Effect of Drain holes for LBNF on neutrino flux

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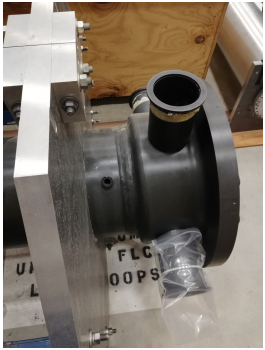
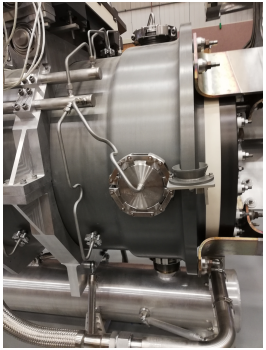
Outline

1. Introduction
2. Field Map
3. Magnetic field comparison
4. Summary

LBNF Magnetic horns

My goal is to understand the effect of the drain holes on the neutrino flux, add the effect of Drain holes on the B field, even when the physical hole is not there.





These pictures are for horn 2 of NuMI beam, 3 drain holes are used as inputs of water and argon.

Field Map

Zhijing simulated the magnetic field at points on a grid

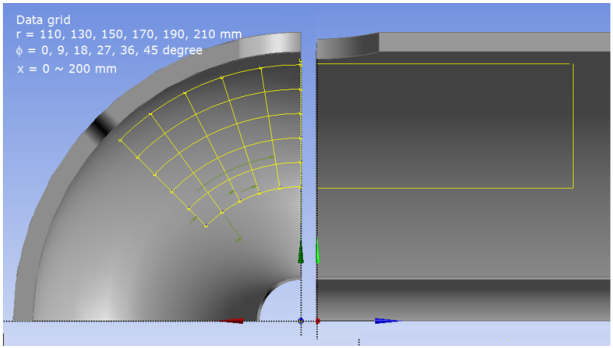


Figure 12 Grid shows where transient magnetic field data are provided

(image from The Magnetic Field of Horn near Drain Hole; Zhijing Tang, October 22, 2018)
Grid with 6 ϕ steps, 41 z steps and 6 R steps

Field Map

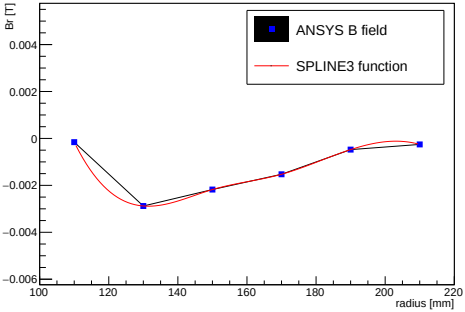
The Nominal B field inside the horn is equal to

$$B_0 = \frac{\mu_0 I}{2\pi R} = \frac{60}{R}$$

where R is in mm and B in T
The magnetic field only has component in the polar direction (toroidal field)
When we add the drain holes, the magnetic field has radial and longitudinal components.

Field Map

I need to make a field map with the characteristics of the ANSYS simulation



I took the points for the ANSYS simulation and I made a fit with Spline function in ROOT for B field

Magnetic field comparison

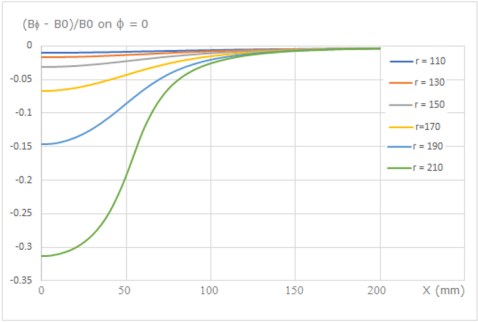
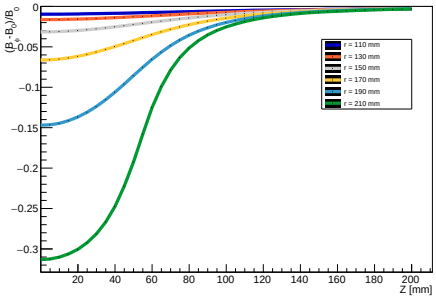


