cling

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Creating cling, an interactive interpreter interface for clang

cling?

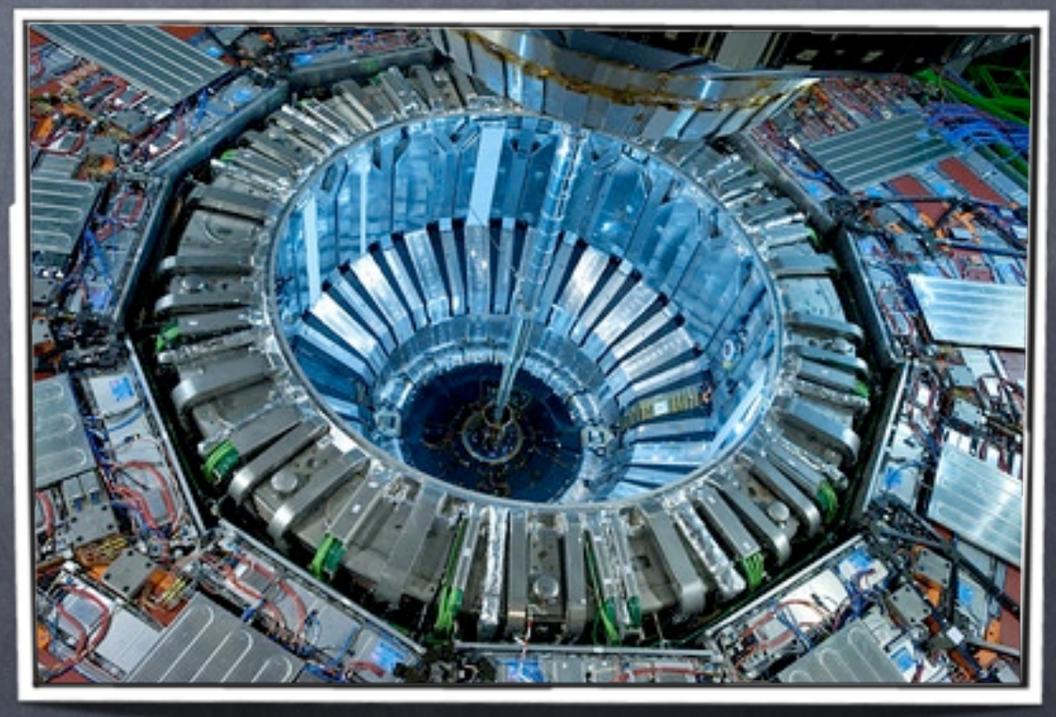
- C++* interpreter*

*: not really

- interactive, i.e. prompt
- used like python, bash and php, but C++
- cling: "C++ LLVM-based Interpreterg"

