Support for LAr Dual Phase detector geometry in LArSoft

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LArSoft geometry "service"

LArSoft geometry description is accessed via the Geometry service.
It contains:

- position and relations of the TPC elements
- information on the optical detector
- *(deprecated?)* access to "auxiliary" detector information (also available via AuxDetGeometry service)
- mapping between logical readout channels and detector elements

It also provides tools to process all detector elements in a loop (e.g., all wire planes), and more stuff.

```cpp
#include "larcore/Geometry/Geometry.h"
// ...
auto const& geom = *(lar::providerFrom<geo::Geometry>());
```

Geometry description in LArSoft

The detector is represented as a hierarchy of components:
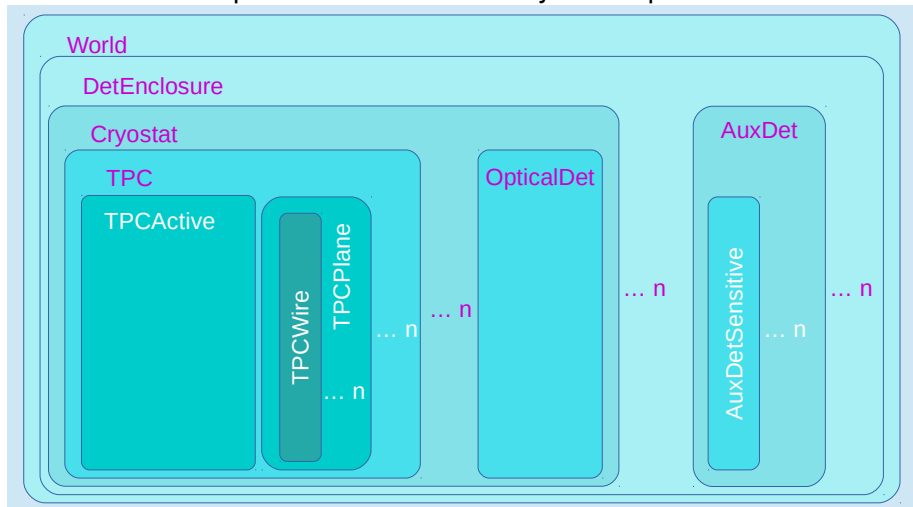
Extending the geometry service

- many times, LArSoft geometry has been extended to accommodate specific needs
- each new detector would challenge assumptions
- the extensions are implemented in a "generic" way

Dual Phase detectors challenge the assumption that the drift direction be horizontal

$\rightarrow$ "horizontal" like in "perpendicular to cosmic rays"

This is the challenge we are set to meet.

Beam Direction

Action list
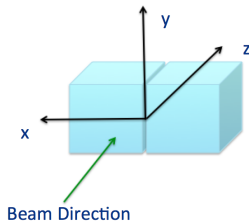
For LArSoft to seamlessly support dual phase detectors:

1. geometry service must provide proper description and algorithms
2. event generators and simulation have to use it correctly
3. reconstruction must use use it correctly, too

The generation and higher level (3D) reconstruction are less affected, while readout simulation is the most sensitive to the drift direction.

This is an update on the first item.

Changes in geometry

The extension of the geometry functionality comprises three areas:

1. remove geometry assumptions from the internals, e.g.
   - $\Rightarrow$ don't take x as the drift component
   - $\Rightarrow$ don't require wires to be cylinders
2. change the interface to allow all necessary information
   - $\Rightarrow$ e.g., NearestWire(**double** y, **double** z) is not going to work

The generation and higher level (3D) reconstruction are less affected, while readout simulation is the most sensitive to the drift direction.

As new unsatisfied assumptions are found, geometry provider will be extended to provide the layer necessary of address it.

