BEYOND THE STANDARD MODEL THEORY OVERVIEW

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| BEYOND THE STANDARD MODEL _ | |
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NEW PHYSICS BEYOND THE STANDARD MODEL

TEV NEW PHYSICS MODELS BEYOND THE STANDARD MODEL

PHYSICS BEYOND THE STANDARD MODEL WE HAVE KNOWN

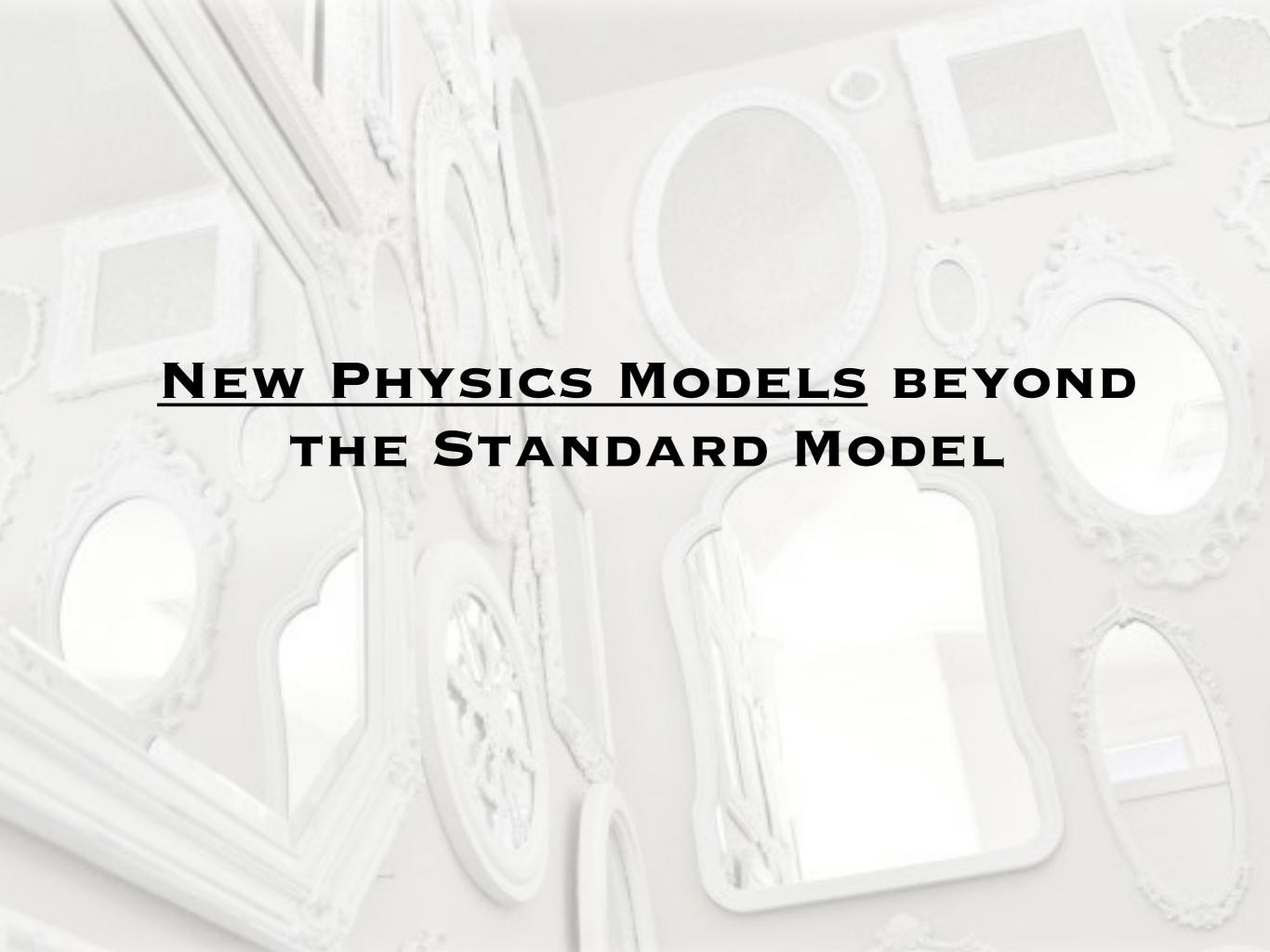
GO BEYOND THE STANDARD MODEL WITH DATA

NEW PHYSICS BEYOND THE STANDARD MODEL

THEORY PROBLEMS AND PHENO PUZZLES

- Quantum gravity
- Cosmological constant hierarchy problems
- Unification of forces
- Higgs mass hierarchy problems
- Vacuum stability
- Origin of electroweak symmetry breaking
- Origin of parity violation
- CP-violation
- QCD vacuum
- Fermion mass hierarchy
- FCNC
- Matter-antimatter asymmetry, baryogenesis
- Dark energy
- Dark matter
- Neutrino mass and oscillation
- Muon g-2 anomaly

• ...



