Heavy Sterile Phenomonology and the MiniBooNE anomaly

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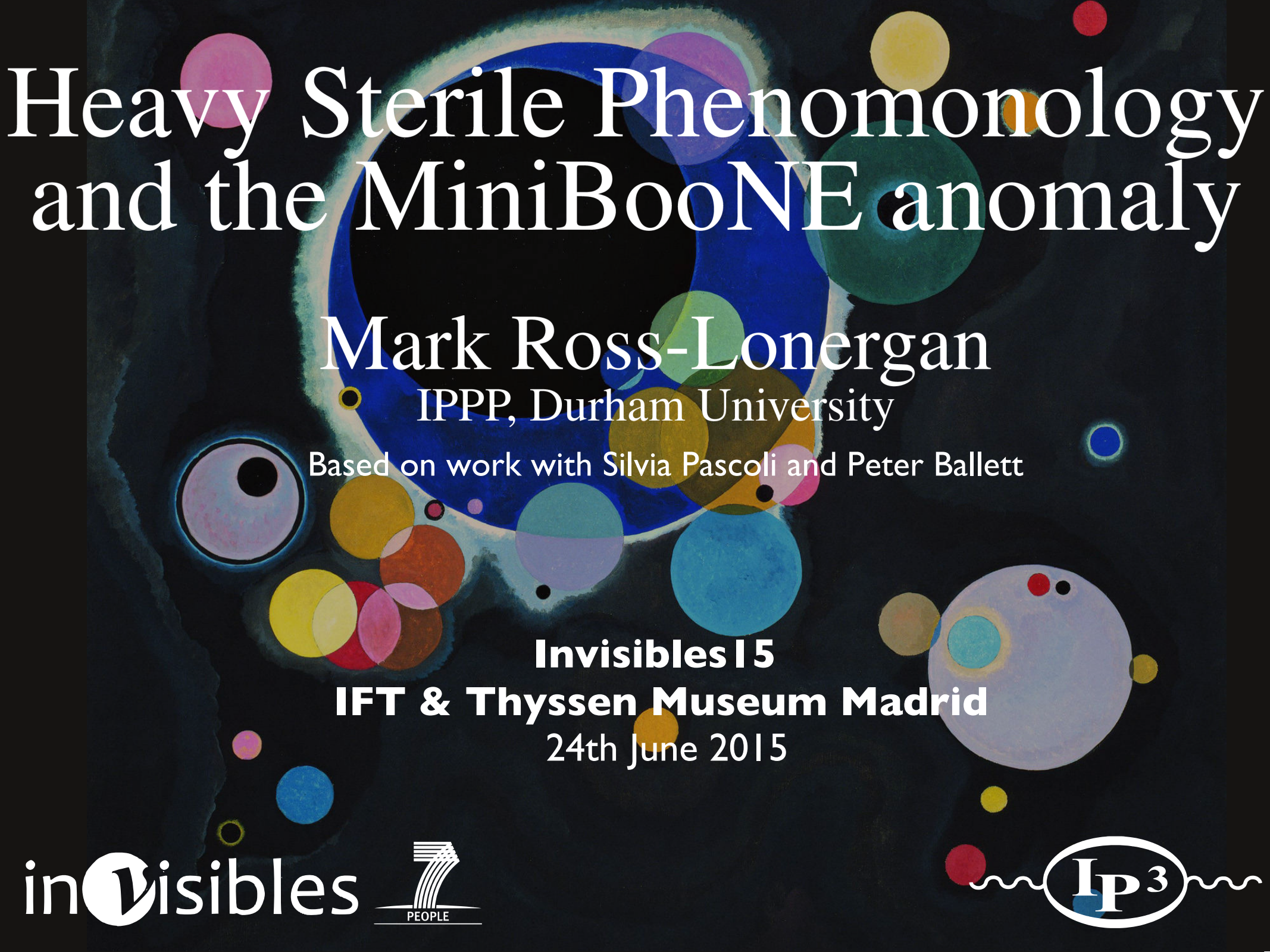
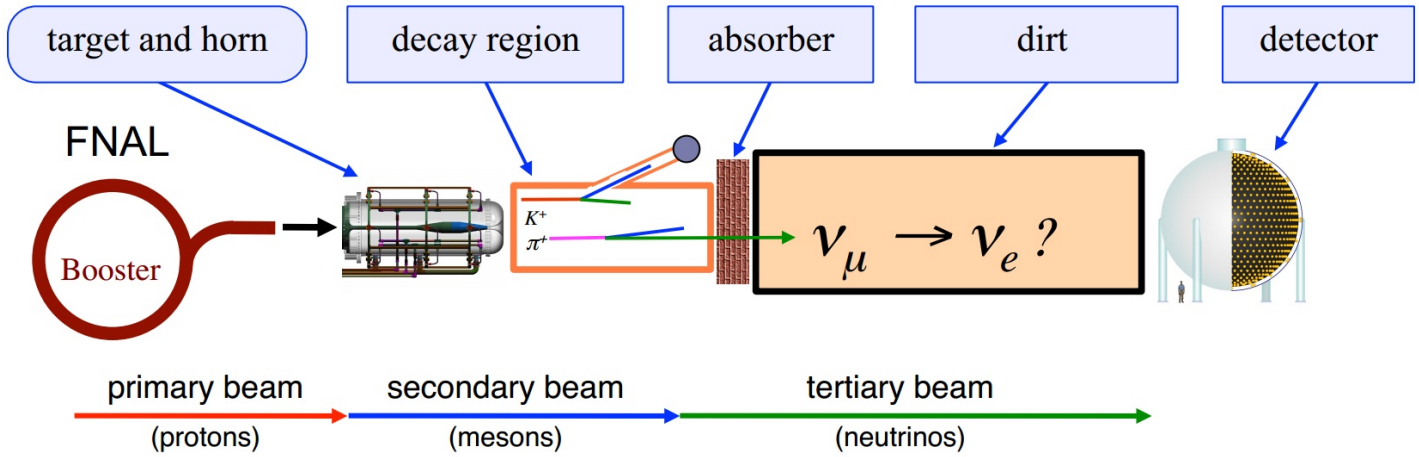
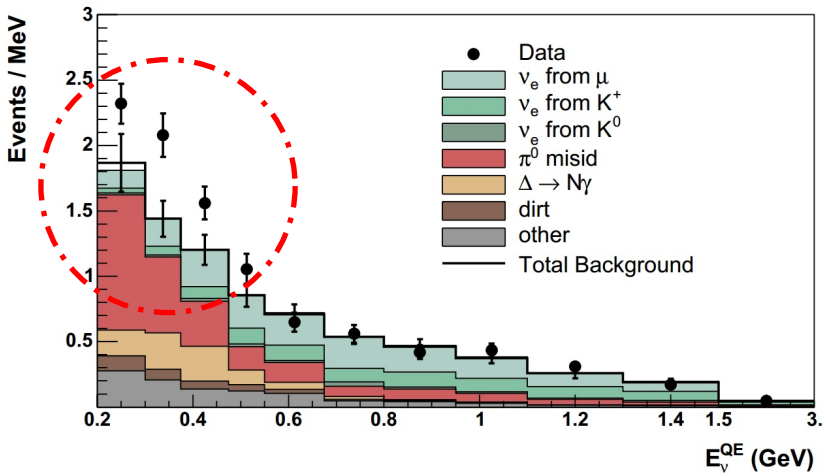
Based on work with Silvia Pascoli and Peter Ballett

