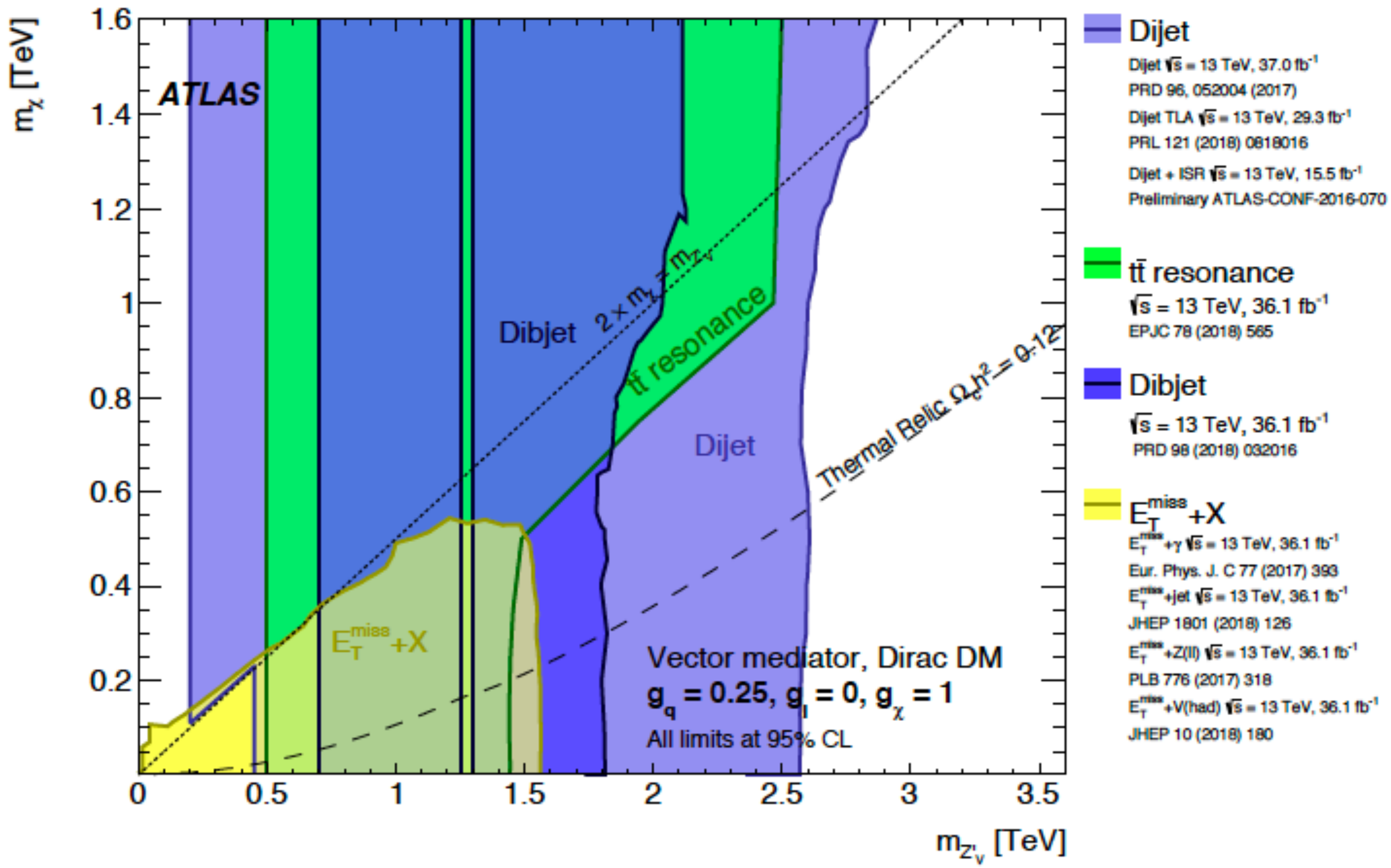
Tools and Monte Carlo 1

Kentarou Mawatari

[1903.01400]

Constraints on mediator-based dark matter and scalar dark energy models using $\sqrt{s} = 13$ TeV pp collision data collected by the ATLAS detector

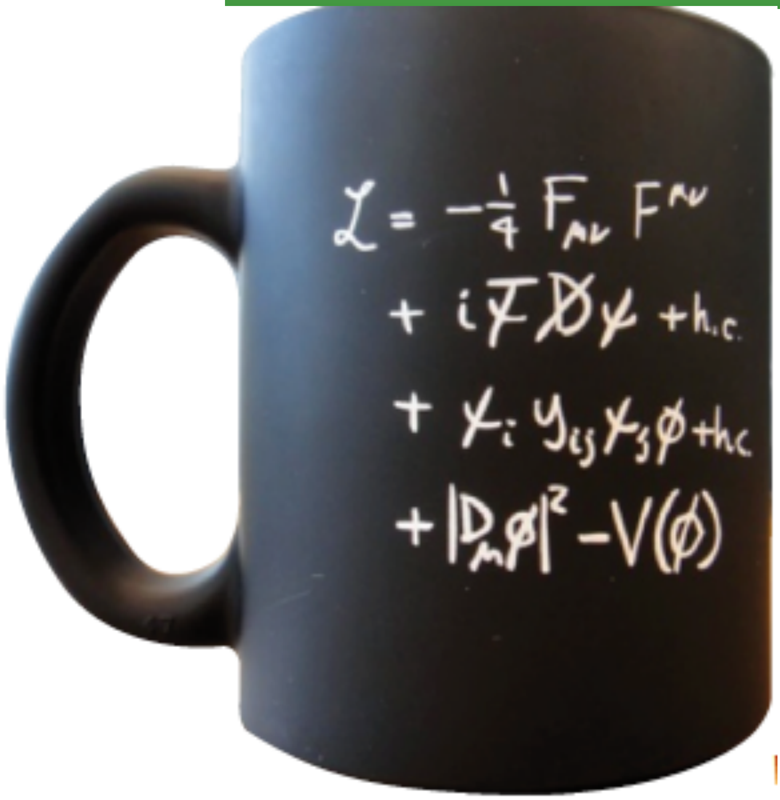


Event generations

Table 2: Details of the generation setup and Universal FeynRules Output (UFO) model used for the spin-1 mediator simplified models, for each signature considered in this paper.

Model and Final State	UFO	Generator and Parton Shower	Cross-section	Additional details
$Z'(\chi\bar{\chi})+j$	DMV [26, 170]	POWHEG-BOX v2 [171] + PYTHIA 8.205 [172]	NLO	Particle-level rescaling of leptophobic Z'_A scenario of Ref. [26] (see Appendix A.1)
$Z'(\chi\bar{\chi})+\gamma$	DMSimp [113, 173]	MG5_aMC@NLO 2.4.3 (NLO) [174] + PYTHIA 8.212	NLO	Leptophobic Z'_A scenario simulated, other scenarios obtained by cross-section rescaling (see Appendix A.1)
$Z'(\chi\bar{\chi})+V$	DMSimp	MG5_aMC@NLO 2.5.3 (NLO) + PYTHIA 8.212	NLO	Particle-level rescaling of LO samples of Ref. [20] to each of the four NLO scenarios (see Appendix A.1)
$Z'(qq)$ or $Z'(qq)$+ISR	DMSimp	MG5_aMC@NLO 2.2.3 (NLO) + PYTHIA 8.210	NLO	Leptophobic Z'_A scenario simulated, other scenario obtained by Gaussian resonance limits and cross-section rescaling [175]
$Z'(b\bar{b})$	DMSimp	MG5_aMC@NLO 2.2.3 (NLO) + PYTHIA 8.210	NLO	Leptophobic Z'_A scenario simulated, other scenario obtained by Gaussian resonance limits and cross-section rescaling [175]
$Z'(\ell\ell)$	DMSimp	MG5_aMC@NLO 2.2.3 (NLO)	NLO	Gaussian resonance limits and cross-section rescaling [175]
$Z'(t\bar{t})$	DMSimp	MG5_aMC@NLO 2.4.3 (LO) + PYTHIA 8.186	LO	Particle-level rescaling of the topcolour-assisted technicolour samples of Ref. [176] (see Appendix A.1)

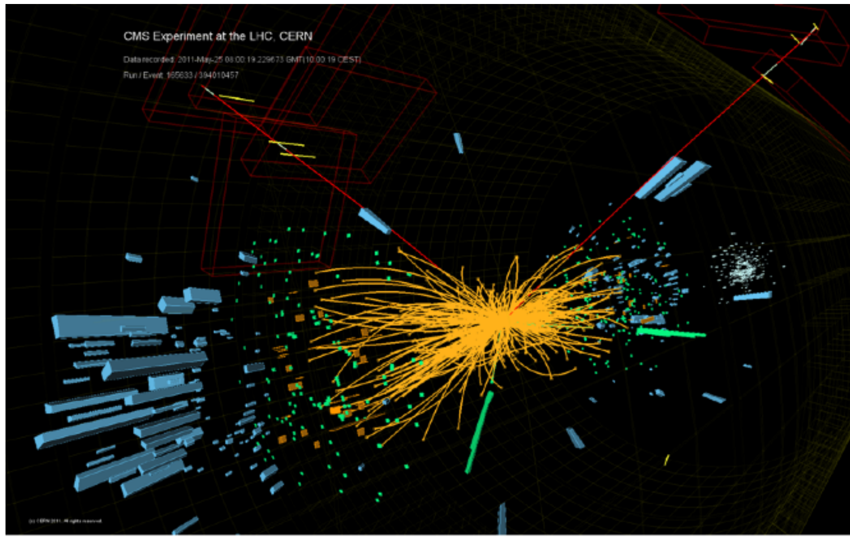
Lagrangian (TH) ⇔ Data (EXP)



simulation tools

prediction

interpretation

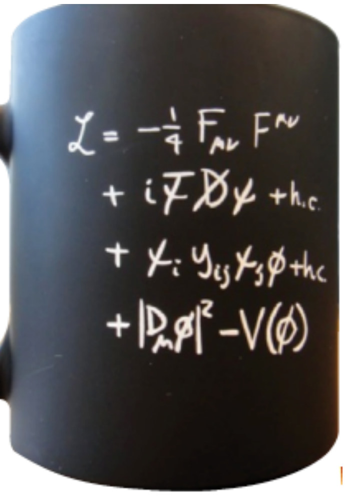


so easy, so powerful!