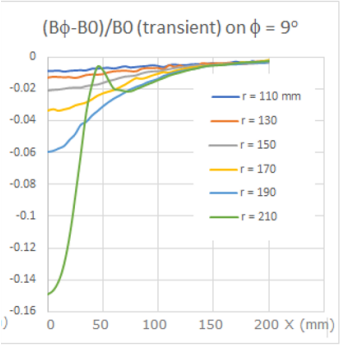
Figure 9 Relative transient magnetic field on $\phi = 0$

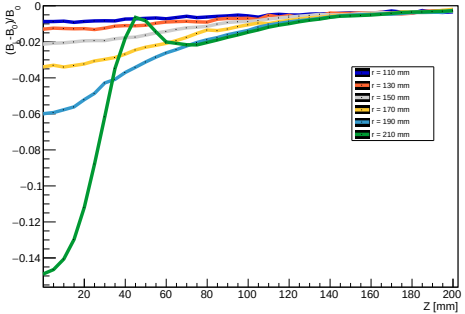


Left: relative magnetic field with an angle equal to zero (image from The Magnetic Field of Horn near Drain Hole; Zhijing Tang, October 22, 2018)— Right: relative magnetic field produced with the field map in the LBNF beam simulation (GEANT4)

$Z = 0$ center of drain hole

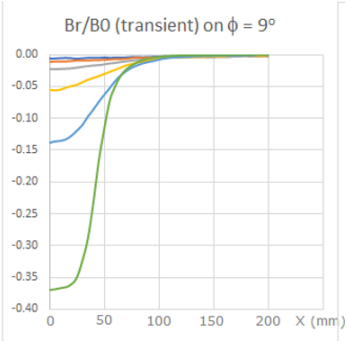
Magnetic field comparison

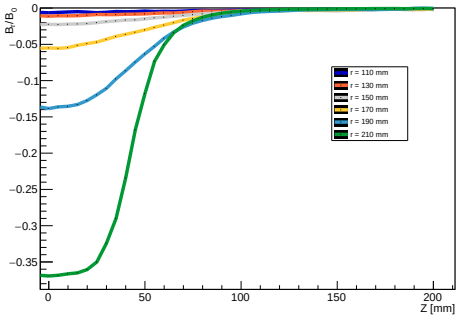




Left: relative magnetic field with an angle equal to 9 degrees (image from The Magnetic Field of Horn near Drain Hole; Zhijing Tang, October 22, 2018)— Right: relative magnetic field produced with the field map in the LBNF beam simulation (GEANT4)

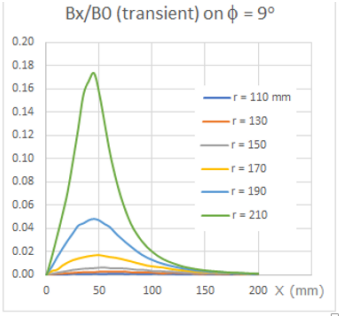
Magnetic field comparison

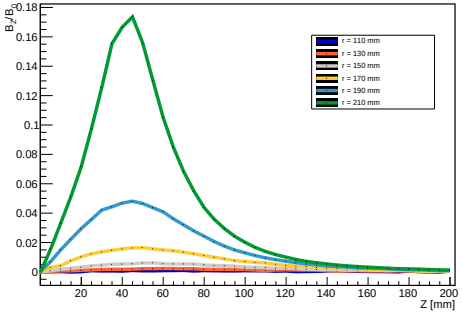




Left: relative magnetic field with an angle equal to 9 degrees (image from The Magnetic Field of Horn near Drain Hole; Zhijing Tang, October 22, 2018)— Right: relative magnetic field produced with the field map in the LBNF beam simulation (GEANT4)

