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“γνώθι σεαυτόν”

-

“Know Thyself”

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**Andreas Papaefstathiou**

**CERN Theory @ Les Houches, 4-6th November 2015**



1



# myself in 30 seconds

- **born:** 1983, Cyprus,
- (**'01-'03:** military service),
- **'03-'07:** Univ. Manchester, undergrad.,
- **'07-'11:** Univ. of Cambridge, PhD (with Bryan Webber),
- **'11-'14:** Univ. Zürich, Post-Doc,
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# past research (in 2 min.)

- past research, in brief:
  - **NMSSM Higgs bosons**: central exclusive production @ LHC.  
[Forshaw, Gunion, Hodgkinson, AP, Pilkington, 0712.3510 ]
  - **W-primes @ NLO** + parton shower (MC@NLO / POWHEG),  
[AP, Latunde-Dada, 0901.3685]
  - **3rd-gen. Leptoquarks @ the LHC**,  
[Gripaios, AP, Sakurai, Webber, 1010.3962]
  - methods to reconstruct **helicity of 3rd-gen resonances**,  
[AP, Sakurai, 1112.3956]
  - **QCD resummation**:
    - ◆ total invariant mass, [ AP, Webber, 0903.2013, 1002.4375]
    - ◆ associated transverse energy in Higgs production.

[AP, Webber, Smillie, 1002.4375] and [Grazzini, AP, Webber, Smillie, 1403.3394]



# past research (in 2 min.)

- past research, continued:
  - colour structure of the the **top-anti-top asymmetry** at the Tevatron, [Gripaios, AP, Webber, 1309.0810]
  - **SUSY decays to Higgs bosons.** [AP, Sakurai, Takeuchi, 1404.1077]

# current research interests

- **multi-Higgs production** at colliders (LHC, pp@100 TeV),
- **multi-jet merging at NLO,**
- **Herwig++/Herwig 7** event generator,
- ...

# why multi-Higgs?

- **multi-Higgs production** allows us to probe the self-coupling Higgs sector, e.g.:

$$\mathcal{L} \supset -\frac{1}{2}m_h^2 h^2 - \frac{m_h^2}{2v} h^3 - \frac{m_h^2}{8v^2} h^4$$

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$\delta, \tilde{\delta}$  : possible deviations from the SM.