THEORY ORIENTED VS PHENO ORIENTED

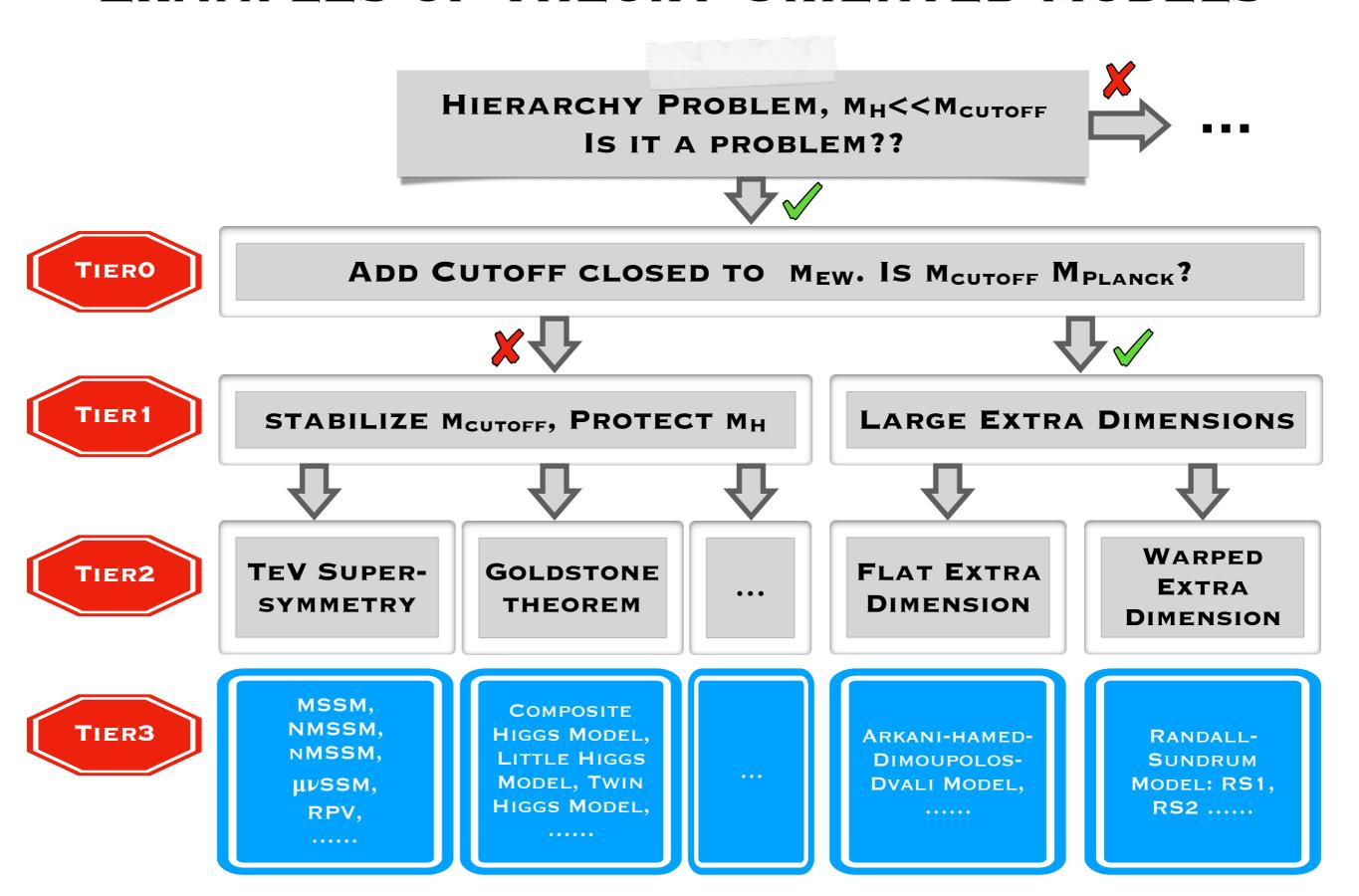
- Superstring
- Grand Unification Theory
 - ► SU(5), SO(10), ...
- SUSY Models
 - ► MSSM, NMSSM, nMSSM, ...
- Extra Dimensions
 - ► UED, ADD, RS, ...
- Composite Higgs Model
- Little Higgs Model
- Left-right Symmetry Model
- Twin Higgs Model

- Seesaw Models
 - ► Type-I,II,III
 - ► Tree level, one-loop, two-loop, ...
- Multi-Higgs Models
 - Singlet: real, complex
 - Doublet: 2HDM, Type-I,II,III,VI
 - **•** ...
- Dark Force
- Flavor Symmetry Models
- Axion
- Effective XXX Models

