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-----
QUERY PLAN
-----
Merge Join  (cost=0.62..1351.74 rows=8893 width=302) (actual time=0.130..45.729 rows=8897 loops=1)
  Merge Cond: (c.customerid = o.customerid)
  -> Index Scan using customers_pkey on customers c  (cost=0.29..845.29 rows=20000 width=268) (actual time=0.032..10.950 rows=19997 loops=1)
  -> Index Scan using ix_order_custid on orders o  (cost=0.29..345.29 rows=8893 width=30) (actual time=0.070..19.943 rows=8897 loops=1)
       Filter: (netamount > '100'::numeric)
       Rows Removed by Filter: 3103
Planning Time: 3.843 ms
Execution Time: 52.293 ms

```

Listing 1: merge join

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-----
QUERY PLAN
-----
Sort  (cost=1033.04..1063.04 rows=12000 width=30) (actual time=9.572..10.531 rows=12000 loops=1)
  Sort Key: orderdate
  Sort Method: quicksort  Memory: 1416kB
  -> Seq Scan on orders  (cost=0.00..220.00 rows=12000 width=30) (actual time=0.024..3.182 rows=12000 loops=1)
Planning Time: 1.529 ms
Execution Time: 11.672 ms

```

Listing 2: sort

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-----
QUERY PLAN
-----
Sort  (cost=7224521.31..7224543.54 rows=8893 width=302) (actual time=111918.890..111919.623 rows=8897 loops=1)
  Sort Key: c.customerid
  Sort Method: quicksort  Memory: 2817kB
  -> Nested Loop  (cost=0.00..7223938.00 rows=8893 width=302) (actual time=205.686..111816.823 rows=8897 loops=1)
       Join Filter: (c.customerid = o.customerid)
       Rows Removed by Join Filter: 177931103
       -> Seq Scan on customers c  (cost=0.00..688.00 rows=20000 width=268) (actual time=8.168..31.380 rows=20000 loops=1)
       -> Seq Scan on orders o  (cost=0.00..250.00 rows=8893 width=30) (actual time=0.006..4.604 rows=8897 loops=20000)
            Filter: (netamount > '100'::numeric)
            Rows Removed by Filter: 3103
Planning Time: 0.777 ms
Execution Time: 111925.339 ms

```

Listing 3: nested loop

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-----
QUERY PLAN
-----
Sort  (cost=1575.48..1590.32 rows=5934 width=304) (actual time=33.584..34.200 rows=5936 loops=1)
  Sort Key: o.netamount
  Sort Method: quicksort  Memory: 1816kB
  -> Hash Join  (cost=938.00..1203.58 rows=5934 width=304) (actual time=12.335..23.709 rows=5936 loops=1)
       Hash Cond: (o.customerid = c.customerid)
       -> Seq Scan on orders o  (cost=0.00..250.00 rows=5934 width=30) (actual time=0.034..5.769 rows=5936 loops=1)
            Filter: (netamount > '200'::numeric)
            Rows Removed by Filter: 6064
       -> Hash  (cost=688.00..688.00 rows=20000 width=268) (actual time=12.254..12.254 rows=20000 loops=1)
            Buckets: 32768  Batches: 1  Memory Usage: 4108kB
            -> Seq Scan on customers c  (cost=0.00..688.00 rows=20000 width=268) (actual time=0.012..5.910 rows=20000 loops=1)
Planning Time: 1.154 ms
Execution Time: 40.343 ms

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Listing 4: hash join

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QUERY PLAN
-----
Seq Scan on customers c  (cost=0.00..788.00 rows=769 width=268) (actual time=0.101..10.838 rows=776 loops=1)
  Filter: ((age < 20) OR (age = 22))
  Rows Removed by Filter: 19224
Planning Time: 0.233 ms
Execution Time: 11.107 ms

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Listing 5: multiple conditions in filter

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-----
QUERY PLAN
-----
Limit  (cost=0.00..0.18 rows=10 width=30) (actual time=0.033..0.041 rows=10 loops=1)
  -> Seq Scan on orders  (cost=0.00..220.00 rows=12000 width=30) (actual time=0.030..0.034 rows=10 loops=1)
Planning Time: 0.154 ms
Execution Time: 0.414 ms
-----
```

