VD 3-view geometry (+ other updates)

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FD Sim / Reco meeting

15.02.2021

Outline

- New geometry layouts

- Simulation hooks

Three views II

Very recent addition:
a shielding plane to protect the readout from sudden change of the cathode voltage.
Total channel count similar to the previous scenarios. Two views also possible.

Induction 1: -48°
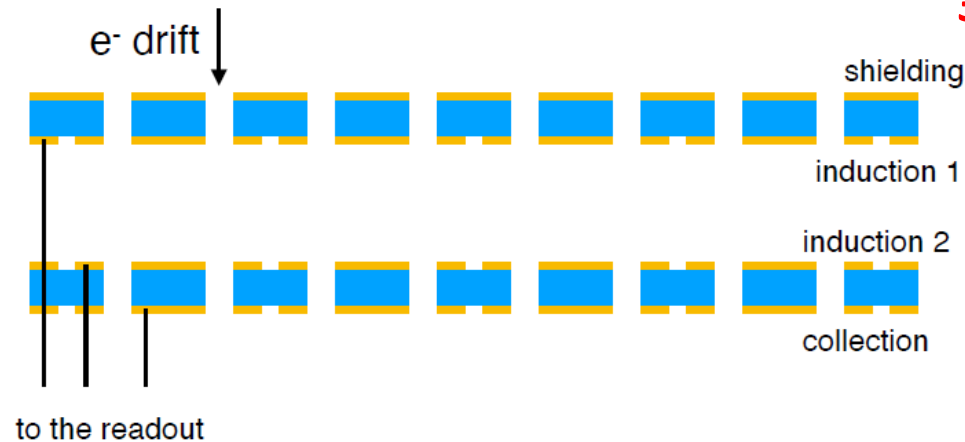Induction 2: 0°
Collection: 90°

"Proposal"

or

Induction 1: -48°
Induction 2: +48°
Collection: 90°

or

Induction 1: -30°
Induction 2: +30°
Collection: 90°

"30deg"

e⁻ drift ↓

shielding

induction 1

induction 2

collection

to the readout

Parametrization of the problem

- **Generate "wires" or strips to cover the area of CRU**

- Input parameters for geo generator:
  - CRU area (somewhat derived from # of orthogonal strips)
  - Strip pitch
  - Strip angle w.r.t beam (x axis on right)
  - Number of channels

- A pitch step Nch times along the pitch direction (perpendicular to strip) to define position for next strip

- Line-crop on the rectangular boundary of CRU to get the correct length and end points