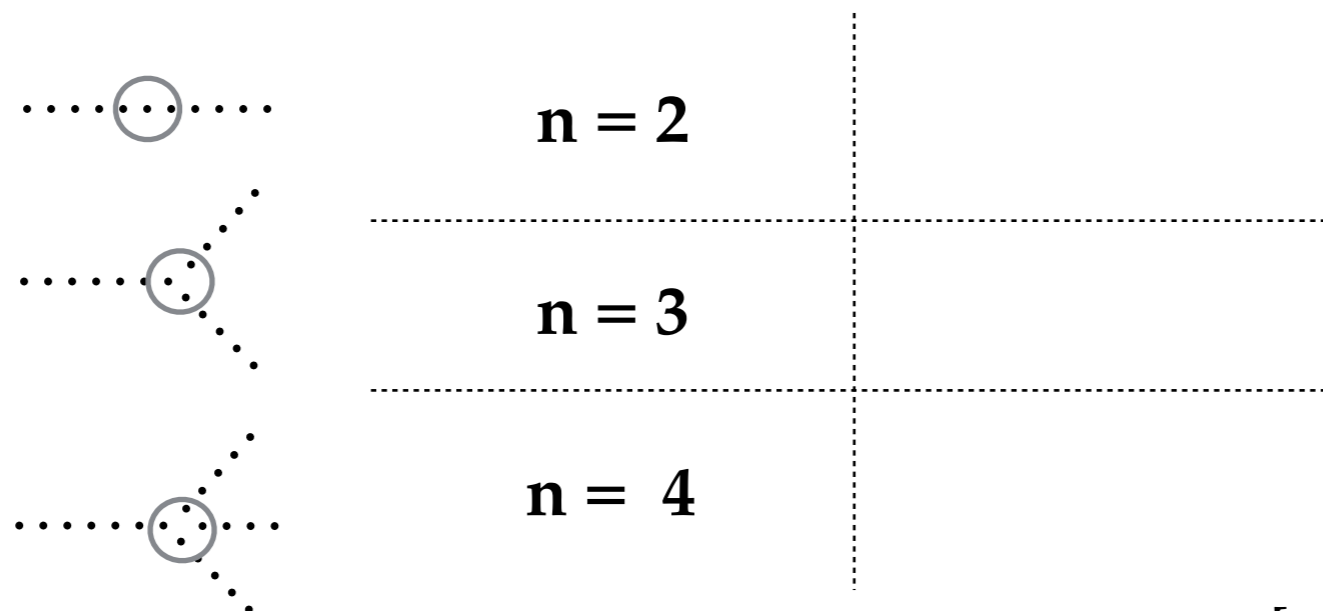
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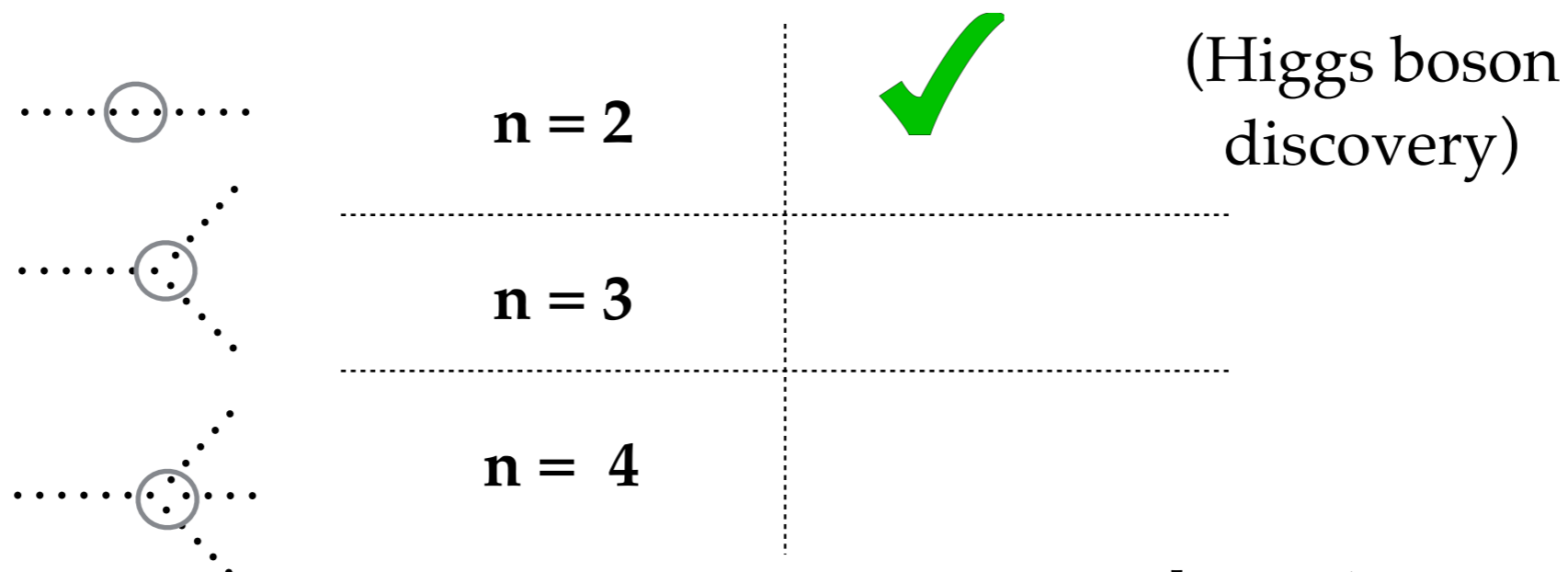
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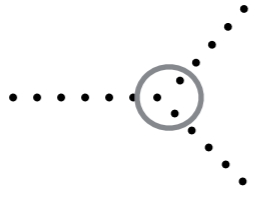
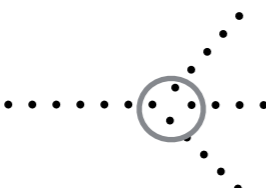
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	$n = 3$	✓	(LHC, FCC-hh)
	$n = 4$		


