A complete magnetic design for the DUNE ND-GAr solenoid magnet

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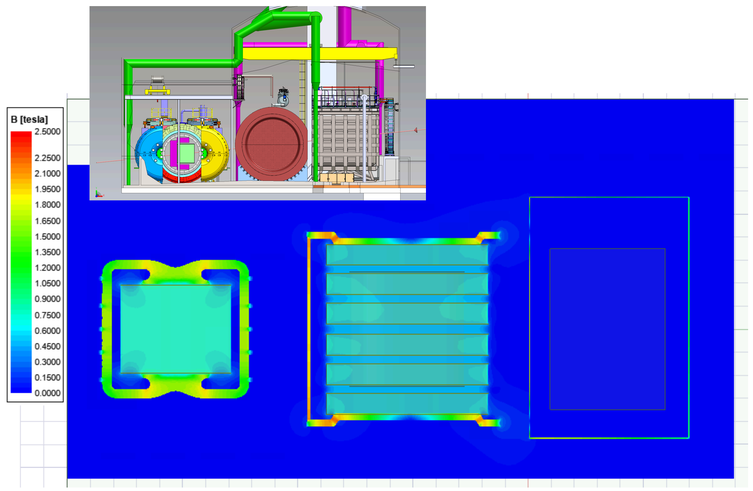
Abstract

The Deep Underground Neutrino Experiment (DUNE) at Fermilab is one the most challenging next-generation experiments in the field of neutrino physics. It will feature two detectors for a detailed study of neutrino oscillations using an unprecedentedly intense neutrino beam. The two detectors are a Near Detector located on the Fermilab site, 574 m away from the neutrino generation, and a Far Detector in South Dakota, 1300 km away. Among the three elements of the Near Detector, designed for the best understanding of the neutrino beam and neutrino interactions on argon, ND-GAr is a High-Pressure gaseous Argon TPC surrounded by a calorimeter, in a 0.5 T magnetic field. The needed magnetic field is transverse to the neutrino beam direction and the solenoid will have a 7 m diameter, 8 m long warm bore. To minimise the material budget along the particle path a thin superconducting solenoid with a partial yoke has been designed. The design of this magnet is tightly bond with the mechanics of the detector, resulting in an unprecedented design. In this paper we present the up-to-date magnetic design and a detailed study for the mechanical integration for this magnet.

ND-GAr in the DUNE Near Detector

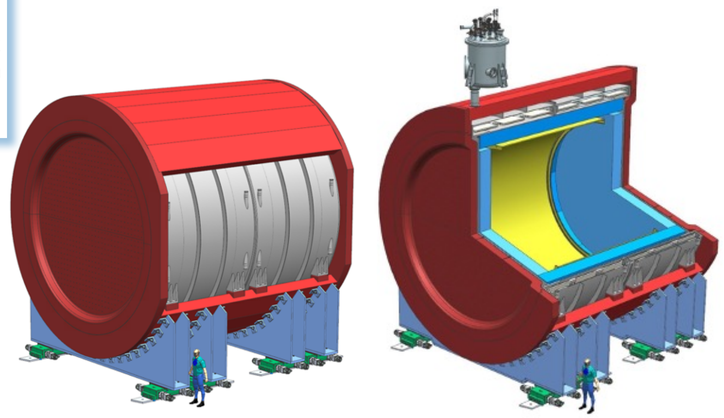
- ND-GAr will be positioned between ND-LAr and SAND
  - ND-LAr is a movable liquid argon time projection chamber
  - SAND is a fixed spectrometer for neutrino beam monitoring
- ND-GAr is made of a argon gas Time Projection Chamber surrounded by an electromagnetic calorimeter
  - the TPC is 5 m in diameter and 5 m long
  - the calorimeter is inside the TPC pressure vessel
  - the pressure is contained the yoke end plates via pushers
- The main requirements for ND-GAr magnet are
  - magnetic field: 0.5T, ±10%, on the tracker
  - magnetic field directed perpendicularly to the neutrino beam
  - movable along magnet axis by 30 m with ND-LAr
  - less than 50 g/cm2 material budget between ND-GAr and ND-LAr
  - material for muon tagging after ND-GAr (asymmetric yoke)
- A Solenoid with Partial Yoke (SPY@DND) has been designed



- Top, detectors arrangement in Near Detector cave
- Bottom, field map on the horizontal plane at ND-GAr centre

Stray magnetic field

- The three ND detectors have been modelled
  - stray field in ND-LAr active volume is 16 - 100 G
  - field of ND-GAr in SANDa active volume is below 10 G
- < 200 G field on the horizontal plane 12 m above cave floor
  - limited to the are on top od ND-LAR, < 100 G elsewhere

