SuperNEMO bar design: technical specification

This documents describes basic technical details of SuperNEMO bar design simulation

Geometry

The main idea is to implement bar design in the frame of SNOVA1 package with minimal deviations from basic design strategy.

The schematic view of setup is shown on Fig.1.

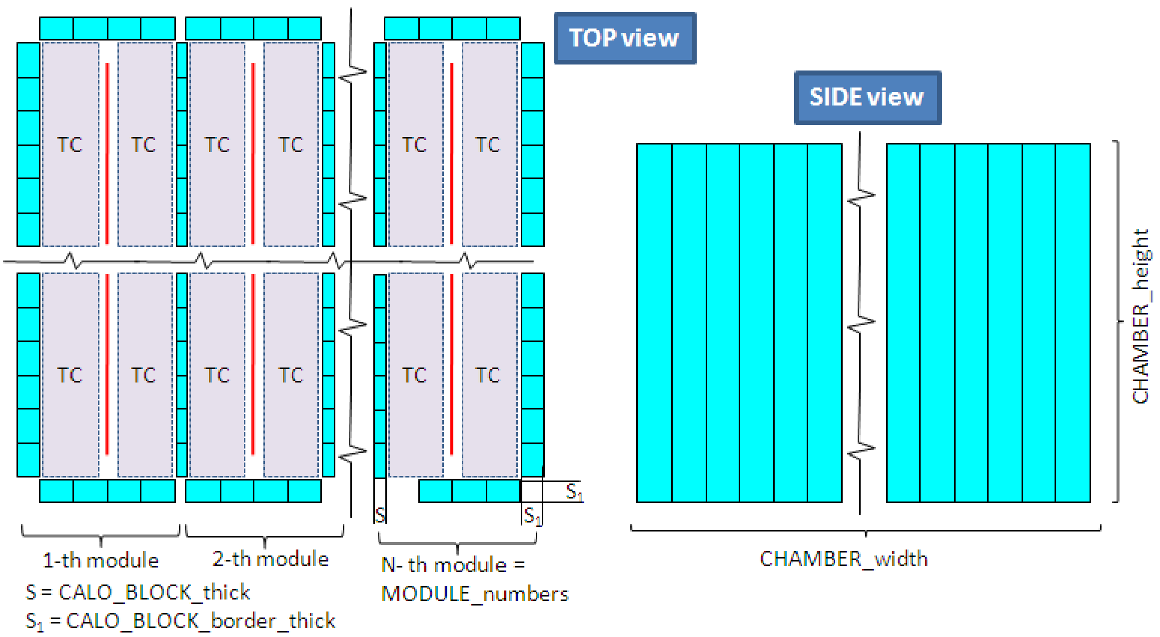

Figure 1. Schema of SuperNEMO detector with bar-based calorimeter.

Main changes are detector modularity and different thickness of inner and outer bars. The global property ***CALORIMETER_type*** is used by all chain of further programs (SUNAMI, CATS, etc.) in order to switch between basic and bar design. In term of geometry definitions (snova1 geometry file) the new settings are:

CALORIMETER

 # GEOMETRY CALORIMETER_type S Basic
GEOMETRY CALORIMETER_type S Bar

MODULE PARAMETERS
 # Number of modules
GEOMETRY MODULES I 10

CALORIMETER BLOCKS
 # Calorimeter thickness of inner bars (wrapper included) (cm)
GEOMETRY CALO_BLOCK_thick D 2.
 # Calorimeter thickness of outer bars (wrapper included) (cm)
GEOMETRY CALO_BLOCK_border_thick D 10.
 # Calorimeter bar total height (wrapper included) (cm)
 # Not needed as for bar design CALO_BLOCK_height = CHAMBER_height
 # But could be kept to backward compatibility
 # GEOMETRY CALO_BLOCK_height D 25.

