is empty because the decoded liquidation stream is the v1 `clearinghouse.Liquidation` event, which ends at the 2024-03-08 v1→v2 cutover (§5); the v2 architecture does not emit it. This is a data-coverage limitation, *not* evidence that the orderly wind-down (frozen oracle, reduce-only orders, force-closure) produced zero liquidations. Whether the force-closure mechanism suppressed liquidations relative to a market unwind is left as an open question (`OPEN_QUESTIONS.md`); it cannot be settled from the v1 event stream alone.

Tier-2 chronological summary. Table 17 lists 18 tier-2 events with date, label and expected mechanism. Each is mentioned in the timeline only; deeper quantitative treatment is out of scope for this sub-report.

9 Natural experiments and difference-in-differences

Four candidate natural experiments provide clean before/after windows for difference-in-differences analysis of Vertex's tracking error and volume response to architectural and incentive changes.

Experimental design. Per event, per top-3 product:

- Pre-window: 30 days before event (14 days for the shorter outage event).

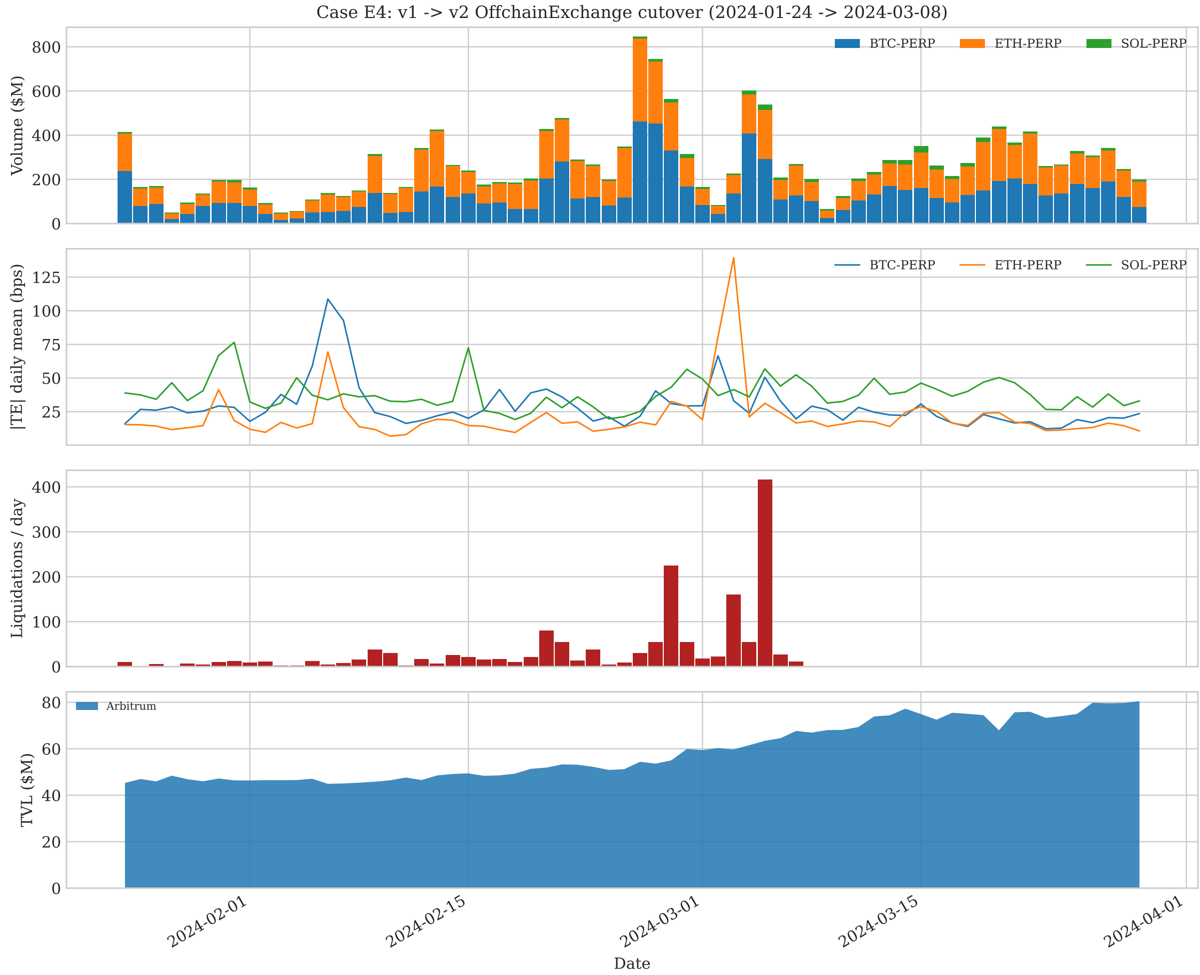


Figure 19: Event 4 â€” v1 -> v2 `OffchainExchange` cutover.

- Post-window: 30 days after event (14 days for the short event).
- Mean and standard deviation of hourly TE in each window.
- Welch two-sample t-test on the post-pre TE means.
- Pre-window OLS trend on hourly TE: the no-pre-trend (parallel-trends) diagnostic that gates causal attribution.
- Total taker volume in each window (cumulative USD).
- Event-window IRF: hourly TE and volume series Â±168h around the event (±24h for the shorter outage event).