Magnetic field comparison

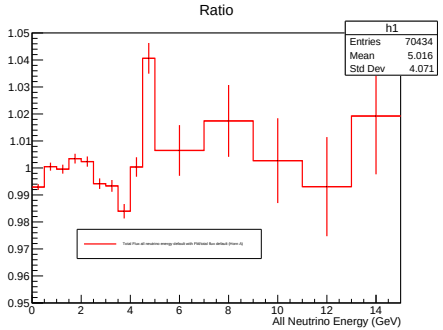


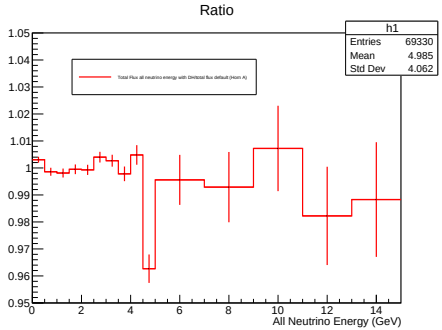


Left: relative magnetic field with an angle equal to 9 degrees (image from The Magnetic Field of Horn near Drain Hole; Zhijing Tang, October 22, 2018)— Right: relative magnetic field produced with the field map in the LBNF beam simulation (GEANT4)

Magnetic field comparison

The last time I presented

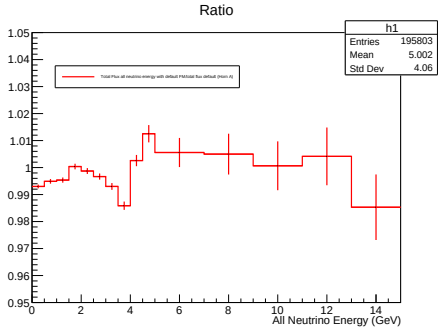


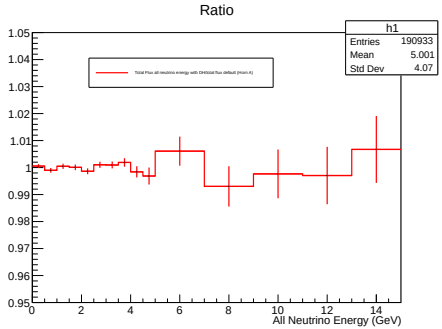


Left: ratio between simulation with field map using the default B field and the nominal simulation. Right: ratio between the Drain holes effect and the nominal simulation with Field map. **The flux is produced with the 4 Drain holes on GEANT4 simulation.**

Magnetic field comparison

I add more statistics to reduce the fluctuation on the last bins

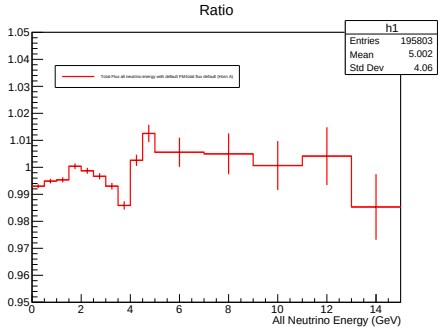


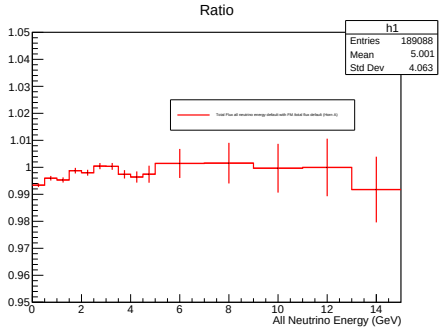


Left: ratio between simulation with field map using the default B field and the nominal simulation. Right: ratio between the Drain holes effect and the nominal simulation with Field map. **There are a shift in the Inner conductor.**

Magnetic field comparison

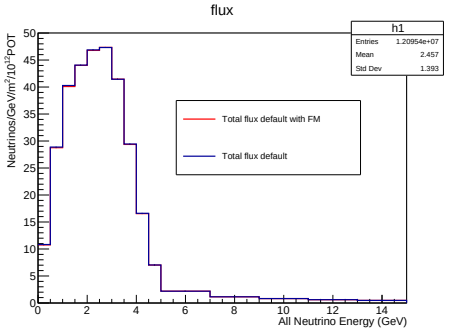
I reduce the step size in R for the field map