Top/Bottom gamma vetos

Given on the Fig.2

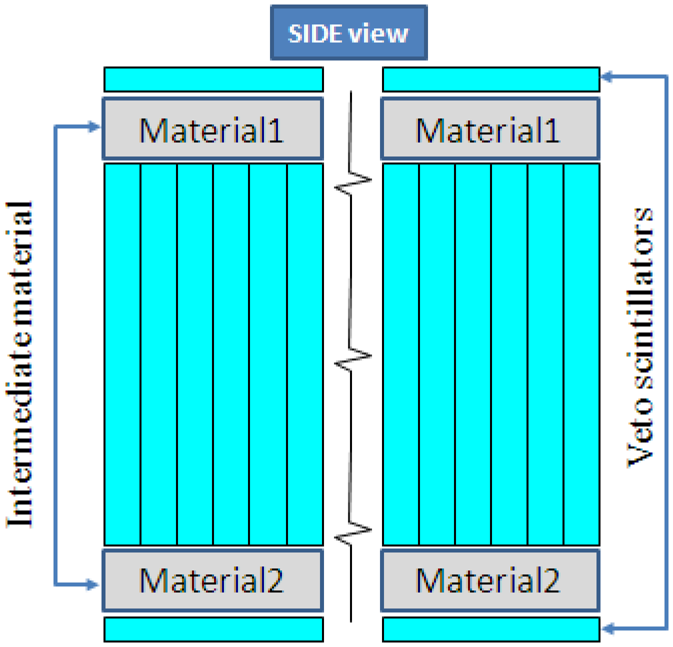

Figure 2. Muon vetos on top and bottom of detector.

Layer of some intermediate materials (spacer) will be between the detector and the veto plastic. To represent it (GG end fitting, wires, electronic, supports etc.) it is proposed to introduce here some material with thickness/density/Z-average as variable parameters. They will have some average values. Additional parameter is thickness of top/bottom plastic. The proposed parameters names

 # VETO definitions
 # Thickness\density\nucleus charge of intermediate material (spacer), cm\g/cm3\charge units
GEOMETRY VETO_SPACER_thick D 20.
GEOMETRY VETO_SPACER_density D 4.
GEOMETRY VETO_SPACER_Zcharge D 10
 # Thickness of scintillators, cm
GEOMETRY VETO_SCIN_thick D 20.

The same vetos are needed for basic design.

SNOVA output for calorimeter/geiger hits

Additional property should be added for calorimeter/geiger hits. It should be different for Z-walls (front/back from foils) hits and Y-walls (side left/right from foils) and Geiger hits. The reason is that internal Z-walls belong to 2 modules simultaneously while Z-walls as well as Geiger chambers are always belong to one module. As a result, for Z-wall bar hits it is proposed to add property:

1. Number of wall. Proposed name ***WALL***, ***WALL*** in range [1,2..,***MODULES***+1]

For Y-wall bar hits and Geiger hits one need to add property:

2. Number of current module. Proposed name ***MODULE***.

Other properties in hits remain the same.

Tracking concept

The main idea here is minimize again the intervention in the current basic design method.

Pattern recognition in CATS could be performed in cycle module per module in two steps:

1. Module event with Geiger and calo hits for particular module is built from full event data using new properties ***WALL*** and ***MODULE*** of SNOVA output described above. It means, that from original MULTI MODULE events (bar/gg hits in different modules) we build SINGLE MODULE event for particular N-th module (bar/gg hits only from module) using selection cuts ***MODULE***=N for outer bars and geigers and ***WALL***=N || N+1 for inner bars.

2. The same tracking procedure as for basic design is carried out with module event

Reconstructed CATS objects should be tagged with ***MODULE*** property. It will allow to made analogous model per module cycle processing in all further chain of programs (NEMORA, ARECIFE, etc.)

In this strategy we minimize our changes (don't change our current tracking core code at all) and just add new selections algorithms. It looks essentially easily to implement in comparison with change of format of basic properties ***CALO_BLK*** and ***GG_CELL*** with heavy interventions in the code without visible advantages. Moreover, this strategy could even keep backward code compatibility, where our multi-module analysis is switching on if ***MODULE***/***WALL*** properties are in data. If not, the standard single module analysis is going on as it is now.