Status of the work

- some internals have been heavily rewritten
- drift- and plane-related projections have been moved to the plane description class
  - $+$ the same for all experiments: interoperable!
  - $-$ the same for all experiments: no customisation!
- extended interface, e.g. with `NearestWire(TVector3 const&)`
- old interface still there, for legacy behaviour
- all unit tests, including geometry tests for LArIAT, ArgoNeuT, MicroBooNE and DUNE geometries, pass
- continuous integration tests (on single phase) fail on DUNE simulation
- other continuous integration tests yield different results and need to be checked

Outlook

- geometry code supporting *generic* drift direction is available: branches `feature/gp_protoDUNEDP_trueOrientation` in `larcoreobj`, `larcore` and `dunetpc`[1]
- `dunetpc` includes a temporary "normal orientation" Dual Phase geometry and a unit test on it
- no performance hit observed so far
- integration test failure is being investigated
- next, I'll propose the merging into LArSoft
- then, event display and simulation need to be addressed
  $\rightarrow$ I'll provide support for these steps

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[1]And `argoneutcode` and `lariatsoft`.

Backup

• test geometry dump for a dual phase detector
• documentation resources on LArSoft geometry

Geometry dump

This is part of the output of `geometry_dunedphase10kt_test` test:

```
There are 1 cryostats in the detector

    Cryostat C:0 volCryostat Dimensions [cm]: 1510.24 x 1510.24 x 6200.24
        mass [kg]: 1.85207e+07
        Cryostat boundaries: -x:-755.12 +x:755.12 -y:-810.09 +y:700.15 -z:-90.12 +z:6110.12
    There are 80 TPCs in the detector

        TPC C:0 T:0 volTPCActive has 2 planes.
        TPC location: ( -301 ; -600 ; 0 ) => ( 0 ; 600.03 ; 301 ) [cm]
        TPC Dimensions (W x H x L, cm): 301 (x) x 1200.03 (y) x 301 (z)
        TPC Active Dimensions: 300 x 1200 x 300 around ( -150.5 ; -0.015 ; 150.5 ) cm
        TPC mass: 151200
        TPC drift distance: 1200.02, direction: ( 0 ; 1 ; 0 )
        plane C:0 T:0 P:0 at (-150.5, 600.023, 150.5) cm, theta: 1.5708 rad
          normal to wire: 0 rad, with orientation horizontal, has 960 wires measuring U with a wire ;
          normal to plane: (0, -1, 0), direction of increasing wire number: (0, 0, 1) [wire frame no
          wire direction: (1, 0, 0); width 300 cm in direction: (0, 0, 1), depth 300 cm in direction
          wires cover 300 x 299.688 cm around ( -150.5 ; 600.023 ; 150.351 )
          bounding box: ( -300.5, 600.015, 0.5 ) -- ( -0.5, 600.03, 300.5 )
          pitch from plane 0 is 0
        plane C:0 T:0 P:1 at (-150.5, 600.007, 150.5) cm, theta: 0 rad
          normal to wire: 0 rad, with orientation horizontal, has 960 wires measuring V with a wire ;
          normal to plane: (0, -1, 0), direction of increasing wire number: (1, 0, 0) [wire frame no
          wire direction: (0, 0, -1); width 300 cm in direction: (0, 0, 1), depth 300 cm in direction
          wires cover 299.688 x 300 cm around ( -150.649 ; 600.007 ; 150.5 )
          bounding box: ( -300.5, 600, 0.5 ) -- ( -0.5, 600.015, 300.5 )
          pitch from plane 0 is 0
        drift direction is towards positive values: ( 0 ; 1 ; 0 )
```

(${MRB_BUILDDIR}/dunetpc/test/Geometry/geometry_dunedphase10kt_test.d/geometry_dunedphase10k.txt)

Resources

- general description of the geometry representation in LArSoft at
  http://larsoft.org/
  important-concepts-in-larsoft/geometry
- documentation in Doxygen format:
  http://nusoft.fnal.gov/larsoft/doxsvn/html
- mailing list, forum, people...