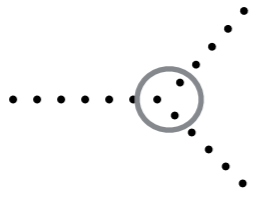
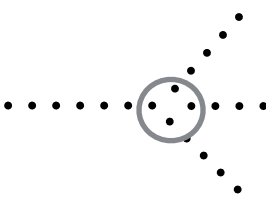
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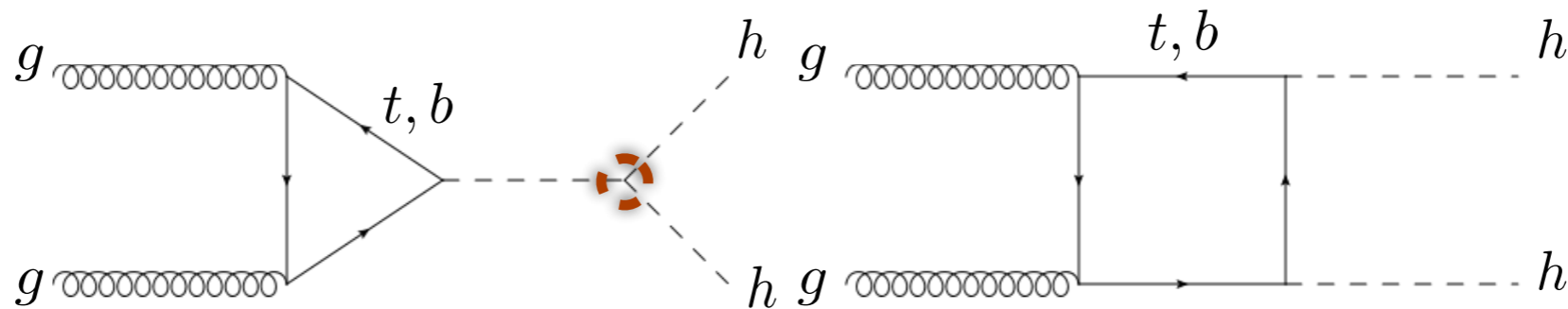
	$n = 2$	✓	(Higgs boson discovery)
	$n = 3$	✓	(LHC, FCC-hh)
	$n = 4$	?	(FCC-hh?)

[AP, Sakurai, 1508.06524]



# e.g. pair production

- Higgs boson pair production @ LHC,



- searches:**  $pp \rightarrow hh \rightarrow (b\bar{b})(W^+W^-)$  [AP, Yang, Zurita, 1209.1489]

use  $\sigma(hh)/\sigma(h)$

[Goertz, AP, Yang, Zurita, 1301.3492]

$pp \rightarrow hh \rightarrow (b\bar{b})(b\bar{b})$

[Ferreira de Lima, AP, Spannowsky, 1404.7139]

# more pair production

- **improved Monte Carlo description** using merged matrix elements obtained via OpenLoops. [Maierhöfer, AP, 1401.0007]
- **dimension-6 operator extension of the SM:** what can we learn from hh production? [Goertz, AP, Yang, Zurita, 1410.3471]
- **hh rare final states at 100 TeV:** new channels opening up at higher energy? [AP, 1504.04621]

