# FASERLiverpool October Update

Sinead Eley

# Neutral Hadrons : Recap

- Neutral hadrons produced from muon decay in rock before FASER
- Expected to be negligible due to low probability of neutral hadrons surviving until Veto scintillators
- Using purpose made samples for neutral hadrons produced by Eli
    - Mu + (980 fb-1) & Mu - (945 fb-1)
- Method:
    - Select neutral hadrons using their PID
    - Apply baseline cuts
    - If there are events that pass all selections, use results to scale neutral hadron PG samples to find yield of a specific species

| **Particle** | **PID** |
| --- | --- |
| $K_L$ | 130 |
| $K_S$ | 310 |
| Neutrons (anti-neutrons) | 2112 (-2112) |
| $\Lambda_0$ ($\bar{\Lambda}_0$) | 3122 (-3122) |

| **MC Cuts** |
| --- |
| Calo E $>$ 20 GeV |
| Timing Signal $<$ 20 pC |
| VetoNu Signal $<$ 40 pC |
| Veto Signal $<$ 40 pC |

# Muons in 2024 Data

- Due to change in LHC optics in 2024, FASER saw an increase in muon flux (of a factor 2)
- As neutral hadrons are secondaries of the muons incident on the rock before FASER
  - Necessary to apply an extra weighting to neutral hadron samples to calculate the background in 2024 data
- Weighting calculated using muon flux in data
  - Apply to sample at the same time as FLUKA weights

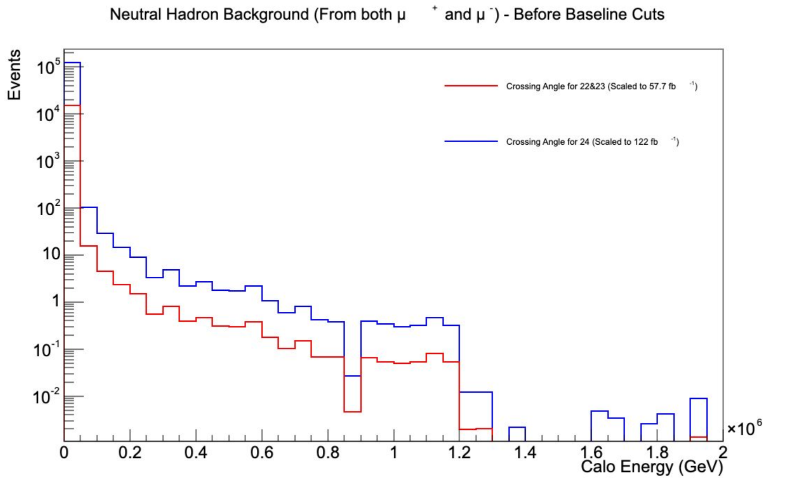
# Neutral Hadrons

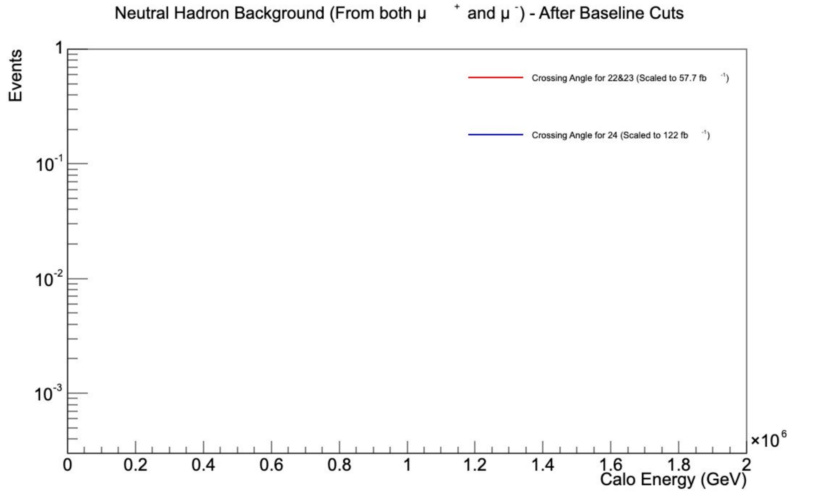
## 2022/23 Neutral Hadron Background

| All Regions [Not leadShield] | | |
|---|---|---|
| Cut | Input | Pass |
| Select Neutral Hadrons | 872486.96 | 15277.58 |
| Calo Energy > 20 GeV | 15277.58 | 80.65 |
| Timing < 20 pC | 80.65 | 0 |
| VetoNu < 40 pC | 0 | 0 |
| Veto < 40 pC | 0 | 0 |

