Summary

Low energy: J. Berengut, E. Fuchs
Tools: G. Durieux, G. Kasciezka, A. Wulzer
BSM Pheno: M. Szewc, T. Vazquez Schroeder, J. Zupan
BSM Higgs: R. D'Agnolo, A. de Wit

BSM Higgs

Higgs Mass Naturalness

1. It’s not calculable
    a. SM-like
    b. Act of God
2. It’s calculable and tuned (missing from the original list, thanks Dario)
3. Symmetry
4. M_QG << M_Pl
5. Multiverse
    a. Anthropic
    b. Dynamical
    c. Statistical
    d. Simulation (Act of God #2)
6. UV/IR Mixing
    a. Dynamical
    b. Consistency
7. Modifications of Gravity
8. It’s not on the list

Higgs Mass Poll

1. Would you take a bet with 30/70 odds on the origin of the Higgs mass?
    a. Yes 10
    b. No 9
    c. Abstained ~ 15
2. Would you take a bet with 5/95 odds on the origin of the Higgs mass?
    a. Yes 8
    b. No 11
    c. Abstained ~ 15
3. Would you bet 1000$ on one of the options on the list (double or nothing)?
    a. Yes 6
    b. No ~ 28
4. Would you bet 10000$ on one of the options on the list (double or nothing)?
    a. Yes 1
    b. No ~ 33

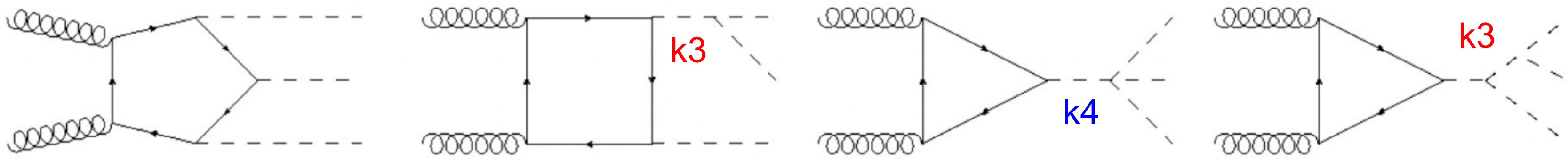
Higgs Mass Poll #2 (Multiple Votes are Allowed)

1. It’s not calculable [2]
2. Symmetry [19]
3. M_QG << M_Pl [4]
4. Multiverse [5]
5. UV/IR Mixing [3]
6. Modifications of Gravity [1]
7. It’s not on the list [3]

Contact: C. Pandini

HHH triple Higgs production (at HL-LHC)

HHH still unexplored by experiments: SM predicts extremely tiny XS (~0.1fb - ~300 events at HL-LHC)
Could we be sensitive to deviations from the SM? Through trilinear or quartic self-coupling deviations?



Target goals

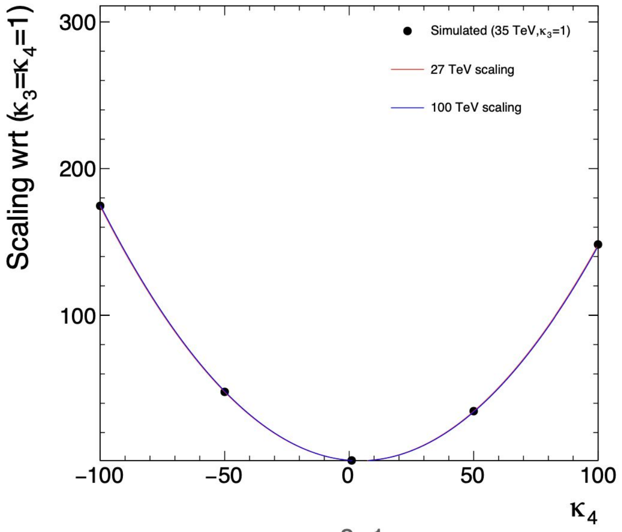
- cross-check: does the analytical form of the HHH XS as a function of (k3,k4) depend on the center-of-mass-energy? (available at 27 and 100TeV from literature)
- 2D map of the HHH XS as a function of k3 and k4, at sqrt(s)=14TeV (coupling strength modifier for trilinear and quartic self-couplings)
- Higgs kinematics as a function of (k3,k4)
- (potentially) sensitivity study of HHH(6b), HHH(4b2tau), …

(Note that we expect larger sensitivity to the trilinear coupling from this process)

Contact: C. Pandini

HHH triple Higgs production (at HL-LHC)

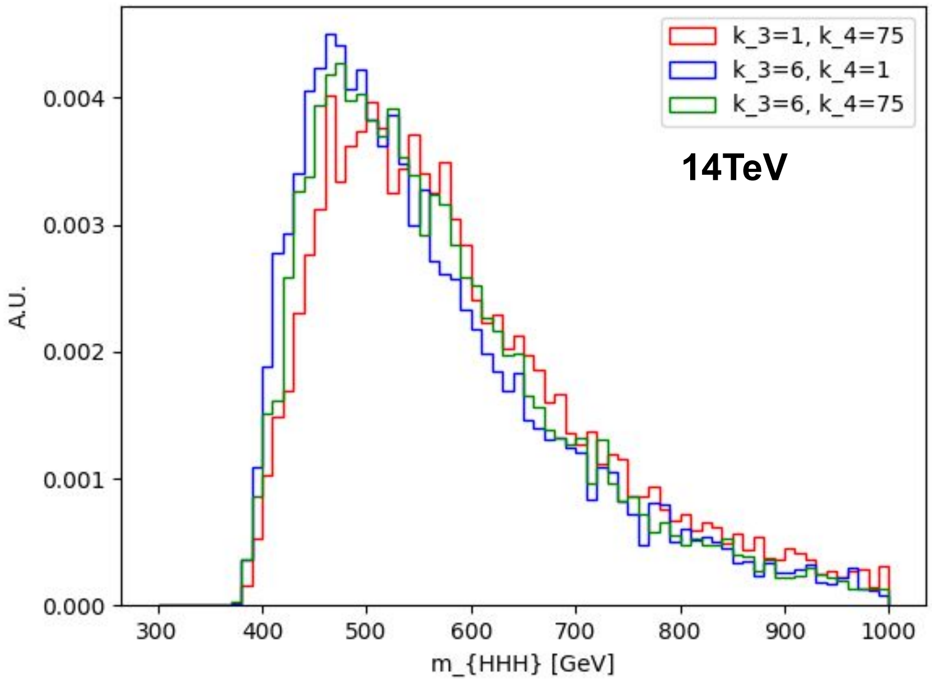
XS(HHH) analytical prediction



κ3=1

$$\sigma(pp \to hhh)_{\text{FCC-pp}} = 5.1 \Big[1 - 0.67\Delta\kappa_3 - 0.11\Delta\kappa_4 + 0.72(\Delta\kappa_3)^2 - 0.14\Delta\kappa_3\Delta\kappa_4 + 1.6\cdot 10^{-2}(\Delta\kappa_4)^2 - 0.20(\Delta\kappa_3)^3 + 4.0\cdot 10^{-2}(\Delta\kappa_3)^2\Delta\kappa_4 + 3.0\cdot 10^{-2}(\Delta\kappa_3)^4\Big]\,\text{fb}\,.$$

m(HHH) as a function of (k3,k4)



$Z \to \gamma\phi$ / $\phi \to \gamma\gamma, b\bar{b}, \tau^+\tau^-$ at LHC and FCCee

Contact: G. Cacciapaglia

Goal: LHC and FCCee prospects for a light (pseudo)scalar produced in the Z boson decays (with a photon).

