The Mapping From Collider Data to Theory Through Production and Decay Topologies

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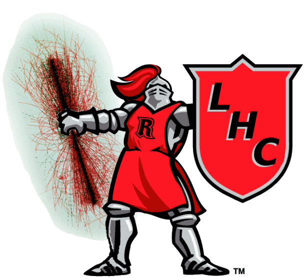

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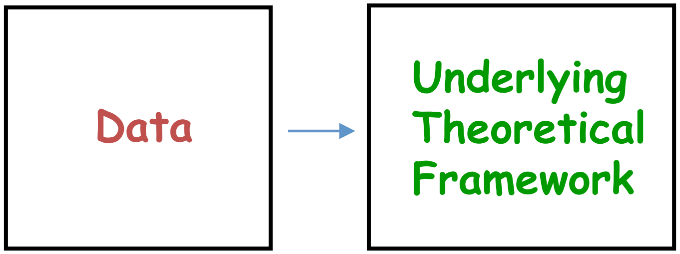
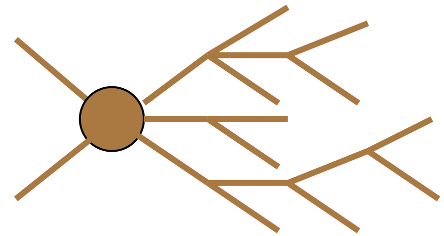
Mapping from Data → Theory





Production + Decay Through Relatively Narrow Intermediate States $\Gamma / m \ll 1$

Production+Decay Trees = Topologies = COSET = SMS ; OSET …

→ Specified by m_i , J_i , Quantum Numbers, (some cases $d\Gamma / dm_{ij}$ decay functions)

Monte Carlo Specification: (Isotropic Decays)

- 2→1 or 2→2 Production – Pythia, Madgraph. …..
  Spectrum + Cascade Decay Tree – SLHA Input file
- Pythia 6.4.24, Marmoset, …

Experimental Results

Triggers + Cuts + Analysis Procedure → Sensitivity from N_{excess} in Given Final States

↓

$(\sigma.Br.A)_f \qquad f = 1,\dots,N_f$

Acceptance A Includes Effects of

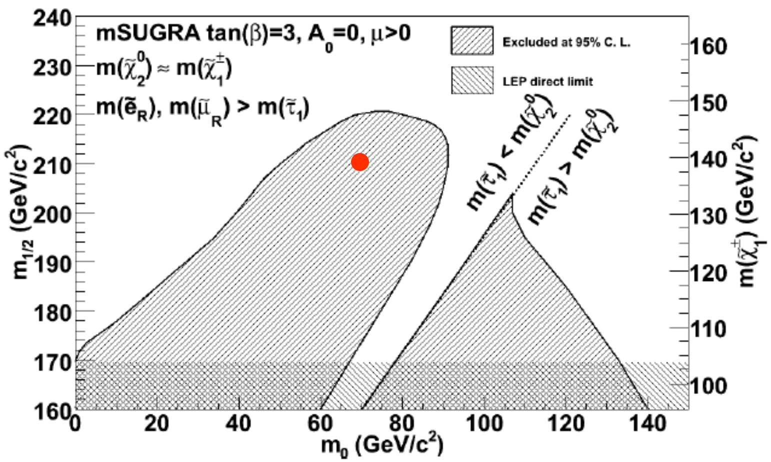
1. Triggers + Cuts + Analysis Procedure
2. Detector Response

For Map Onto Theoretical Framework A Also Includes

3. Mass Spectrum, Spins, Quantum Numbers, Decay Distributions

Model Space Interpretation of Results

- Example – Tevatron Tri-Lepton Searches



mSUGRA parameter space

Presentation of Search Results:

Mapping from σ.Br.A Results in Multiple Channels Onto Model Space n =0,1,2,3 τ

Information Lost !