Invisibles15
IFT & Thyssen Museum Madrid
24th June 2015



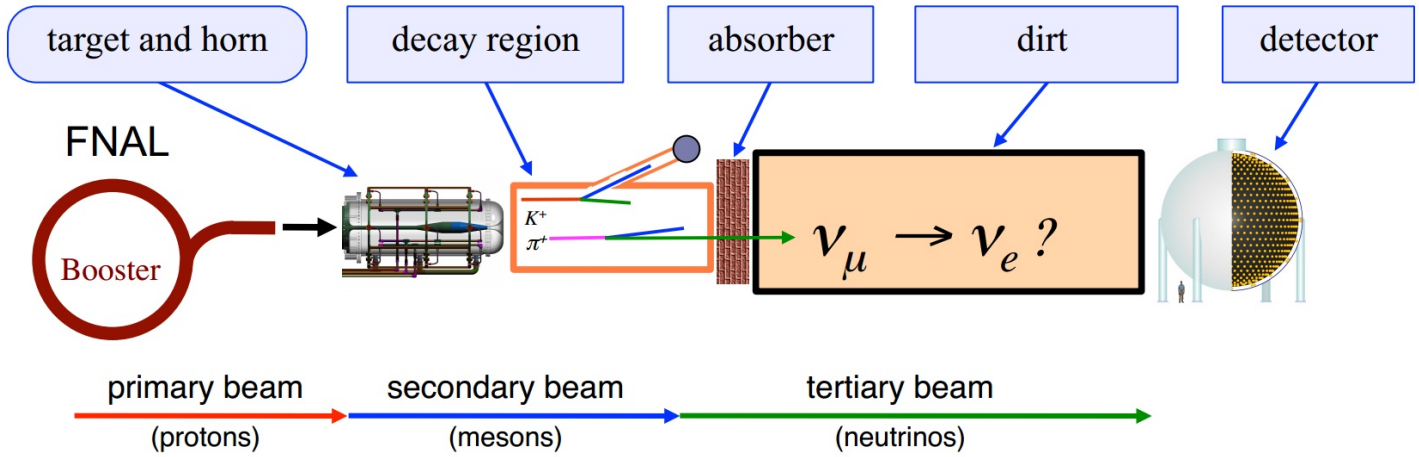
MiniBooNE

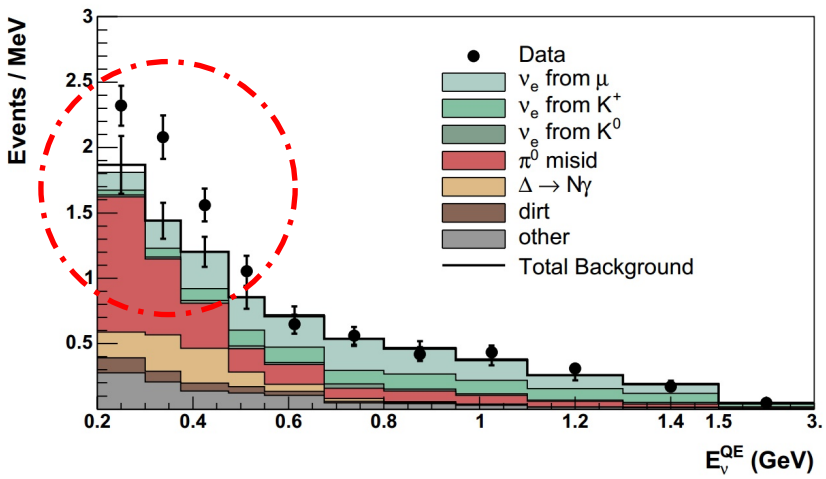


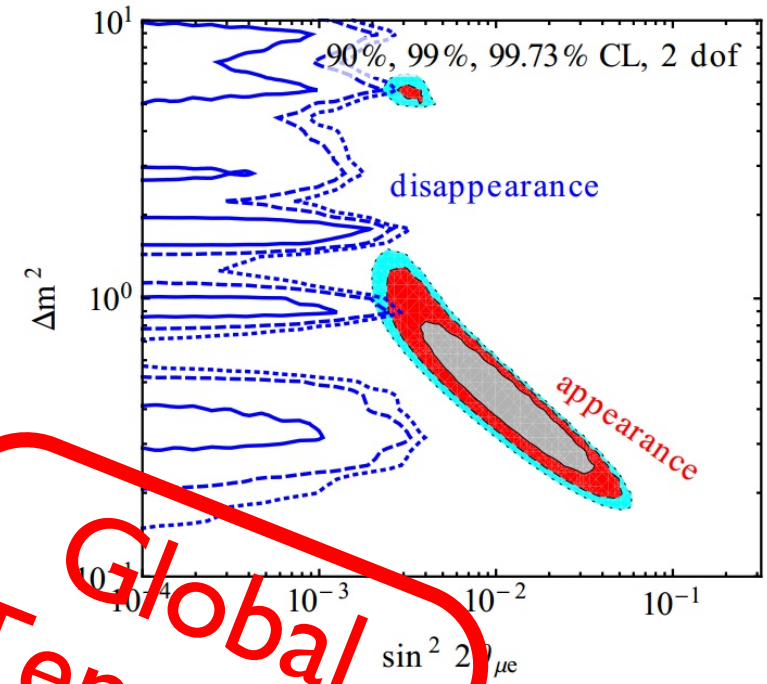


Observed an excess of approximately 180 events at low energy, < 0.5 GeV.

