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Explicit State Representation and the ATLAS Event Data Model

Theory and Practice

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Introduction

- The Scope: Athena – ATLAS offline software framework
  - Management of data objects – transient and persistent
  - Event data persistency based on POOL and ROOT technologies
- The Problem: Schema Evolution
  - Unavoidable for production data
  - Must be possible without forfeiting the ability to read old data
- The Solution: Persistent state representation
  - Implementation
  - Performance implications
  - Direct access from ROOT

Schema Evolution

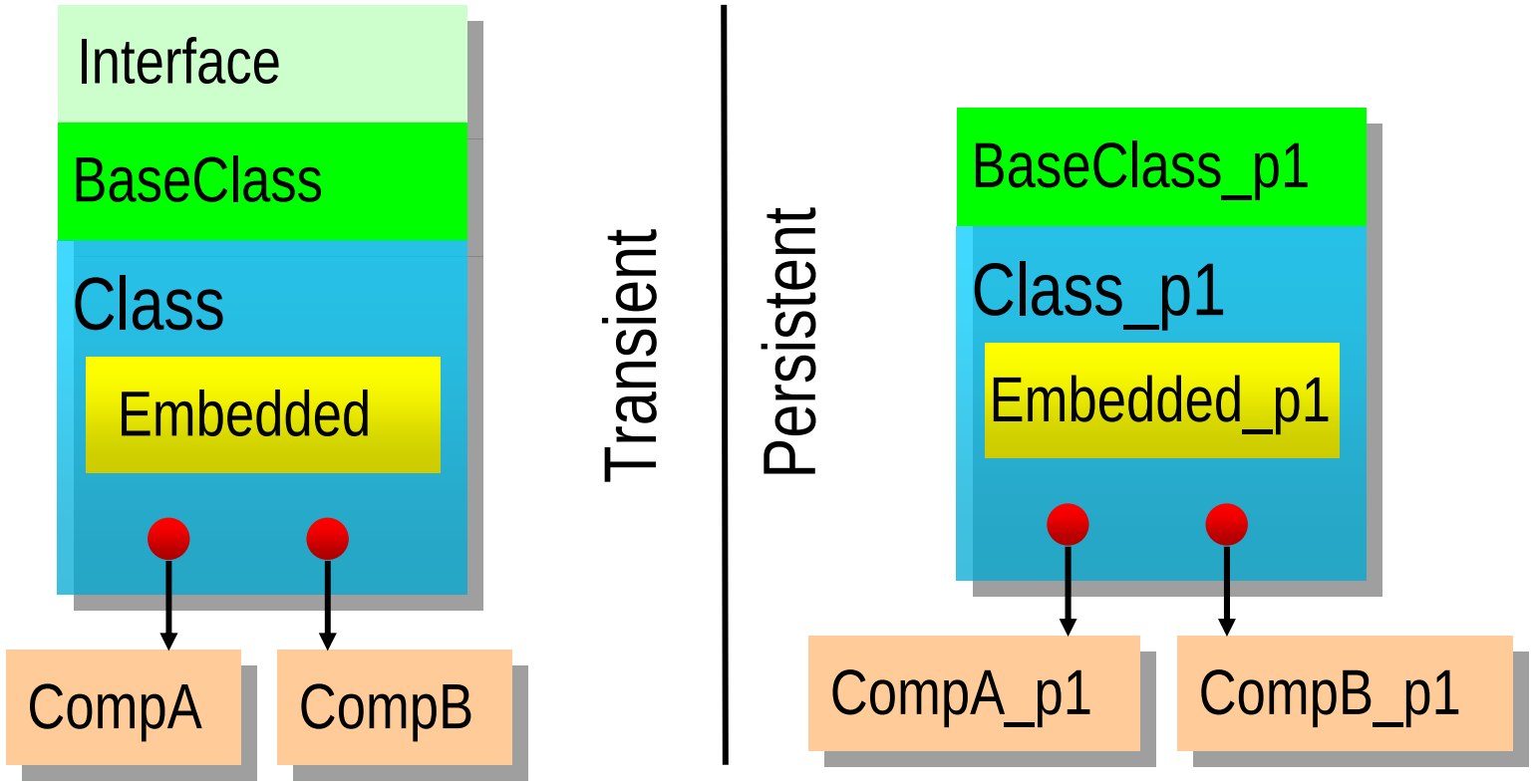
- Schema evolution is happening all the time
  - Often unnoticed on the application (transient) side
    - Class names do not change
    - Data representation is hidden behind interfaces
    - No ‘memory’ of the previous class shape
  - Quite visible on the persistent side
    - Data is more exposed
    - History of different class shapes, reaching years in the past
    - Class names still do not change
      How can we keep track of the different versions?
- Occasional redesigns of large portions of the data model
- Ideally schema evolution should be supported by the persistency layer
  - ROOT automatic schema evolution
    - Works in simple cases, fails in more complicated ones
  - ROOT custom streamers
    - Work in streamed mode, do not work in the split mode
- No satisfactory solution – maybe ATLAS needs to provide their own