Any Point in Model Space -
Model Dependent Correlations
Among Spectrum, σ, and Br's, and A

Unnecessary Assumption

Experimentalists: Please Always Give this Information

Interpretation of Results

- **Simplified Topologies**

  Benchmarks

  * Probe All Relevant Corners of Signature Space

- **Present Results in Simple Model Spaces**
- **Forum for Submitting Models to Collaborations**
- **General Problem of Mapping Data → Theory**

  1. Useful Both Pre- and Post-Discovery
  2. Include Multiple Experimental Channels
  3. Include Arbitrary Combinations of Multiple Topologies with Arbitrary σ + Mass Spectra + Br's
  4. Useful in Archival Form in Future

Mapping Data → Theory

Given Experimental Sensitivities in Multiple Final State Channels

$(\sigma.Br.A)_f$ $f = 1,\ldots,N_f$ ← Start From This Data

↳ Map onto Any Theoretical Framework
Defined by a General Set of
Production + Decay Tree Topologies with
General Spectrum, Cascade Decay Br's, and σ's

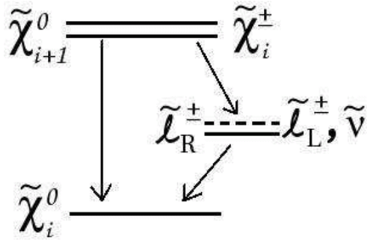
Factorized Mapping Data → Theory

(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

Model Independent Method for Presenting and Interpreting Multi-Channel Results

Data → Multiple Topologies or Directly into Model Space

- Form <u>Hypothesis</u> for Production + Decay Tree Topologies – Test Hypothesis



Can Include
Multiple Topologies and
Multiple Final State Channels

Factorized Mapping Data → Theory

(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

Trees   # Decays in Each Tree

$$(\sigma \cdot \mathrm{Br} \cdot \mathcal{A})_f = f(\sigma_t, \mathrm{Br}_{\alpha_t}, m_{i_t}) = \sum_{t=1}^{N_t} \sigma_t \cdot \prod_{\alpha_t=1}^{N_{\mathrm{Br}_t}} \mathrm{Br}_{\alpha_t} \cdot \mathcal{A}_{f,t}(m_{i_t})$$

Acceptance for Tree t in Final State f

- **Factorized Parameterization of $(\sigma.BR.A)_f$ for <u>Any</u> Incoherent Combination of Production+Decay Tree Topologies**

- **Provides a Mapping Theory → Data**

  $\mathrm{Dim} = N_t \,.\, N_{BR,t} \,.\, N_{mt}$ → $\mathrm{Dim} = N_f$

- **Acceptance $A_{f,t}(m_i)$ function in Mass Spectrum Space Only**

- **Free to Impose (Model Dependent) Relations among**
  σ_t , $Br_{\alpha t}$, m_{it}

Factorized Mapping Data → Theory

(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

The Acceptance in Spectrum Space

$A_{f,t}(m_i) \approx \mathrm{A} \, . \, \varepsilon$ ← Resolution, Reconstruction, Material, Conversions, Isolation Criteria, Fakes

↑ (A): Geometry, Kinematics

$$\mathcal{A}_{f,t}(m_i) \simeq \int d\widetilde{\Phi}_f(m_i) \prod_{i=1}^{N_p,f} \mathcal{P}_i(\eta_i, p_{T,i}; \eta_j, p_{T,j}) \cdot \varepsilon_i(\eta_i, p_{T,i})$$

- $d\widetilde{\Phi}_f(m_i)$: Dimensionless Phase Space
- $\mathcal{P}_i$: Geometric + Kinematic Acceptance Including Inter-Object Isolation
- ε_i: Intra-Object Efficiency

The first two ↓ Easily Simulated: Monte Carlo Tools, Object Reconstruction

Intra-Object Efficiency ↓ Parameterize

Theory Detector Simulator (TDS)

β-Version Testing

Simulate Geometric + Kinematic $A_{f,t}(m_i)$ <u>Only</u>

- **Form Objects from MC Stable Particle Information**

  e , μ , γ , jets

  → Fast-Jet on Tracks or All Hadrons (Anti-Kt)