Upper anode
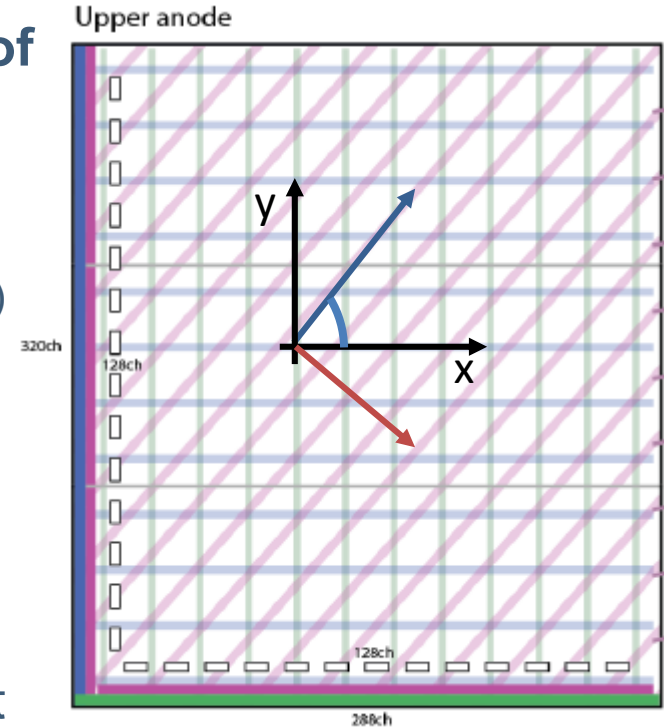
Calculator (no strip bridging b/w CRUs)

```
Inputs --->
CRU dimenions    : 1500 x 1690 mm2
Channel pitch    : 8.75 mm
Number of chans  : 256
Wire angle       : 48.0 (deg)
```
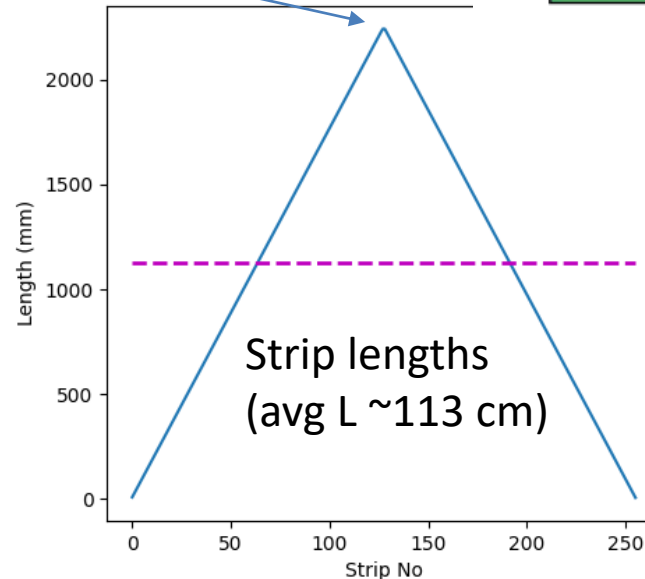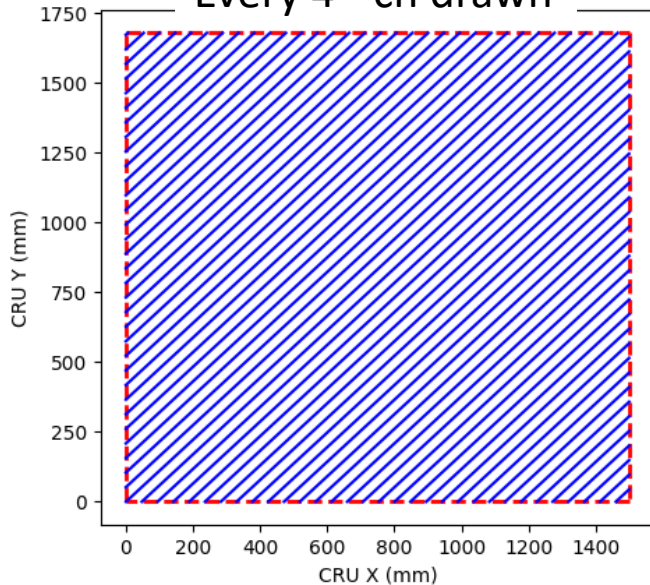
Inputs (not the latest numbers)

```
origin      : [    0 1690]
pitch dir : [ 0.74314483 -0.66913061]
wire dir  : [0.66913061 0.74314483]
dotprod    : 0.00000
total number of strips  : 256
strips per left side    : 129
strips per right side   : 129
strips per bottom side  : 127
strips per top side     : 127
Wire 127 has max length 2241.714824796913 (mm)
```
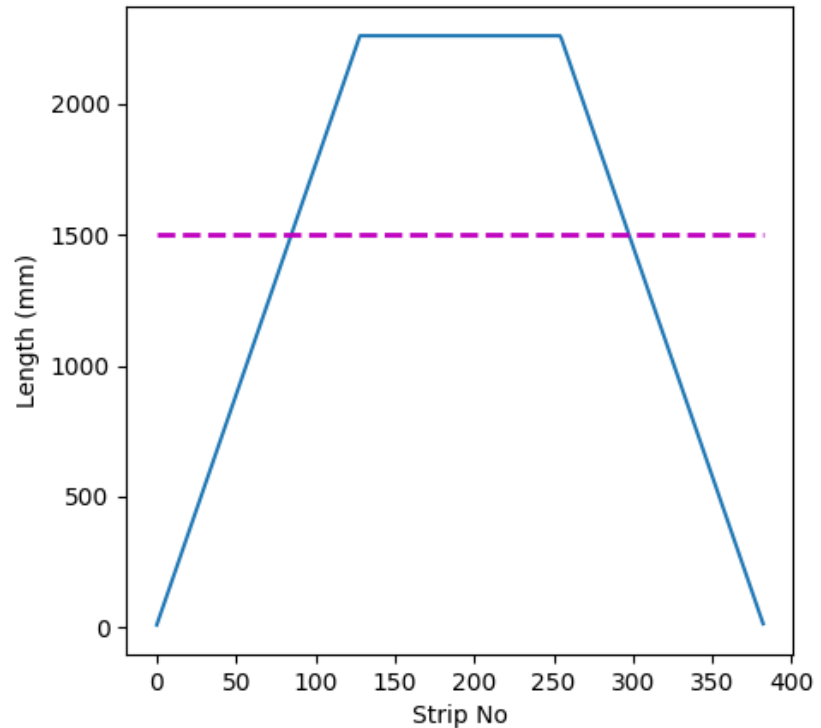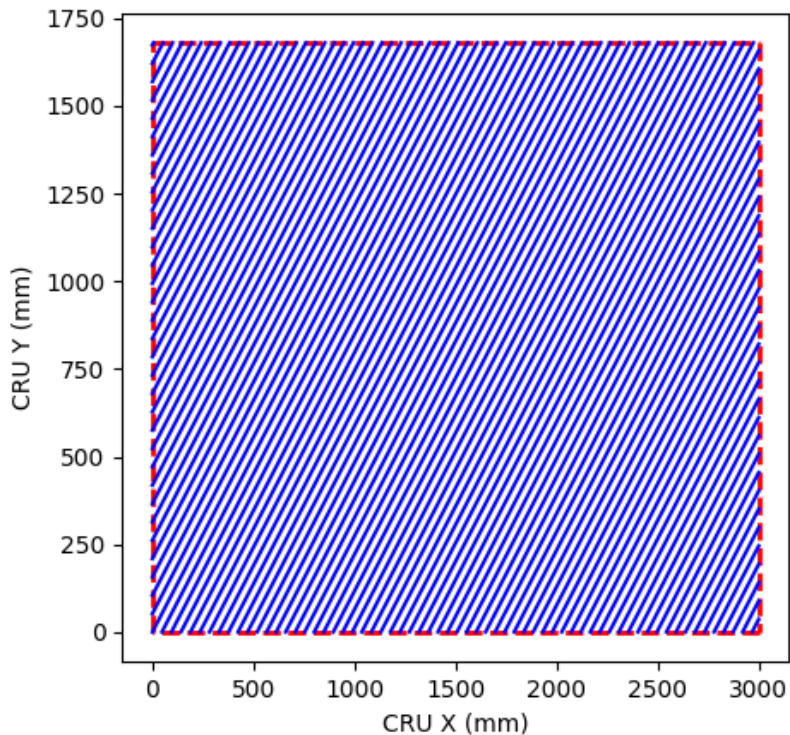
Upper anode

Every 4th ch drawn

Strip lengths
(avg L ~113 cm)
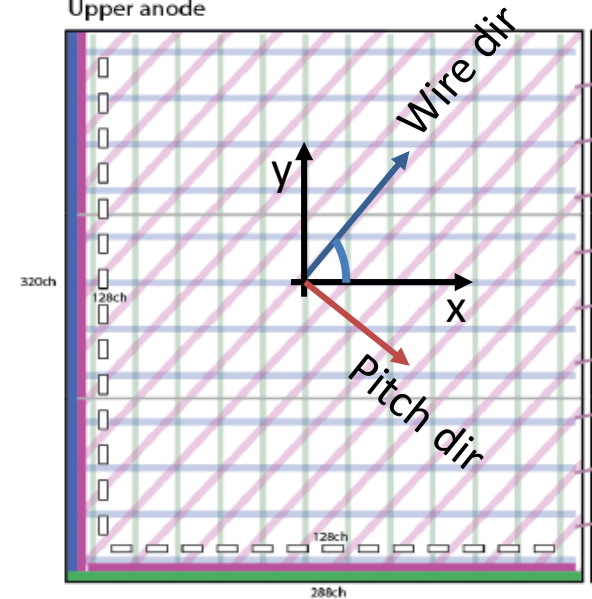
Calculator cont'd

As an exercise extend the length to two CRUs (~ bridged diagonal strips)

The average length is now 1.5 m.