Supporting Schema Evolution in Athena

- Starting requirements:
  - Preserve old versions of the schema
    - Maintain a library of conversion methods for reading the old data
  - Prevent ROOT automatic schema evolution in cases where it would fail
- Solution: create a separate, independent persistent data model
  - Typenames in the persistent data model are different from their transient equivalents
  - Schema version is part of the persistent typename
    - All versions are stored in the data dictionary
  - By introducing new versions we can ensure that persistent classes do not change beyond the limits of ROOT automatic schema evolution
  - Data objects need to be written as persistent types
    - Not possible in ROOT to write one type and read it as another type
    - Conversion has to happen both when reading and writing

The Persistent Data Model

- Example of a transient class and its persistent representation:

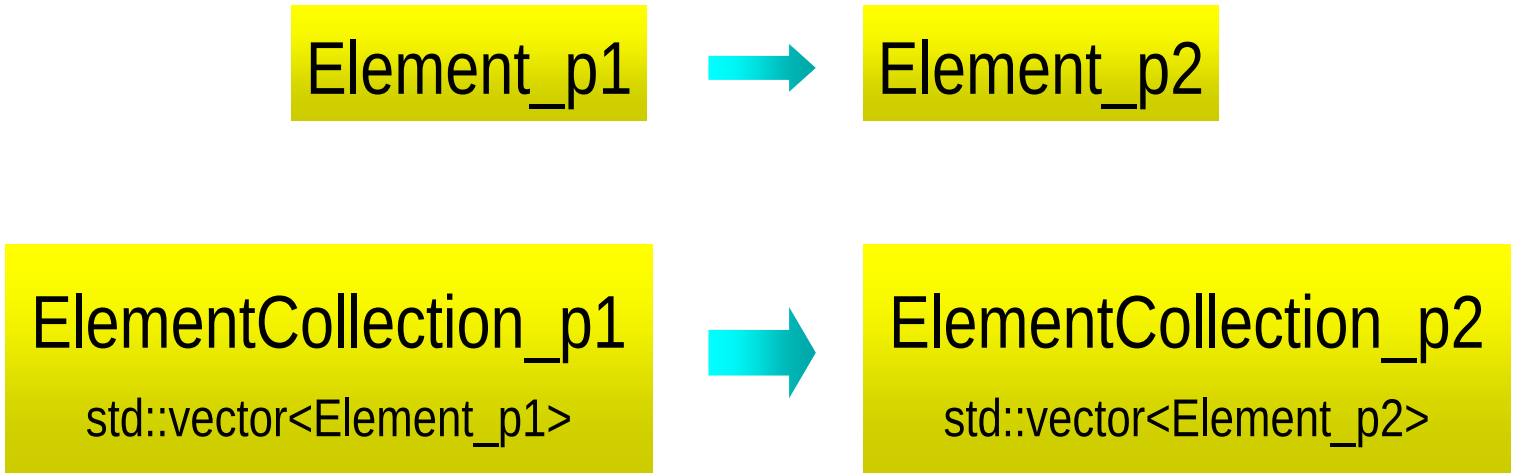


T/P Converters

- T/P Converters provide methods to convert data objects between their transient and persistent representations
  - One converter per each persistent representation
    - Old versions provide only persistent->transient conversion for reading
- T/P Converters are separate classes from persistent representations
  - Conversion methods need to operate on transient types – better to keep them apart to maintain data model separation
  - To make implementation easier, they are created by specialized base converter template classes
    - Simple and elegant on transient side, ugly in the data dictionary
    - Originally T/P converters were strictly transient objects
      - Now for direct ROOT access they need to be in the data dictionary
  - Abstract converter API makes handling converters easy even if the object type is not known

Chain Effect in Schema Evolution

- „Chain effect” is a result of introducing version numbers in the type names of the persistent data model. Changing the version of a type referenced by another object is causing a schema change for the referencing object, and the effect propagates

