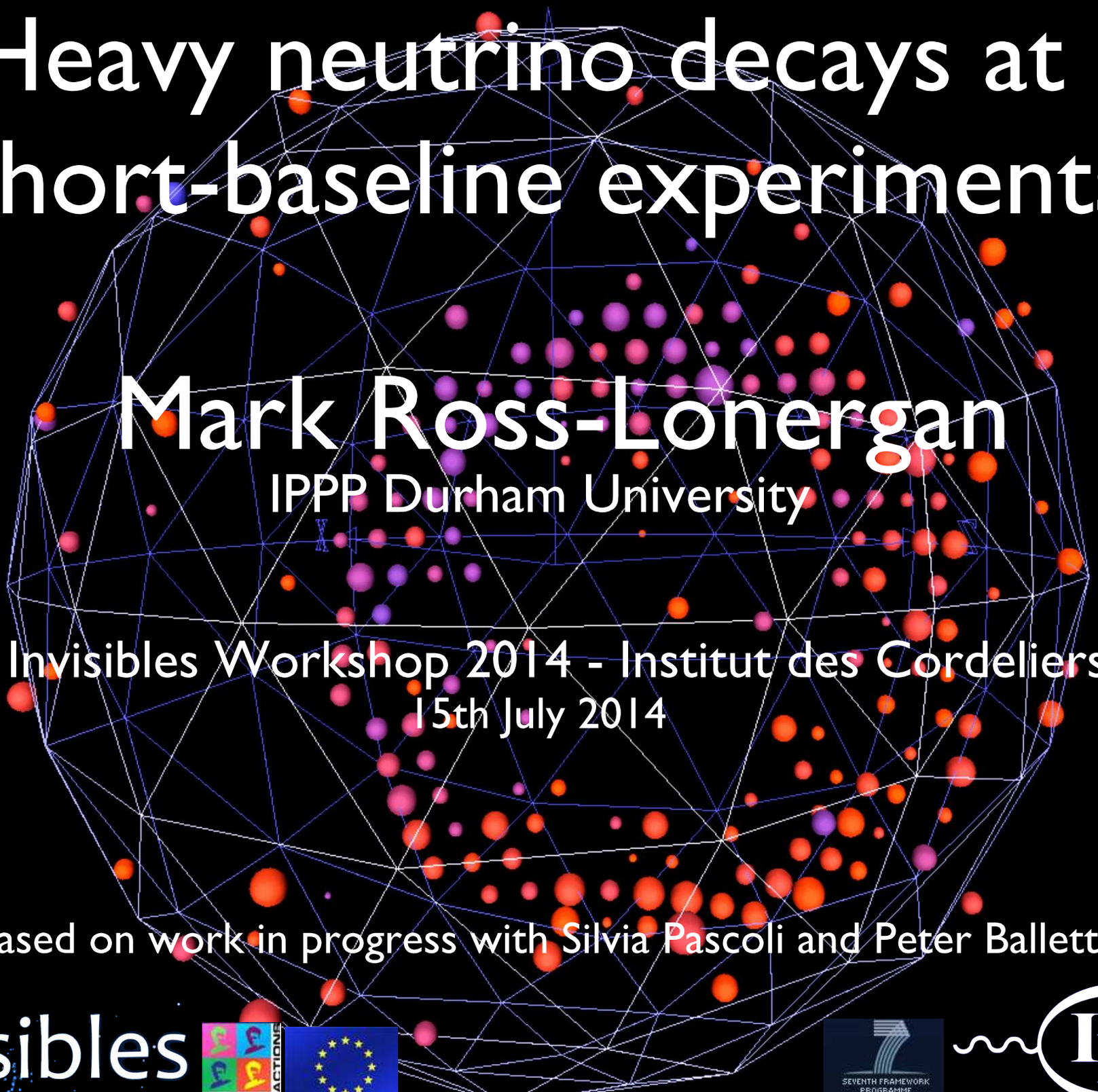
Heavy neutrino decays at short-baseline experiments