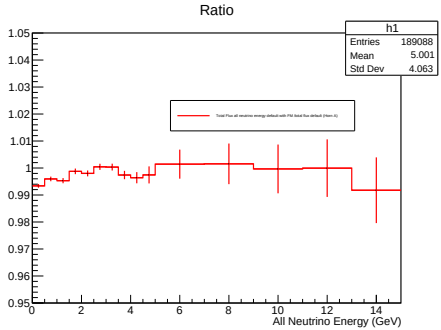




Left: ratio between simulation with field map using the default B field and the nominal simulation (**Old version**). Right: ratio between simulation with field map using the default B field and the nominal simulation (**New version, reduce in R step size**).

Magnetic field comparison

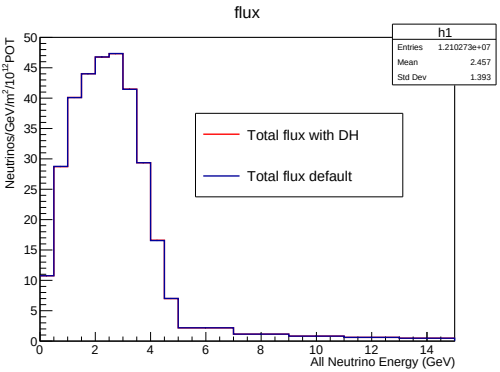


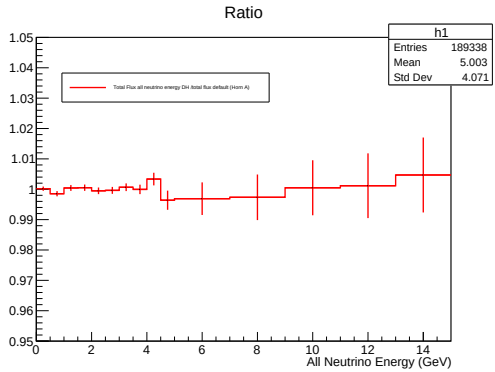


Left: Total flux LBNF far detector (Red: total flux with Field map, default magnetic field. Blue: total flux default simulation)— Right: Ratio (flux with FM over default flux)

For the next slides I take the simulation with field map as Default simulation for the reminder of this talk.

Magnetic field comparison



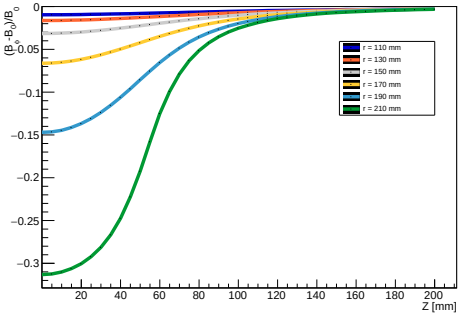


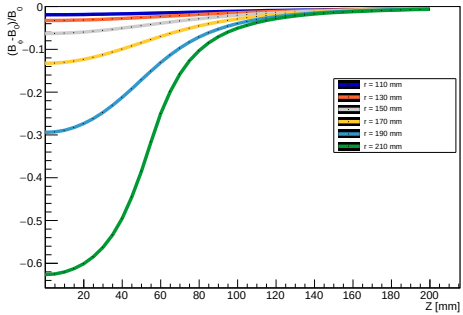
Left: Total flux LBNF far detector (Red: total flux with Drain Holes. Blue: total flux default simulation)— Right: Ratio (flux with DH over default flux)

Magnetic field comparison

We increased the effect of the drain holes to 200% to see how the flux is ...