= so dangerous...

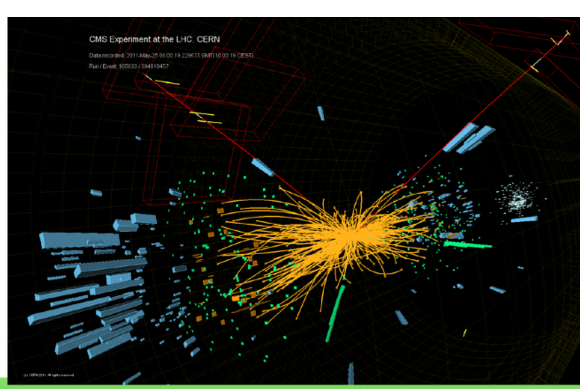
Let's learn its proper usage!

BSM workflow (I) before LHC

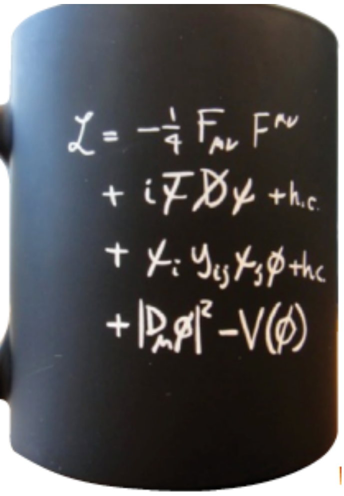


- take a BSM model (symmetry, particle contents,…), i.e. Lagrangian
  - derive the Feynman rules
    - draw Feynman diagrams for interesting 2→2 processes
      - compute the amplitude (squared)
        - implement it into a generator manually
          - generate events
            - parton-shower/hadronisation

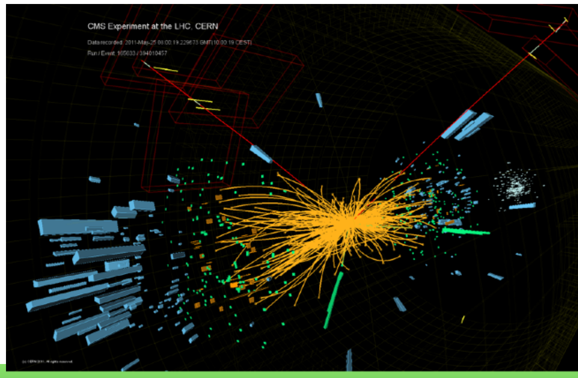
              Herwig, Pythia
              - detector simulation
                - analysis



BSM workflow (II) before LHC



- take a BSM model (symmetry, particle contents,…), i.e. Lagrangian
  - derive the Feynman rules
    - make the model file (make subroutines to compute helicity amplitudes)
      - draw Feynman diagrams for interesting any processes
        - compute the amplitude (squared) MadGraph4
          - generate events
            - parton-shower/hadronisation Herwig, Pythia
              - detector simulation
                - analysis



TH

Idea

The Hierarchy Problem and New Dimensions at a Millimeter

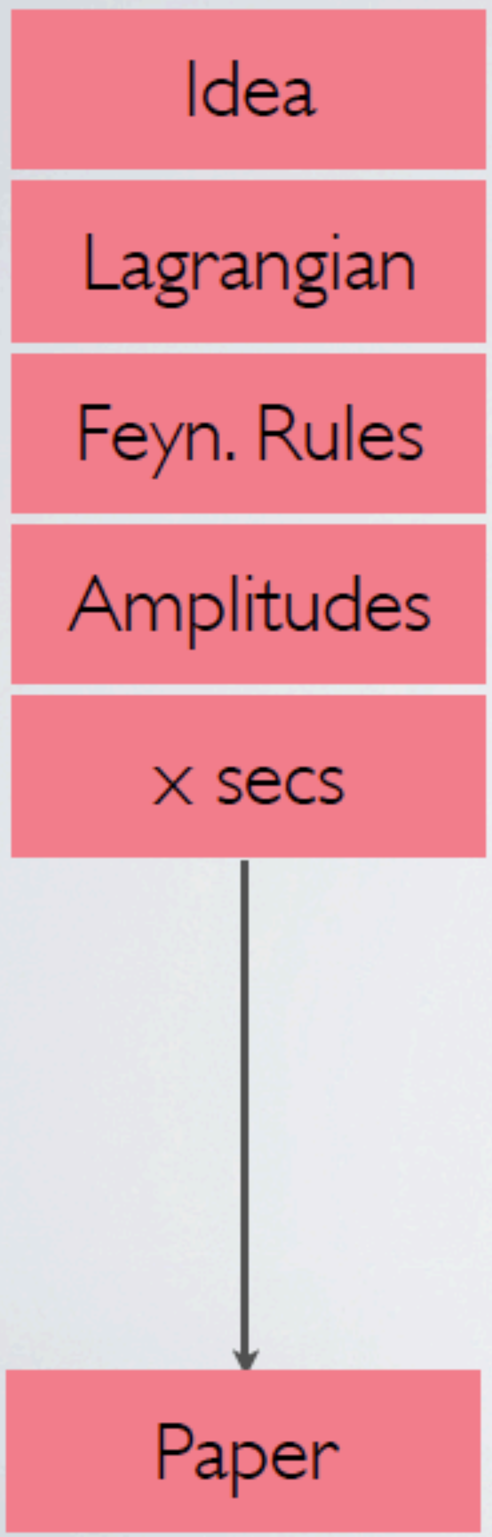
Nima Arkani–Hamed*, Savas Dimopoulos** and Gia Dvali†
* SLAC, Stanford University, Stanford, California 94309, USA
** Physi … , USA

large extra dimension model
"ADD model"

We propose a new framework for solving the hierarchy problem which does not rely on either supersymmetry or technicolor. In this framework, the gravitational and gauge interactions become united at the weak scale, which we take as the only fundamental short distance scale in nature. The observed weakness of gravity on distances $\gtrsim 1$ mm is due to the existence of $n \geq 2$ new compact spatial dimensions large compared to the weak scale. The Planck scale $M_{Pl} \sim G_N^{-1/2}$ is not a fundamental scale; its enormity is simply a consequence of the large size of the new dimensions. While gravitons can freely propagate in the new dimensions, at sub-weak energies the Standard Model (SM) fields must be localized to a 4-dimensional manifold of weak

In summary, there are many new interesting issues that emerge in our framework. Our old ideas about unification, inflation, naturallness, the hierarchy problem and the need for supersymmetry are abandoned, together with the successful supersymmetric prediction of coupling constant unification [12]. Instead, we gain a fresh framework which allows us to look at old problems in new ways. Lagrangean parameters become parameters of solutions and the phenomena that await us at LHC, NLC and beyond are even more exciting and unforseen.

TH

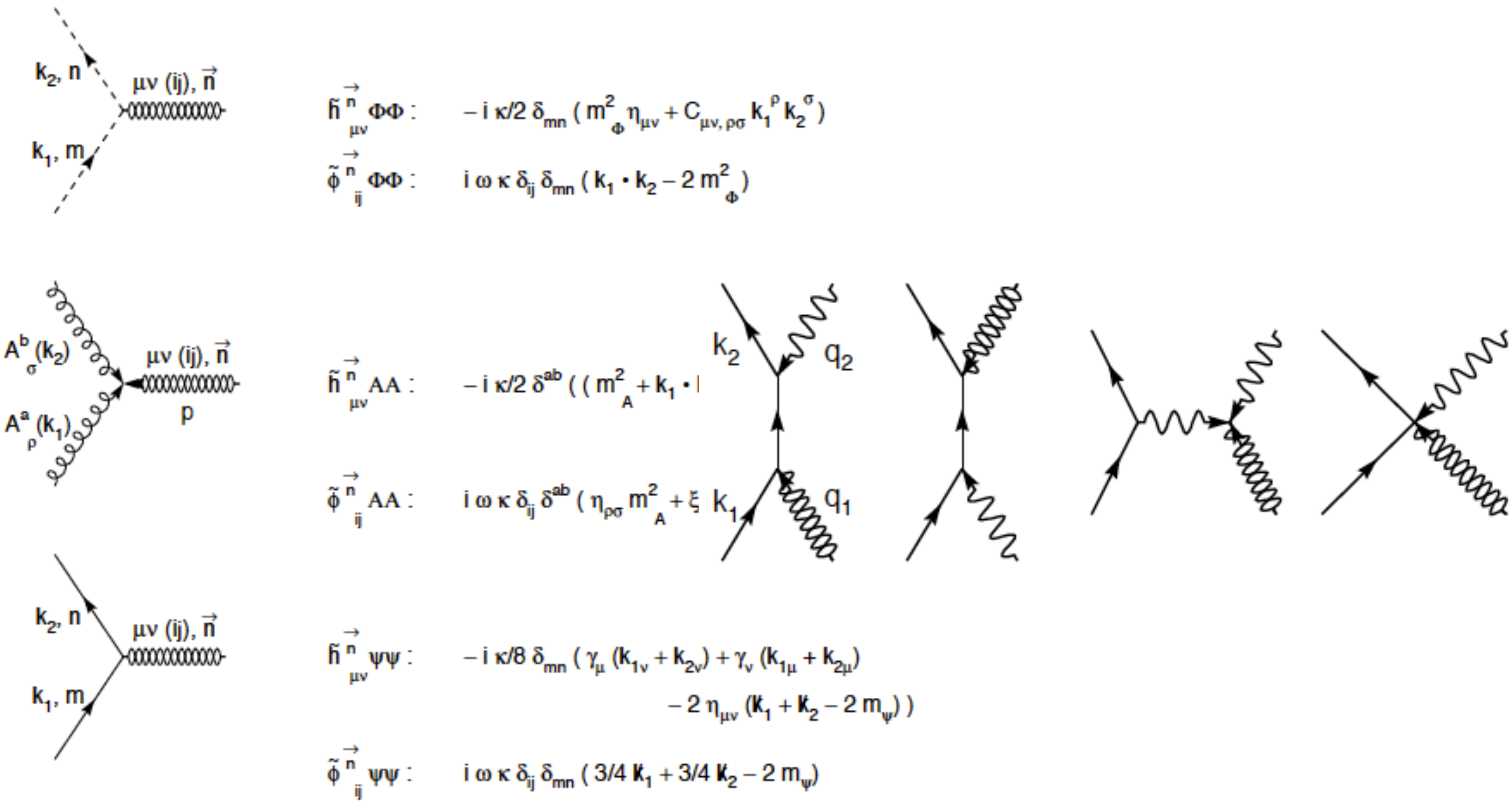


Kaluza-Klein States from Large Extra Dimensions

Tao Han[a], Joseph D. Lykken[b] and Ren-Jie Zhang[a]