Ex. Pseudo-scalar $\phi = a$

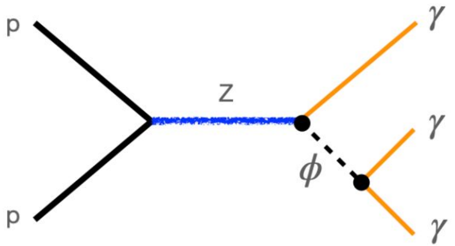
$$\mathcal{L}_{WZW} = a\left(g^2 \frac{C_W}{\Lambda} W_{\mu\nu}\tilde{W}^{\mu\nu} + g'^2 \frac{C_B}{\Lambda} B_{\mu\nu}\tilde{B}^{\mu\nu}\right)$$

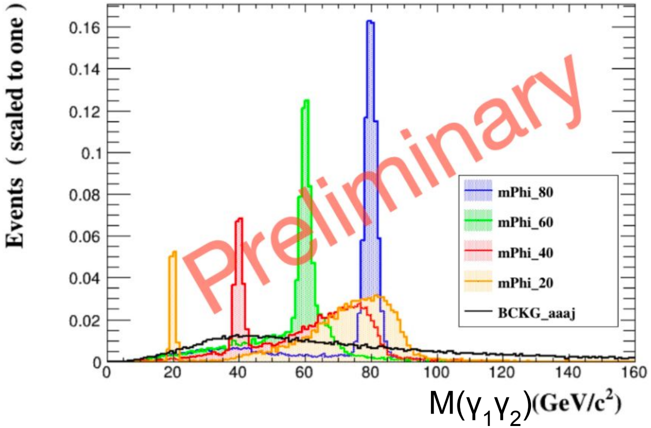
Inspired by composite models:

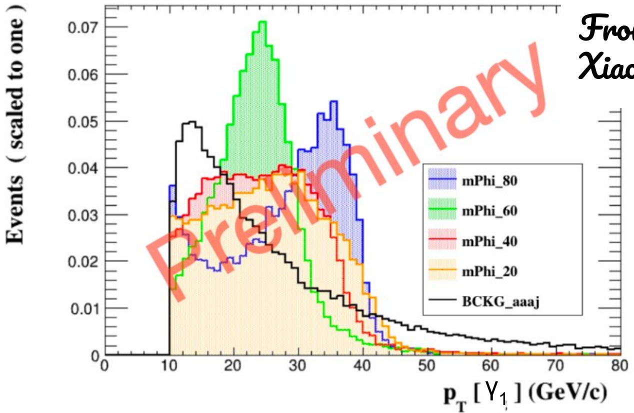
$C_B = -C_W \to$ photophobic

$C_B = C_W \to a \to \gamma\gamma \quad \sim 100\,\%$

- Low-mass diphoton trigger
- Strategy: di-photon invariant mass
- ATLAS $Z \to \gamma\gamma\gamma$ interpretation/extension
- Prospects for HL-LHC and FCC-ee
- Analysis of $b\bar{b}$, $\tau\tau$ channels







From E. Jourd'hui & J. Xiao

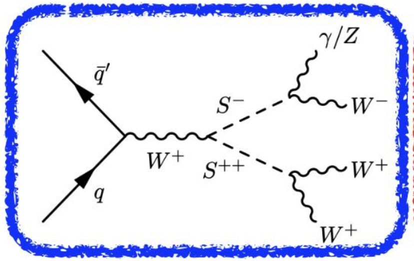
Composite EW scalar vademecum

Contact: G. Cacciapaglia

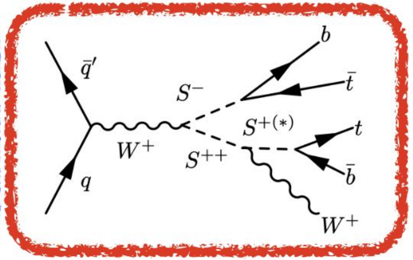
Goal: classify branching ratios of composite EW scalars in various models.
Identify interesting/new final states from pair production.

Coset	N_{mesons}	EW basis	particles and BRs	
SU(4)/Sp(4)	5	1_0	η_0: $\gamma\gamma\,0\%$, $Z\gamma\,19\%$, $ZZ\,16\%$ $W^+W^-\,65\%$	WZW
SU(5)/SO(5)	14	3_0	$\eta_1^\pm$: $W^\pm\gamma\,78\%$, $W^\pm Z\,22\%$	WZW
			η_1^0: $\gamma\gamma\,34.5\%$, $Z\gamma\,31\%$, $ZZ\,34.5\%$, $W^+W^-\,0\%$	WZW
		$3_{\pm1}$	$\eta^{\pm\pm}$: $W^\pm W^\pm\,100\%$	WZW v^2/f^2
			$\eta_2^\pm$: $W^\pm\gamma\,78\%$, $W^\pm Z\,22\%$	mixing
			η_2^0: $\gamma\gamma\,34.5\%$, $Z\gamma\,31\%$, $ZZ\,34.5\%$, $W^+W^-\,0\%$	mixing
			φ^0	cascades
		1_0	η_3^0: $\gamma\gamma\,6.5\%$, $Z\gamma\,5.5\%$, $ZZ\,23\%$, $W^+W^-\,65\%$	WZW

Fermiophobic:



Fermiophilic:



- Identify new final states that we would want to study.
- $\eta_1^0\eta_2^0 \to (\gamma\gamma)(W^+W^-)$
- $\eta^+\eta^- \to (\gamma W^+)(\gamma W^-)$
- …

Contact: A. Crivellin

Generalized Georgi Machacek Model

- Assess the consistency of the like-sign WW excess in VBF of ATLAS with the CMS limit
- Is the neutral component compatible with the 95 GeV excess?
- Perform updated global fit with HEPfit
- Study possible cascade decays, i.e. $H^{++} \to H^{+}W$
- Propose dedicated searches
- Recast existing analyses

9 people in the working group (Skype chat)

Contact: A. Crivellin

Associated Production of a 95 GeV Scalar

- Take 95 GeV as a benchmark point to reduce the parameter space
- DY production via Z, W, photon
- Resonant symmetric Y->95+95 and asymmetric production Y->95+X
- Model independent associate production
  - 95+b, W ,Z ,t , j, lepton...
- Associate production from VLQ decays
- Perform Z->bb+WW as SM and NP search

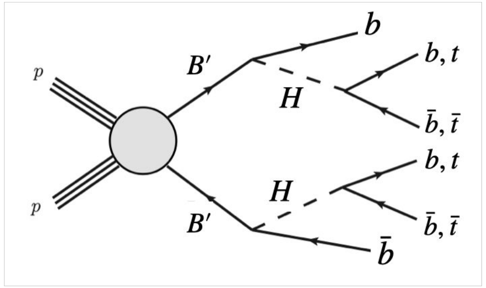
11 people in the working group (Skype chat)

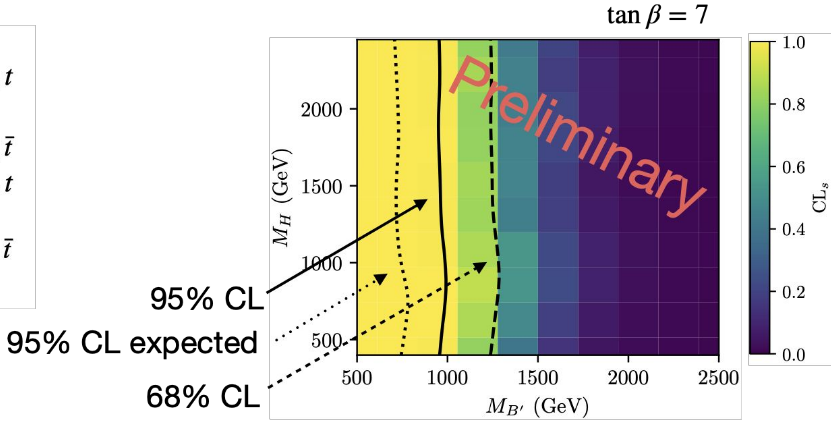
VLQ decays through new scalars

From R. Dermisek and J. Butterworth

Goal: set limits on VLQs decaying through new scalars

- starting example: $H, A, H^{\pm}$ in 2HDM with Type-II couplings and B'
- BRs set by quantum numbers and $\tan\beta$
- limits obtained using the UFO model to generate events with Herwig, and passing them to Contur/Rivet for comparison to a wide range of ATLAS and CMS differential cross section measurements





$(BSM)^2$

Contact: M. Spira

Precision BSM

- Goal: compile list of cases where precision calculations are important for BSM searches.
- Possible ways to improve precision (e.g. faster higher order corrections) → code improvements
- Awareness (e.g. large uncertainties in particular observable shapes)

Precision BSM

Contact: M. Spira

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Precision BSM
=============

- improved Born approximations: effective couplings, mixing angles etc.

- 'classifying' relevant HO corrections: 'generic' rules of thumb? generic origins of sizeable corrections? Shape uncertainties? Universality of HO corrections (e.g. DY, DIS-like)?
   Speed up existing codes, when moving to HO?

- realistic estimates of uncertainties for BSM predictions: sources, sizes, PDF uncertainties
           (how large is the uncertainty of missing BSM corrections in the PDF fits themselves? <- SMEFT fits by NNPDF)

- changes of shapes of distributions: 'generic' list where relevant? Sources (large logs, double logs, gluonic initial states etc.)?

- RGEs for SMEFT and other EFTs, decoupling of contributions to the running for LHC physics? Proper implementation of input scale and physical scales,
  shifts of input parameters, translations of different bases at HOs, impact of canonical normalization?
  E.g. d_t alpha_s = beta(NF,alpha_s) + c MH^2/Lambda^2 c_HG = light quark loops + top loop + Higgs loop <- decouple top, Higgs
   ==> d_t alpha_s = beta(5,alpha_s)

- backgrounds (<-> Session 1): tails of distributions, uncertainties (shapes, normalization), list of relevant background processes

- relevance of interference effects: SM+BSM, BSM+BSM -> rules of thumb? typical size?