Mark Ross-Lonergan

IPPP Durham University

Invisibles Workshop 2014 - Institut des Cordeliers

15th July 2014

Based on work in progress with Silvia Pascoli and Peter Ballett

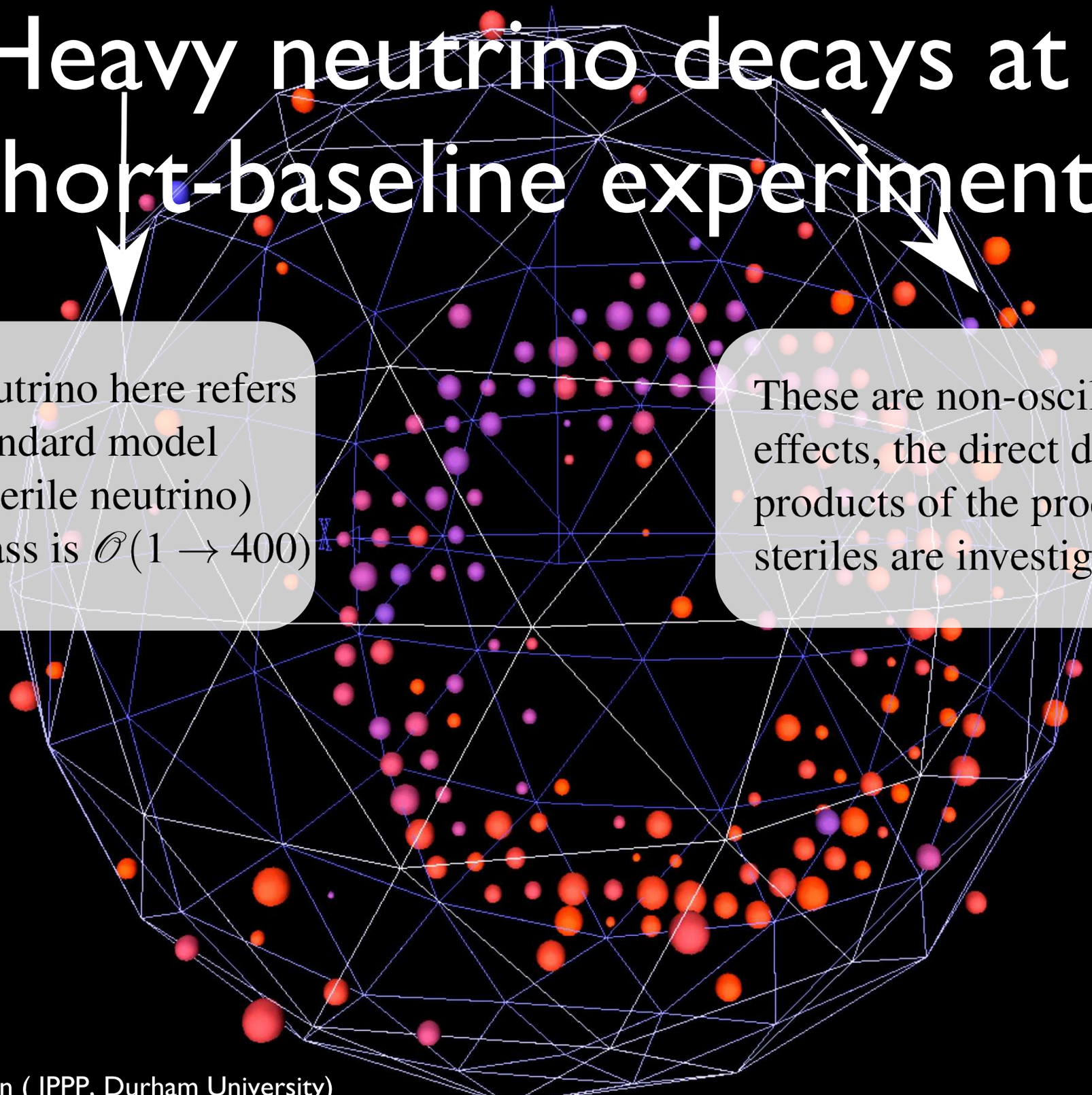
invisibles

MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

IP3

Heavy neutrino decays at short-baseline experiments



Heavy neutrino here refers to any standard model singlet (sterile neutrino) whose mass is $\mathcal{O}(1 \rightarrow 400)$ MeV

These are non-oscillatory effects, the direct decay products of the produced steriles are investigated.

M. Ross-Lonergan (IPPP, Durham University)

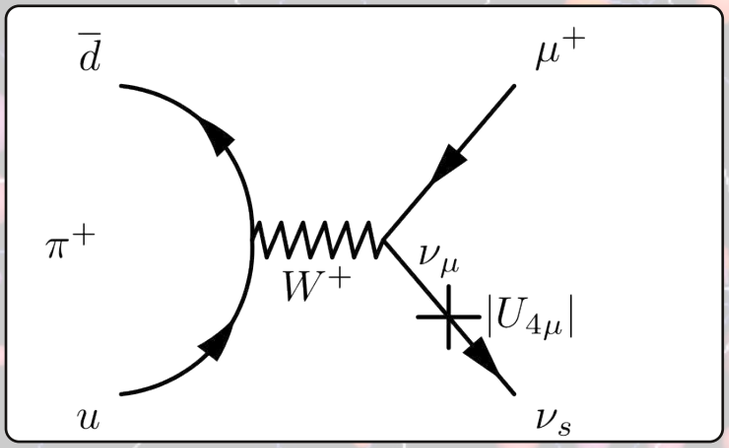
Outline

- Phenomenology of sterile decays at SBL facilities
- Case study: MiniBooNE low-energy anomaly
- Decays in flight
- Decays in transit
- Summary and Outlook

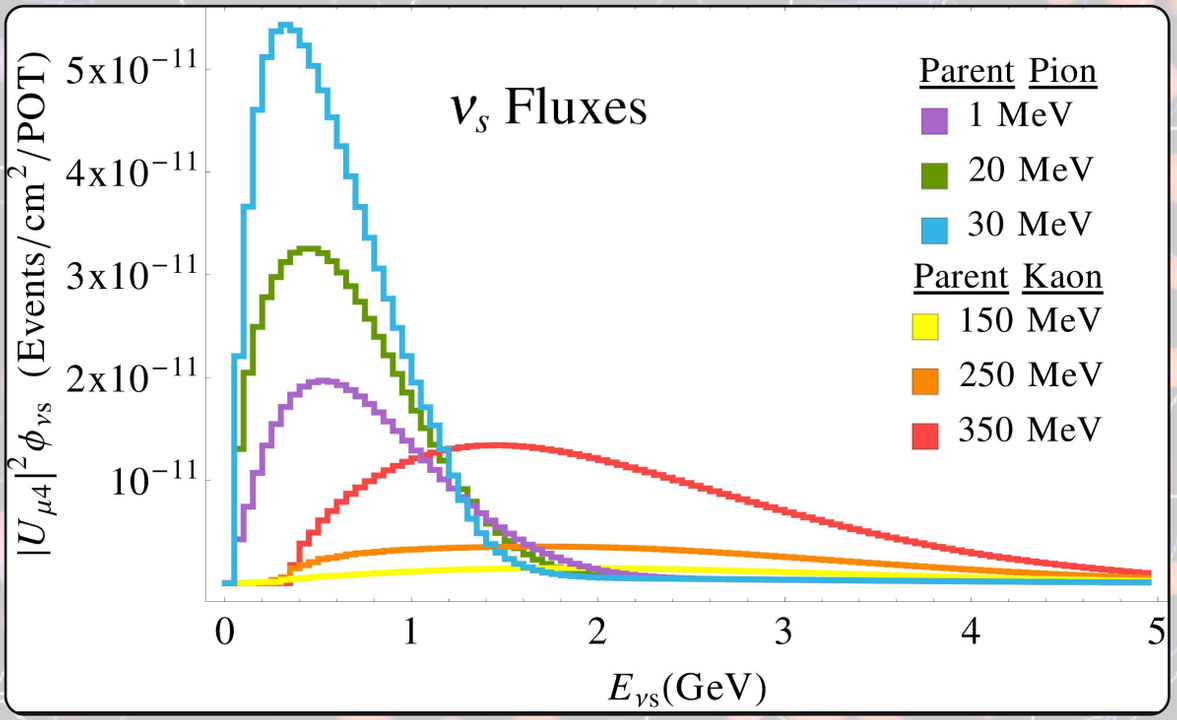
Sterile Production at SBL

- Directly produced in meson decays alongside that of the regular neutrino beam, at first approx $\phi_s \approx |U_{f4}|^2 \phi_{\nu_f}$

Approach uses full spectral analysis of steriles based on T.Asaka et al. hep-ph/1212.1062



