2015 expectations

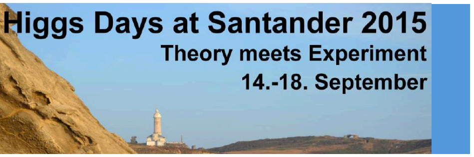
2015 expectations and reality

[Courtesy of Mauro Donegà]

MIDDLE WAY

KAPPAS
FIDUCIAL CROSS-SECTIONS

EFFECTIVE FIELD THEORY
WILSON COEFFICIENTS



André David (CERN)

KAPPAS
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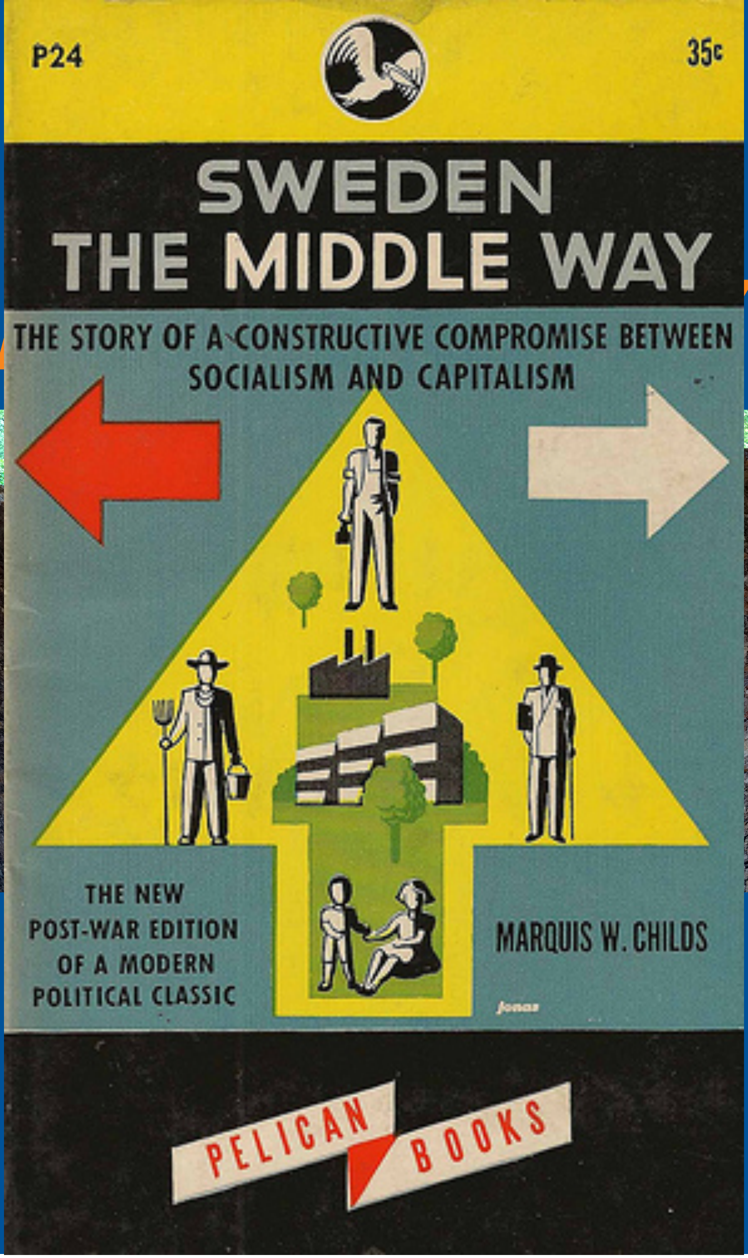

EFFECTIVE FIELD THEORY
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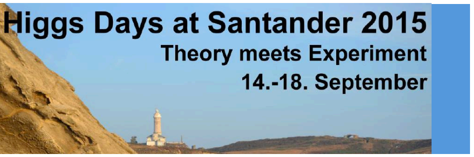


André David (CERN)

4-box summary

Kappas cannot describe many SM deformations.

Fiducial cross-sections are not Physics.

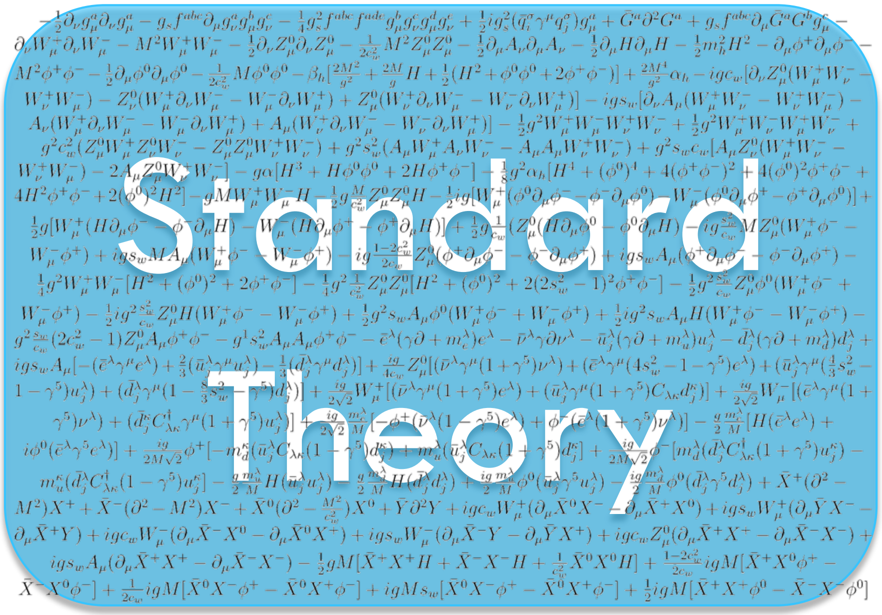
Wilson coefficients are not physical.

Need to **extend kappas** to something **between the other two.**

As seen on (Spanish) TV

The Next Standard Model

[http://cern.ch/go/dW6z]



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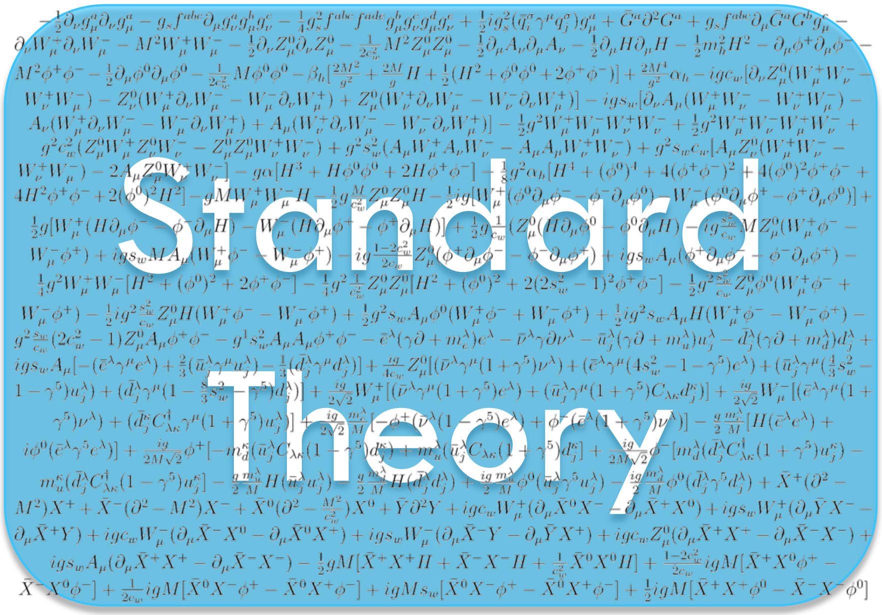

+

Something else

As seen on (Spanish) TV

Supplementing the Standard Theory

Concrete BSM

- SUSY: MSSM, NMSSM, etc.
- Possibly:
  - Light new physics.
  - Other states.
  - Non-decoupled.
- Specific benchmarks.
  - LHC HXSWG WG3.

EFT expansion

- Add higher-dimensional operators.
- Assumes:
  - Heavy new physics.
  - Indirect effects, loops.
  - Decoupled.
- Generic interpretation.
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Not all EFT are born the same

[http://cern.ch/go/L98Q]

Top-down EFT	**Bottom-up EFT**
Full theory known: - Matching conditions bridge EFT and full theory.	Full theory **un**known: - Add operators as theory can calculate and data can discern.