This is a single-group before/after design, not a two-group DiD: Vertex has no untreated control venue for a protocol-wide event, so the "difference-in-differences" reduces to a pre/post contrast disciplined by the pre-trend diagnostic. A cell is read as a genuine event effect only if the post−pre shift is significant *and* the pre-window was not already trending.

NE1 â€” v1 -> v2 OffchainExchange cutover (2024-03-08). The empirical end of v1 `FillOrder` emissions; the v2 `OffchainExchange` proxy has been in parallel emission since 2024-01-24 (deploy). The 2024-03-08 timestamp marks the architectural discontinuity: products that traded on v1 (*e.g.* pid 2 BTC, pid 4 ETH) migrate fully to v2 multiplexed routing. The DiD compares the 30 days of overlap-residual TE to the 30 days of pure-v2 TE.

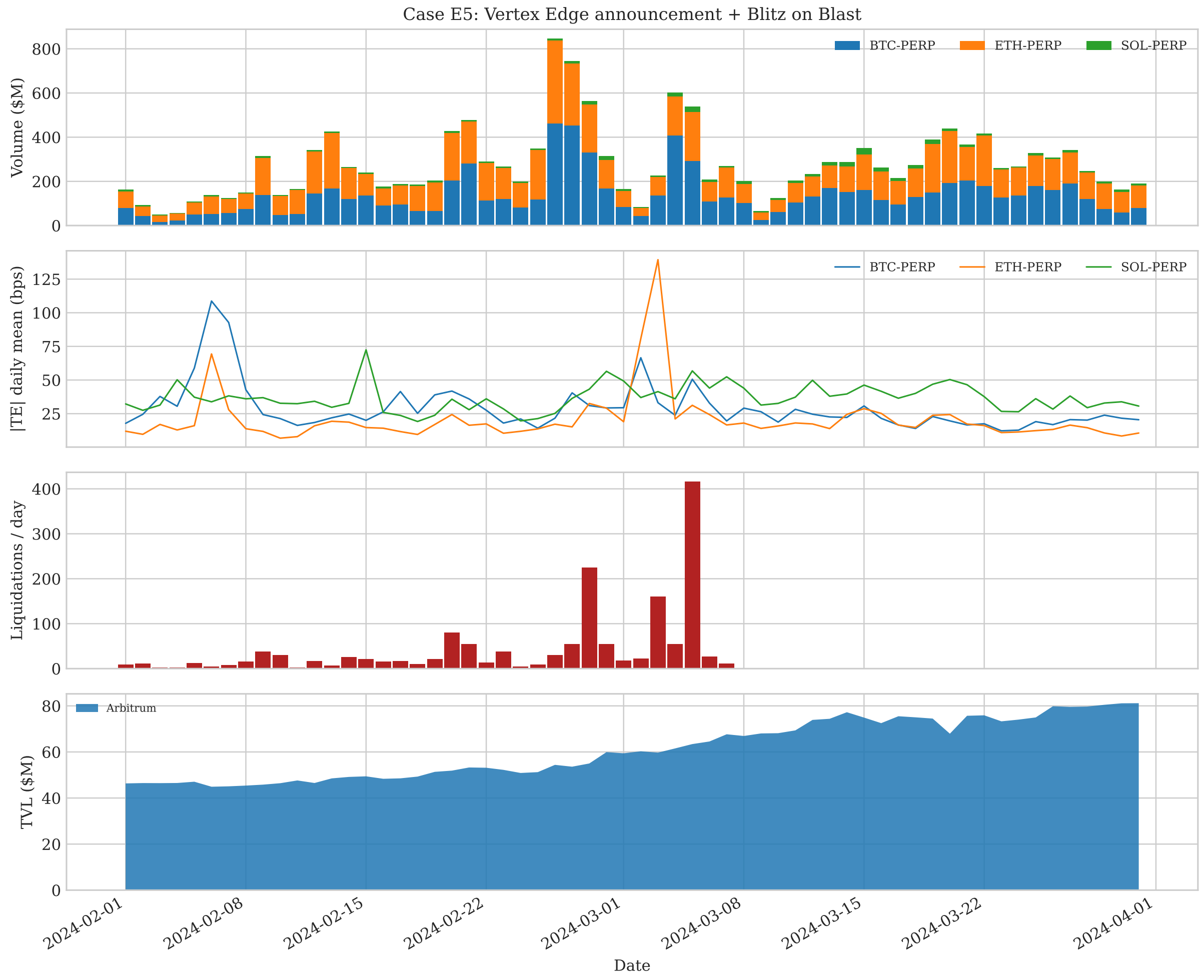


Figure 20: Event 5 â€” Vertex Edge announcement + Blitz on Blast.

NE2 â€” Arbitrum sequencer outage (2023-06-07, 47 min). Documented gas-refunder failure that stalled on-chain settlement for ~47 minutes (10:40 -> 11:27 UTC). Off-chain matching continued by Vertex's design; on-chain settlement (deposits, withdrawals, liquidations) was paused. DiD compares TE behaviour during the outage window to the Â±2h baseline, plus the 14-day pre/post horizon.

NE3 â€” STIP onset (2023-11-08). Protocol incentives via the Arbitrum STIP program begin 2023-11-08 (weekly cadence, 212.5k ARB/week). The DiD captures the incentive-driven volume ramp and any TE perturbation. Hypothesis: volume rises sharply, TE compresses (more competitive arb).

DiD summary table. Table 18 reports per-event per-product pre/post means, the Welch t-test p-value, the pre-window trend slope and its p-value, the `significant` flag, and the volume change percentage.