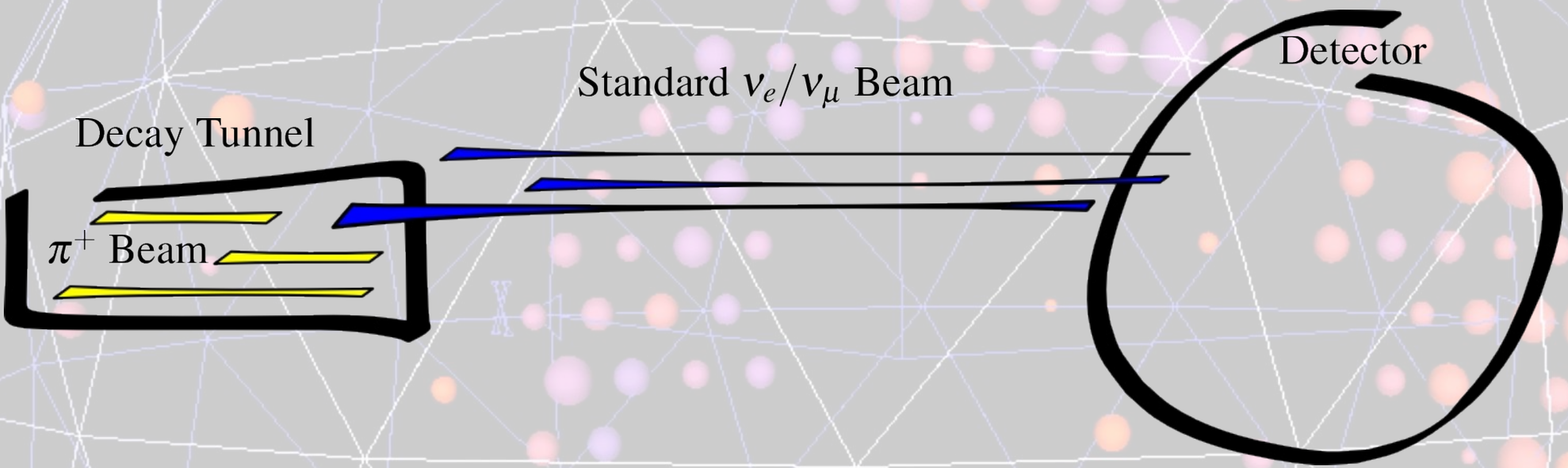
- Extend SBL study to include faster decaying steriles, and their contribution to the flux impinging the detector[2][3]



[2]Palomares-Ruiz,Pascoli,Schwetz. hep-ph/0505216. [3] Ma,Rajasekaran, Stancu. hep-ph/0505216.

Regimes of Decay

- Depending on $|U|$, M_s and Γ_{Decay}, two regimes of decay possible



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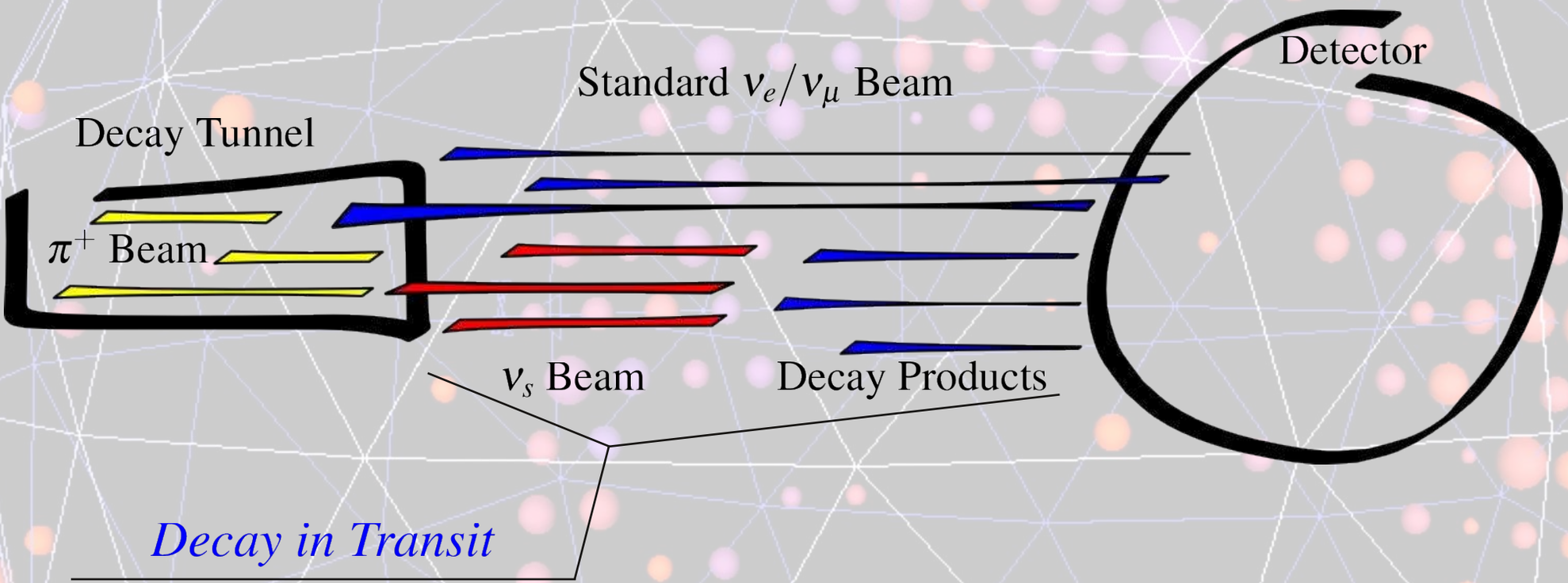

Decay in Transit

- Larger Γ_{Decay} and $|U_{\mu 4}|^2$
- Decay to SM ν's *before* detector
- Increased number/flavour ratios in ν_f CCQE events