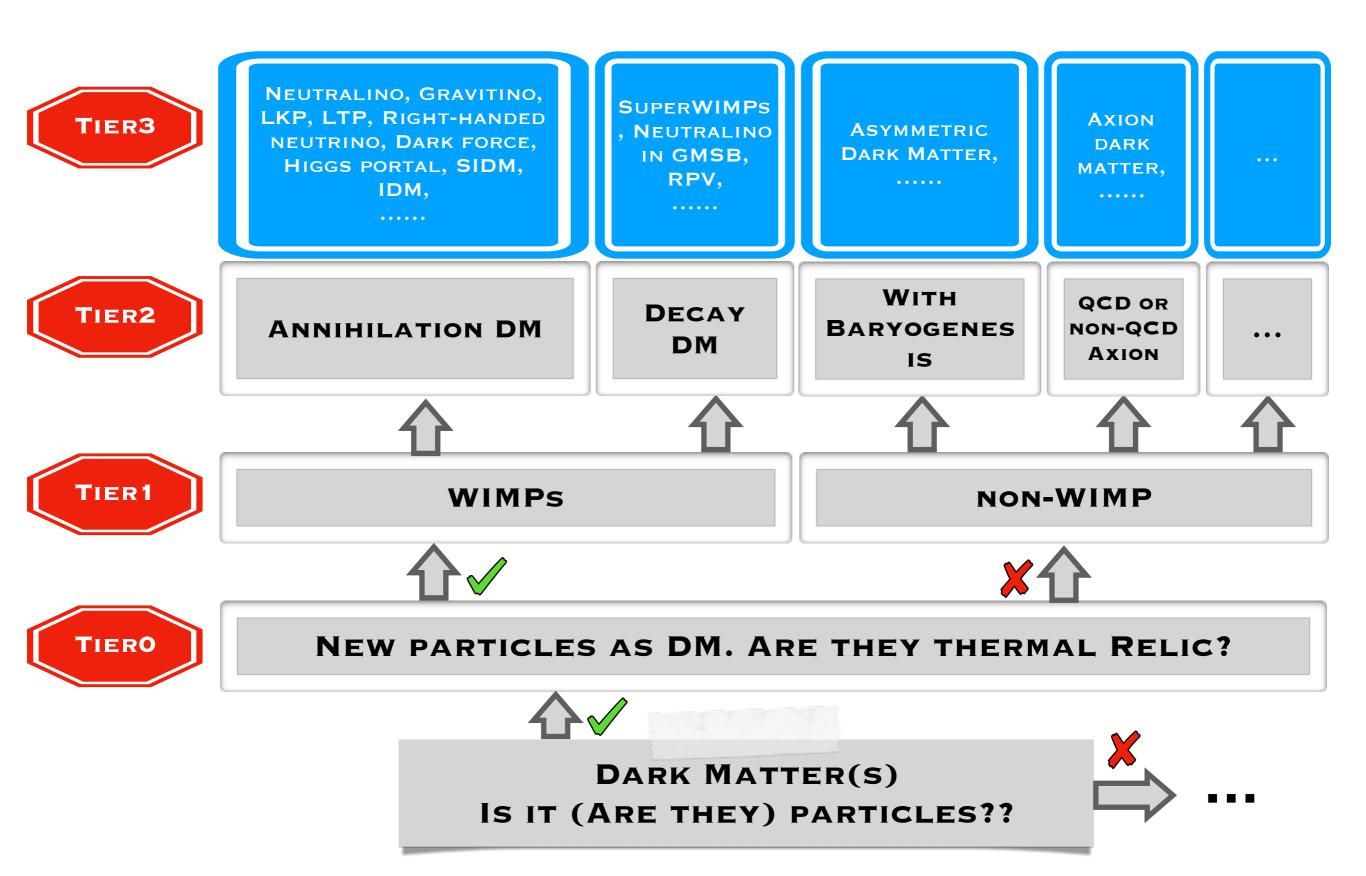
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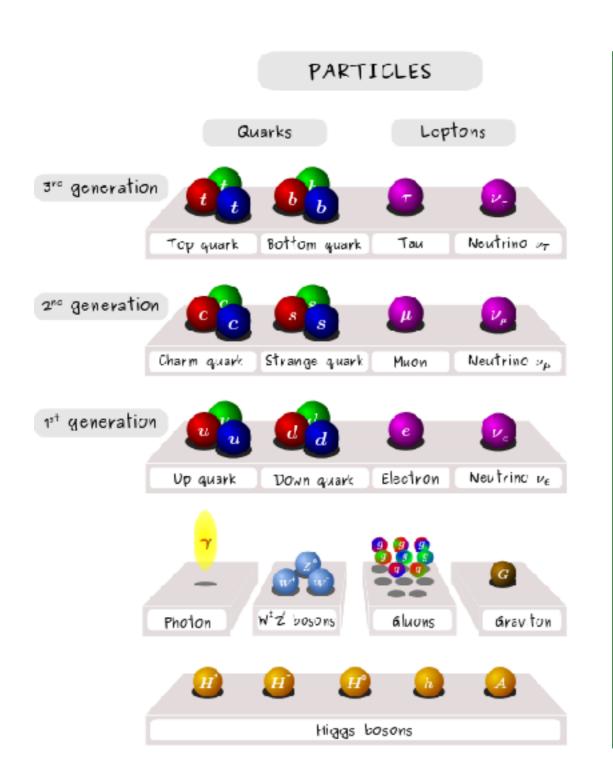
EXAMPLES OF THEORY ORIENTED MODELS