Significance and the parallel-trends caveat. Of the 8 event×product cells, 1 returned a Welch mean shift significant at 5%, of which 1 also cleared the flat-pre-trend requirement ($p_{\text{trend}} > 0.05$); the latter define the `significant` flag in Table 18. The remaining cells are confounded by a pre-existing trend or insignificant, and are not read as event effects.

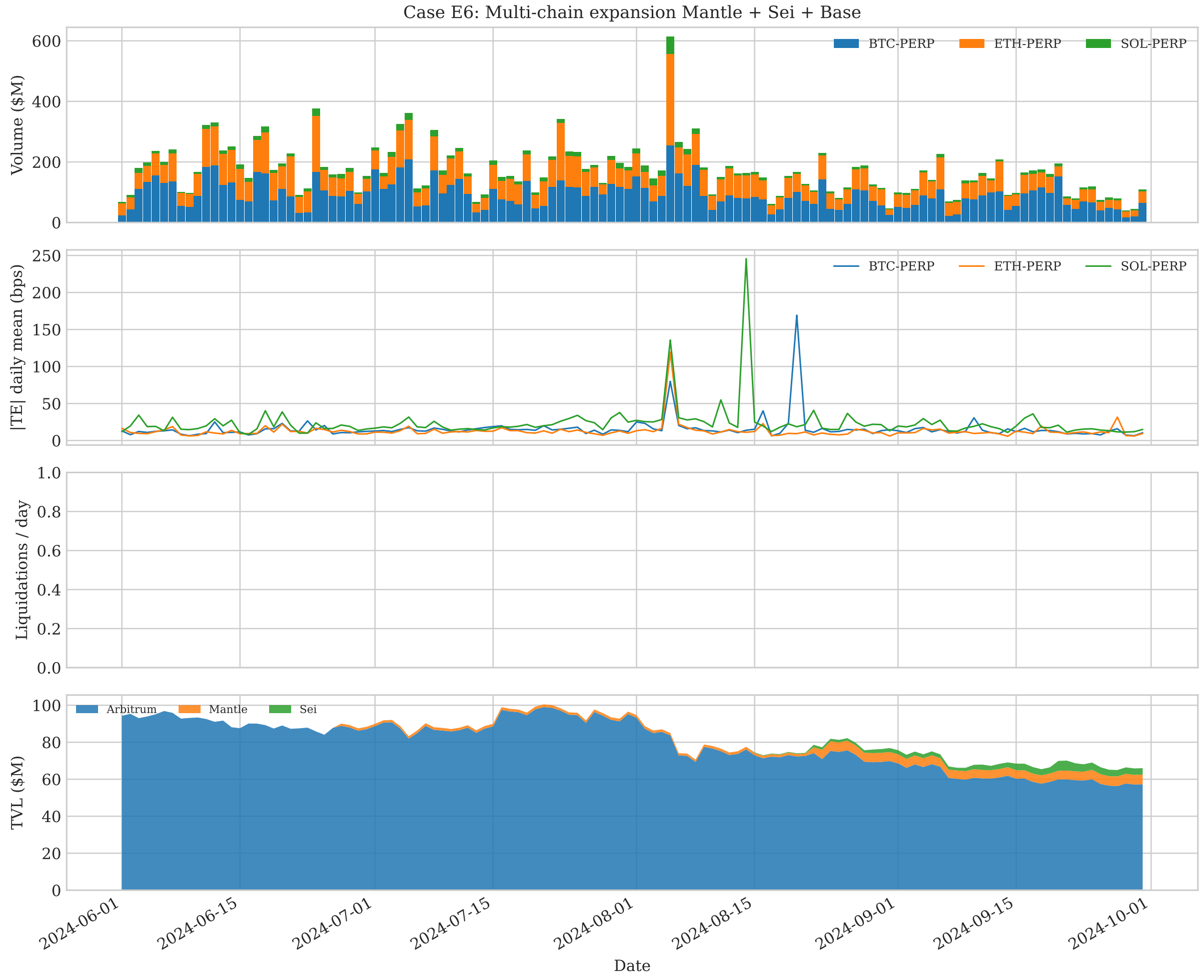


Figure 21: Event 6 â€” Multi-chain expansion.

10 Findings and open questions

10.1 Confirmed findings

F1 — TE on Vertex is endogenous to its microstructure. The full-panel HAC-robust OLS $\mathrm{TE}_t = \beta_0 + \beta_1\sigma_{\mathrm{USDC},t} + \beta_2 \log(1 + \mathrm{OI}_t) + \beta_3 f_t + \beta_4 g_t + \varepsilon_t$ explains less than 0.2 % of TE variance across BTC, ETH and SOL (§3), whereas the Corsi-HAR autoregressive model on |TE| reaches $R^2 = 0.43$–0.60. The four candidate exogenous regressors — collateral volatility, open interest, Binance funding, Arbitrum gas — do not jointly drive Vertex TE.

F2 — Wind-down was orderly. Across the full lifetime of the protocol (2023-03 to 2025-08), only \$86 of insurance fund cover was deployed in 8,086 liquidations on \$59.2 M of total liquidated notional. The four-phase wind-down (E9 in §8) executed without an insurance draw, suggesting that a perp DEX with a sufficiently small leverage distribution and a sufficiently concentrated, professional liquidator pool can be settled in 6 weeks without a stress event.