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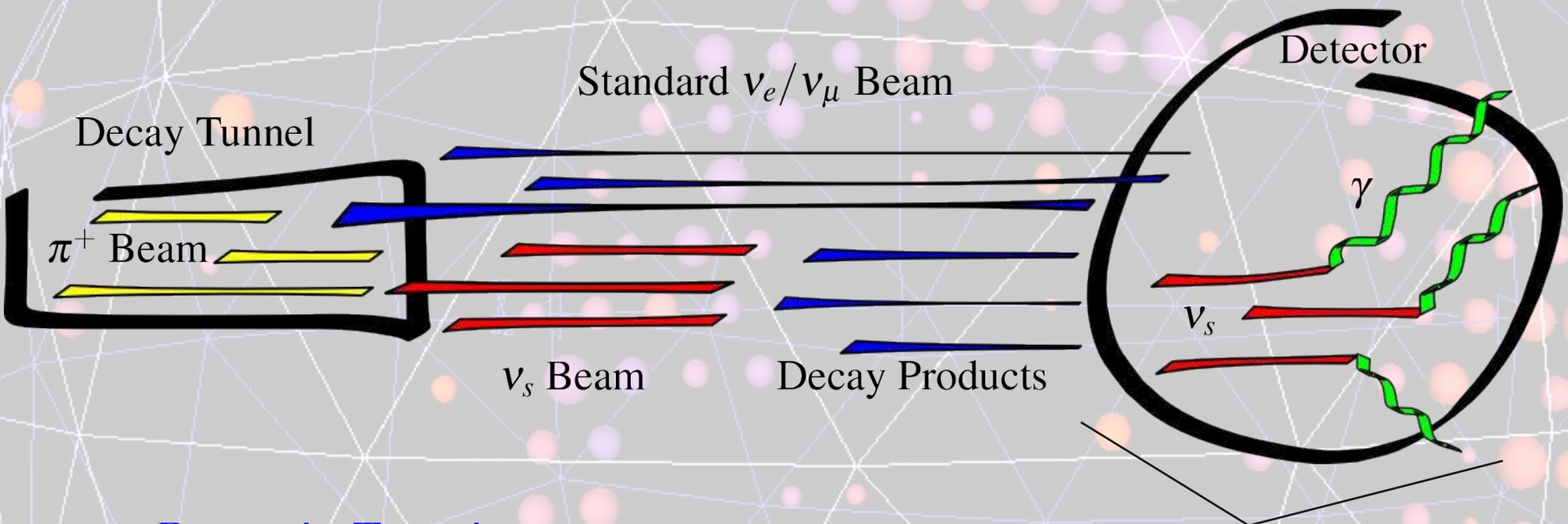

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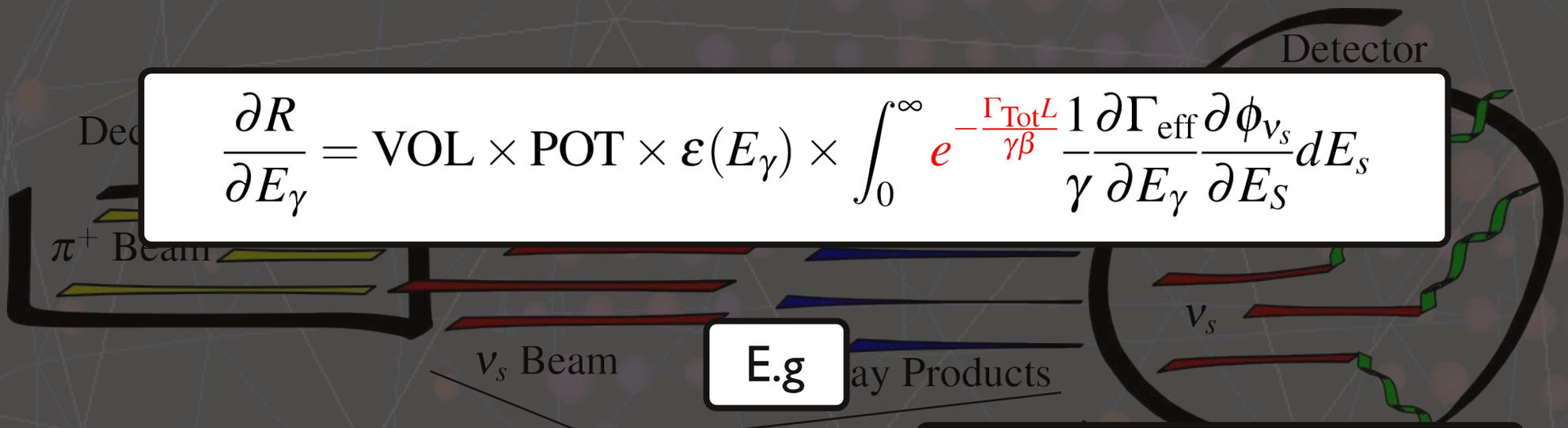
Decay in Flight

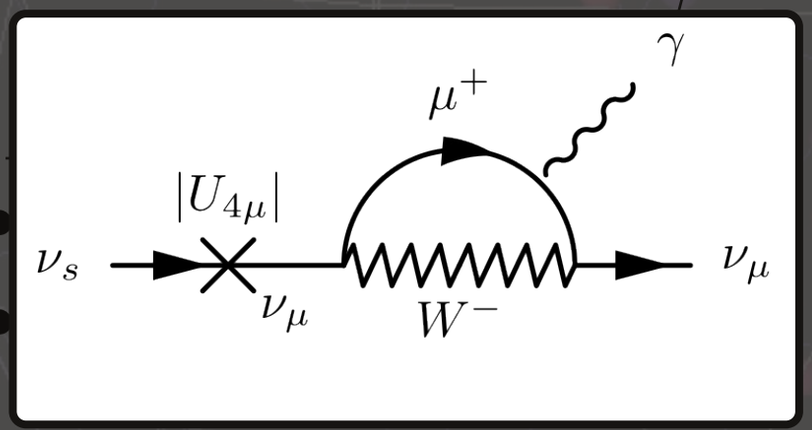
- Smaller Γ_{Decay} and $|U_{\mu 4}|^2$
- Some survive and decay *inside* detector
- Decay fakes CCQE events

Regimes of Decay

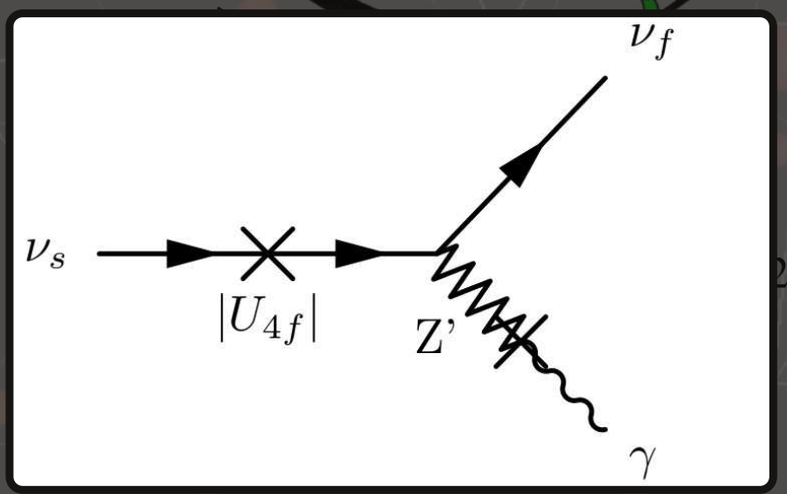
- Depending on $|U|$, M_s and Γ_{Decay}, two regimes of decay possible

$$\frac{\partial R}{\partial E_\gamma} = \text{VOL} \times \text{POT} \times \varepsilon(E_\gamma) \times \int_0^\infty e^{-\frac{\Gamma_{\text{Tot}} L}{\gamma \beta}} \frac{1}{\gamma} \frac{\partial \Gamma_{\text{eff}}}{\partial E_\gamma} \frac{\partial \phi_{\nu_s}}{\partial E_S} dE_s$$