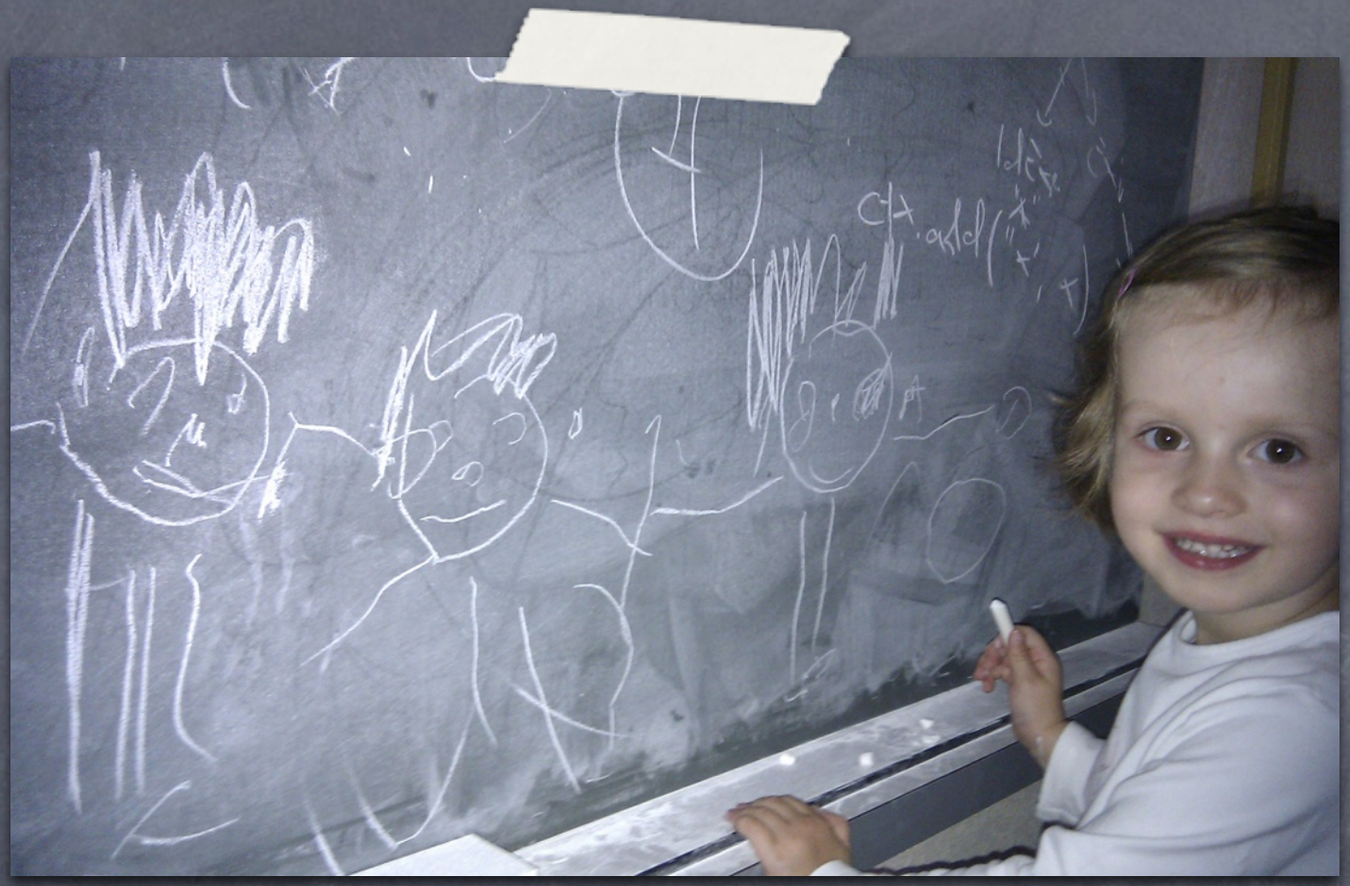
context:

- CERN's LHC: petabytes of serialized C++ objects / year
- analyzed by >10,000 physicists world-wide
- performance counts
- approx 20M LOC C++



legacy:

- experience through CINT:
  C++ interpreter, 15 years old
- main use in data analysis framework
  @ http://root.cern.ch
- limitations, limitations... (parsing, design)
- re-write with clang the obvious solution!



C++ dialect:

- statement at translation unit scope

```
f();
```

- implicit #includes

```
void f(){Klass o; o.f();}
```

- automatic loading of dynamic libraries
- implicit auto keyword

```
i=12;
```

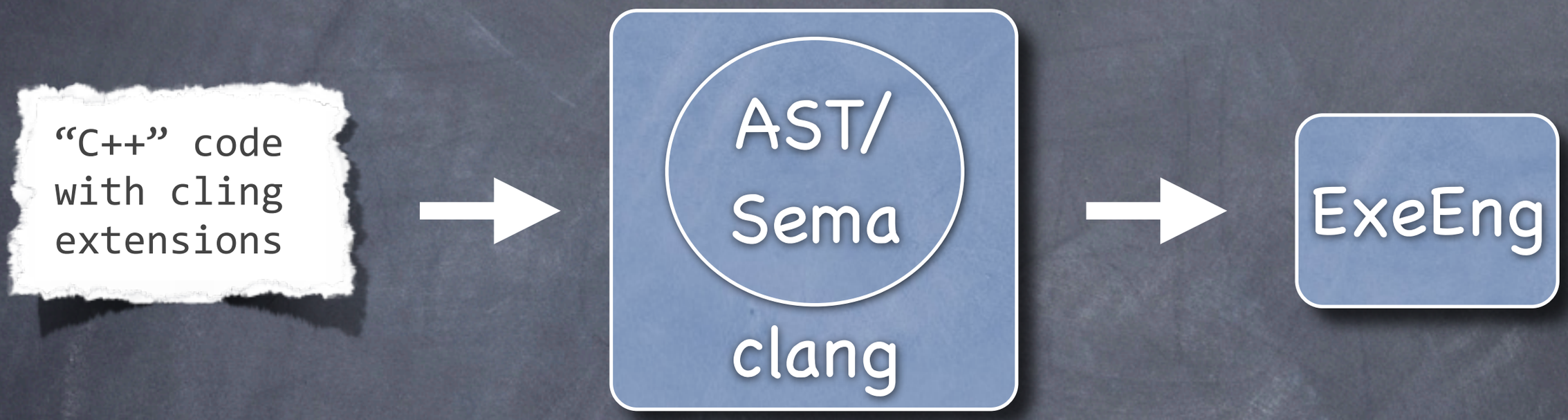
- dynamic scopes

```
void f(){
  File f("f.root");
  hist->Draw();
}
```