VD geo available workspace layouts

- Single drift cell (upper)

- 3 x 3 CRPs (= 6x6 CRUs)

  - Active volume: 6.5 x 9 x 10 m3 (10m along z ~ beam direction)

Geometry/geometry_dune.fcl

```
dunevd10kt_1x6x6_2view_v1_geo: @local::dune10kt_geo
dunevd10kt_1x6x6_2view_v1_geo.Name: "dunevd10kt_2view_v1_1x6x6"
dunevd10kt_1x6x6_2view_v1_geo.GDML: "dunevd10kt_2view_v1_1x6x6.gdml"
dunevd10kt_1x6x6_2view_v1_geo.ROOT: "dunevd10kt_2view_v1_1x6x6.gdml"
dunevd10kt_1x6x6_2view_geo: @local::dunevd10kt_1x6x6_2view_v1_geo
```
→ VD 2-view layout

```
dunevd10kt_1x6x6_3view_v1_geo: @local::dune10kt_geo
dunevd10kt_1x6x6_3view_v1_geo.Name: "dunevd10kt_3view_v1_1x6x6"
dunevd10kt_1x6x6_3view_v1_geo.GDML: "dunevd10kt_3view_v1_1x6x6.gdml"
dunevd10kt_1x6x6_3view_v1_geo.ROOT: "dunevd10kt_3view_v1_1x6x6.gdml"
dunevd10kt_1x6x6_3view_geo: @local::dunevd10kt_1x6x6_3view_v1_geo
```
→ VD 3-view layout "proposal"

```
dunevd10kt_1x6x6_3view_30deg_v1_geo: @local::dune10kt_geo
dunevd10kt_1x6x6_3view_30deg_v1_geo.Name: "dunevd10kt_3view_30deg_v1_1x6x6"
dunevd10kt_1x6x6_3view_30deg_v1_geo.GDML: "dunevd10kt_3view_30deg_v1_1x6x6.gdml"
dunevd10kt_1x6x6_3view_30deg_v1_geo.ROOT: "dunevd10kt_3view_30deg_v1_1x6x6.gdml"
dunevd10kt_1x6x6_3view_30deg_geo: @local::dunevd10kt_1x6x6_3view_30deg_v1_geo
```
→ VD 3-view layout "30deg"

```
dunevd10kt_1x6x6_geo: @local::dunevd10kt_1x6x6_2view_geo

# temporarily assign workspace geometry
dunevd10kt_geo : @local::dunevd10kt_1x6x6_geo
```
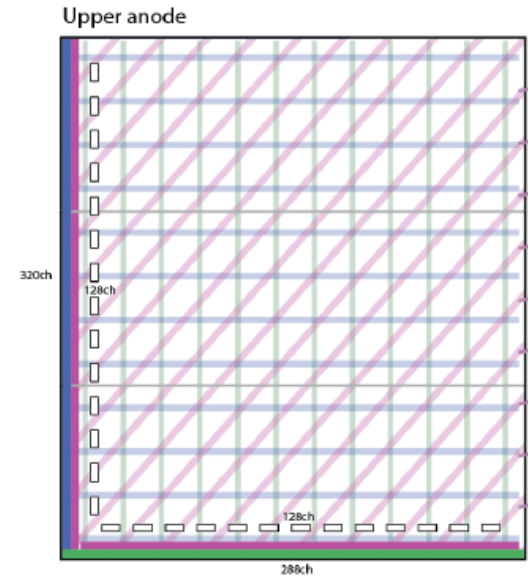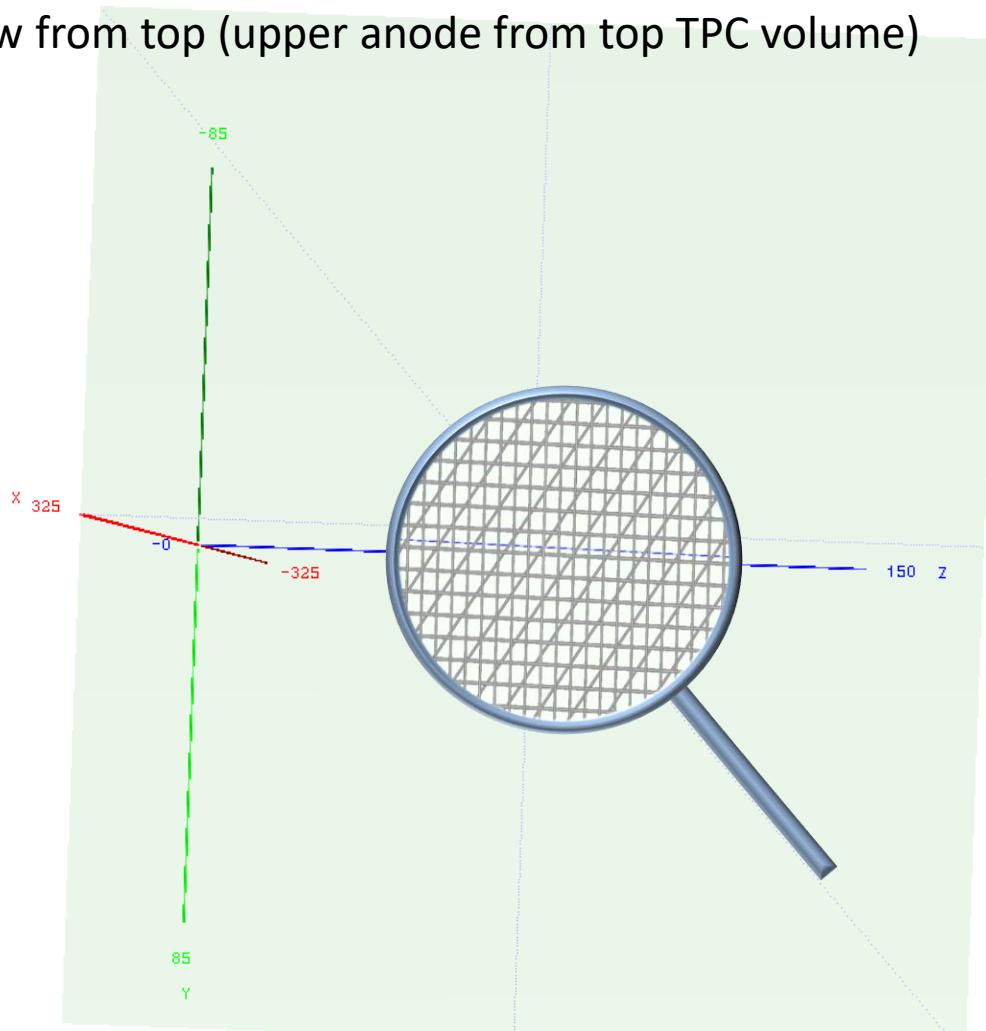→ No full VD geo yet