Radiative Decay

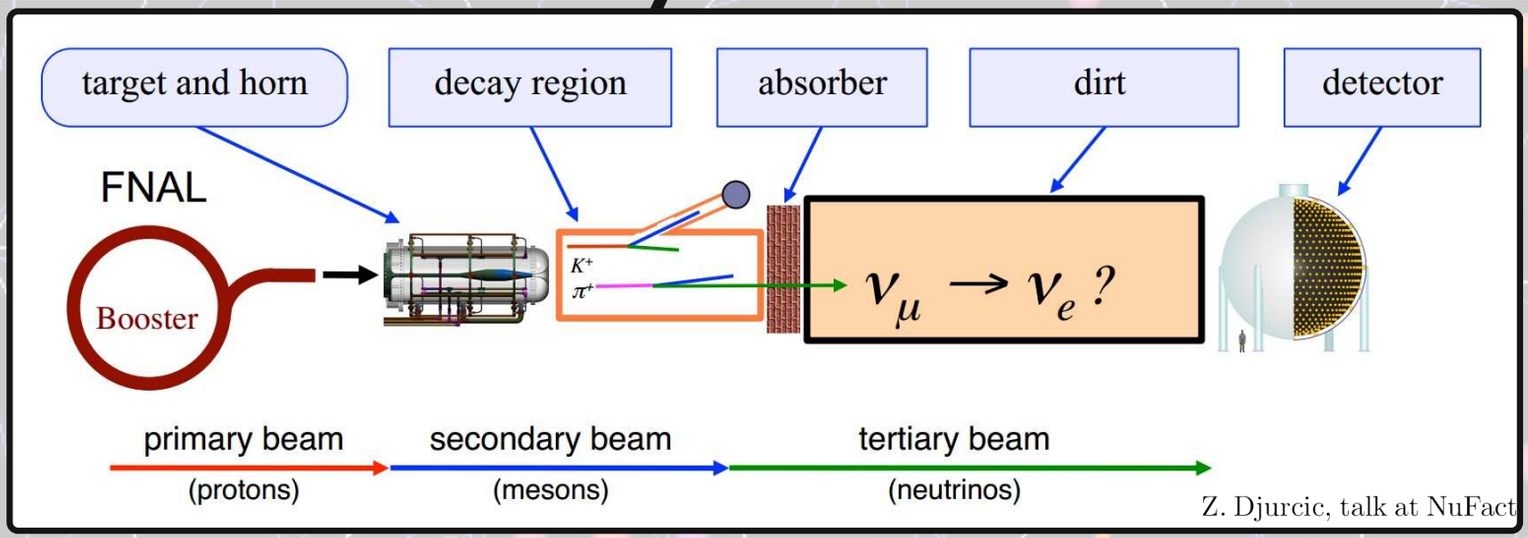


B-L Gauge Z' Coupling

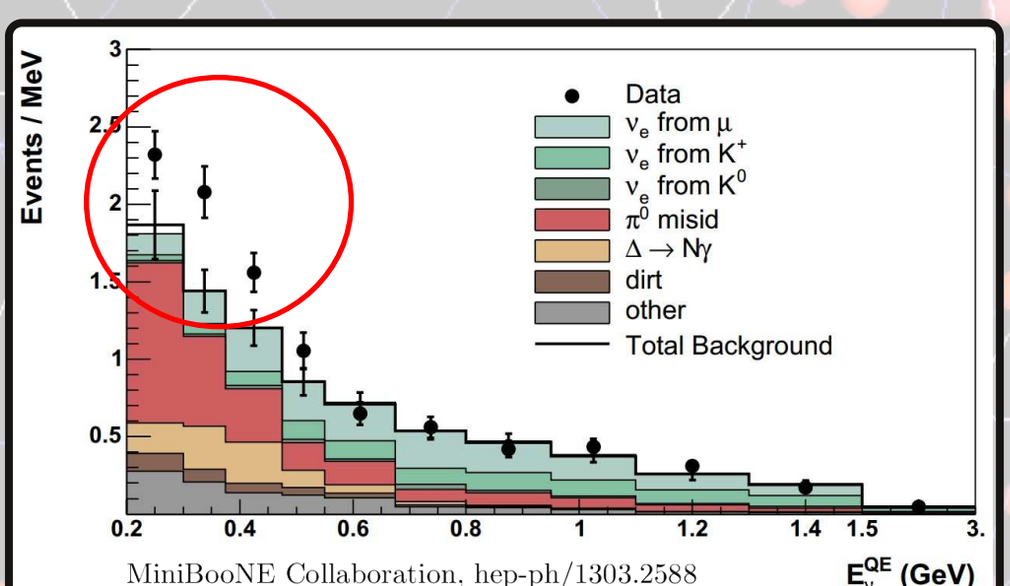
- In… ratios in ν_f CCQE events

CCQE events

Case Study: MiniBooNE



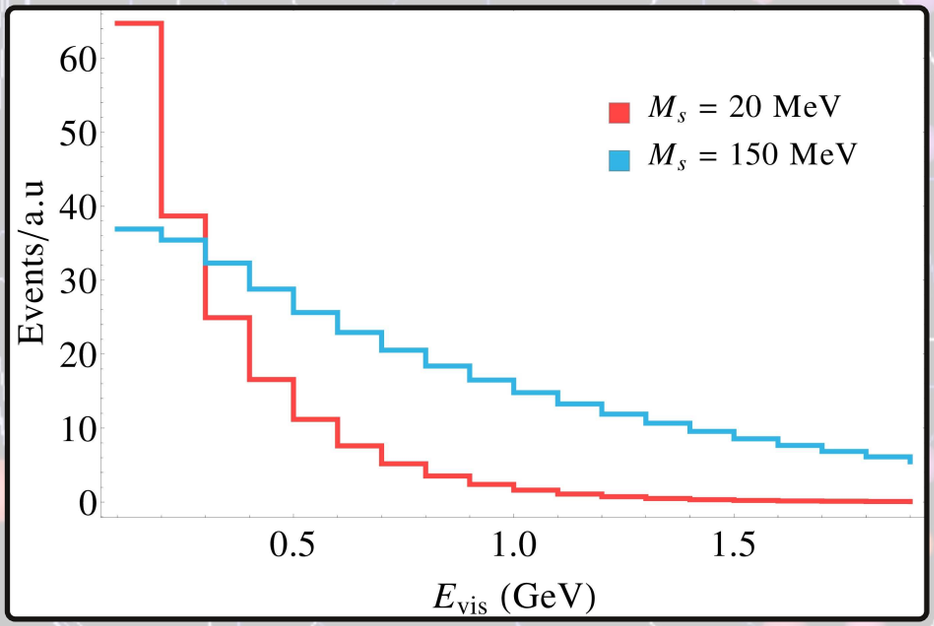
- Modern SBL experiment operated at Fermilab
- 6m diameter mineral oil cherenkov detector
- Situated 550m downstream of proton target
- Observed anomalous low-energy (< 400 MeV) excess in electron like events