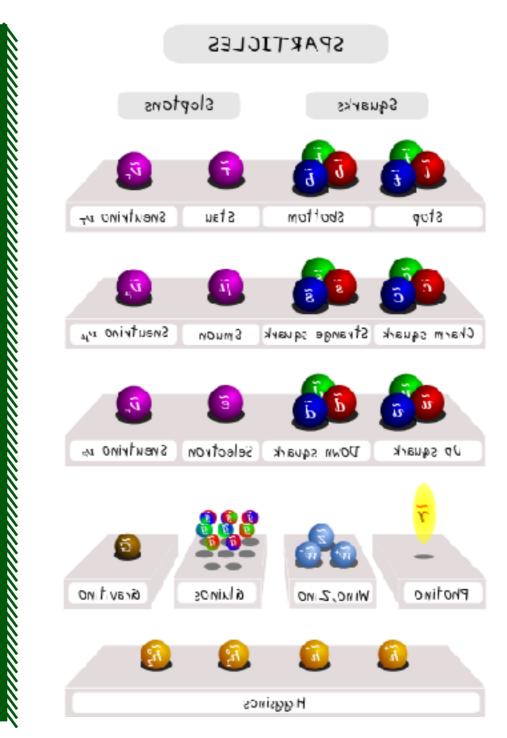


EXAMPLES OF PHENO ORIENTED MODELS

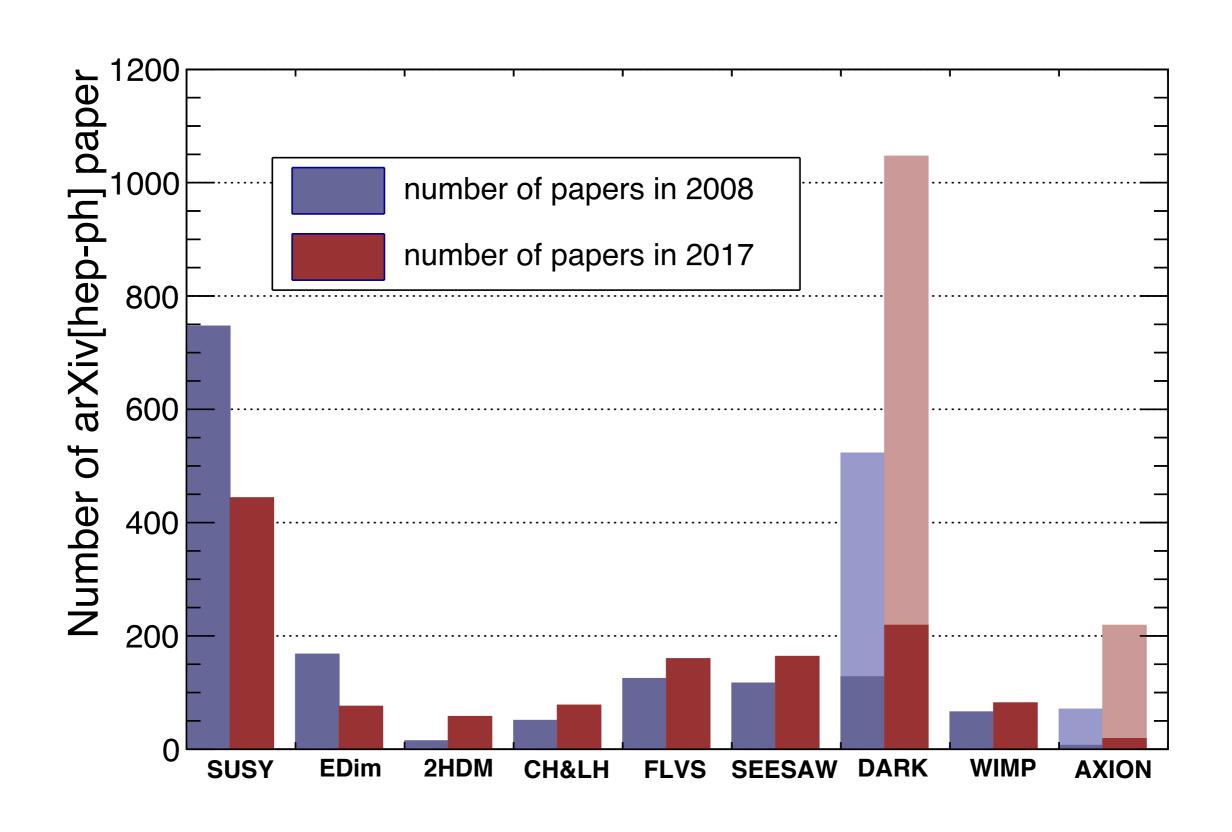


A LOT OF EXOTIC PARTICLES





NEW PHYSICS BEFORE AND IN THE LHC ERA



WHERE IS THE NEW PHYSICS? WHICH MODEL IS BETTER? ANY SUGGESTION?

NEW PHYSICS MODELS: WHICH ONE IS BETTER?

$$P\left(\mathcal{M}_{i}\right)_{\text{posterior}} = P\left(\mathcal{M}_{i}|\mathcal{D}\right) = \frac{p\left(\mathcal{D}|\mathcal{M}_{i}\right)P\left(\mathcal{M}_{i}\right)_{\text{prior}}}{p\left(\mathcal{D}\right)}$$
$$\propto p\left(\mathcal{D}|\mathcal{M}_{i}\right)P\left(\mathcal{M}_{i}\right)_{\text{prior}}$$

 \mathcal{M}_i GENERATOR — THEORISTS

 $p\left(\mathcal{D}\right)$ Measurer — Experimentalists