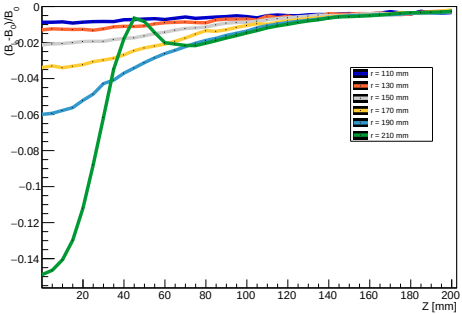
Magnetic field comparison

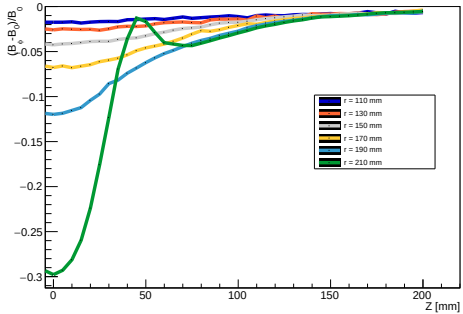




We increase the effect of Drain holes to 200%. (left: relative B field for Drain holes. Right: relative B field at 200%)

Magnetic field comparison





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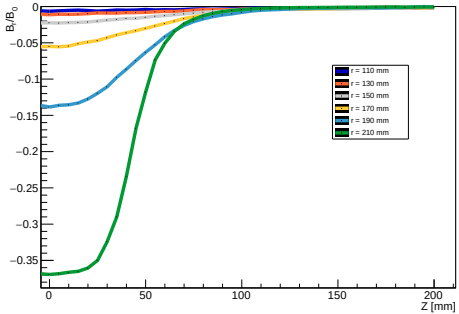
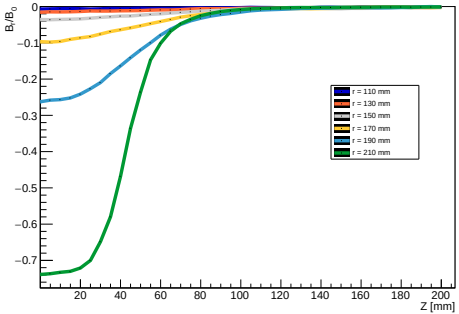
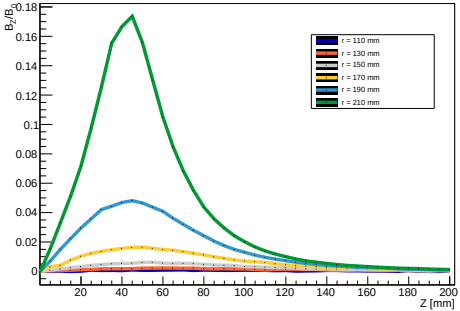
Magnetic field comparison

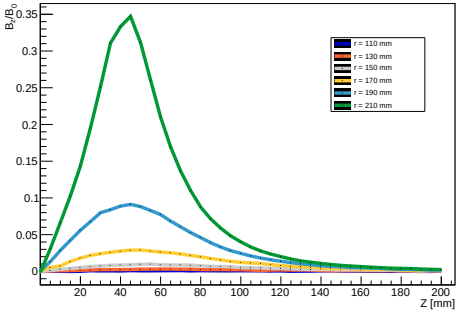




We increase the effect of Drain holes to 200%. (left: relative B field for Drain holes. Right: relative B field at 200%)

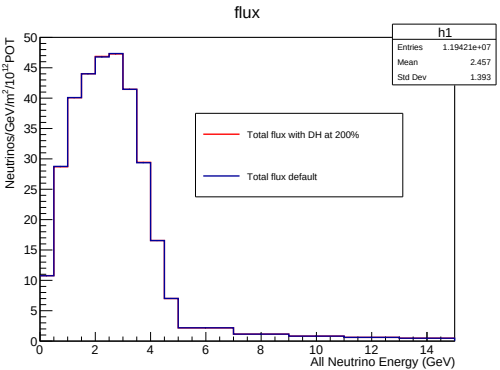
Magnetic field comparison

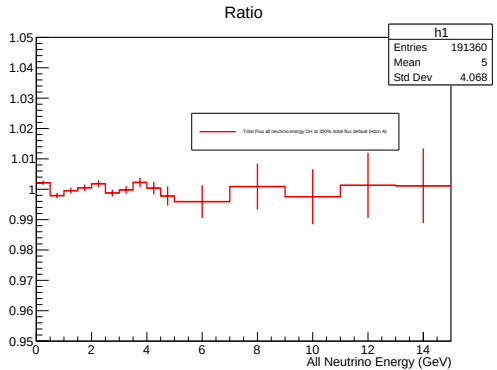




We increase the effect of Drain holes to 200%. (left: relative B field for Drain holes. Right: relative B field at 200%)