Decay in Flight

For example, the two body decay to photon and neutrino, parameterized by Γ_{eff} where the photon is mis-identified as an electron

Energy Spectrum, Shape only



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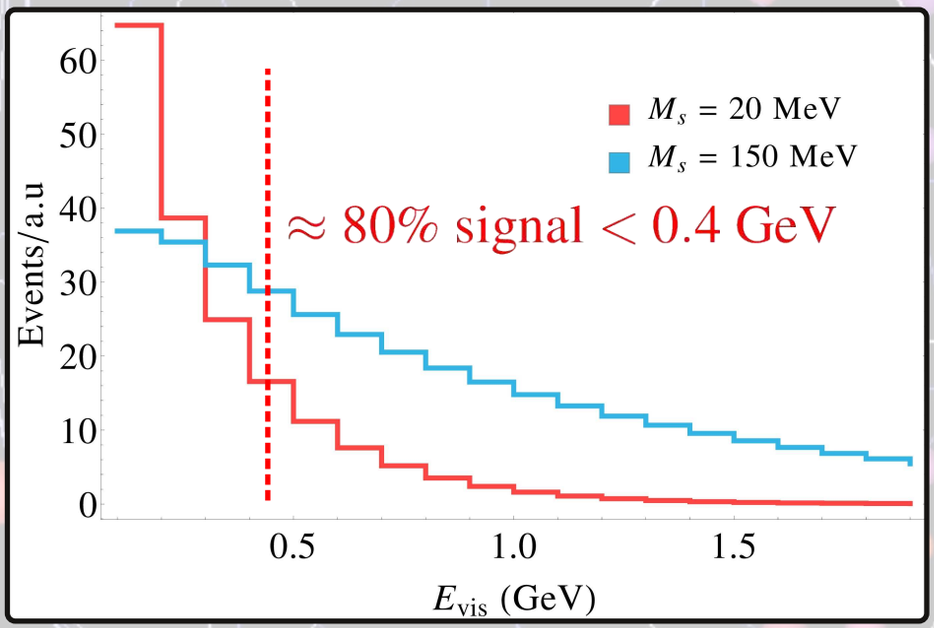

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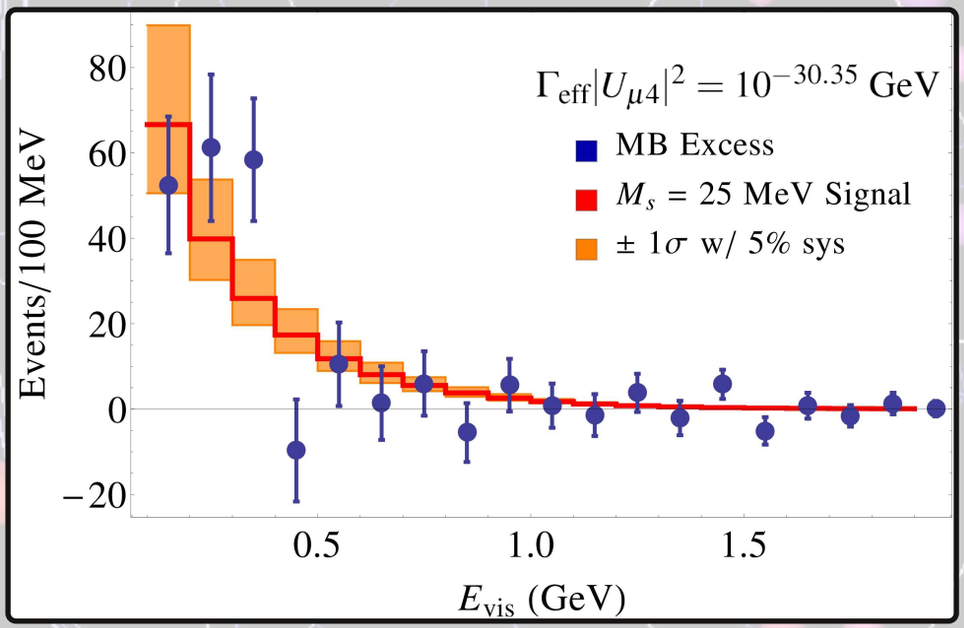

Energy alone, one can reject background only model in favour of that of decaying steriles at $\approx 3\sigma$

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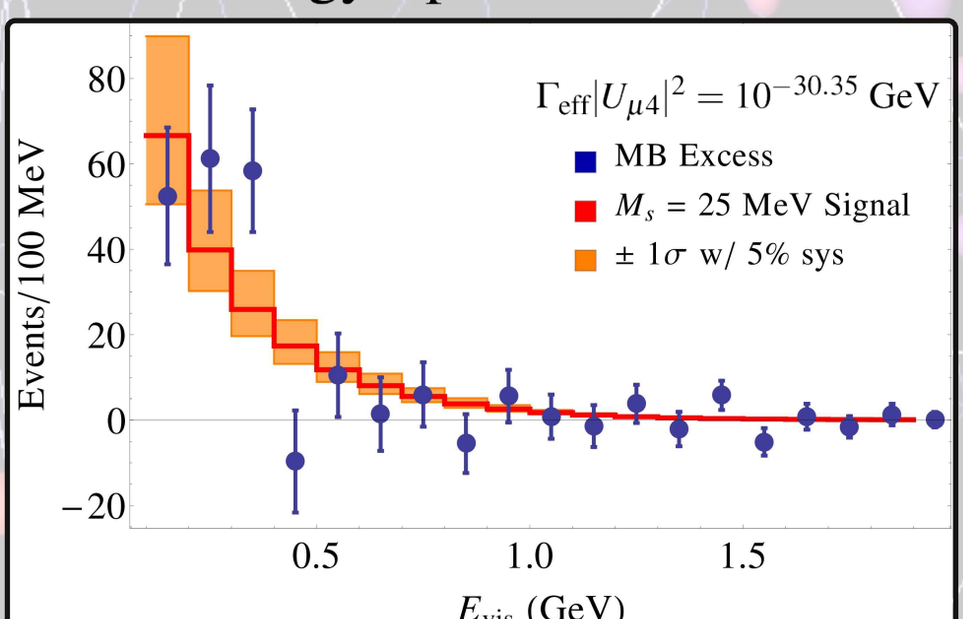

