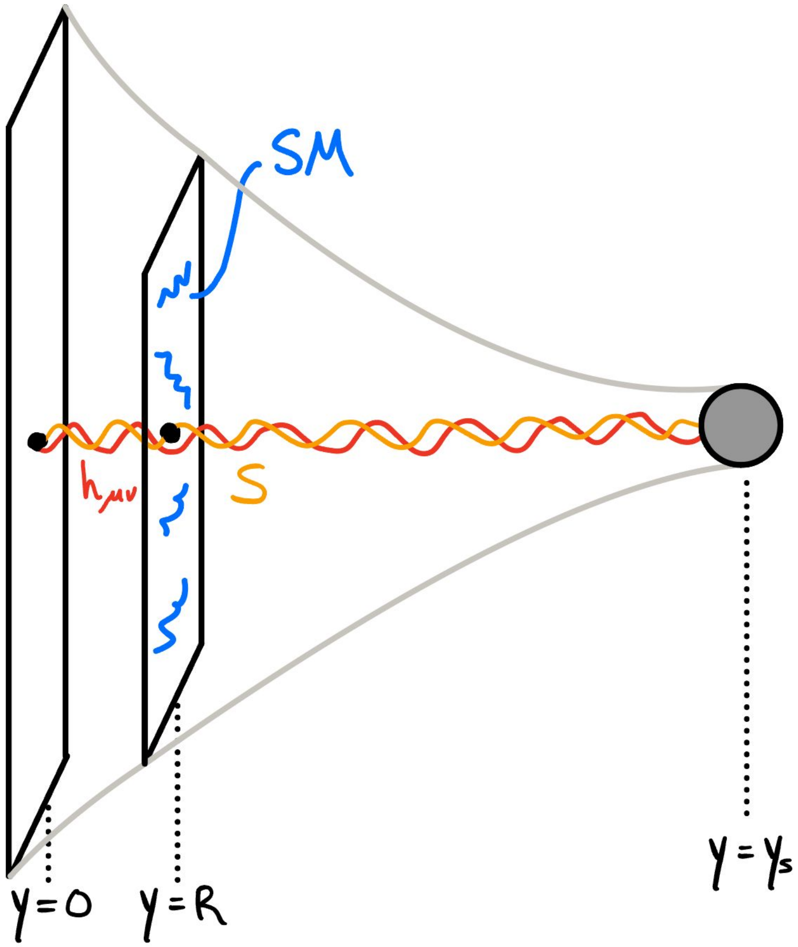
Collider Signatures of Near-Continuum Dark Matter

Steven Ferrante, Maxim Perelstein, (Cornell U.)
Seung J. Lee (Korea U.)

(Work In Progress)

Continuum DM

- Planck brane @ y = 0
- SM brane @ y = R
- Coupled system of graviton and scalar leads to singularity @ $y = y_s$ (" soft-wall ")



Quiros et al., 0907.5361

Csaki, Perelstein, et al., 2105.07035, 2105.14023

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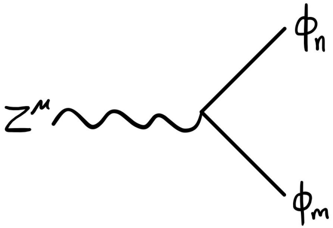

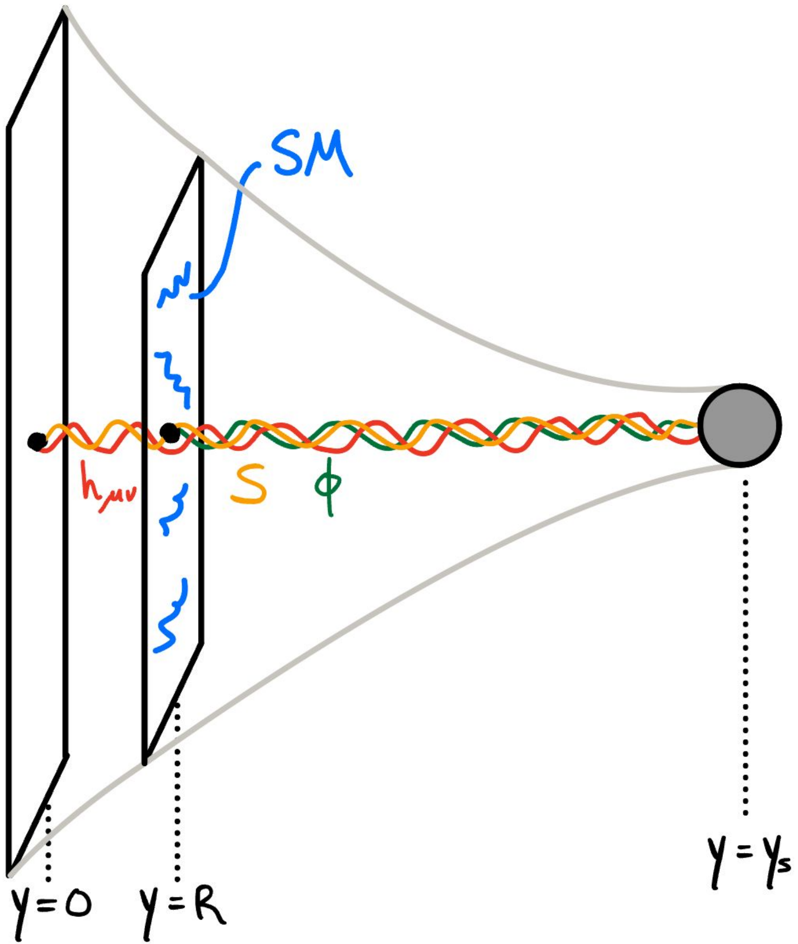

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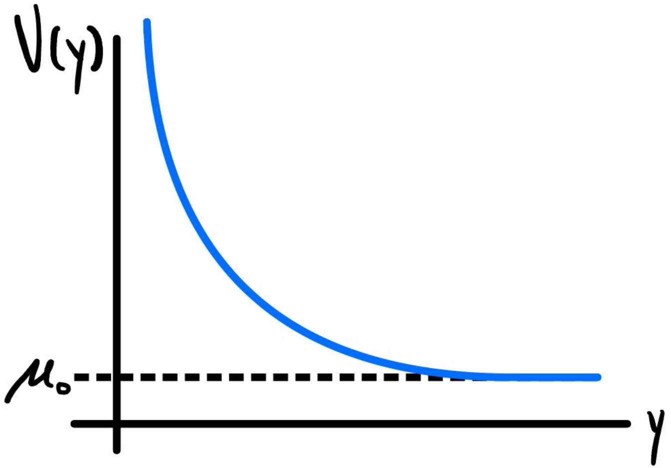

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$$-f_n'' + V(z) f_n = m_n^2 f_n$$

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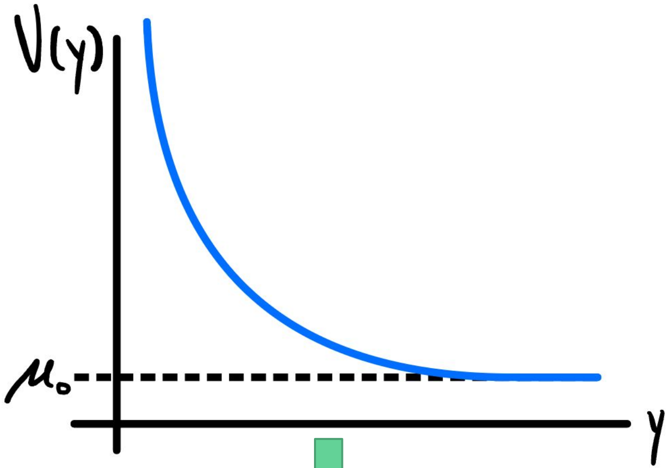
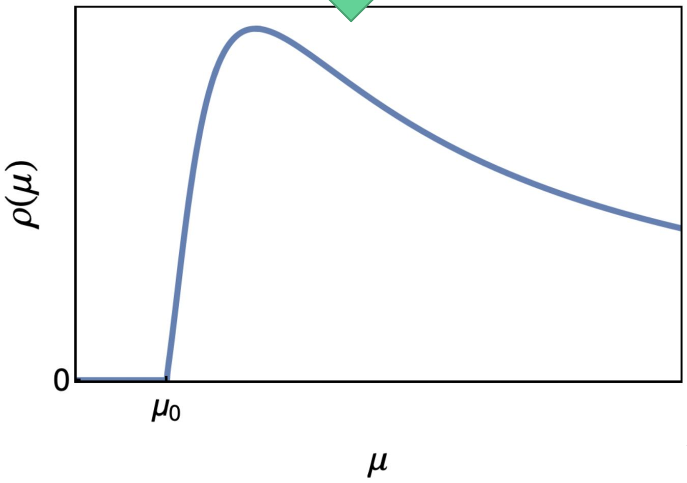
- Result: Φ gets a gapped continuous KK spectrum !
- Goal: What is the pheno for continuous spectra ?