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Bottom-up EFT

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EFT vs. Effective Lagrangians

arXiv.org > hep-ex > arXiv:1508.02507

High Energy Physics – Experiment

Constraints on non-Standard Model Higgs boson interactions in an effective field theory using differential cross sections measured in the $H \to \gamma\gamma$ decay channel at $\sqrt{s} = 8$ TeV with the ATLAS detector

ATLAS Collaboration

(Submitted on 11 Aug 2015)

- Let's look at the relevant references:
  - [3] Sec. 10.4 is titled "**Effective Lagrangians** for Higgs interactions".
  - [4] titled "**Effective lagrangian** analysis […]".
  - [5] abstract "dimension-six operators in the **effective Lagrangian**".
  - [6] abstract "An **effective […] Lagrangian** approach".
  - [7] an actual **EFT** basis that is not used in the preprint.
  - [8] titled "**Effective Lagrangian** for a light Higgs-like scalar".
  - [10] is titled "Phenomenology of the Higgs **Effective Lagrangian** via FeynRules".
  - [11] mentions in the abstract "parametrizing BSM effects with **dimension-six operators**".
  - [12] is the only one to mention "**effective field theory**" (in the abstract, not the title).
- Ref. [10] **neglects operators** by using "a set of […] operators assumed to encompass all possible effects of new physics on the Higgs sector".
  - **Whether this assumption is a good one depends on the goal: see, e.g., 1508.05060.**

A taxonomy of dim-6 SMEFT operators

[Trott et al. JHEP 04 (2014) 159]

Class	N_{op}	CP-even			CP-odd		
		n_g	1	3	n_g	1	3
$1: X^3$	4	2	2	2	2	2	2
$2: H^6$	1	1	1	1	0	0	0
$3: H^4 D^2$	2	2	2	2	0	0	0
$4: X^2 H^2$	8	4	4	4	4	4	4
$5: \psi^2 H^3 + \mathrm{h.c.}$	3	$3n_g^2$	3	27	$3n_g^2$	3	27
$6: \psi^2 X H + \mathrm{h.c.}$	8	$8n_g^2$	8	72	$8n_g^2$	8	72
$7: \psi^2 H^2 D$	8	$\frac{1}{2}n_g(9n_g+7)$	8	51	$\frac{1}{2}n_g(9n_g-7)$	1	30
$8: (\overline{L}L)(\overline{L}L)$	5	$\frac{1}{4}n_g^2(7n_g^2+13)$	5	171	$\frac{7}{4}n_g^2(n_g-1)(n_g+1)$	0	126
$8: (\overline{R}R)(\overline{R}R)$	7	$\frac{1}{8}n_g(21n_g^3+2n_g^2+31n_g+2)$	7	255	$\frac{1}{8}n_g(21n_g+2)(n_g-1)(n_g+1)$	0	195
$8: (\overline{L}L)(\overline{R}R)$	8	$4n_g^2(n_g^2+1)$	8	360	$4n_g^2(n_g-1)(n_g+1)$	0	288
$8: (\overline{L}R)(\overline{R}L)$	1	n_g^4	1	81	n_g^4	1	81
$8: (\overline{L}R)(\overline{L}R)$	4	$4n_g^4$	4	324	$4n_g^4$	4	324
8 : All	25	$\frac{1}{8}n_g(107n_g^3+2n_g^2+89n_g+2)$	25	1191	$\frac{1}{8}n_g(107n_g^3+2n_g^2-67n_g-2)$	5	1014
Total	59	$\frac{1}{8}(107n_g^4+2n_g^3+213n_g^2+30n_g+72)$	53	1350	$\frac{1}{8}(107n_g^4+2n_g^3+57n_g^2-30n_g+48)$	23	1149

Table 2. Number of CP-even and CP-odd coefficients in $\mathcal{L}^{(6)}$ for n_g flavors. The total number of coefficients is $(107n_g^4+2n_g^3+135n_g^2+60)/4$, which is 76 for $n_g=1$ and 2499 for $n_g=3$.

EFT questions

- From 2499 dim-6 operators to ~60 operators.
  - **Symmetries** guide the culling:
    - Flavour, ~custodial, CP.
    - Each assumption needs **testing** measurements/observables.

- But to go down from ~60:
  - Guidance from **experimental sensitivity**.
  - Use **complementary information**:
    - LEP, Tevatron, etc experimental constraints.
    - aTGC/aQGC, top quark, EDM searches, etc.

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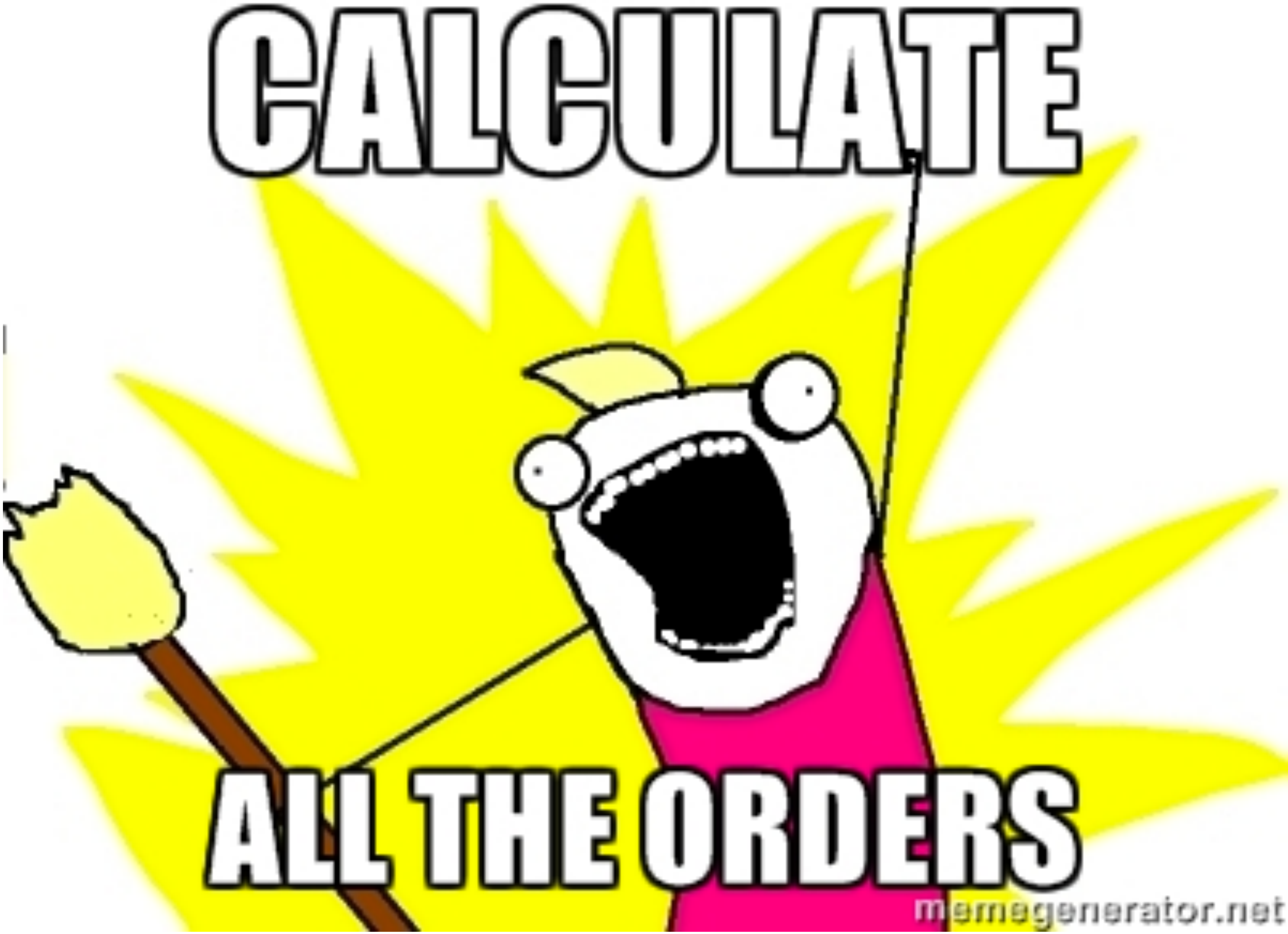
EFT cuts across