GDML view "wires" layout

View from top (upper anode from top TPC volume)

2-view geometry workspace

Filippo Resnati,
*VD TF Jan Collab*

```
$nChannelsViewInd = 320;
$nChannelsViewCol = 288;

$wirePitchY       = 0.527; # $widthPCBActive / $nChannelsViewInd;
$wirePitchZ       = 0.518; # $lengthPCBActive / $nChannelsViewCol;

$widthPCBActive   = $wirePitchY * $nChannelsViewInd;
$lengthPCBActive = $wirePitchZ * $nChannelsViewCol;

$borderCRM        = 0.05;      # dead space at the border of each CRM
```

- **The "active area" is calculated from on pitch and number of channels**
- The border gap around each CRU is 0.5 mm
- No variable spacing at CRP / super-CRP
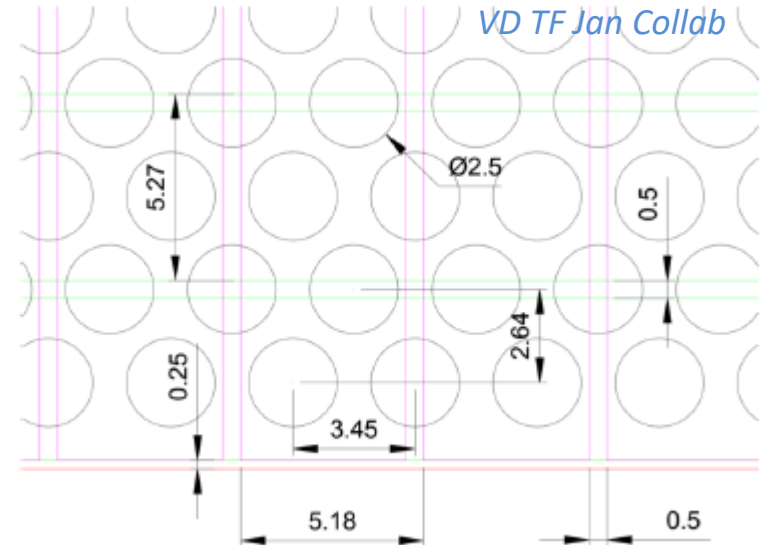
```
TPC C:0 T:35 (650.04 x 168.74 x 149.284) cm^3 at (0.02,421.85,821.012)
  drift direction (1,0,0) from cathode around (-325,421.85,821.012) through 650.03 cm toward 2 wire planes
  maximum wires on any plane: 320
  active volume (650 x 168.64 x 149.184) cm^3, front face at (0,421.85,746.42) cm;
  main directions: width (1,0,0) height (0,1,0) length (0,0,1)

  View type geo::kY
  View is geo::kInduction
  Number of wires : 320
  Wire pitch      : 0.527
  Theta Z         : 2.10734e-08

  View type geo::kZ
  View is geo::kCollection
  Number of wires : 288
  Wire pitch      : 0.518
  Theta Z         : 1.5708

Total number of channel wires = 21888
```

Readout pitch:

induction view:	5.27mm
collection view:	5.18mm
Anode board thickness:	3.2mm
Bias voltage:	1kV

CRU channel counts:

|	
induction view:	320
collection view:	288

3-view geometry proposal workspace

In the 3-view design, the 3rd (collection) view strips remain orthogonal to the beam. The 1st view is set along the diagonal of the CRU (48°). Strips across the long gap between a pair of CRUs on the same CRP are interconnected to save readout channels.

