**1. Asset Universe & Feature Engineering**

* **Select ~10–20 liquid crypto perpetual futures (e.g. BTC, ETH, SOL) from Binance, Bybit, etc.**
* **Extract and preprocess key features:**
  + **Log returns**
  + **Volatility (price & volume)**
  + **Half-life of mean reversion**
  + **ADF stationarity**
  + **GARCH(1,1) volatility persistence**
  + **Average hourly volume**
  + **Funding rate + funding volatility**

**2. PCA + Cluster Construction**

* **Apply PCA to reduce dimensionality of feature vectors.**
* **Use K-Means clustering (monthly) to group coins by co-movement.**
* **Output: K groups (baskets) with statistically similar behaviour.**

**3. Pair Filtering & Pre-Trade Constraints**

**Apply filters to pairs within each cluster:**

* **ADF p-value < 0.05**
* **Spread half-life < 12 hrs**
* **GARCH(1,1): α + β < 0.9**
* **Avg. hourly volume > $1M**
* **Remove funding/volatility outliers**

**4. Rolling Cointegration & Whitelisting**

* **Use rolling window (30–60 days) to test:**
  + **Engle-Granger or Johansen cointegration**
* **Whitelist pairs that remain cointegrated ≥ 70% of the time.**

**5. Spread Construction & Signal Logic**

* **Construct log spread:**

**Compute rolling z-score:**

* **Signal Rules:**
  + **Enter: |Z| > 1.5**
  + **Exit: Z ≈ 0 or holding time > 48 bars**
  + **Stop-loss: |Z| > 2.5 or inverse volatility breach**

**6. Regime Detection & Adaptive Filtering**

* **Volatility Regime Detection:**
  + **Compute rolling volatility percentiles**
  + **Detect high-volatility regimes (e.g. top 1%)**
  + **Optionally use HMMs for classification**
* **Spread Stability Monitoring:**
  + **Re-check mean and std of z-score over rolling windows**
  + **Flag shifts > 2σ as regime changes**
* **Cointegration Re-Validation:**
  + **Remove pairs with degraded cointegration**
* **Suspend Trading During Extremes:**
  + **Stop entry if regime unstable or spreads widen sharply**
  + **Pause trading around news/funding events**

**7. Risk Management & Position Sizing**

* **Size ∝ inverse spread volatility:**
* **Optional caps:**
  + **Exposure < 5% of avg. 1h volume**
  + **Avoid trading ±2 min around funding**
  + **Suspend in >99th percentile volatility**

**8. Backtesting & Evaluation**

* **Historical 1-min/tick backtest**
* **Include:**
  + **Fees (maker/taker)**
  + **Slippage**
  + **Latency/fill simulation**
* **Evaluate:**
  + **Sharpe, Sortino**
  + **Max drawdown**
  + **Win rate, PnL distribution**
  + **Volatility regime performance**
* **Validation:**
  + **Walk-forward analysis**
  + **Monte Carlo stress testing**

**9. Execution (Go Live)**

* **Use limit/post-only orders to reduce slippage**
* **Monitor order book depth + spreads**
* **Cancel stale orders if price mean-reverts pre-fill**
* **Continuously re-evaluate:**
  + **Signal performance**
  + **Cointegration integrity**
  + **Regime stability**