Basic bar design

- Full size: 10 x 10 x 2 m
- Number of modules: 10
- Inner bars: 2 x 10 x 200 cm
- Outer bars: 10 x 10 x 200 cm

Other parameters are identical to basic design. The full snova geometry file for proposed basic bar design is given in Appendix I.

Option: Cancel thicker bars on outer walls as we will loose resolution on outer walls which is rather big! Maybe, it's better to have external gamma-capturer around all setup instead? In addition we simplify G4 code with single shape bars – no change is needed for at all.

Bar output

As bar is connected to 2 PMs, the output signal is principally different from scintillator block output in basic SuperNEMO design (see Fig.3). Top E_1/T_1 and bottom E_2/T_2 signals should be reconstructed in SUNAMI instead of single Energy/Time signal. At first approximation it could be calculated as:

$$E_1=E_2=E\_dep/2;\ t_1=Z_1/V_C,\ t_2=Z_2/V_C;\ \sigma_E(E_1)=\ \sigma_E(E_2)=const;\ \sigma_t(t_1)=\ \sigma_t(t_2)=const \qquad 1)$$

More sophisticated error functions $\sigma_E = \sigma_E(E,Z)$ and $\sigma_\tau = \sigma_\tau(E,Z)$ could be introduced for Gaussian spreading of E/T after parameterization using experimental data.

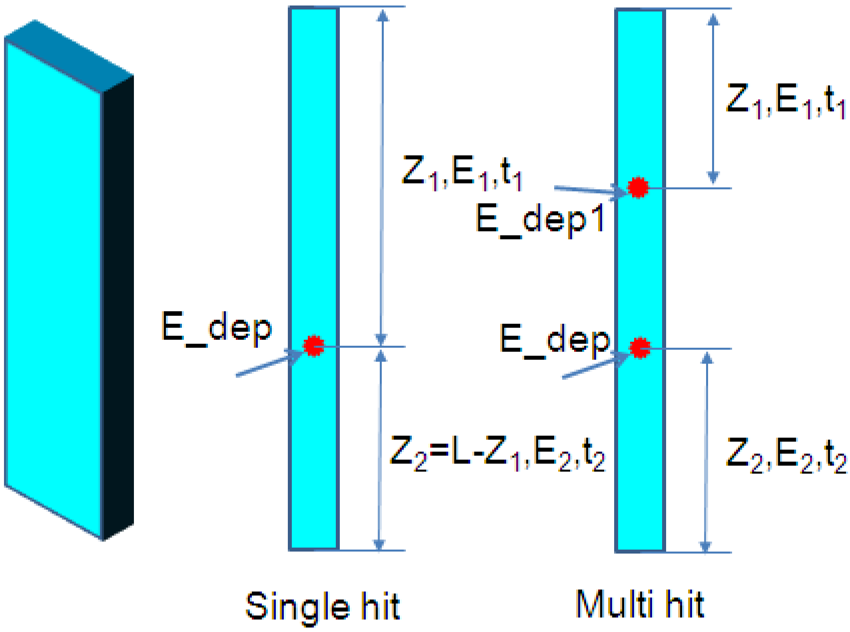

Figure 3. Hits and signals in bar.

Changes in SUNAMI output in comparison with basic design:

- ADC-like output of upper PM E_1 (proposed property name AT)
- ADC-like output of bottom PM E_2 (proposed property name AB)
- Time of upper PM T_1 (proposed property name TT)
- Time of bottom PM T_2 (proposed property name TB)
- No E and TIME properties.

Processing of multiple hits is desired but not the first priority task.

In further analysis longitudinal hit point in bar is reconstructed as:

$$Z = L/2*(T_1-T_2)/(T_1+T_2) \qquad 2)$$

where L= ***CHAMBER_height*** is bar length.

Simulation plans

1. Sensitivity simulations for $0\nu\beta\beta + 2\nu\beta\beta$
2. Setup optimization for internal ^{208}Tl tagging and sensitivity simulations for $0\nu\beta\beta + 2\nu\beta\beta + ^{208}$Tl.
3. ^{214}Bi + external γ's.