MiniBooNE







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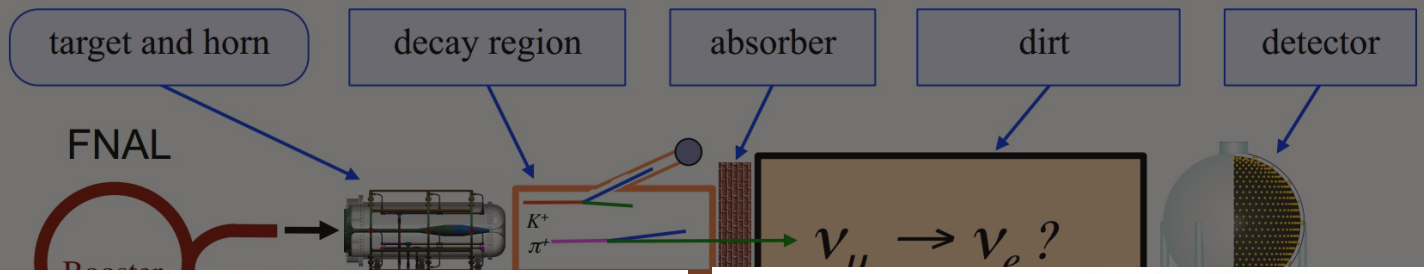
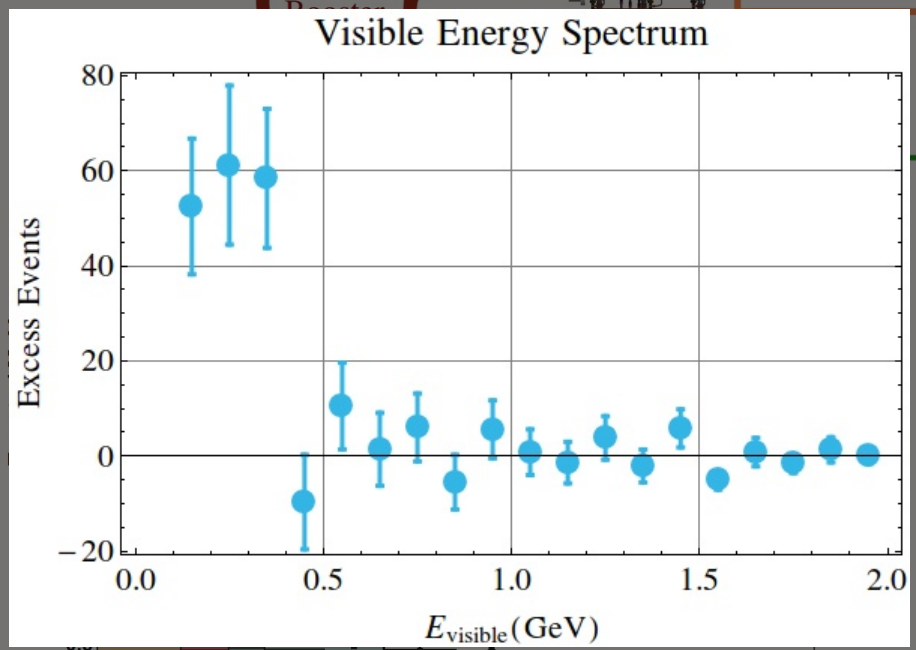
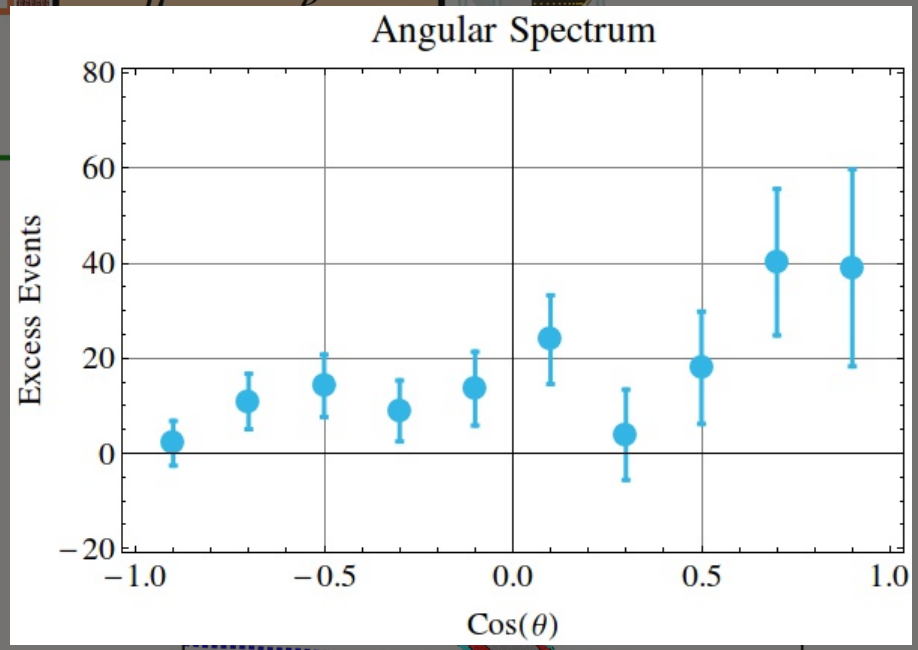
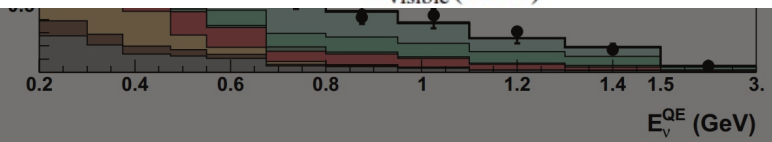
Global Tension

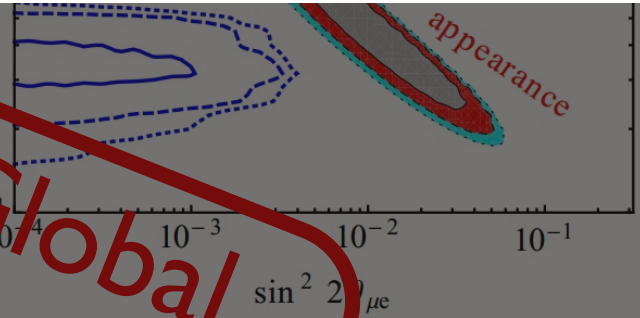
MiniBooNE











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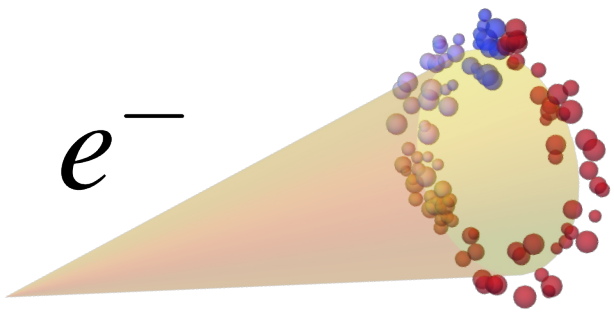
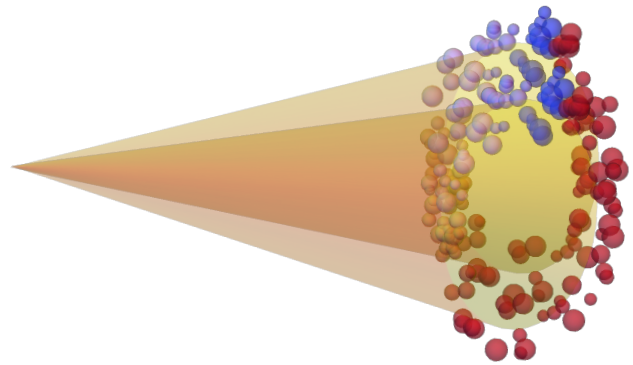
Global Tension

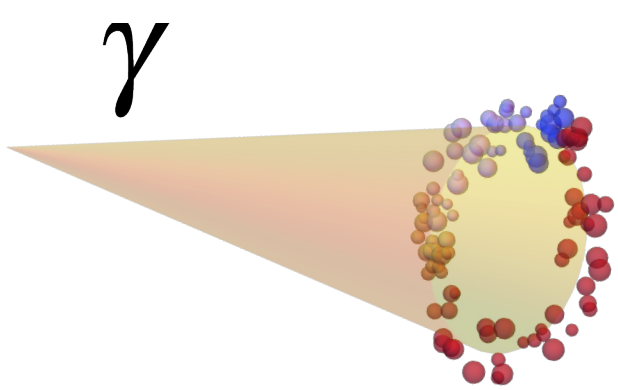
What's the Signal?