colliders (ee, eh),

sectors (multi-bosons, top),

and **searches** (LFV, EDM)…


CALCULATE
ALL THE ORDERS
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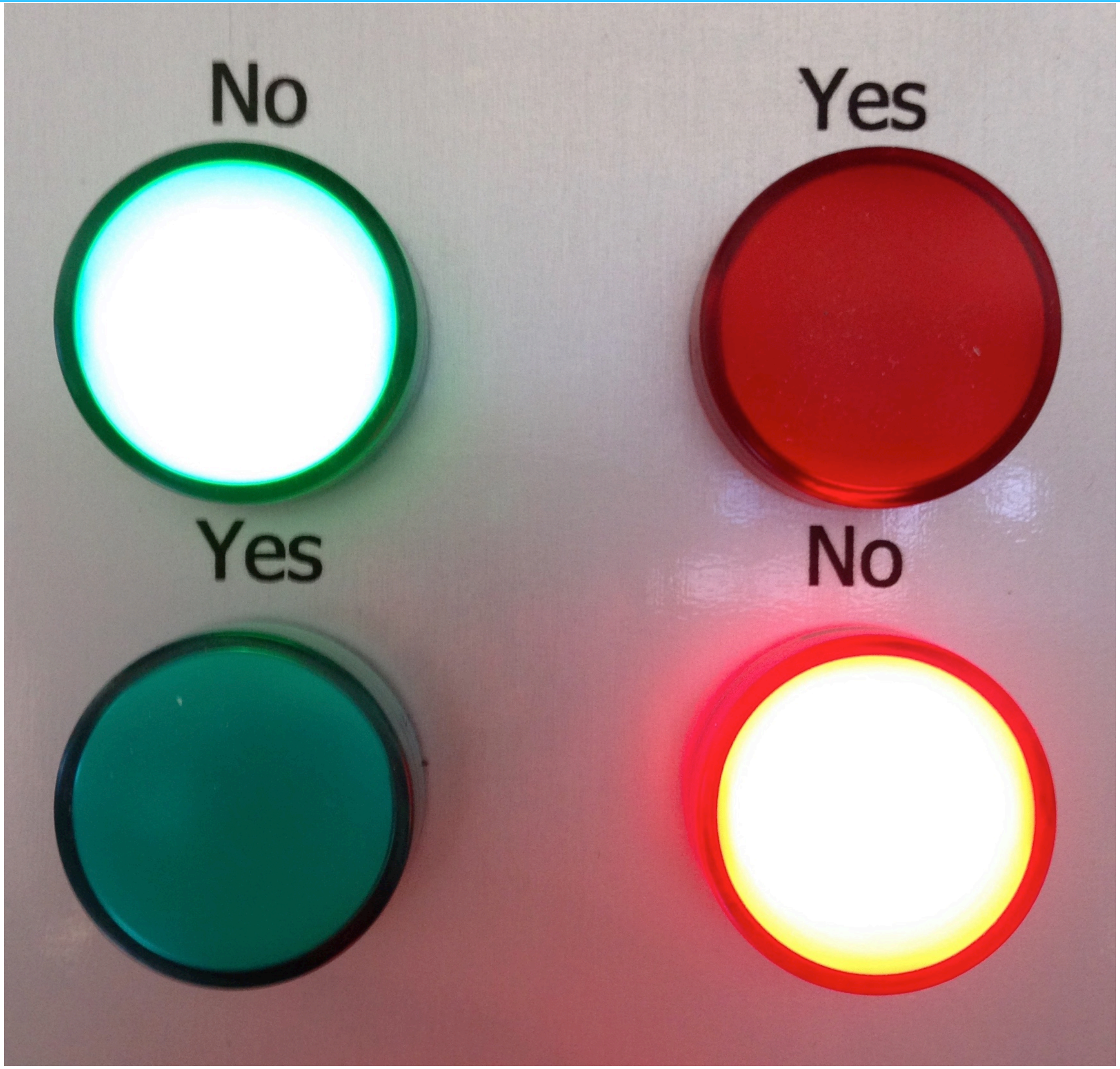
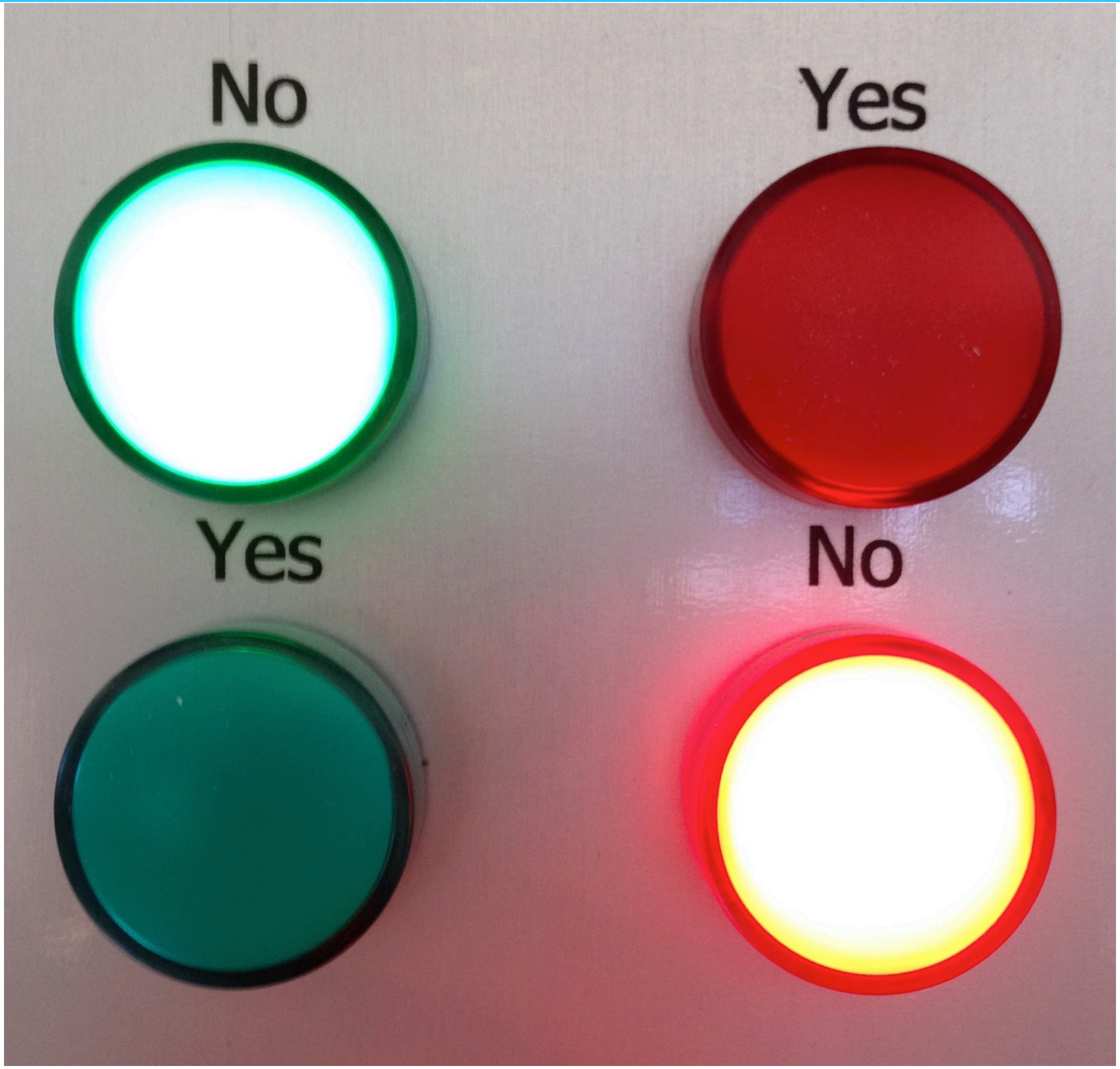
Summary: Effective Lagrangians



Summary: Effective Lagrangians

Can't we just fit one operator at a time?

Are we ready to do the global fit?