## 2024 Neutral Hadron Background

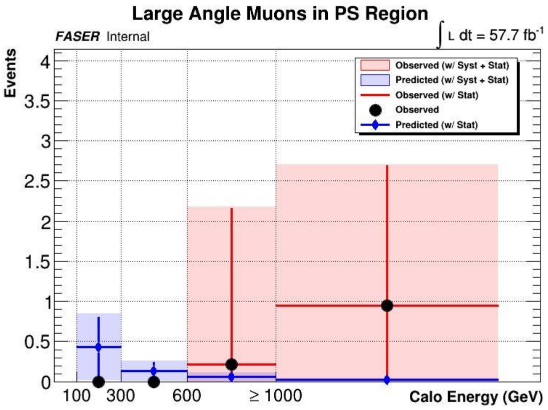
| All Regions [Not leadShield] | | |
|---|---|---|
| Cut | Input | Pass |
| Select Neutral Hadrons | 1938564 | 126093.58 |
| Calo Energy > 20 GeV | 126093.58 | 530.17 |
| Timing < 20 pC | 530.17 | 0 |
| VetoNu < 40 pC | 0 | 0 |
| Veto < 40 pC | 0 | 0 |

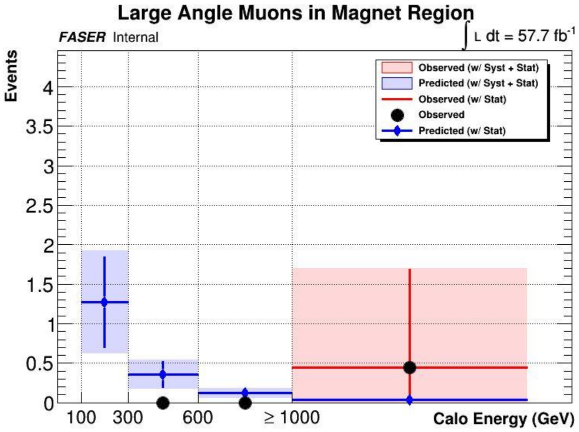


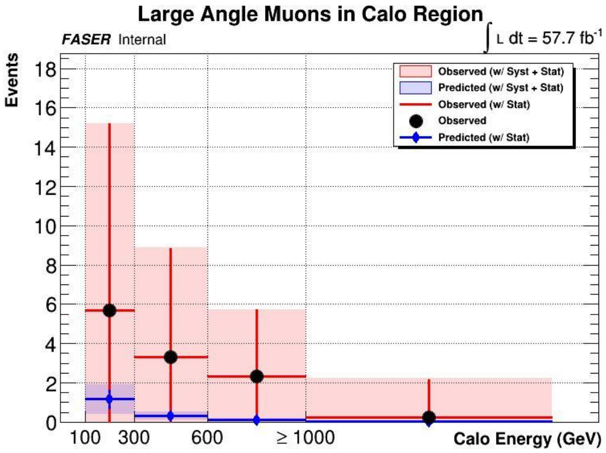



# ALPtrino - Geometric Muon Estimates (22 & 23 Data)

- Observed and predicted events agree within errors
- Geom. Muons in lead shield to be estimated
- Largest estimate in calo region - prediction falls off massively after 1st bin