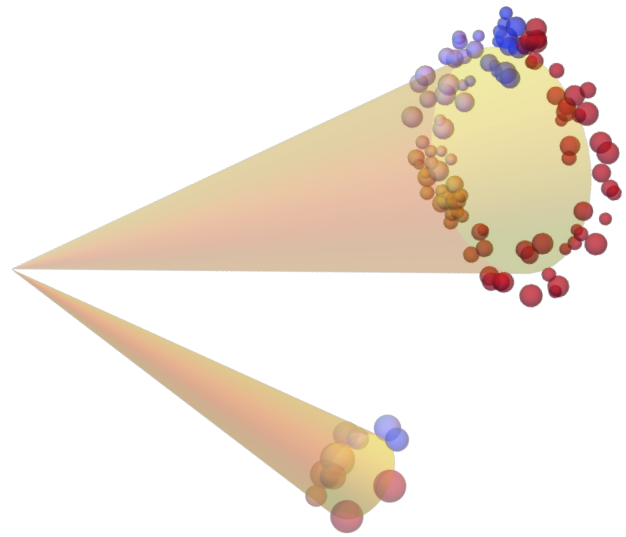
Overlapping e^+e^-





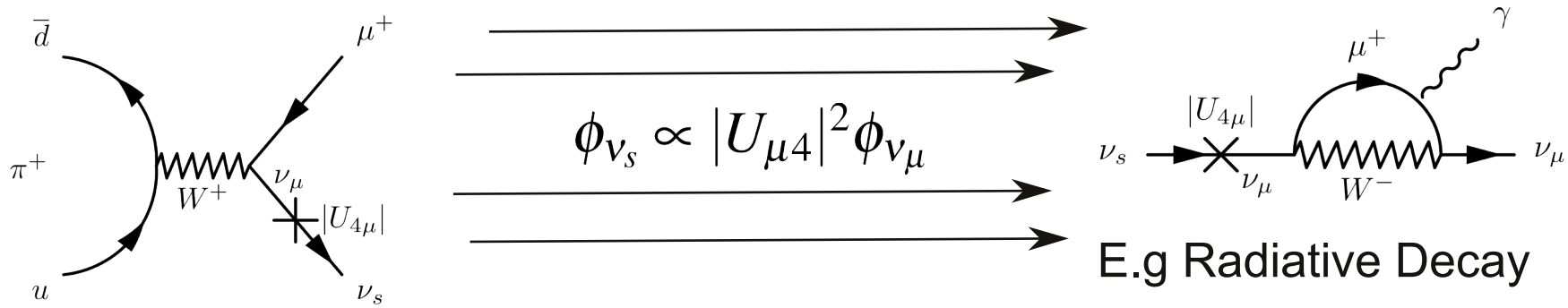
Highly Asymmetric e^+e^-



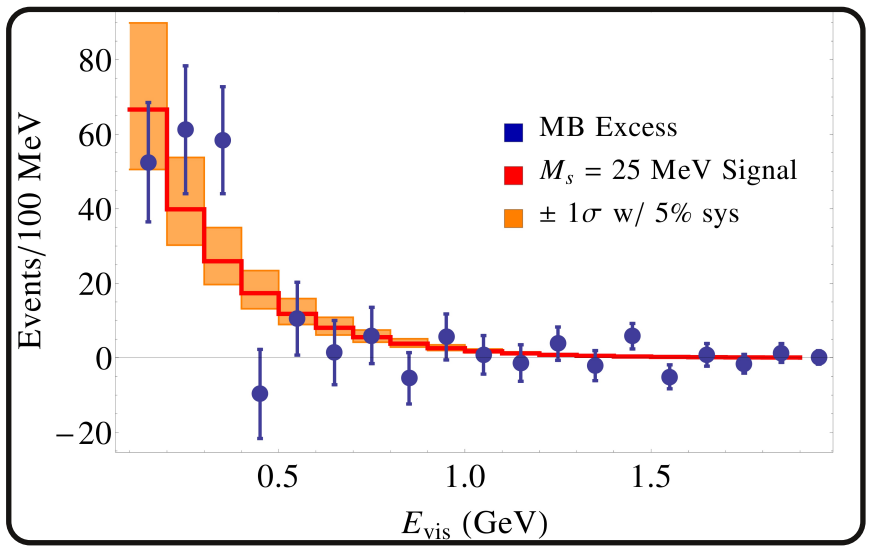


Alternative Scenarios

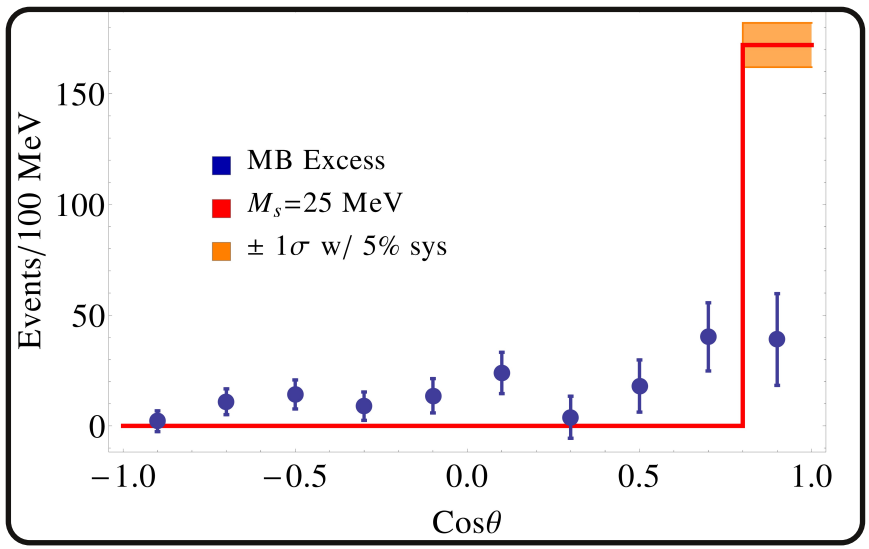
Sterile Neutrinos in the MeV-GeV Range have a very rich phenomonology in SBL facilities. A flux of sterile neutrinos created alongside the standard neutrino beam can reach the detector and subsequently decay.