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Near-Continuum DM

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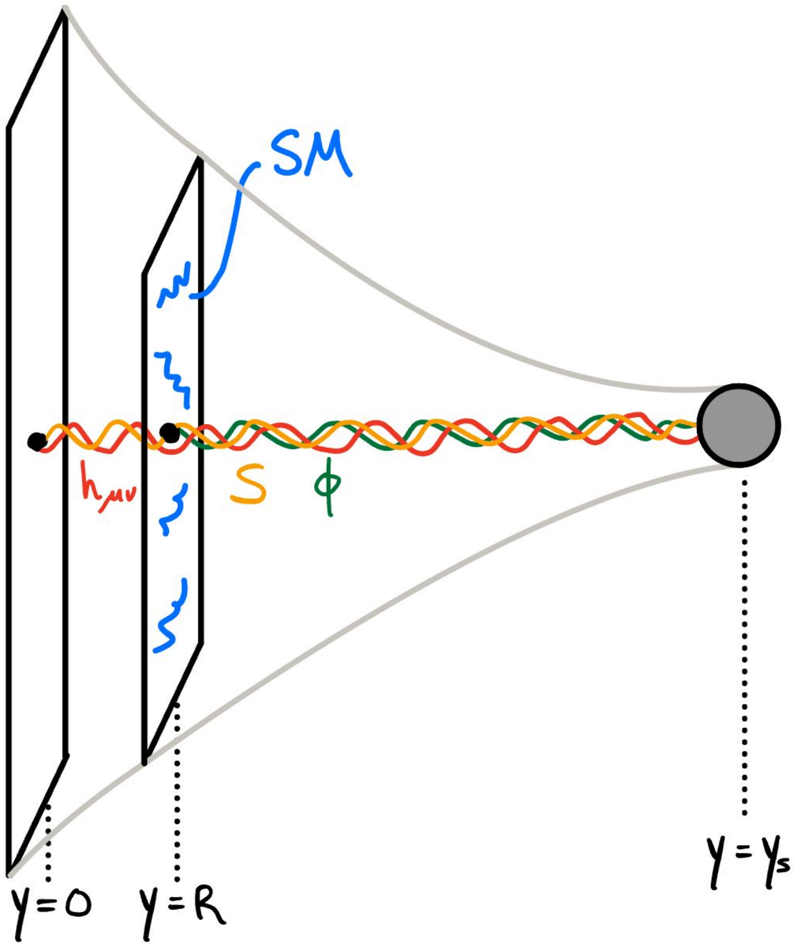

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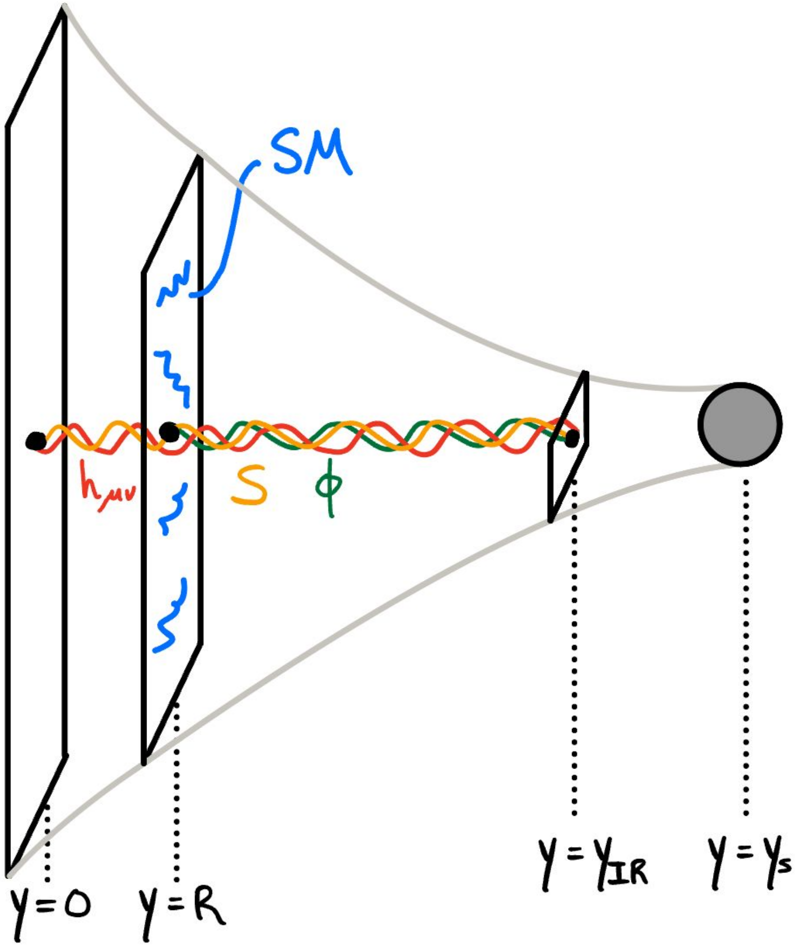

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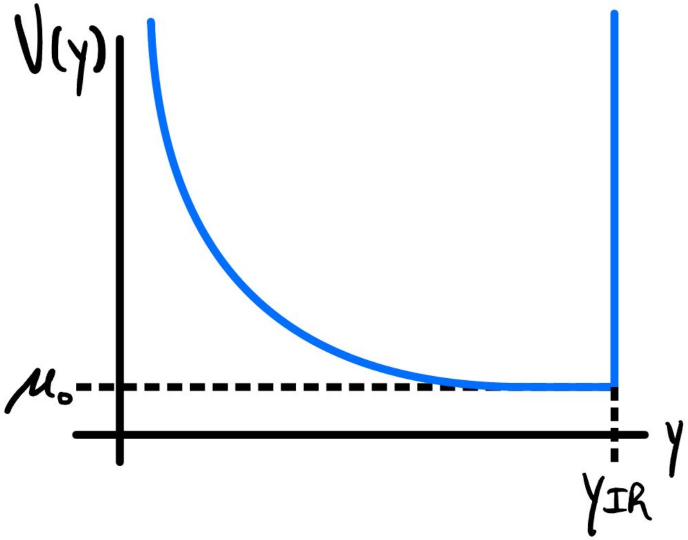

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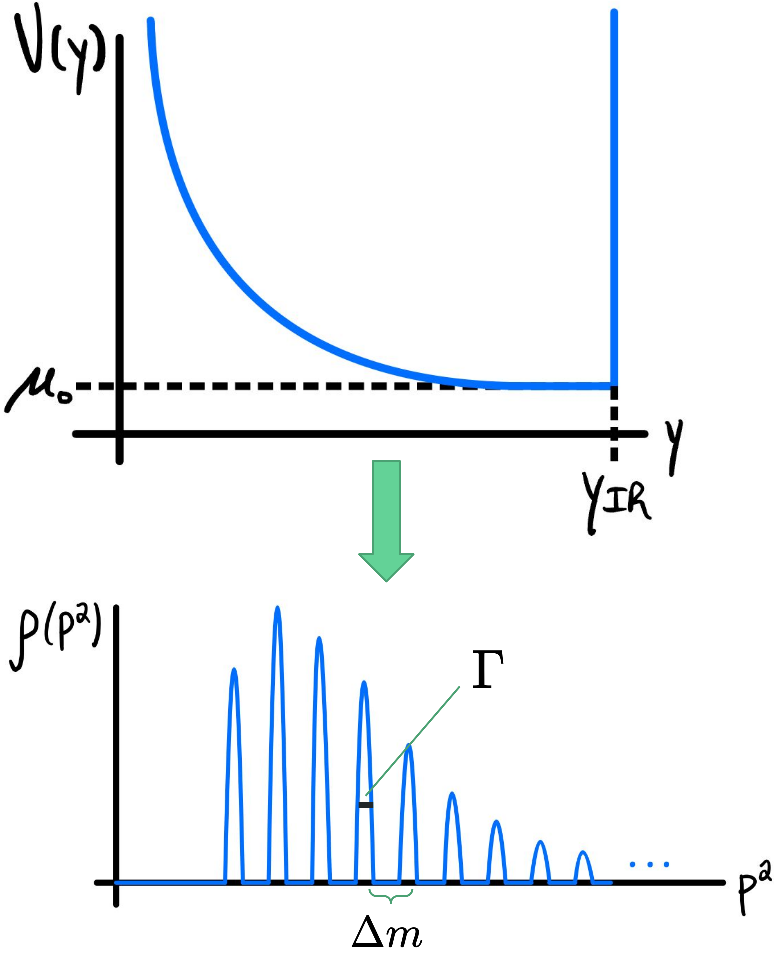