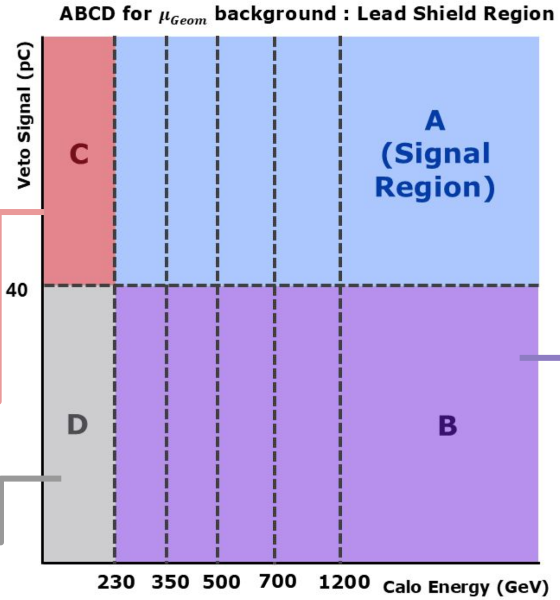



# Lead Shield ABCD Data Cutflows per ABCD region

- Unlike other regions:
  - Veto > 40 pC
  - No timing cut
  - Veto Ratio < 0.6 (Veto Ratio = Veto St 0/ Veto St 1)
- Inverting veto nu cut and applying ABCD method in diagram
  - Resulted in no stats :(

| C | | |
|---|---|---|
| Cut | Input | Pass |
| Excluded Times | 1475574815 | 1467902034 |
| Colliding | 1467902034 | 1467561631 |
| Calo trigger | 1467561631 | 8747741 |
| VetoNu Raw/Fitted Signal | 8747741 | 8598644 |
| Veto > 40pC | 8598644 | 8462564 |
| Veto Ratio < 0.6 | 8462564 | 2360113 |
| Calo_E_fit_raw_compatible | 2360113 | 2357905 |
| Calo E > 20 GeV | 2357905 | 721202 |
| Calo Timing > - 5 ns and < 10 ns | 721202 | 690647 |
| 25 < Calo E < 100 GeV | 690647 | 410968 |




| D | | |
|---|---|---|
| Cut | Input | Pass |
| Excluded Times | 1475574815 | 1467902034 |
| Colliding | 1467902034 | 1467561631 |
| Calo trigger | 1467561631 | 8747741 |
| VetoNu Raw/Fitted Signal | 8747741 | 8598644 |
| No Veto Signal | 8598644 | 17218 |
| Veto Ratio < 0.6 | 17218 | 10670 |
| Calo_E_fit_raw_compatible | 10670 | 10656 |
| Calo E > 20 GeV | 10656 | 1084 |
| Calo Timing > - 5 ns and < 10 ns | 1084 | 1053 |
| 25 < Calo E < 100 GeV | 1053 | 571 |

PROBLEM!

| B | | |
|---|---|---|
| Cut | Input | Pass |
| Excluded Times | 1475574815 | 1467902034 |
| Colliding | 1467902034 | 1467561631 |
| Calo trigger | 1467561631 | 8747741 |
| VetoNu Raw/Fitted Signal | 8747741 | 8598644 |
| No Veto Signal | 8598644 | 17218 |
| Veto Ratio < 0.6 | 17218 | 10670 |
| Calo_E_fit_raw_compatible | 10670 | 10656 |
| Calo E > 20 GeV | 10656 | 1084 |
| Calo Timing > - 5 ns and < 10 ns | 1084 | 1053 |
| Calo E > 100 GeV | 1053 | 0 |

Veto Station Ratio = VetoSt10_raw_charge/VetoSt21_raw_charge

# Alternative Approach?

- Rather than construct ABCD method using veto signal
  - Use veto signal instead
- Super high prediction.... ?

| | MC | Data | Data-MC |
|---|---|---|---|
| B1 (100-300 GeV) | 485 | 203806 | 203321 |
| B2 (300-600 GeV) | 82 | 52421 | 52339 |
| B3 (600-1000 GeV) | 12 | 17159 | 17147 |
| B4 (> 1000 GeV ) | 4 | 4906 | 4902 |
| | | | |
| C | 179 | 410968 | 410968 |
| D | 2049 | 977143 | 977143 |
| | | | |
| A1 | | | 85655.36 |
| A2 | | | 22049.45 |
| A3 | | | 7223.713 |
| A4 | | | 2065.122 |