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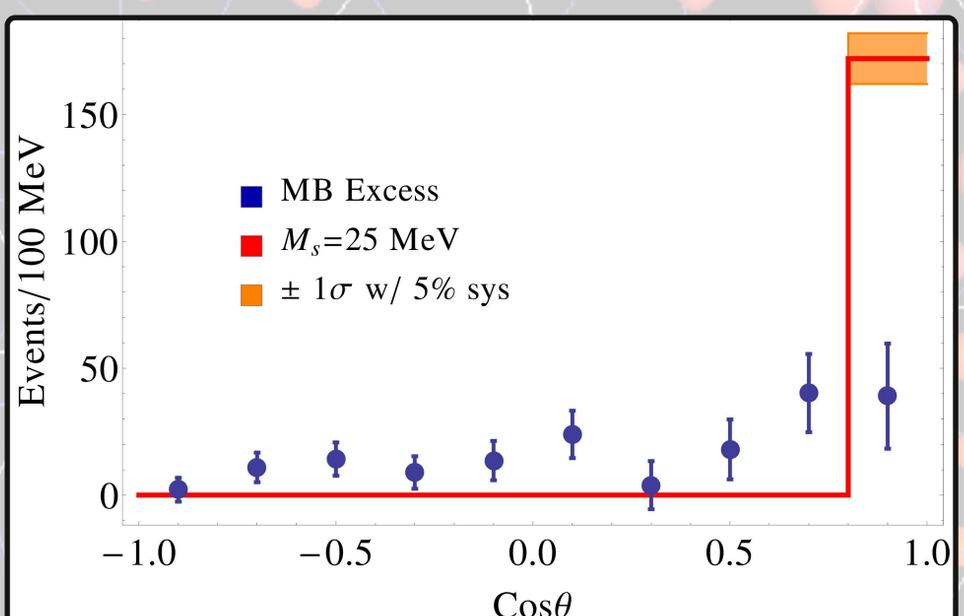
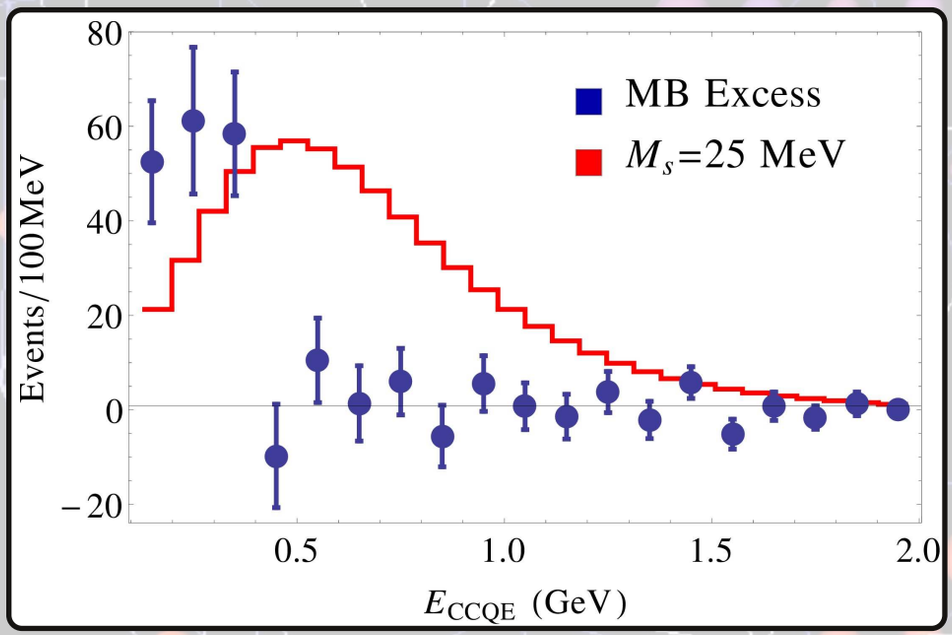
Angular Spectrum



Angular Spectrum *significantly* more constraining for decay in flight models

Decay in Transit

- If the sterile has a much shorter lifespan, the decay products integrated over the baseline must be considered
- Hadronic and charged leptonic remnants will be absorbed inside the dirt in transit
- Any final state with SM neutrino's could alter the observed CCQE flavour ratios and give rise to an anomalous signal



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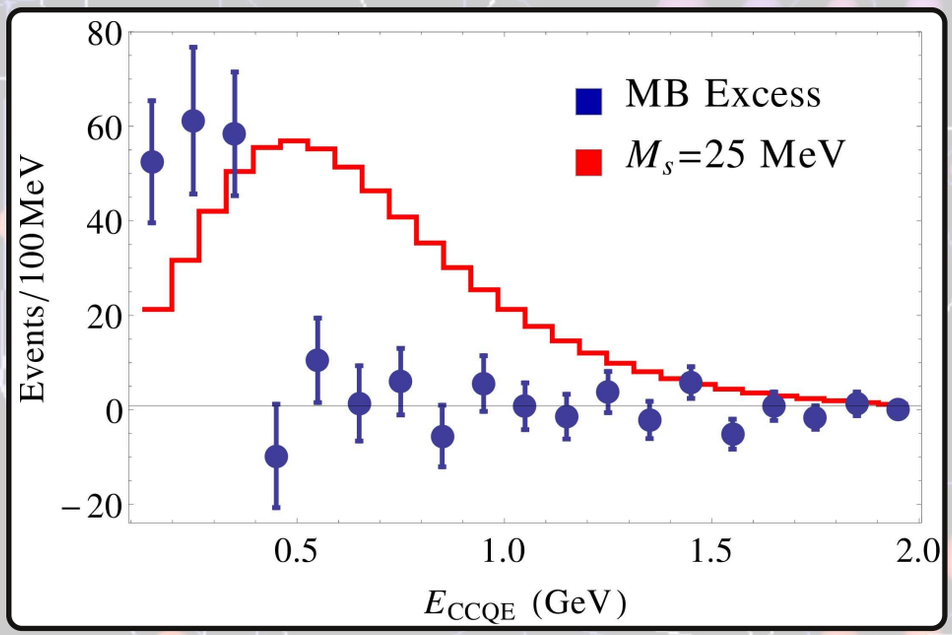