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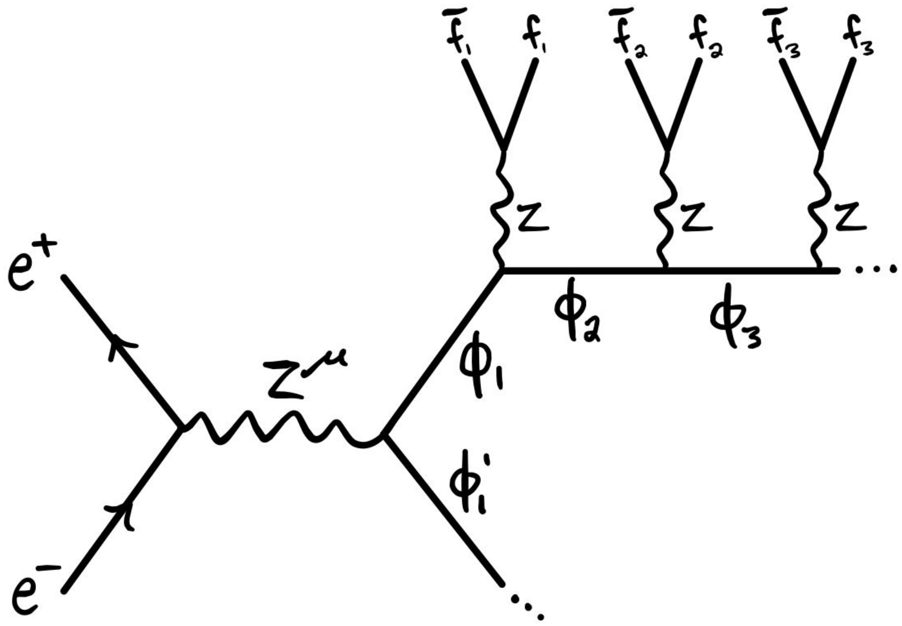
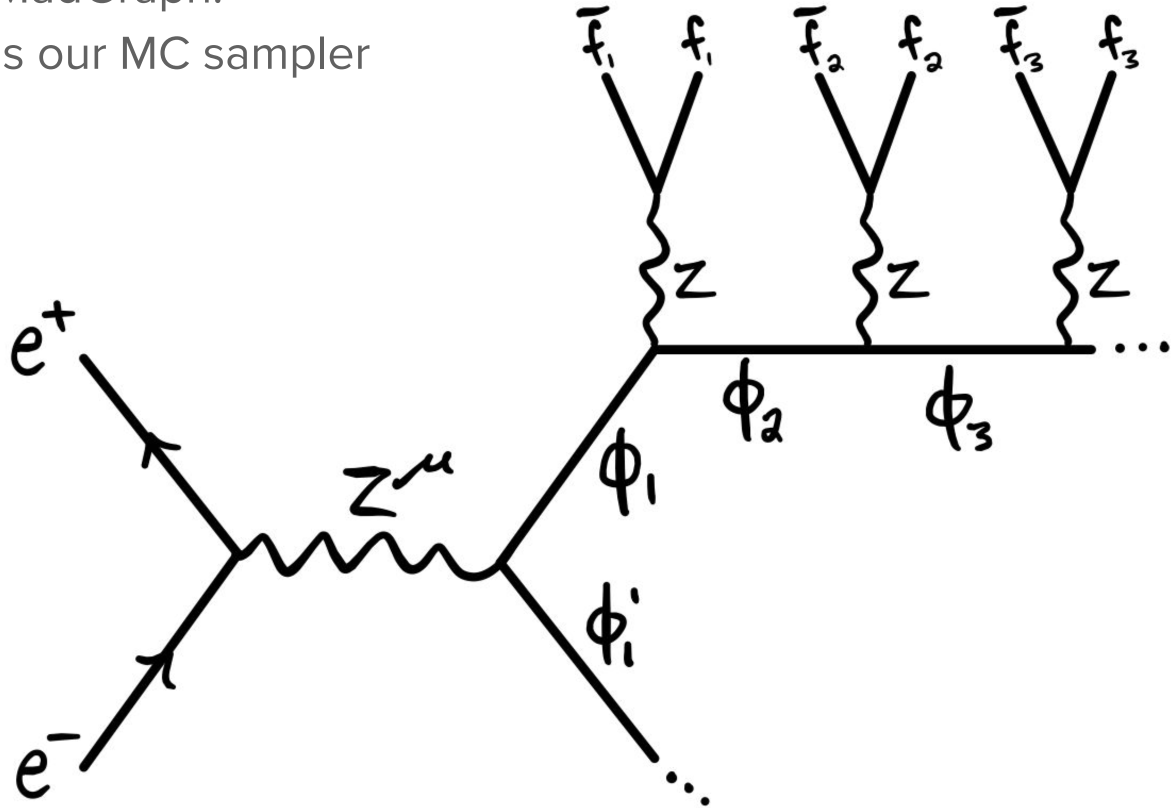
- Z-portal & $\mathbb{Z}_2$ allows for "cascade decay"
- DM states become increasingly light & stable
- Requires $\Gamma_Z > \Gamma_g$ to be "**visible**"



<u>See Also:</u> **Dienes et al., 1204.4183, 1106.4546**

Near-Continuum Phenomenology -- Visible Cascade

- Cannot use MadGraph!
- Use Vegas as our MC sampler



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Benchmark Point:

e+e- Collider

$\sqrt{s}$ = 500 GeV

μ_0 = 100 GeV

g_{eff} = 0.0074

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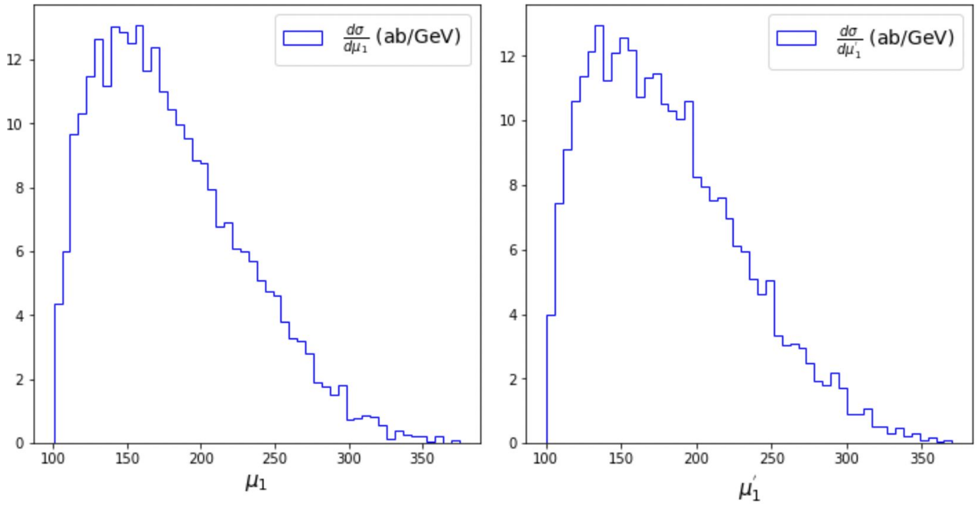
~ 135 ab



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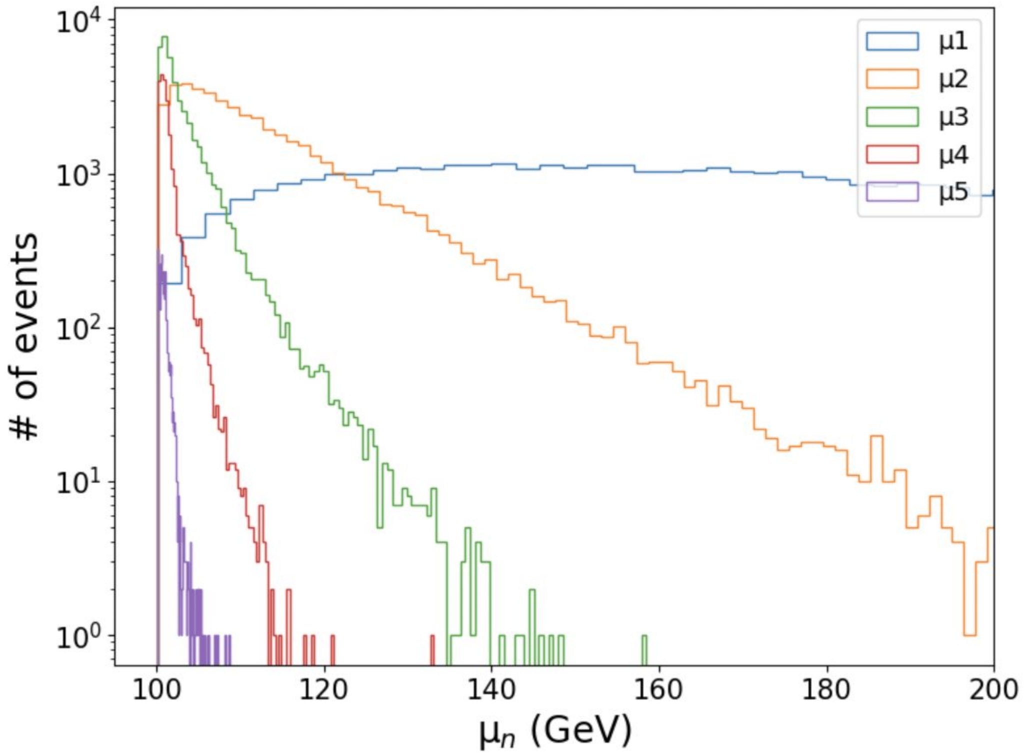
Non-Observables

- Φ_n masses at each step



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- Φ_n velocities at each step
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(backup)

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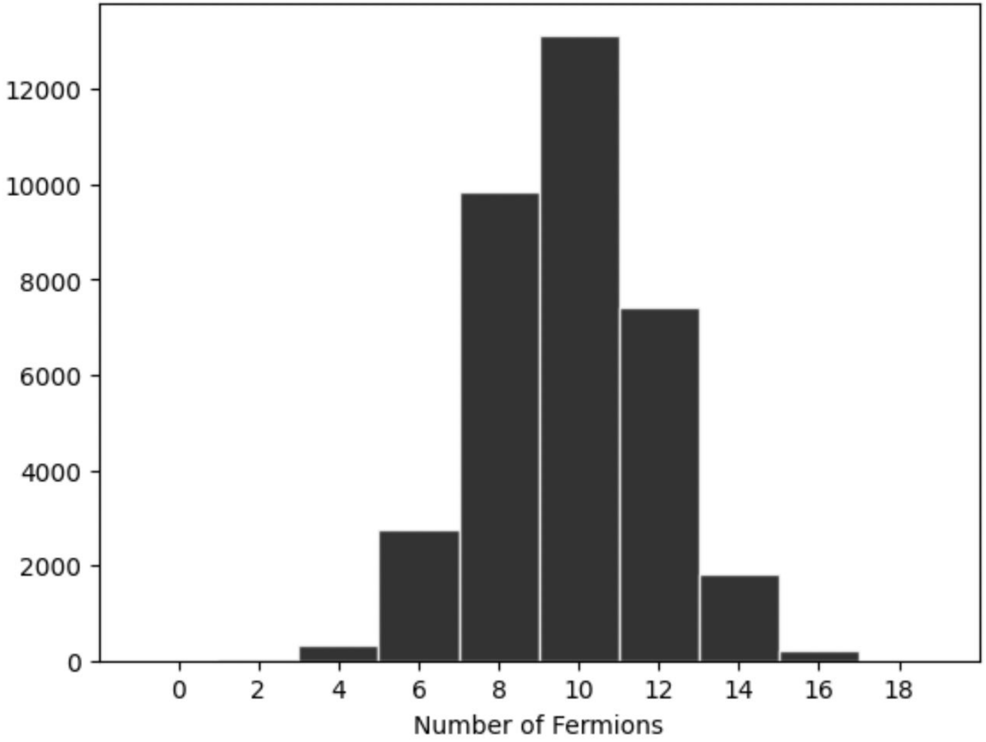
- Multiplicities