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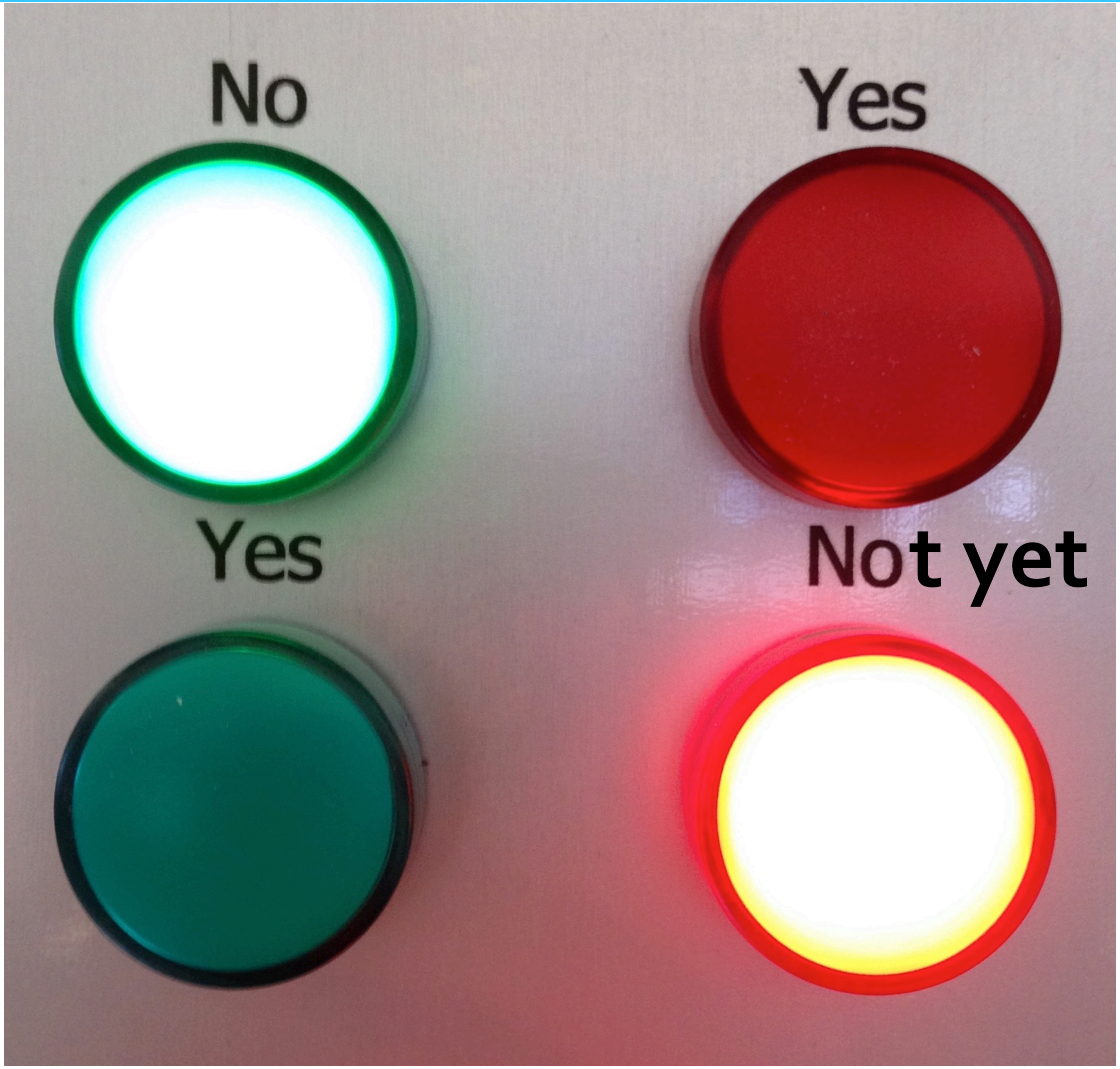

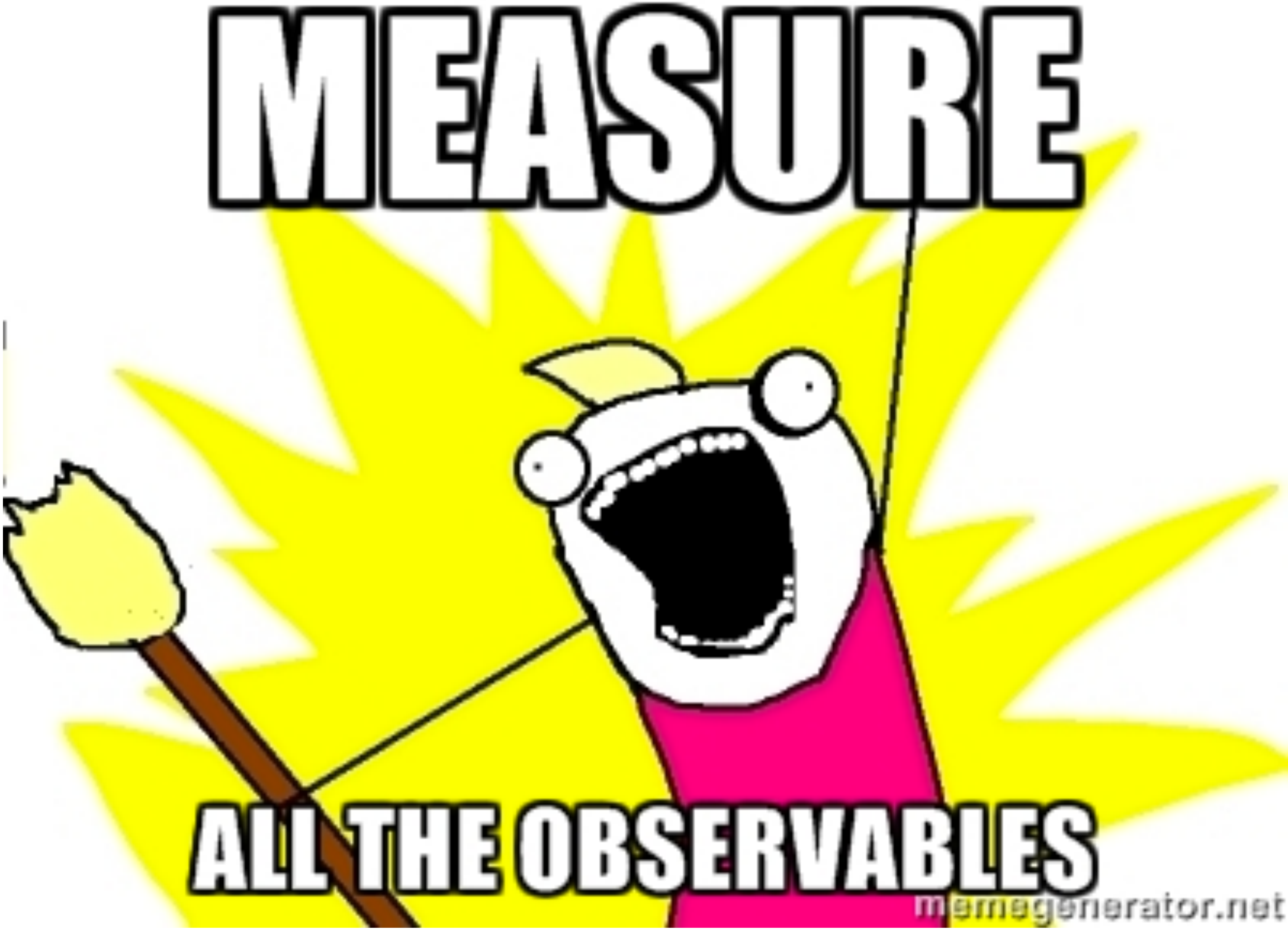
MEASURE
ALL THE OBSERVABLES
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ONE ?
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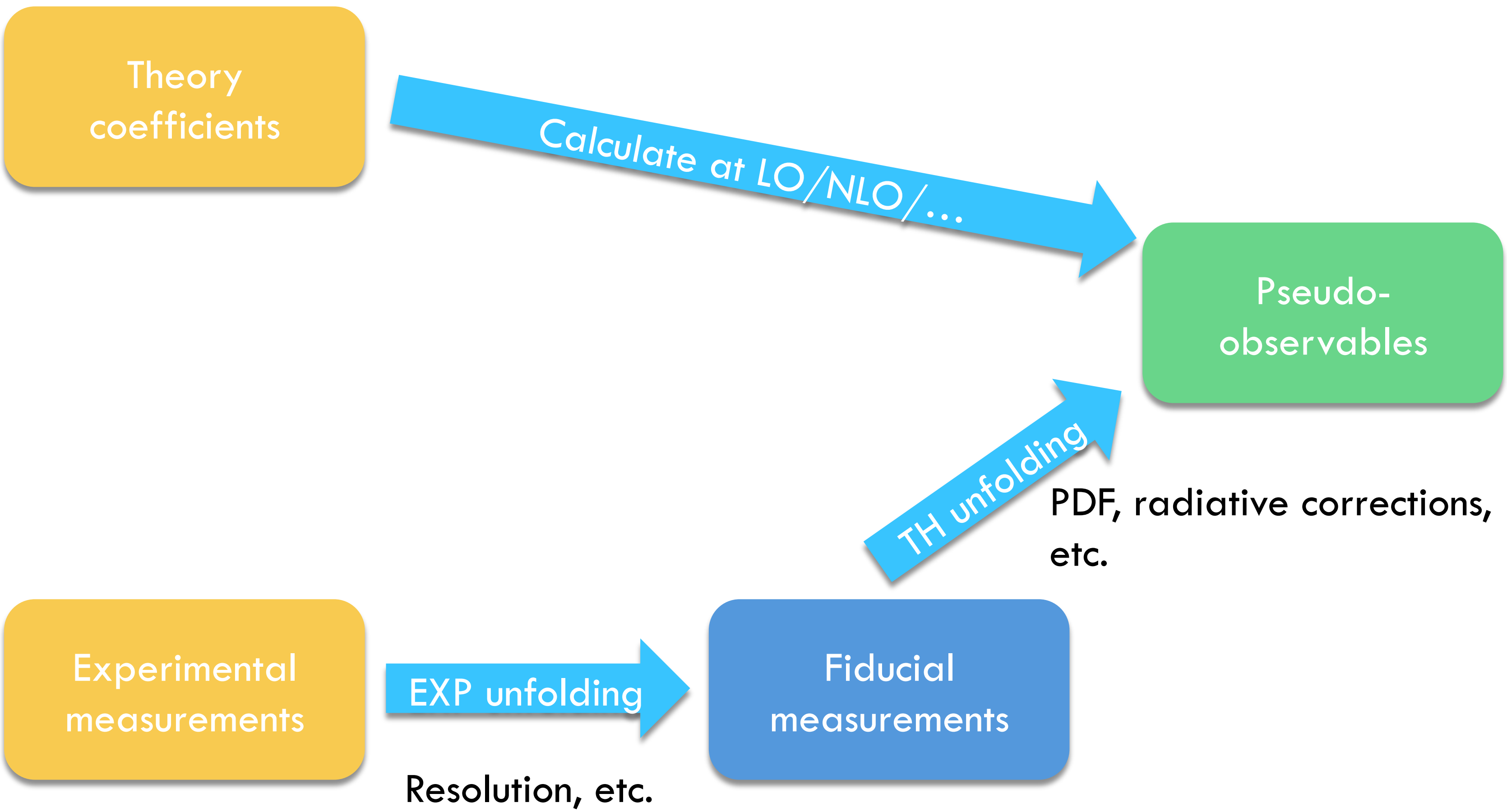
The need for the middle way