- missing calculations: wishlist?

- what to do with BSM models that are not renormalizable? Uncertainties estimable? (guess not...)

Agreed tasks
============
Andi Crivellin: QED corrections to light charged scalar production   ✔
Engage experimentalists   ✔
```

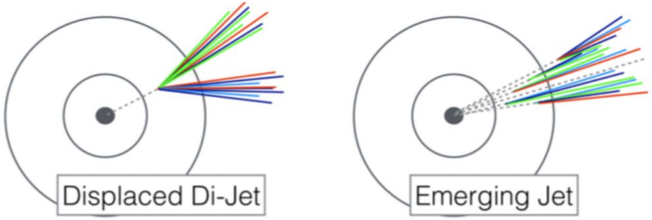
List of topics linked here: https://phystev.cnrs.fr/wiki/_media/2023:precisionbsm.txt

→ Writeup outlining the issues (improving awareness)

Contact: José Zurita, Manuel Szewc

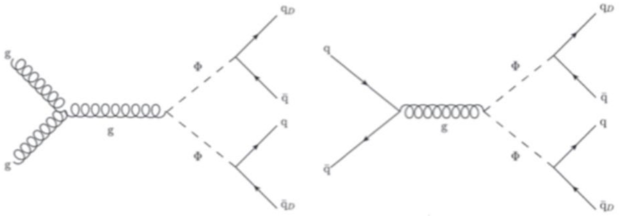
Emerging Jets

Dark mesons from a strongly-interacting dark sector have macroscopic lifetimes, $c\tau \sim 10^{-3} - 1$ m.
For shorter (longer) lifetimes, multi-jet (missing energy) searches apply.



t-channel (bifundamental) production

$$\mathscr{L} \supset -\kappa_{\alpha i}\, q_D^{\alpha}\, \phi\, \bar{q}_{Ri} + h.c.$$



Schwaller, Stolarski, Weiler, 1502.05409

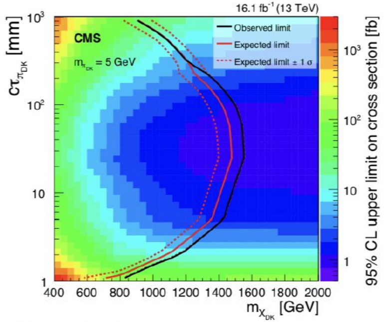
CMS search:

$R = 0.4$ jets, $N_j \geq 4$, $|\eta(j)| < 2.4, H_T > 900$ GeV

\+ EJ tagger based on displaced jet variables

Request 2 EJ and 2 normal jets (or 1 EJ+large MET)

First experimental result for emerging jets!



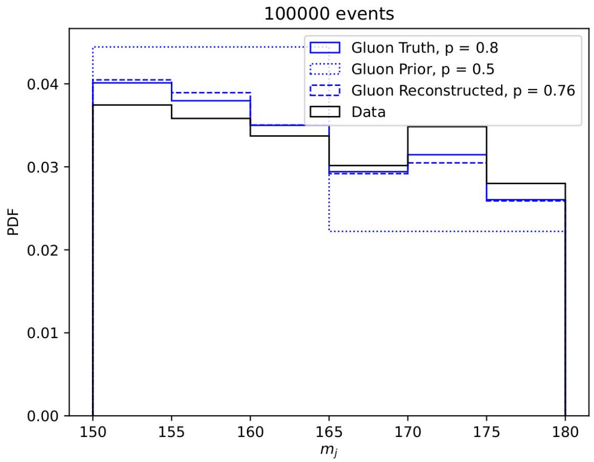
CMS Collaboration, 1810.10069

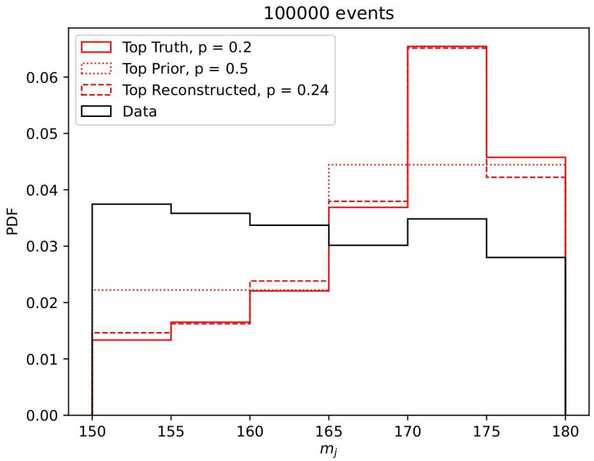
Emerging Jets

Contact: José Zurita,
Manuel Szewc

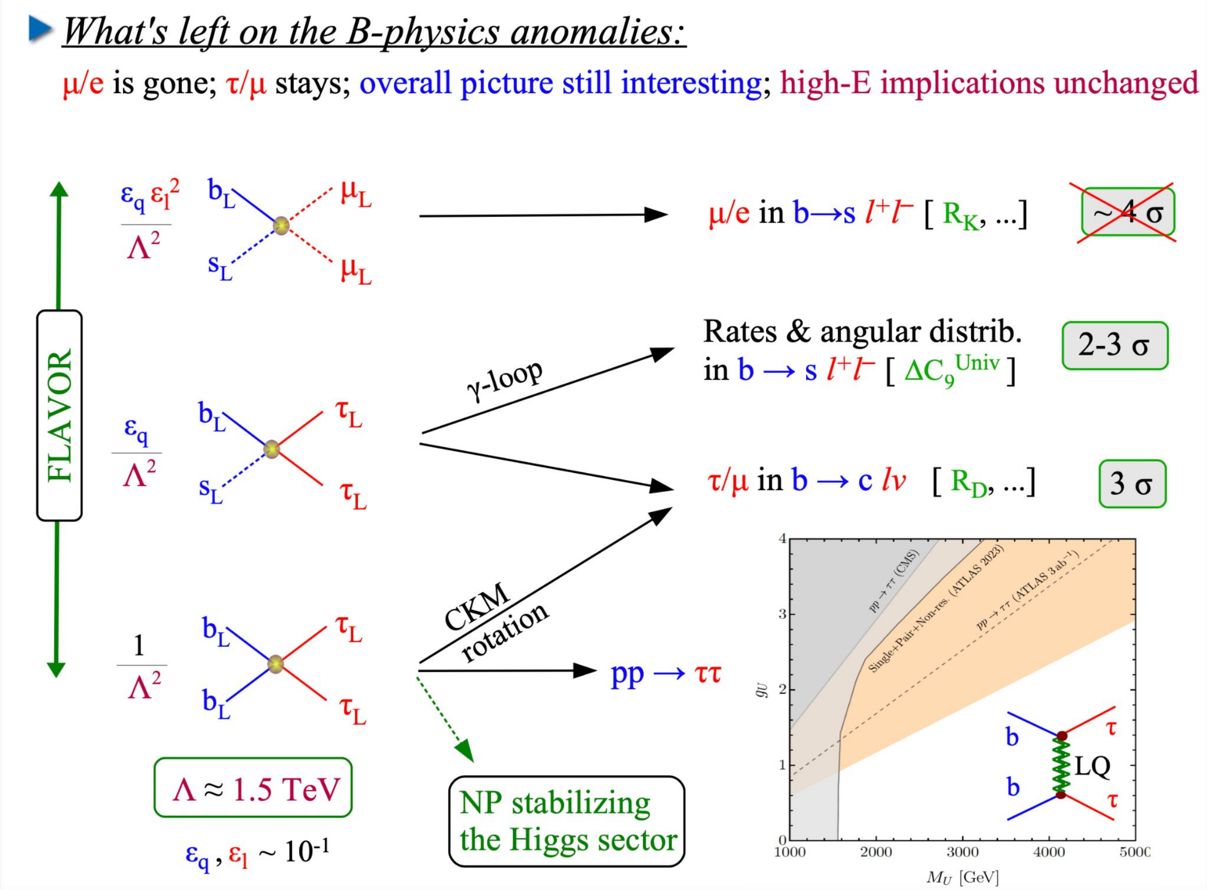
First crack: model p(jets) using a permutation invariant hierarchical mixture model

Example: gg vs tg, gt with toy data generated from MC data → Model recovers themes + proportion





Let it B: what's left of the B-anomalies



Contact: Andre Lessa

LLP Reinterpretation

Participants: Andrea Coccaro, Sabine Kraml, Andre Lessa, Zhen Liu, Sezen Sekmen, Jose Zurita

- Discussions about reinterpretation material for two LLP searches:
  - ATLAS-SUSY-2018-42: search for heavy stable charged particles
  - CMS-PAS-SUS-21-006: disappearing track - Newly published.
    - → Recommendations for reinterpretation material (LLP efficiencies, dE/dx,...)

- Ongoing/Future developments:

I. Delphes Module for LLPs:

- An official module for filtering LLPs and their daughters would be extremely useful
- A simple implementation by Andre Lessa exists. Plan to make it available for public use, and further, discuss with the Delphes team the possibility to make it a recognized part of Delphes releases.

II. Validation of CMS disappearing track recasting material (not yet available)

III. Physics impact of HSCP and DT searches on specific BSM scenarios (IDM?)

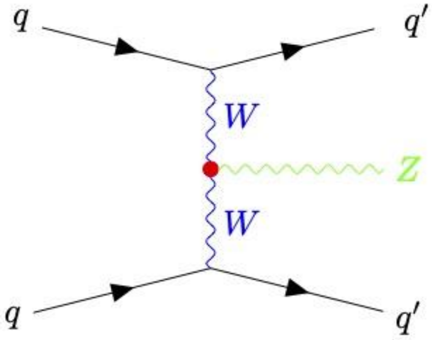
Tools

SMEFT searches: Z j j

Enough with EFT interpretations, let's **search** for it!

Showcase: triple gauge coupling (TGC) in the SMEFT at dim-6

$$\frac{\mathcal{L}_{WWV}}{-ig_{WWV}} = (1+\delta g_1^V)\left(W^+_{\mu\nu}W^{-\mu}V^{\nu} - W^+_{\mu}V_{\nu}W^{-\mu\nu}\right) + (1+\delta\kappa_V)W^+_{\mu}W^-_{\nu}V^{\mu\nu} + \frac{i\delta\lambda_V}{m_W^2}V^{\mu\nu}W^{+\rho}_{\nu}W^-_{\rho\mu}$$



$$\delta g_1^Z = \frac{1}{4\sqrt{2}G_F}\left(c_{\varphi D} - 4c_{\varphi l}^{(3)} + 2c_{ll} + 4\frac{m_Z}{m_W}\sqrt{1-\frac{m_W^2}{m_Z^2}}c_{\varphi WB}\right)$$

