Search for New Matter effect in Atmospheric Neutrino Oscillations

M.Nizam [1,2] S. Uma Sankar [3]

[1]TIFR, [2]HBNI, [3]IITB

Motivation

- LHCb measured $R_K = \frac{B(B \longrightarrow K\mu^+\mu^-)}{B(B \longrightarrow Ke^+e^-)}$, $1.0 < q^2 < 6.0$ GeV^2 $= 0.75 \pm 0.10$

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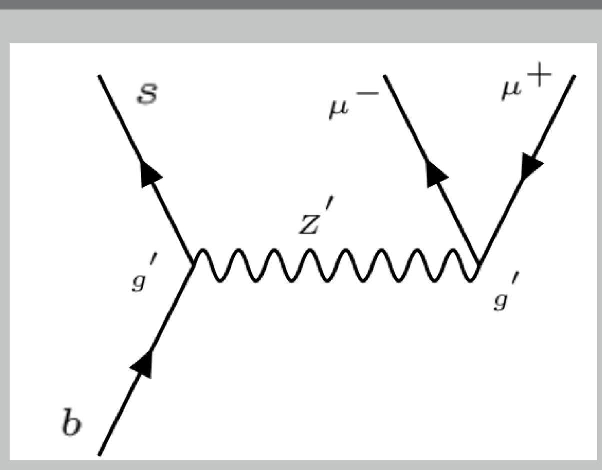
$$R_{K^*} = \frac{B(B \longrightarrow K^*\mu^+\mu^-)}{B(B \longrightarrow K^*e^+e^-)} , 1.0 < q^2 < 6.0 \text{ GeV}^2 = 0.69 \pm 0.01$$

SM prediction is 1.0
Both measurements are about 2.5σ away from SM

- The New Physics Amplitudes which can explain these discrepancies are about ~ -0.25*SM amplitude.
$[C_9^{NP} \approx -1$ vs $C_9^{SM} \approx 4]$ in units of $(\alpha G_F V_{tb} V_{ts}^* / \sqrt{2}\pi)$
C_9 is the Coefficient of the operator $\bar{S}\gamma^{\alpha}\gamma_L b \bar{\mu}\gamma_{\alpha}\mu$

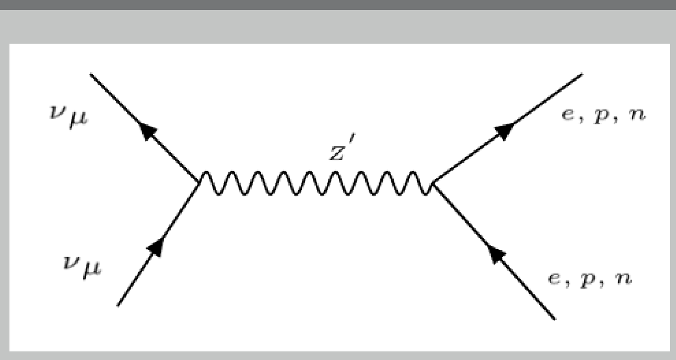
- Such New Physics amplitude can arise in models containing Z' with non-diagonal flavour couplings.



- $C_9^{NP} \approx \frac{g'^2}{M_{Z'}^2}$

New Matter effect

- Such a Z' will, in general, couple to ν_μ also and will lead to NC matter term via the scattering

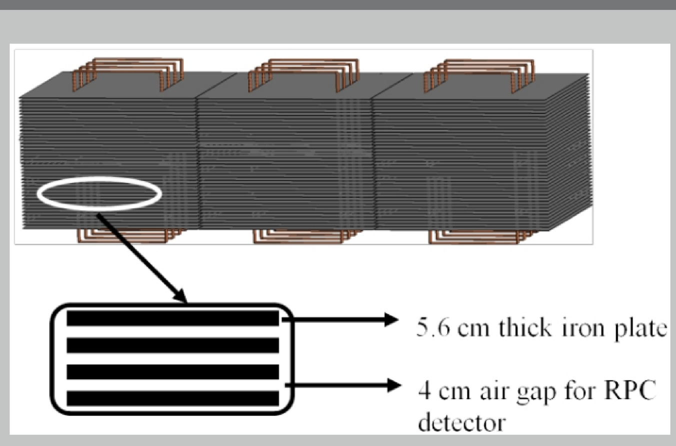


- $C_9^{NP} \approx \frac{g'^2}{M_{Z'}^2}$

- We parametrize this new matter term as A^{NP}=q . A^{std} (q:0.0 - 1.0)
Where A^{std} is the standard Wolfenstien matter term given by $0.76 \times 10^{-4}\rho$(gm/cc) E(GeV).