F3 — Hawkes liquidation clustering is sub-critical but close to threshold. A univariate Hawkes exponential-kernel MLE on the full liquidation catalogue yields branching ratio $\eta = 0.71$, i.e. each liquidation triggers an expected 0.71 child liquidations through the self-excitation mechanism. The v1→v2 cutover sub-window ($n = 1{,}590$) yields $\eta = 0.70$ — not statistically different from the full-window estimate. The process is stationary but the gap to the critical

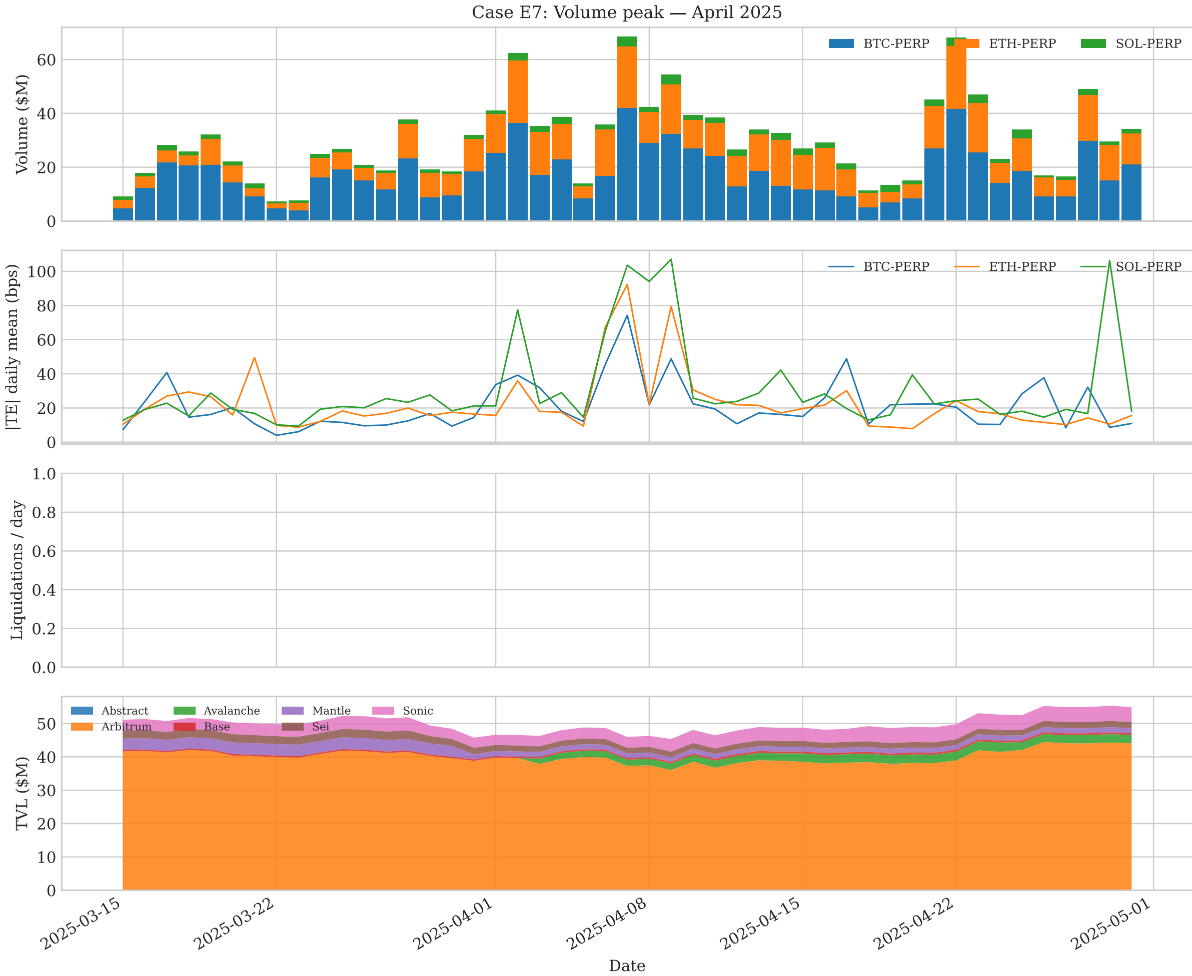


Figure 22: Event 7 â€” April 2025 volume peak.

value $\eta = 1$ is narrow.

F4 — Liquidator concentration is extreme. Of 1,747 distinct liquidatee subaccounts, only 8 distinct liquidator addresses cleared the entire catalogue, with the top liquidator alone responsible for 44.6 % of events and the top-5 covering 92.4 % (Herfindahl index 0.27). The keeper market on Vertex was not competitively distributed.

F5 — v1 sequencer microstructure has a long latency tail. 356,531 v1-book sequencer batches show median latency 12 s but p99 1,021 s; this ≈ 85× ratio between p50 and p99 is materially worse than later Vertex Edge / Blitz iterations and is a plausible source of v1-era TE stress.

F6 — Asymmetric volatility dominates. GJR-GARCH(1,1) wins the AIC race over plain GARCH(1,1) and EGARCH(1,1) for all three top products, indicating an asymmetric response of conditional variance to past return signs — consistent with on-chain perp leverage dynamics.