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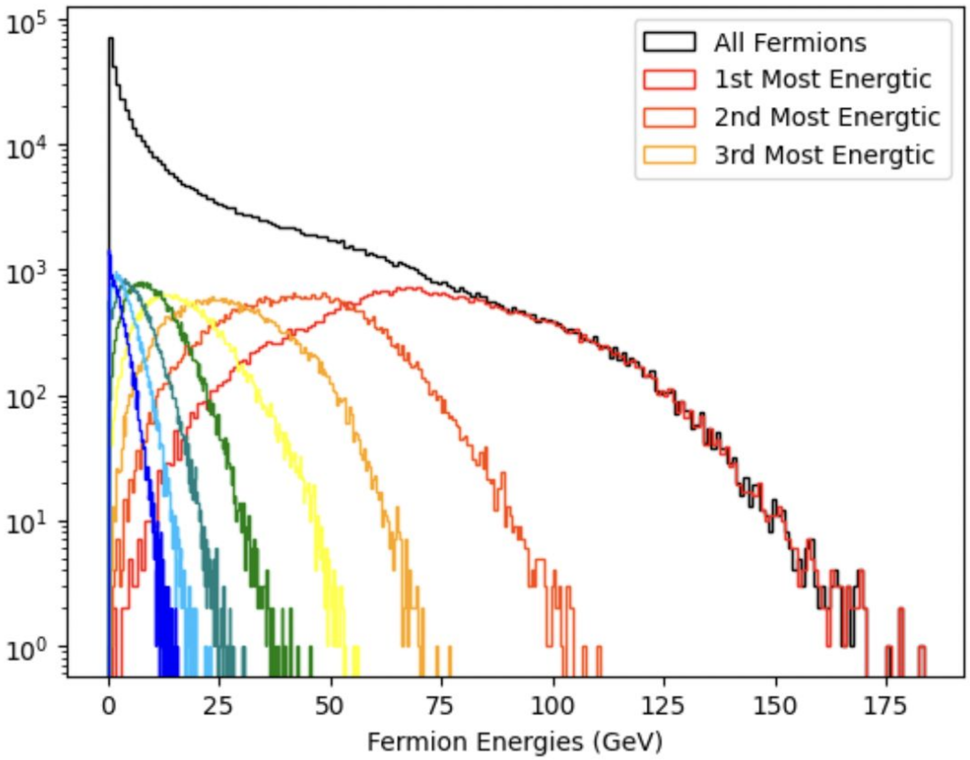

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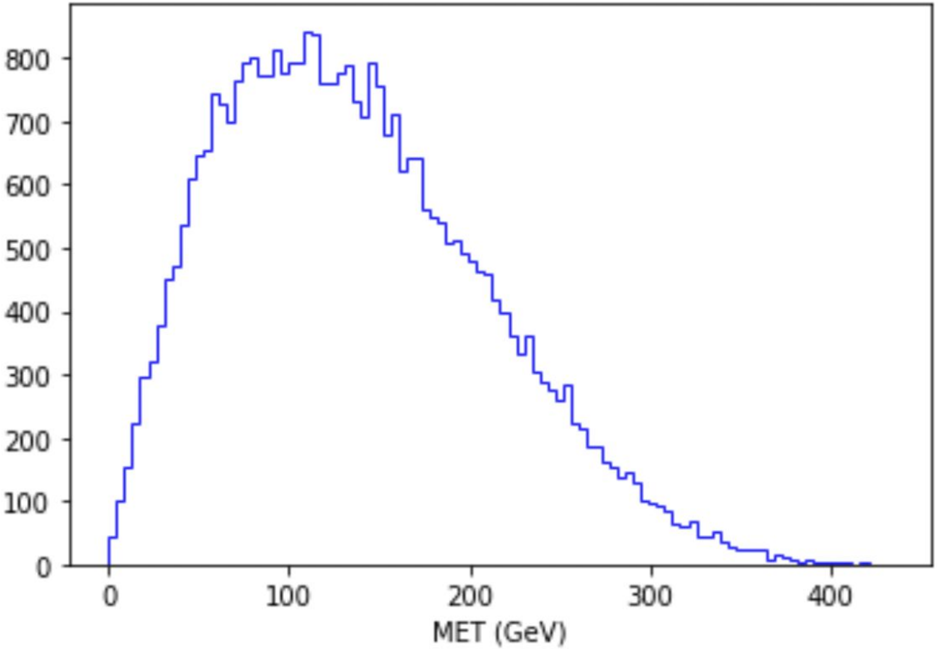

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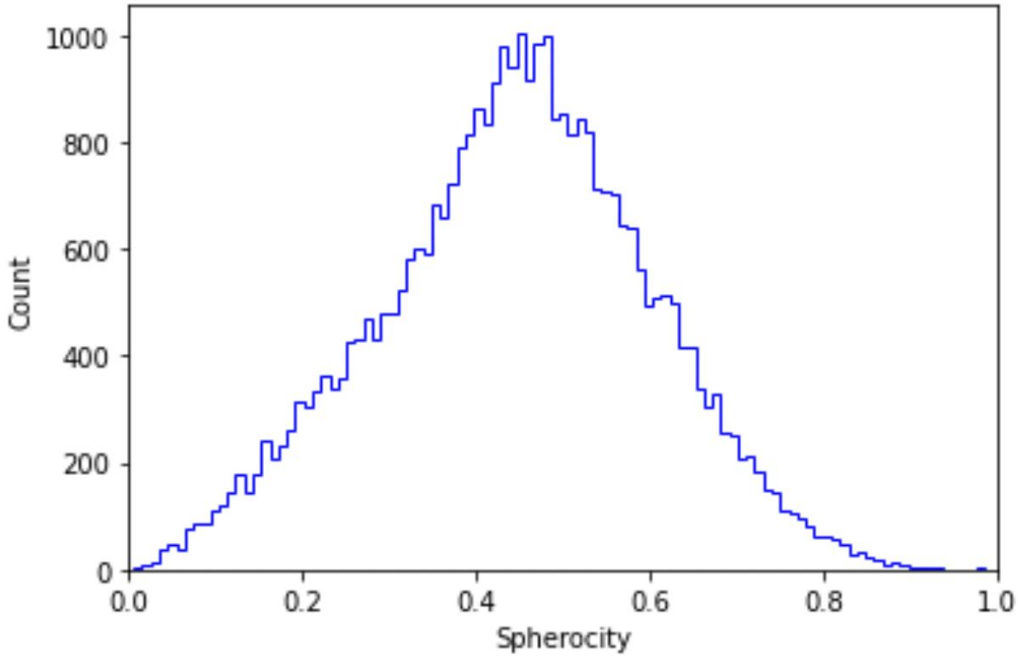

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- etc ...

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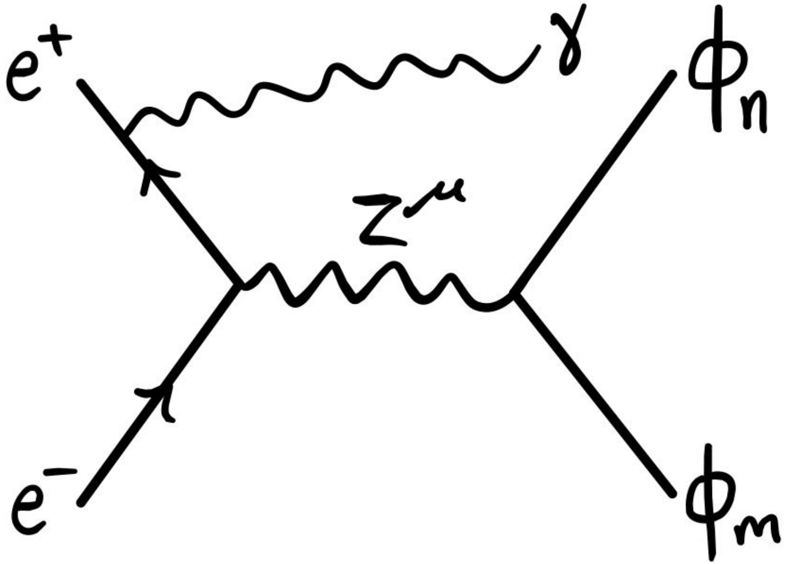