Listing 6: limit

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-----
QUERY PLAN
-----
Hash Right Join  (cost=938.00..1189.51 rows=20000 width=298) (actual time=10.990..29.612 rows=23004 loops=1)
  Hash Cond: (o.customerid = c.customerid)
  -> Seq Scan on orders o  (cost=0.00..220.00 rows=12000 width=30) (actual time=0.010..1.664 rows=12000 loops=1)
  -> Hash  (cost=688.00..688.00 rows=20000 width=268) (actual time=10.940..10.940 rows=20000 loops=1)
      Buckets: 32768  Batches: 1  Memory Usage: 4108kB
      -> Seq Scan on customers c  (cost=0.00..688.00 rows=20000 width=268) (actual time=0.016..4.918 rows=20000 loops=1)
Planning Time: 0.707 ms
Execution Time: 32.227 ms
-----
```

Listing 7: hash right join

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-----
QUERY PLAN
-----
Index Scan using orders_pkey on orders  (cost=0.29..2.30 rows=1 width=30) (actual time=1.361..1.366 rows=1 loops=1)
  Index Cond: (orderid = 3)
Planning Time: 0.191 ms
Execution Time: 1.673 ms
-----
```

Listing 8: index cond

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-----
QUERY PLAN
-----
Hash Join  (cost=22.91..127.58 rows=974 width=500) (actual time=2.509..21.365 rows=2922 loops=1)
  Hash Cond: (a.attreleid = c.oid)
  Join Filter: has_column_privilege(c.oid, a.attnum, 'select'::text)
  -> Seq Scan on pg_attribute a  (cost=0.00..96.61 rows=3061 width=238) (actual time=0.022..1.327 rows=2922 loops=1)
  -> Hash  (cost=17.96..17.96 rows=396 width=266) (actual time=2.444..2.445 rows=396 loops=1)
      Buckets: 1024  Batches: 1  Memory Usage: 89kB
      -> Seq Scan on pg_class c  (cost=0.00..17.96 rows=396 width=266) (actual time=0.024..1.064 rows=396 loops=1)
Planning Time: 0.896 ms
Execution Time: 24.740 ms
-----
```

Listing 9: non parenthesized join filter

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-----
QUERY PLAN
-----
Hash Join  (cost=142.19..179.59 rows=6 width=869) (actual time=14.330..15.259 rows=467 loops=1)
  Hash Cond: ((s.stareleid = c.oid) AND (s.staattnum = a.attnum))
  -> Seq Scan on pg_statistic s  (cost=0.00..32.67 rows=467 width=369) (actual time=0.023..0.133 rows=467 loops=1)
  -> Hash  (cost=127.58..127.58 rows=974 width=504) (actual time=14.277..14.278 rows=2922 loops=1)
      Buckets: 4096 (originally 1024)  Batches: 1 (originally 1)  Memory Usage: 982kB
      -> Hash Join  (cost=22.91..127.58 rows=974 width=504) (actual time=2.217..8.851 rows=2922 loops=1)
          Hash Cond: (a.attreleid = c.oid)
          Join Filter: has_column_privilege(c.oid, a.attnum, 'select'::text)
          -> Seq Scan on pg_attribute a  (cost=0.00..96.61 rows=3061 width=238) (actual time=0.010..0.554 rows=2922 loops=1)
          -> Hash  (cost=17.96..17.96 rows=396 width=266) (actual time=2.190..2.190 rows=396 loops=1)
              Buckets: 1024  Batches: 1  Memory Usage: 89kB
              -> Seq Scan on pg_class c  (cost=0.00..17.96 rows=396 width=266) (actual time=0.023..0.944 rows=396 loops=1)
Planning Time: 2.122 ms
Execution Time: 18.919 ms
-----
```

Listing 10: 'originally' in hash node

QUERY PLAN

Limit

(cost=143.31..182.10 rows=6 width=401) (actual time=6.445..6.501 rows=10 loops=1)

-> Nested Loop Left Join

(cost=143.31..182.04 rows=6 width=401) (actual time=6.443..6.496 rows=10 loops=1)

-> Hash Join

(cost=143.18..180.58 rows=6 width=475) (actual time=6.412..6.425 rows=10 loops=1)