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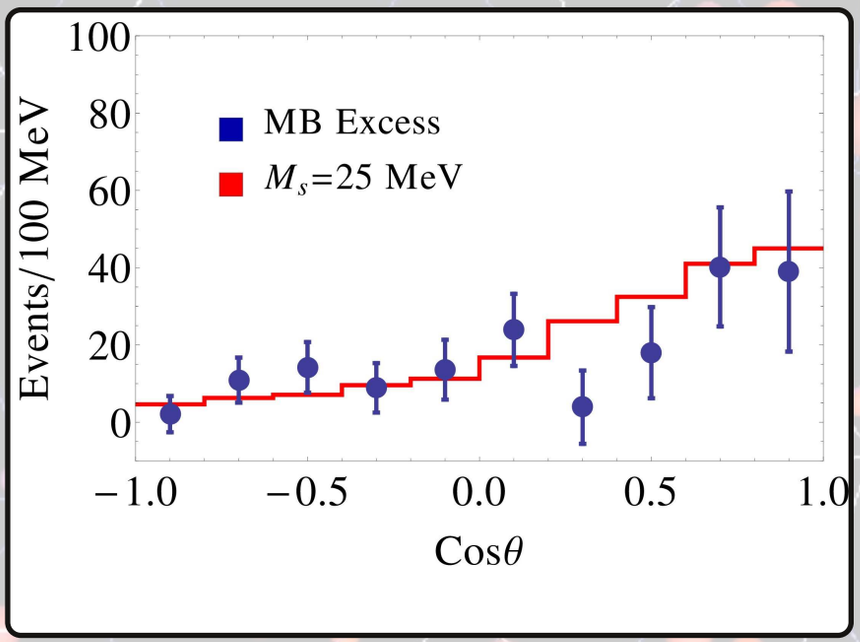
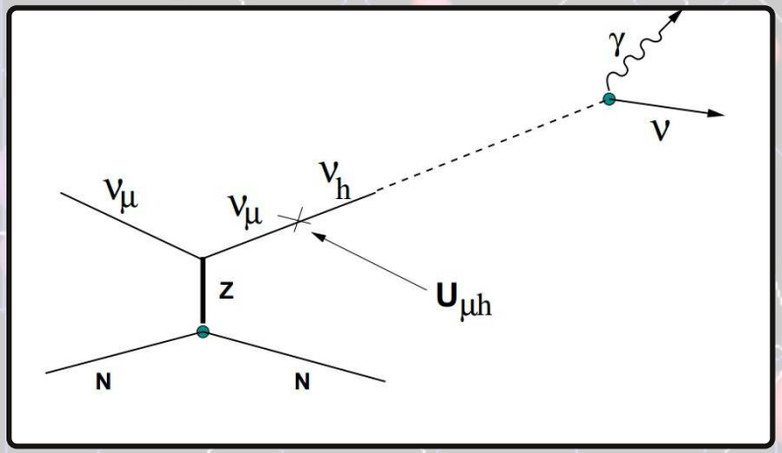
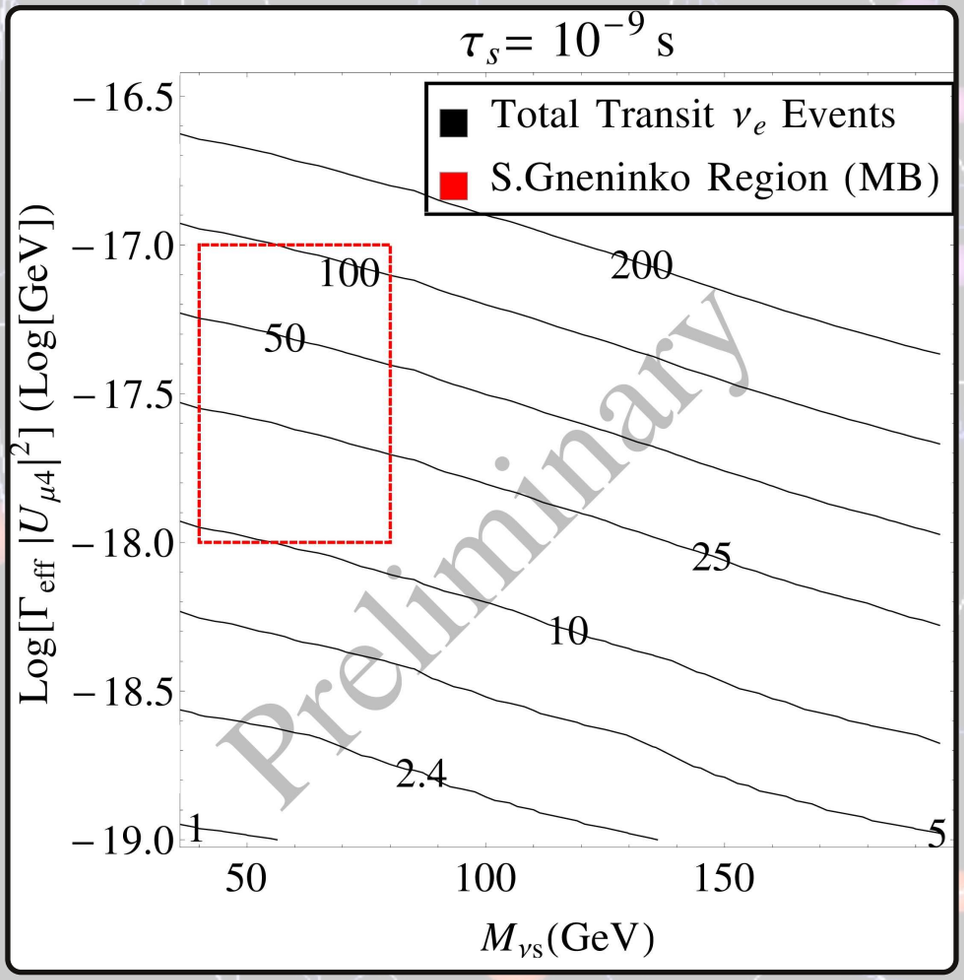


Angular Spectrum

Several models in the literature use steriles in the parameter range such that they may be affected by decays in transit/flight.





S. Gninenko[4] uses an additional anomalous magnetic moment to enhance sterile-photon decays, and uses detector-side production to propose explanations to both the LSND and MiniBooNE anomaly

[4] S. Gninenko. hep-ph/1009.5536

Summary and Outlook

- Regards the MiniBooNE low-energy events, models which decay in flight or in transit can be *ruled out* as the source for the anomalous signal by their angular and energy spectral shapes respectively, irregardless of irrespective space.
- Furthermore, models which take advantage of shorter lifetimes must be careful not to generate extra unwanted events from sterile decay products, but this is model and parameter dependant.
- Ongoing work is considering further decay channels, and the possibility of putting competitive bounds on specific models' parameter space using SBL experiments