 $p\left(\mathcal{D}|\mathcal{M}_i\right)$ Calculator — Phenomenologists (AND EXPERIMENTALISTS)

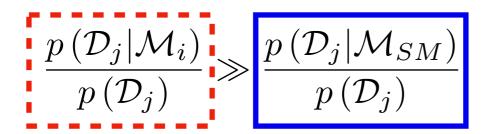
 $P\left(\mathcal{M}_i\right)_{\mathrm{prior}}$ — Theoretical motivations, experiences, taste, BIAS, ...

WHAT IS OUR MISSION?

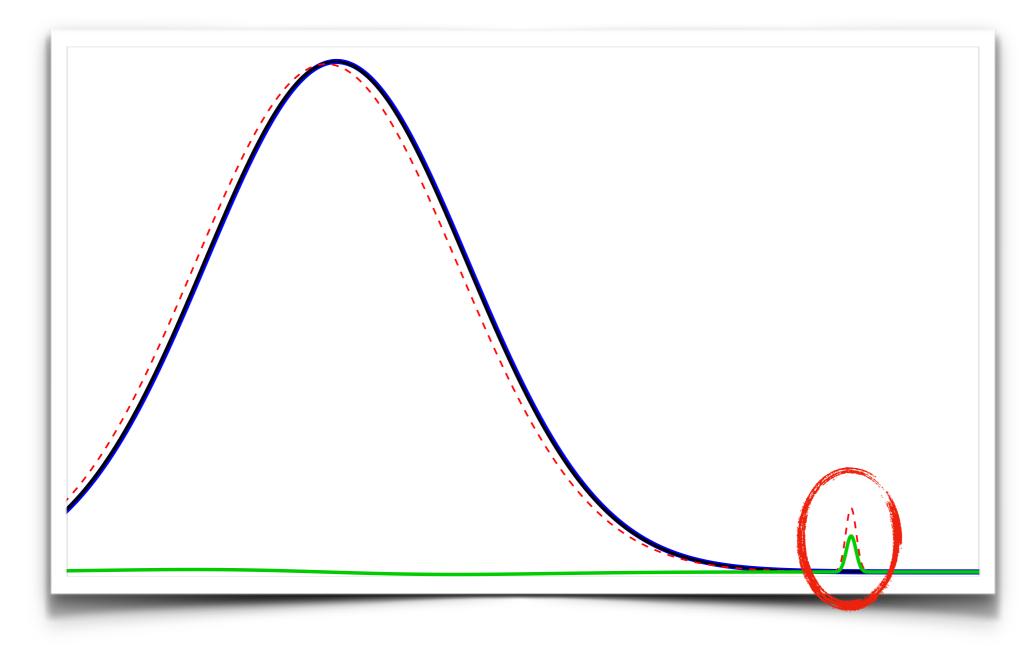
$$P\left(\mathcal{M}_{i}\right)_{\text{posterior}} = P\left(\mathcal{M}_{i}|\mathcal{D}\right) = \frac{p\left(\mathcal{D}|\mathcal{M}_{i}\right)P\left(\mathcal{M}_{i}\right)_{\text{prior}}}{p\left(\mathcal{D}\right)}$$
$$\propto p\left(\mathcal{D}|\mathcal{M}_{i}\right)P\left(\mathcal{M}_{i}\right)_{\text{prior}}$$

INCREASE $P(\mathcal{M}_i)_{ ext{posterior}}$ and decrease $P(\mathcal{M}_{SM})_{ ext{posterior}}$ Look for \mathcal{M}_i and \mathcal{D}_j s.t.