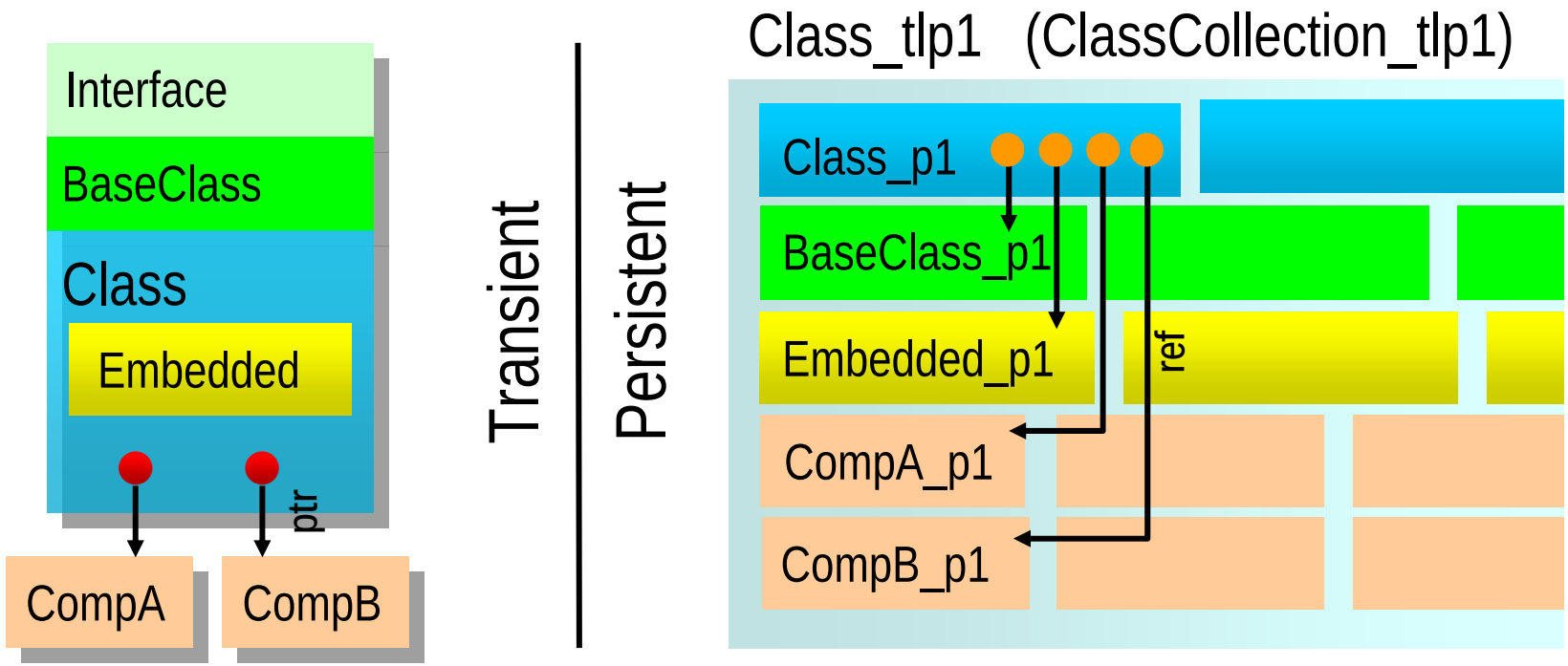


Typeless Persistent References

- To avoid the chain effect, we decided to replace direct C++ type dependencies in the persistent data model by typeless persistent references (TPObjRef)
  - TPObjRef contains only integers that have meaning to the TP converters
  - The new persistent data model does not any more (in general) contain pointers, inheritance or embedding
- Object components referenced by TPObjRef are not part of the same object in the C++ sense, so ROOT will not write them out automatically