- **EFT** is all-encompassing, calculable, and evolving.
  - **But** too costly to redo all analyses if/when higher order calculations become available.
- **Fiducial cross-section** could be produced differentially for many quantities.
  - **But** no physical interpretation of every single bin by itself.
- **The middle way: pseudo-observables (PO).**
  - LEP-inspired scheme where theory and experiment intersect at clearly-defined points.

With some LEP inspiration



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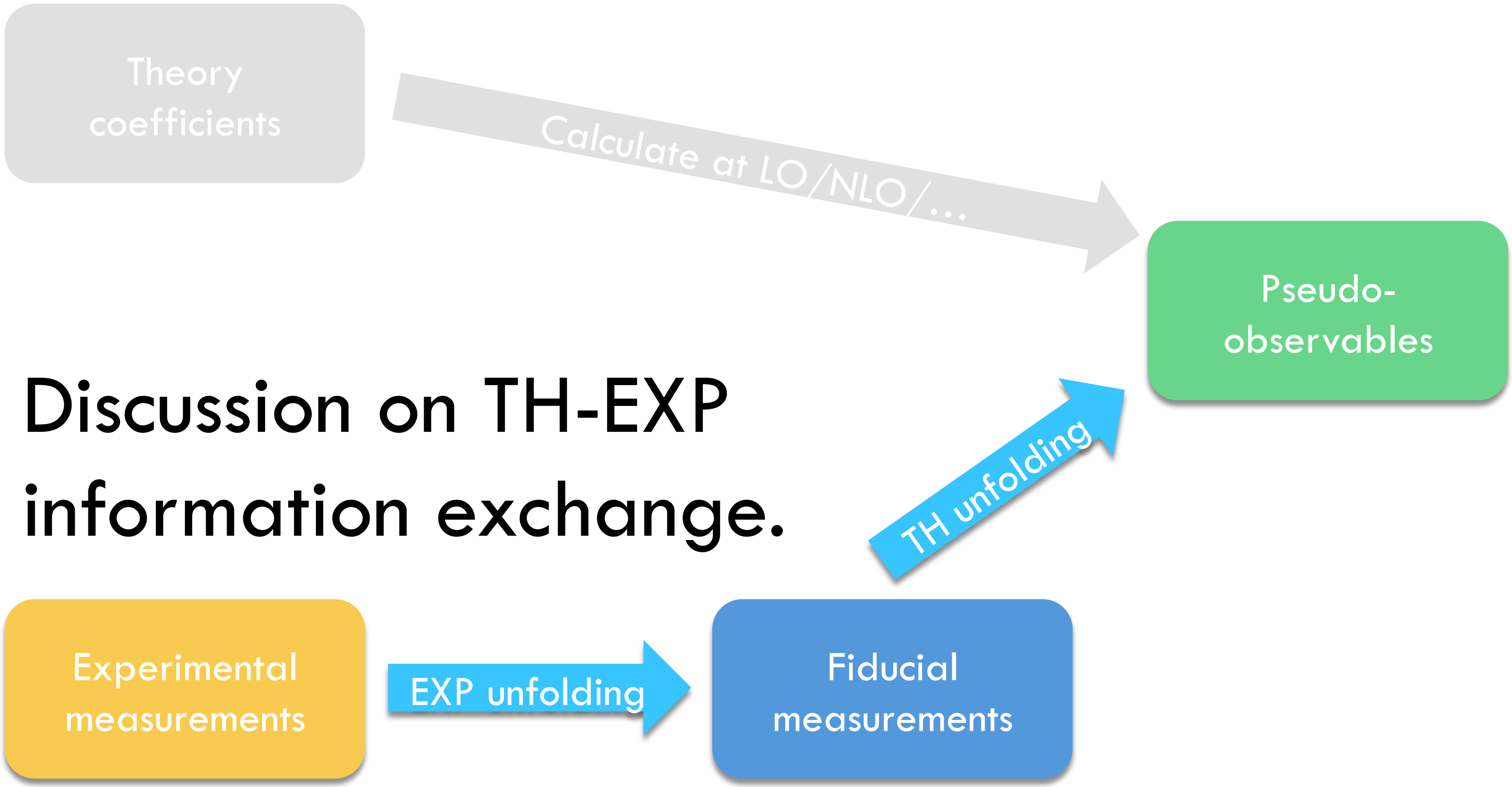
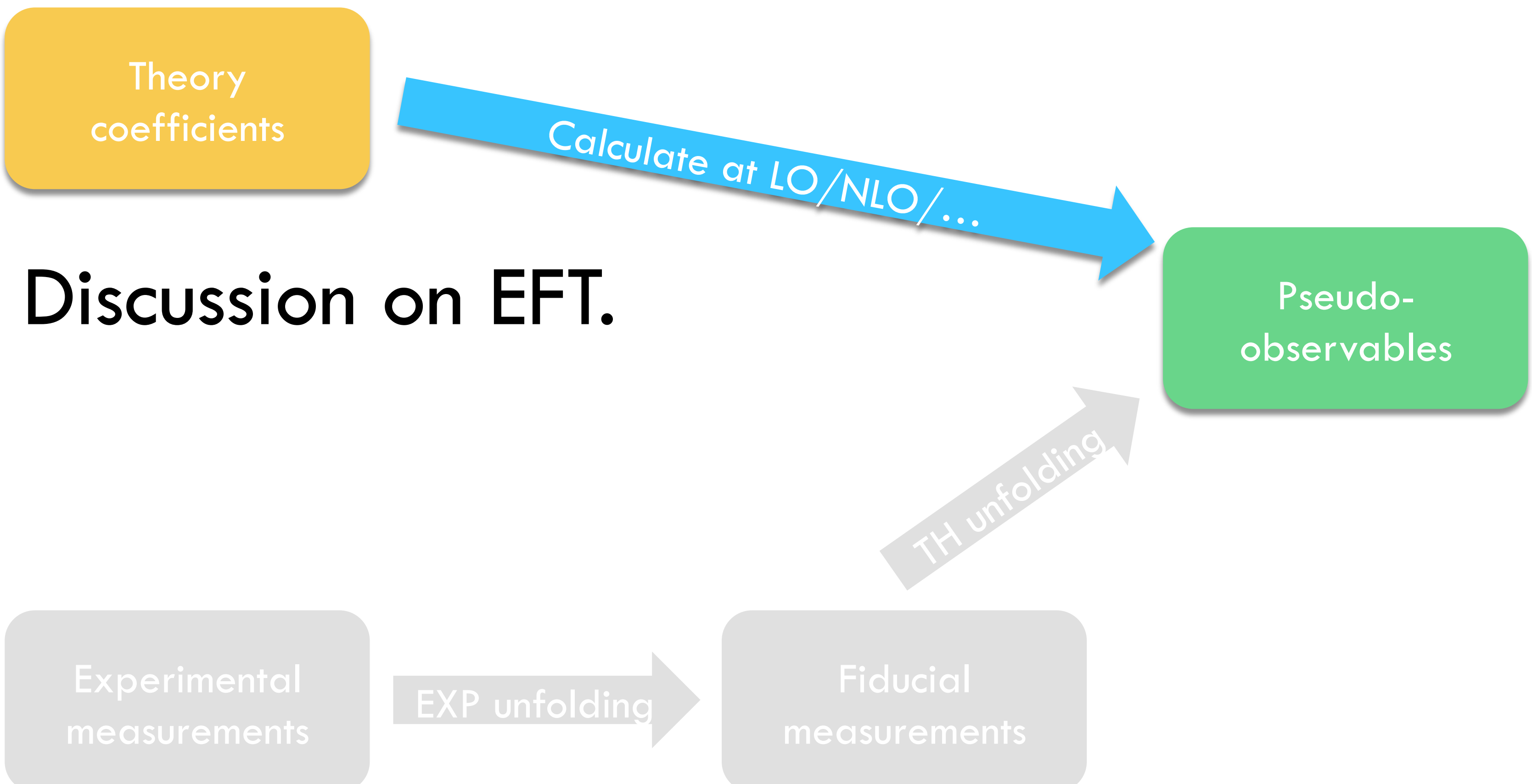


