

# Status of Field Calculations

Methods

Geometries

Weighting Potentials

Drift Potentials and Fields

Software

To do

# Weighting Potential

Shockley-Ramo construction:

1. Identify one electrode,  $k$ .
2. Set to unit voltage, all others set to 0V.
3. Calculate its *weighting* potential  $\phi_{weight,k}$  in the volume.
4. Calculate the associated E-field  $\vec{E}_{weight,k}$ .
5. Calculate the overall *drift* potential and E-field  $\vec{E}_{drift}$ .

Induced current on the electrode  $k$  from charge  $q$  moving with velocity  $\vec{v}$ :

$$i_k = q \vec{E}_{weight,k} \cdot \vec{v}$$

And, electron drift velocity, for given mobility  $\mu$ :

$$\vec{v} = \mu \vec{E}_{drift}$$

# Boundary Element Method for Electrostatic Potential

1. Discretize (mesh) boundary electrodes.
2. Define potential on each mesh element.
3. Integrate Laplace  $\nabla^2\phi = 0$ .
4. Fit integral equations to boundary values.
5. Evaluate solution on points in the volume.

# Element Methods: Boundary vs. Finite

## BEM

- ▶ Meshes the surfaces.
- ▶ Fast for low surface-to-volume.
- ▶ Performance relies on relatively new math discoveries.
- ▶ Relatively few software implementations.

## FEM

- ▶ Meshes the volume.
- ▶ Fast for high surface-to-volume.
- ▶ Adaptive meshes can improve performance.
- ▶ Many implementations, heavily used in industry.

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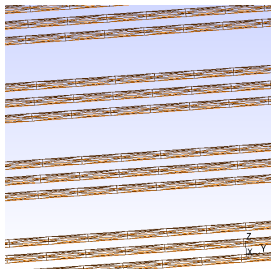
Weighting Potentials

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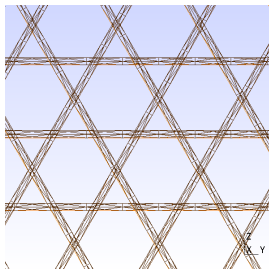
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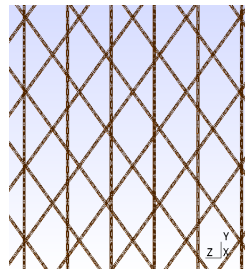
# Wires Meshes



**“Parallel”:**  
3mm pitch and gap  
all wires parallel

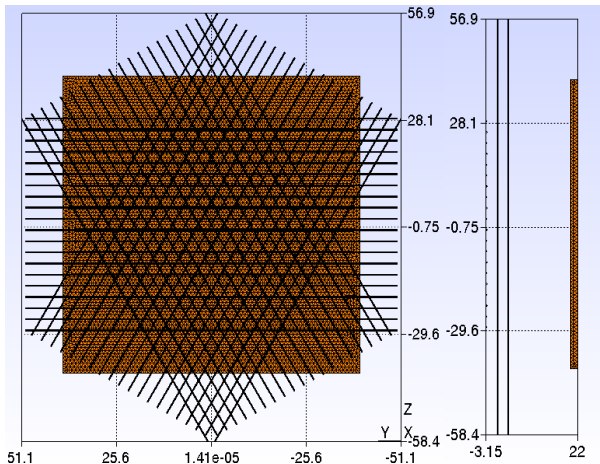


**“MicroBooNE”:**  
3mm pitch and gap  
 $60^\circ$  angles for U/V.



**“DUNE”:**  
5mm pitch and gap  
 $35.7^\circ$  angles for U/V.

## Add Cathode (MicroBooNE)



- ▶ “Cathode” is near wires with voltage adjusted to give 500V/cm.
- ▶ Do calculations at center, far enough away from edge effects.