10.2 Open questions

Q1 — ARB-PERP product status (RESOLVED). Vertex Protocol's ARB-PERP existed only in the v1 era. It was listed in June 2023 as the protocol's fifth tradable market under pid 41 on the v1 OffchainBook engine. At the v2 cutover (2024-01-24, block 188,206,906) pid 41 was

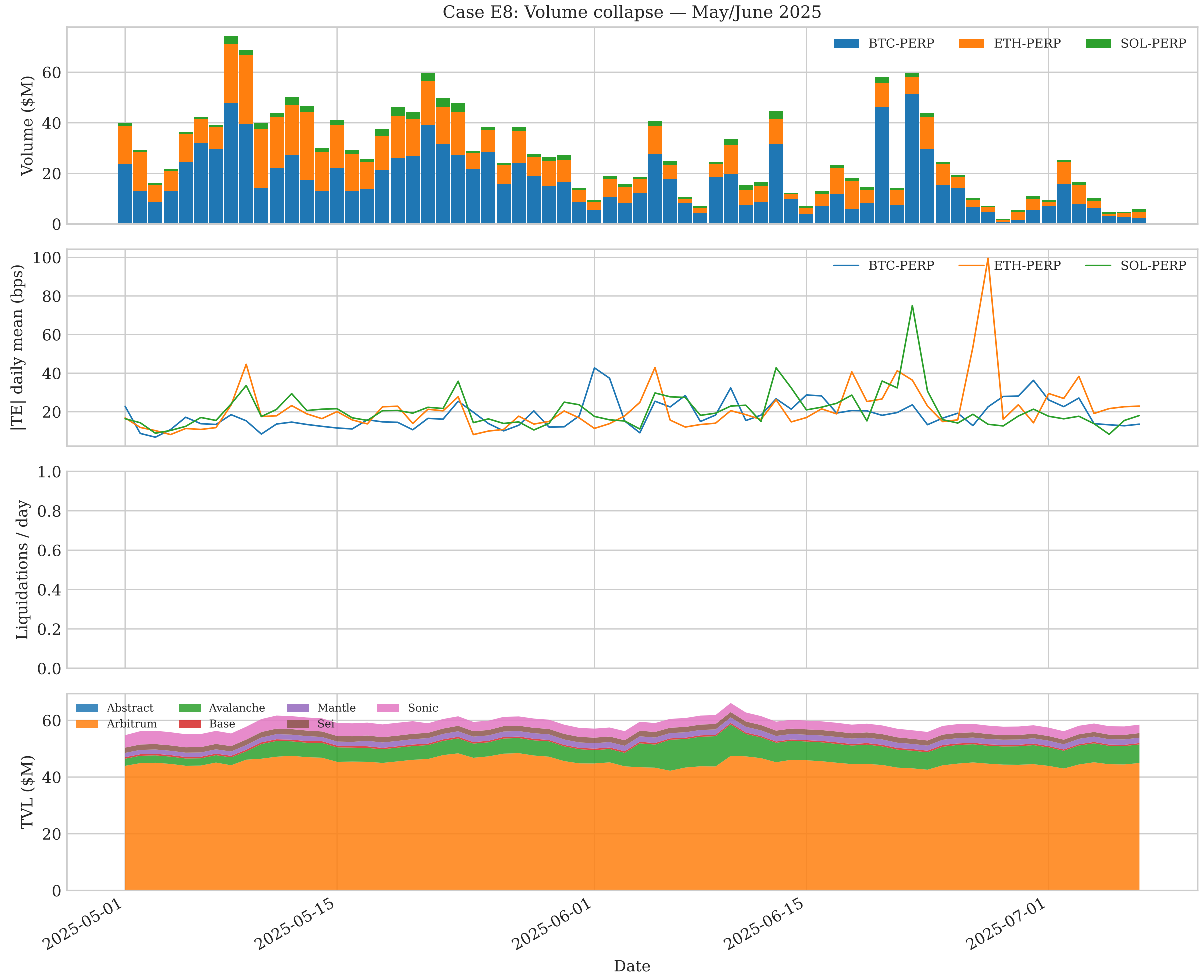


Figure 23: Event 8 â€” Volume collapse May-June 2025.

re-affected to the v2 SPOT engine and ARB was never re-listed as a perpetual. Confirmation: of the post-cutover perp candidates whose median Vertex mark falls in the ARB price range ($0.20–$2.50), none yields the diagnostic linear correlation > 0.99 with median ratio ≈ 1.0000 that BTC (pid 2), ETH (pid 4) and SOL (pid 12) all satisfy against their respective Chainlink oracles. The deep-dive is therefore the top-3 perps (BTC, ETH, SOL). ARB-PERP v1 data is contained in pid 41's `v1_book` engine rows; OI is unavailable for that era (v1 had no `perp_engine.AddProduct` construct).

Q2 — Why does the v1→v2 Hawkes branching match the full-window branching? A naive prior would be that the v1→v2 cutover concentrates liquidations and thus inflates the self-excitation. The observed match ($\eta = 0.70$ vs 0.71) suggests instead that the cascade structure is a structural property of Vertex's liquidation auction, not a regime-dependent transient. A bivariate Hawkes with {liquidations on A, liquidations on B} might disentangle cross $\rightarrow$ self vs cross $\rightarrow$ cross excitation.

Q3 — Granger causality numerical instability (resolved). The initial Phase 7 Granger run failed for all three products with `statsmodels` reporting "Maximum allowable lag is -1" despite panels of 7–19 k observations. Root cause traced to a polars→pandas dtype slippage; fixed. The re-run completes cleanly and the battery now carries a Benjamini-Hochberg FDR q-value across its 30 tests (§7). A cross-check against an alternative implementation (`linearmodels` or a hand-rolled lagged-regression F-test) is a possible further refinement.