# multi-jet merging at NLO (FxFx)

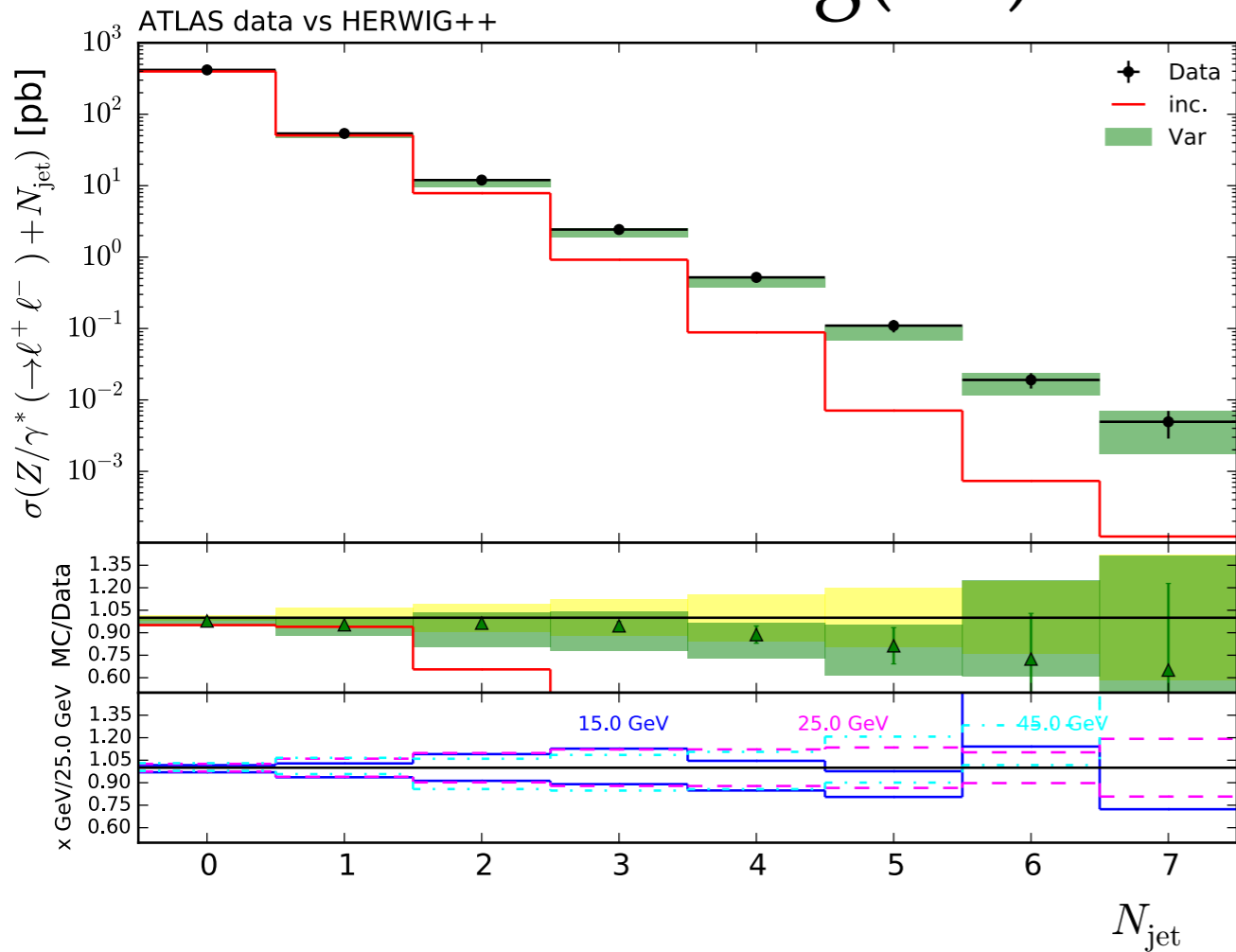
[Frederix, Frixione, AP, Prestel, Torrielli, 1511.xxxxx]

- MC@NLO method matches the parton shower with next-to-leading order QCD calculations.
- to improve: add higher-multiplicity NLO-matched samples.
- e.g.  $Z+0j$  @ NLO+PS &  $Z+1j$  @ NLO+PS &  $Z+2j$  @ NLO+PS & [...]