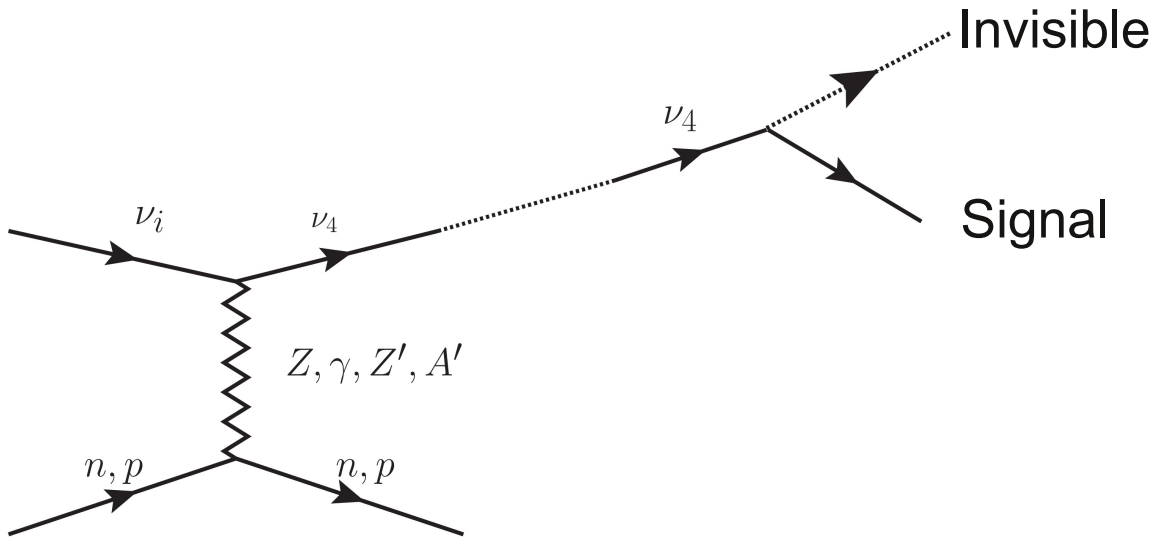
Energy Excess



Angular Excess



Angular spectrum is *key* tool in excluding large classes of sterile scenarios. Need to produce more isotropic daughter events from sterile decay.



Z_{SM}

- $M_{SM} \gg E_{exp}$
- $\frac{\partial \sigma_{\nu\nu}}{\partial Q^2}$ favours larger $Q^2 \Rightarrow$ isotropy
- σ_{TOT} is very small due to $G_F^2 |U_{\mu 4}|^2$

γ, γ-like

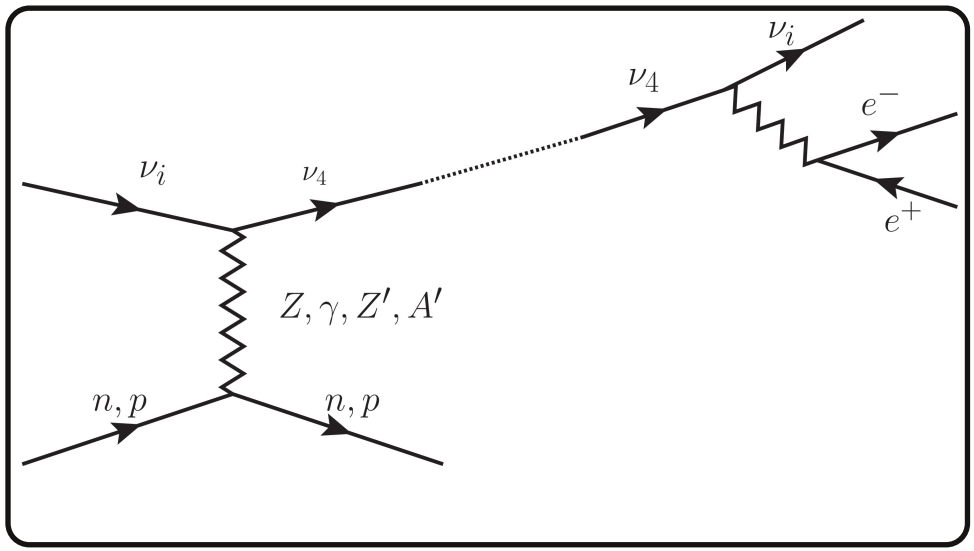
- Need large anomalous magnetic moment
- $\frac{\partial \sigma_{\nu\nu}}{\partial Q^2}$ favours very small $Q^2 \Rightarrow$ very forward

Z'

- $M_{SM} \approx E_{exp}$
- $\frac{\partial \sigma_{\nu\nu}}{\partial Q^2}$ between Z_{SM} and γ-like
- σ_{TOT} increased by $\approx \left(\frac{M_{Z_{sm}}}{M_{Z'}}\right)^4$

- As a concrete model we intoduce a single MeV scale sterile degree of freedom charged under a new U(1)' symmetry. Although no standard model particles initially feel this new force, they obtain a microcharge due to kinetic mixing with the SM hypercharge boson. In the flavour basis

