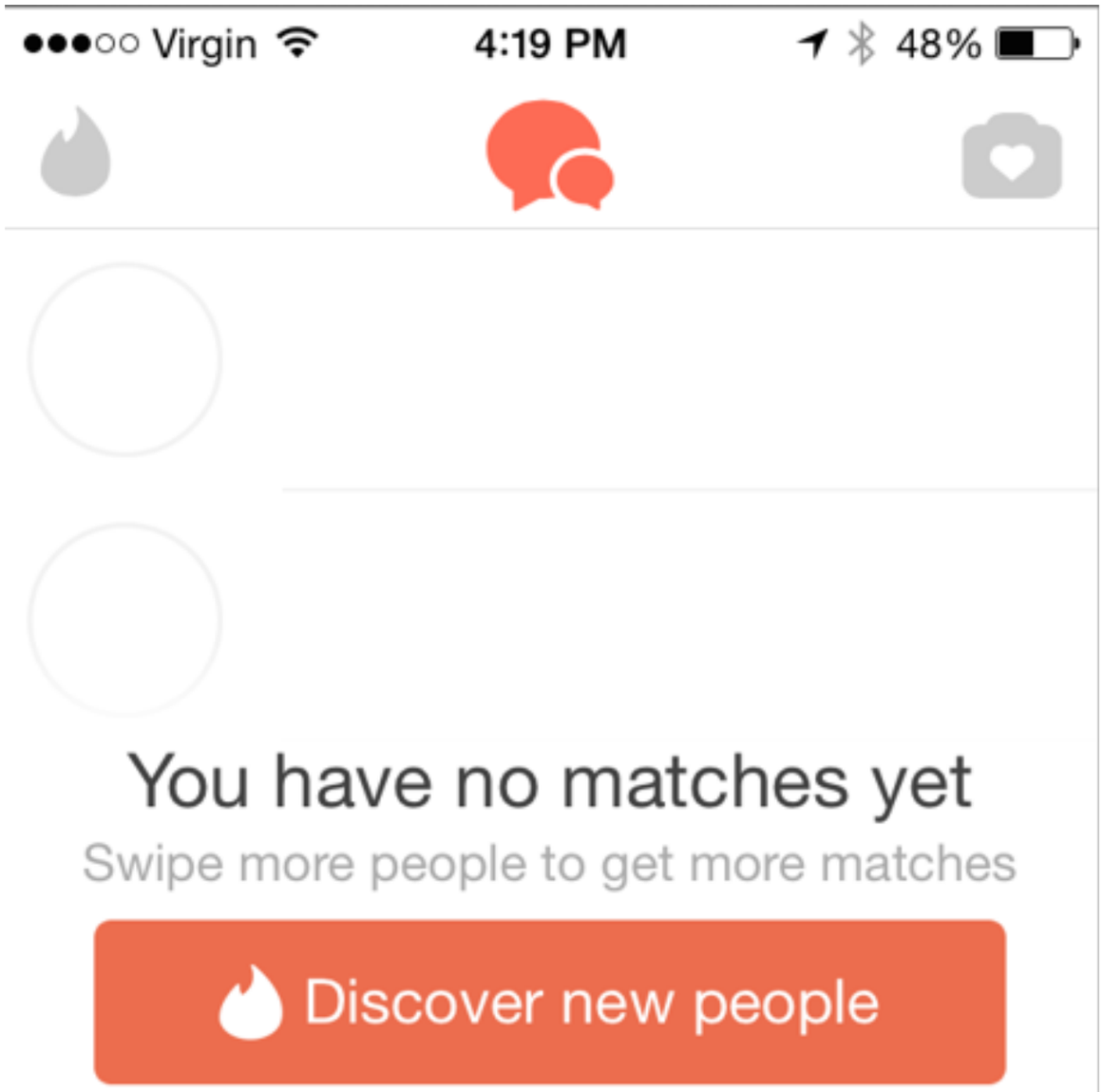
LARGE-N AND MIMESIS AT HADRON COLLIDERS

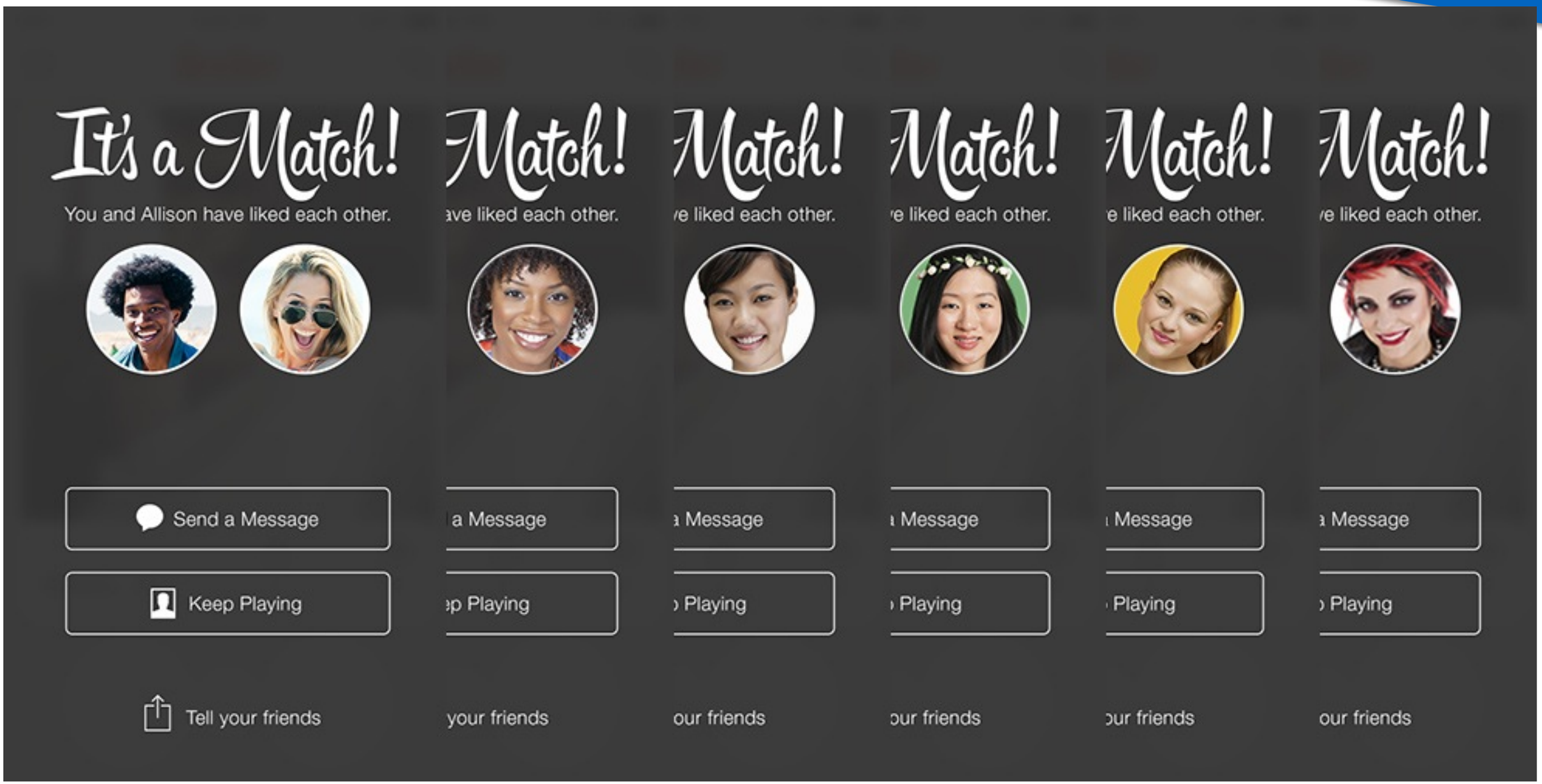
Raffaele Tito D’Agnolo (SLAC)

The Future of Particle Physics: A Quest for Guiding Principles - KIT - Oct 2018

WHY HAVE WE SEEN NOTHING SO FAR?



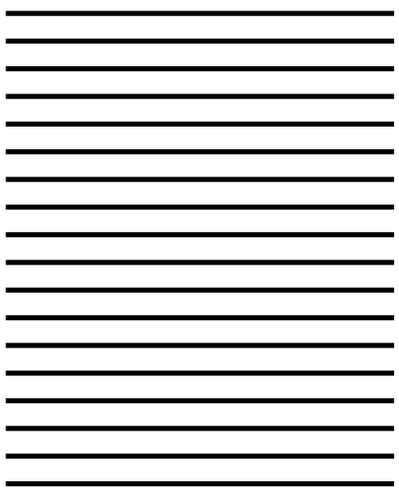
EXPLANATION #1:
THERE IS NOTHING TO SEE



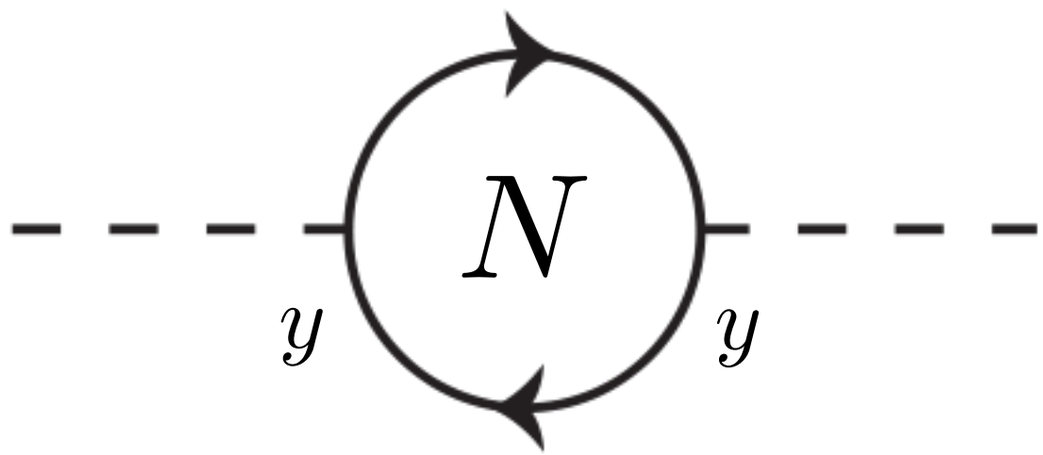
EXPLANATION #2:
THERE ARE TOO MANY NEW PARTICLES