$$\delta\kappa_Z = \frac{1}{4\sqrt{2}G_F}\left(c_{\varphi D} - 4c_{\varphi l}^{(3)} + 2c_{ll}\right)$$

$$\delta\lambda_Z = -6\cos\theta_W\frac{m_W^2}{g_{WWZ}}c_W$$

Slide from Luca Mantani

Contact person: Admir Greljo

TO-DO list: strategy for a systematic EFT search

1. Choose a process / final state (Z j j) ✓
2. Theory: identify **target operators** ($c_{\varphi D}, c_{\varphi WB}, c_W$) ✓
3. Take into account constraints coming from other observables (EWPO) ✓
4. Study effects of operators at the matrix element level, **use physics intuition** to devise **sensitive observables at colliders** (e.g. lepton angular observables)
5. Perform a **fully-fledged simulation**: background, signal (SM + EFT), binned analysis on the promising observables
6. Are we better than machines? Compare results with a likelihood free inference based on ML methods (**ML4EFT**).

Next steps:

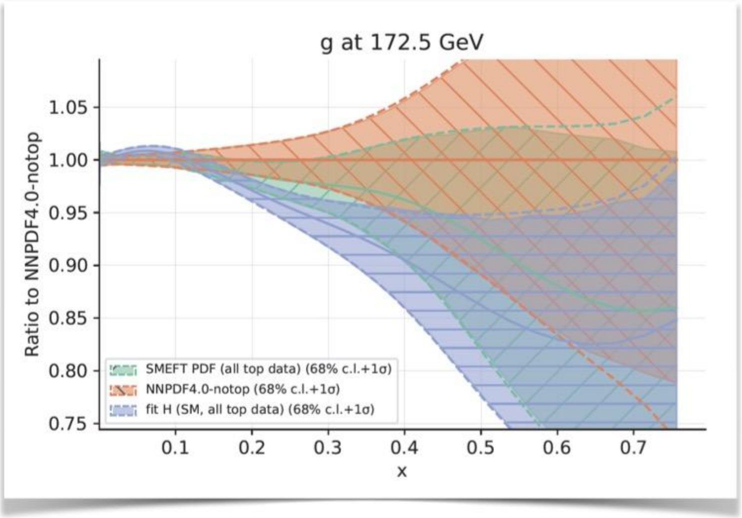
- Run madgraph + SMEFT@NLO to produce MC samples
- Study the helicity amplitudes, identify angular observables

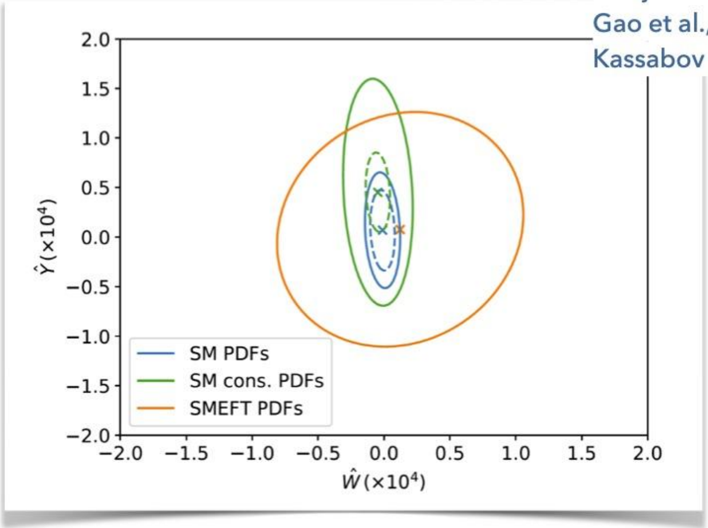
Slide from Luca Mantani

LES HOUCHES 2023: PDF–EFT

Neglecting the PDF-EFT interplay can lead to biased results in both SM and BSM predictions

Carrazza et al., 1905.05215
Greljo et al., 2104.02723
Gao et al., 2211.01094
Kassabov et al., 2303.06159





Goal: **assess possible 'contamination' of New Physics (NP) in PDF fits**

Contact: Maria Ubiali

LES HOUCHES 2023: PDF-EFT

Plan:

1. Assume the existence of NP in Nature and generate NP 'contaminated' pseudodata (eg, with a non-zero Wilson coefficient)
2. Fit PDFs to a global dataset (affected and not affected by NP)
3. Define quality metrics which could flag 'contaminated' datasets
4. See in which cases NP can be absorbed by the PDFs
5. Determine possible ways in which to disentangle this contamination (eg, ratio observables probing the same parton channels)

Alioli et al., 1706.03068
Farina et al., 1811.04084

An interesting case: $-\frac{Z}{2m_W^2}(D_\mu G^{\mu\nu A})^2$ affecting $t\bar{t}$ and jets

Thank you for your attention 🏔️

Contact: Marc Riembau

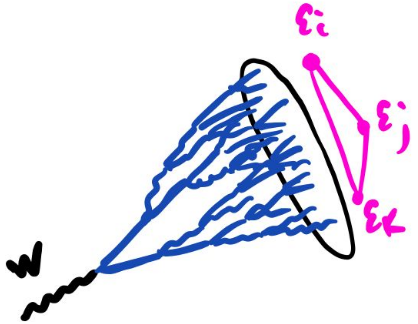
Energy correlators

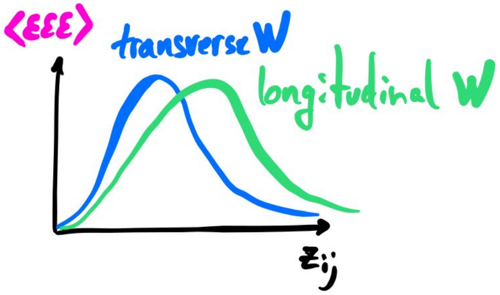
- Energy correlators are field-theoretically clean probes of QCD dynamics. In Les Houches we discussed explored potential phenomenological applications.

Main discussion around

How to construct statistically optimal

probes of the W boson density matrix out of ECs.





We've also discussed many other exciting directions:

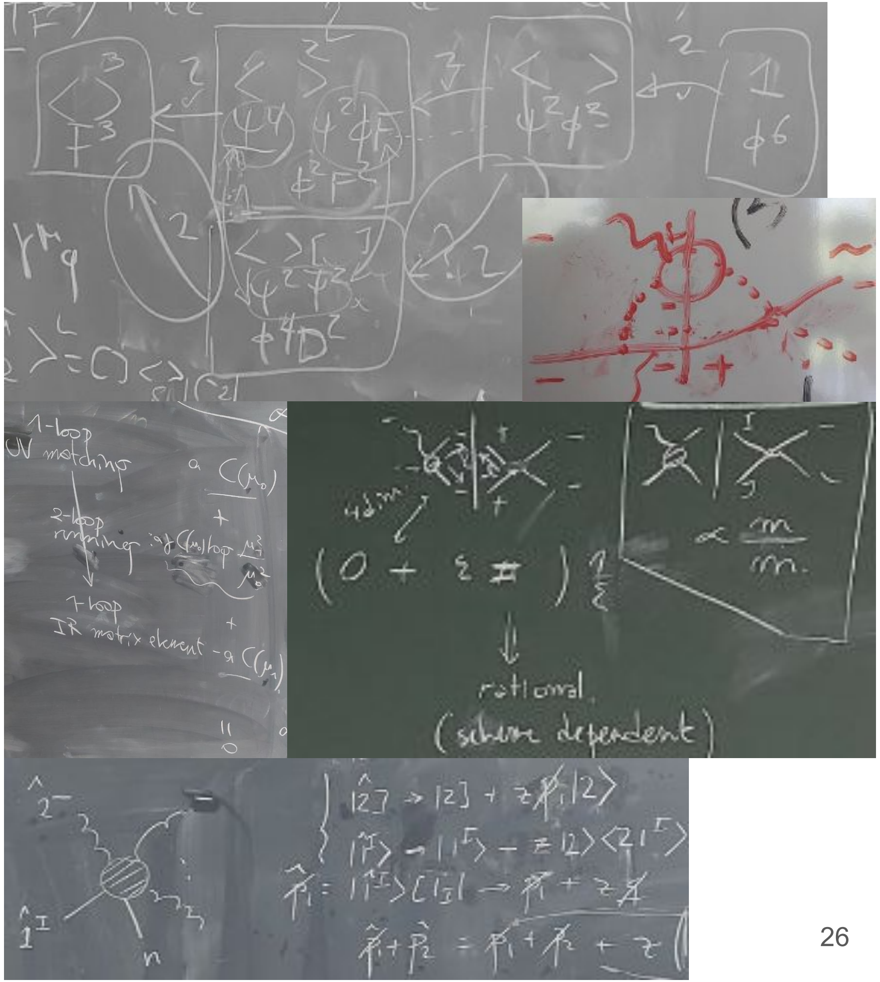
- Can we use them for dissecting top quark decay? A cleaner extraction of the top mass?
- Automatization of multi-dimensional EC calculation.
- Flavoured Energy Correlators?
- Probe EFT operators via back-to-back correlations in dijet searches
- Time-dependent energy correlators

EFT on-shell

contact: Gauthier Durieux

Several topics discussed: [Hesham, Julie, Marc, …]

- Missing “easy” two-loop anomalous dims