Channel count per CRU pair
1st view: 384
2nd view: 640
3rd view: 576
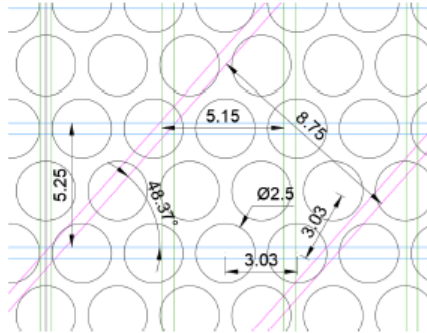
Filippo Resnati,
VD TF Jan Collab

Top anode single CRU

Upper anode

```
# views and channel counts
%nChans = ('Ind1', 256, 'Ind2', 320, 'Col', 288);
$nViews = keys %nChans;
#print "$nViews %nChans\n";

# first induction view
$wirePitchU     = 0.870;  # cm
$wireAngleU     = -48.37;  # deg

# second induction view
$wirePitchY     = 0.525;
$widthPCBActive = $wirePitchY * $nChans{'Ind2'};

# last collection view
$wirePitchZ     = 0.515;
$lengthPCBActive = $wirePitchZ * $nChans{'Col'};

#
$borderCRM      = 0.05;        # border space aroud each CRM
```
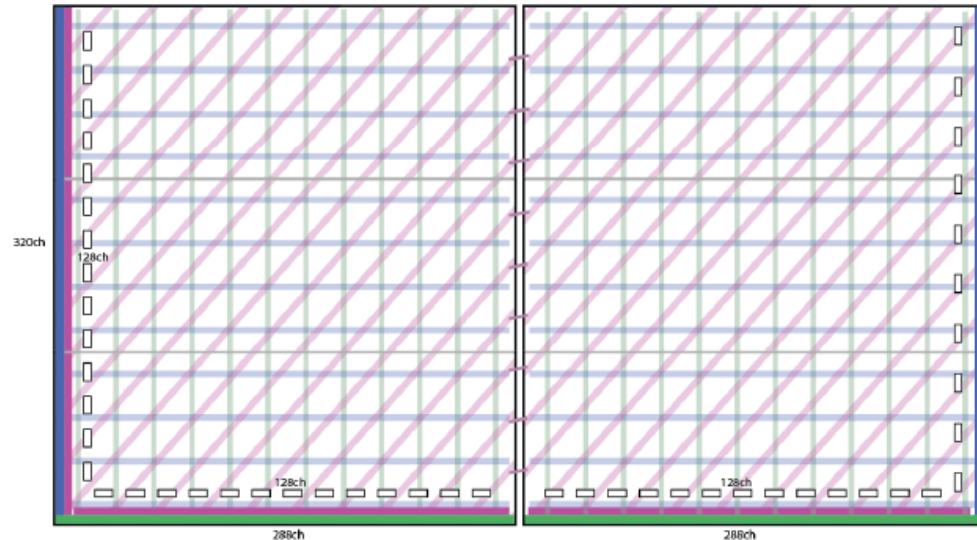
```
TPC C:0 T:35 (650.06 x 168.1 x 148.42) cm^3 at (0.03,420.25,816.26)
    drift direction (1,0,0) from cathode around (-325,420.25,816.26) through 650.05 cm toward 3 wire planes
    maximum wires on any plane: 320
    active volume (650 x 168 x 148.32) cm^3, front face at (0,420.25,742.1) cm;
    main directions: width (1,0,0) height (0,1,0) length (0,0,1)

    View type geo::kU
    View is geo::kInduction
    Number of wires : 256
    Wire pitch      : 0.87
    Theta Z         : 2.29738

    View type geo::kY
    View is geo::kInduction
    Number of wires : 320
    Wire pitch      : 0.525
    Theta Z         : 2.58096e-08

    View type geo::kZ
    View is geo::kCollection
    Number of wires : 288
    Wire pitch      : 0.515
    Theta Z         : 1.5708

Total number of channel wires = 31104
```
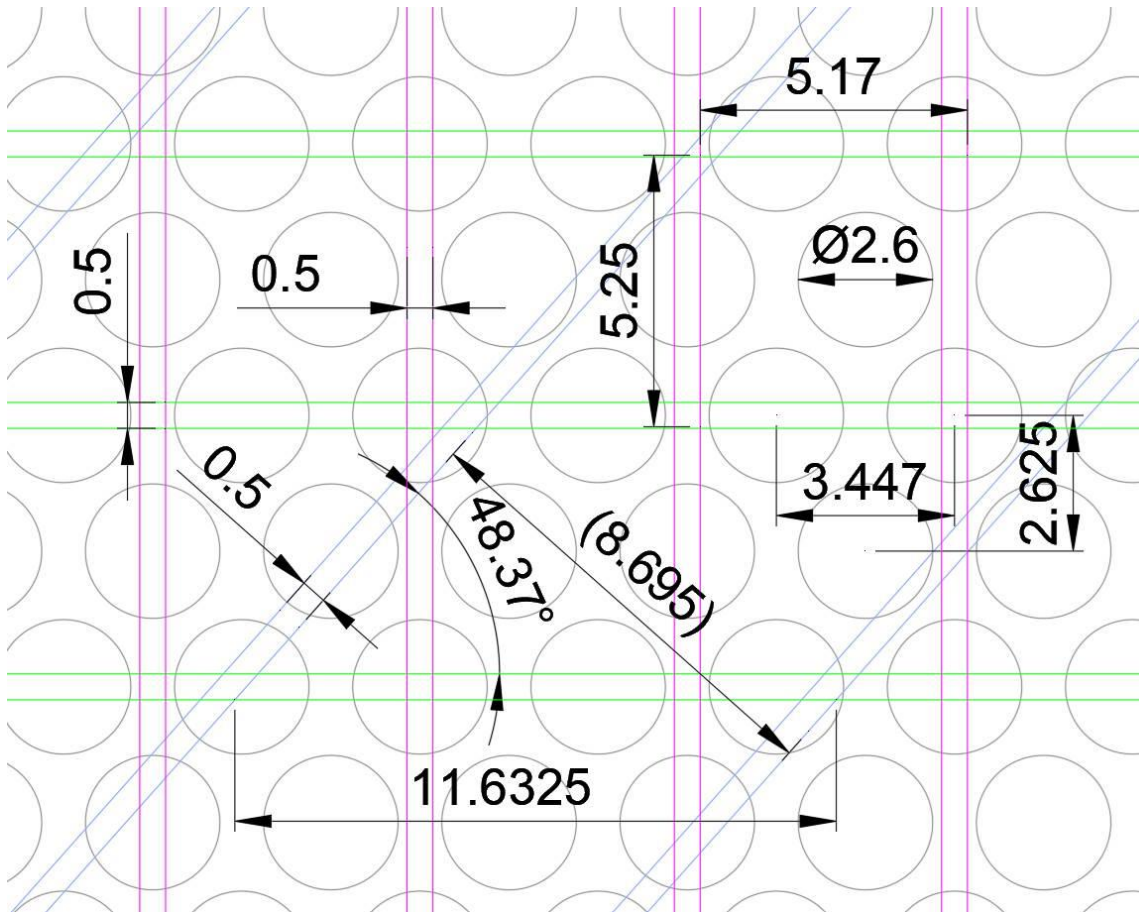
←No bridging CRUs