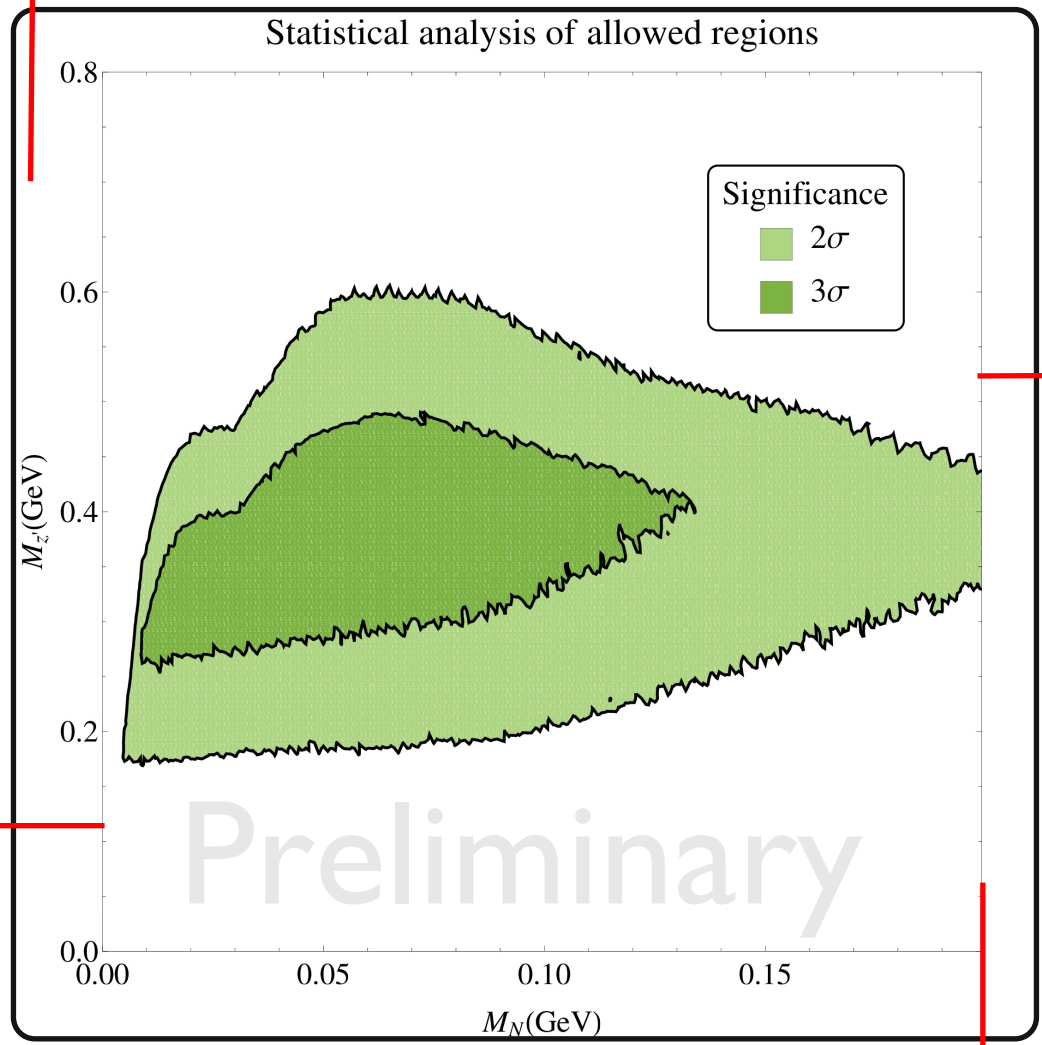
$$\mathscr{L} = L_{sm} - \frac{1}{4}F'^{2}_{\mu\nu} - \chi F'_{\mu\nu}B^{\mu\nu} + \frac{M_{Z'}}{2}X'^{2} - ig'\overline{\nu_s}\gamma^{\mu}\nu_s X'_{\mu},$$



- Post EWSB there will exist a tree level coupling between Massive Z', ν_4 and $\nu_{1,2,3}$.
- Fraction of subsequent decays to e^+e^- mis-identified as CCQE electrons
- Kinetic mixing χ^2 alongside $|U_{e4}|^2, |U_{\mu 4}|^2$ and $|U_{\tau 4}|^2$ constrained to be below current 90% C.L bounds.

Heavier Z' Masses cannot achieve a large enough event rate

Increasing Mz'



Heavier Sterile Masses cannot successfully reproduce the peaked energy spectrum.

Increasing Mn

Decreasing Mn

Lighter Sterile Masses cannot achieve a large enough decay rate

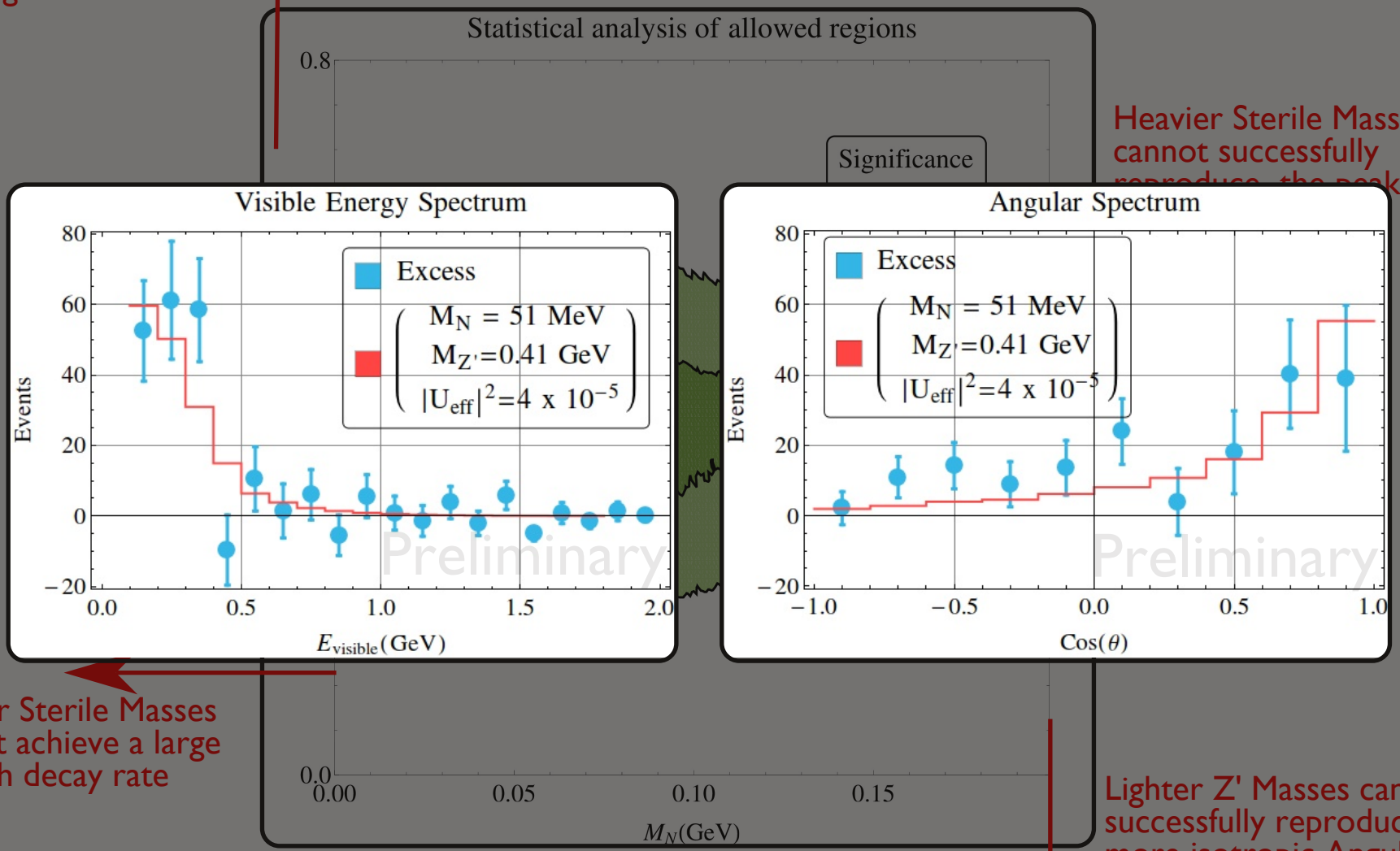
Lighter Z' Masses cannot successfully reproduce the more isotropic Angular Apectrum.