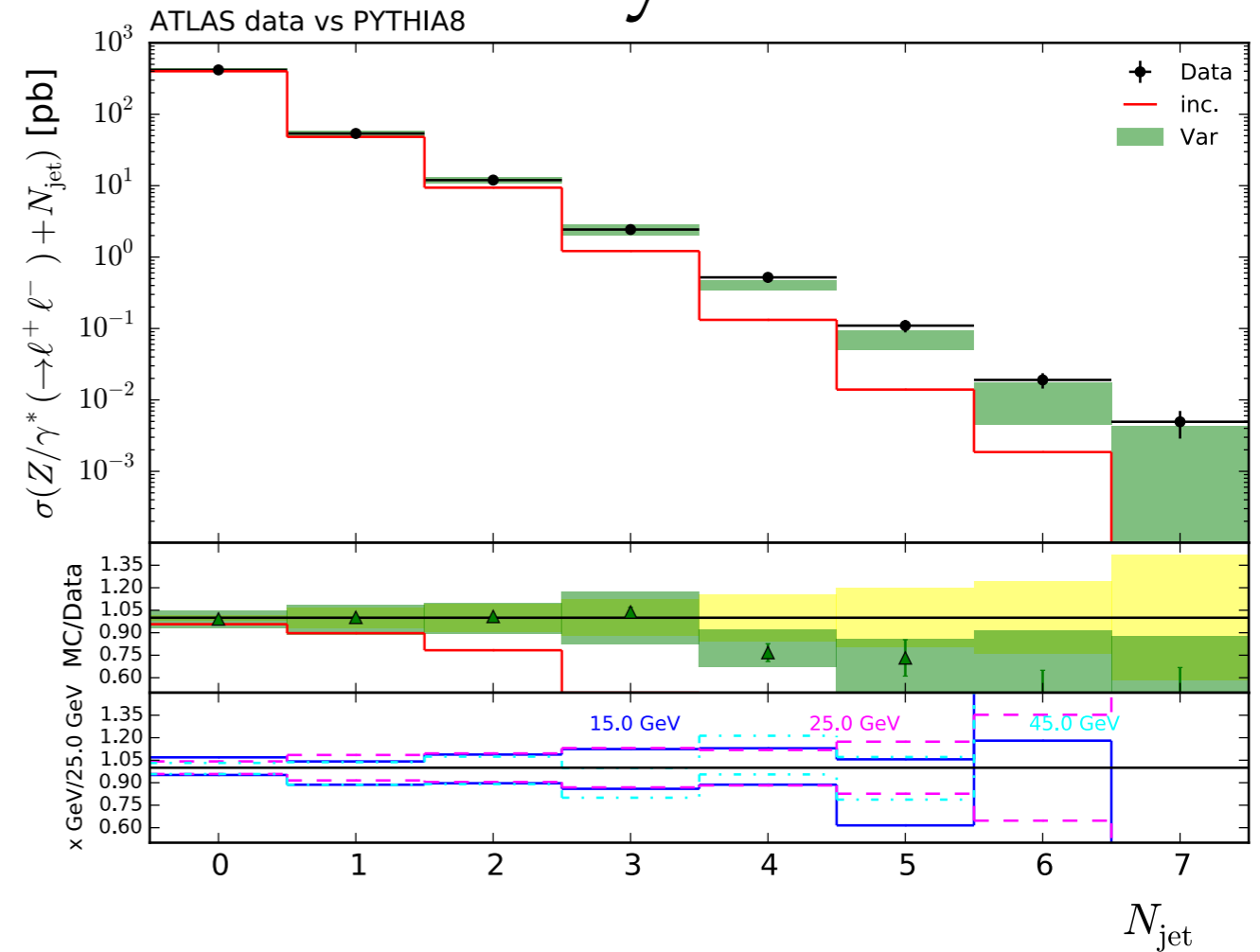
# e.g. ATLAS@7 TeV exclusive jet multiplicity in Z+jets VS aMC@NLO FxFx with Herwig++ or Pythia8:

[Frederix, Frixione, AP, Prestel, Torrielli, 1511.xxxxx]

## Herwig(++)



## Pythia8



NLO-Merged (FxFx): Z+0/1/2j.

MC@NLO: Z+0j.