Hash Cond: ((s.starelid = c.oid) AND (s.staattnum = a.attnum))

-> Seq Scan on pg_statistic s

(cost=0.00..32.67 rows=467 width=349) (actual time=0.011..0.012 rows=10 loops=1)

-> Hash

(cost=128.57..128.57 rows=974 width=142) (actual time=6.390..6.390 rows=2922 loops=1)

Buckets: 4096 (originally 1024) Batches: 1 (originally 1) Memory Usage: 529kB

-> Hash Join

(cost=23.90..128.57 rows=974 width=142) (actual time=0.394..4.966 rows=2922 loops=1)

Hash Cond: (a.attrelid = c.oid)

Join Filter: has_column_privilege(c.oid, a.attnum, 'select'::text)

-> Seq Scan on pg_attribute a

(cost=0.00..96.61 rows=3061 width=70) (actual time=0.006..1.253 rows=2922 loops=1)

Filter: (NOT attisdropped)

-> Hash

(cost=18.95..18.95 rows=396 width=72) (actual time=0.378..0.378 rows=396 loops=1)

Buckets: 1024 Batches: 1 Memory Usage: 49kB

-> Seq Scan on pg_class c

(cost=0.00..18.95 rows=396 width=72) (actual time=0.007..0.243 rows=396 loops=1)

Filter: ((NOT relrowsecurity) OR (NOT row_security_active(oid)))

-> Index Scan using pg_namespace_oid_index on pg_namespace n

(cost=0.13..0.16 rows=1 width=68) (actual time=0.003..0.003 rows=1 loops=10)

Index Cond: (oid = c.relnamespace)

Planning Time: 3.761 ms

Execution Time: 8.801 ms

Listing 11: left join

QUERY PLAN

Aggregate

(cost=250.00..250.01 rows=1 width=8) (actual time=5.717..5.717 rows=1 loops=1)

-> Seq Scan on orders

(cost=0.00..220.00 rows=12000 width=0) (actual time=0.025..3.280 rows=12000 loops=1)

Planning Time: 0.172 ms

Execution Time: 5.895 ms

Listing 12: aggregate

QUERY PLAN

Nested Loop

(cost=0.00..1650315.00 rows=100000000 width=16) (actual time=0.241..30211.690 rows=100000000 loops=1)

-> Seq Scan on foo

(cost=0.00..145.00 rows=10000 width=8) (actual time=0.121..3.643 rows=10000 loops=1)

-> Materialize

(cost=0.00..235.00 rows=10000 width=8) (actual time=0.001..1.454 rows=10000 loops=10000)

-> Seq Scan on bar

(cost=0.00..145.00 rows=10000 width=8) (actual time=0.112..1.599 rows=10000 loops=1)

Planning Time: 0.829 ms

Execution Time: 33763.432 ms

Listing 13: materialize

QUERY PLAN

Index Only Scan using customers_pkey on customers

(cost=0.29..2.31 rows=1 width=4) (actual time=0.797..0.805 rows=1 loops=1)

Index Cond: (customerid = 3)

Heap Fetches: 1

Planning Time: 2.832 ms

Execution Time: 0.996 ms

Listing 14: index only scan

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-----
QUERY PLAN
-----
Sort (cost=12520.13..12542.37 rows=8893 width=302) (actual time=70.046..70.841 rows=8897 loops=1)
  Sort Key: c.customerid
  Sort Method: quicksort  Memory: 2817kB
-> Nested Loop (cost=0.30..11936.82 rows=8893 width=302) (actual time=0.096..58.465 rows=8897 loops=1)
    -> Seq Scan on orders o (cost=0.00..250.00 rows=8893 width=30) (actual time=0.035..6.143 rows=8897 loops=1)
        Filter: (netamount > '100'::numeric)
        Rows Removed by Filter: 3103
    -> Bitmap Heap Scan on customers c (cost=0.30..1.31 rows=1 width=268) (actual time=0.004..0.004 rows=1 loops=8897)
        Recheck Cond: (customerid = o.customerid)
        Heap Blocks: exact=8897
        -> Bitmap Index Scan on customers_pkey (cost=0.00..0.30 rows=1 width=0) (actual time=0.003..0.003 rows=1 loops=8897)
            Index Cond: (customerid = o.customerid)
Planning Time: 0.781 ms
Execution Time: 76.834 ms

```

Listing 15: bitmap heap scan

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-----
QUERY PLAN
-----
Nested Loop (cost=0.57..4.62 rows=1 width=4) (actual time=0.046..0.046 rows=0 loops=1)
  -> Index Only Scan using customers_pkey on customers c (cost=0.29..2.31 rows=1 width=4) (actual time=0.045..0.045 rows=0 loops=1)
      Index Cond: (customerid = 1000000)
      Heap Fetches: 0
  -> Index Only Scan using ix_order_custid on orders o (cost=0.29..2.30 rows=1 width=4) (never executed)
      Index Cond: (customerid = 1000000)
      Heap Fetches: 0
Planning Time: 0.152 ms
Execution Time: 0.161 ms