  - From just tree-level amplitudes (triple cuts) and possibly also finite one-loops (double cuts)
- Rational ε/ε terms due to Dirac algebra in d-dim vs. 4-dim on-shell cuts
  - “Evanescent” operators, d-dim Fierz and associated scheme dependences
- Tree-level recursion relations with massive particles and EFT interactions

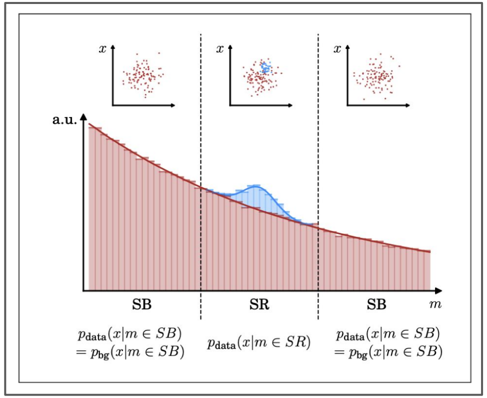


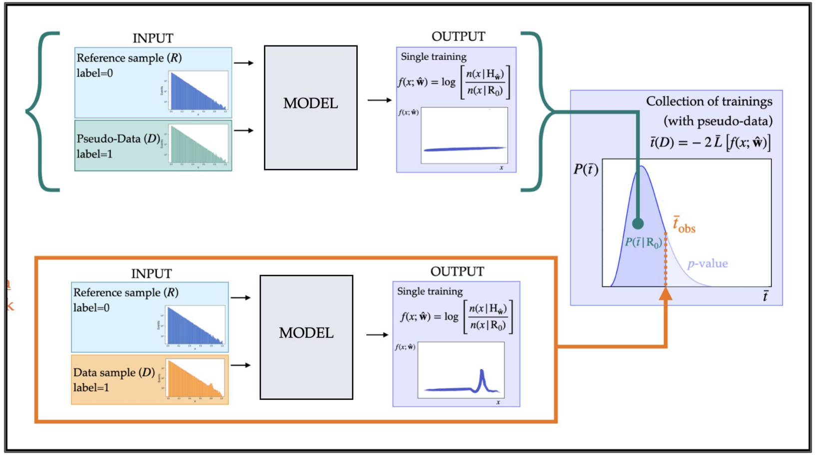
Contact: M. Sommerhalder, G. Grosso

Signal agnostic searches based on ML tools

Classifying Anomalies THrough Outer Density Estimation (CATHODE, 2109.00546)

- Resonant **anomaly detection**
- Assumption: **localised signal** in y variable
- Learn p(x|SM) from the side band (SB) regions
- Train a **classifier c(x)** to distinguish data and background samples in the signal region (SR)
- Apply a **selection** based on the **classifier output** score (c(x)>thr) to get a signal enriched sample
- Scan windows in y (**BumpHunt** search)





New Physics Learning Machine (NPLM, 1806.02350)

- Signal agnostic **statistical test** for New Physics discovery (GOF method)
- **Maximum likelihood ratio test**, solved as a ML problem (output a p-value)
- Deals with **systematic uncertainties** affecting the background model (2111.13633)

Contact: M. Sommerhalder, G. Grosso

Resonance searches *without BumpHunt*?

CATHODE+NPLM

Possible combinations that we want to test:
- p(x, y|SM), c(x), y[c(x)>thr] (CATHODE) —> NPLM on y[c(x)>thr] (**1 dimensional analysis**)
- p(x, y|SM), c(x) (CATHODE) —> NPLM on (y, c(x)) (**2 dimensional analysis**)
- p(x, y|SM) (CATHODE) —> NPLM on (y, x) (**n+1 dimensional analysis**)

Study the trade-off between:
- Sensitivity degradation due to scale of dimensionality in NPLM
- Robustness of hyper-parameter selection in CATHODE

Datasets: LHC Olympics dataset (moving to NPLM benchmarks, QCD/top jets dataset in the future)

Points emerged from the first **hands-on sessions**:
- We identified some technical issues affecting the combination and figured out possible strategies to solve them
- We discussed the problem of **systematic uncertainties** that may arise from CATHODE modelling of the background: which ones and how to properly describe them through nuisance parameters?
- We considered to compare with the alternative solution proposed by Manuel Szewc et al. (2210.02226) to test for independence of y and c(x))

Code availability (longer term goal): general framework for signal agnostic tools

Classifier-based metrics for generative models at HEP

Various generative models on the market, but only limited thoughts on how well do their jobs. Idea: Propose new metrics and evaluate them on a class of generative models.

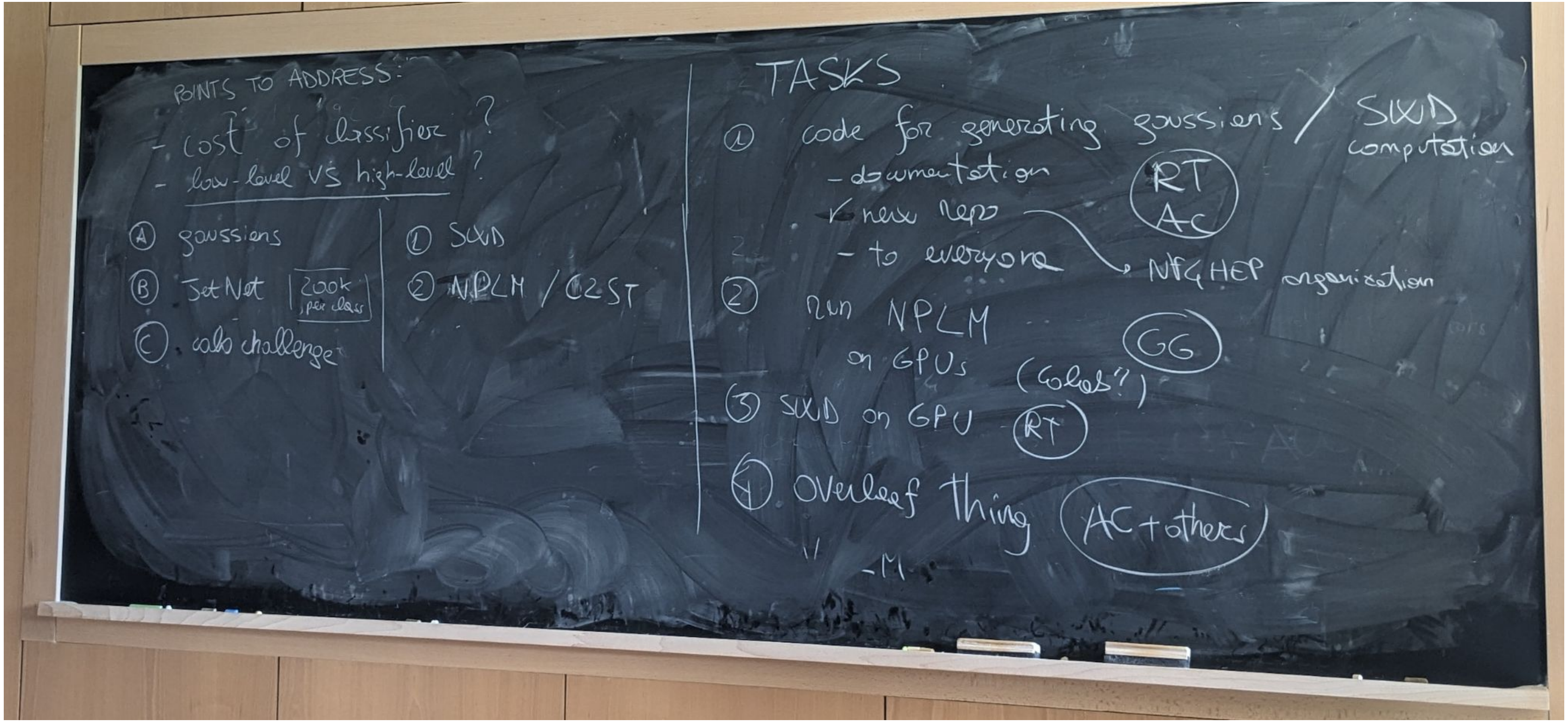
Work while at Les Houches

- Review of generative metrics and related literature
  - GAN and VAE are no longer the status-of-the-art, investigated also with ATLAS full-sim in 2210.06204
  - More focus on NF, diffusion models are gathering interest
  - Some recent efforts more towards NF, see 2302.12024, 2211.10295