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Need to update with the latest pitch numbers from Bo

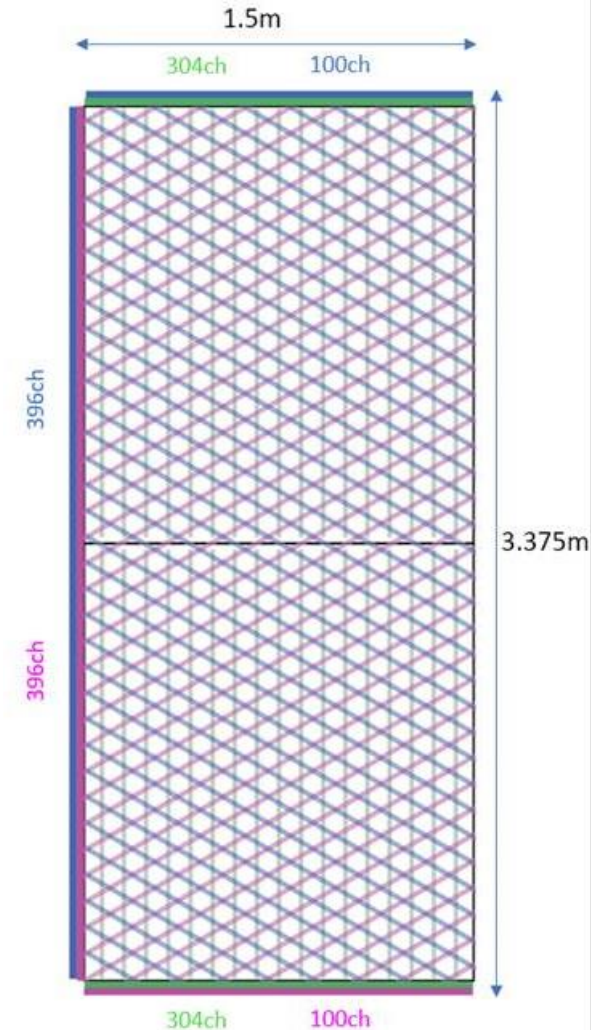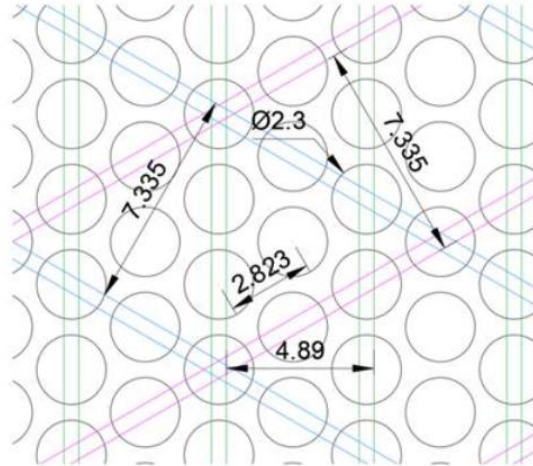# 3-view geometry proposal layout update

From Bo Yu

3-view geometry 30deg

- +/- 30 deg induction views at 7.335 mm pitch
- 4.89 mm pitch for collection (at 90deg)

Geo "wires" per CRU:
- 304 collection channels
- 298 per each angular view


```
TPC C:0 T:35 (650.06 x 168.1 x 148.756) cm^3 at (0.03,420.25,818.108)
    drift direction (1,0,0) from cathode around (-325,420.25,818.108) through 650.05 cm toward 3 wire planes
    maximum wires on any plane: 304
    active volume (650 x 168 x 148.656) cm^3, front face at (0,420.25,743.78) cm;
    main directions: width (1,0,0) height (0,1,0) length (0,0,1)


    View type geo::kU
    View is geo::kInduction
    Number of wires : 298
    Wire pitch      : 0.7335
    Theta Z         : 2.61799

    View type geo::kV
    View is geo::kInduction
    Number of wires : 298
    Wire pitch      : 0.7335
    Theta Z         : 0.523599

    View type geo::kZ
    View is geo::kCollection
    Number of wires : 304
    Wire pitch      : 0.489
    Theta Z         : 1.5708

Total number of channel wires = 32400
```

```
# views and channel counts
%nChans = ('Ind1', 298, 'Ind2', 298, 'Col', 304);
$nViews = keys %nChans;
#print "$nViews %nChans\n";

# first induction view
$wirePitchU      = 0.7335;  # cm
$wireAngleU      = -30.0;   # deg

# second induction view
$wirePitchV      = 0.7335;  # cm
$wireAngleV      = 30.0;    # deg


# last collection view
$wirePitchZ      = 0.489;   # cm

$lengthPCBActive = $wirePitchZ * $nChans{'Col'};
$widthPCBActive  = 168.0;

#
$borderCRM       = 0.05;     # border space aroud each CRM
```

No bridging CRUs

GeoObjectSorter and ChannelMapAlg for VD

- Added VD-specific sorter for Geo objects and channel map algorithm

ChannelMapCRUAlg

GeoObjectSorterCRU

Assumptions for drift directions hardcoded! (X-drift)