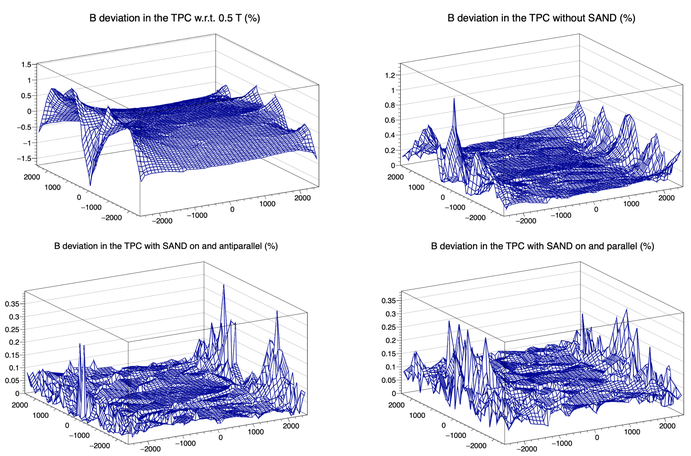


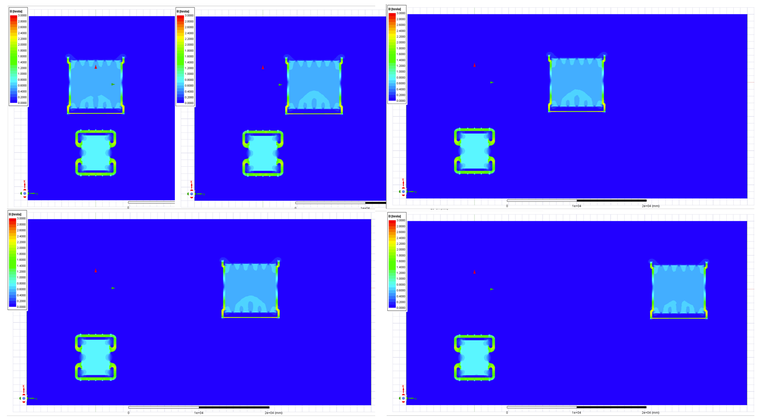
A view and a cross section of SPY@DND

- On the left, the large opening in the yoke is visible
- On the right, the various subsystem are visible
  - TPC structure in yellow
  - calorimeter in blue (inside the high pressure vessel)
  - coils and yoke in grey and red respectively

Solenoid features

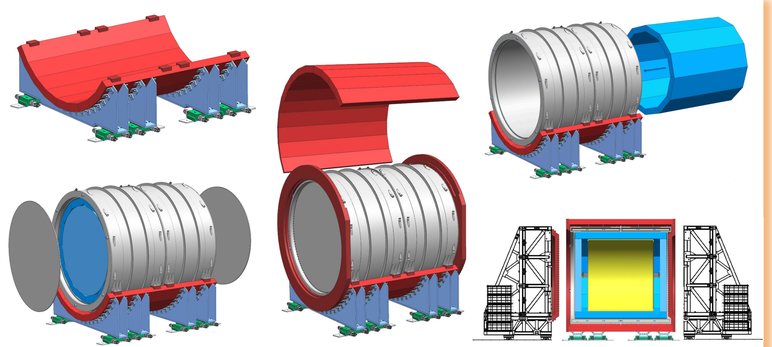
- Single layer solenoid made of 6 sub coils
  - inner diameter 7000 mm
  - proposed cable thickness 20 mm
  - 900 mm width, 120 turns for each sub coil
- Field calculation main results
  - Field on TPC: (0.499 ±0.008) T (±1.6%)
  - Total current: 3.3 MA turn
  - Force along beam due to yoke asymmetry: 150 kN
  - Force acting on SAND yoke (on axis): < 10 kN
  - Force acting on ND-LAr support structure: < 70 kN





Magnetic model

- < 10 G variation of B in 95% of TPC volume in any configuration
- Displacement from on axis to 30 m away of ND-GAr w.r.t SAND
  - SAND and ND-GAr fields must be in the same direction to be less sensitive to relative position
  - B variation on TPC of the order of 10 G



Assembly procedure

- First part of the yoke is built on Hillman rollers and support
- Cryostat is placed on the yoke and detectors are installed
- Pressure vessel end plates are bolted directly to the cryostat
- End rings and the rest of the yoke are assembled
- Yoke end plates are installed and pushers put in contact