  τ_h Derived Object from 1,3 Prong jets
  (b-tagging) from MC matching to jet Parent

- **Very Straightforward Simulation Tool – Easily Reproduced**

  Detector Response from $\varepsilon_i(\eta_i , p_{Ti})$ – Input from Full Simulation

PGS Alone Doesn't do a Great Quantitative Job on $A_{CMS,ATLAS}$
$A_{CMS,ATLAS} = (A_{PGS} \cdot \varepsilon_{PGS})\, \varepsilon^{-1}_{PGS} \cdot \varepsilon_{CMS,ATLAS}$ Not Practical / Painful

Factorized Mapping Data → Theory

(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

- Parameterize Factorized $A_{f,t}(m_i)$ for Each Hypothesis Topology Using TDS and Parameterized Detector Efficiencies; Br's=1

- Validate <u>Both</u> $A_{f,t}(m_i)$ and $\varepsilon_{f,t}(m\_i)$ Against Full Detector Simulation on Benchmark Topologies

Defines Mapping

$(\sigma.Br.A)_f|_{THEORY} = f(\sigma_t, Br_{\alpha t}, m_{it})$ ←→ $(\sigma.Br.A)_f|_{EXP}$

- Form Likelihood Entropy $L=L(\sigma_t, Br_{\alpha t}, m_{it})$ on Theory Space Based on Pulls for Sensitivity in Each Final State Channel

(Can Also Form Composite σ function Weighted by Experimental Sensitivity in Each Final State Channel – See Sunil on Saturday)

(Initially Can/Should Impose Relations Among $\sigma_t, Br_{\alpha t}, m_{it}$ to Limit Dimensionality of Theory Space)

Factorized Mapping Data → Theory

(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

Likelihood or Composite σ Functions –
Uncorrelated Across Final State Channels Requires
Exclusive Search in These Channels
(Events fall in Only Single Channel)

Background Hierarchically Ordered Exclusive Combination
of Channels Always Provides Better Sensitivity Anyway
(Tri-leptons CDF, Multi-leptons CMS, …)

Experimentalist:

1. Report Exclusive Sensitivities in All Channels $(\sigma.Br.A)_f$
   (Please Always do This Anyway)

2. Provide Both $A_{f,t}(m_i)$ and $\varepsilon_{f,t}(m_i)$ Information from
   Full Simulation for Appropriate Benchmark Topologies
   Including SM Processes Validated in Data

Factorized Mapping Data → Theory

Features:

- Production σ's Factor Out of Problem
- Cascade Br's Factor Out of Problem
- Multiple Topologies + Multiple Channels Easily Combined
- "Model Independent" Within Specified
  Topology Set Spectrum Space –
  No Relation Among $\sigma_t, Br_{\alpha t}, m_{it}$ Need be Specified
- Only Requires Simulating Factorized form of Acceptance
  $A = \mathrm{A} \; . \; \varepsilon$ in Spectrum Space of Relevant Toplogies
- Can Add More Topologies Later
  (Since Don't Simulate Combinations of Topologies)

Applicable to:

- Null Results – Exclusion Contours in Spectrum + Br + σ
  Space or Directly in Model Space
- Positive Result – Likelihood Function in Spectrum + Br + σ
  Space or Directly in Model Space
- Archival Presentation and Usage of Results

Tractable Simplified Model Topologies

1. Only Few/One Topologies

2. Very Few States

3. Numerous States –
   Subspace of General Spectrum Space

↑

- Best Simplified Models Probe All Relevant Corners of Signature Space

Solved or Solvable Mappings Data → Theory

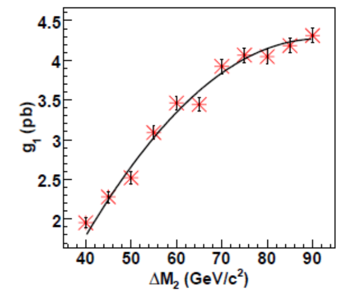
(Dube, Glatzer, Somalwar, Sood, ST arXiv:0808.1605)