In ChannelMapAlg for VD is included in DUNEGeometryHelper_service.cc

```
// DUNE 10kt vd
} else if ( detectorName.find("dunevd10kt") != std::string::npos ) {
    channelMap = std::make_unique<geo::ChannelMapCRUAlg>(pset);
```

- The views are correctly assigned "induction" / "collection" type now

- The channel map algorithm is currently trivial : 1-to-1 wire channel map

- For angular views with strips that are bridged between CRUs need to be mapped to a single channel

- **Is this a critical and therefore of high priority (e.g., to study robustness of disambiguation algorithms)?**

Other simulation hooks

Standard services for VD

DUNE FD VD services in services_dune.fcl are taken for the most part to be the same as for DUNE FD APA detector

The exceptions are geometry & detector properties & detector clocks
ChannelGroupService is removed for now

```
###########################################
### Dune FD Vertical Drift Single Phase ###
###########################################
dunefdvd_services:                    @local::dunefd_services
dunefdvd_services.Geometry:                   @local::dunevd10kt_geo
dunefdvd_services.DetectorPropertiesService: @local::dunefdvd_detproperties
dunefdvd_services.DetectorClocksService:     @local::dunefdvd_detectorclocks
dunefdvd_services.ChannelGroupService:       @erase

dunefdvd_simulation_services:   @local::dunefd_simulation_services
dunefdvd_simulation_services.Geometry:                  @local::dunevd10kt_geo
dunefdvd_simulation_services.DetectorPropertiesService: @local::dunefdvd_detproperties
dunefdvd_simulation_services.DetectorClocksService:     @local::dunefdvd_detectorclocks

# placeholder for reco services ...
dunefdvd_reco_services:           @local::dunefdvd_services
dunefdvd_reco_services.RawDigitExtractService:    @local::rdx_std
dunefdvd_reco_services.RawDigitPrepService:       @local::adcprep_with_services_sim
dunefdvd_reco_services.AdcDeconvolutionService:   @local::adcdco_dunefd
dunefdvd_reco_services.AdcRoiBuildingService:     @local::adcroi_dunefd
dunefdvd_reco_services.AdcWireBuildingService:    @local::adcwire_std
```

Detector properties

8500 samples time window

```
dunefdvd_detproperties:                    @local::standard_detproperties
dunefdvd_detproperties.Temperature:        87
dunefdvd_detproperties.Electronlifetime:   3.0e3
dunefdvd_detproperties.Efield:             [0.5, 1.0, 1.0]  #(placeholder val
dunefdvd_detproperties.ElectronsToADC:     6.8906513e-3 # 1fC = 43.008 ADC co
dunefdvd_detproperties.NumberTimeSamples: 8500            # drift length/drift
dunefdvd_detproperties.ReadOutWindowSize: 8500            # as per proposal
dunefdvd_detproperties.TimeOffsetU:        0.
dunefdvd_detproperties.TimeOffsetV:        0.
dunefdvd_detproperties.TimeOffsetX:        0.
dunefdvd_detproperties.TimeOffsetY:        0.
dunefdvd_detproperties.TimeOffsetZ:        0.
```

Detector clocks

```
#include "detectorclocks.fcl"

BEGIN_PROLOG

dunefd_detectorclocks: @local::standard_detectorclocks

# dunefd_detectorclocks.TrigModuleName:         ""
dunefd_detectorclocks.InheritClockConfig:    false
dunefd_detectorclocks.G4RefTime:               0.   # G4 time [us] where electronics clock counting start
dunefd_detectorclocks.TriggerOffsetTPC:        0.   # Time [us] for TPC readout start w.r.t. trigger time
dunefd_detectorclocks.FramePeriod:          1600.   # Frame period [us]
dunefd_detectorclocks.ClockSpeedTPC:           2.   # TPC clock speed in MHz
dunefd_detectorclocks.ClockSpeedOptical:    62.5 # Optical clock speed in MHz
dunefd_detectorclocks.ClockSpeedTrigger:    16.   # Trigger clock speed in MHz
dunefd_detectorclocks.DefaultTrigTime:         0.   # Default trigger time [us].
dunefd_detectorclocks.DefaultBeamTime:         0.   # Default beam time [us].

# Vertical drift FD
dunefdvd_detectorclocks: @local::dunefd_detectorclocks
dunefdvd_detectorclocks.FramePeriod:        4250.   # Frame period [us]
```

Same as HD apart from "FramePeriod"

Refactored larg4 hooks

Simulation/larg4services_dune.fcl

```
dunevd10kt_1x6x6_larg4detector:
{
    category        : "world"
    gdmlFileName_   : @local::dunevd10kt_1x6x6_geo.GDML
    volumeNames     : ["volTPCActive"] # list of volume
    stepLimits      : [0.4]            # corresponding
}
```
Step limit same as for FD HD 1x2x6 workspace

Utilities/services_refactored_pdune.fcl

```
dunevd10kt_1x6x6_larg4_services:
{
  @table::common_larg4_services

  ParticleListAction: @local::dune_particle_list_action
  PhysicsList:        @local::dune_physics_list_fastoptical
  LArG4Detector:      @local::dunevd10kt_1x6x6_larg4detector
}
```

This is 2view geo declared in geometry_dune.fcl
If the dimensions of volTPCActive, its positions, and origin definitions are independent of # of views, it should not matter for generating sim::SimEnergyDeposit
But currently volTPCActive have slightly different dimensions for different layouts

Particle gun simulation check

Look at simulation directly on sim::SimChannel:

- Raw charge in # of e assigned to a channel by simulation

- Make sure topology of drifted charge → wire assignment is reasonable

- Use SimDriftElectrons module to propagate sim::SimEnergyDeposit to sim::SimChannel

- No convolution with anode / electronics response

  - DetSim inherited from HD requires U/V/Z view assignments (Y view generates exceptions)