  - To assure all elemental object components are stored together, they are gathered in special container objects, called top-level persistent objects

Top-Level Storage Objects

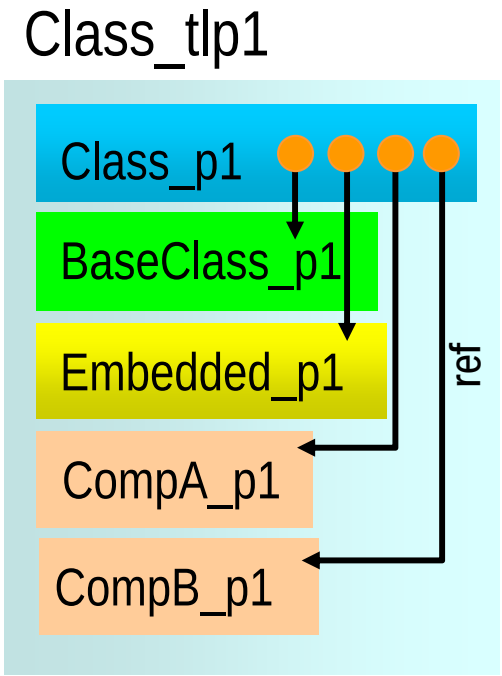
- Top-level persistent objects consist of vectors of component objects



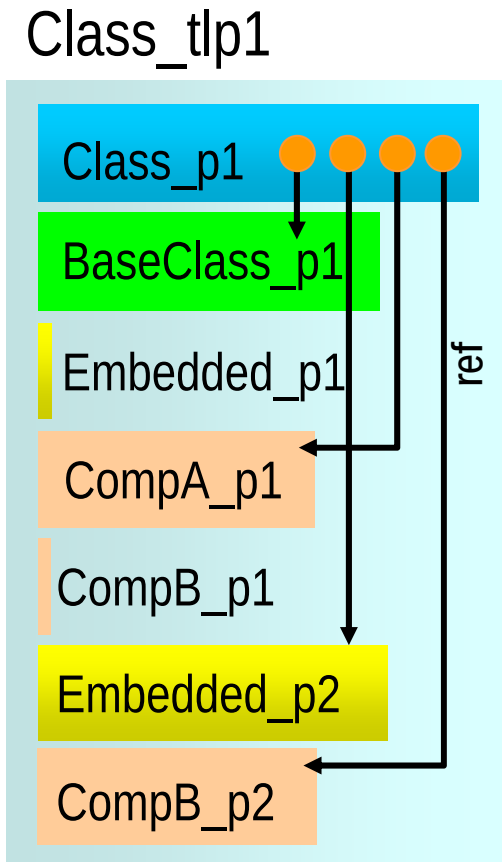
- Top-level objects are managed by top-level TP converters
  - Top-level converters own all TP converters for component objects
  - They take care of placing objects in the storage vectors