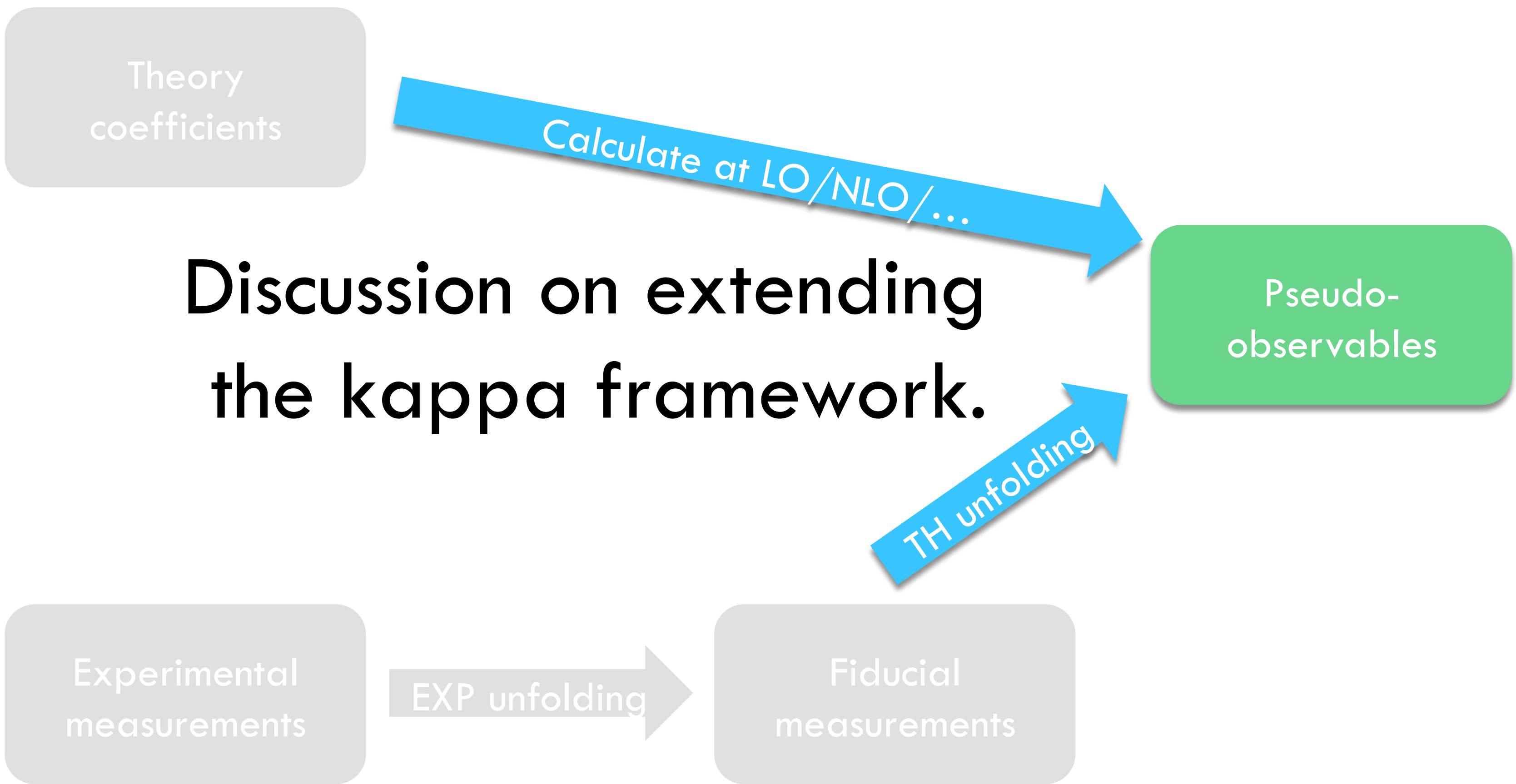
Discussion on TH-EXP information exchange.

With some LEP inspiration



Discussion on EFT.

With some LEP inspiration



Discussion on extending the kappa framework.

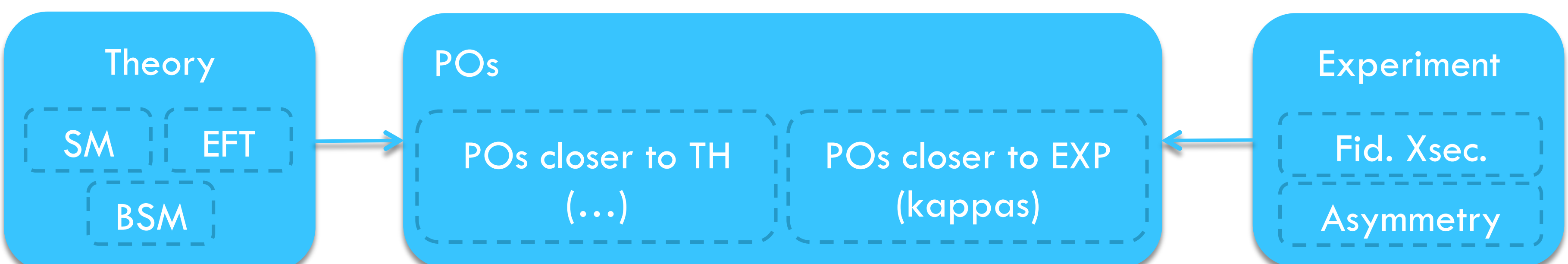
From kappas that fit little stuff…

…to kappas that fit more stuff.

Kappas might have been our first POs

- Kappas **must be extended** to:
  - Differential quantities.
  - Remove some assumptions.
  - Cover smooth deviations from the SM.