Magnetic field comparison



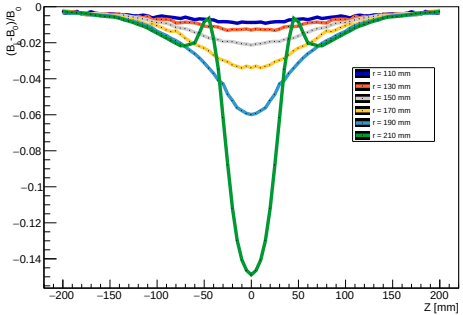


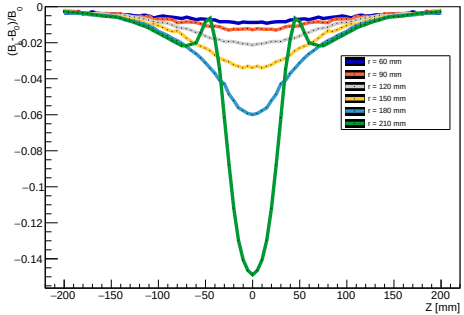
Left: Total flux LBNF far detector (Red: total flux with Drain Holes effect of 200%. Blue: total flux default simulation)— Right: Ratio (flux with DH at 200% over default flux)

Magnetic field comparison

To see if the field map modifies the flux, a deeper effect was applied

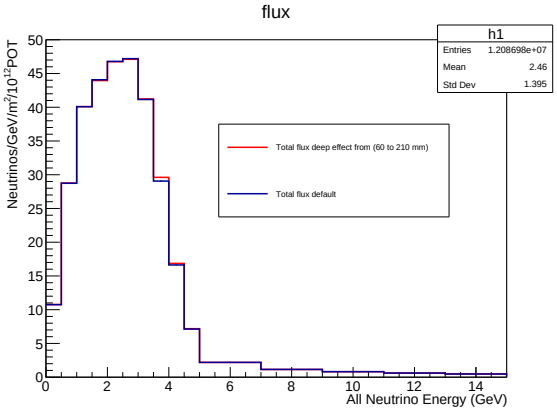
Magnetic field comparison

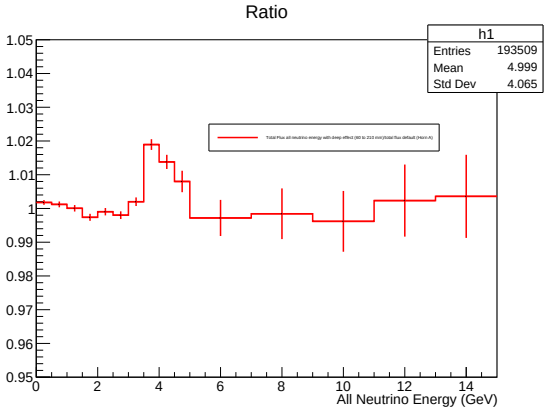




Left: Drain holes effect. Right: effect that starts at 60 mm of radii (deep effect).
The change is on the legend, the Left plot starts at 110 mm with steps of 20 mm, the Right plot starts at 60 mm with steps of 30 mm.

Magnetic field comparison





Left: Total flux LBNF far detector (Red: total flux with deep effect. Blue: total flux default simulation)— Right: Ratio (flux with deep effect over default flux)

Summary

- A study for the effect of the drain holes on the horn A for LBNF simulation was made, the effect on flux is less than 0.5%.
- the field map was tested with a deeper effect to probe that a distortion could modify the flux