[a] *Department of Physics, University of Wisconsin, Madison, WI 53706*

[b] *Theory Group, Fermi National Accelerator Laboratory, Batavia, IL 60510*



TH

PHENO

Idea

Lagrangian

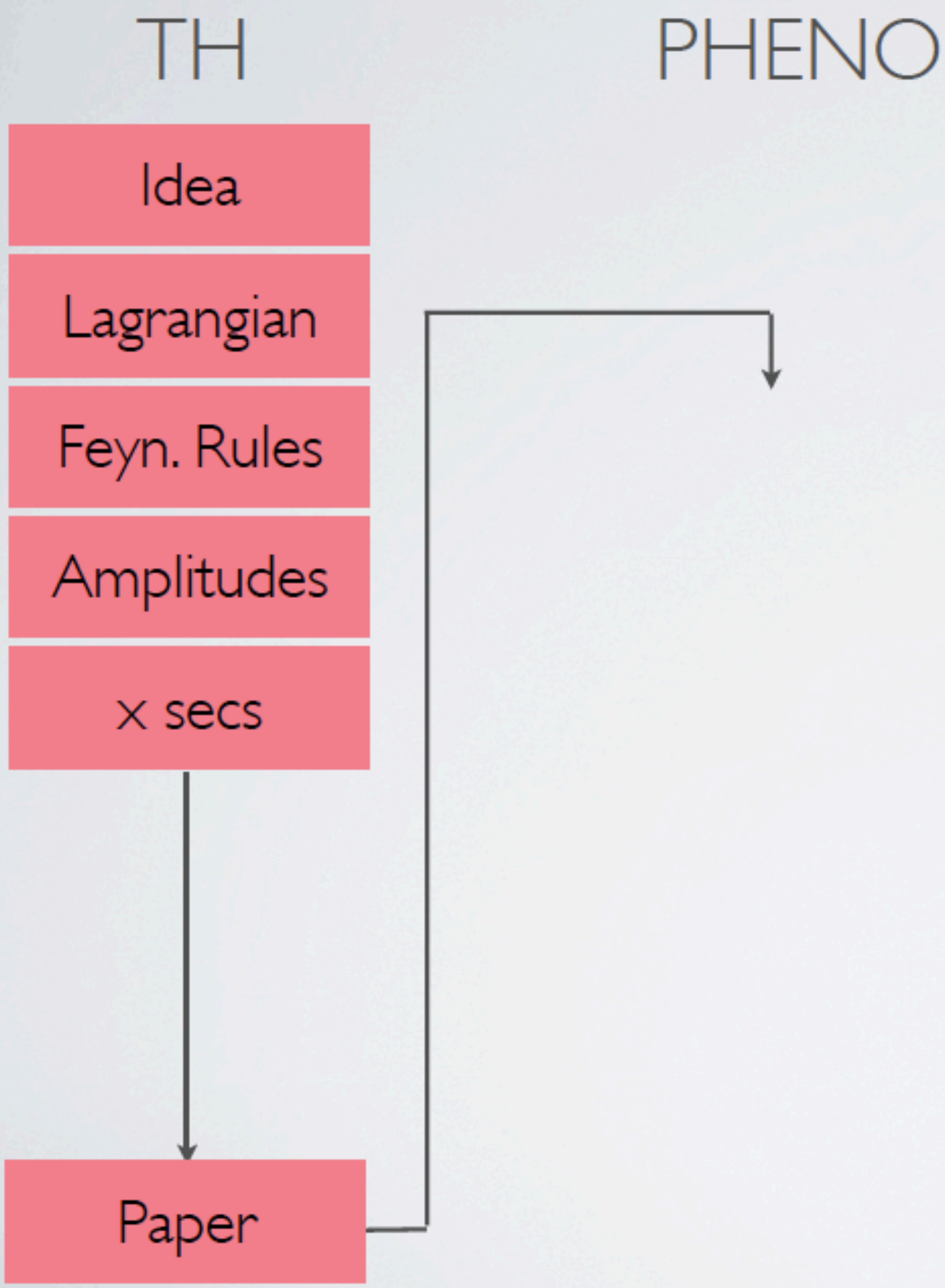
Feyn. Rules

Amplitudes

x secs

↓

Paper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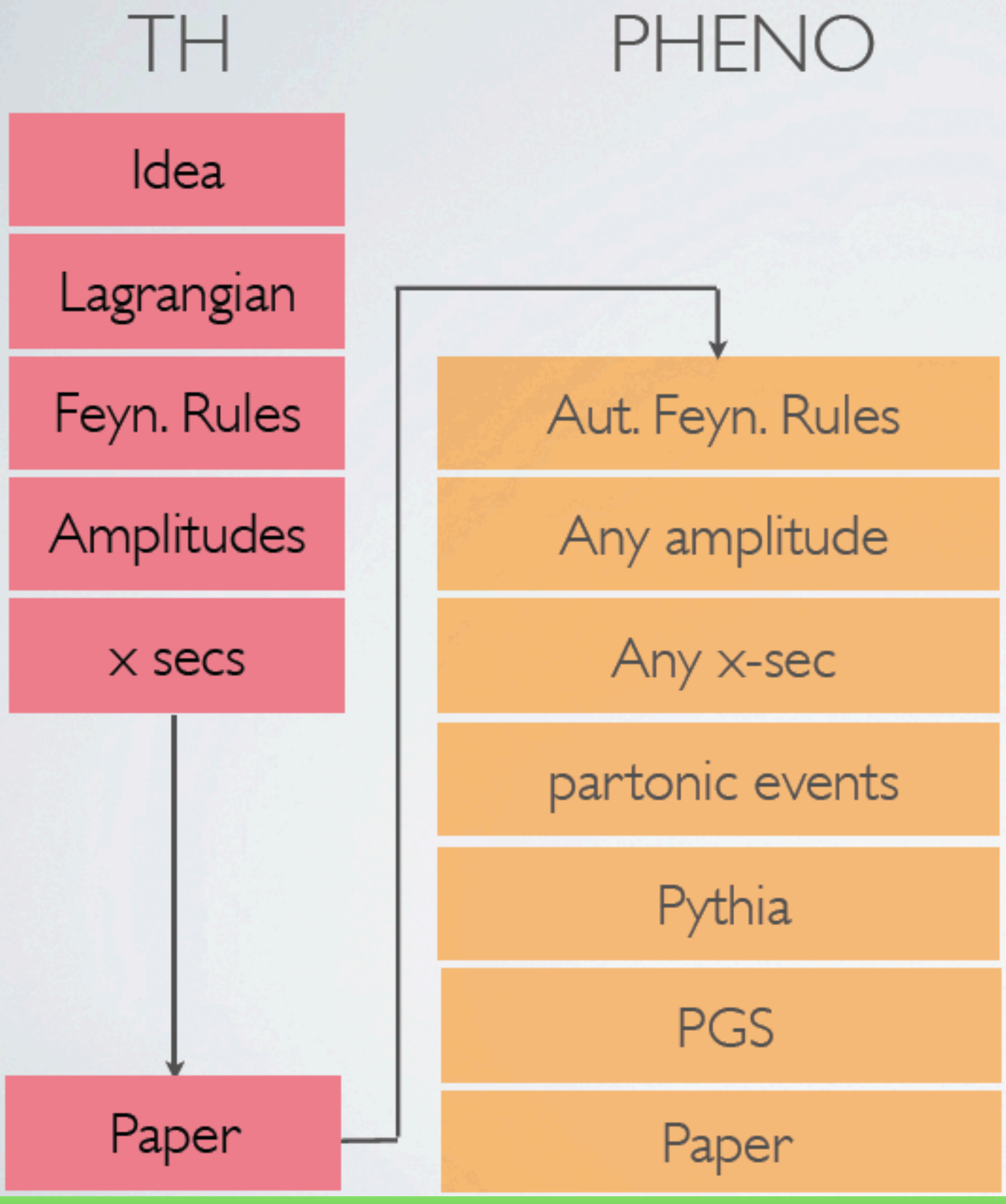
Paper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Amplitudes
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Aut. Feyn. Rules
Any amplitude
Any x-sec
partonic events
Pythia
PGS
Paper

Eur. Phys. J. C
DOI 10.1140/epjc/s10052-008-0663-x

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

[arXiv:0805.2554]

HELAS and MadGraph/MadEvent with spin-2 particles

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[4]School of Physics, Korea Institute for Advanced Study, Seoul 130-7