LARGE N BASICS

$$yh\sum_{i=1}^{N}\bar{\psi}_i\psi_i$$



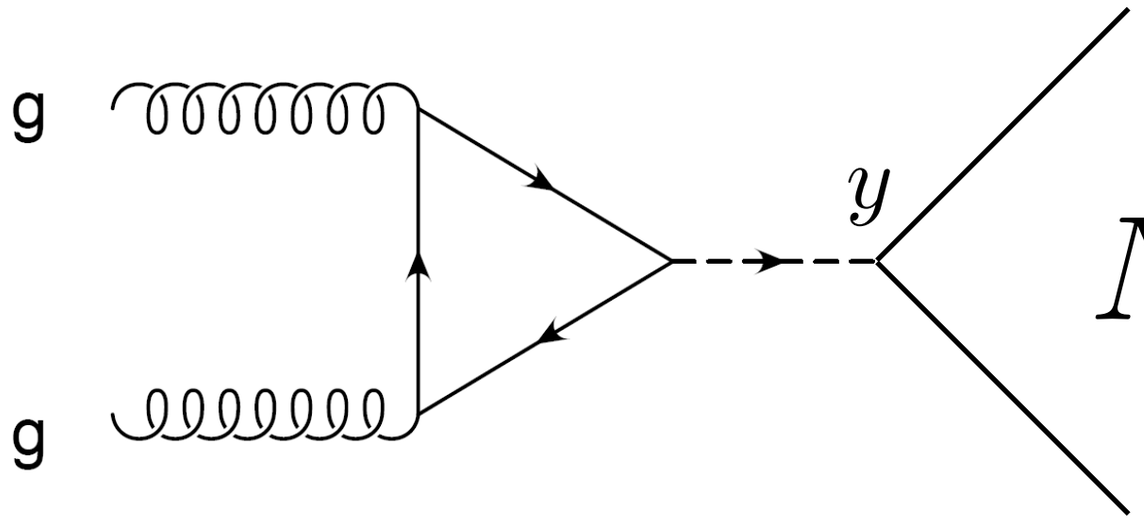
ψ_i



PERTURBATIVITY

$$y \sim \frac{1}{\sqrt{N}}$$

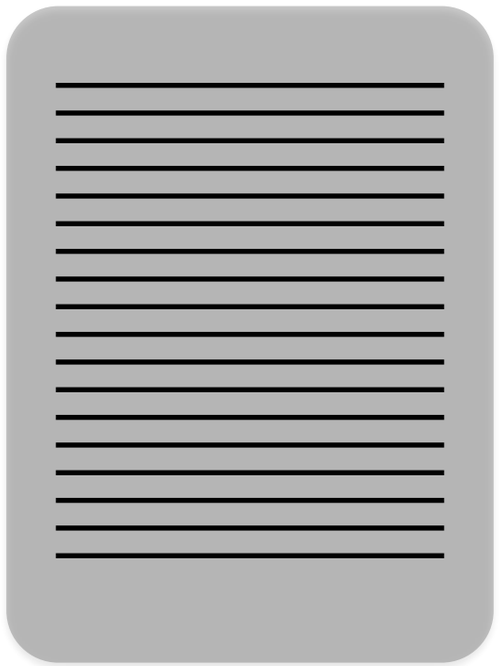
LARGE N BASICS



$$\sigma = y^2 \sum_{i=1}^{N} \sigma_i \sim N y^2 \sim 1$$

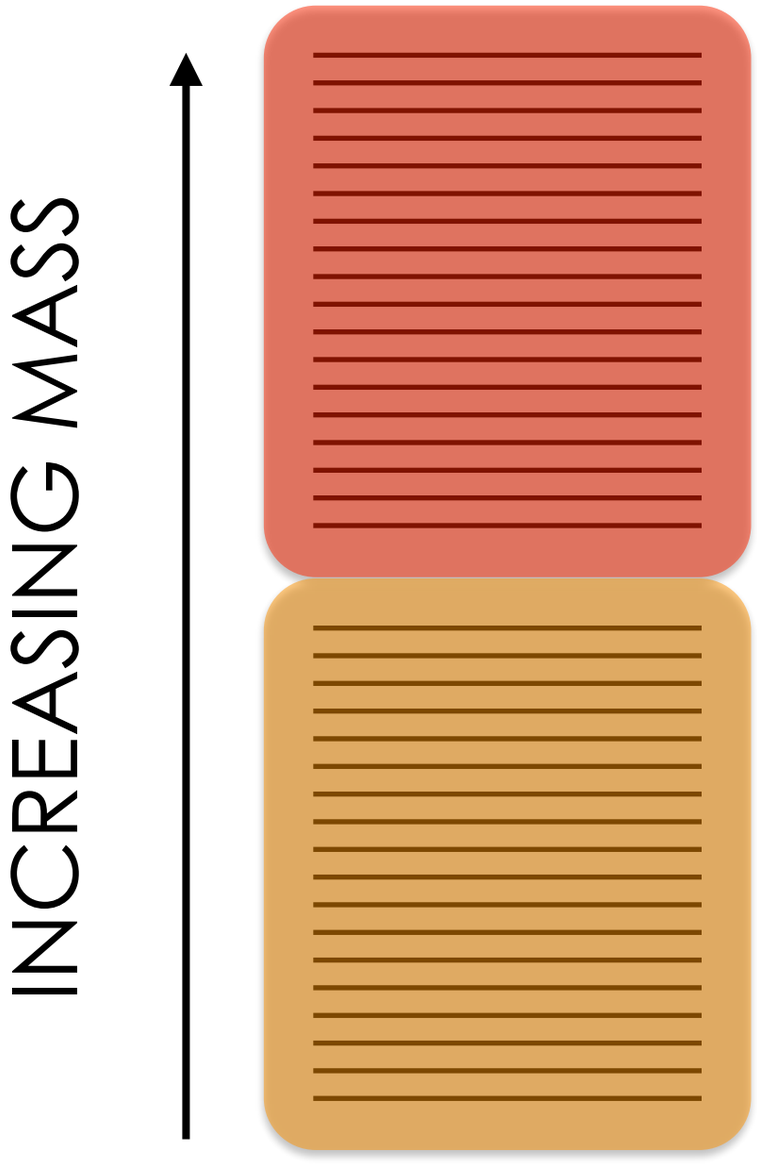
LARGE N CONSEQUENCES

OUT OF REACH



$$\sigma \sim \frac{1}{N}$$

LARGE N CONSEQUENCES



LONG DECAY CHAIN,
LOW PT FINAL OBJECTS,
LOW VISIBLE ENERGY

=

MISSED BY CURRENT TRIGGERS

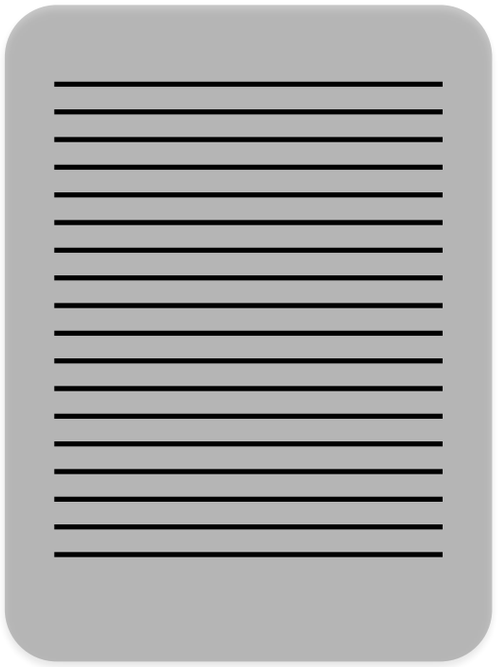
SHORT DECAY CHAIN,
SMALL MASS

=

TOO MUCH BACKGROUND OR "UNTRIGGERABLE"

A TOY EXAMPLE

OUT OF REACH



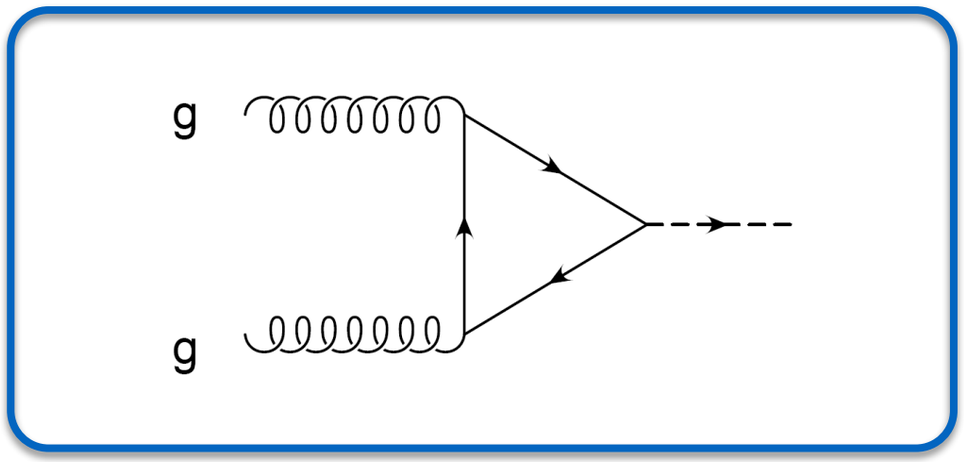
$$-\mathcal{L} \supset m\phi_2^\dagger \phi_1^2 + \epsilon m \left(\phi_1 + \phi_2\right) |H|^2 + \text{h.c.}$$

$$\epsilon \sim \frac{1}{N} \ll 1$$

ϕ_2 350 GeV

ϕ_1 300 GeV

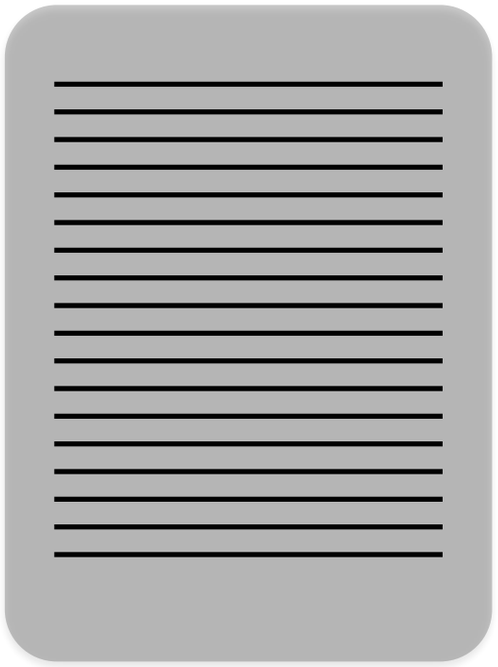
PRODUCTION



$\phi_2 \approx 100$ events @ HL-LHC

A TOY EXAMPLE

OUT OF REACH



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$$\epsilon \sim \frac{1}{N} \ll 1$$

ϕ_2 350 GeV

ϕ_1 300 GeV

DECAY

$$\phi_2 \to \phi_1 \phi_1^* \to hh\bar{b}b$$

$$\phi_1 \to hh$$

PHENOMENOLOGY OF A MULTI-PARTICLE SECTOR

MODEL BUILDING CHOICES

1. GAUGE SINGLETS. NO LANDAU POLES CLOSE BY

2. NO EXTRA LIGHT MEDIATORS (ASSUMPTION)

TODAY

$$\boxed{\phi|H|^2} \quad \boxed{\phi^2|H|^2} \quad LH\psi \quad \boxed{\frac{\psi^2|H|^2}{\Lambda}} \quad \cdots$$

PAPER

TODAY'S MODEL

$$-\mathcal{L} \supset \sum_{\alpha=1}^{N} \frac{m_\alpha^2}{2}\phi_\alpha^2 + \sum_{\alpha,\beta,\gamma,\delta=1}^{N} \lambda_{\alpha\beta\gamma\delta}\phi_\alpha\phi_\beta\phi_\gamma\phi_\delta$$