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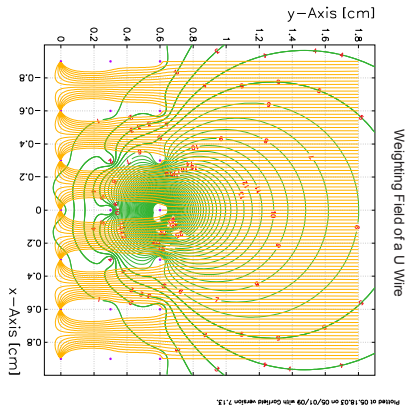
Drift Potentials and Fields

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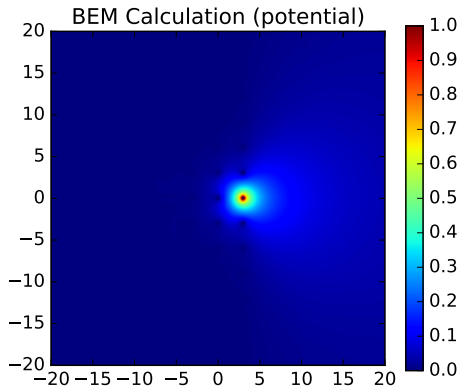
To do



# Weighting Potential - 2D vs “2D”



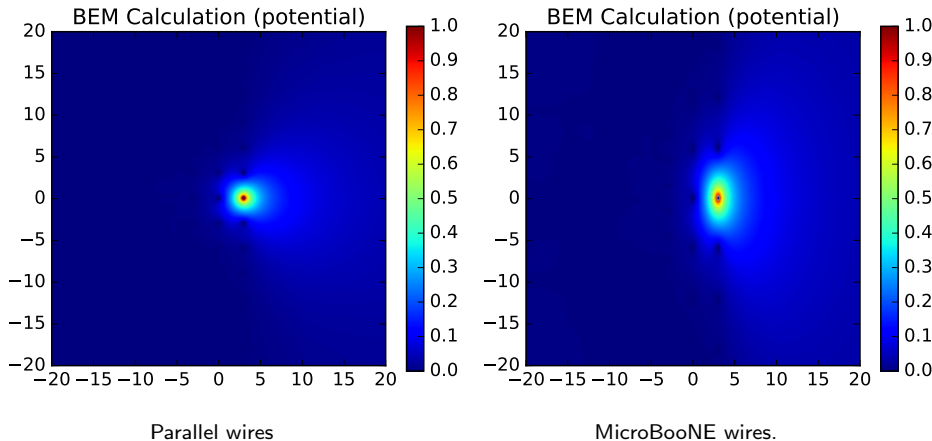
Garfield 2D calculation from Bo



3D BEM, parallel wires, sliced at Y=0.

Initial, qualitative agreement. More checks needed.

# Weighting Potential - 2D vs. 3D wire pattern



Clear distortion in extent and shape. Not surprising.

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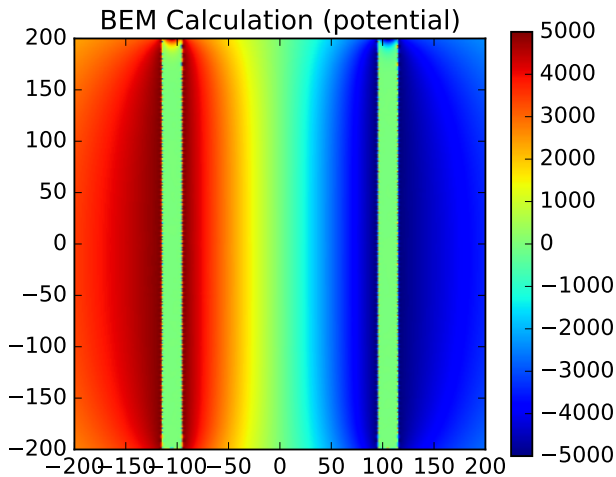
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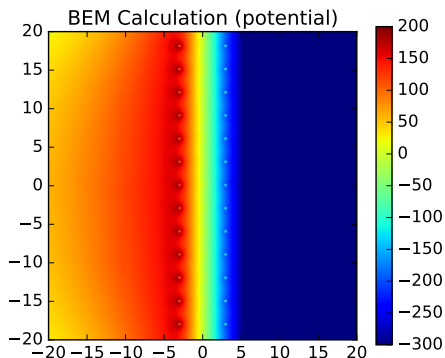
To do