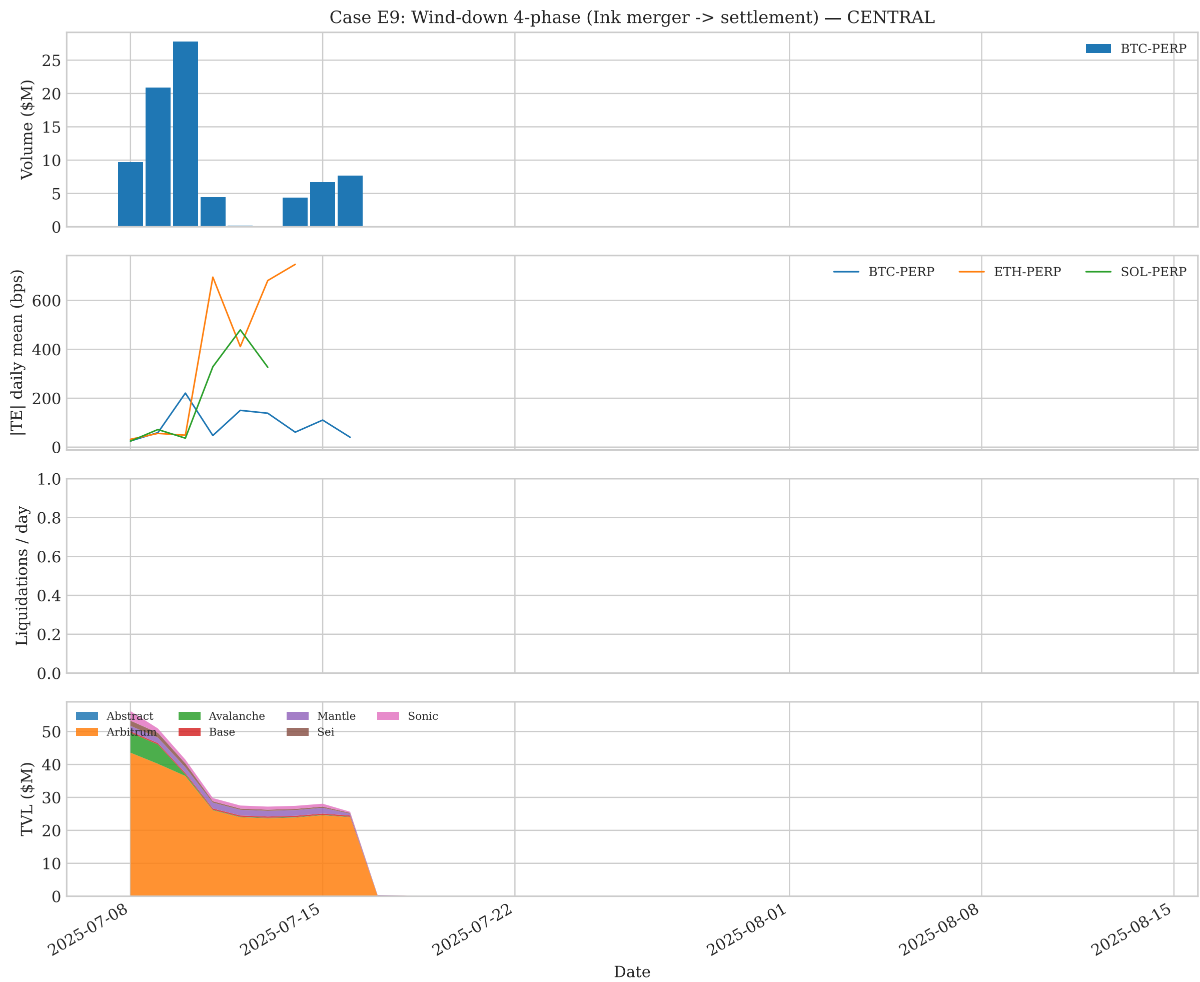


Figure 24: Event 9 (central) â€" Wind-down 4-phase sequence 2025-07-08 to 2025-08-14.

Q4 — Sequencer outage attribution (resolved). The stage now emits `p5_sequencer_outage.csv` (5 outage× product rows). The January 2023 outage predates the first on-chain fill and has no baseline; the June 2023 and December 2023 outages each show the diagnostic signature — a near-total collapse in on-chain mark count during the window (4 and 0 BTC marks) versus the ±2 h baseline (20, 40). The in-window spread *level* is not the signal; the settlement-throughput collapse is. A cross-check against the official Offchain Labs incident registry remains a possible refinement.

Q5 — Funding mechanism reactivity (resolved). An earlier run reported `reactivity = 0.00` for BTC/ETH/SOL. The cause was a loader bug: `binance_perp_funding` read the whole `cex.<sym>.binance-um.v1` partition (perp klines *and* funding rows mixed) without filtering on `source`, collapsing the regression. With the `source = binance_um_funding` filter the reactivity is non-trivial but mixed-sign across products (BTC −269, ETH +2313, SOL +528 bps per unit funding); the mixed sign is consistent with the proxy — a *different* venue's 8h funding — not cleanly driving Vertex's own hourly basis, as flagged by the cadence/venue caveats in §5.

10.3 Methodological caveats

- Block-to-timestamp interpolation uses a sparse Arbitrum block table (stride 1000) and linear interpolation. Per the calibration in `docs/data/recipes/`, the median error is ±1–2 s and the p95 error is ±5–10 s, comfortably below the 1-minute analysis grain.