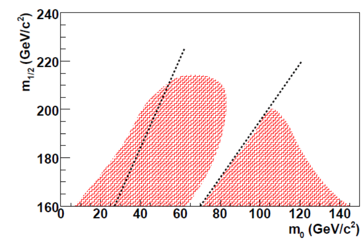
1. Tevatron Tri-lepton Wino→Slepton→Bino

   Full Parameterization of $A_{f,t}(m_i)$ in Spectrum Space Tractable

   Sunil will Describe on Saturday …

   Private Simulation Tools for $A_{f,t}(m_i)$. ε Test - Results Mapped onto mSUGRA Space Agree Well with Full Simulation

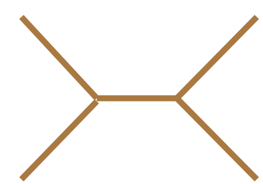




2. Di-Jet Resonances

   Simplest Topology

   Parameterized by <u>Single</u> σ, Single m, for 3 final states qq, qg, gg



Di-Jet Resonance Mapping Data → Theory

$\mathcal{A} = A \,.\, \varepsilon$

Geometry → A Resolution → ε

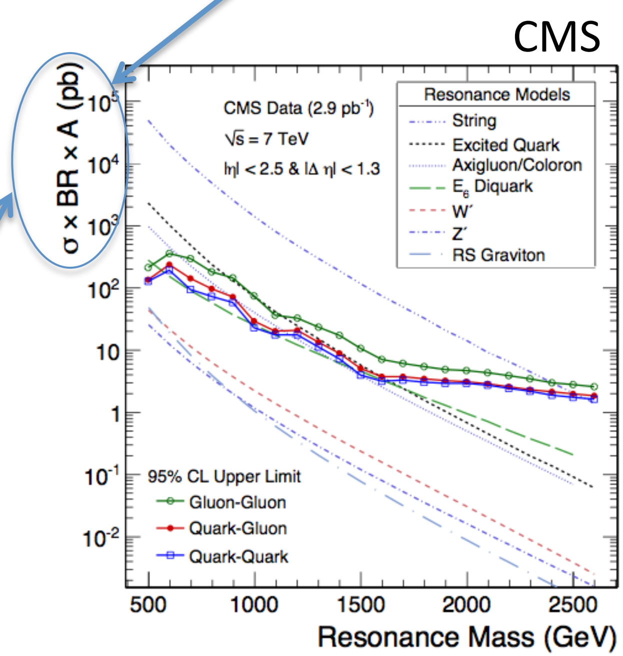
Jim's Talk
Later Today

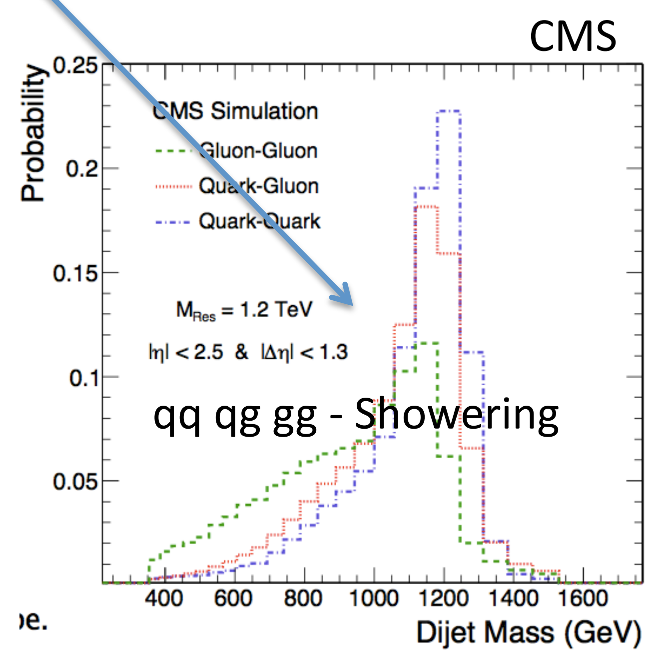
$\mathcal{A}=\mathcal{A}(m)$ $\varepsilon=\varepsilon(m)$