Iron CALorimeter (ICAL) at INO

- The India-based Neutrino Observatory (INO) is proposed to be built in Bodi West Hills, in Theni district of Tamil Nadu in South India.



- The main detector proposed to be built at the INO is the magnetised Iron CALorimeter (ICAL) with a mass of 50 kt.

ICAL	
No. of modules	3
Module dimension	16 m × 16 m × 14.5 m
Detector dimension	48 m × 16 m × 14.5 m
No. of layers	151
Iron plate thickness	5.6 cm
Gap for RPC trays	4.0 cm
Magnetic field	1.5 Tesla
RPC	
RPC unit dimension	2 m × 2 m
Readout strip width	3 cm
No. of RPC units/Layer/Module	64
Total no. of RPC units	∼ 30,000
No. of electronic readout channels	3.9×10^6

- ICAL can distinguish neutrinos from antineutrinos.
- The fast response time of the RPCs (of the order of nanoseconds) will allow for a discrimination of the upward-going muon events and downward-going ones.

INO simulations

- We generate 10 yrs of unoscillated Nuance ν_μCC event sample.

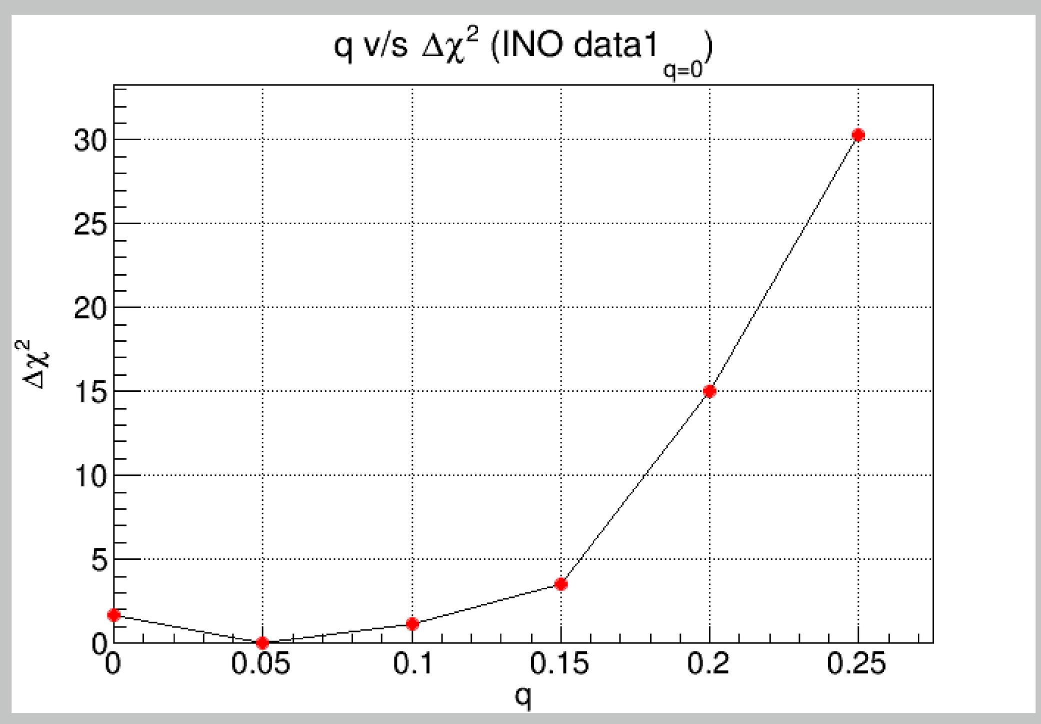
- Multiply a new factor "q" while calculating probabilities for matter oscillations and with $\triangle m^2 = 2.5 \times 10^{-3}$eV^2, $\sin^2 2\theta = 1.0$ and a constant $\rho = 5.0$g/cc(density of matter) for two cases (a) q=0 and (b) q=0.1