   Tested parameters:

   1) Foil thickness and material: ^{82}Se/^{150}Nd; 20/40/60/80 mg/cm^2

2) Bar thickness: 1/2/3 cm

3) Bar width: 8/10/12 cm

4) Tracking chamber width: 20/40/50 cm

Appendix I: snova geometry input for bar design

#SNOVA bar design 10 x 10 x 2 m geometry options file
 # inner scin bars: 2 x 10 x 200 cm
 # outer scin bars: 10 x 10 x 200 cm

SOURCE FOIL

 # SOURCE thickness (Z axis) (mm)
GEOMETRY SOURCE_thick D 0.080

 # SOURCE height (Y axis) (cm)
GEOMETRY SOURCE_height D 150.

 # SOURCE width (X axis) (cm)
GEOMETRY SOURCE_width D 950.

 # SOURCE materials (Options: Molibdenium, Selenium, Neodymium, ...)
GEOMETRY SOURCE_mat S Selenium

TRACKING CHAMBER

 # Tracking Chamber total length (Z axis) (cm)
GEOMETRY CHAMBER_length D 100.

 # Tracking Chamber height (Y axis) (cm)
GEOMETRY CHAMBER_height D 200.

 # Tracking Chamber width (X axis) (cm)
GEOMETRY CHAMBER_width D 1000.

TRACKING BLOCKS DISTRIBUTION & CONSTITUTION

 # Number of GG blocks in one side of the Chamber
GEOMETRY num_blocks I 3

 # Number of planes in every GG block
GEOMETRY planes_per_block V 3
3
3
3
 # Gap size (cm) for every GG block
GEOMETRY gaps_Z V 3
6.
6.
6.
GEIGER CELLS

 # Geiger cell diameter (mm)
GEOMETRY GG_CELL_diam D 30.

 # Geiger ground wires diameter (mm)
GEOMETRY GG_GRND_diam D 50.e-3

 # Geiger anode wires diameter (mm)
GEOMETRY GG_ANODE_diam D 50.e-3

```
# Geiger ground wires material (Options: Inox, ...)
GEOMETRY GG_GRND_mat S Inox

# Geiger anode wire material (Options: Inox, ...)
GEOMETRY GG_ANODE_mat S Inox

# Place extra ground wire between adjacent cells of same plane
GEOMETRY extra_grnd_cell I 1

# Place extra ground wire between adjacent cells of adjacent planes
GEOMETRY extra_grnd_plane I 1

### CALORIMETER ###
# GEOMETRY CALORIMETER_type S Basic
GEOMETRY CALORIMETER_type S Bar

### MODULE ###
# Number of modules
GEOMETRY MODULE_numbers I 10

### CALORIMETER BARS ###

# Calorimeter thickness of inner bars (wrapper included) (cm)
GEOMETRY CALO_BLOCK_thick D 2.

# Calorimeter thickness of outer bars (wrapper included) (cm)
GEOMETRY CALO_BLOCK_border_thick D 10.

# Calorimeter bar total height (wrapper included) (cm)
# Not needed as for bar design CALO_BLOCK_height = CHAMBER_height
# But could be kept to backward compatibility
# GEOMETRY CALO_BLOCK_height D 25.

# Calorimeter bar total width (wrapper included) (cm)
GEOMETRY CALO_BLOCK_width D 12.

# Calorimeter bar wrapper thickness (mm)
GEOMETRY CALO_WRAP_thick D 0.012

# Calorimeter bar wrapper material (Mylar, ...)
GEOMETRY CALO_WRAP_mat S Mylar

### MAGNETIC FIELD ###

# Magnetic field (B) intensity (in Gauss) (Y axis) (10 KGauss = 1 Tesla)
GEOMETRY B_int D 25.0

# VETO definitions
# Thickness|density|nucleus charge of intermediate material (spacer), cm|g/cm3|charge units
GEOMETRY VETO_SPACER_thick D 20.
GEOMETRY VETO_SPACER_density D 4.
GEOMETRY VETO_SPACER_Zcharge D 10
# Thickness of scintillators, cm
GEOMETRY VETO_SCIN_thick D 20.
```