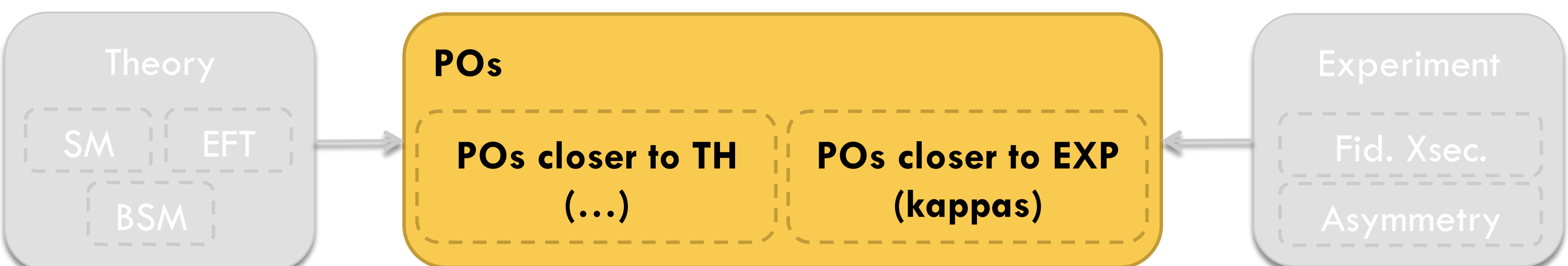
- With better/more POs, kappas may remain as part of the PO framework:



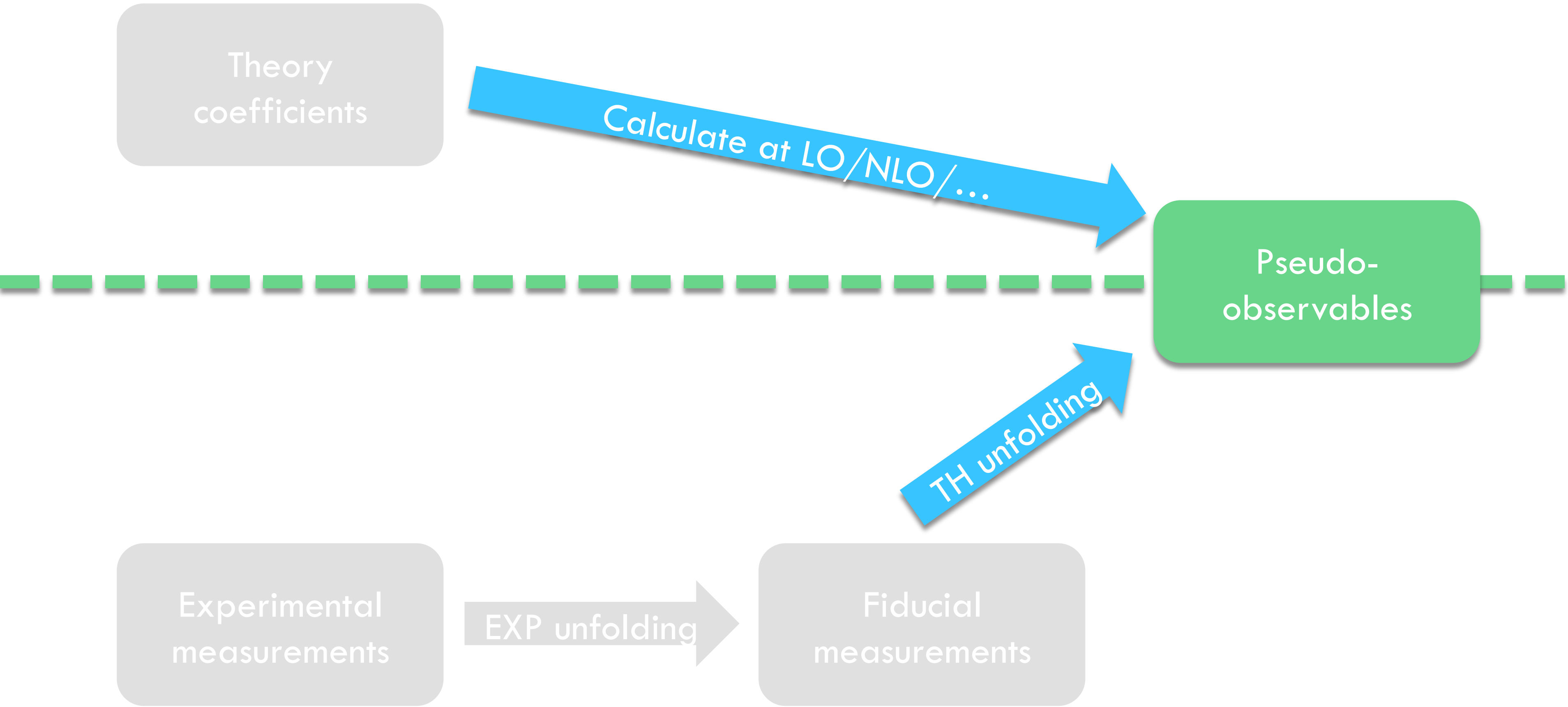
Inspiration for building PO

- If we assume that:
  Next SM ~ |dim-4 + dim-6 + dim-8 + … |^2

- Then POs can be motivated to parametrize:
  $\delta(PO_i) \sim (Data - d4^2) = d4 \times d6 + d6^2 + d4 \times d8 + \ldots$

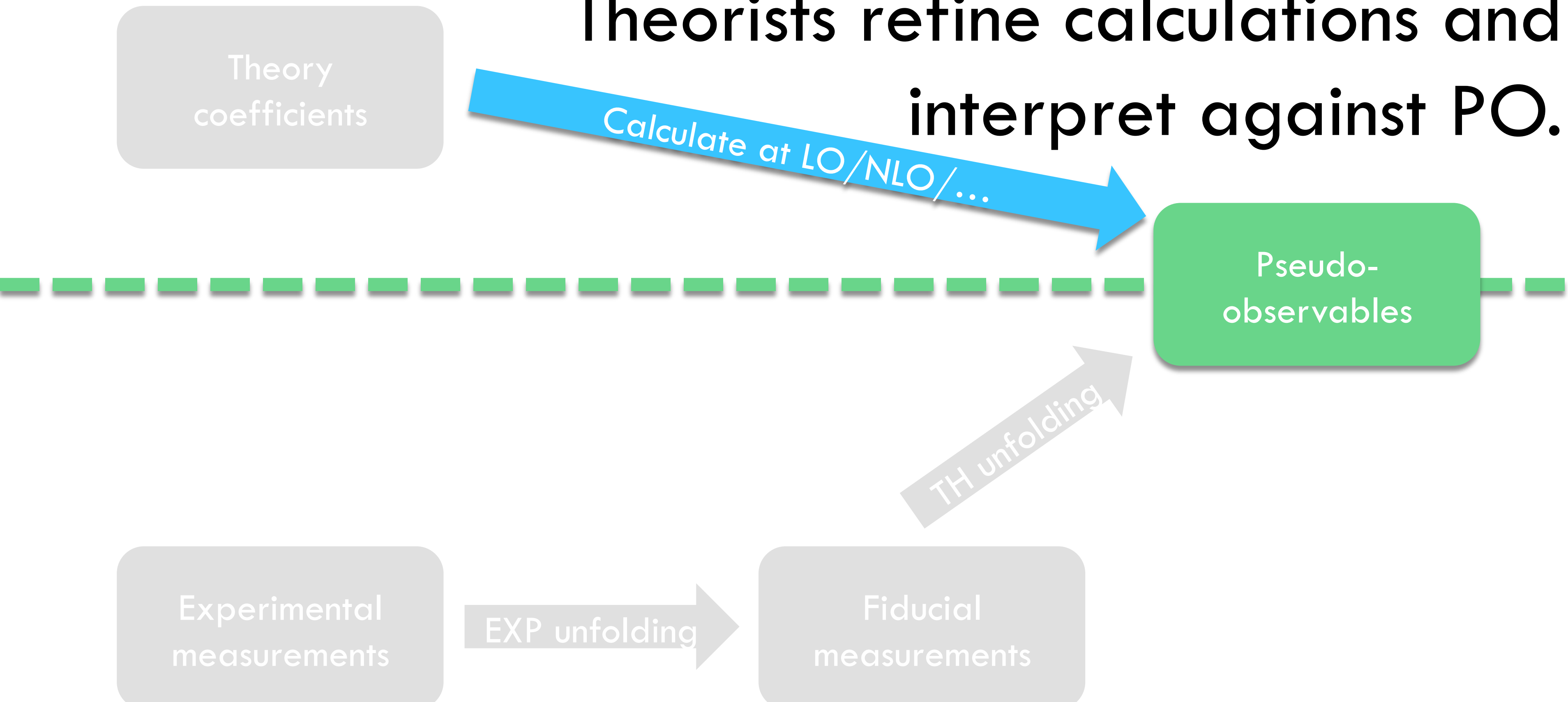


The middle way in action



The middle way in action

Theorists refine calculations and interpret against PO.