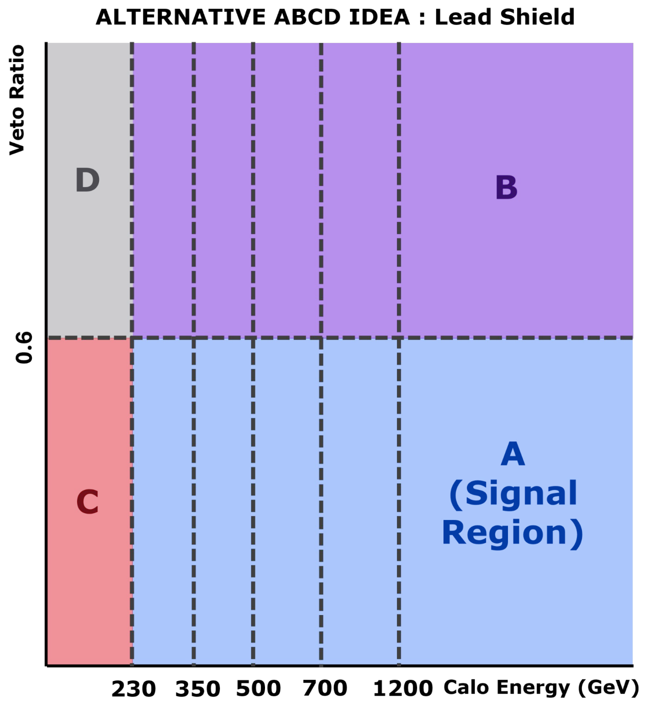
Cuts Applied
Calo E > 20 GeV

VetoNu Raw/Fitted Signal

Veto > 40pC

Veto Ratio >= 0.6

| | MC | Data | Data-MC |
|---|---|---|---|
| SR1 (100-300GeV) | 2040 | 28 | -2012 |
| SR2 (300-600GeV) | 662 | 3 | -659 |
| SR3 (600-1000GeV) | 200 | | -200 |
| SR4 (>1000 GeV) | 68 | | -68 |



# Summary / Next Steps

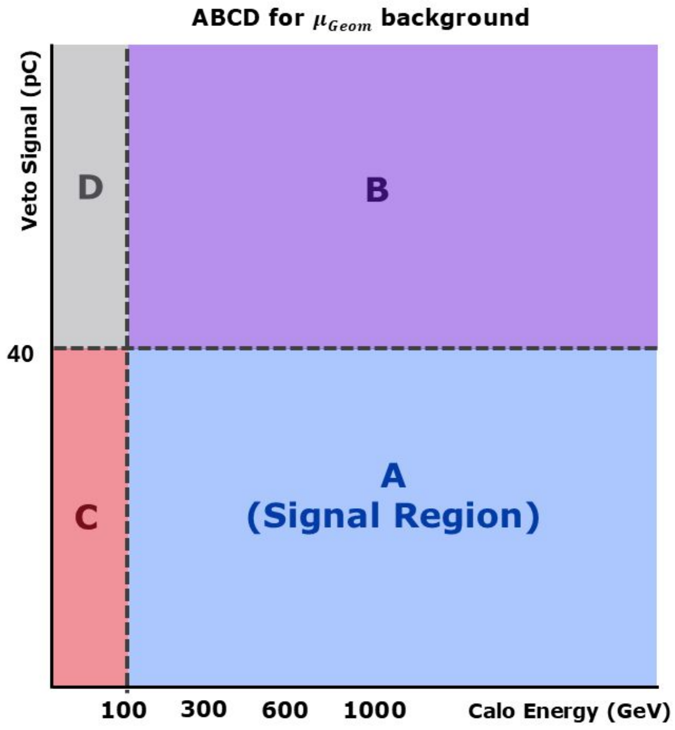
- Now have predictions for the 22/23 geometric muon background in most regions
- Get prediction for geometric muons in lead shield region
- Continue writing alptrino int note
- Reevaluate preshower fudge factor for MC24
    - Requires large FLUKA samples in MC24 to evaluate photon conversions in both data and MC