DS

$$m_\alpha \in [m_1, m_2]$$

UNIFORMLY DISTRIBUTED

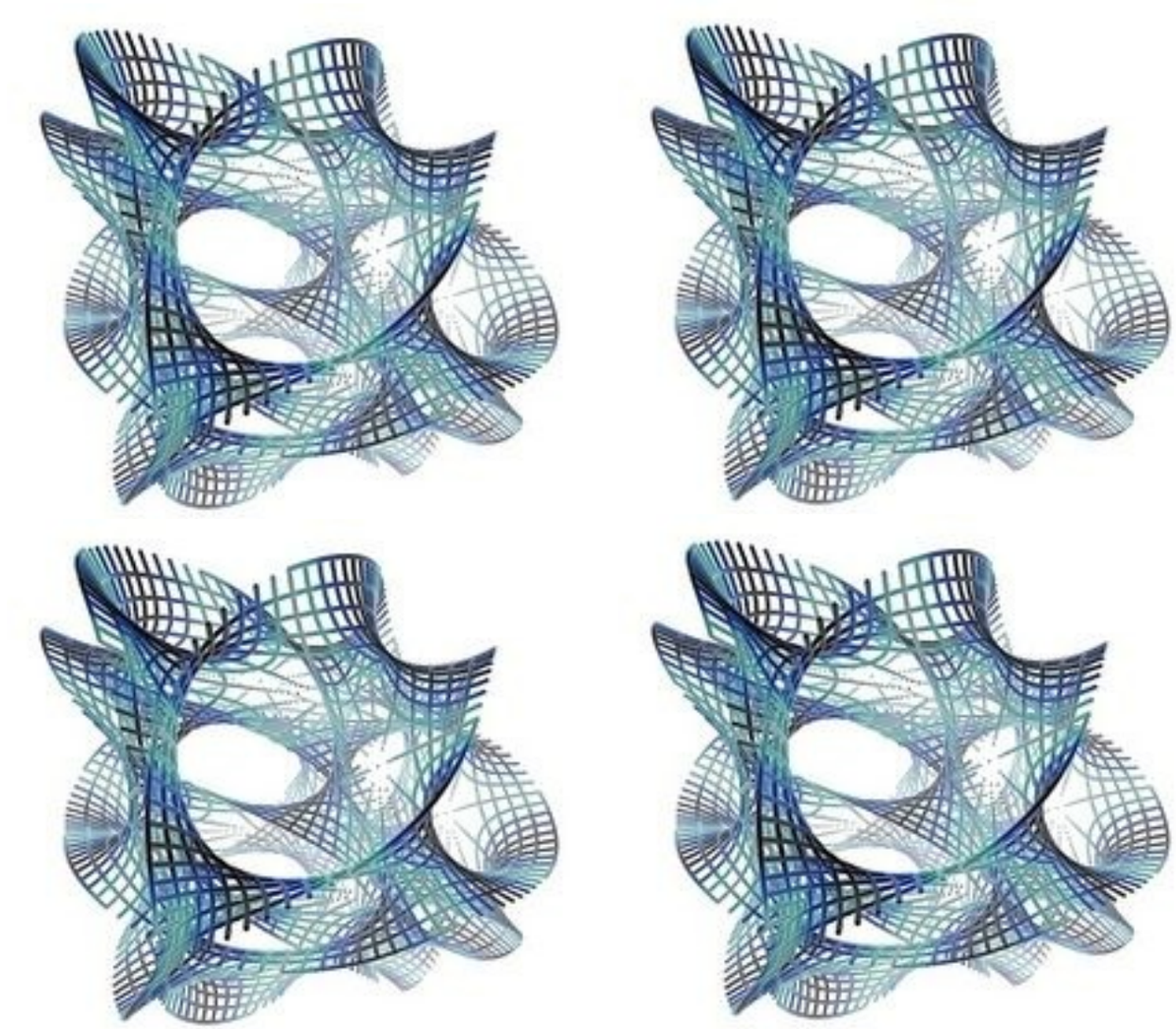
$$\lambda_{\alpha\beta\gamma\delta} = \frac{1}{N}, \quad \forall(\alpha,\beta,\gamma,\delta)$$

FOR SIMPLICITY

SM

$$-\mathcal{L} \supset |H|^2 \sum_{\alpha,\beta=1}^{N} \lambda_{H\alpha\beta}\phi_\alpha\phi_\beta \qquad \lambda_H = \frac{1}{N}$$

WHERE ARE THEY COMING FROM?



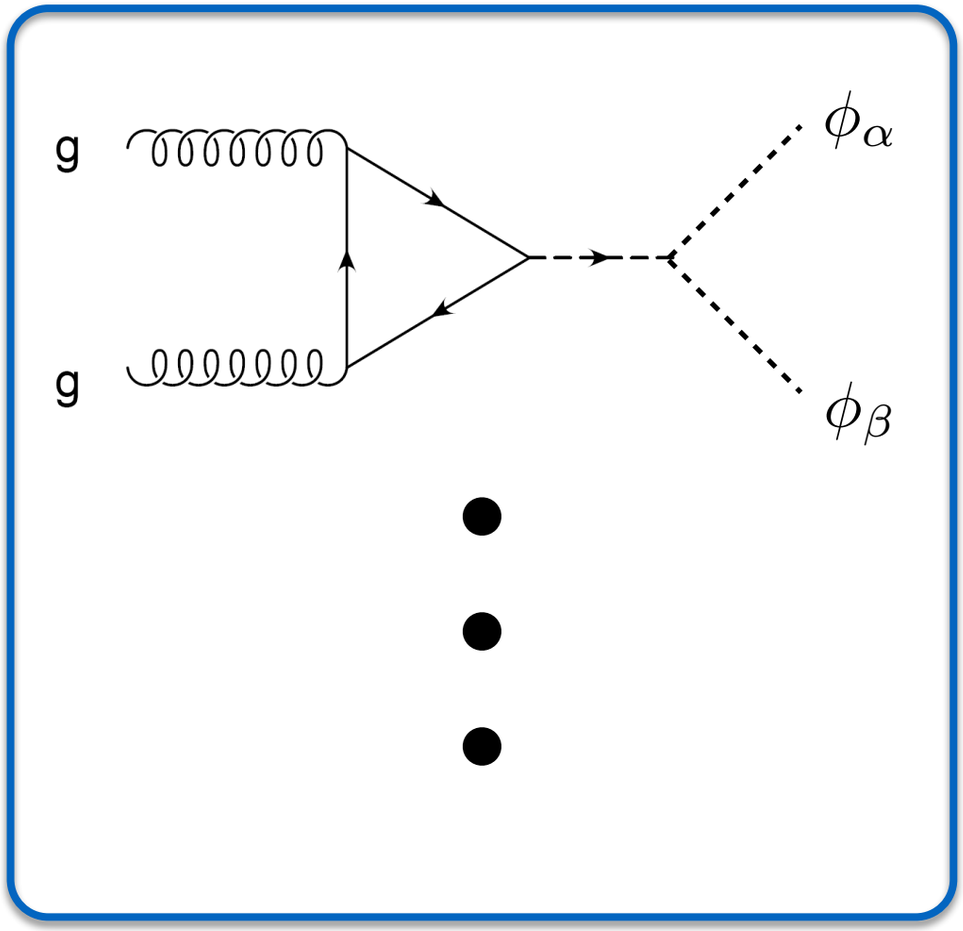
- MODULI
- GOLDSTONES ASSOCIATED TO THE POSITION OF BRANES
- FERMIONS FROM STRINGS ENDING ON BRANE STACKS
- (PSEUDO) SCALARS FROM HIGHER FORMS IN STRING THEORY
- SECTOR OF THE LANDSCAPE
- ALSO CONSIDERED FOR SYMMETRY NON-RESTORATION IN THE EWPT (SCALARS)
- …

PRODUCTION AND DECAYS

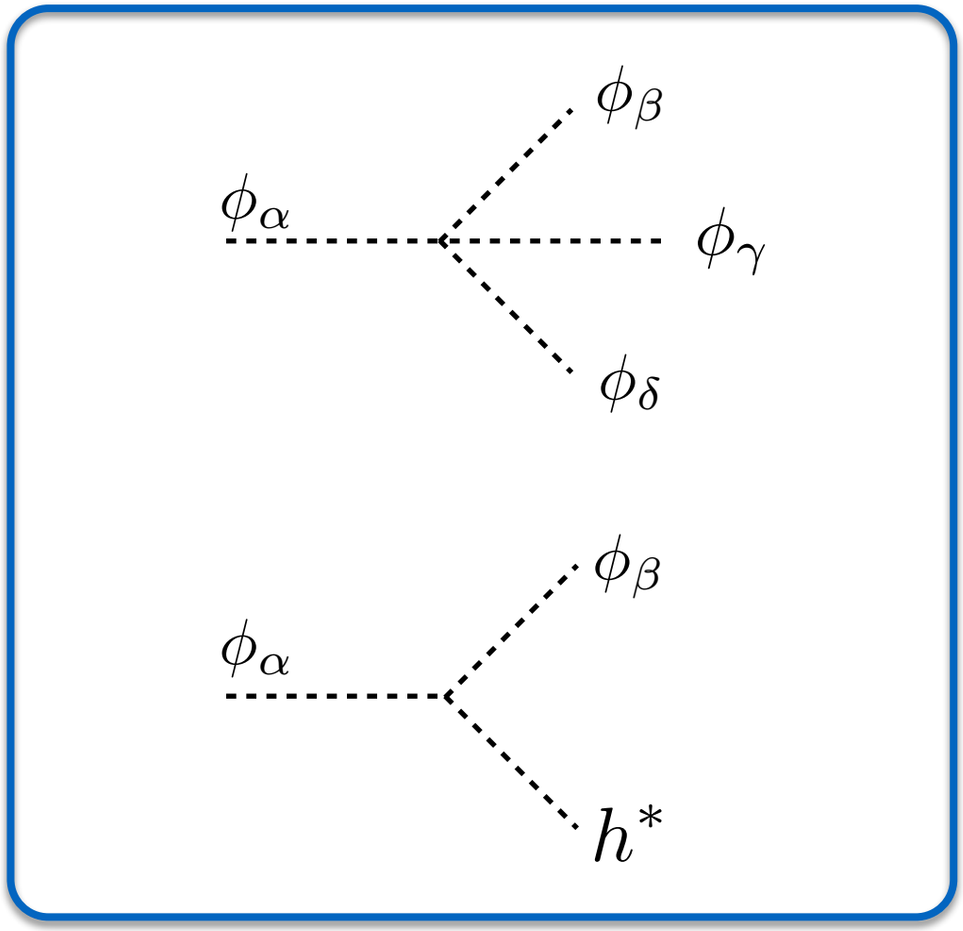
$$-\mathcal{L} \supset |H|^2 \sum_{\alpha,\beta=1}^{N} \lambda_{H\alpha\beta}\phi_\alpha\phi_\beta$$