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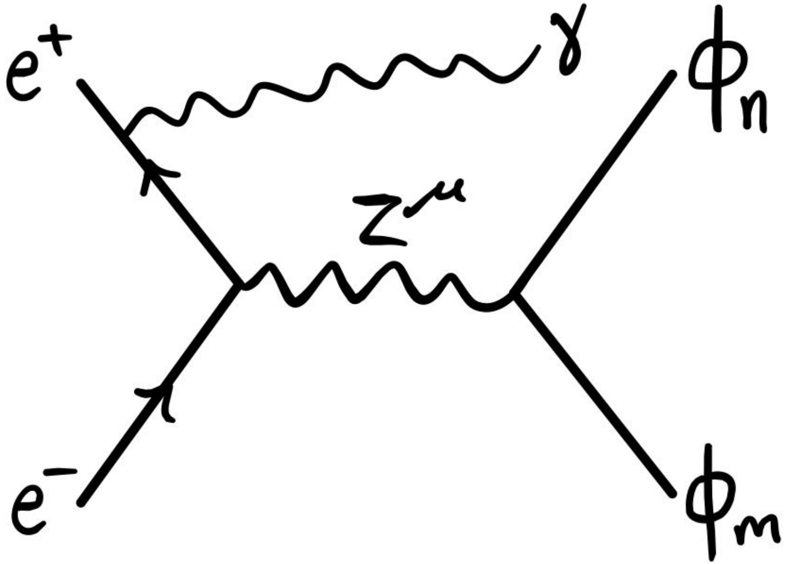
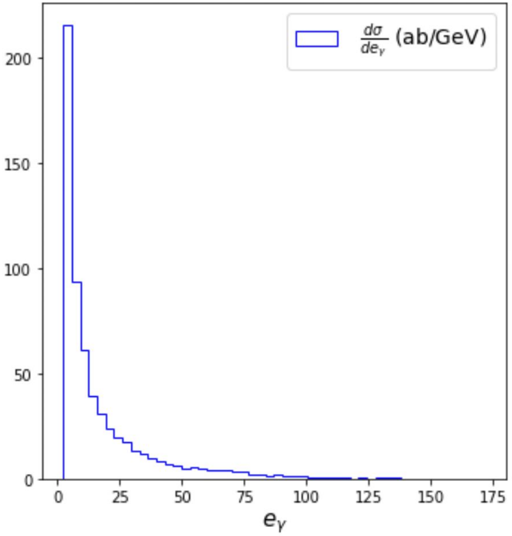
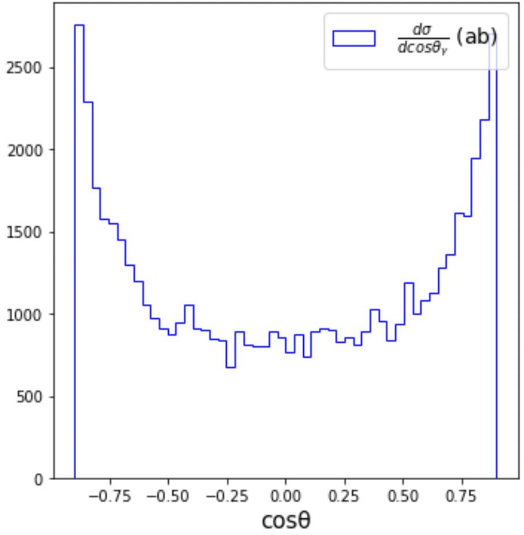
- Only observables are the photon energy & angle







Back to Continuum DM: take the **Continuum Limit** $\Delta m \to 0$

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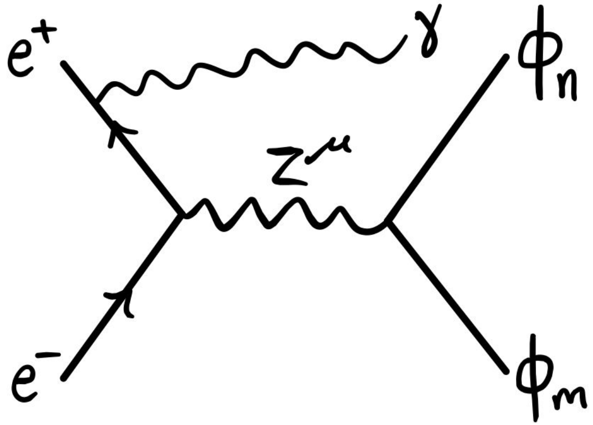

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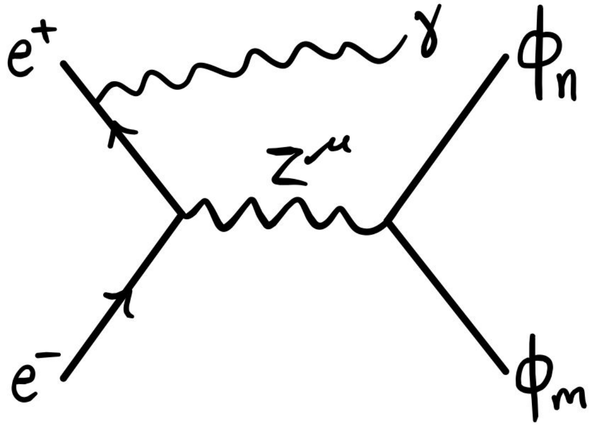

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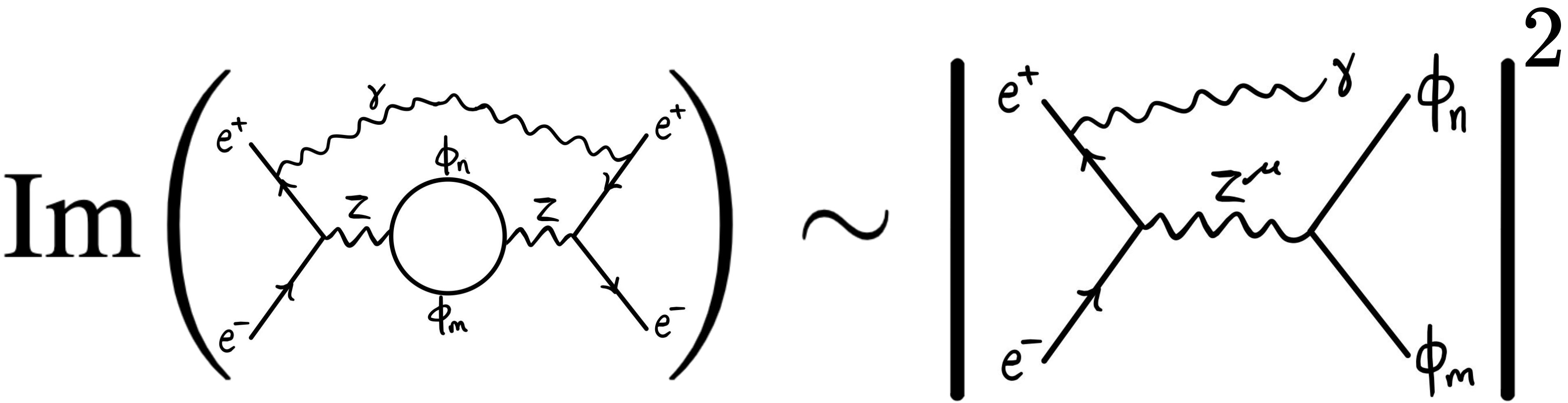

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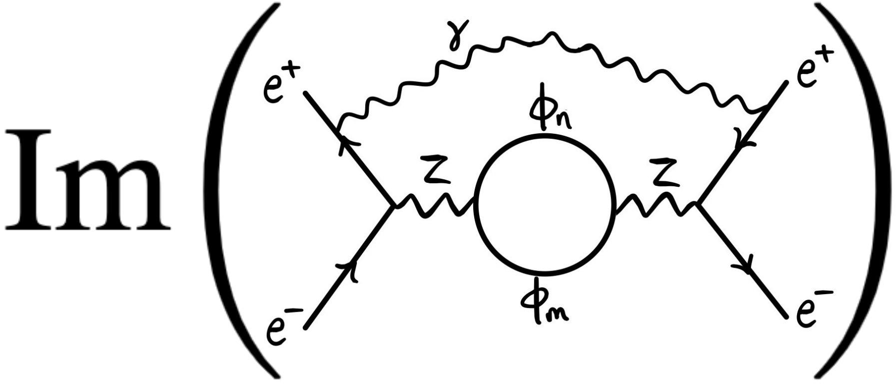
- Assume the signal is invisible → ISR signal
- But the KK modes aren't asymptotic states!
- Need to use the Optical Theorem … not clear if it works for continuum propagators
- Should still be equivalent to the Feynman diagram treatment

(as in the Invisible case)



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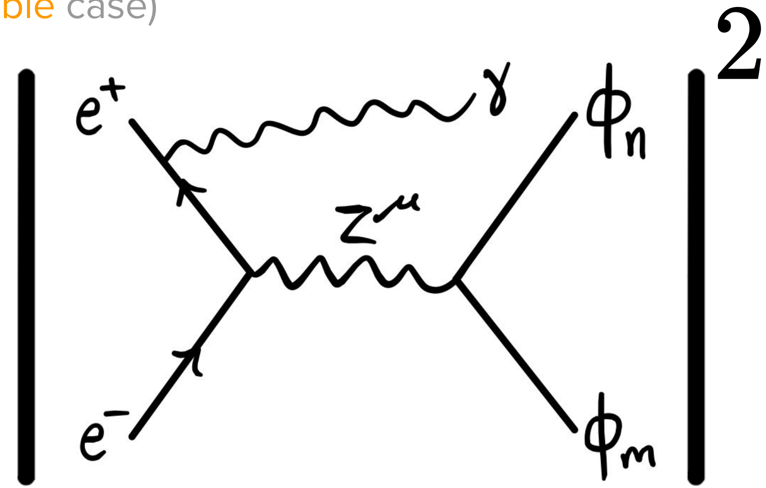

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Outlook

- LHC Simulations
- Comparison to backgrounds
- Can consider other continuum models
- Strongly coupled dual description?