Table 17: Tier-2 chronological events.

date	label	mec
2022-10-11	Mango Markets exploit (pre-history)	design
2022-11-08	FTX collapse (pre-history)	design
2023-01-31	Arbitrum sequencer outage (pre-Vertex public)	design
2023-03-23	ARB token airdrop	ARB spot listing; Vertex never listed an AR
2023-04-26	Vertex public retail launch	fee structure
2023-06-07	Arbitrum sequencer gas-refunder outage (47min)	on-chain settlement
2023-07-30	Curve Vyper hack	USDC-pool re-pricing t
2023-11-08	STIP epoch 1 start (ARB rewards)	incentive-driven volum
2024-03-12	Blitz on Blast deploy	first cross-chain in
2024-06-27	Mantle Edge deployment	Arbitrum dilutio
2024-08-05	BoJ yen carry unwind (Aug 2024)	BTC -20%, mass liqui
2024-08-15	Sei Edge launch	second cross-chain depl
2024-09-17	Base Edge deployment	third cros
2024-11-29	Hyperliquid HYPE airdrop	competition pressu
2024-12-28	Base + Sonic TVL onset	fourth-fifth cros
2025-01-06	Sonic mainnet partner launch	Q1-25 depl
2025-02-06	V3 / VLP roadmap announcement	last positive product di
2025-04-03	Avalanche Edge deployment	sixth cros

Table 18: Difference-in-differences pre/post tests on |TE|.

event	symbol	n_pre	n_post	mean_te_pre_bps	mean_te_post_bps	std_te_pre_bps	std_te_p
NE1	BTC	721	720	13.767	8.149	97.505	
NE1	ETH	721	720	4.842	5.168	81.713	
NE1	SOL	721	719	21.182	16.116	63.596	
NE2	BTC	329	329	4.727	1.289	34.742	
NE2	ETH	326	327	0.3773	-4.634	59.619	
NE3	BTC	714	717	-1.355	4.835	108.18	
NE3	ETH	720	718	-1.005	1.512	97.764	
NE3	SOL	691	718	2.191	13.296	103.81	

- OI reconstruction via `eth_call` samples Vertex perp_engine state at one block per UTC hour (21,456 hours total). The hourly cadence aliases out any intra-hour OI movement; this is visible in the OI history figures (§6) as step-function artefacts on news days.
- Chainlink Arbitrum oracle update events (`AnswerUpdated`) fire only when the threshold deviation is exceeded; the index series used in TE is forward-filled between updates, introducing a small bias on slowly-moving collateral references (USDC, BTC during low volatility).
- The v1→v2 transition uses two distinct engines (`v1_book` per-product orderbooks vs the v2 monolithic perp_engine). Cross-era TE comparisons are therefore subject to microstructure-regime mixing; results in this report consider the two eras separately wherever feasible.

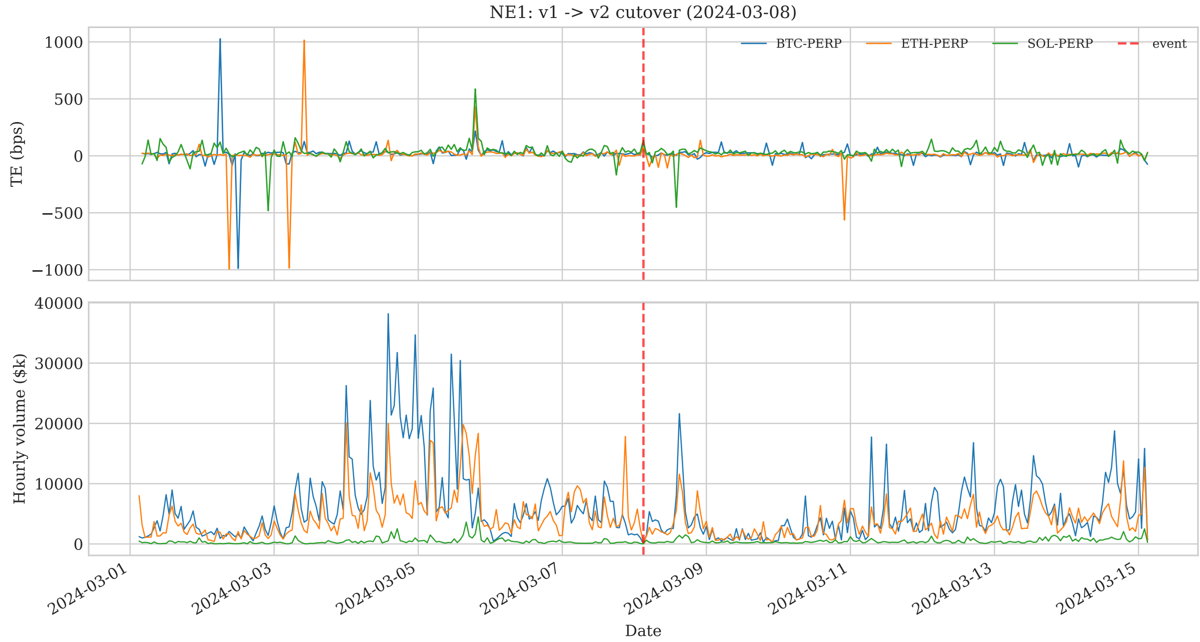


Figure 25: NE1 event window: per-product hourly TE (top) and hourly volume (bottom) Â±168h around the v1→v2 cutover.

