ROOT as a Python module

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Data Analysis Framework

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Introduction

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PyROOT

- ROOT can be used as a Python module via PyROOT
  - Python-C++ bindings
  - `import ROOT`
- Access all the ROOT C++ functionality from Python
  - And also user-defined C++ code!
- Automatic, dynamic
  - No static wrapper generation
  - Dynamic python proxies for C++ entities
  - Lazy class/variable lookup
- Powered by the ROOT type system and Cling
  - Reflection information, JIT C++ compilation, execution

The New PyROOT

- Available since v6.22
- Based on Cppyy
  - Set of packages for automatic Python-C++ binding generation
  - Forked from old PyROOT by Wim Lavrijsen
- Goal: benefit from all the new features of Cppyy
  - Modern C++ support
- ROOT-specific *pythonizations* added on top

A Concrete Example

- Automatic bindings + Pythonizations

```
import ROOT

f = ROOT.TFile('myfile.root')

t = f.mytree
# vs f.GetObject('mytree')
```

`TFile` is a (dynamic) Python proxy of a C++ class

`f` is a (dynamic) Python proxy of a C++ object

Pythonization: access tree as an attribute

ROOT Pythonizations

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A Pythonic ROOT

- **Pythonization**:
  - Code that modifies the behaviour of a C++ class when used from Python
  - Makes it easier / more “pythonic” to use that class
- A number of pythonizations are already available (*docs* in the reference guide!):
  - TFile, TTree, RDataFrame, RVec, …
  - RooFit → see Jonas’ presentation on Wednesday

RDataFrame ⟷ NumPy

- Process dataset with `RDataFrame`, convert columns to NumPy arrays

```
from ROOT import RDataFrame
df = RDataFrame('myTree', 'file.root')

# Apply cuts, define new columns
df = df.Filter('x > 0').Define('z', 'x*y')

cols = df.AsNumpy() # cols is a dict of NumPy arrays
```

Tutorial here

- Construct an `RDataFrame` from NumPy arrays

```
df = ROOT.RDF.MakeNumpyDataFrame({'x': x, 'y': y})
```

Tutorial here

Since v6.18

Python Callables in RDF Operations

- New decorator to just-in-time compile Python callables
  - Can be used e.g. in `Filter`, `Define`

```
df = RDataFrame('myTree', 'file.root')

df.Filter('x > 0') # jitted C++ expression

@ROOT.Numba.Declare(['int'], 'bool')
def my_cut(x):
   return x > 0

df.Filter('Numba::my_cut(x)') # jitted Python callable
```

Tutorial here

Since v6.22

Python Callables in RDF Operations (II)

- Coming soon:
  - No decorator needed
  - Jitting done under the hood

```
df = RDataFrame('myTree', 'file.root')

def my_cut(x):
   return x > 0

df.Filter(my_cut, ['x']) # jits Python callable
# or even df.Filter(lambda x: x > 0, ['x'])
```

TFile Context Manager

- Use `TFile` instances in a `with` block à la Python file
  - The `TFile` is closed no matter what happens in the block
  - You can read or write into the `TFile`
  - Objects owned by the `TFile` won't survive the end of the block!

```
with TFile.Open('file.root', 'recreate') as f:
   h = TH1F('my_histo', 'My histo', 10, 0, 10)
   ...
   f.WriteObject(h, 'my_histo')

# h is None here!
```

Tutorial here

Will be in v6.28

User Pythonizations

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Define Your Own Pythonizations

- New decorator to create pythonizations for user C++ classes
  - User defines a function that performs the pythonization
  - The function is decorated with `@pythonization` → **registers** pythonization
  - The function is executed **lazily**, only if the class is used

```
@pythonization('MyCppClass')
def my_pythonizor_function(klass):
   # Inject new behaviour in the class
   klass.__str__ = lambda o : 'A MyCppClass object'

obj = ROOT.MyCppClass() # triggers pythonization

print(obj) # prints 'A MyCppClass object'
```

Python proxy of the C++ class

Since v6.26

How To Use @pythonization

- Pythonize classes in namespaces (default is global)

```
@pythonization('vector<int>', ns='std')
def my_pythonizor_function(klass):
    ...
```

- Pythonize all classes with a certain prefix

```
@pythonization('vector<', ns='std', is_prefix=True)
def my_pythonizor_function(klass):
    ...
```

How To Use @pythonization (II)

- Decorators for multiple classes can be stacked

```
@pythonization('A')
@pythonization('B')
def my_pythonizor_function(klass):
    ...
```

- To learn more:
  - See this tutorial
  - Check how the decorator is applied to ROOT classes for real pythonizations on ROOT's github repository

A bit on building PyROOT

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Multi-Python Builds

Since v6.22

- Single ROOT build for Python 2 & 3
  - Eases the transition from Python 2 to 3
  - Support Python 2 for as long as the experiments need it
- How it works
  - By default, it will build for both if it finds them in the system
  - Hints can be provided to point to specific Python installations
  - Building for a single Python version is still possible
  - More info on the ROOT website