Vertex	Inputs	Output	Subroutine
SST	SST	Amplitude	SSTXXX
	ST	S	HSTXXX
	SS	T	USSXXX
FFT	FFT	Amplitude	IOTXXX
	FT	F	FTIXXX, FTOXXX
	FF	T	UIOXXX
VVT	VVT	Amplitude	VVTXXX
	VT	V	JVTXXX
	VV	T	UVVXXX
FFVT	FFVT	Amplitude	IOVTXX
	FVT	F	FVTIXX, FVTOXX
	FFT	V	JIOTXX
	FFV	T	UIOVXX
VVVT	VVVT	Amplitude	VVVTXX
	VVT	V	JVVTXX
	VVV	T	UVVVXX
VVVVT	GGGGT	Amplitude	GGGGTX
	GGGT	G	JGGGTX
	GGGG	T	UGGGGX

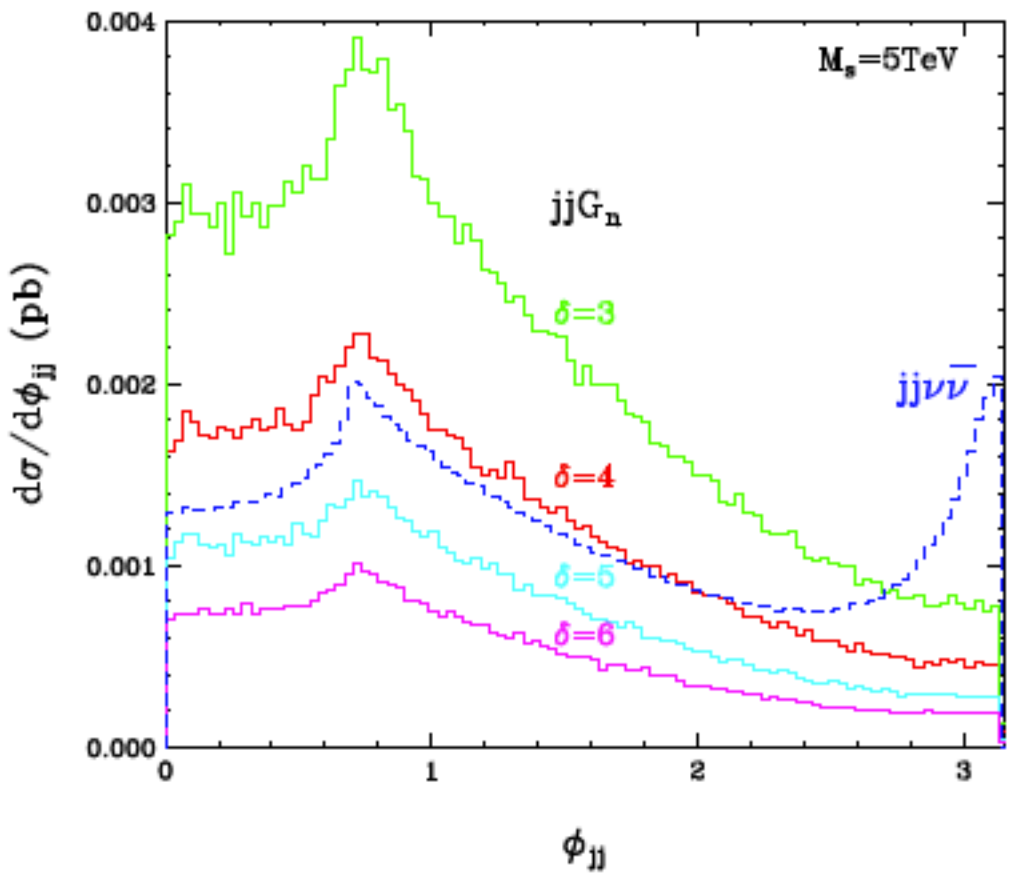
```
      TKK = TKK - T12*(pv1(1)*pv2(2) + pv1(2)*pv2(1))
     &          - T13*(pv1(1)*pv2(3) + pv1(3)*pv2(1))
     &          - T14*(pv1(1)*pv2(4) + pv1(4)*pv2(1))
     &          + T23*(pv1(2)*pv2(3) + pv1(3)*pv2(2))
     &          + T24*(pv1(2)*pv2(4) + pv1(4)*pv2(2))
     &          + T34*(pv1(3)*pv2(4) + pv1(4)*pv2(3))

      TK1V2 = TK1V2 - T12*(pv1(1)*v2(2) + pv1(2)*v2(1))
     &              - T13*(pv1(1)*v2(3) + pv1(3)*v2(1))
     &              - T14*(pv1(1)*v2(4) + pv1(4)*v2(1))
     &              + T23*(pv1(2)*v2(3) + pv1(3)*v2(2))
     &              + T24*(pv1(2)*v2(4) + pv1(4)*v2(2))
     &              + T34*(pv1(3)*v2(4) + pv1(4)*v2(3))

      TVV = TVV - T12*(v1(1)*v2(2) + v1(2)*v2(1))
     &          - T13*(v1(1)*v2(3) + v1(3)*v2(1))
     &          - T14*(v1(1)*v2(4) + v1(4)*v2(1))
     &          + T23*(v1(2)*v2(3) + v1(3)*v2(2))
     &          + T24*(v1(2)*v2(4) + v1(4)*v2(2))
     &          + T34*(v1(3)*v2(4) + v1(4)*v2(3))

      TK2V1 = TK2V1 - T12*(v1(1)*pv2(2) + v1(2)*pv2(1))
     &              - T13*(v1(1)*pv2(3) + v1(3)*pv2(1))
     &              - T14*(v1(1)*pv2(4) + v1(4)*pv2(1))
     &              + T23*(v1(2)*pv2(3) + v1(3)*pv2(2))
     &              + T24*(v1(2)*pv2(4) + v1(4)*pv2(2))
     &              + T34*(v1(3)*pv2(4) + v1(4)*pv2(3))

      vertex = (ft(1,1)-ft(2,2)-ft(3,3)-ft(4,4))*( K1V2*K2V1 - V1V2*F )
     &       + F*TVV + V1V2*TKK - K2V1*TK1V2 - K1V2*TK2V1
```

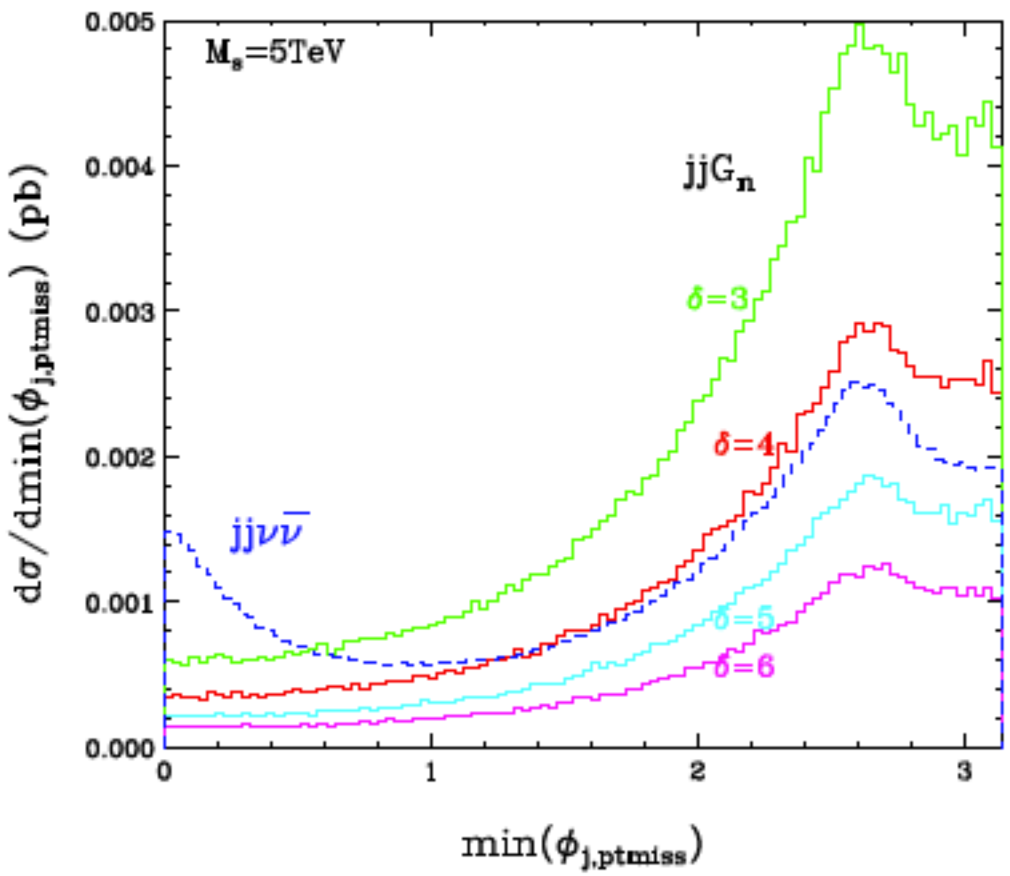
[arXiv:0801.1794]