$$\lambda_H \sim \frac{1}{N} \sim \lambda_{\alpha\beta\gamma\delta}$$

PRODUCTION



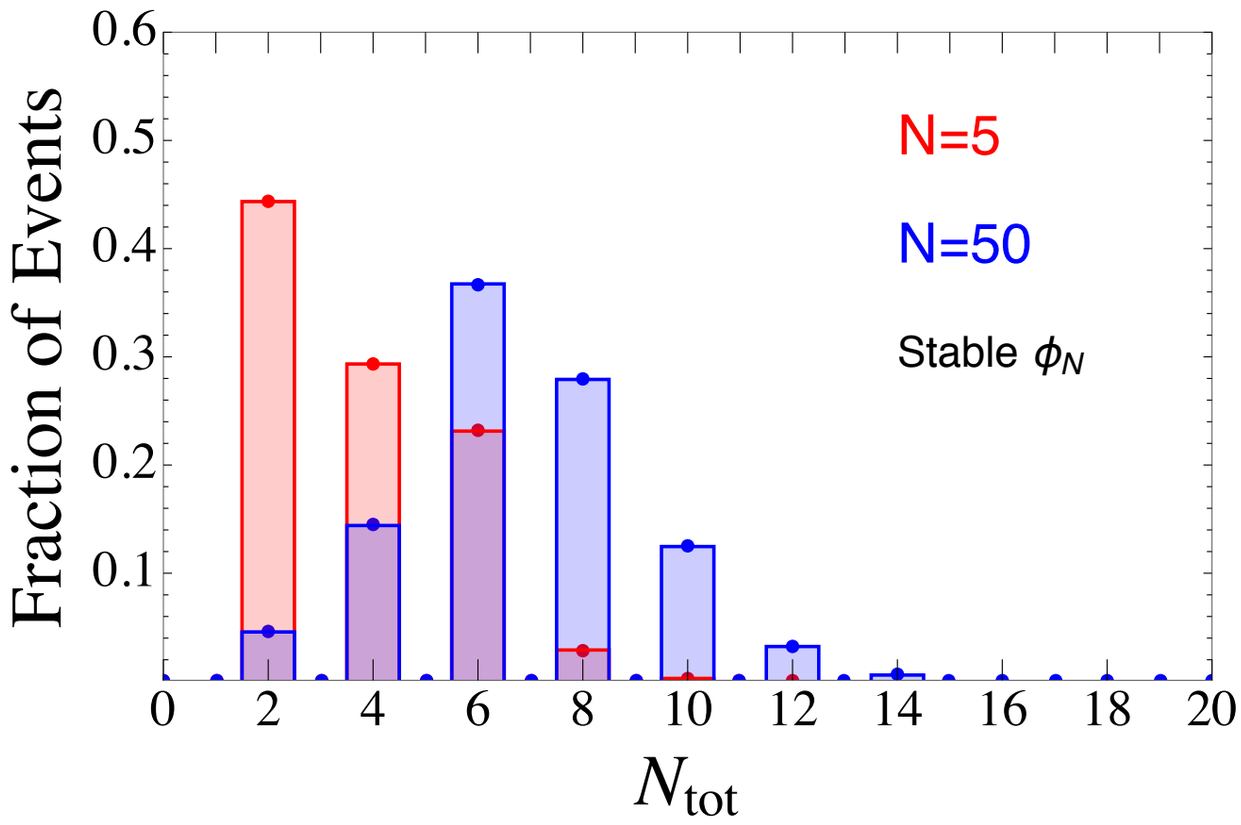
DECAYS

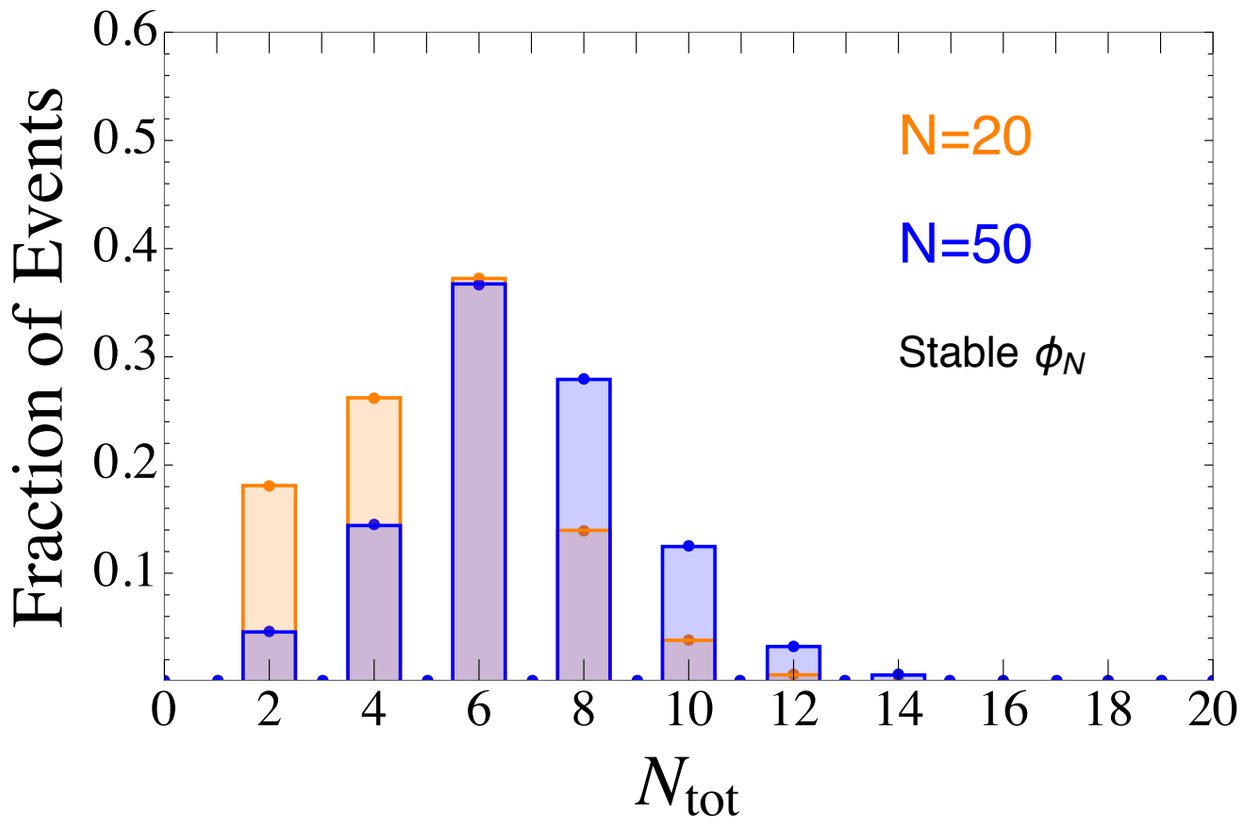


PARTICLE MULTIPLICITIES

$$N_{\rm tot} = b, c, \mu, s, W, Z, g, \gamma, \phi_N$$

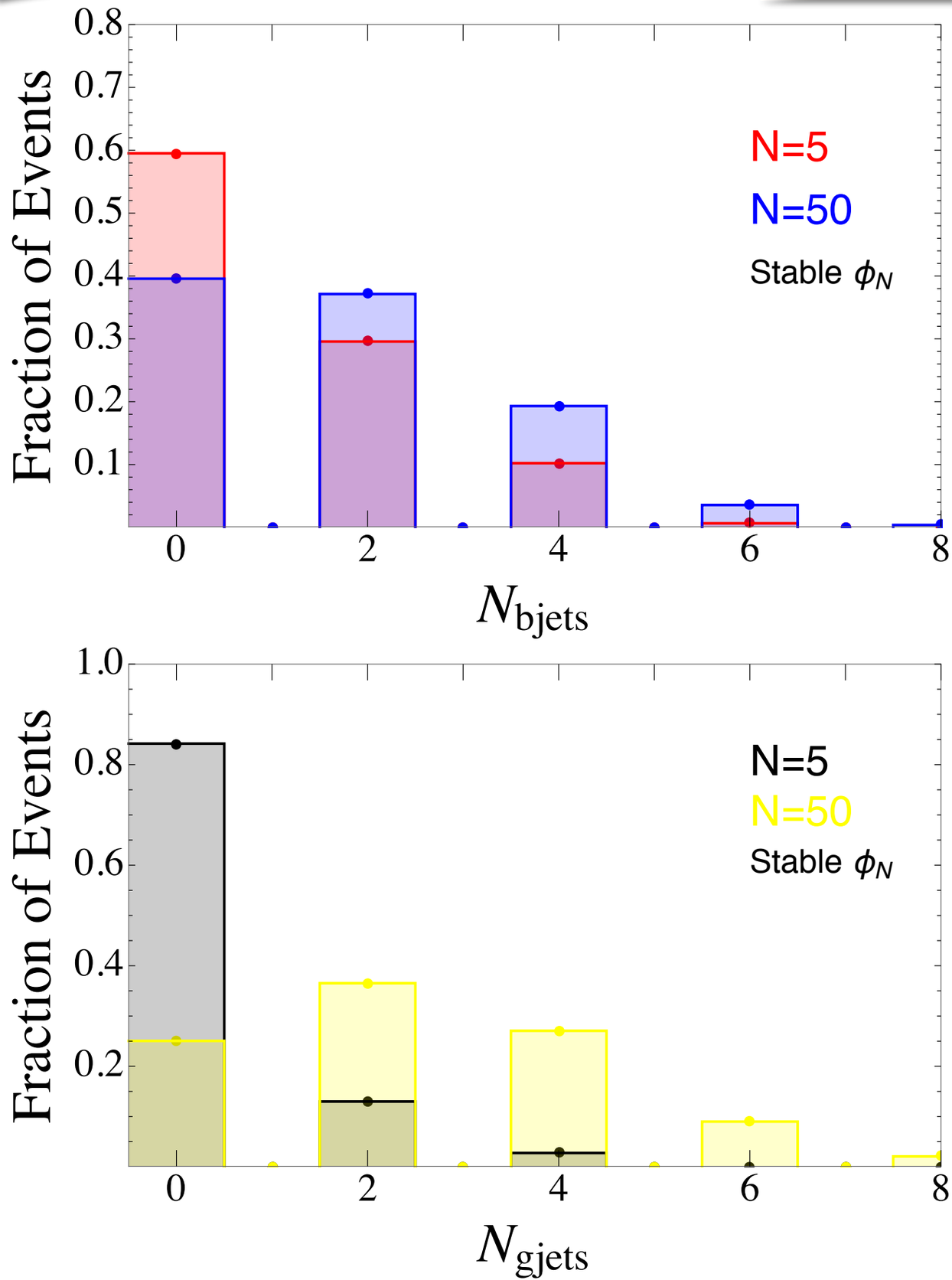
$$m_\alpha \in [100, 600]$$

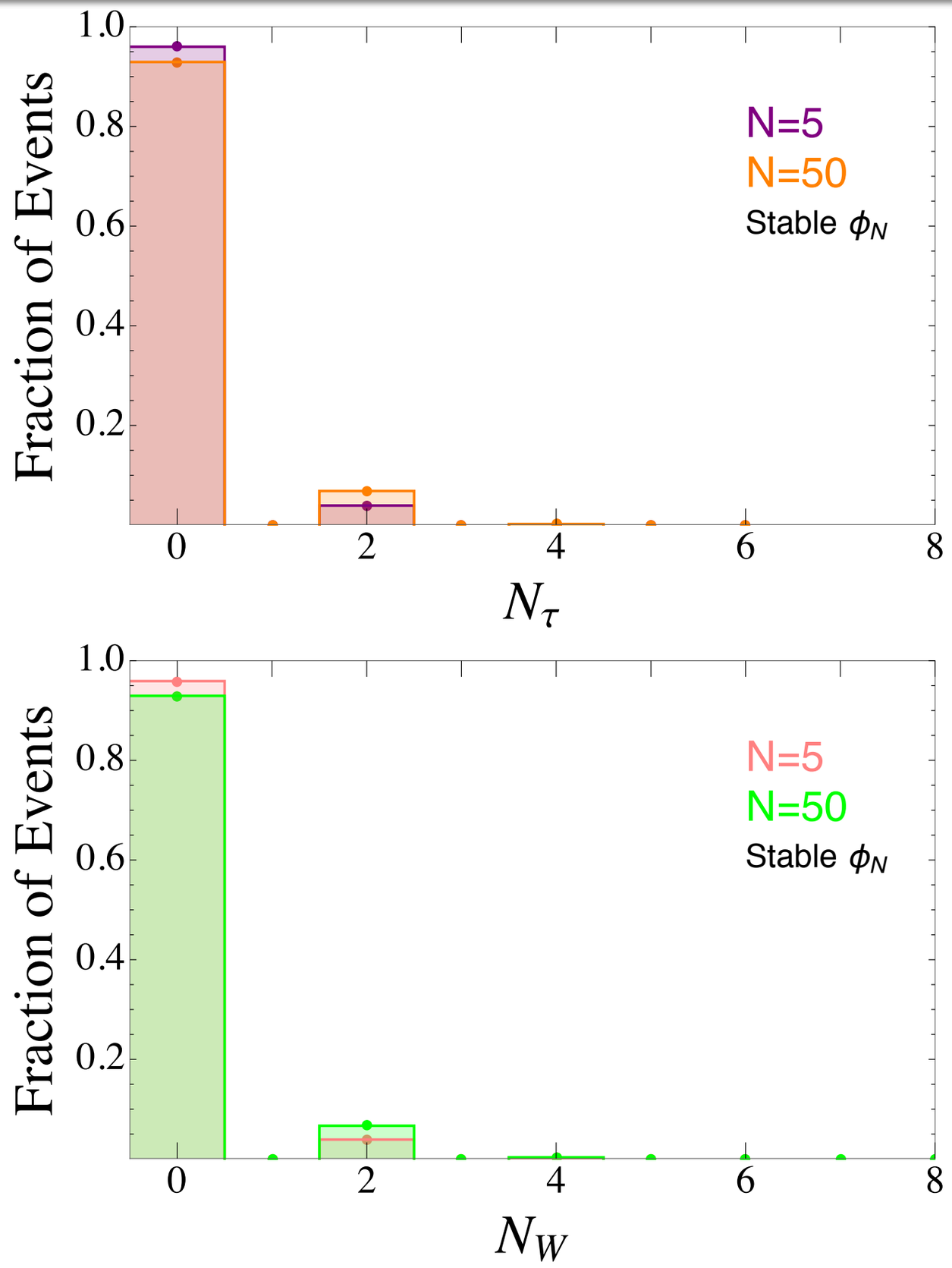




N.B. THERE ARE ALWAYS TWO INVISIBLE PARTICLES