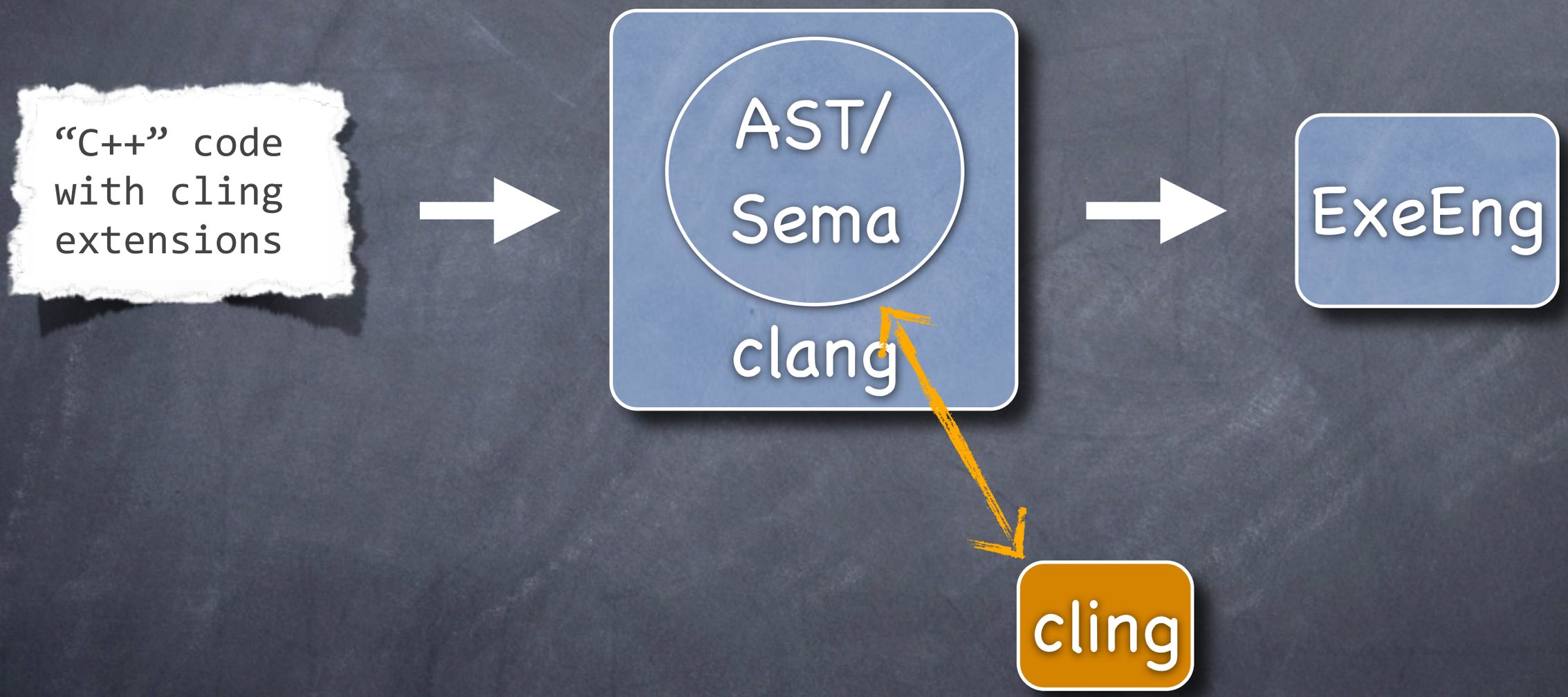
"interpreter"?

