Contents

docs/en/architecture.md

1 chameleonDB Architecture

Figure 1: Chameleon logo

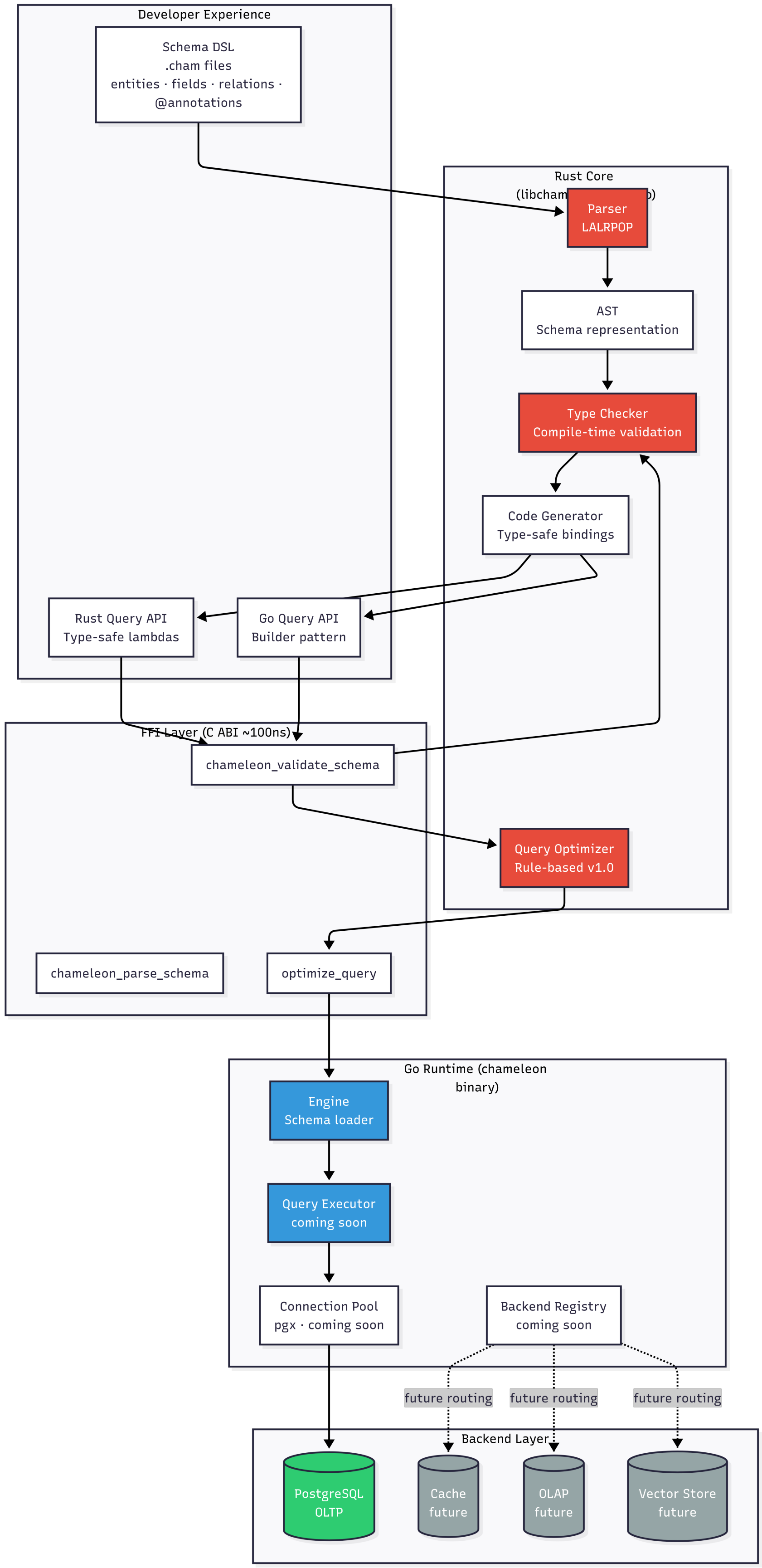


Figure 2: System Overview diagram

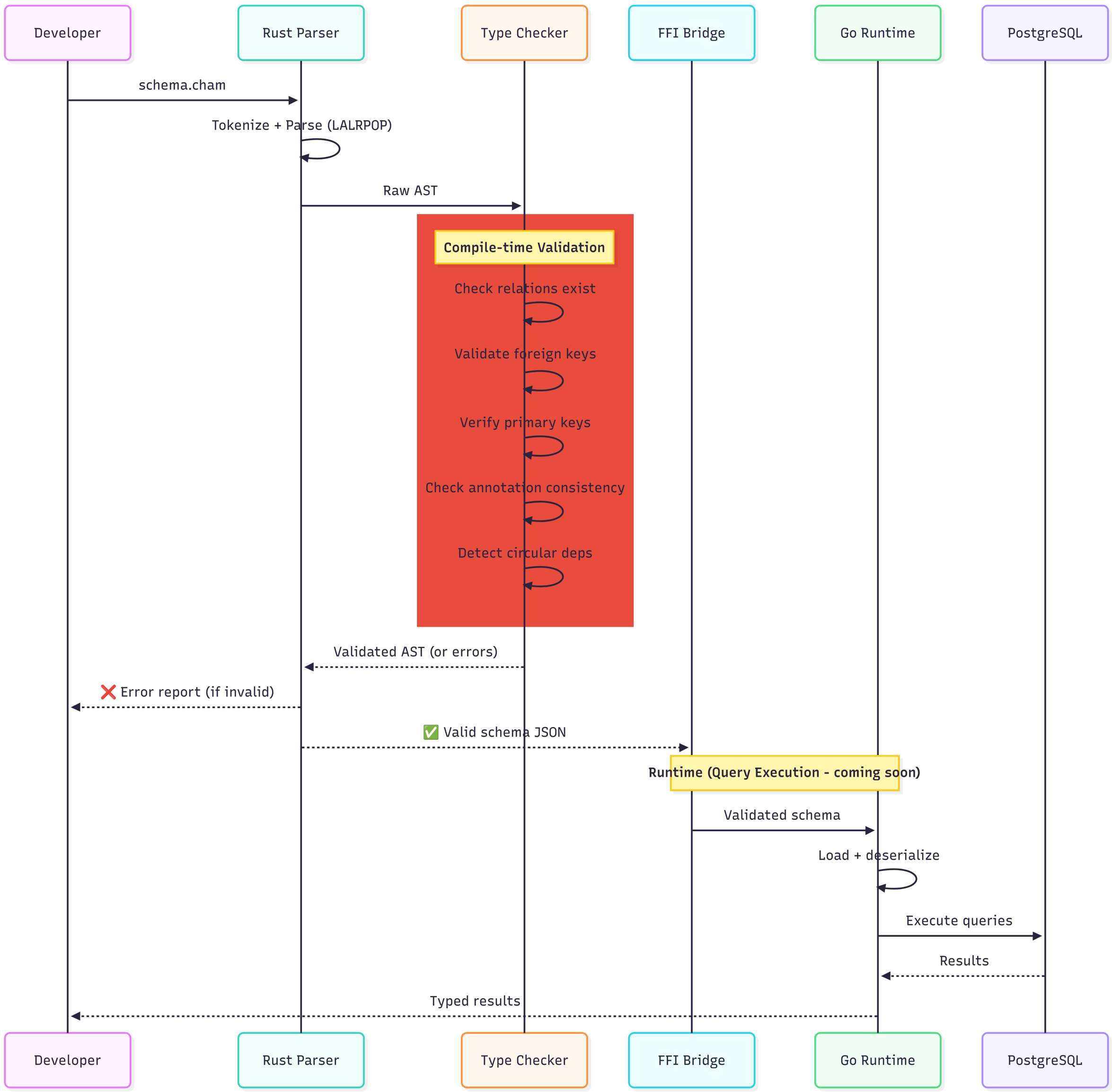


Figure 3: Compilation Flow

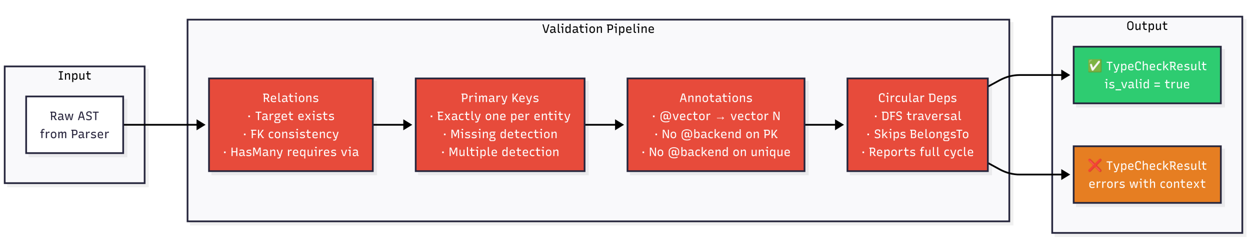


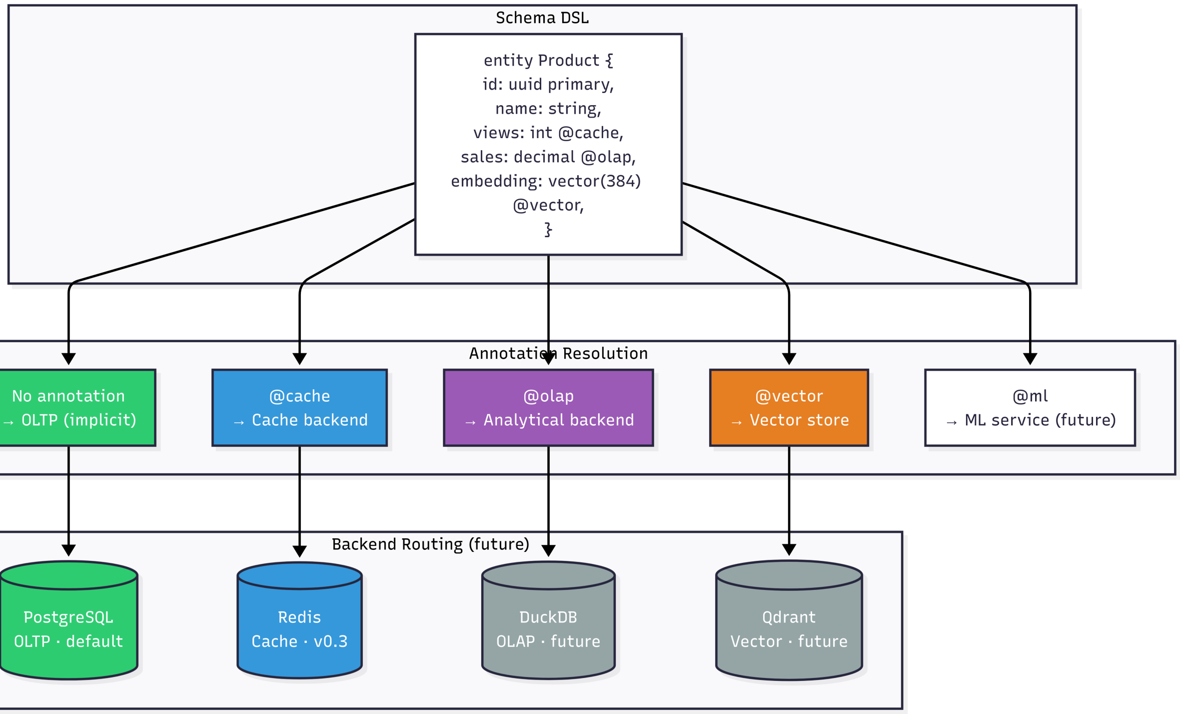
Figure 4: Type Checker Detail

1.1 System Overview

1.2 2. Compilation & Validation Flow

1.3 Type Checker Detail

1.4 Backend Annotations Model



Component Responsibilities

1.4.1 Rust Core (`chameleon-core`)

Parser — Transforms `.cham` source into an AST using LALRPOP grammar. Handles all syntax including entities, fields, relations, type modifiers, default values, and backend annotations.

Type Checker — Validates the AST before it reaches the runtime. Organized in three focused modules: `relations.rs` checks all entity references and foreign