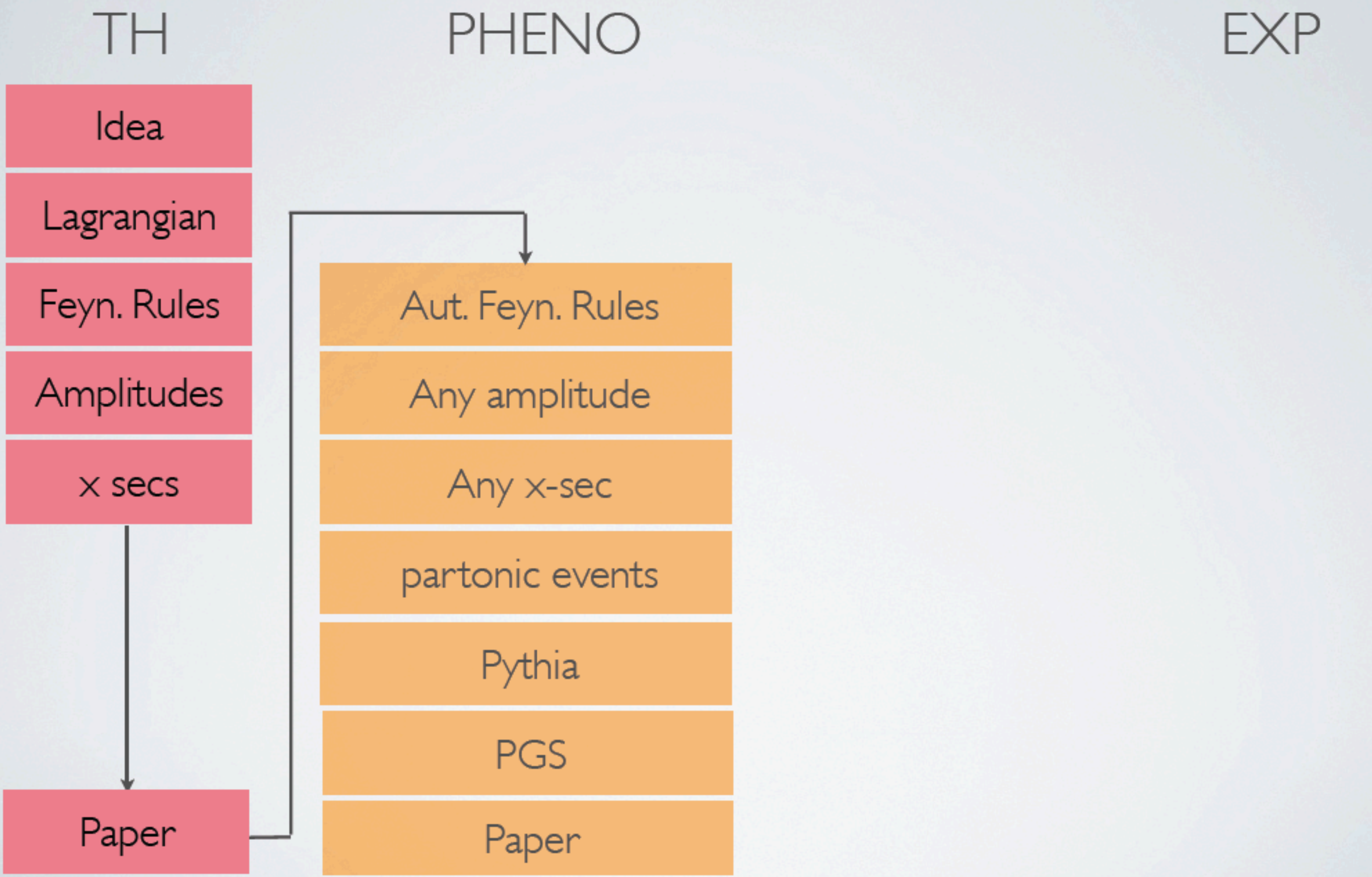
Published by Institute of Physics Publishing for SISSA
Received: *January 18, 2008*
Revised: *January 29, 2008*
Accepted: *March 25, 2008*
Published: *April 4, 2008*

Graviton production with 2 jets at the LHC in large extra dimensions

Kaoru Hagiwara,[a] Partha Konar,[bc] Qiang Li,[c] Kentarou Mawatari[d] and Dieter Zeppenfeld[c]



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Any amplitude
Any x-sec
partonic events
Pythia
PGS
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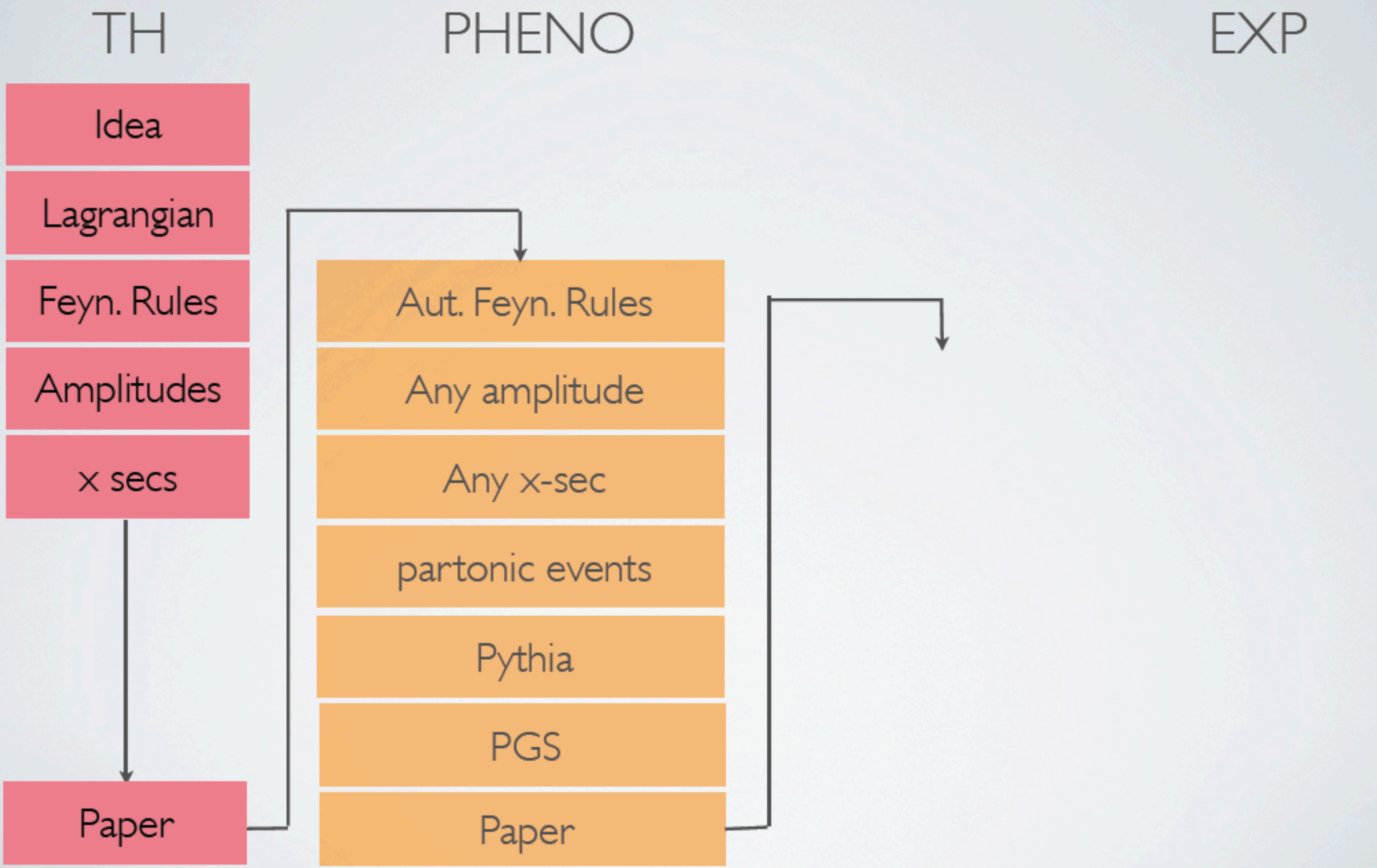
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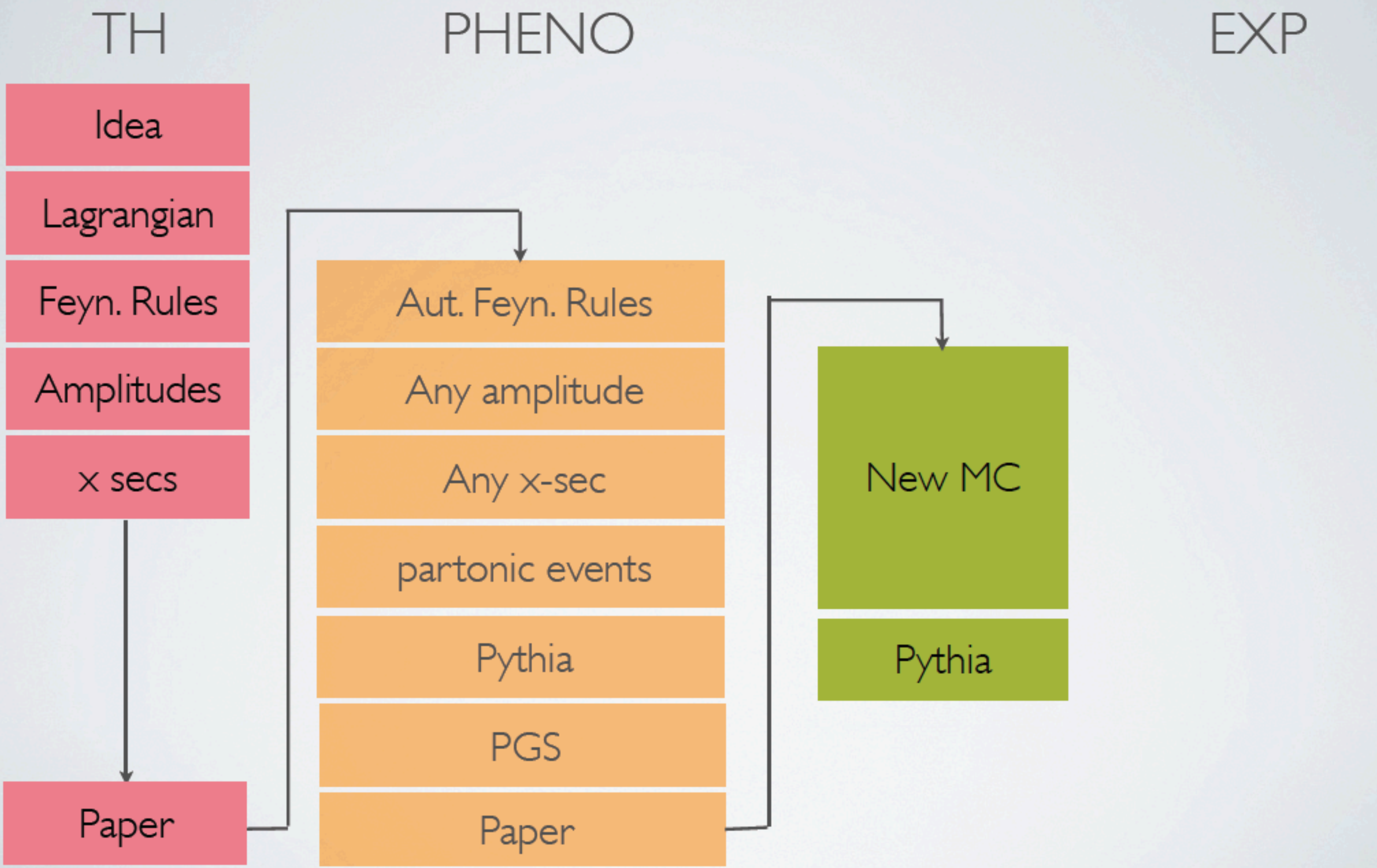
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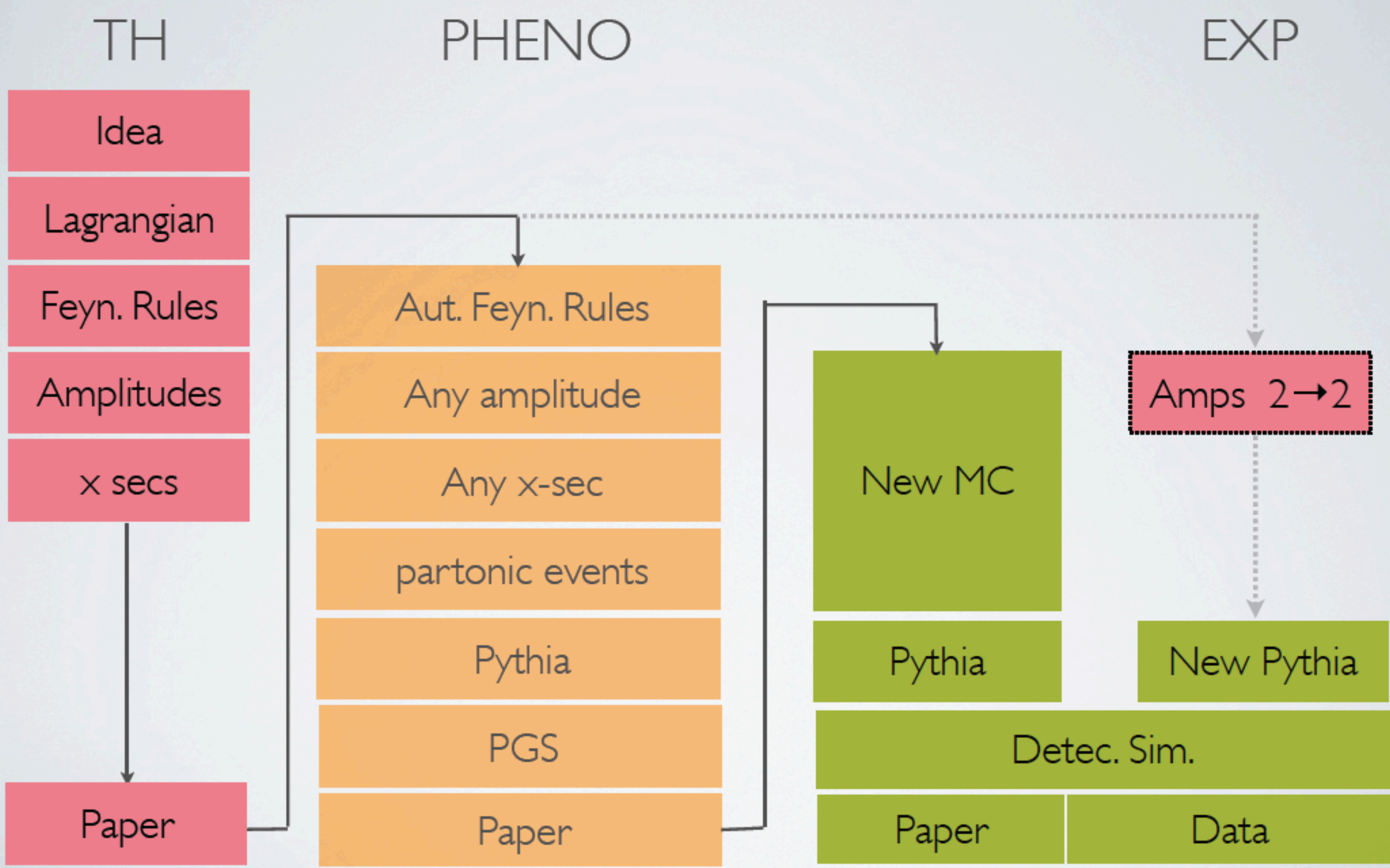
New MC
Pythia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PGS
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New MC
Pythia
Detec. Sim.
Paper
Data
Amps 2→2
New Pythia