  - View types are assigned by geo::PlaneGeo::UpdateView() algorithm

  - Maybe can force that in GeoObjectSorter; otherwise would need to add "new" services to DetSim

Will be supplanted by wire-cell plugin module

Refactored G4 simulation fcl

- Added to dunefd (fcl/dunefd/g4/standard_g4_refactored_dunevd10kt_1x6x6.fcl)

- There is "dunefddp" directory. Should one have "dunefdvd"?

```
#include "LArG4_dune.fcl"
#include "IonAndScint_dune.fcl"
#include "PDFastSim_dune.fcl"
#include "services_dune.fcl"
#include "services_refactored_pdune.fcl"

process_name: G4

services:
{
  # Load the service that manages root files for histograms.
  TFileService:           { fileName: "g4_hist.root" }
  TimeTracker:            {}
  MemoryTracker:          {} # default is one
  RandomNumberGenerator: {} #ART native random number generator
  FileCatalogMetadata:    @local::art_file_catalog_mc

  @table::dunefdvd_simulation_services
  @table::dunevd10kt_1x6x6_larg4_services

  NuRandomService:        @local::dune_prod_seedservice
}
services.Geometry:        @local::dunevd10kt_1x6x6_geo
```
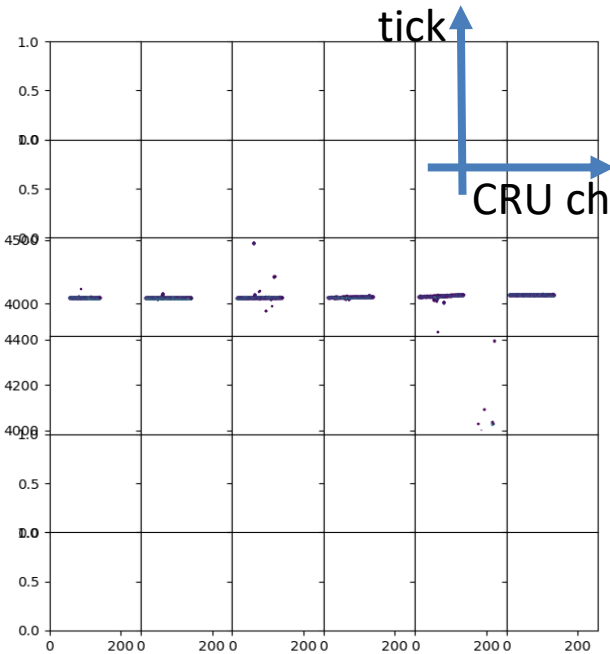
Muon gun : horizontal along Z

Starting position (0, 20, 50)cm → (4063 ticks, 38 chY, 96 chZ)
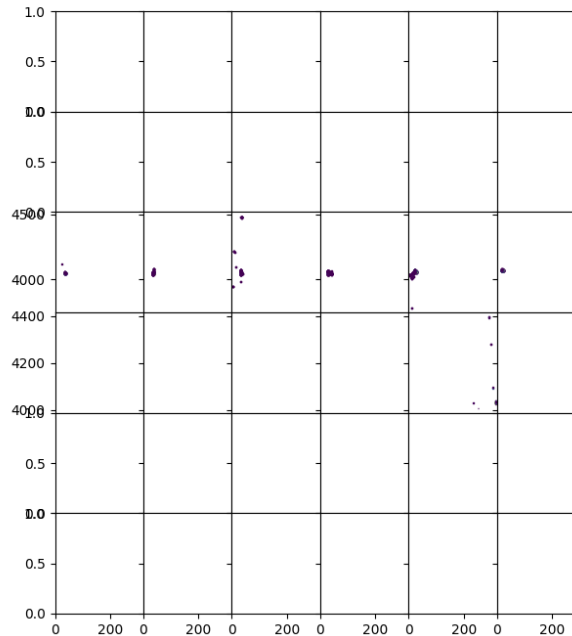
Charge deposits from sim::SimChannel dump

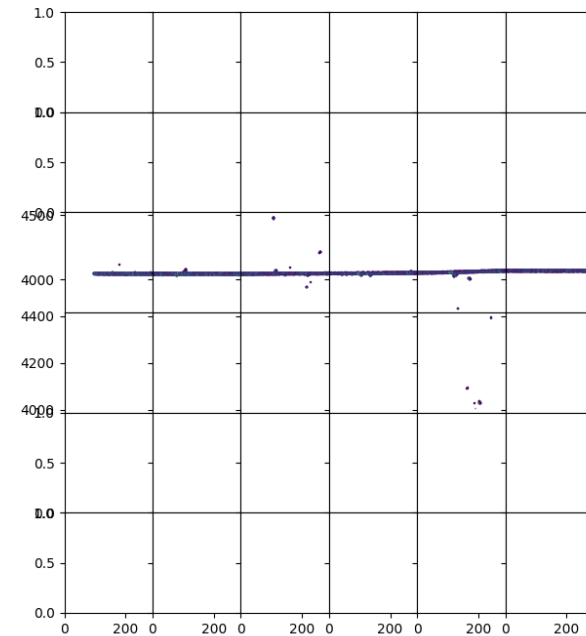1st induction view @ 48deg   2nd induction view @ 0deg   Collection view @ 90deg

Tried also for +/- 30 deg VD layout, but there I had an issue with +30 deg view traced to a problem with "wire sorter" algorithm. Should fix it soon

Summary

- Prepared 1st version of VD workspace geometry for 3 different readout layouts

  - Re-tune pitch for "3-view proposal" layout to the latest values

- Some shortcomings to be improved:

  - No possibility of introducing different spacing at the level of CRPs or Super-CRP structures

  - No way to generate position mis-alignment for CRPs

  - Only a single drift cell (upper)

  ➔ Set up geo generator in DuneGGD, but have yet to test it

- Appropriate channel mapping for angular views needs to be implemented

- DetSim implementation