Thanks for (fine)tuning in

Backup

Near-Continuum KK Spectrum -- Narrow Width ✓ & Visible

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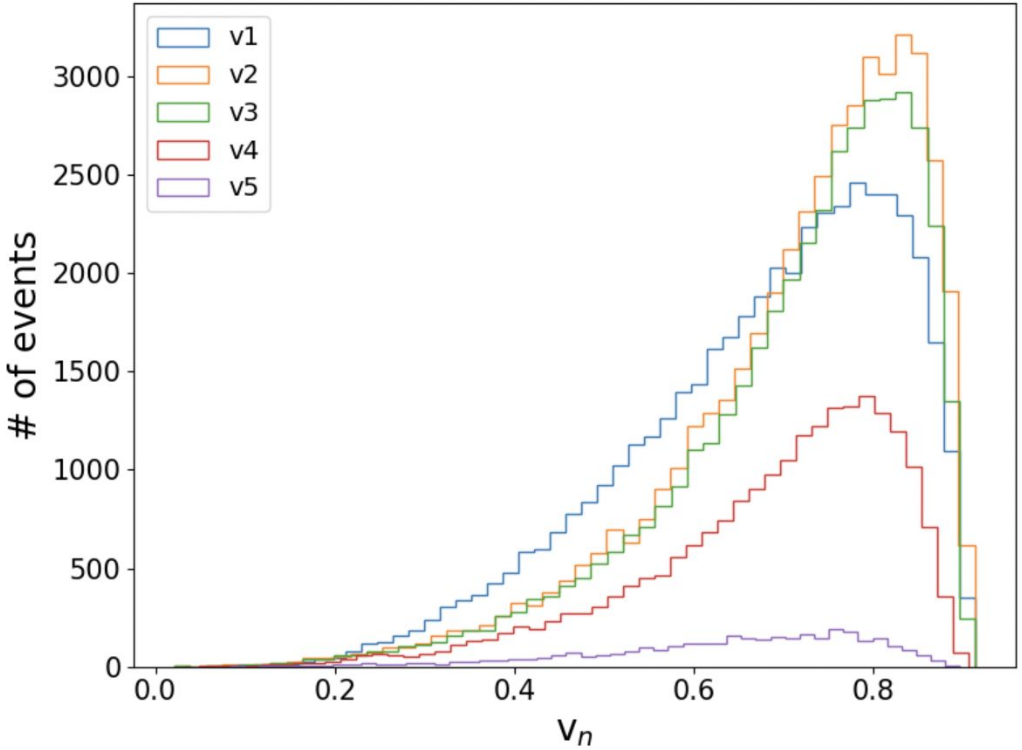

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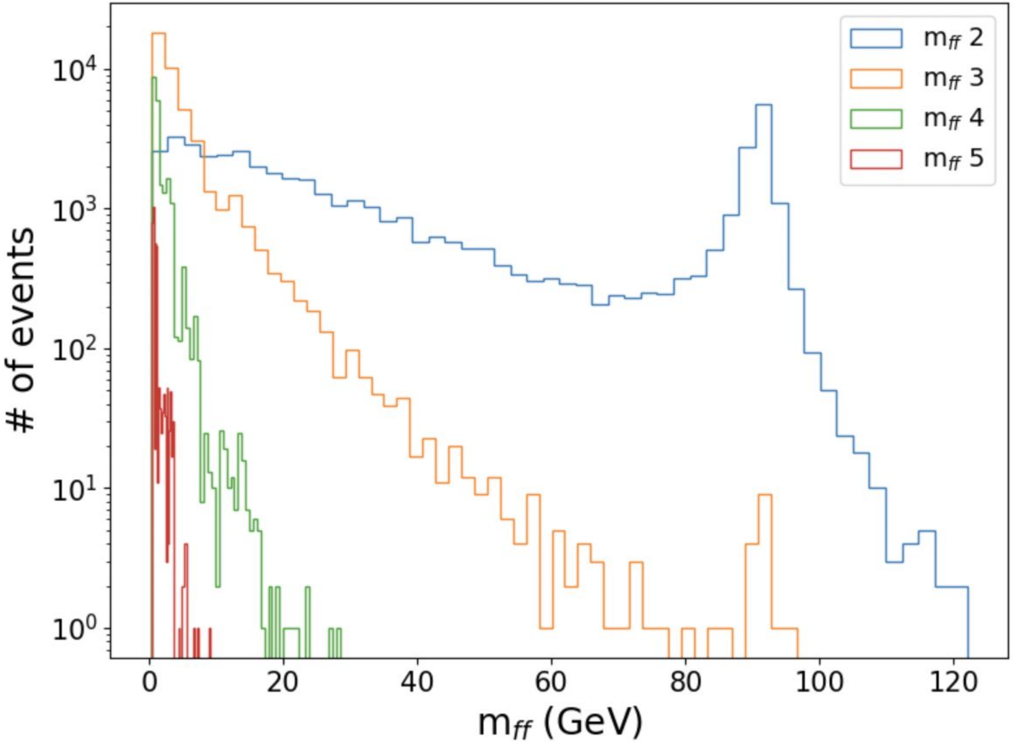

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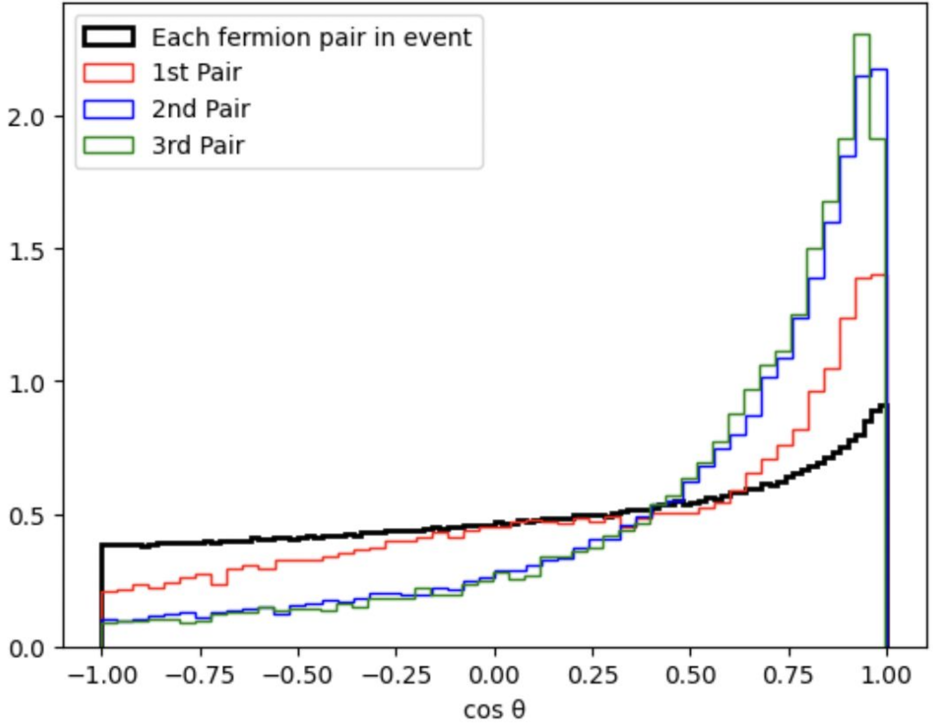

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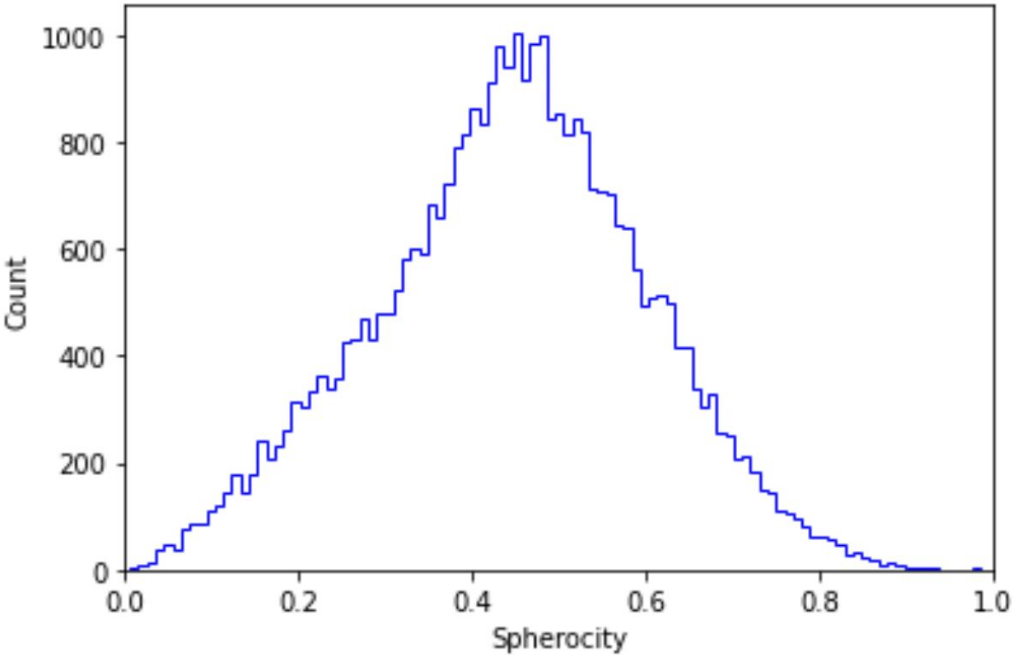

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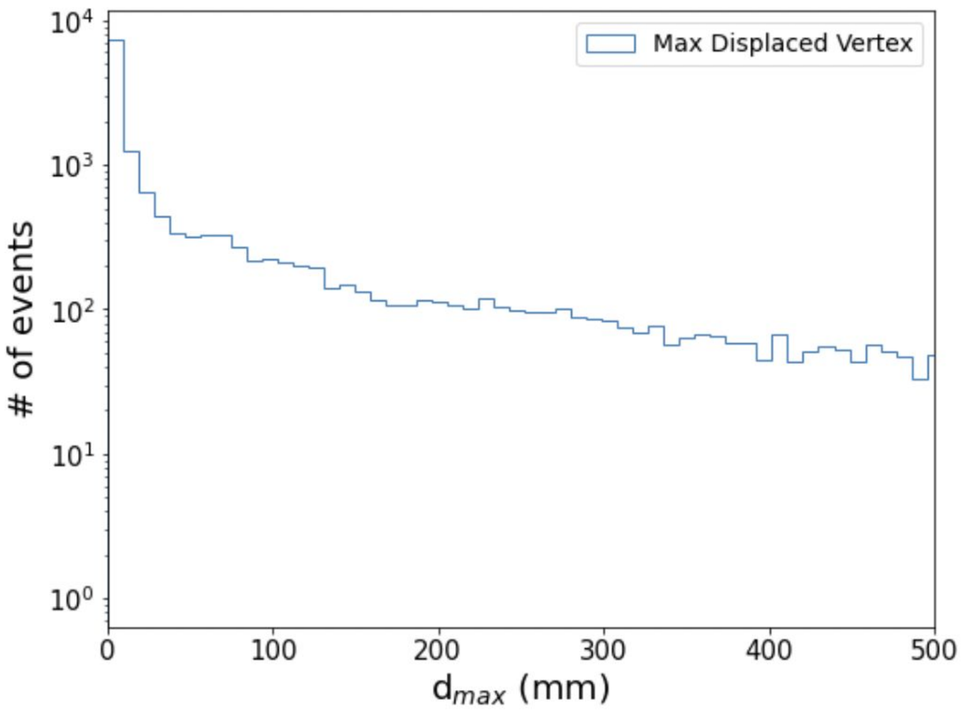