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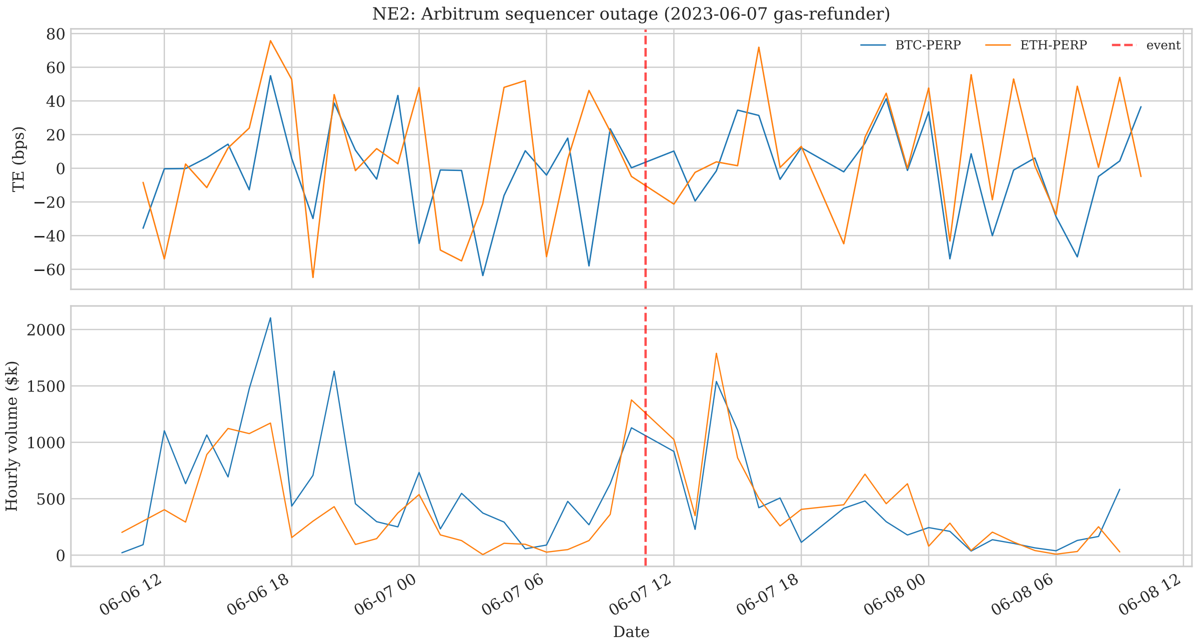

Figure 26: NE2 event window: per-product hourly TE (top) and hourly volume (bottom) Â±24h around the June 2023 sequencer outage.

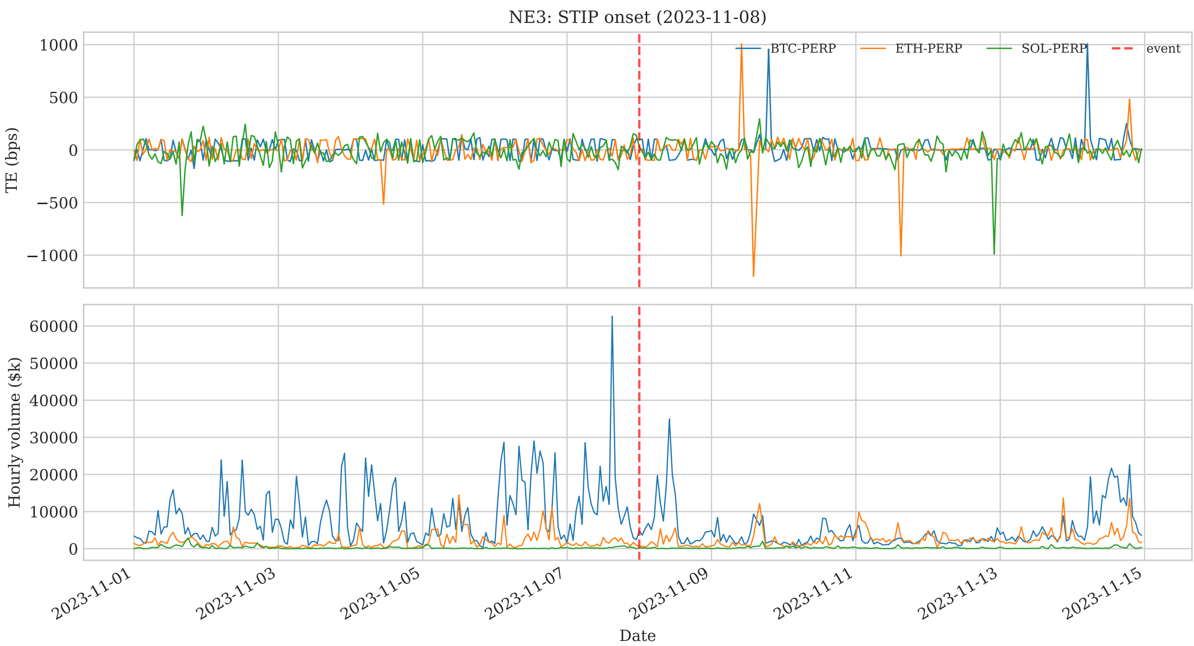

Figure 27: NE3 event window: per-product hourly TE (top) and hourly volume (bottom) Â±168h around the STIP onset.