Schema Evolution with Top-Level Objects

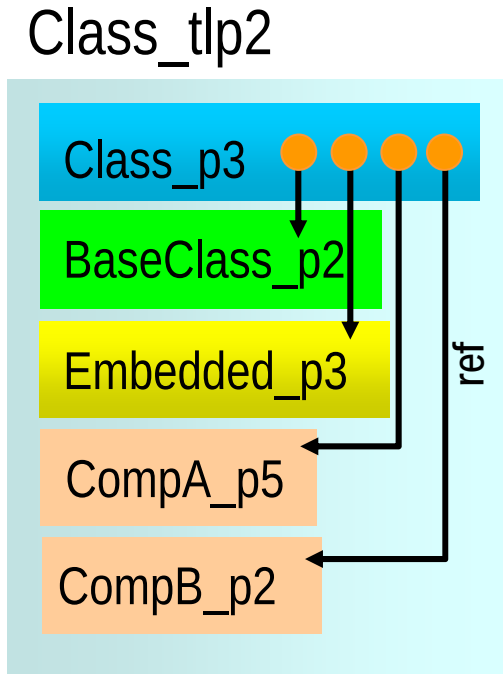
Automatic schema evolution – no changes



New versions of the component objects



New version of the Top-level object

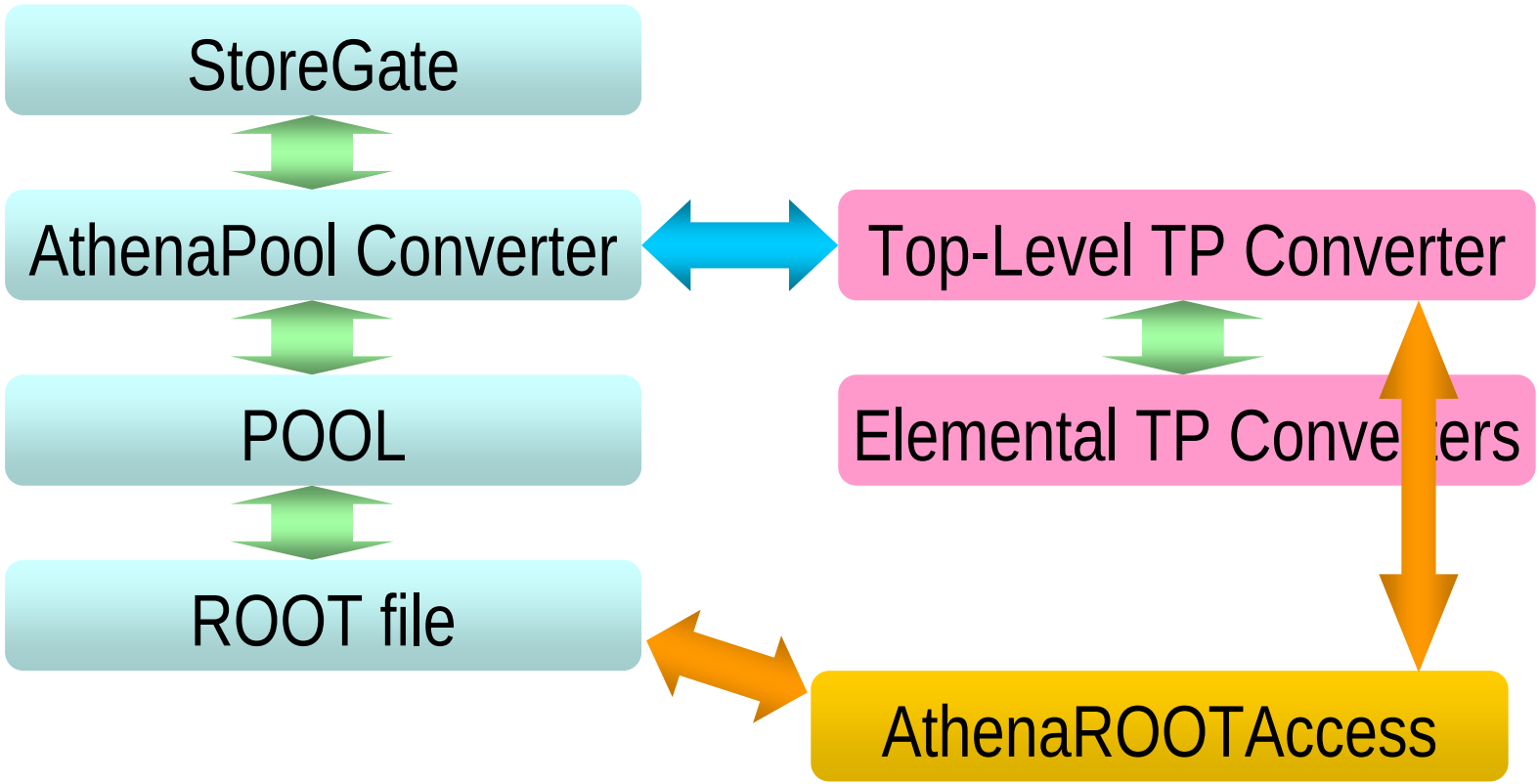


T/P Separation and AthenaPool Converters

- The T/P separation framework is inserted between Athena and the POOL persistency layer at the level of AthenaPool converters
  - Each StoreGate object type has an AthenaPool converter
    - The converters are used for writing to and reading from POOL
  - By default they are generated automatically by CMT and they do no conversion
    - AthenaPool converters can be customised
- A custom AthenaPool converter is needed to use T/P separation
  - Custom AthenaPool converter should own instances all versions of the top-level T/P converters for a given StoreGate object type
    - The newest version is always used when writing
  - After writing an object, AthenaPool converter returns POOL Token
    - All Tokens are stored as strings in the Event DataHeader
  - When reading, the correct version of a top-level TP converter is determined using type information from the Token

Complete Persistency Stack in AthenaPool

Original persistency layers in Athena
Persistency layers in Athena with T/P separation



Performance

- Improving I/O performance was not the original goal
  - Main focus was on schema evolution support
  - The solution was only supposed not to seriously degrade performance
    - Conversion between transient and persistent state had to introduce additional CPU load
- The first prototype based on the tracking data model showed:
  - Decrease in disk space usage by about 25%, caused mainly by:
    - Simpler data model (but not by much)
    - Better control over what data is written out
  - Slight improvement in I/O performance – the time spent in data conversion was recuperated by:
    - Less time spent in ROOT due to somewhat simpler data model
    - Smaller file size
  - Performance requirement was met

Performance with Top-Level Objects

- The new persistent state representation (with top-level objects, typeless references and object decomposition) improved read performance by a surprising factor