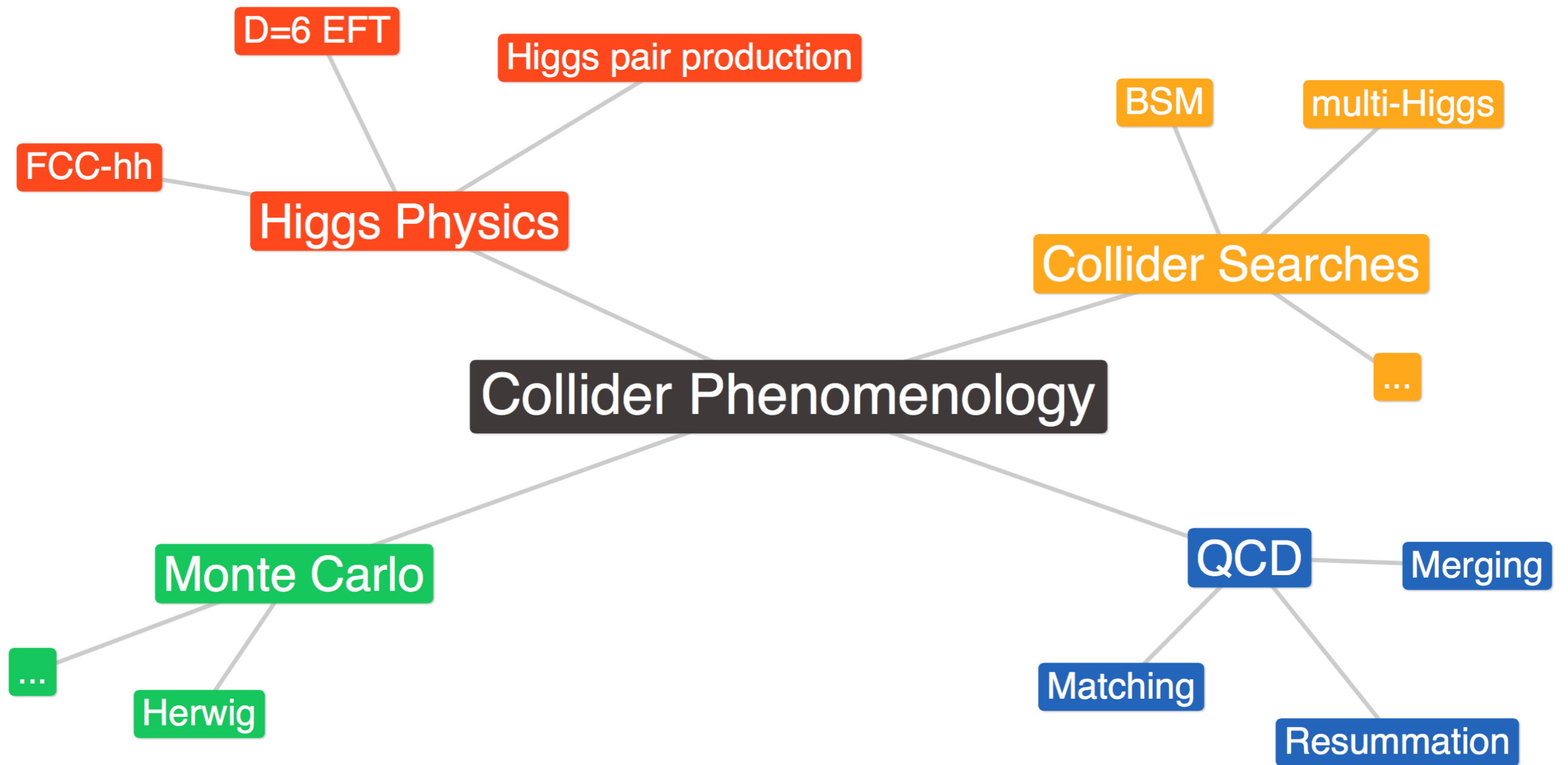
**improved description  
of higher-  
multiplicities!**



# “bleeding edge”

- the spin-2 form-factor Higgs boson pair production: are we missing something here?
- “true” next-to-leading log parton showers: where are they? do we need them?
- di-Scalar production at 14 TeV / 100 TeV,
- [...]