# Capacitor

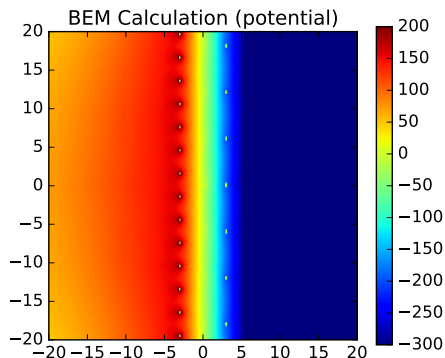


Simple test with parallel-plates at  $\pm 5000\text{V}$ .

# Drift Potential - 2D vs. 3D wire pattern



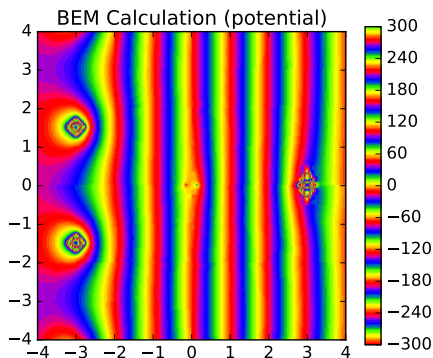
Parallel wires



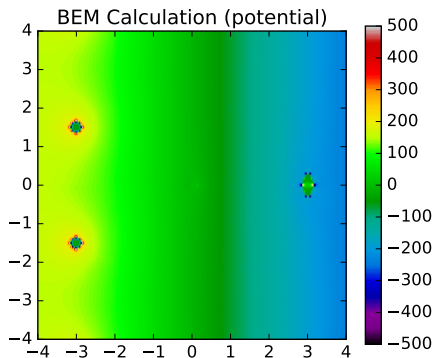
MicroBooNE wires.

Electrodes (from left-to-right)  $W \rightarrow V \rightarrow U \rightarrow$  Cathode (off scale)

## Some Issues - Mesh Granularity



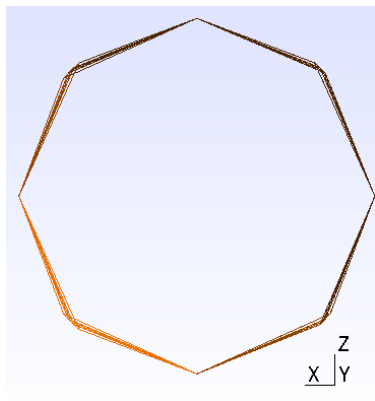
Major features look okay.



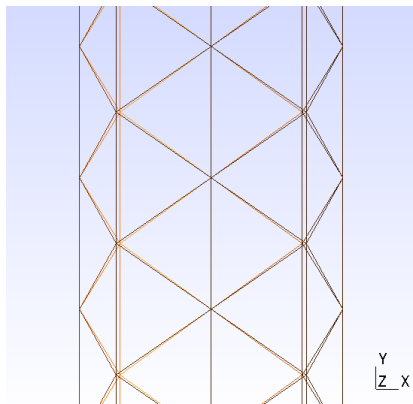
Large  $\pm$  fluctuations near wires.

- Drift potential has large fluctuations right near the wires.

# Wire Mesh Closeup



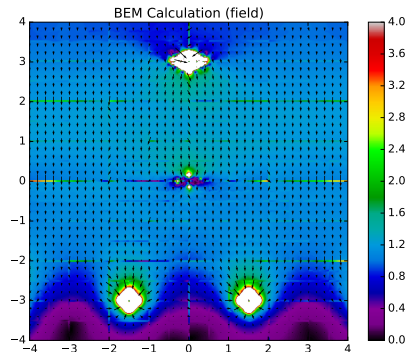
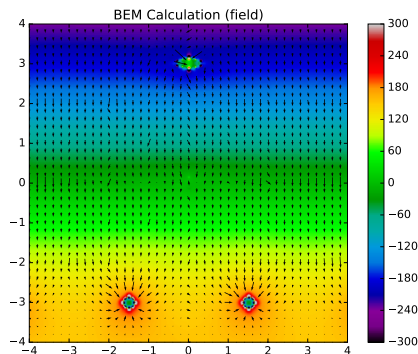
Wire cross section.