key consistency, `constraints.rs` validates primary keys and annotation rules, and the main `mod.rs` orchestrates the pipeline and produces structured error reports.

Code Generator — Produces type-safe bindings for Rust and Go from validated schemas. (Coming soon.)

Query Optimizer — Rule-based optimization for query execution plans. Deterministic, no ML in v1.0.

1.4.2 Go Runtime (`chameleon`)

Engine — Entry point for the Go side. Loads schemas via FFI, deserializes JSON into Go types, and exposes the public API. Custom JSON marshal/unmarshal handles extended types like `vector(N)` and arrays.

Query Executor — Translates validated queries into backend-specific operations. (Coming soon.)

Connection Pool — pgx-based PostgreSQL connection management. (Coming soon.)

Backend Registry — Routes queries to the correct backend based on field annotations. Manages fallback strategies. (Coming soon.)

1.4.3 FFI Boundary

The FFI layer uses C ABI for maximum compatibility. Communication happens via JSON — schemas are serialized in Rust and deserialized in Go. Memory is explicitly managed: Rust allocates strings for return values, and the Go caller frees them via `chameleon_free_string`. Overhead is approximately 100ns per call.

1.5 Design Decisions

1.5.1 Why Rust for Core?

Rust provides true lambdas and closures (essential for the future query API), extreme type safety that catches errors at compile time, operator overloading for natural query syntax, and excellent performance on the parser and type-checker hot paths.

1.5.2 Why Go for Runtime?

Go offers a simple concurrency model via goroutines (ideal for connection pooling), an excellent PostgreSQL driver (pgx), easy single-binary deployment, and great tooling for debugging.