Search for Large Extra Dimensions in the Monojet + $\not\!\!E_T$ Channel at DØ

V.M. Abazov,[21] B. Abbott,[55] A. Abdesselam,[11] M. Abolins,[48] V. Abramov,[24] B.S. Acharya,[17] D.L. Adams,[53] M. Adams,[35] S.N. Ahmed,[20] G.D. Alexeev,[21] A. Alton,[47] G.A. Alves,[2] E.W. Anderson,[40] Y. Arnoud,[9] C. Avila,[5] V.V. Babintsev,[24] L. Babukhadia,[52] T.C. Bacon,[26] A. Baden,[44] S. Baffioni,[10] B. Baldin,[34] P.W. Balm,[19] S. Banerjee,[17] E. Barberis,[46] P. Baringer,[41] J. Barreto,[2] J.F. Bartlett,[34] U. Bassler,[12] D. Bauer,[26] A. Bean,[41] F. Beaudette,[11] M. Begel,[51] A. Belyaev,[33] S.B. Beri,[15] G. Bernardi,[12] I. Bertram,[25] A. Besson,[9] R. Beuselinck,[26] V.A. Bezzubov,[24] P.C. Bhat,[34] V. Bhatnagar,[15] M. Bhattacharjee,[52] G. Blazey,[36] F. Blekman,[19] S. Blessing,[33] A. Boehnlein,[34] N.I. Bojko,[24] T.A. Bolton,[42] F. Borcherding,[34] K. Bos,[19] T. Bose,[50] A. Brandt,[57] R. Breedon,[29]
oss,[34] D. Buchholz,[37] M. Buehler,[35] V. Buescher,[14]
alho,[3] D. Casey,[48] Z. Casilum,[52] H. Castilla-Valdez,[18]
.K. Cho,[51] S. Choi,[32] S. Chopra,[53] J.H. Christenson,[34]
W.E. Cooper,[34] D. Coppage,[41] S. Crépé-Renaudin,[9]
. Davis,[51] K. De,[57] S.J. de Jong,[20] M. Demarteau,[34]
[24] S. Desai,[52] H.T. Diehl,[34] M. Diesburg,[34] S. Doulas,[46]
A. Duperrin,[10] A. Dyshkant,[36] D. Edmunds,[48] J. Ellison,[32]
G. Eppley,[59] P. Ermolov,[23] O.V. Eroshin,[24] J. Estrada,[51]
F. Filthaut,[20] H.E. Fisk,[34] Y. Fisyak,[53] F. Fleuret,[12]
.N. Galyaev,[24] M. Gao,[50] V. Gavrilov,[22] R.J. Genik II,[25]
B. Gómez,[5] P.I. Goncharov,[24] H. Gordon,[53] L.T. Goss,[58]