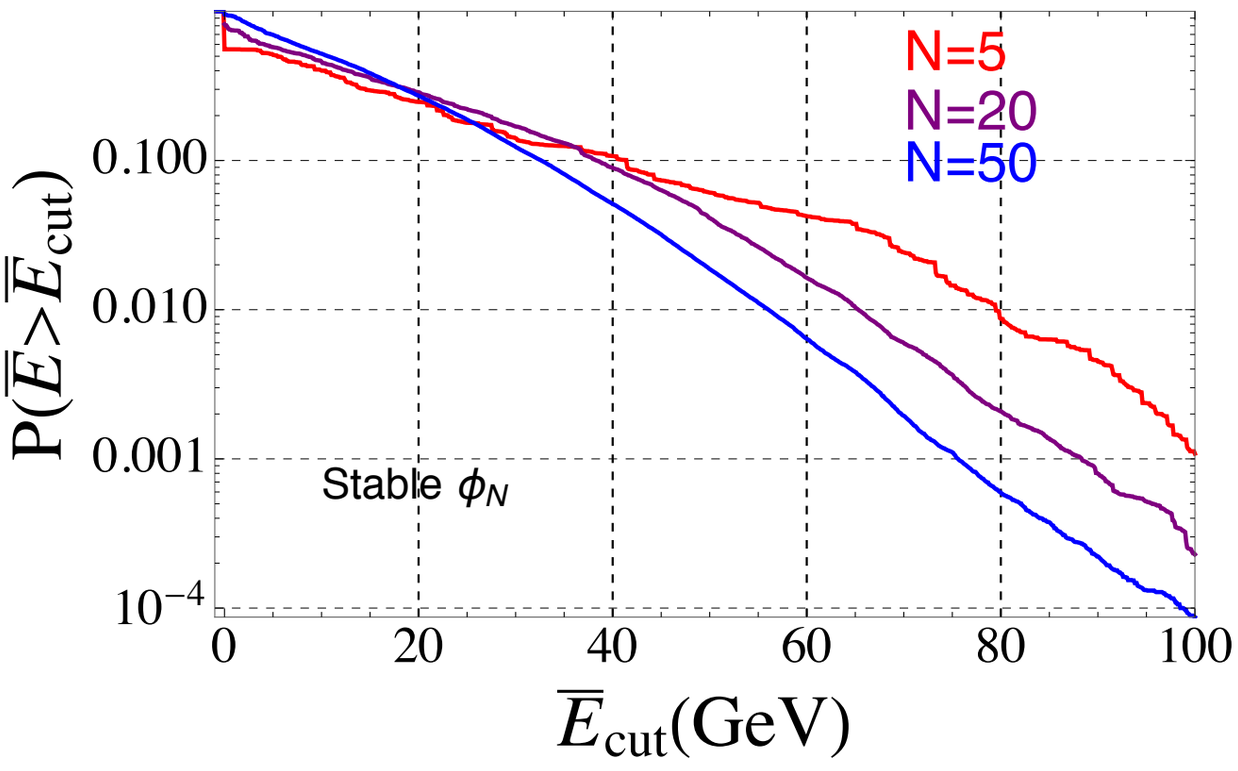
FINAL STATE PARTICLES



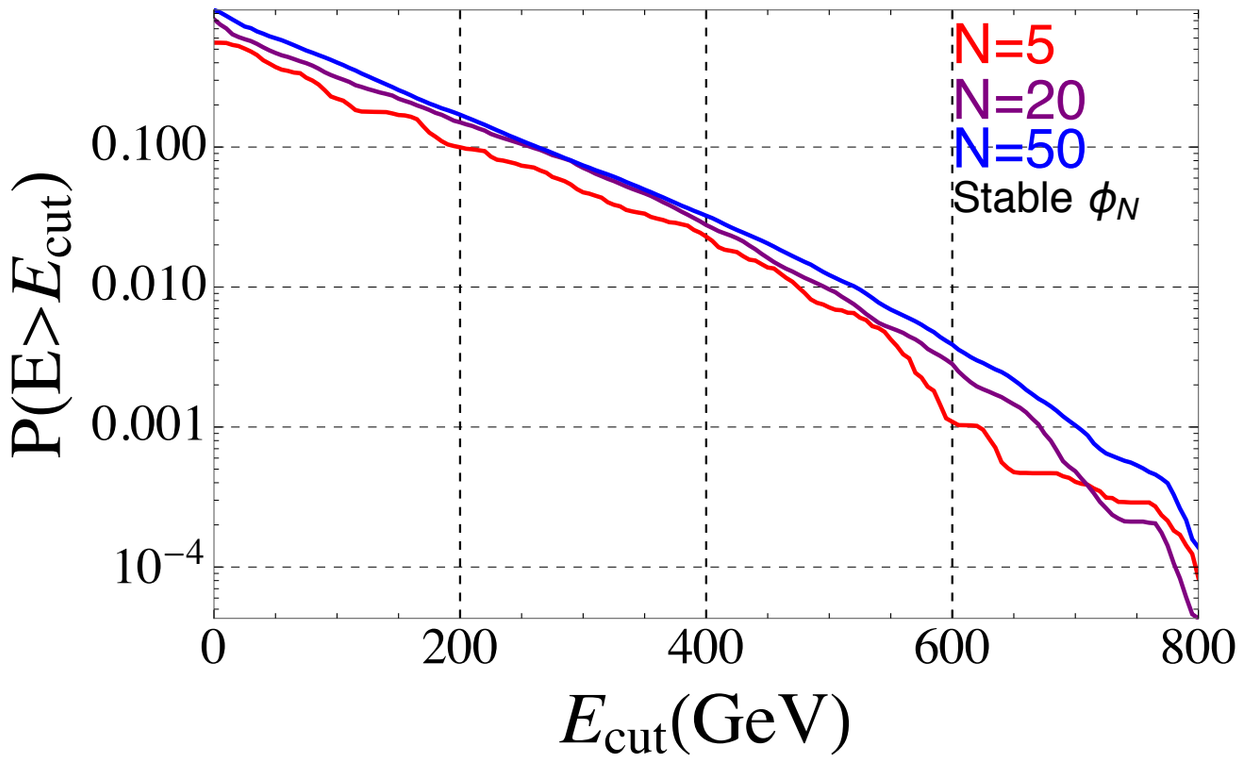


FINAL STATE ENERGIES

AVERAGE VISIBLE ENERGY PER PARTICLE



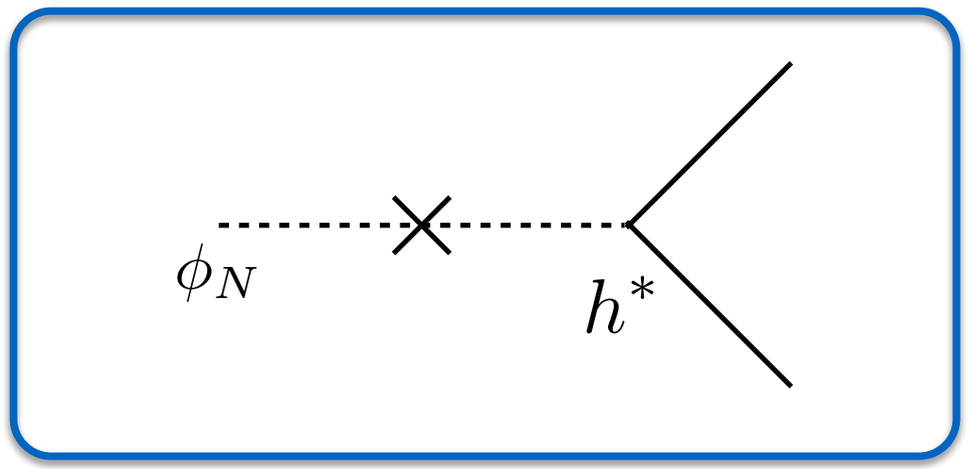
TOTAL VISIBLE ENERGY IN THE EVENT



N.B. THERE ARE ALWAYS TWO INVISIBLE PARTICLES

MAKE IT UNSTABLE

$$-\mathcal{L} \supset a_H \sum_{\alpha=1}^{N} \phi_\alpha |H|^2 \qquad a_H \ll \lambda_H v \sim \lambda_{\alpha\beta\gamma\delta} v$$