  - The Tracking data read speed improved 4 times
  - Various packages read speed improved up to 10 times
  - Winner: LArRawChannel data - **20 times faster**
    - DataVector with 183'000 small elements (~20 bytes each)
- File size reduction remained in the 20%-40% region
- We believe the reason for performance improvement is the difference in ROOT streamed and split writing mode
  - Streamed mode writes type information for every object and sub-object
    - Requires more processing per object
  - Removing pointers from ATLAS persistent data model allows ROOT writing in the split mode

Direct Access From ROOT

- End users may want to work with data files directly from ROOT
  - Without the Athena framework overhead
  - But using the transient classes, not the persistent state representations
- AthenaROOTAccess
  - Package enabling automatic use of T/P converters without Athena
  - Creates a proxy TTree with branches corresponding to the transient schema
    - The tree contains branches of special new type: TBranchTPConvert
    - Friend of the original TTree with persistent data
  - Accessing the 'transient' TTree automatically triggers reading from the 'persistent' TTree and T/P conversion
    - Standard tools like TTree::Draw() work as well
    - The end-user is entirely insulated from the persistent representations
  - Locating the correct T/P converters is done via the data dictionary
    - T/P converters must be entered into the dictionary now

Conclusions

- T/P separation is being widely adopted in ATLAS EDM
  - Persistent classes are being added in Athena release 13
  - With the goal to have the entire EDM T/P separated in release 14
- Explicit persistent state representation of data objects allows support for schema evolution and dramatically improves read performance
  - ATLAS expects to be able to achieve 10-15MB/s read speed
- Creating persistent classes by hand resulted in optimized and better thought through data model
  - Reduced file size
  - Quite a few old errors found and fixed
  - The extra effort required from the developers is hopefully justified
- The effects of explicit state representation on ATLAS ability to evolve EDM while maintaining backward compatibility will be visible in the future
  - Time will tell