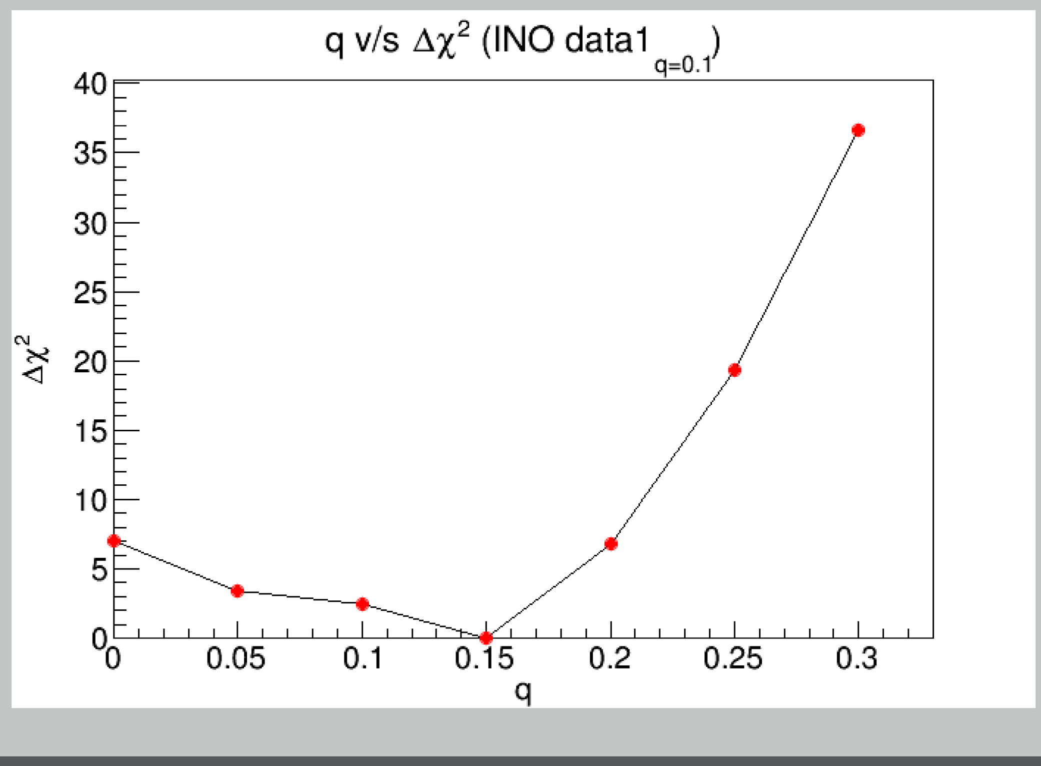
- Bin these events according to $\cos\theta_\mu$, (-1.0 to -0.5) 5 bins in steps of 0.1 and (0.5 to 1.0) 5 bins in steps of 0.1. Energy bins are E_μ (1.0,2.0),(2.0,3.0),(3.0,4.0),(4.0,5.0), (5.0,6.0),(6.0,7.5),(7.5,9.0),(9.0,11.0),(11.0,14.0),(14.0,17.0) GeV, 10 bins.Total 100 bins.
We call this $\frac{d^2N_\mu}{d\cos\theta_\mu dE_\mu}|_{data}$.

- We generate test samples for 500 yrs with $\triangle m^2 = 2.5 \times 10^{-3}$eV^2, $\sin^2 2\theta = 1.0$ $\rho = 5.0$g/cc(density of matter) and varying value of q (0 to 0.5) in steps of 0.05. Scale down each sample to 10 yrs. Bin these event samples according to the binning scheme described above. We call these samples $\frac{d^2N_\mu}{d\cos\theta_\mu dE_\mu}|_{test}$

- Calculate χ^2 and $\triangle\chi^2$ between data and test.

Results





References

1. arXiv:1805.04370 (LHCb Collaboration)
2. Shakeel Ahmed et al. (ICAL Collaboration) 10.1007/s12043-017-1373-4
3. Ali Ajmi et al. (DOI: 10.1088/1742-6596/888/1/012151)

Contact Information

- Email: mohammad.nizam@tifr.res.in
- Phone: +91 9867977206