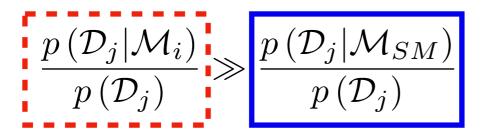
$$\frac{p\left(\mathcal{D}_{j}|\mathcal{M}_{i}\right)}{p\left(\mathcal{D}_{j}\right)} \gg \frac{p\left(\mathcal{D}_{j}|\mathcal{M}_{SM}\right)}{p\left(\mathcal{D}_{j}\right)}$$



How to find it?

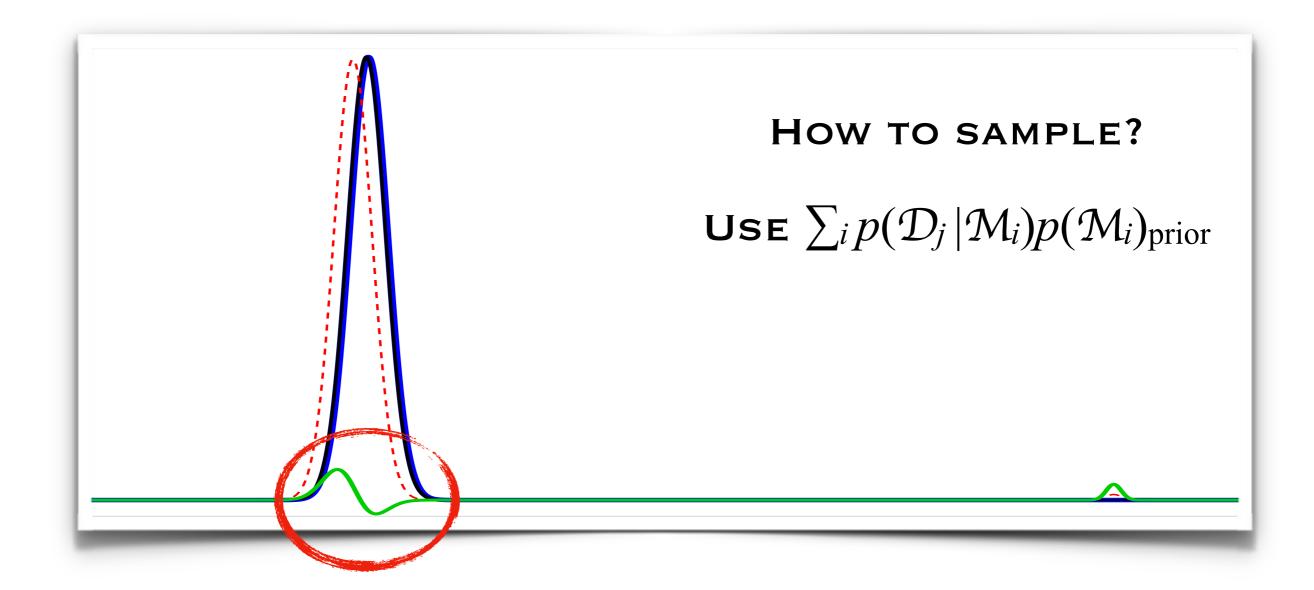


EXPLORER: PROPOSE AN \mathcal{M}_i WITH LARGE $P(\mathcal{M}_i)_{\text{prior}}$ AND SEARCH IT WITH \mathcal{D}_j WHICH MAXIMIZES $p(\mathcal{D}_j | \mathcal{M}_i)/p(\mathcal{D}_j | \mathcal{M}_{SM})$



How to find it?

Model-Independent: Simulate $p(\mathcal{D}_j)$ and find out the \mathcal{D}_j which minimizes $p(\mathcal{D}_j | \mathcal{M}_{SM})/p(\mathcal{D}_j)$



PHYSICS BEYOND THE STANDARD MODEL WE HAVE KNOWN

SOME EXAMPLES

The Yukawa couplings

- Absolute values
- (relative) Arguments

The gauge group

► TGC

The unitarity

Gauge boson scatterings at high energy scale

The EWSB

- VV, hVV and hhVV, are they consistent?
- $ightharpoonup m_W, m_Z, m_t$

The Higgs

- Its CP property (any tiny non-zero CP-odd component?)
- ▶ di-Higgs, tri-Higgs, ...