# “summary”

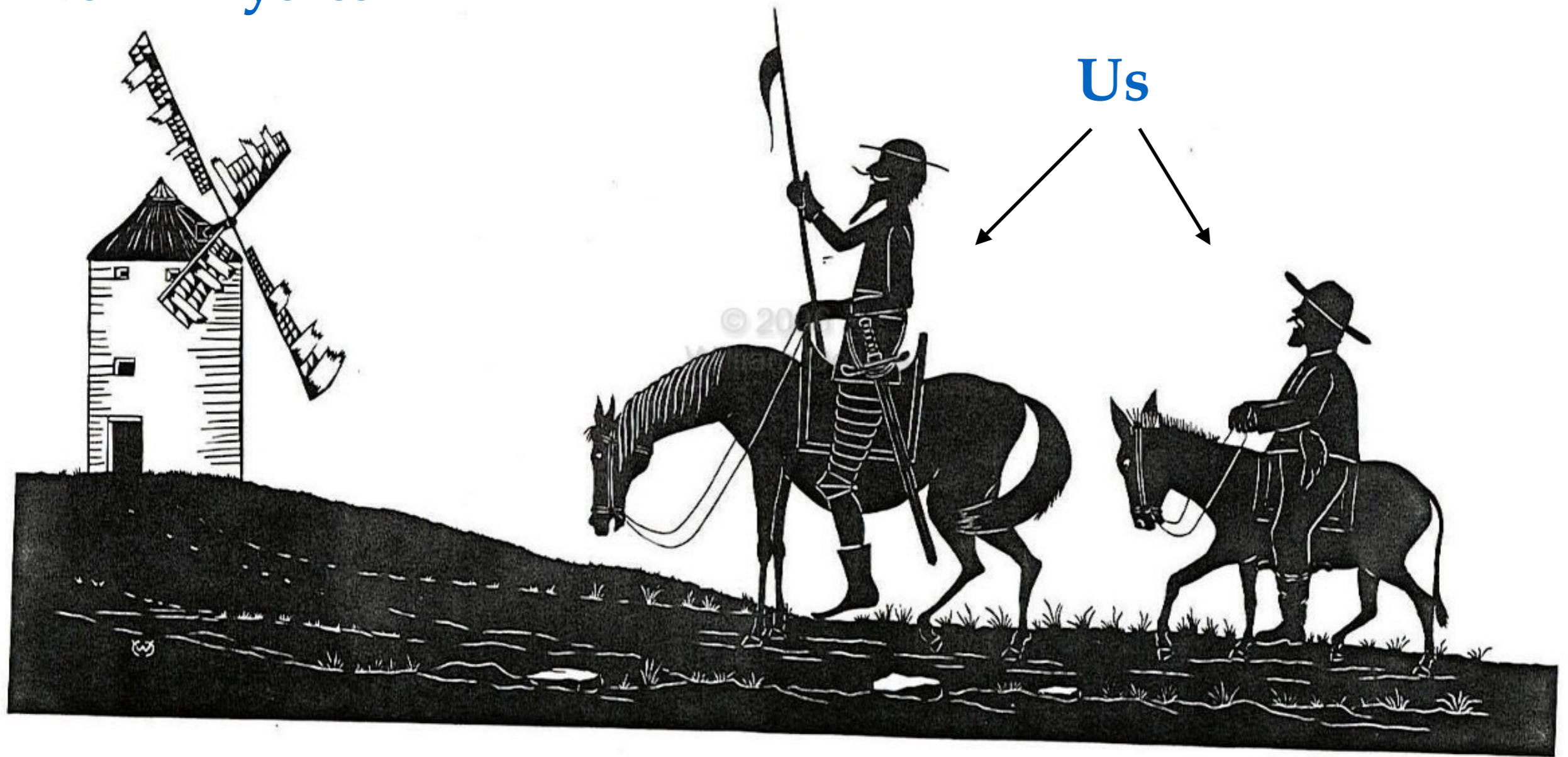


# New Physics?



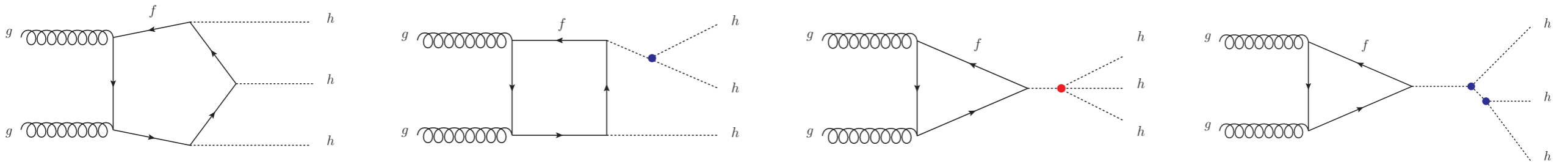
# Thanks for your attention!

## New Physics?





# triple production at 100 TeV



- tiny cross section at LHC14 ( $\sim 0.1$  fb),
- still challenging at FCC-hh: SM  $\sigma$  @ 100 TeV  $\sim 5$  fb!

[Plehn, Rauch, hep-ph/0507321, Binoth, Karg, Kauer, Rückl, hep-ph/0608057, Maltoni, Vryonidou, Zaro, 1408.6542]

- ‘high-luminosity’ FCC-hh could probe it (30 / ab).
- e.g. in  $hhh \rightarrow (b\bar{b})(b\bar{b})(\gamma\gamma)$ . [AP, Sakurai, 1508.06524]
- but: quartic hard to probe!