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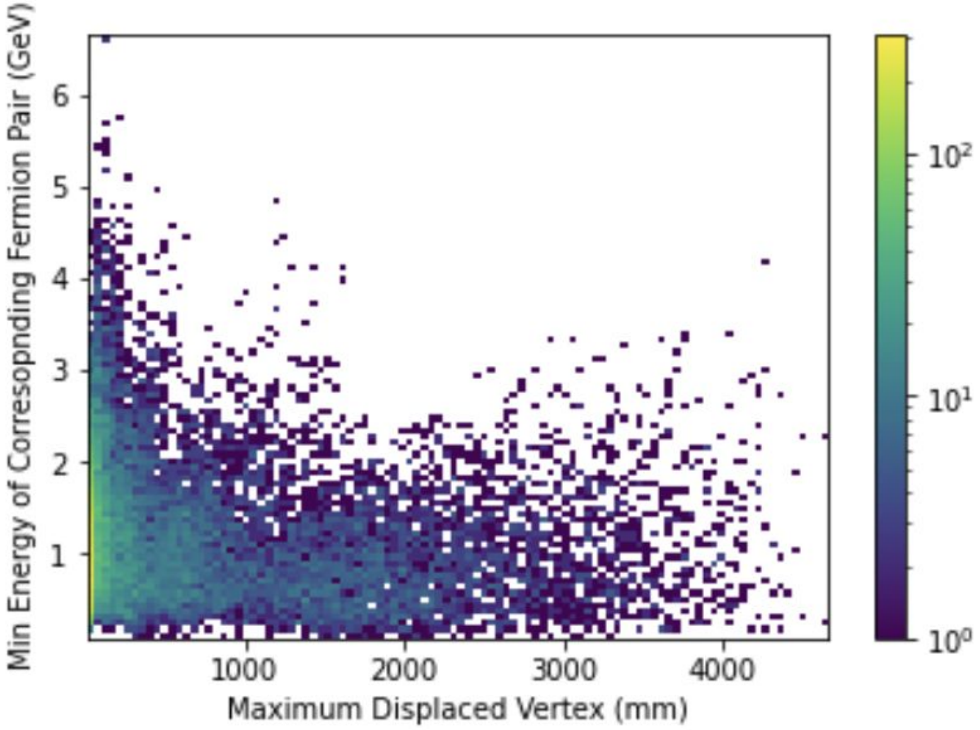

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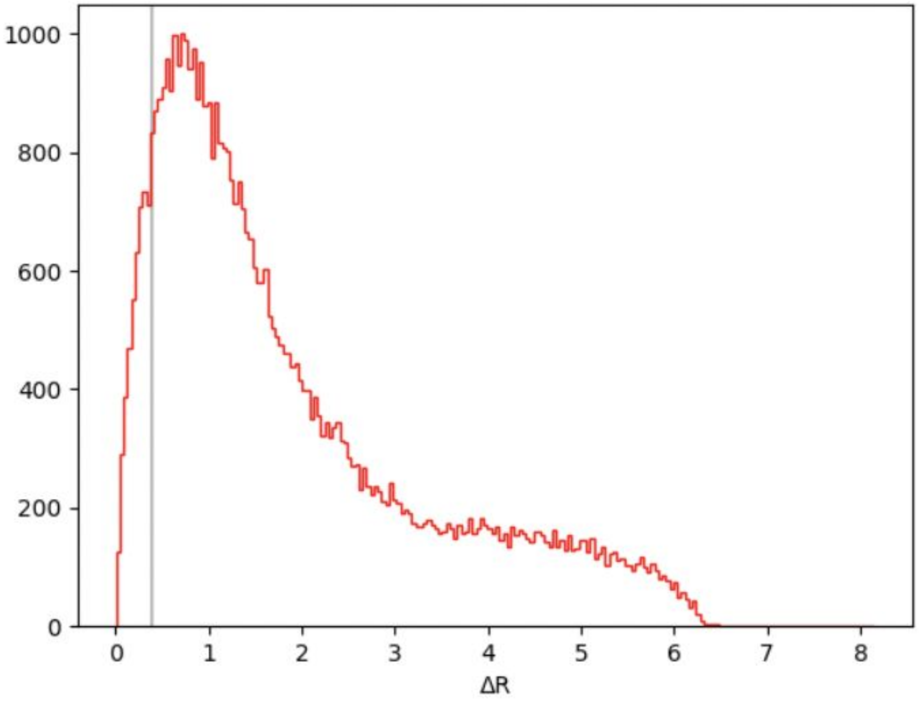

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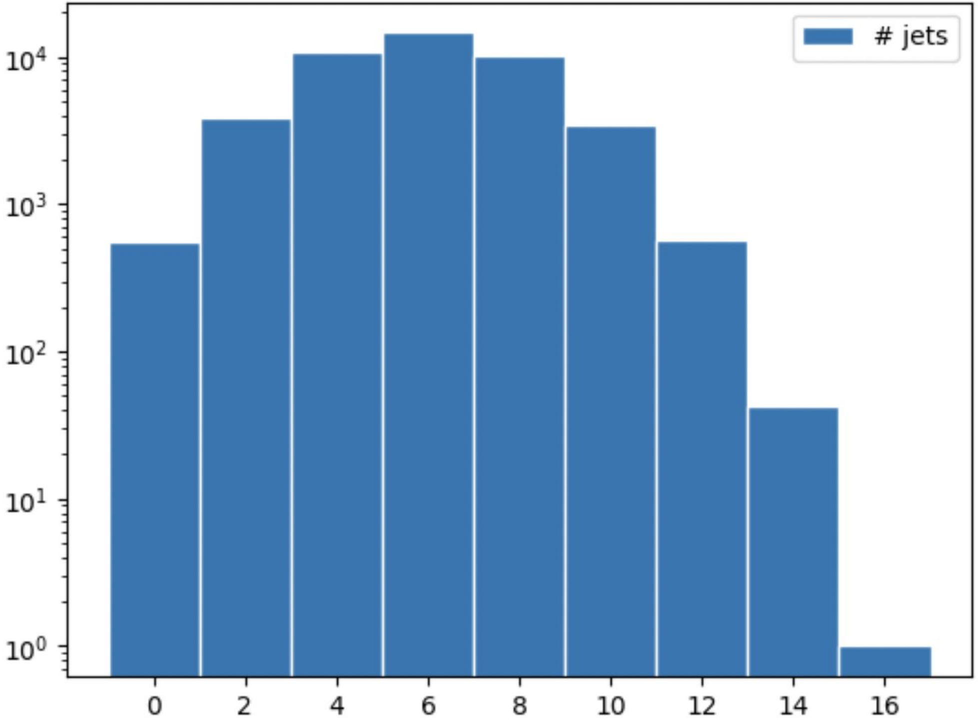

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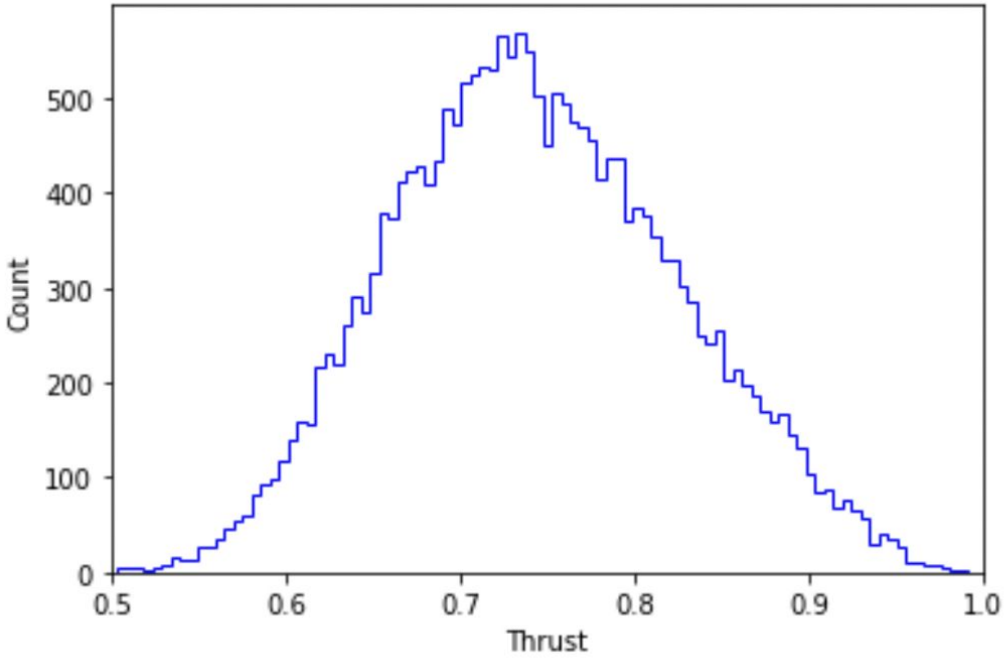

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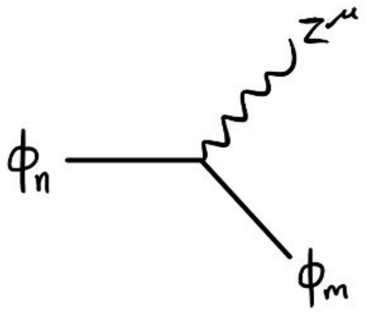