```

Listing 16: never executed node

```

-----
QUERY PLAN
-----
Gather (cost=1000.00..217018.43 rows=1 width=97)
  Workers Planned: 2
  -> Parallel Seq Scan on pgbench_accounts (cost=0.00..216018.33 rows=1 width=97)
      Filter: (filler ~~ '%x%'::text)

```

Listing 17: parallel gather

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-----
QUERY PLAN
-----
Finalize Aggregate (cost=11597.40..11597.41 rows=1 width=4) (actual time=124.383..124.383 rows=1 loops=1)
  -> Gather (cost=11597.19..11597.40 rows=2 width=4) (actual time=124.261..127.909 rows=3 loops=1)
      Workers Planned: 2
      Workers Launched: 2
      -> Partial Aggregate (cost=10597.19..10597.20 rows=1 width=4) (actual time=117.534..117.534 rows=1 loops=3)
          -> Parallel Seq Scan on foo (cost=0.00..9460.15 rows=454815 width=4) (actual time=0.025..67.197 rows=370000 loops=3)
Planning Time: 0.289 ms
Execution Time: 128.039 ms

```

Listing 18: partial aggregate

```

-----
Merge Join (cost=1002.35..8595.96 rows=1 width=16) (actual time=221.121..225.824 rows=3 loops=1)
  Merge Cond: (foo.id = bar.id)
  -> Gather Merge (cost=1000.45..30009.29 rows=4 width=8) (actual time=221.072..221.322 rows=4 loops=1)
      Workers Planned: 2
      Workers Launched: 2
      -> Parallel Index Scan using foo_pkey on foo (cost=0.43..29008.80 rows=2 width=8) (actual time=72.653..142.791 rows=3 loops=3)
          Filter: (a = ANY ('{1,2,3}'::integer[]))
          Rows Removed by Filter: 369997
  -> Index Scan using bar_pkey on bar (cost=0.29..318.29 rows=10000 width=8) (actual time=0.042..3.300 rows=10000 loops=1)
Planning Time: 0.871 ms
Execution Time: 225.952 ms

```

Listing 19: gather merge

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-----
QUERY PLAN
-----
Gather (cost=119887.82..232027.23 rows=55050 width=16) (actual time=2701.114..5316.387 rows=5505000 loops=1)
  Workers Planned: 2
  Workers Launched: 2
  -> Parallel Hash Join (cost=118887.82..225522.23 rows=22938 width=16) (actual time=2690.280..4270.563 rows=1835000 loops=3)
    Hash Cond: (bar.id = foo.id)
    -> Parallel Seq Scan on bar (cost=0.00..94592.18 rows=4587518 width=8) (actual time=0.035..567.615 rows=3670000 loops=3)
    -> Parallel Hash (cost=118598.50..118598.50 rows=23146 width=8) (actual time=1370.159..1370.159 rows=1851667 loops=3)
      Buckets: 131072 (originally 65536) Batches: 64 (originally 1) Memory Usage: 4480kB
      -> Parallel Seq Scan on foo (cost=0.00..118598.50 rows=23146 width=8) (actual time=0.029..777.546 rows=1851667 loops=3)
        Filter: ((a % 2) = 1)
        Rows Removed by Filter: 1851667
Planning Time: 0.845 ms
Execution Time: 5554.032 ms
-----
```

Listing 20: parallel hash join