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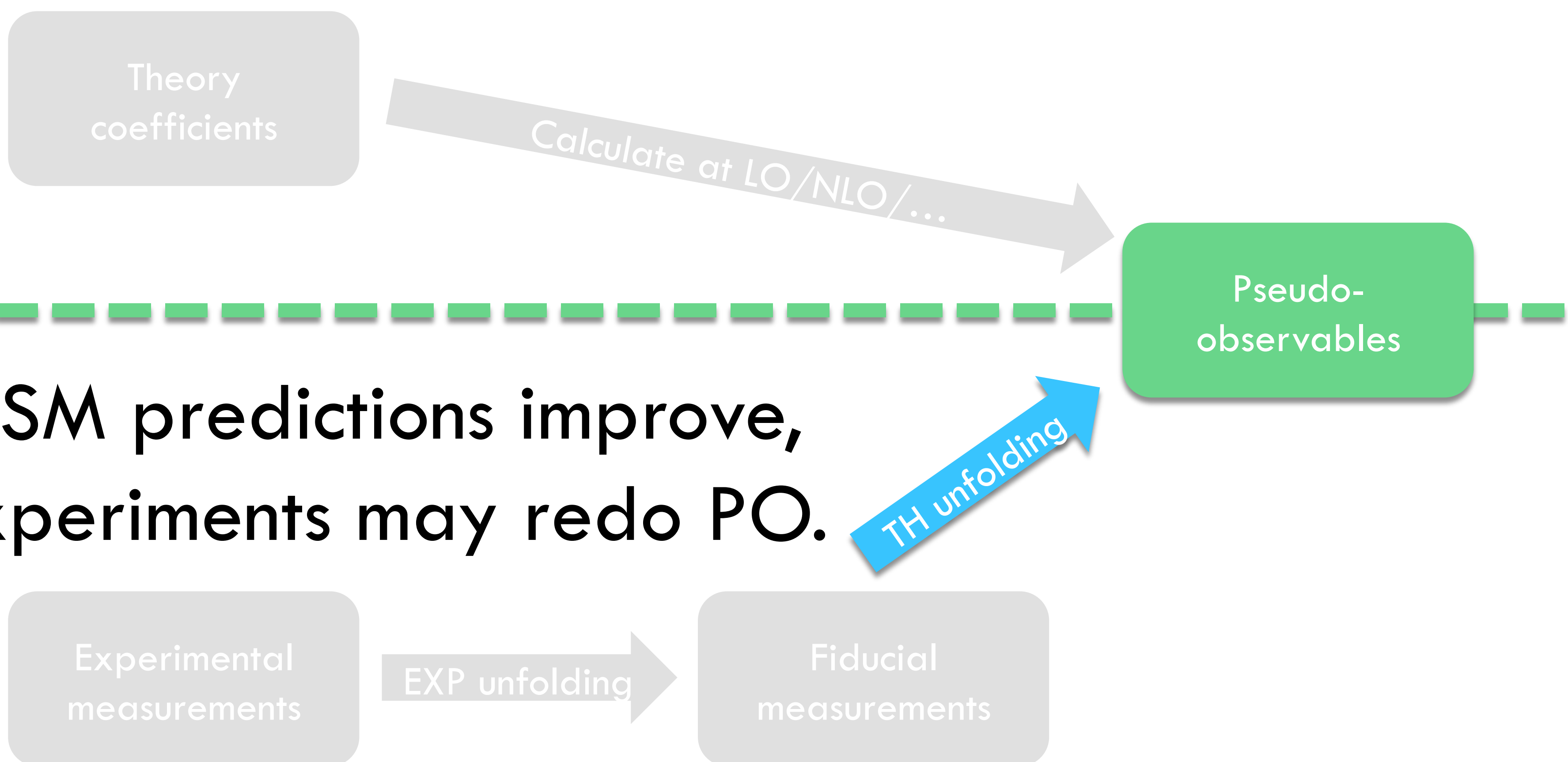

If SM predictions improve, experiments may redo PO.

Summary: PO

- Proposition 1:
  - **EXP** can (sort of) fit parameters of models to data.
  - **TH** can fit parameters of models to (sort of) data.
- Proposition 2:
  - **EXP** do not want (to produce) 10^3x10^3 covariances.
  - **TH** do not want (to digest) 10^3x10^3 covariances.
- Synthesis:
  We have to get (our act) together and define PO.

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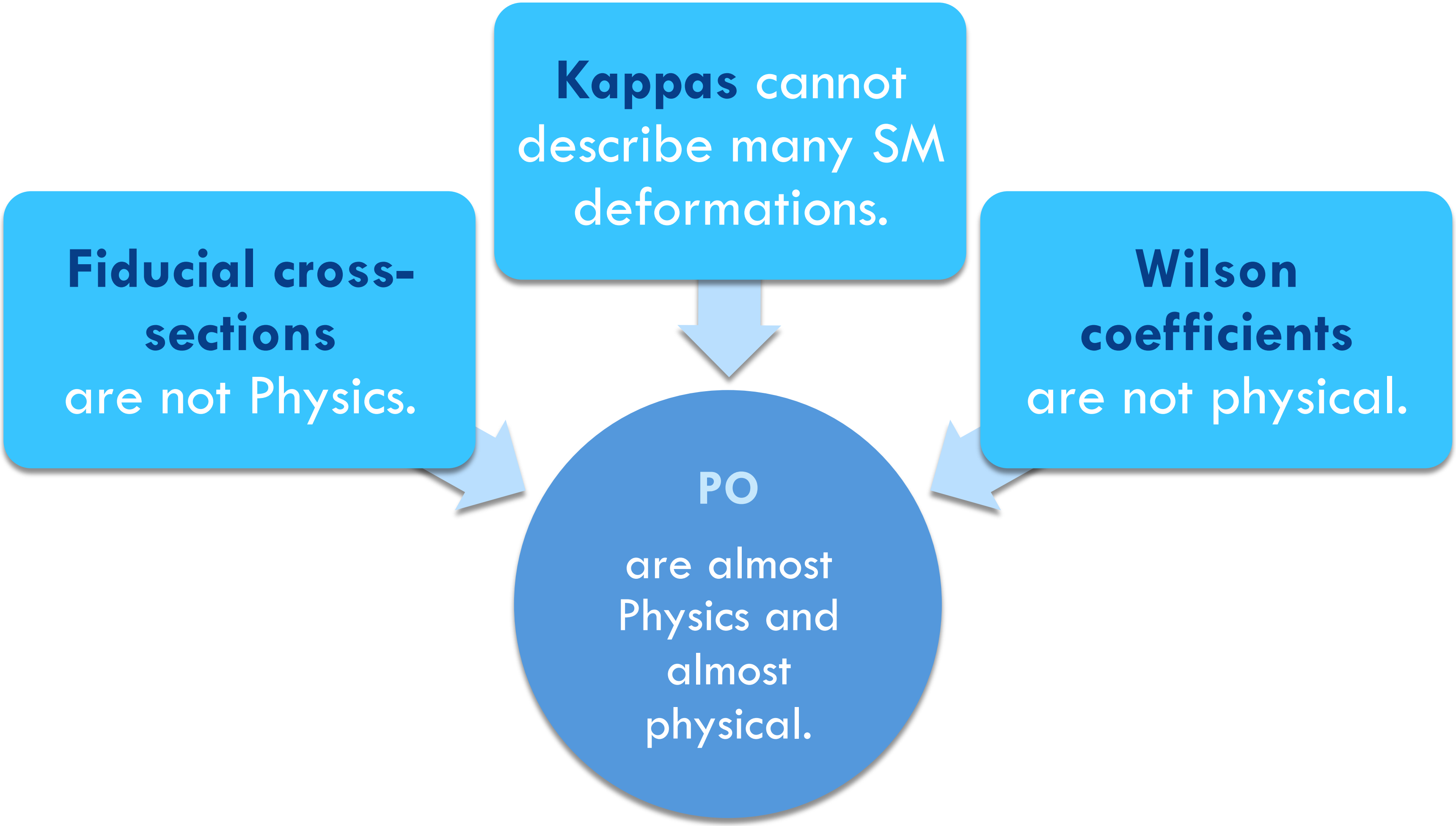

Coming up

PO

are almost Physics and almost physical.

Decay: smooth deformations from power expansion. (Gino)

Production: template cross sections. (Michael)

Have an idea? lhc-higgs-properties-convener@cern.ch

Conclusions

- What is EFT and what is an Effective Lagragian:
  - "**One operator at a time**" phenomenology useful to explore the operator phase-space.
  - **Global approach** mandatory when interpreting data.

- What to do with data:
  - **Data results** should be comprehensively reported.
  - **Pseudo-observables**: calculable, measurable, compressing redundant information.

As seen on (Spanish) TV

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