SOME EXAMPLES

The Yukawa couplings

- Absolute values
- (relative) Argumer
- The gauge group
 - ► TGC
- The unitarity
 - Gauge boson sca
- The EWSB
 - ► VV, hVV and hhV
 - ► *m*_W, *m*_Z, *m*_t
- The Higgs
 - Its CP property (a
 - di-Higgs, tri-Higg

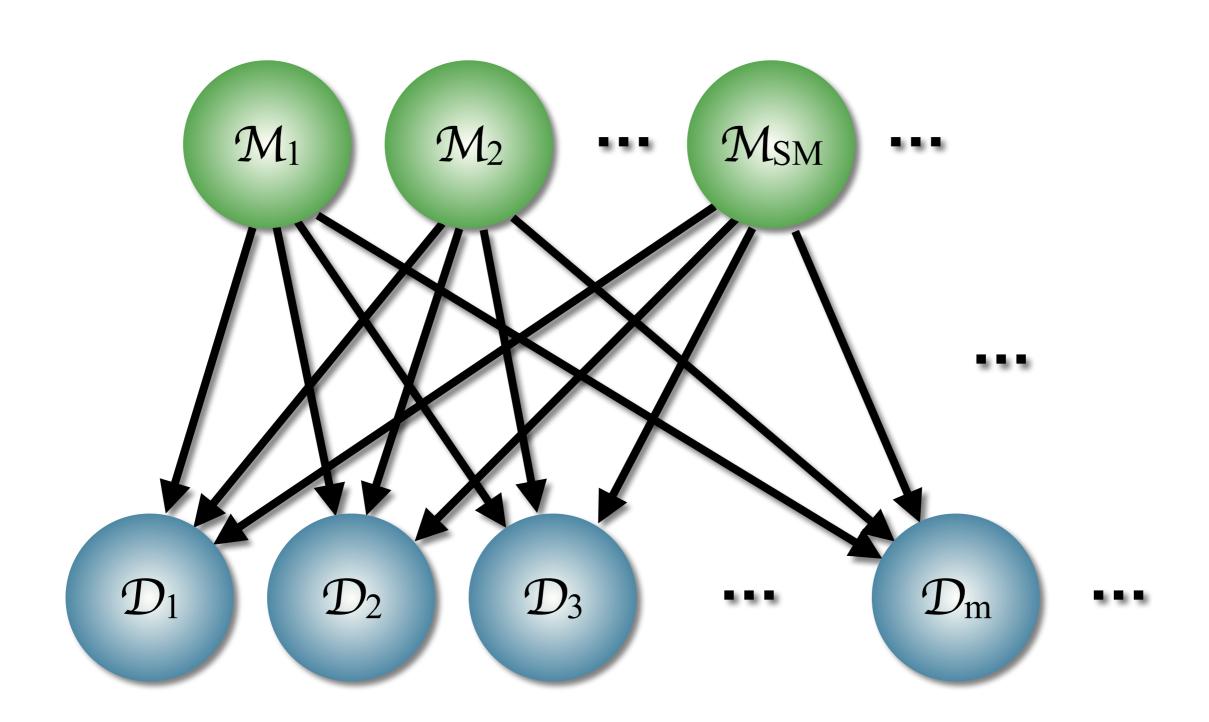
THESE WORKS ARE NOT
"JUST" (BORING?) PRECISELY
MEASUREMENTS! THEY ARE
NEW PHYSICS SEARCHING!

IF YOU ARE FREQUENTIST, YOU ARE REJECTING THE BKGD-ONLY MODEL.