# Back Up

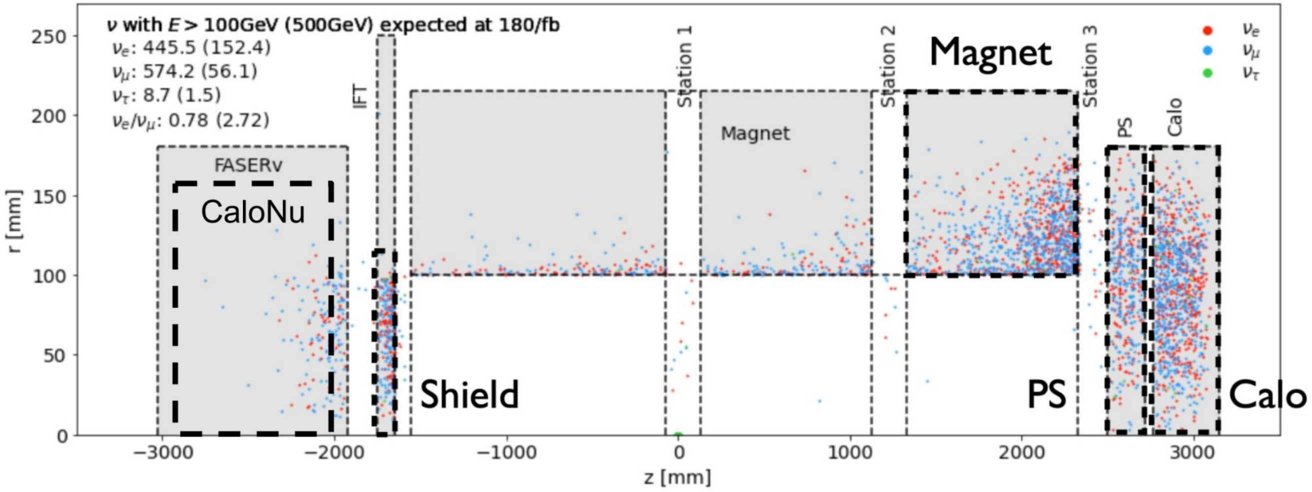
# ABCD Method for Geometric Muons

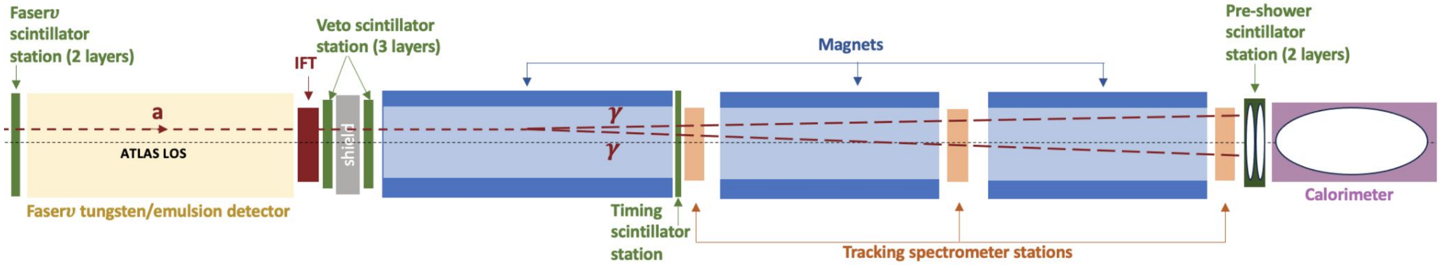
- Calorimeter, Magnet and Preshower regions

$$N_i^{\mu\text{Geometric}} \approx \left(B_i^{\text{Data}} - B_i^{\text{MC}}\right) \frac{C^{\text{Data}} - C^{\text{MC}}}{D^{\text{Data}} - D^{\text{MC}}} f$$



# Regions


ν with E > 100GeV (500GeV) expected at 180/fb
ν_e: 445.5 (152.4)
ν_μ: 574.2 (56.1)
ν_τ: 8.7 (1.5)
ν_e/ν_μ: 0.78 (2.72)
FASERν
CaloNu
IFT
Shield
Station 1
Magnet
Station 2
Magnet
Station 3
PS
Calo
PS
Calo
ν_e
ν_μ
ν_τ
r [mm]
z [mm]
0
50
100
150
200
250
−3000
−2000
−1000
0
1000
2000
3000


Faserν scintillator station (2 layers)
IFT
Veto scintillator station (3 layers)
Magnets
Pre-shower scintillator station (2 layers)
a
ATLAS LOS
shield
γ
γ
Faserν tungsten/emulsion detector
Timing scintillator station
Tracking spectrometer stations
Calorimeter