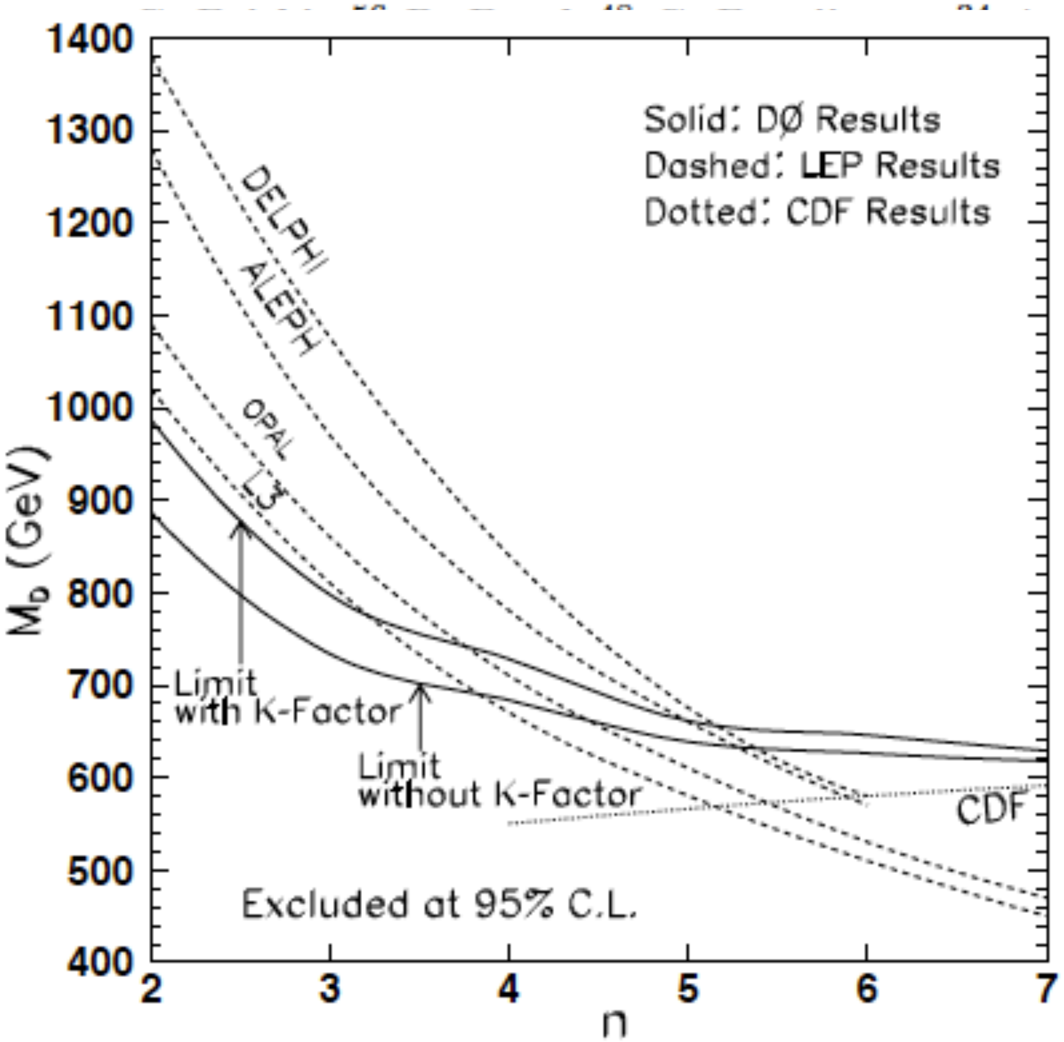
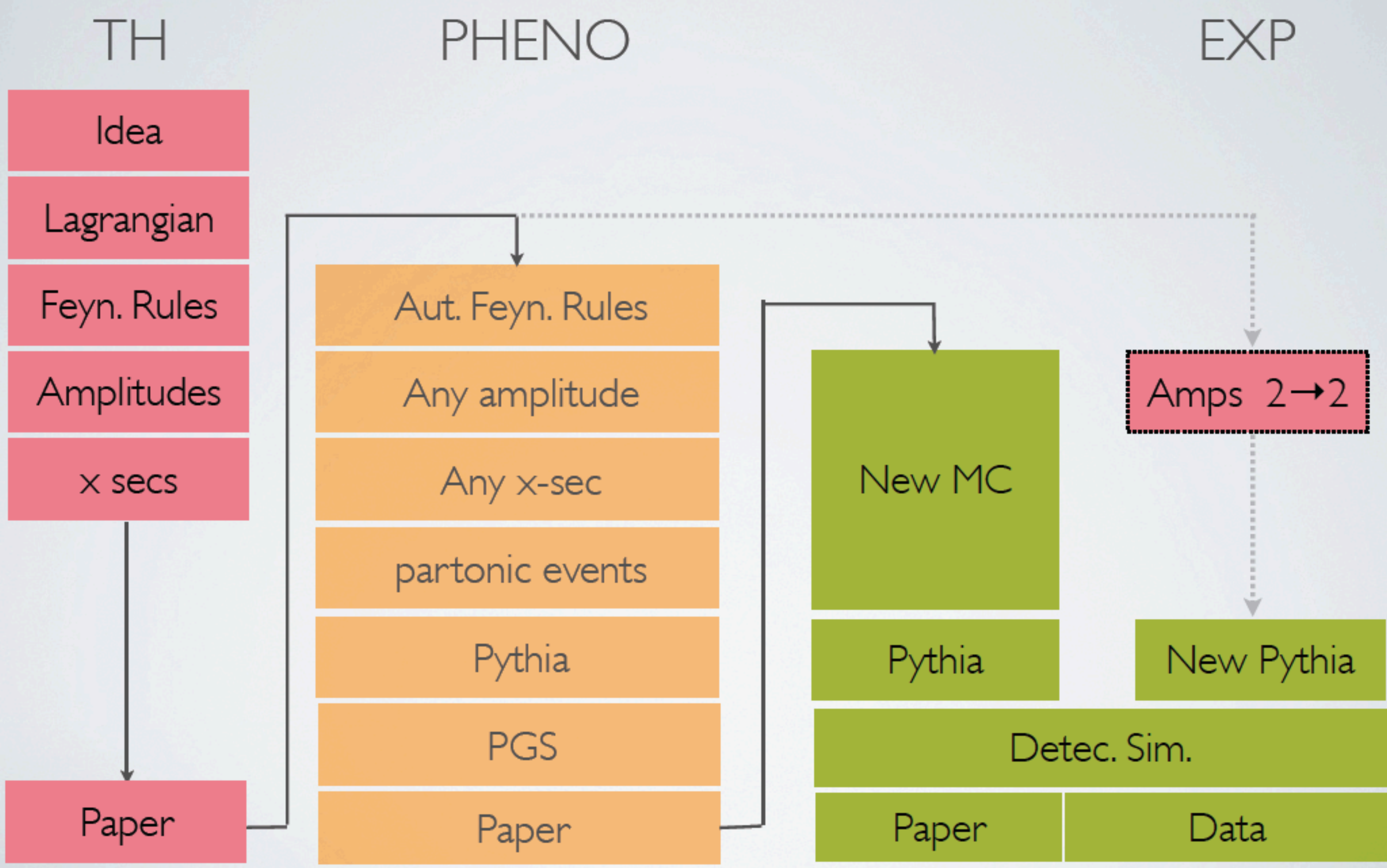


FIG. 2: The 95% C.L. exclusion contours on the fundamental Planck scale (M_D) and number of extra dimensions (n) for monojet production at DØ (solid lines). The dashed curves correspond to limits from LEP, and the dotted curve is the limit from CDF, both for $\gamma + G_{KK}$ production.

TABLE III: 95% C.L. lower limits on M_D.

n	2	3	4	5	6	7
M_D limit without K-factor scaling (TeV)	0.89	0.73	0.68	0.64	0.63	0.62
M_D limit with K-factor scaling (TeV)	0.99	0.80	0.73	0.66	0.65	0.63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Paper
Data

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Lagrangian		
	Aut. Feyn. Rules	
	Any amplitude	
	Any x-sec	
	partonic events	
		Pythia
		Detec. Sim.
		Data

TH

EXP

- One path for all
- Physics and software validations streamlined
- Robust and efficient Th/Exp communication
- It works top-down and bottom-up

Idea

Lagrangian

FeynRules

ME Generator

Signal & Bkg

Events

PS+Had

PGS

Detect. Sim.

Papers

Data

PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: July 17, 2013
REVISED: September 23, 2013
ACCEPTED: October 18, 2013
PUBLISHED: November 6, 2013

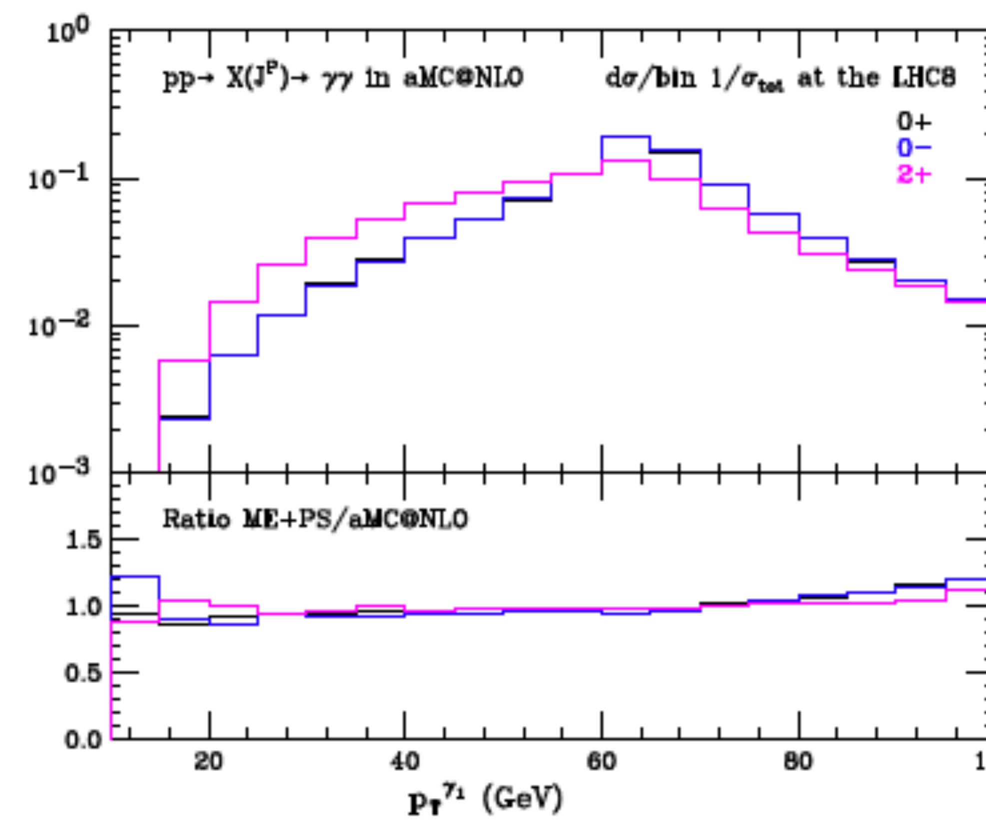
[arXiv:1306.6464]

A framework for Higgs characterisation

P. Artoisenet,[a] P. de Aquino,[b] F. Demartin,[c] R. Frederix,[d] S. Frixione,[d,e] F. Maltoni,[c] M. K. Mandal,[f] P. Mathews,[g] K. Mawatari,[b] V. Ravindran,[h] S. Seth,[g] P. Torrielli[i] and M. Zaro[c]

$$\mathcal{L}_2^V = -\frac{1}{\Lambda} \sum_{V=Z,W,\gamma,g} \kappa_V T^V_{\mu\nu} X_2^{\mu\nu}$$

$$T^\gamma_{\mu\nu} = -g_{\mu\nu}\left[-\frac{1}{4}A^{\rho\sigma}A_{\rho\sigma} + \partial^\rho\partial^\sigma A_\sigma A_\rho + \frac{1}{2}(\partial^\rho A_\rho)^2\right] - A_\mu{}^\rho A_{\nu\rho} + \partial_\mu\partial^\rho A_\rho A_\nu + \partial_\nu\partial^\rho A_\rho A_\mu\,,$$