1.5.3 Why FFI instead of a single language?

Each language handles what it does best. The FFI overhead is minimal (~100ns). This approach is also future-proof: bindings for other languages (Node, Java, Python) can be added without changing the core.

1.5.4 Why annotations are declarative (not routing)

Backend annotations are part of the schema definition, not the execution layer. This means schemas can be written and validated today, and routing strategies can evolve independently. When a new backend is added, no schema changes are needed — only the runtime routing logic changes.

1.5.5 Why BelongsTo is excluded from circular dependency detection

`User → Order` (HasMany) and `Order → User` (BelongsTo) represent the same relationship from two sides. Treating both as directed edges would flag every bidirectional relationship as circular. Only ownership relationships (HasMany, HasOne) are traversed during cycle detection.

1.6 Future Architecture (v2.0+)

1.7 Performance Targets (v1.0)

Operation	Target	Notes
Schema parse	< 10ms	One-time, cold start
Type check	< 5ms	Per schema validation
FFI call overhead	< 100ns	Per boundary crossing
Query compilation	< 1ms	Per query
Query execution	DB-bound	Optimized SQL generation

1.8 Current Status

Component	Status	Notes
Parser	Complete	LALRPOP, all types and annotations
AST	Complete	Serializable, extensible

Component	Status	Notes
Type Checker	Complete	Relations, constraints, cycles
FFI Layer	Complete	Parse + validate via C ABI
Go Runtime	Basic	Engine + CLI functional
Query Builder	Next	Filter, include, select
PostgreSQL Backend	Upcoming	Connection pool + execution
Backend Registry	Upcoming	Annotation-based routing
Migration Generator	Upcoming	Schema $\rightarrow$ SQL diff
Code Generator	Upcoming	Type-safe API bindings

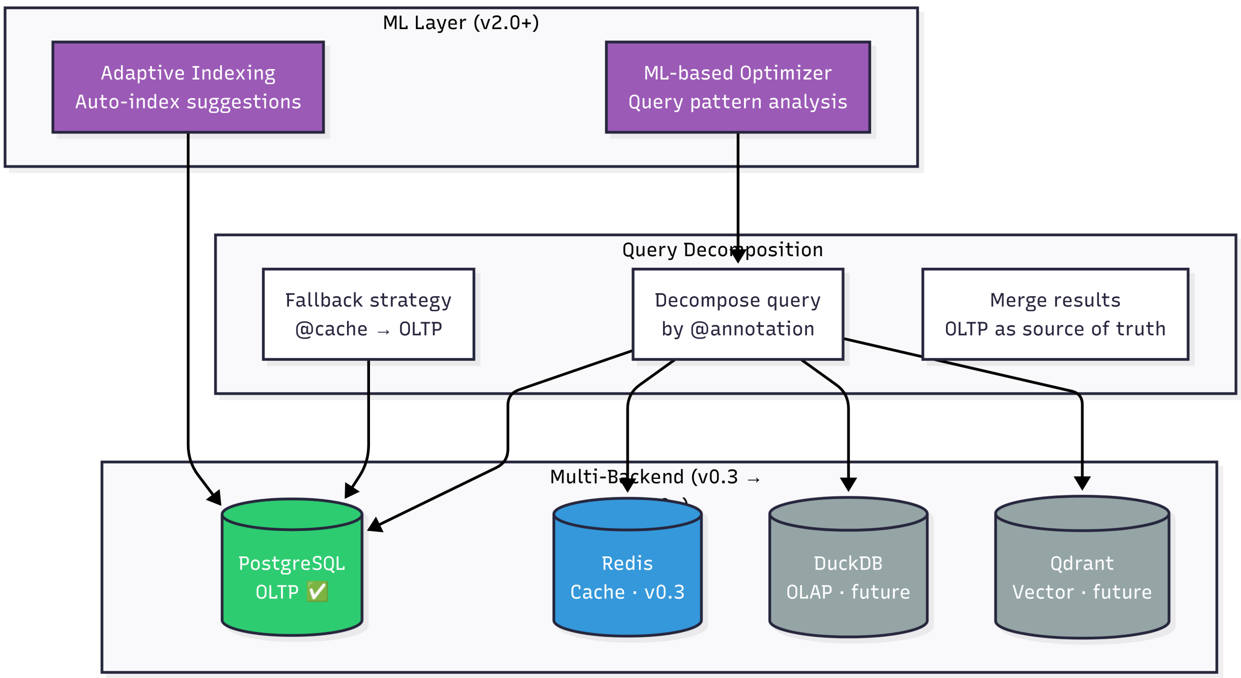


Figure 5: Future Architecture