THE LIGHTEST NEW STATE CAN DECAY

PARTICLE MULTIPLICITIES

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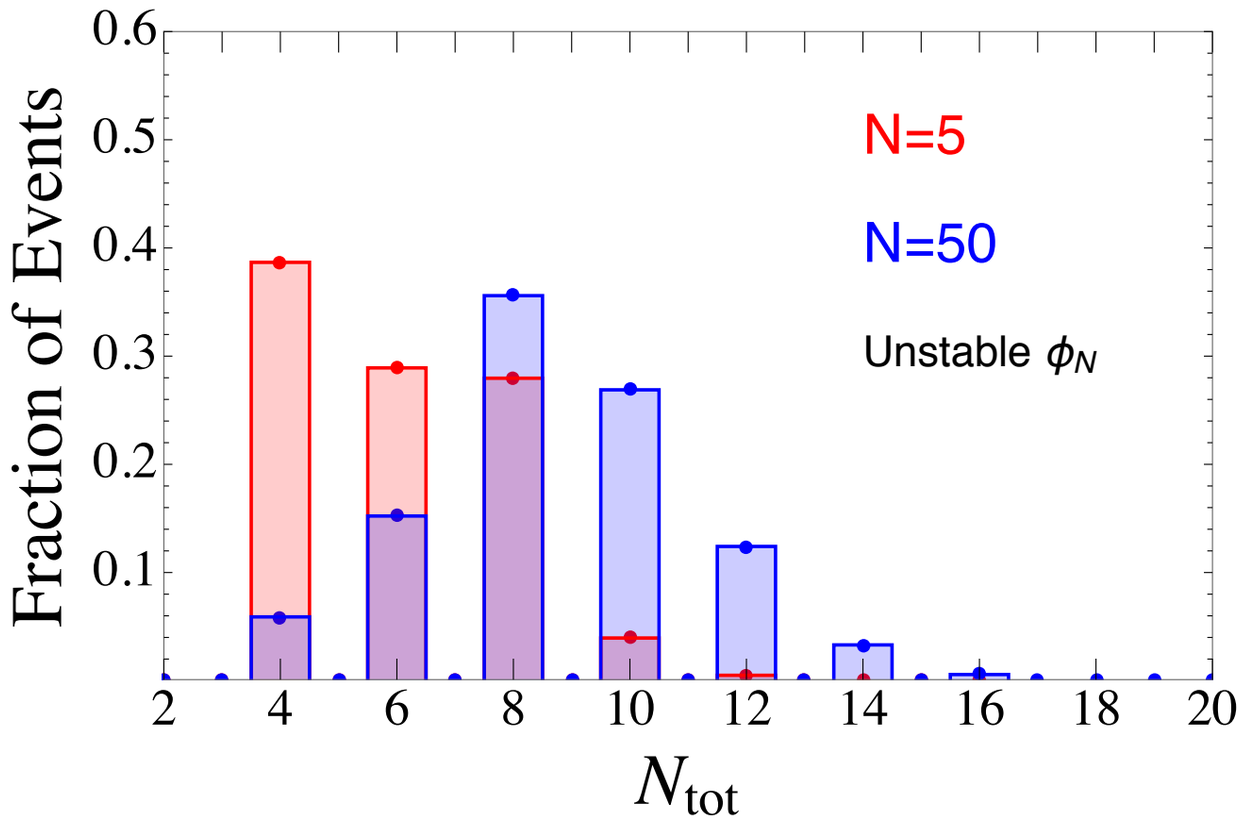
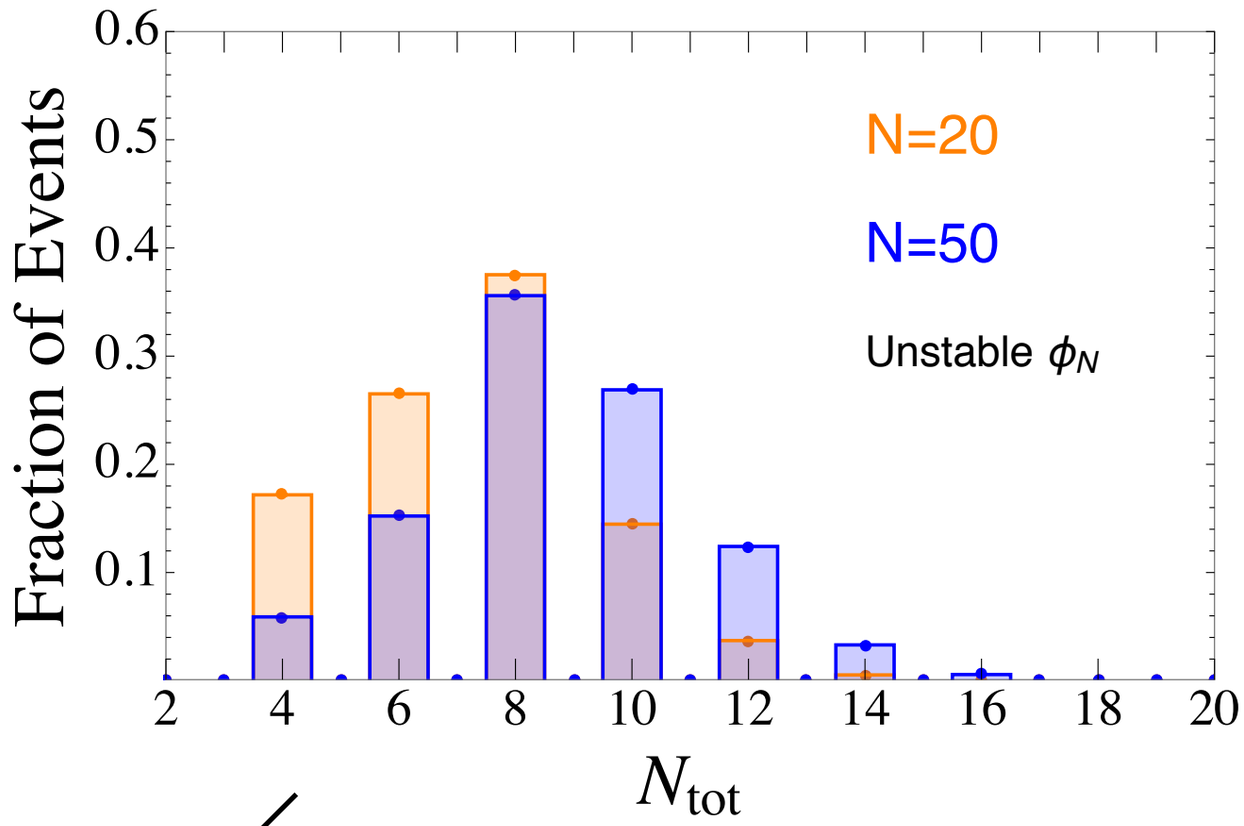
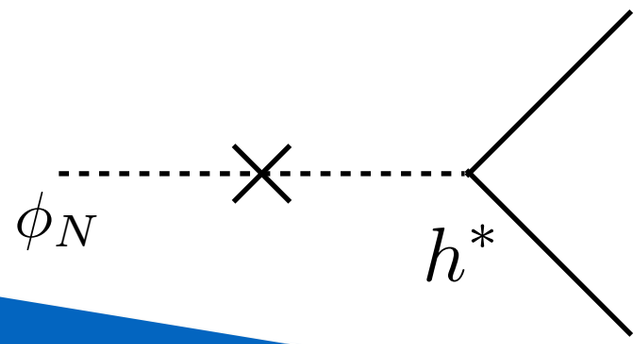
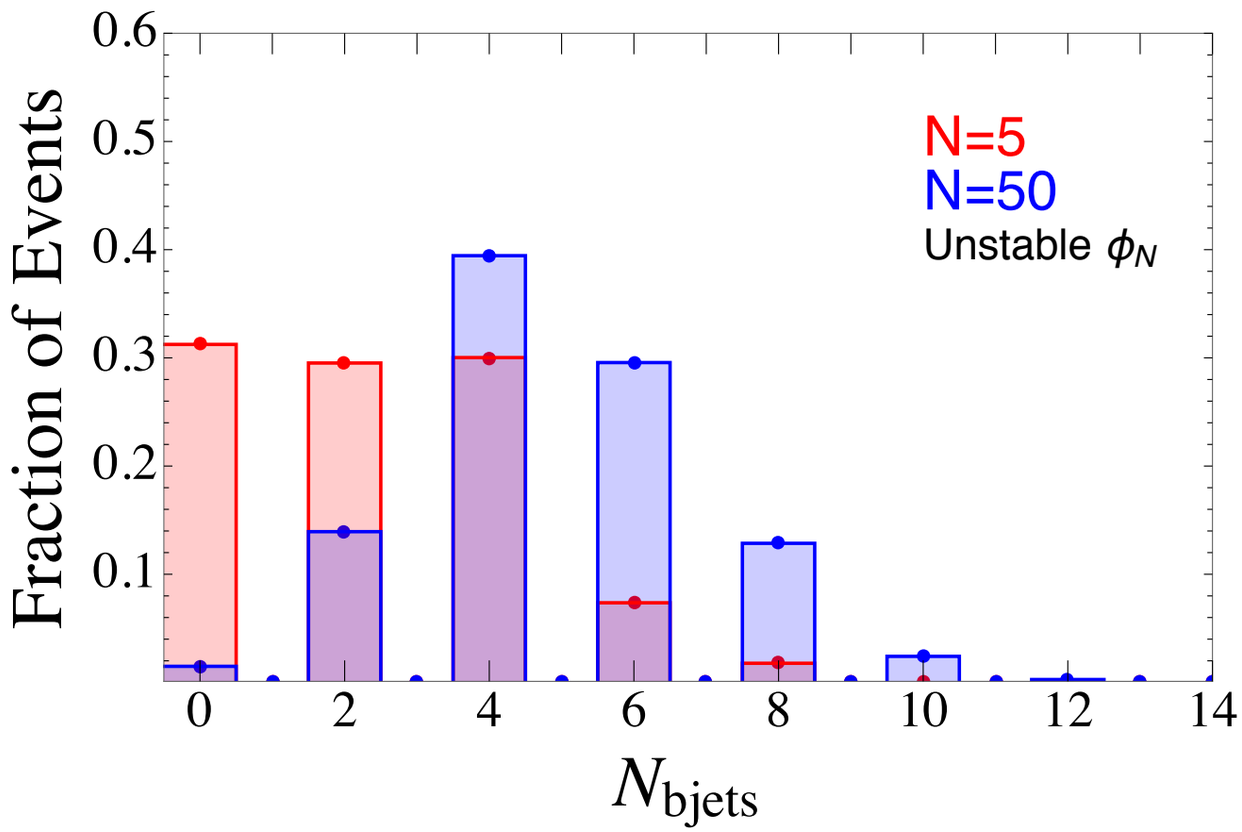
$$m_\alpha \in [100, 600]$$