Wire side view.

- Trade-off between mesh granularity and CPU time.

# An Initial E-Field Calculation



- Trade-off between mesh granularity and CPU time.



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# Main Dependencies

## BEM++

- ▶ Solves Laplace, Helmholtz and Maxwell eqns using BEM
- ▶ C++ with Python interface.
- ▶ General, but low-level. Requires some understanding.
- ▶ Multithreaded.

## GMSH

- ▶ 3D Grid generator and visualization.
- ▶ Volume and surface meshes.
- ▶ Interactive and scripted geometry definition.

Python:

- ▶ NumPy, Matplotlib and **LARF**

# LARF - Liquid ARgon TPC Field Calculator

For now, code lives at:

<https://github.com/brettviren/larf>

```
$ larf mesh -o uboone.msh ubone
$ gmsh uboone.msh      # <-- to visualize the generated mesh
$ larf solve -d 11 -g near -o uboone-near-d11.npz uboone.msh
$ larf plot -p near -o uboone-near-d11.pdf uboone-near-d11.npz
```

Processing directed by a `larf.cfg` configuration file, specify things like:

- `geometry` naming the mesh generators and parameters
- `problem` to solve (weighting vs drift)
- `gridding` to use for both the solution and any plots
- `plot` describing what plotting code to apply to a solution

- ▶ Solution results are saved as Python NumPy array files.
- ▶ Will extend this as the to-do list is tackled.

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# Much Still To Do

- ▶ Include calculations for DUNE detector geometry.
- ▶ Visualize E-fields, do more careful comparisons to 2D results.
- ▶ Go from 2D slices to full 3D volumetric data.
- ▶ Dynamics:
  - ▶ Charge drifting and wire-current signal generation.
  - ▶ Let's make a new simulated animation!
- ▶ Responses as a function of position.
  - ▶ Repeat Yichen's study on intra- and inter-wire-regions
- ▶ Finally, develop some response functions for signal extraction.
  - ▶ How detailed? (per-plane?, per wire?)
  - ▶ How to validate?
- ▶ Other ideas:
  - ▶ Jim: Edge effects near field cage, TPC-TPC gaps, inside APA.
  - ▶ Milind: calculate transparency of induction planes.
  - ▶ Others?

## Other Efforts - FEM

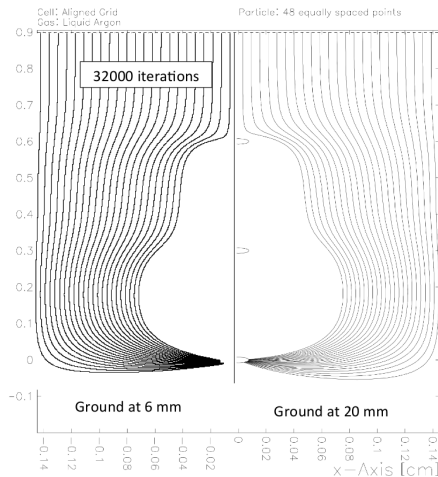
### Leon Rochester @ SLAC

- ▶ [MicroBooNE DocDB 5892](#)
- ▶ FEM using custom code (“DIY Garfield”)
- ▶ C++ rewritten from ICARUS FORTRAN.
- ▶ Good looking initial results on drift field and with particle stepping.
- ▶ I expect we will do a systematic comparison at some point.

### Manhong Zhao @ BNL

- ▶ Initial discussions to do FEM using ANSYS + the “multi physics” module.
- ▶ Beefy workstation on order.

**Not to forget hardware-based measurements!**



Left half is Leon's FEM after 32k iterations with Garfield 2D on right half.