- Discussion on possible datasets and usecases
  - Multi-D gaussians, not limited by statistics, code available, more in 2302.12024
  - CaloChallenge, 2022 edition, more here
  - Z+jets events used in 2305.10475
- Discussion on metrics and next steps
  - Non-classifier metrics: Wasserstein distance, Frechet physics distance, Frobenius norm, KS test, etc.
  - Classifier metrics: classifier accuracy (2106.05285), multi-model classifier (2211.11765), classifier weights (2305.16774), NPLM (1806.02350)

Main direction of investigation: investigate NPLM on NF trained on gaussians, then possibly expand on more datasets and generative methods.

Classifier-based metrics for generative models at HEP

- GitHub with some code is already available in NF4HEP organisation, link
- First task assigned, overleaf document will grow here
- Looking forward to keep working on this project. Contacts: A. Coccaro & R. Torre



Contact:
Tomasz Procter, Sezen Sekman

ML reinterpretation: Guidelines for the future

Many analyses use advanced ML methods for both object/event handling.
Publishing ML models + validation information is crucial to enable reinterpretation.

Only small handful of analyses with public ML material.

Goal is to provide a “LH guidelines/wishlist” document focusing on

- Storing and sharing networks
- Validation Information: inputs, outputs and the network itself.
- Impacts on analysis design
  - Can we use more helpful inputs?
  - When are efficiencies/a surrogate a better choice?

Started documenting on overleaf.

ML reinterpretation: surrogate models

- Can a model trained on high level features give us
- a good representation of a low level tagger?
- Made workflow for initial tests using open data
- Parton vs Particle vs Reco approach
- Some promising early results!
- Feel free to throw your own NNs at the dataset!

Full low level features: particle flow constituents with kinematic, PID & displacement
Target Model: ParT_Full

Already available

Restricted low level features: particle flow constituents with kinematic, ~~PID & displacement~~
Target Model: ParT_Kin

Reco Level Surrogate

High level features from Delphes/Smearing
jet: pt, η, ϕ, E
nparticles, $m_{softdrop}$
τ1, τ2, τ3, τ4

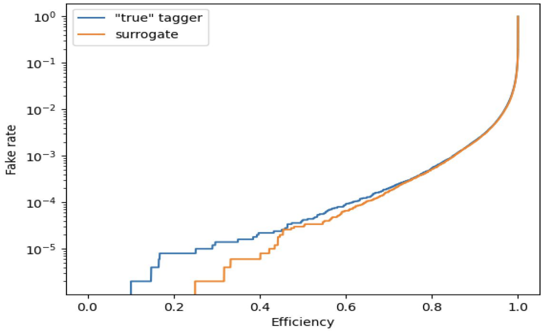
Parton Level Surrogate

Truth level kinematics including parent label
jet η, ϕ, pid, pt, truthmatch

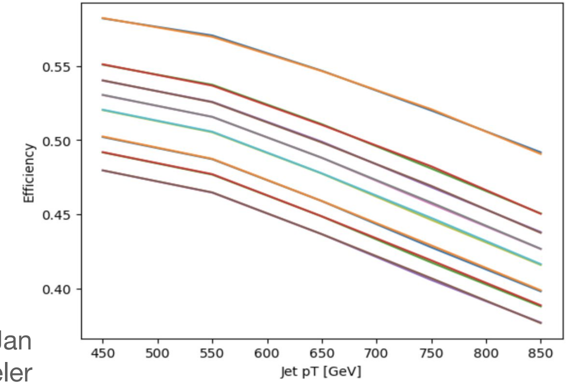
Particle Level Surrogate

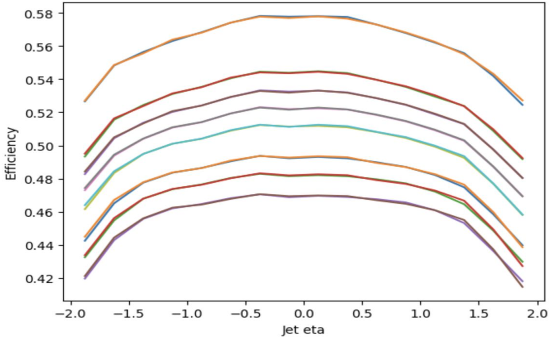
Truth level kinematics (stable Pythia particles but no parent ID)

Diagram: Gregor Kasieczka



Plots: Jan Kieseler

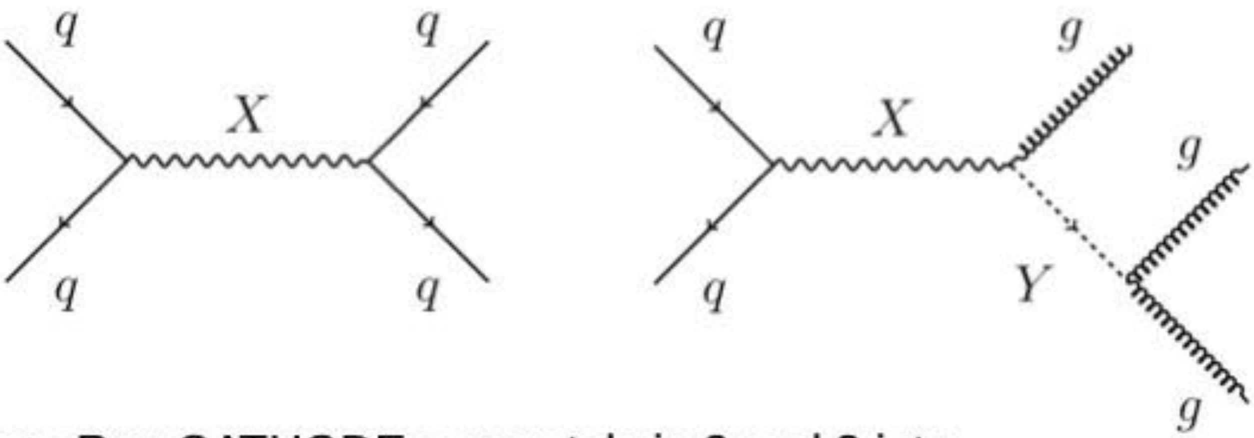




Anomaly with multiple final states

Detecting resonant anomalies with a single final state is essentially solved

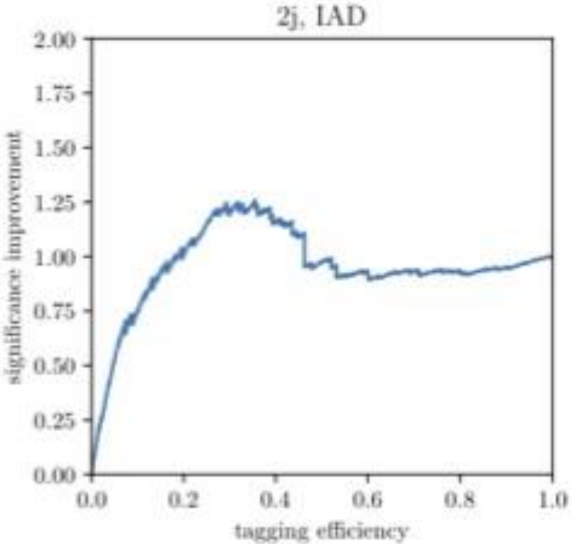
More challenging: multiple decay modes, e.g. LHCO Black Box 3 [2101.08320]

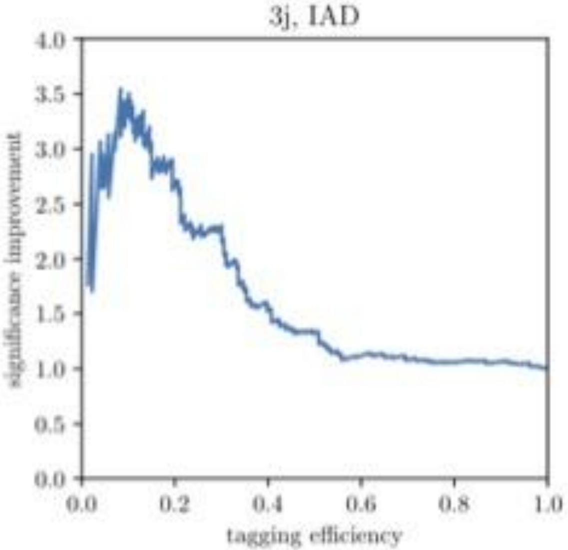


Strategy: Run CATHODE separately in 2 and 3 jets events, then combine results

Anomaly with multiple final states

Trained an idealised setup with perfect background estimation