Sensitivity $\sigma.Br.\mathcal{A} = (\sigma.Br.A)\ \varepsilon$

Model Independent

Experimentalists
Have Factored
Resolution out of
Sensitivity





Di-Jet Resonance Mapping Data → "All" Theory

- Narrow Width – Perturbative Showering

(Kats, Kilic, ST ; Mangano, Mrenna, …)

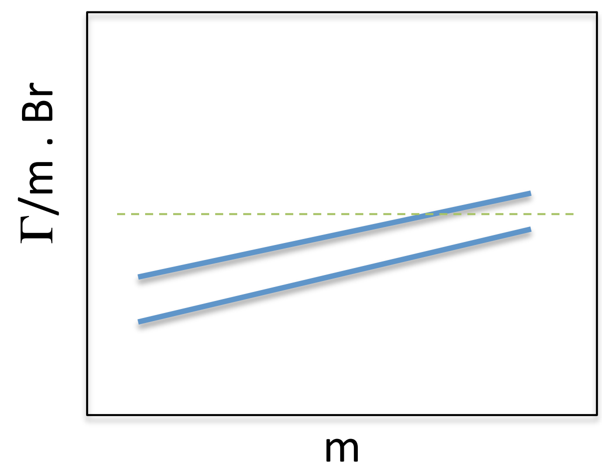
$$\frac{d\sigma(12\to 3)}{d\cos\theta} = 16\pi^2 \frac{(2J_3+1)\dim(R_3)\ S\ \mathrm{Br}(3\to 12)}{(2J_1+1)(2J_2+1)\dim(R_1)\dim(R_2)} f_{J_3}(\cos\theta)\frac{\Gamma_3}{m}\delta(s-m^2)$$

Spin + Color, Angular Distribution, Strength All Factorize

Table of $\mathcal{A}$(m) – Minimal Couplings
(Subcategories)

	J = 0	1/2	1	3/2	….
qq					
qg					
gg					

Mapping → "All" Models



Workshop: Propose We Fill In Table
+ (Test Color Re-Connection Systematic for Different Reps)
Collaborations can Use to Present Future Results

Simplified Model Topologies Submitted from Rutgers

- General Neutralino NLSP → Goldstino

  X → (g , h , Z) + G   Di-Bosons + MET

- Stau + Slepton Co-NLSP → Goldstino

  l → l + G   Multi-Lepton + MET

- Jets + Leptons + MET

  Various Orderings SUSY Spectrum - Neutralino LSP
  Interpolate Between Multi-Jets, Mono-Leptons,
  OS + SS Dileptons, Tri-Leptons, Multi-Leptons, All + MET

- High Multiplicity Jets

- Multiple Tau Resonances

- Multi-Jet Resonances

Variable Strong-Weak
Compression +
Squeezable Splittings
Probe Corners of Signatures

Applicable 2010 Data Set

Conclusions

- Data → Underlying Theoretical Framework
- Factorized Mapping Method

  Provides In-Principle as Well as Practical Solution to
  Data → Theory Problem (Existence Proof - Sunil Saturday)

  Experimental Collaborations Present σ.Br.A Sensitivies in
  Multiple Exclusive Channels

  Requires a Little Coordination – Collaborations Provide
  $A(m_i)$ and $\varepsilon(m_i)$ for Relevant Topologies

  Applicable Both to Exclusion + Post Discovery and
  Useful for Archival Presentation and Usage of Data Results

- Propose: We Fill in the Dijet Resonance
  $A(m_i)$ Grid to Completely "Solve" the Most General
  Data → Theory Mapping for This case