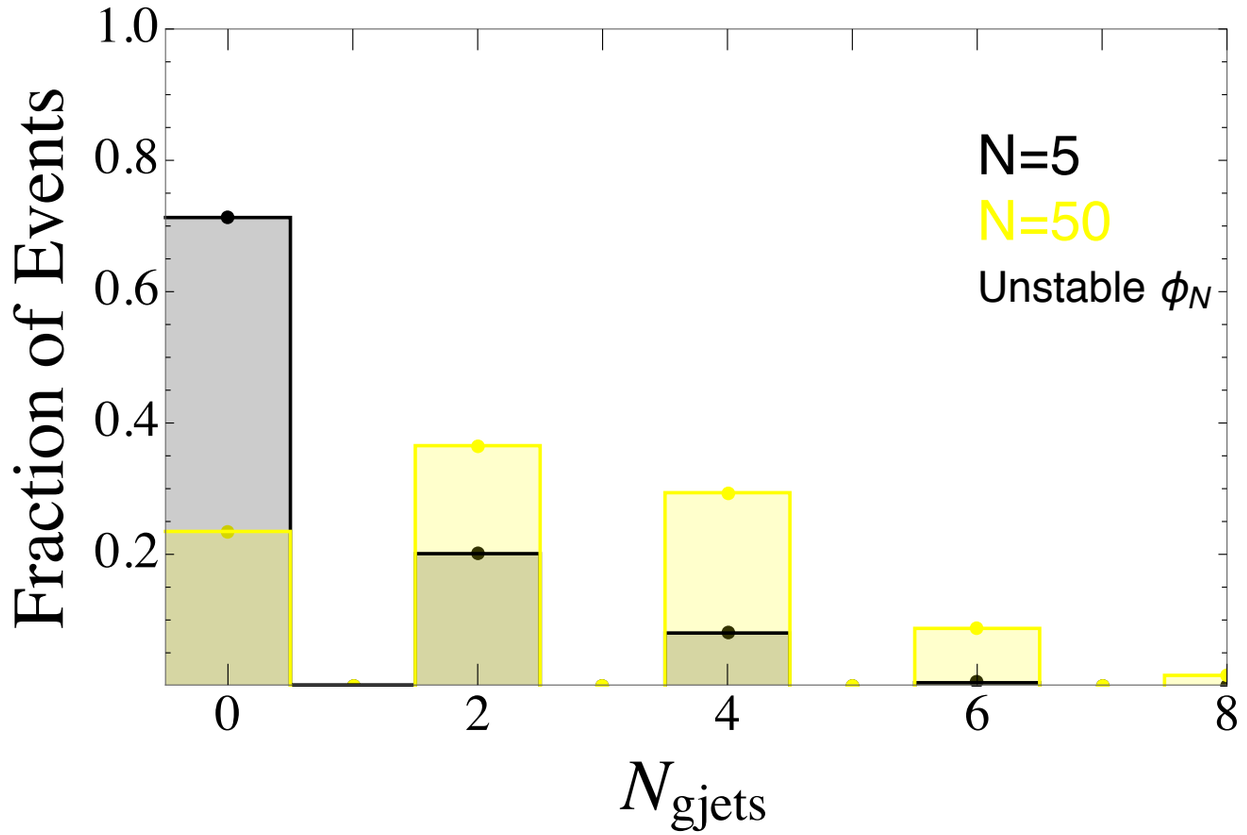






FINAL STATE PARTICLES





FINAL STATE ENERGIES

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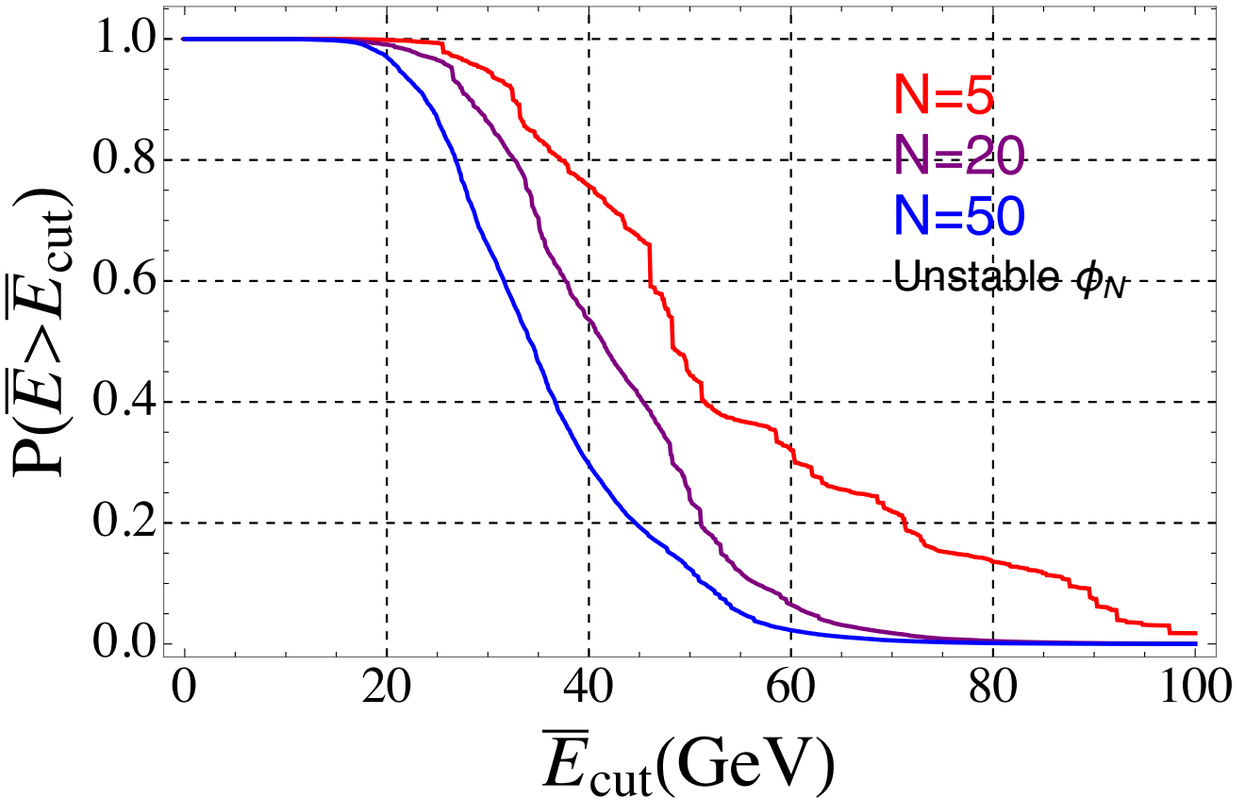
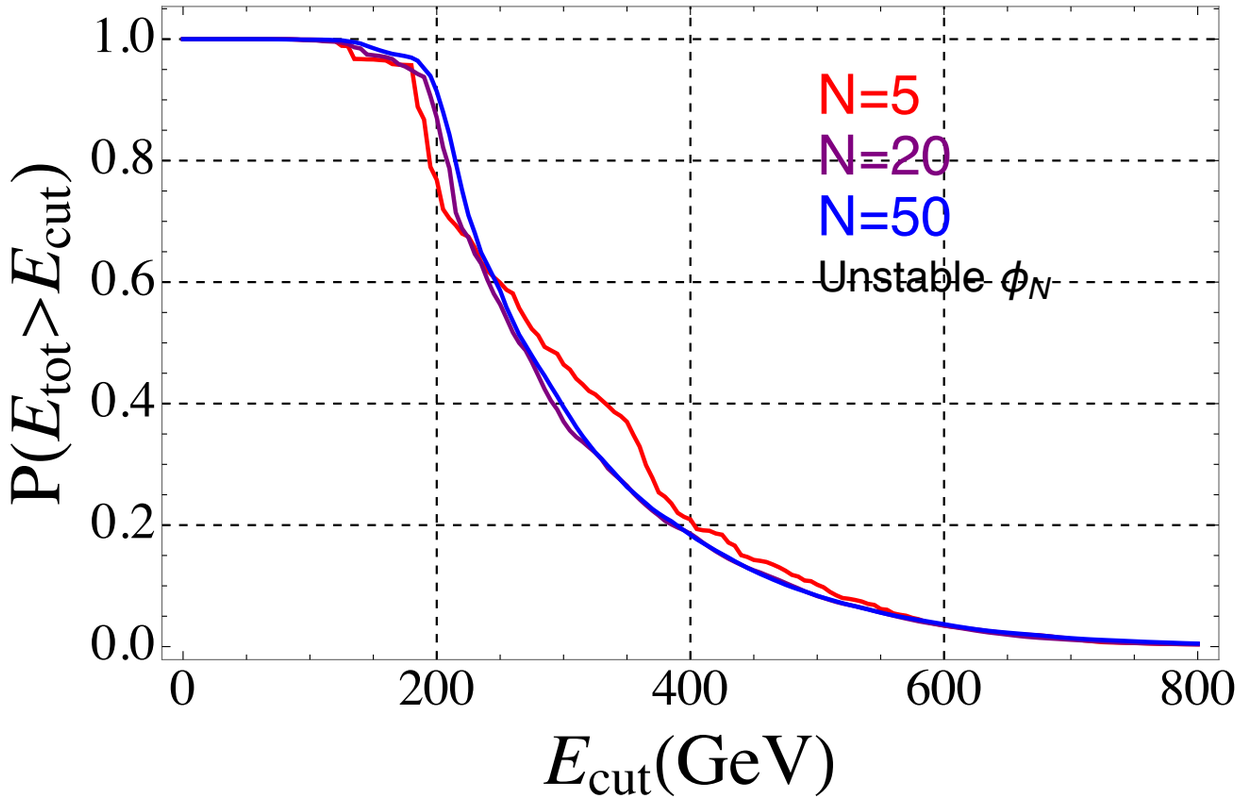




TOTAL VISIBLE ENERGY IN THE EVENT

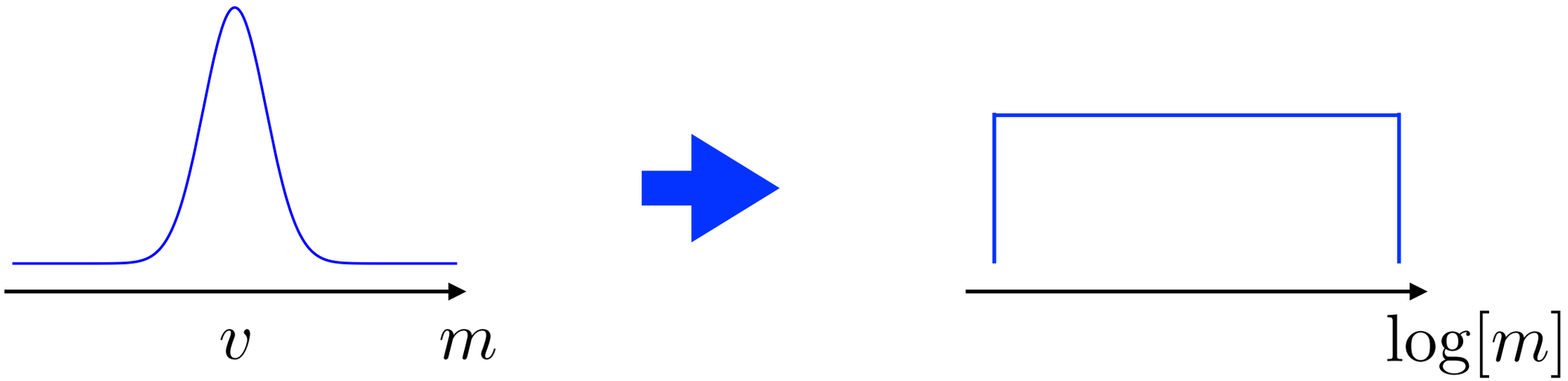
OUTLOOK

- NEW SECTORS WITH MANY NEW PARTICLES ARE A REALISTIC POSSIBILITY WITH A PLAUSIBLE TOP-DOWN MOTIVATION FROM THEORIES WITH EXTRA DIMENSIONS, INCLUDING STRING THEORY

- A LARGE NUMBER OF NEW PARTICLES DOES NOT NECESSARILY MAKE NEW PHYSICS EASIER TO DETECT, ESPECIALLY GIVEN THE CURRENT BIAS IN THE TRIGGER TABLES TOWARDS HIGH ENERGY EVENTS

- DISORDER AND HIGH MULTIPLICITIES HAVE NOT BEEN EXPLORED MUCH AT THE WEAK SCALE, BUT THEY CAN GIVE RISE TO INTERESTING NEW PHENOMENA (MAYBE A WAY TOWARDS ANSWERING THE QUESTIONS THAT WE TRULY CARE ABOUT?)

WHERE IS NEW PHYSICS?