Summary

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Summary

- New PyROOT available since v6.22
  - Access to modern C++ thanks to cppyy
- Pythonizations
  - Make it easier to use C++ entities from Python
  - Many ROOT pythonizations already available
  - User-defined pythonizations are also possible with the `@pythonization` decorator

Backup Slides

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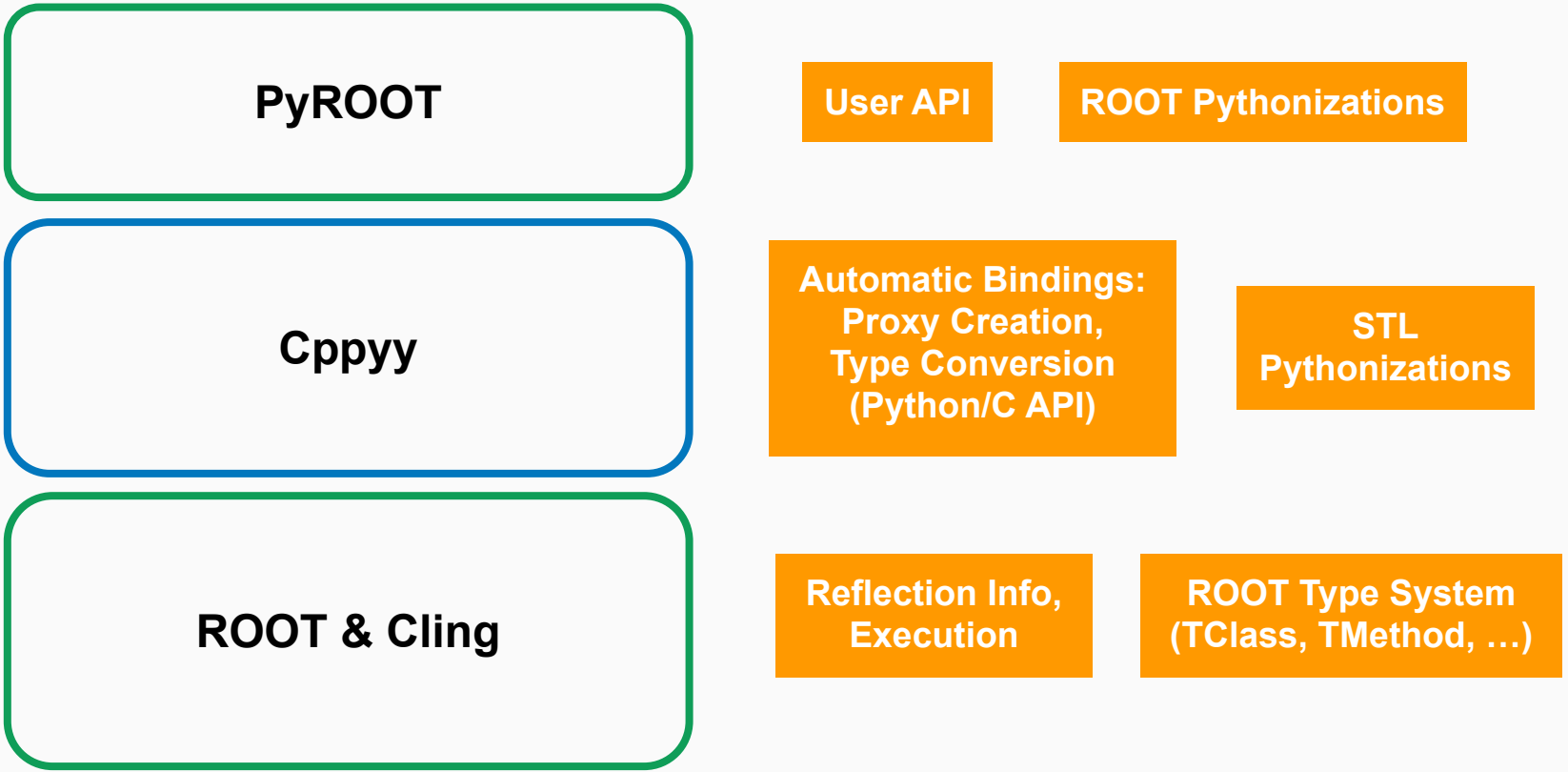
The New Structure



New PyROOT: Variadic Templates

- Support for variadic template arguments of functions

```
>>> import ROOT
>>> ROOT.gInterpreter.ProcessLine("""
template<typename... myTypes>
int f() { return sizeof...(myTypes); }
""")
0L
>>> ROOT.f['int', 'double', 'void*']()
3
```

New PyROOT: Lambdas

- Possible to use C++ lambdas from Python

```
>>> import ROOT
>>> ROOT.gInterpreter.ProcessLine(
"auto mylambda = [](int i) { std::cout << i << std::endl; };")
140518947094560L
>>> ROOT.mylambda
<cppyy.gbl.function<void(int)>* object at 0x35f9570>
>>> ROOT.mylambda(2)
2
```