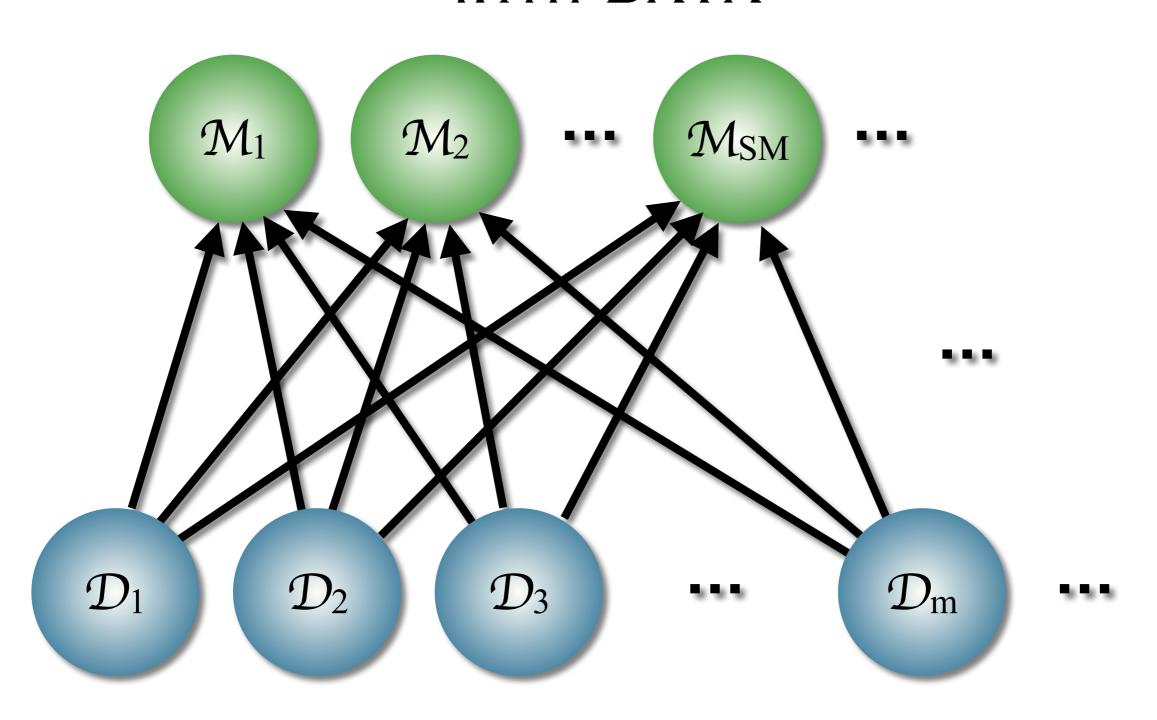
IF YOU ARE BAYESIAN, YOU ARE SAMPLING WITH THE WEIGHT ACCORDING TO THE PRIOR PROBABILITY.

GO BEYOND THE STANDARD MODEL WITH DATA

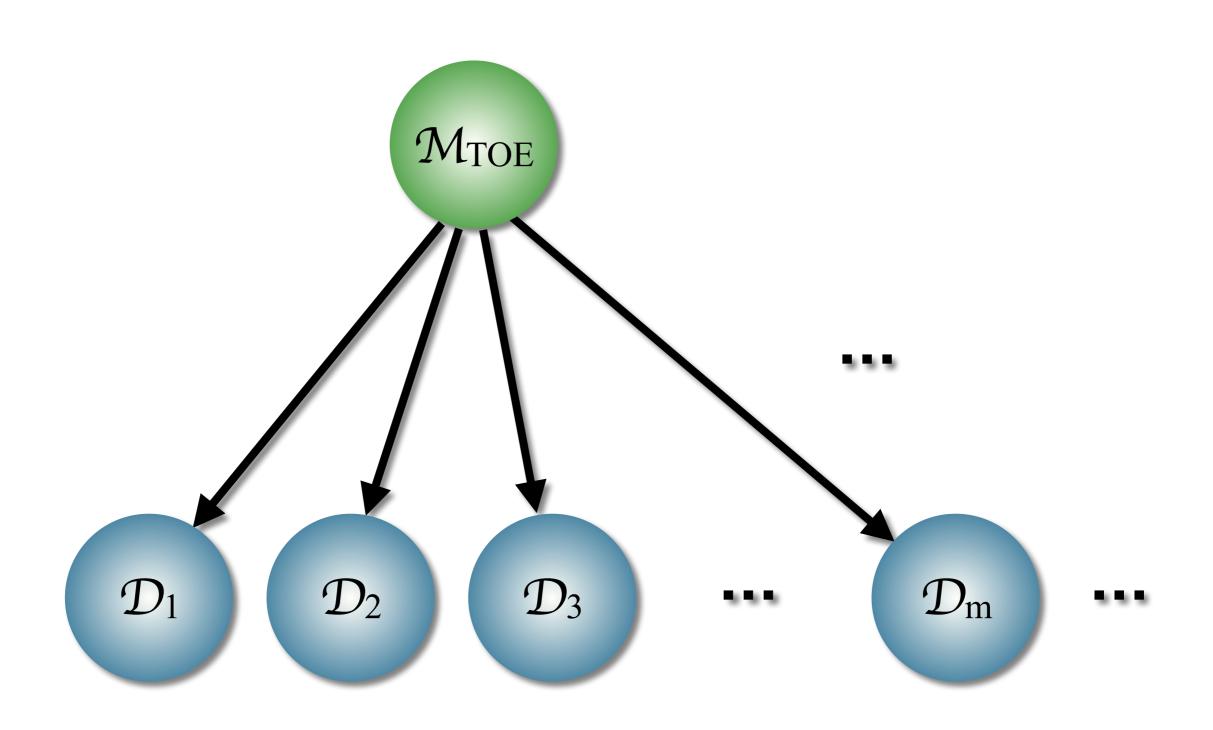
CHOOSING OBSERVABLES WITH PRIOR PROB



UPDATING OUR POSTERIOR KNOWLEDGE WITH DATA



REMAIN TRUE TO OUR ORIGINAL ASPIRATION AND KEEP OUR MISSION FIRMLY IN MIND













THANK YOU!