~~QCD~~ **ML** Room

Significance improvement of **~2** on the combined dataset

Low-energy precision tests

Image: Andy Potts/ https://www.5280.com/countrys-accurate-atomic-clock-boulder/

Big questions

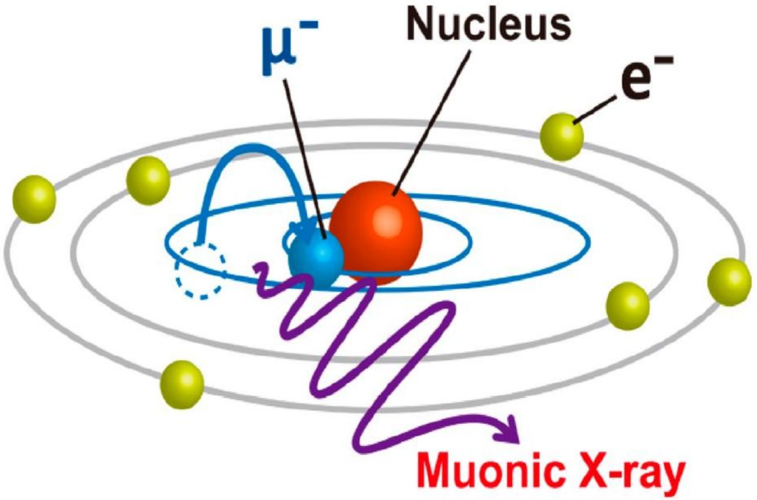
Which well-motivated models predict light new particles?

Which observables in atoms & ions can be measured very precisely?

Find motivated scenarios that are testable in the near future

Mentally challenging muonic atoms

Slide by Natalia Oreshkina



Asocial far from electrons, always H-like

Unhealthy lifetime: 0.1 - 2.2 microseconds

Destructive $\mu^- + p \rightarrow n + \nu_\mu$

Non-cooperative passive spectroscopy 5g - 4f - 3d - 2p - 1s

Demanding complicated many-loops bound QED

Co-dependent highly sensitive to nuclear structure:
dynamical structure/splitting $|\mu\rangle \rightarrow |\mu\rangle \otimes |N\rangle$
And now to the bad part... nuclear polarization: includes the complete muon and nuclear spectra

Why don't we ignore it? Give best probes of the short-ranged interactions

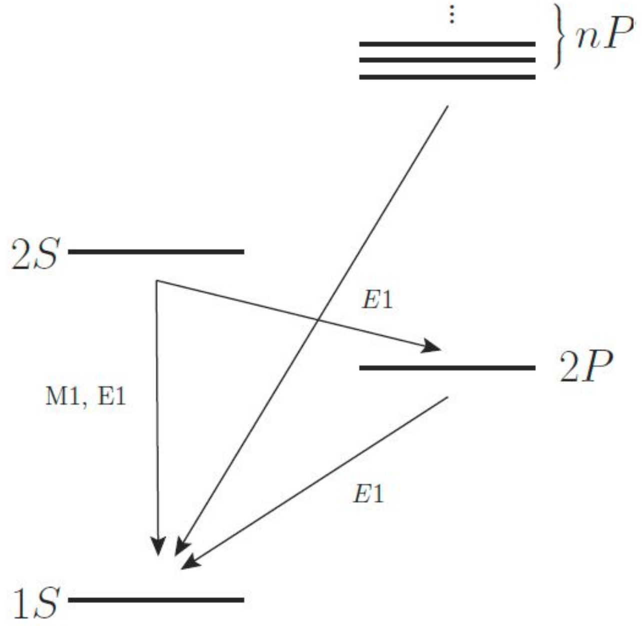
Finding a suitable system of muonic atoms for APV

Slide by Sebastian Lahs

Challenges:

- How to increase production of muonic atoms (choice of target)
- How to bring the maximal number into the 2S state?
- How to reduce backgrounds from other transitions?
- What is the best scheme to measure the dipole-forbidden, parity-allowed transition?

- Cf. Excited to excited PV test in Dysprosium



New Physics contributions to Atomic Parity Violation

Goal:

Calculate BSM shift to APV

1. Classify NP according to Lorentz structure

   ⟶ Independent of exp. system

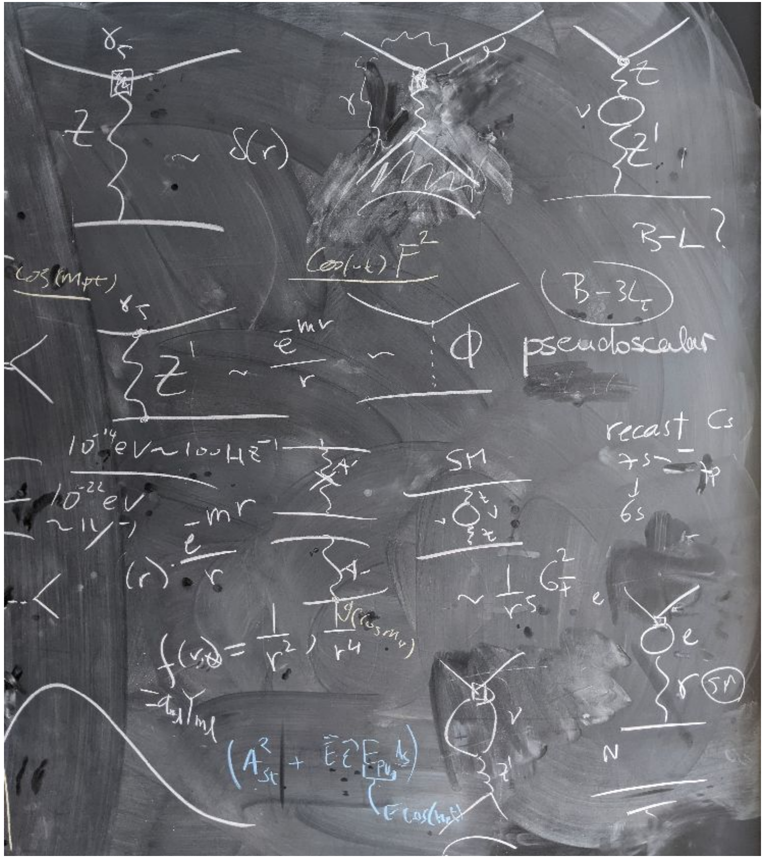
2. Calculate the NP contributions to APV

   ⟶ in muonic & electronic atoms

   r-dependent part of form factor

3. Interpret existing bounds in different NP models

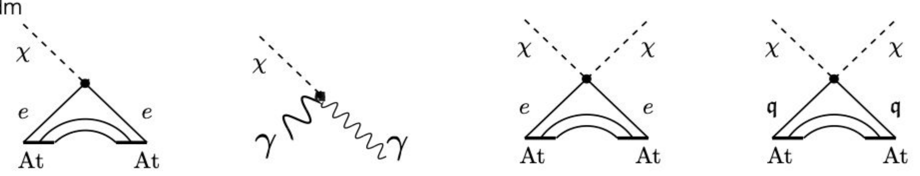
4. Suggest new measurements



Dictionary: EFT from high to low energies

e.g. **absorption** process **scattering** process

gw, nu, dm



The ***first*** job of the theorist:

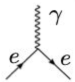
classify the possible relevant interactions (from different motivations)

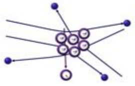
e.g. $\bar{\psi}_e O \psi_e \chi$ $\bar{\psi}_e \bar{\chi} O \psi_e \chi$

compare with standard model interactions

$\bar{\psi}_e \gamma^\mu \psi_e A^\mu$

electron-photon



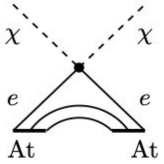


atoms with surrounding gas

Kibble 1304.3486

The ***second*** job of the theorist:

connect fundamental terms to the **effective theory** relevant for the experiment



e.g. $\bar{\psi}_e \gamma^\mu \gamma_5 \psi_e \bar{\chi} \gamma_\mu \chi \rightarrow \vec{S}_e \cdot \vec{p}_\chi$

compare with standard EM interactions

$\bar{\psi}_e \gamma^\mu \psi_e A_\mu \rightarrow \vec{p}_e \cdot \vec{A}$, $g_e \vec{S}_e \cdot \vec{B}$

doing this **comprehensively** is a pending task!

Diego Blas' Slide

Job of the Dictionary

↓

A complete translation of Low Energy Hamiltonian to High Energy Physics Operators