Decreasing Mz'

Sample Points

Heavier Z' Masses cannot achieve a large enough event rate

Increasing Mz'

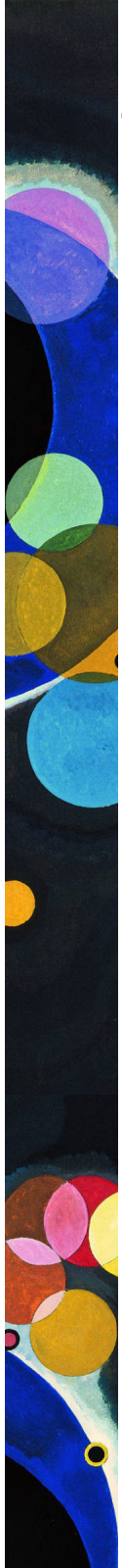


Heavier Sterile Masses cannot successfully reproduce the peaked

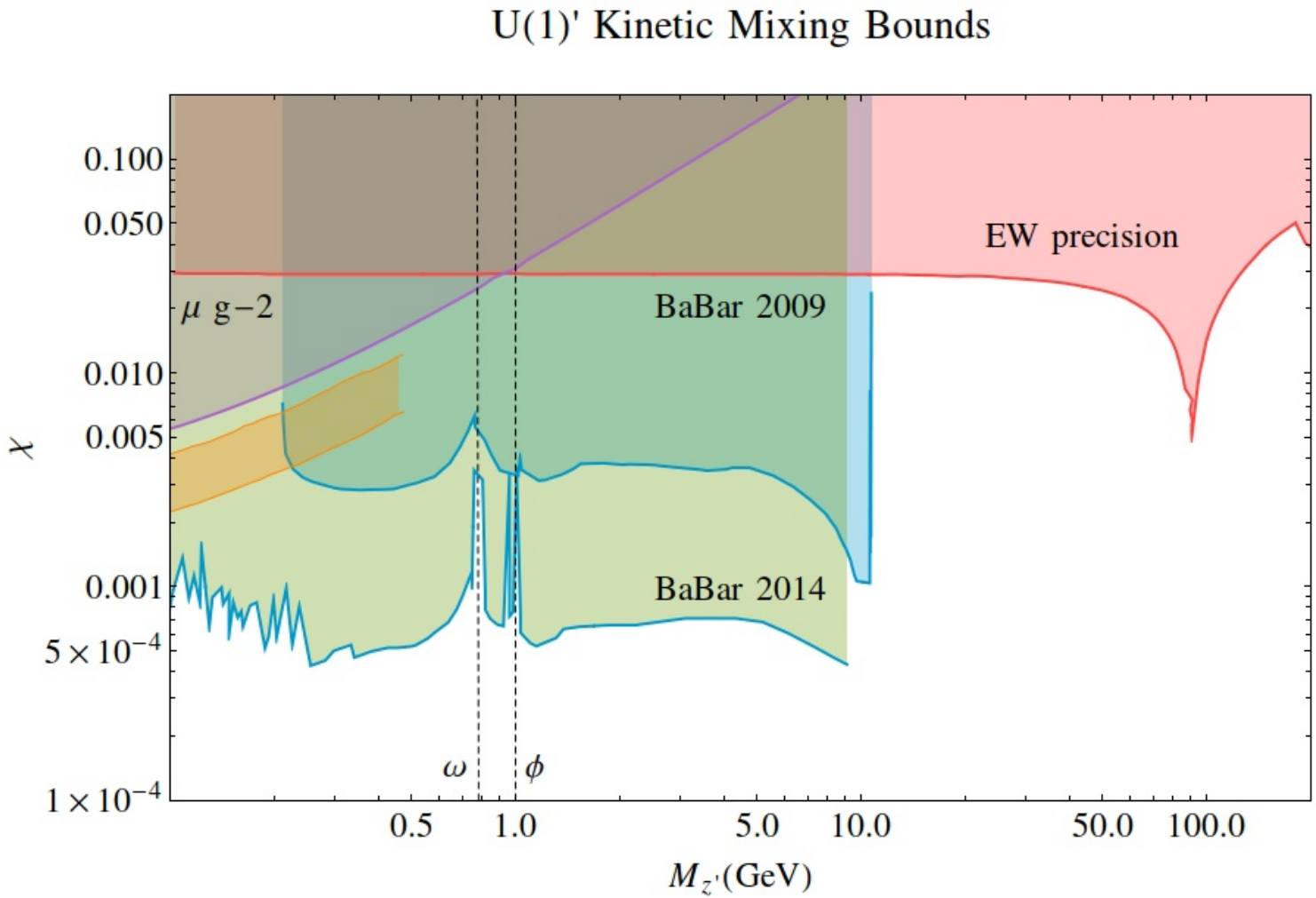
Lighter Sterile Masses cannot achieve a large enough decay rate

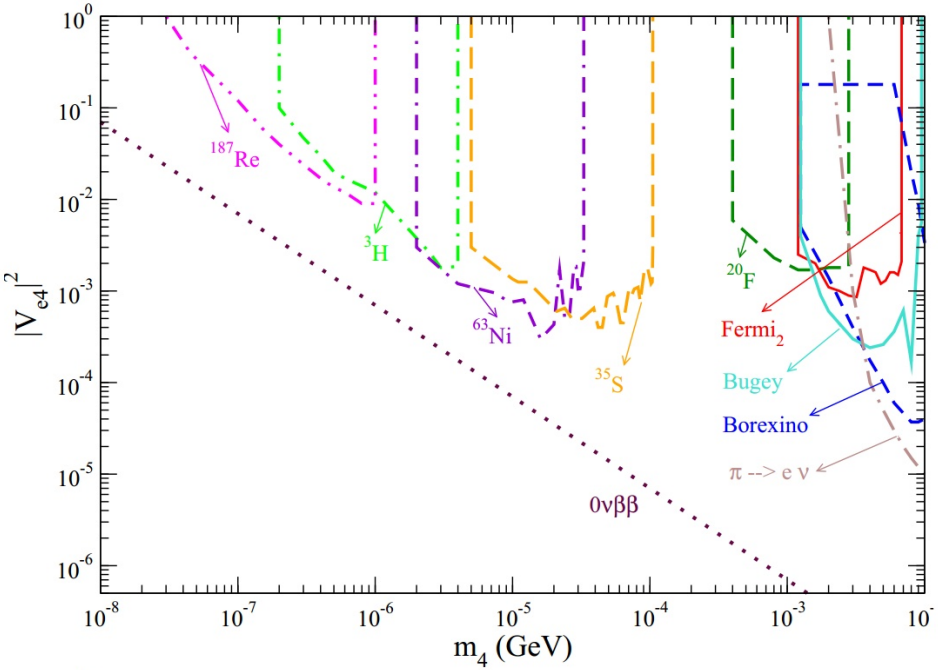
Decreasing Mz'