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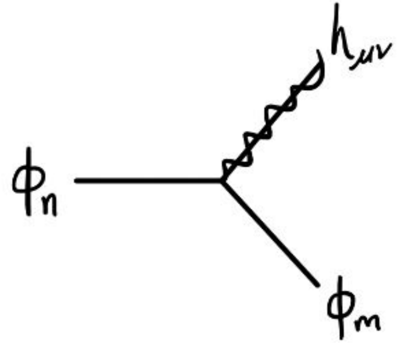

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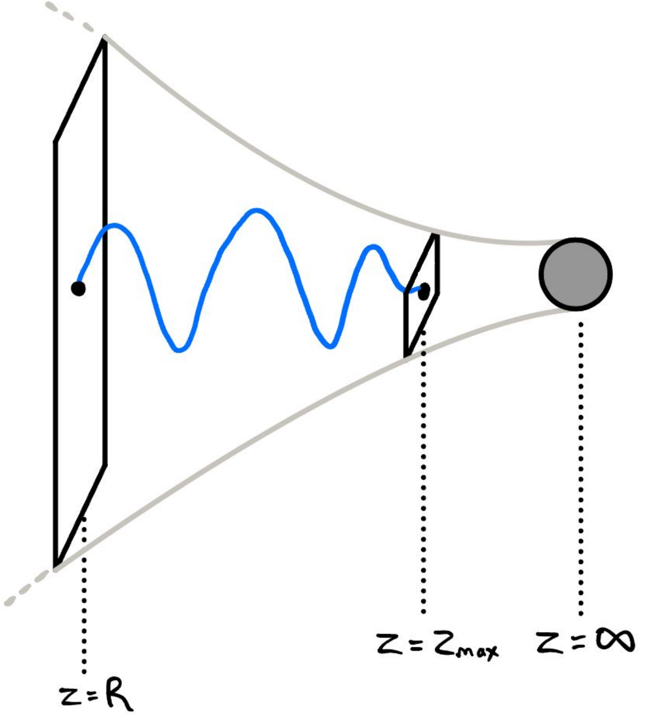

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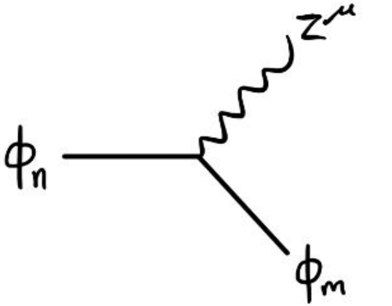

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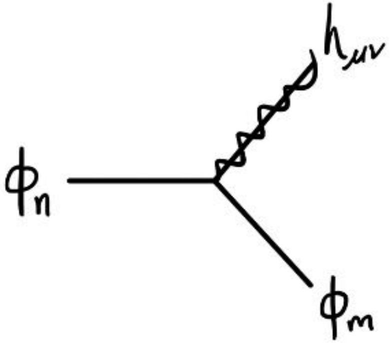

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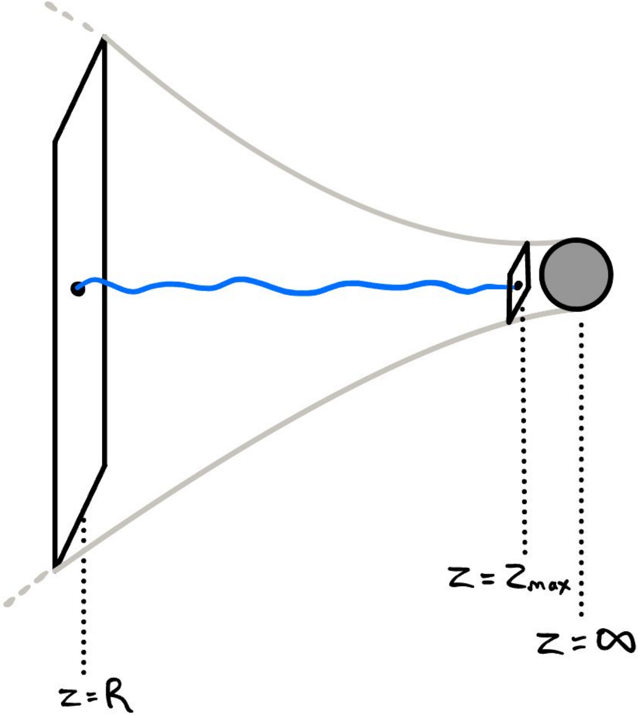

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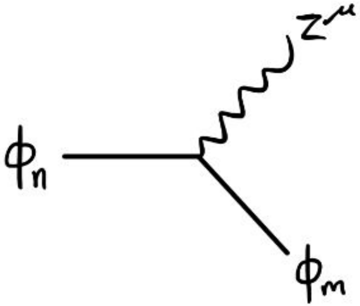
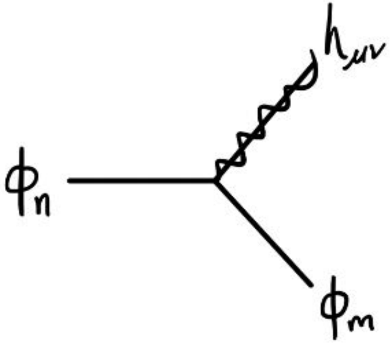
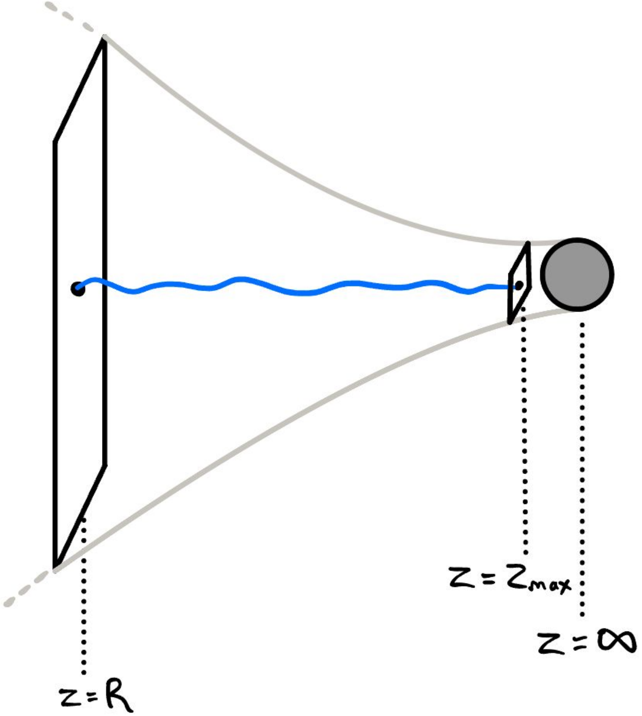


$$\to 0$$

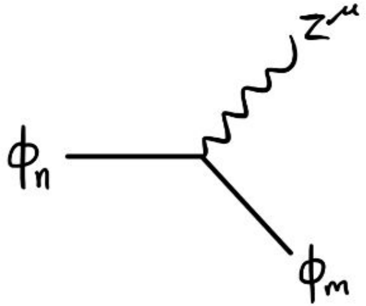


$$\not\to 0$$

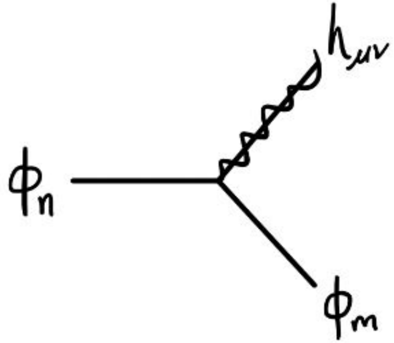


Near-Continuum KK Spectrum -- Narrow Width ✗

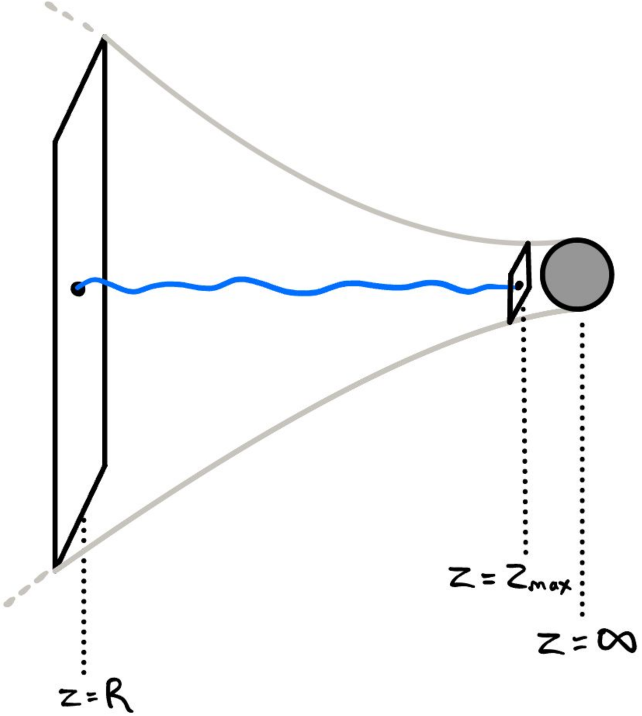
- Assume NWA holds, & consider the limit $z_{\text{max}} \to \infty$ ... then $\Delta m \to 0$
- By the time NWA breaks, $\Gamma_g > \Gamma_Z$ ➜ Invisible



$$\to 0$$



$$\not\to 0$$



Alternate explanation of $\Gamma_Z \to 0$

$$
\begin{aligned}
< \Phi(x,0)\Phi(x,0) > \;&=\; \textstyle\sum_{n,m} f_n(0) f_m(0) < \Phi_n(x)\Phi_m(x) > \\
&=\; \textstyle\sum_n |f_n(0)|^2 \frac{i}{p^2 - m_n^2} \\
&=\; \int dm^2 \underbrace{\left(\lim \frac{|f_n(0)|^2}{\Delta m^2} \right)}_{\to\, \rho(m^2)} \frac{i}{p^2 - m^2}
\end{aligned}
$$