Contact : Diego Blas, Fiona Kirk, Ben Roberts, Dipan Sengupta

Dictionary: EFT from high to low energies

Slide by Dipan Sengupta, Fiona Kirk

High Energy Physics Lagrangian

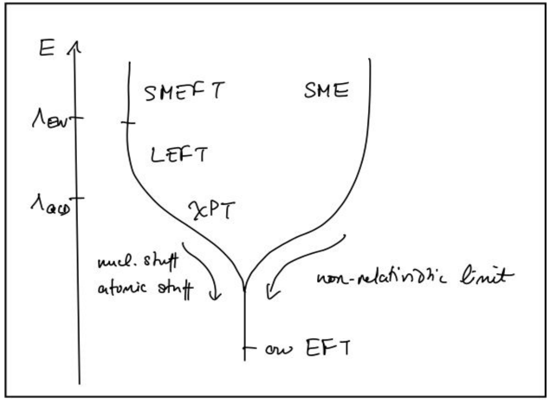
↓

Lorentz Violating
Kostelecky Basis

↓

Is there anything left to be done ? Literature search/holes etc

Lorentz Conserving
Diego Blas +Les Houches Classification

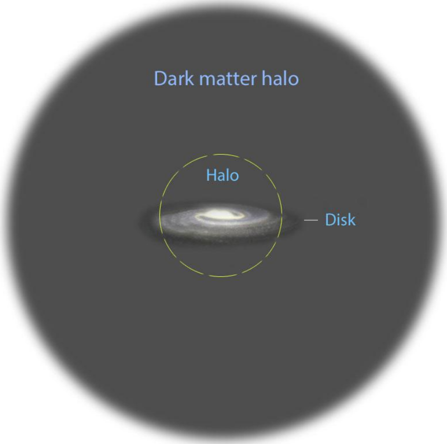


Many to One Mapping from High Energy to Low Energy

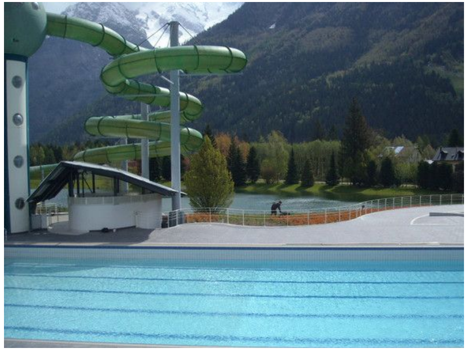
Matching Ultralight DM onto the SME (SM Extension)

Slide by Fiona Kirk

Spot the similarity



Milky Way model



Chamonix swimming pool

An ultralight dark matter background spontaneously breaks Lorentz invariance.
-> e.g. Cherenkov radiation

[Submitted on 24 Sep 1998]

Lorentz-Violating Extension of the Standard Model

Don Colladay, Alan Kostelecky

$$\mathcal{L}^{\rm CPT-even}_{\rm lepton} = \tfrac{1}{2} i (c_L)_{\mu\nu AB} \overline{L}_A \gamma^\mu \overleftrightarrow{D^\nu} L_B + \tfrac{1}{2} i (c_R)_{\mu\nu AB} \overline{R}_A \gamma^\mu \overleftrightarrow{D^\nu} R_B \quad ,$$

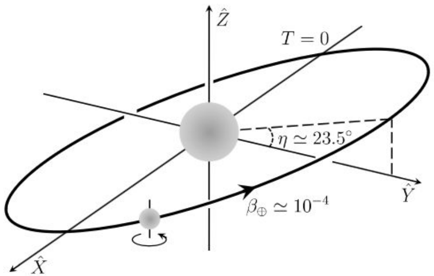
$$\mathcal{L}^{\rm CPT-odd}_{\rm lepton} = -(a_L)_{\mu AB} \overline{L}_A \gamma^\mu L_B - (a_R)_{\mu AB} \overline{R}_A \gamma^\mu R_B$$

[Submitted on 1 Jan 2008 (v1), last revised 9 Jan 2023 (this version, v16)]

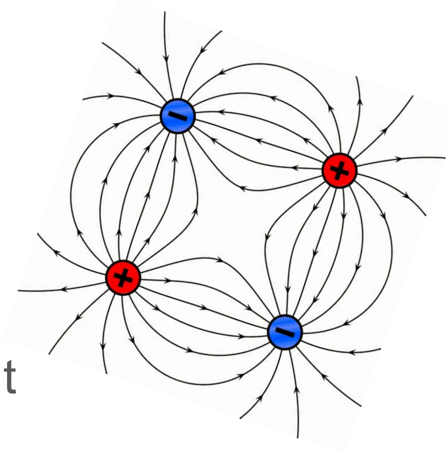
Data Tables for Lorentz and CPT Violation

Alan Kostelecky, Neil Russell

$d=4$	Coefficient	Sensitivit
	$k^{(4)}_{(E)20}$	10^{-35}
	$\mathrm{Re}\, k^{(4)}_{(E)21}$	10^{-35}
	$\mathrm{Im}\, k^{(4)}_{(E)21}$	10^{-35}
	$\mathrm{Re}\, k^{(4)}_{(E)22}$	10^{-35}



Ultralight Quadrupolar dark matter



- If dark matter only interacts through quadrupole interactions, (and it is too light, to be detected in recoil experiments), it might avoid a lot of experimental constraints
- As an ultralight bosonic field, it might lead to the oscillation of atomic energy levels with quadrupole moment
- $$i\kappa_\Lambda V^\dagger_\mu V_\nu F^{\mu\nu} + \frac{i\lambda_\Lambda}{\Lambda^2} V^\dagger_{\lambda\mu} V^\mu{}_\nu F^{\nu\lambda}$$
- One could construct a UV model for quadrupole DM based on dark SU(4).

Slide by Sebastian Lahs, Deog Ki Hong

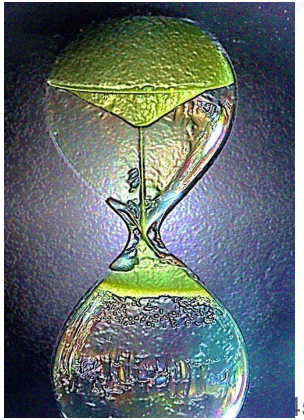
light *TOPE* Boson

Slide based on Sebastian Lahs'

light *TOPE* Boson

Slide by Sebastian Lahs

- TOPE = T odd, P even => C odd
- If a new physics TOPE interaction is transmitted through a short range mediator, EDM measurements give very strict constraints
- If it is however a long range interaction, it is suppressed by the smallness of Parity violation in atoms
- It might be interesting to construct new TOPE models (maybe a dark matter one)
- New experiments are needed to put direct limits on TOPE -> how to make one?



Big questions

Which well-motivated models predict light new particles?

Which observables in atoms & ions can be measured very precisely?

Going beyond minimal models and exploited atomic systems!