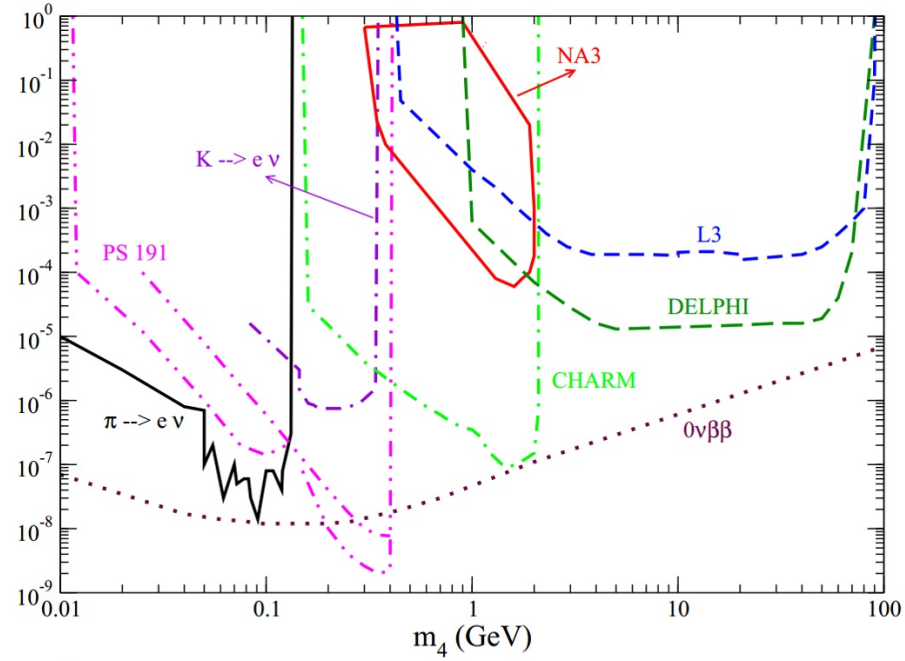
Lighter Z' Masses cannot successfully reproduce the more isotropic Angular Apectrum.

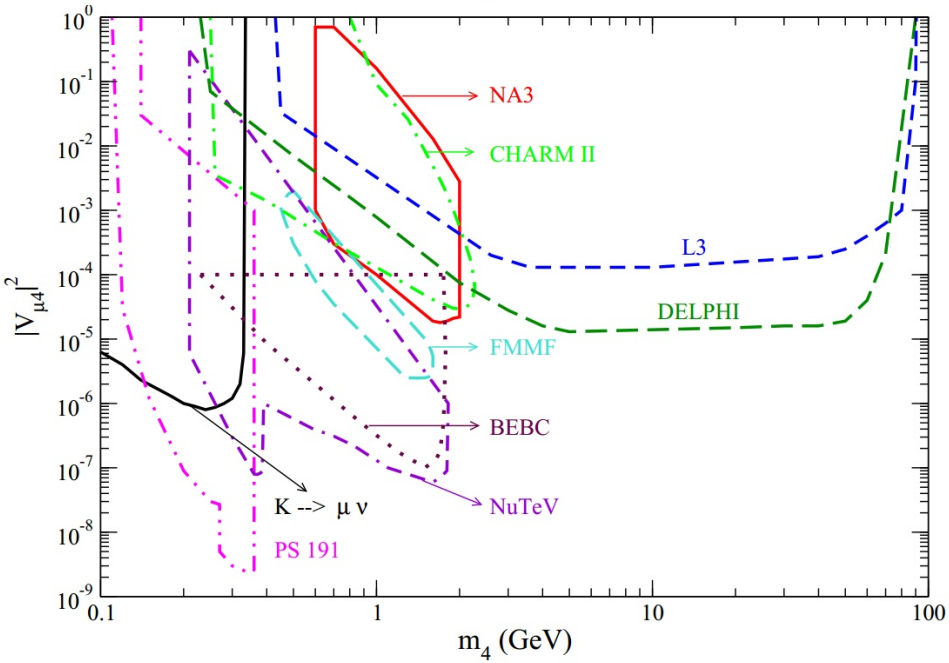


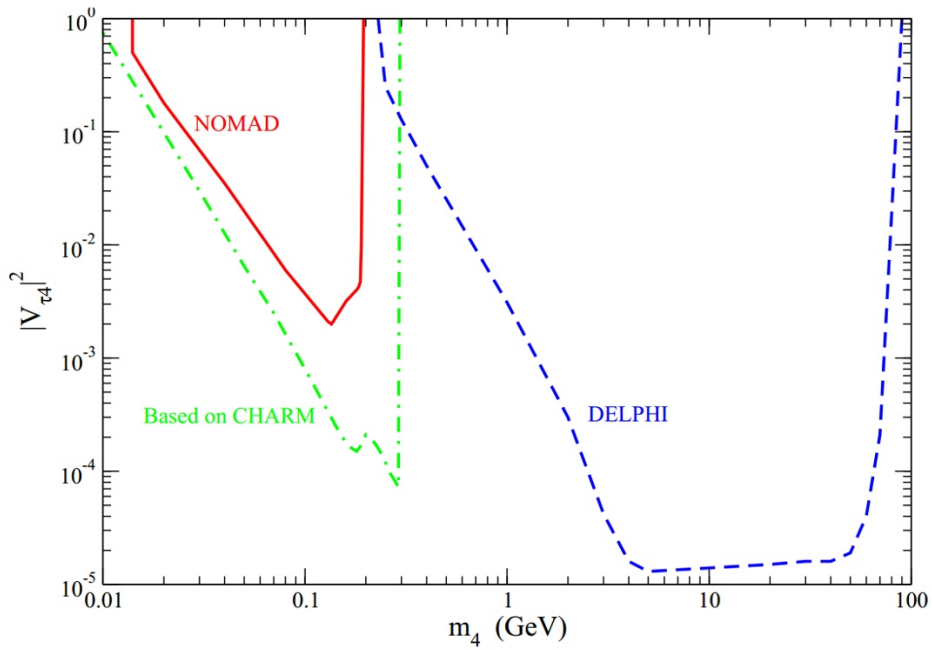
Thank You!


U(1)' Kinetic Mixing Bounds
0.100
0.050
0.010
0.005
0.001
5×10^{-4}
1×10^{-4}
χ
μ g−2
BaBar 2009
EW precision
BaBar 2014
ω
ϕ
0.5
1.0
5.0
10.0
50.0
100.0
$M_{z'}$(GeV)


$|V_{e4}|^2$
m_4 (GeV)
^{187}Re
^{3}H
^{63}Ni
^{35}S
^{20}F
Fermi$_2$
Bugey
Borexino
π --> e ν
0νββ


NA3
K --> e ν
PS 191
L3
DELPHI
CHARM
π --> e ν
0νββ
m_4 (GeV)


$|V_{\mu 4}|^2$
m_4 (GeV)
NA3
CHARM II
L3
DELPHI
FMMF
BEBC
NuTeV
K --> μ ν
PS 191


$|V_{\tau 4}|^2$
m_4 (GeV)
NOMAD
Based on CHARM
DELPHI