- not lli, not a traditional interpreter
- instead:
  - runtime evaluation
  - pseudo-instantaneous response
    (c.f. compile + link + load + disk I/O)
  - ahead of time compilation where possible

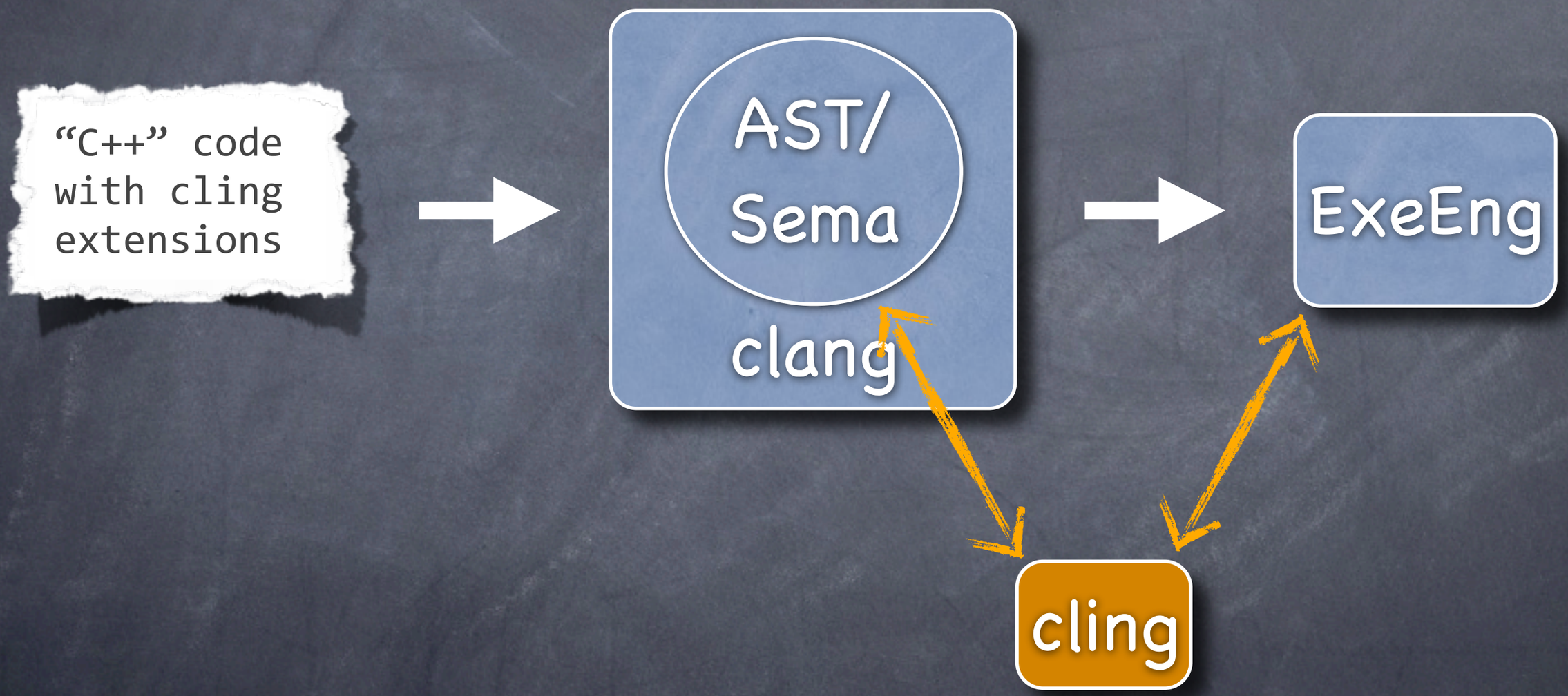
big picture:



big picture:



big picture:



use cases!

use case: development

- explorative development of algorithms:

```
$ .x myCode.C(47, ”argument”)
```

```
// myCode.C:
void myCode(int, const char*){}
```

- edit, run, unhappy about [illegible], run, unhappy a

```
void f() {}
```

  - in CINT, re-interpret
    300x faster than full recompile, link, load!

use case: dev't (2)

- code looks the same wherever it is (C++!)
- easy migration from physicist to framework
- simple transition interpreted / compiled:

```
$ .x myCode.C
```

```
$ .x myCode.C+
```

use case: signal / slot

- intuitive function call:

```
fCheck->Connect("Toggled(Bool_t)",
   "MyClass",this,"CallMe(12)");
```

- runtime binding
- runtime parameter values
- easily extensible (a string!)

use case: plugins

- function call through string

```
void P110_THDFSFile() {
   gPluginMgr->AddHandler("TFile", "^hdfs:", "THDFSFile",
      "THDFSFile(const char*,Option_t*,const char*,Int_t)");
}
```