[arXiv:1701.07008]

Eur. Phys. J. C (2017) 77:326
DOI 10.1140/epjc/s10052-017-4871-0

THE EUROPEAN PHYSICAL JOURNAL C

CrossMark

Regular Article - Theoretical Physics

Simplified dark matter models with a spin-2 mediator at the LHC

Sabine Kraml[1], Ursula Laa[1,2], Kentarou Mawatari[1,3,a], Kimiko Yamashita[4]

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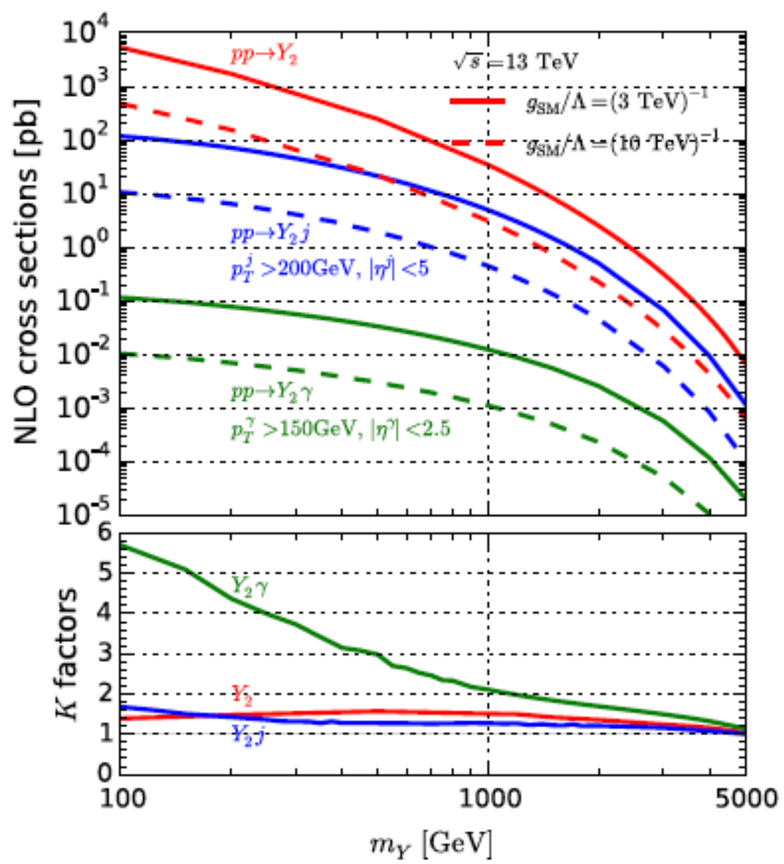
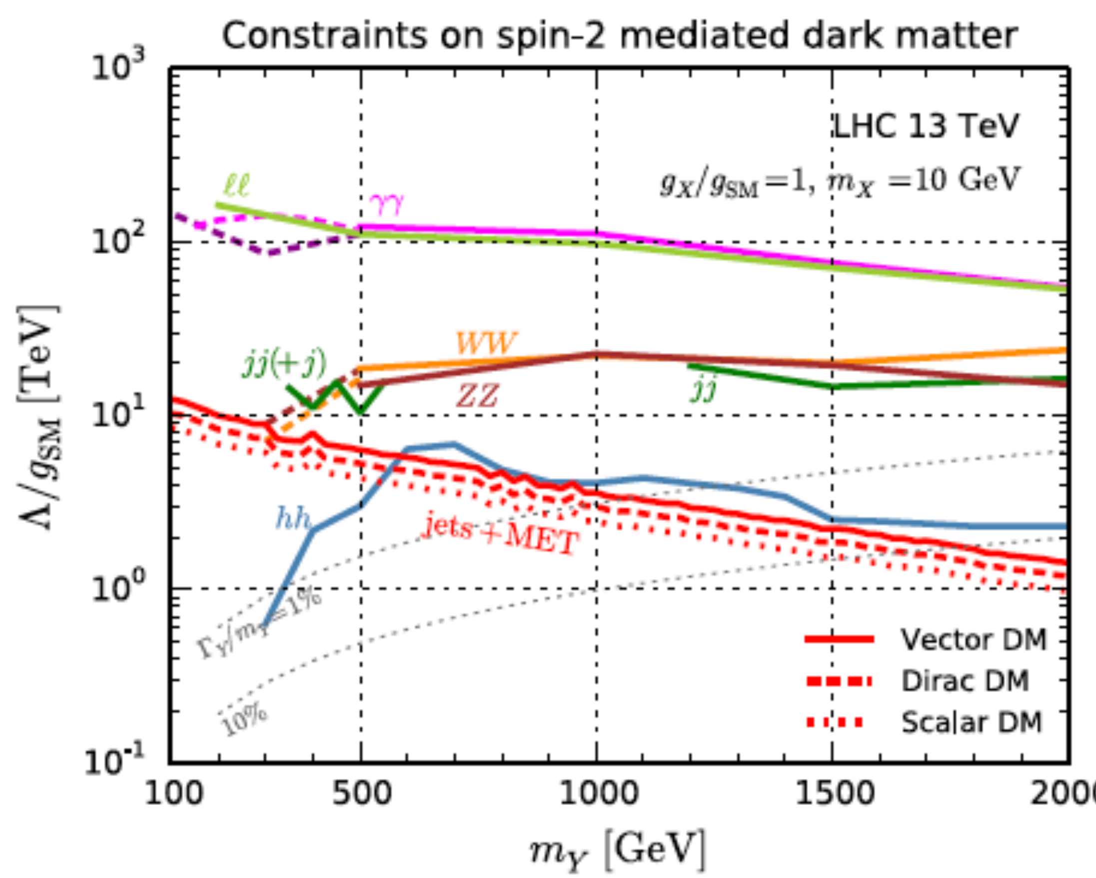
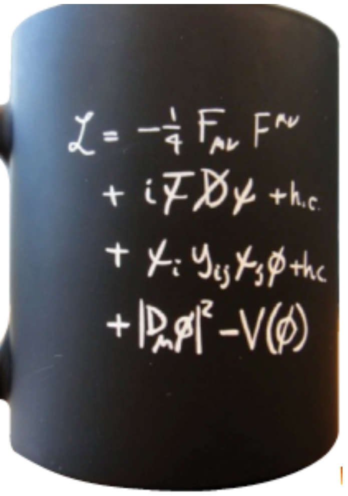
[4] Department of Physics, Graduate School of Humanities and Sciences, and Program for Leading Graduate Schools, Ochanomizu University, Tokyo 112-8610, Japan



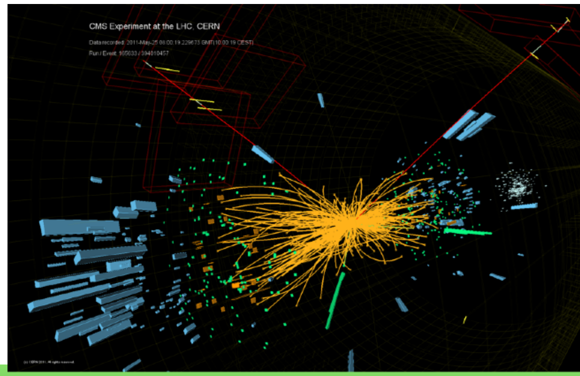


BSM workflow after LHC

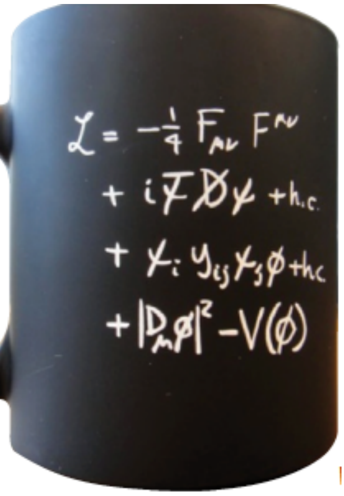


- take a BSM model (symmetry, particle contents,…), i.e. Lagrangian
  - derive the Feynman rules — Model providers
    - draw Feynman diagrams for interesting any processes
      - compute the amplitude (squared) — Matrix-element generators
        - generate events
          - parton-shower/hadronisation — Shower MC
            - detector simulation — Detector simulation tools
              - analysis — Analysis tools

DM physics tool
DM annihilation
(relic, indirect detection)
DM-N cross section
(direct detection)

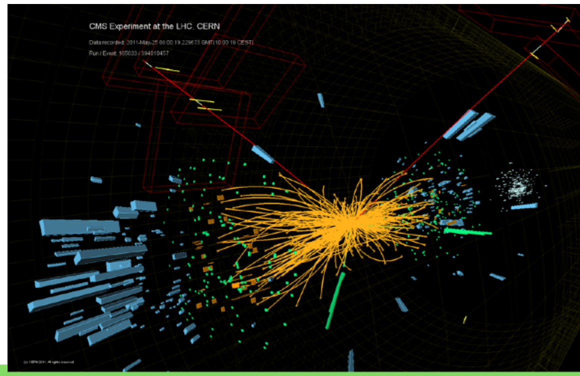


BSM workflow after LHC



- take a BSM model (symmetry, particle contents,…), i.e. Lagrangian
  - derive the Feynman rules — FeynRules
    - draw Feynman diagrams for interesting any processes
      - compute the amplitude (squared) — MadGraph5_aMC@NLO
        - generate events
          - parton-shower/hadronisation — Pythia8
            - detector simulation — Delphes
              - analysis — MadAnalsysi5

MadDM



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