ONE
LARGE COLLIDER

MANY
SMALL EXPERIMENTS

ONE OR MORE
LARGE COLLIDERS

FIND NOTHING = LEARN SOMETHING

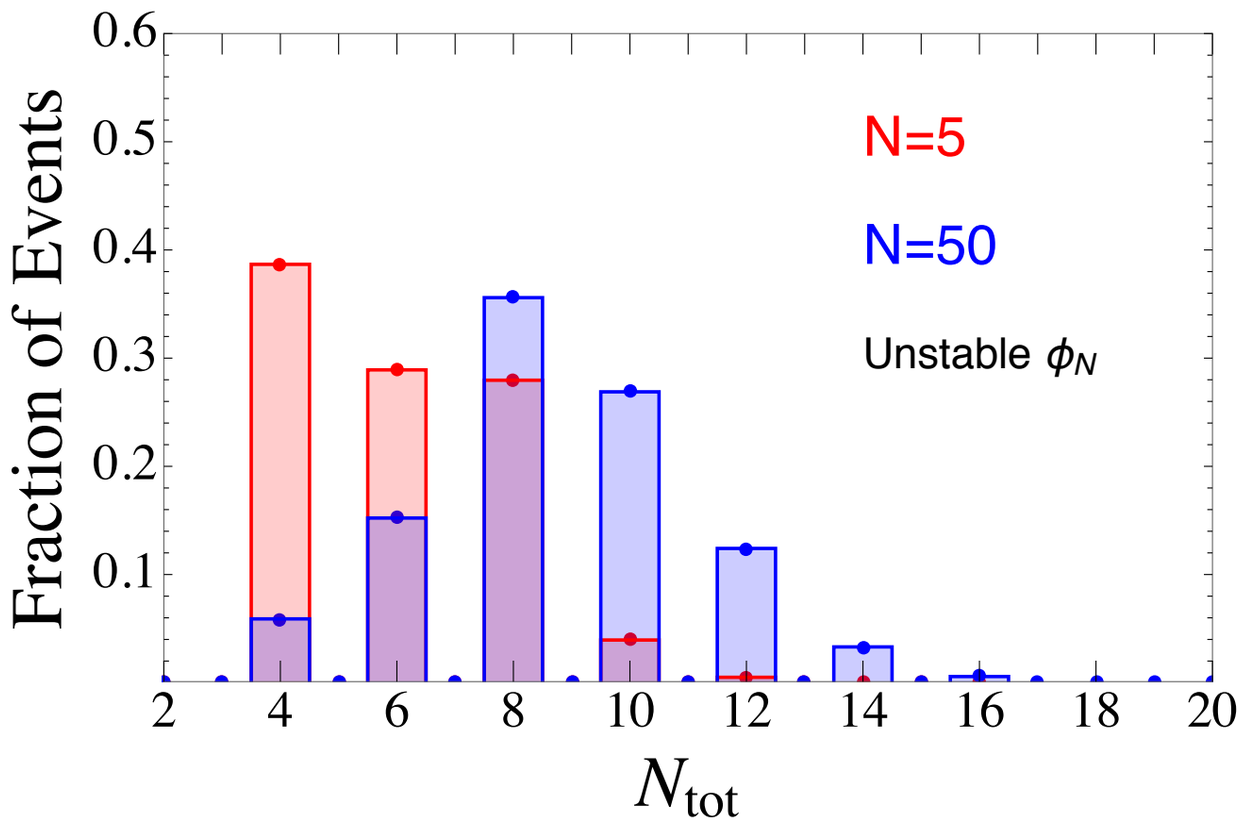
MANY
SMALL EXPERIMENTS

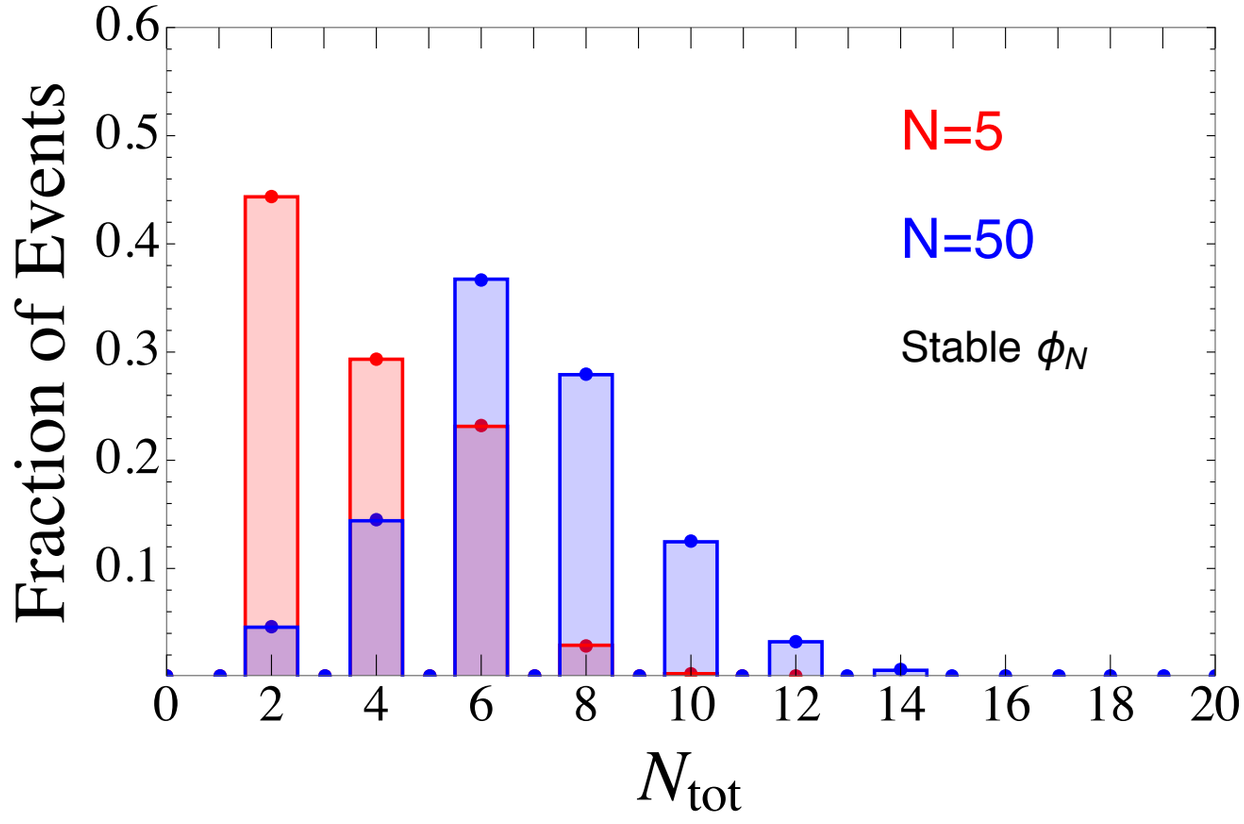
COVER MUCH MORE TERRITORY,
BUT FIND NOTHING = LEARN VERY LITTLE

BACKUP

PARTICLE MULTIPLICITIES

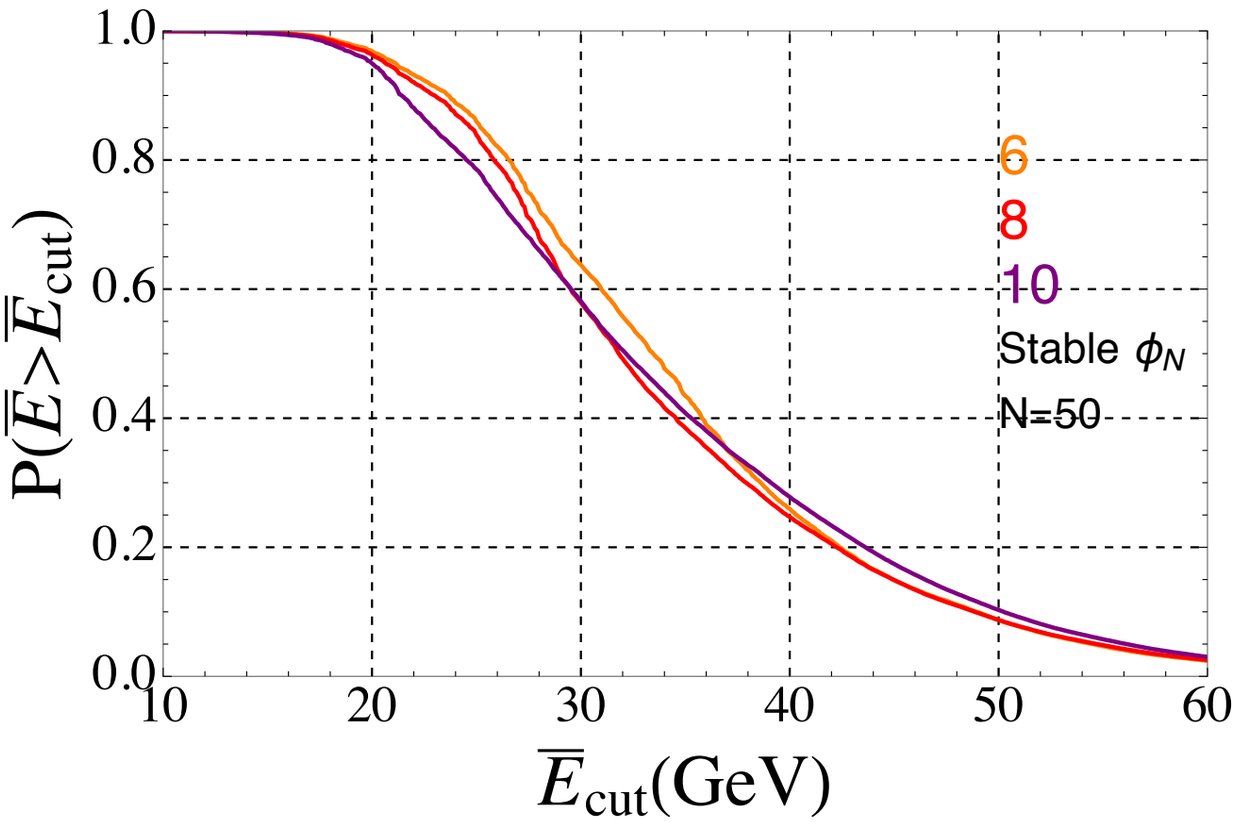
$$N_{\rm tot} = b, c, \mu, s, W, Z, g, \gamma$$

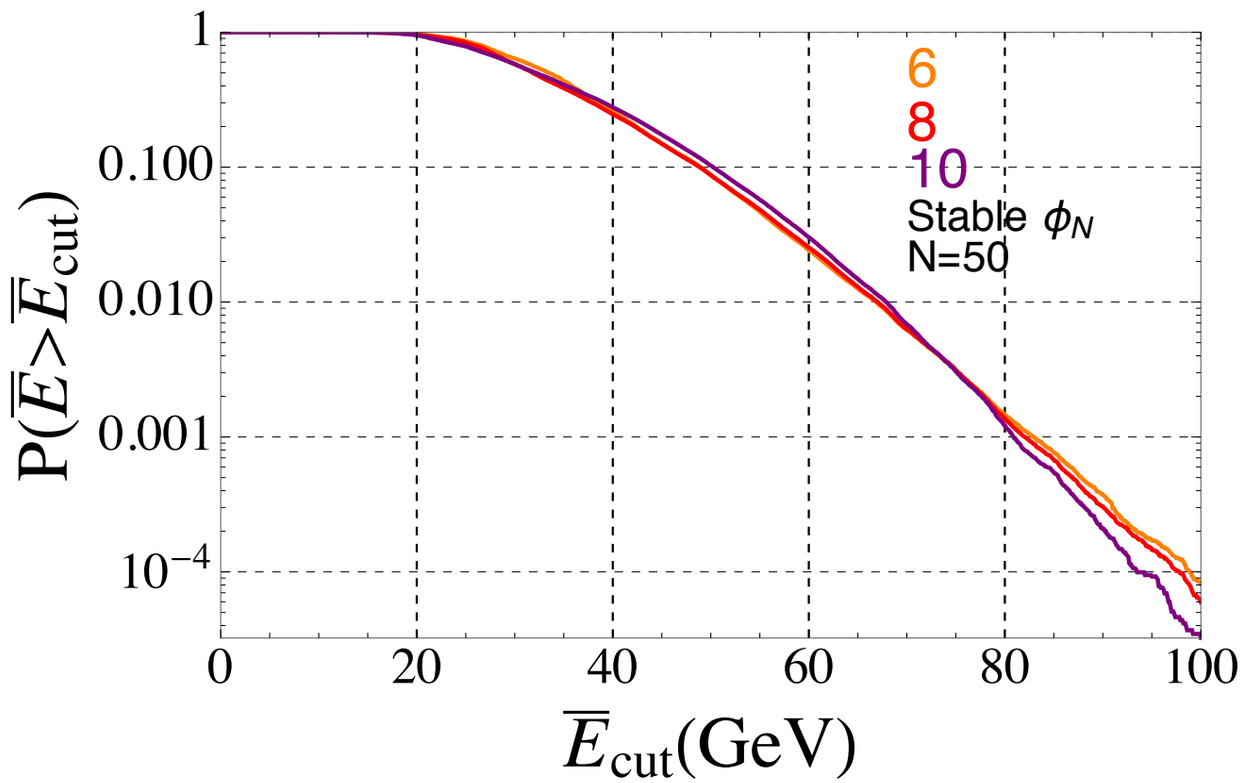




FINAL STATE ENERGIES

AVERAGE VISIBLE ENERGY PER PARTICLE
HIGH MULTIPLICITY EVENTS





PAIR PRODUCTION CROSS SECTION