- can depend on runtime
- loose, optional coupling of libraries

use case: python binding

- C++ reflection + interpreter: control over objects and calls
- runtime discovery of types + functions: no stubs
- both ways: python <-> C++

use case: python binding

```
// Create a one dimensional function and draw it
fun1 = new TF1("fun1", "abs(sin(x)/x)", 0, 10);
fun1->Draw();
```

```
from ROOT import TF1
# Create a one dimensional function and draw it
fun1 = TF1('fun1', 'abs(sin(x)/x)', 0, 10)
fun1.Draw()
```

- use the same (C++) library

and more use cases:

- configuration management
- reflection for serialization, documentation
- beyond high energy physics:
  - AI for computer game
  - remote configuration of integrated devices
- add your own (e.g. debugger?)

dissecting cling!

parts:

- interpreter: parses, JITs, executes (C++)
- meta processor: e.g. unload source file, debug (steer)
- user interface: e.g. prompt loop, exception handling

prompt $

think of

prompt $

think of

```
$ int i(17)
$
```

prompt $

think of

```
$ int i(17)
$ i=42
$
```

prompt $

think of

```
$ int i(17)
$ i=42
$ int f() {
   ...
```

prompt $

think of

```
$ int i(17)
$ i=42
$ int f() {
   ... return
   ...
```

prompt $

think of

```
$ int i(17)
$ i=42
$ int f() {
   ... return
   ... ++i;}
$
```

prompt $

think of

```
$ int i(17)
$ i=42
$ int f() {
   ... return
   ... ++i;}
$ f();
```

prompt $

```
$ int i(17)
$ i=42
$ int f() {
   ... return
   ... ++i;}
$ f();
```

1. transform input: declarations vs. statements
2. add to existing AST ("ever-growing AST")
3. remap globals
4. run only new initializers
5. call statement stub

```
using namespace __cling;
namespace __cling {
  int i={17};
  int f() { return ++i; }
}
void cling_prompt_0() {i=42;}
void cling_prompt_1() {f();}
```

library auto-loading:

1. intercept on unresolved symbol
2. look up in our symbol -> library map
3. dlopen
4. rewire global mapping to symbol

#includes optional:

- PCH for everything
- multiple PCHs
- need to prune PCH overlaps / vetoed types via AST manipulation and dependency analysis

compiled <-> interpreted

- recursive* ExecutionEngine / JIT invocation

```
void f() { cling::Interpret("f();"); }
```

```
$ .x f.C
```

* yes, perfect recursion!

- symbol resolution into libraries

dynamic scoping:

```
void f(){
  File f("f.root");
  hist->Draw();
}
```

- file opens a dynamic scope
- unknown id: query file's objects
- but need valid AST:
  - mark unknown identifiers dependent
- transform into delayed evaluation:

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- file opens a dynamic scope
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```
void f(){
  File f("f.root");
  hist->Draw();
}
```

```
void f(){
  File f("f.root");
  cling::eval("hist->Draw();");
}
```

un-/reloading

```
// Struct.h, v1.0
struct S {
  int f() { return 17; }
};
```

```
// Struct.h, v2.0
struct S {
  int f() { return 42; }
};
```

```
$ .L Struct.h
$ S o
$ o.f()
17
$ .U Struct.h

// edit Struct.h

$ .L Struct.h
$ S o
$ o.f()
42
```

un-/reloading

- checkpoint ever-growing AST (undo points)
- prune top level decls if dependency analysis allows
- global mapping magic

conclusion

cling:

- ahead-of-time compiler
- extends C++ for ease of use as interpreter
- interfaces clang
- isn't finished yet!

main ingredients:

- interactive prompt
- library auto-loading
- #includes optional
- dynamic scoping
- calling compiled <-> interpreted
- un- / reloading of libraries and source

wish list:

- growing MemoryBuffer with "top level decl not finished" callback
- AST dependency analysis:
  - AST still valid after removal of node N?
- shortcut JIT -> shared lib

santa:

- can anybody help us with AST dependency graph?
  need to do it ourselves?
- possible use cases: code dependency / dead code analysis, refactoring

status:

- some things work: simple prompt, library <-> interpreter (even recursion), auto-loading libs
- currently attacking dynamic scope, extending prompt, interface to high energy physics data analysis software
- for the rest, you have seen the plan!

where we are:

- svn co http://root.cern.ch/svn/root/branches/dev/cling
- code's copyright / license points to clang's
- would like to move into clang repo once cling is a bit more mature / usable - hopefully within this calendar year (santa!)