Brout-Englert-Higgs

BEH characterisation framework

Kentarou Mawatari (馬渡 健太郎)

(Vrije Universiteit Brussel and International Solvay Institutes)

K.Hagiwara, Q.Li, KM, JHEP07(2009)101 [arXiv:0905.4314]
C.Englert, D.Goncalves-Netto, KM, T.Plehn, JHEP01(2013)148 [arXiv:1212.0843]
K.Hagiwara, T.Li, KM, J.Nakamura, appear in EPJC soon [arXiv:1212.6247]
P.Artoisenet et al. [arXiv: 1306.6464]

July 4th, 2012, at CERN

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

BROKEN SYMMETRIES, MASSLESS PARTICLES AND GAUGE FIELDS

P. W. HIGGS
Tait Institute of Mathematical Physics, University of Edinburgh, Scotland

Received 27 July 1964

Vrije Universiteit Brussel

Phenomenology group at the Vrije Universiteit Brussel

- Since October 2010, to make a chain between the theoretical and experimental groups at the VUB.

Vrije Universiteit Brussel pheno

ULB UNIVERSITÉ LIBRE DE BRUXELLES — Englert, Frere, Hambye, Tinyakov, Tytgat, Argurio, ...

UCL Université catholique de Louvain — Maltoni, ... CMS

iihe BRUXELLES BRUSSEL — CMS, IceCube, H1, OPERA, ...

- Contact to
  - http://we.vub.ac.be/HEPVUB/
  - pheno@vub.ac.be, kentarou.mawatari@vub.ac.be

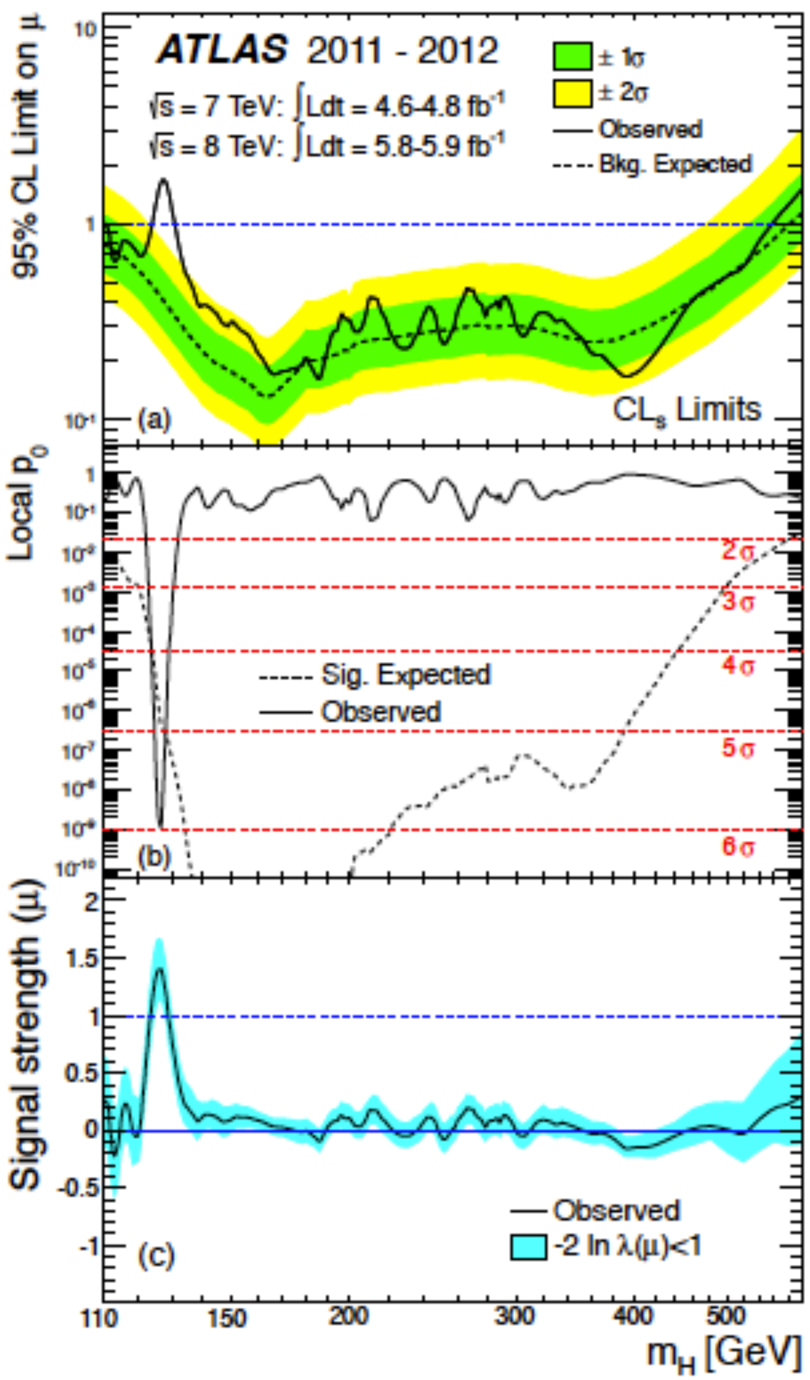
Vrije Universiteit Brussel

HEP@VUB

High Energy Physics Research Centre @VUB

- The 5-year pheno project was rearranged into a larger framework in January 2013
  - Theory: Ben Craps, Alexander Sevrin (string/cosmology)
  - Collider physics: Jorgen D'Hondt, Freya Blekman, Steven Lowette (CMS)
  - Astor-particle physics: Catherine De Clercq, Nick Van Eindhoven (IceCube)
  - Phenomenology: Kentarou Mawatari
- Pheno members
  - Kentarou Mawatari - Project leader since 2010
  - Laura Lopez Honorez - PD since 2012
  - Priscila de Aquino - PD since 2012
  - Bettina Oexl - PhD since 2010
  - Karen De Causmaecker - PhD since 2011

  - Pantelis Tziveloglou (from Ecole Polytechnique, CPHT) - PD since 2013
  - Jonathan Lindgren (from Chalmers U. of Tech) - PhD since 2013



Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC

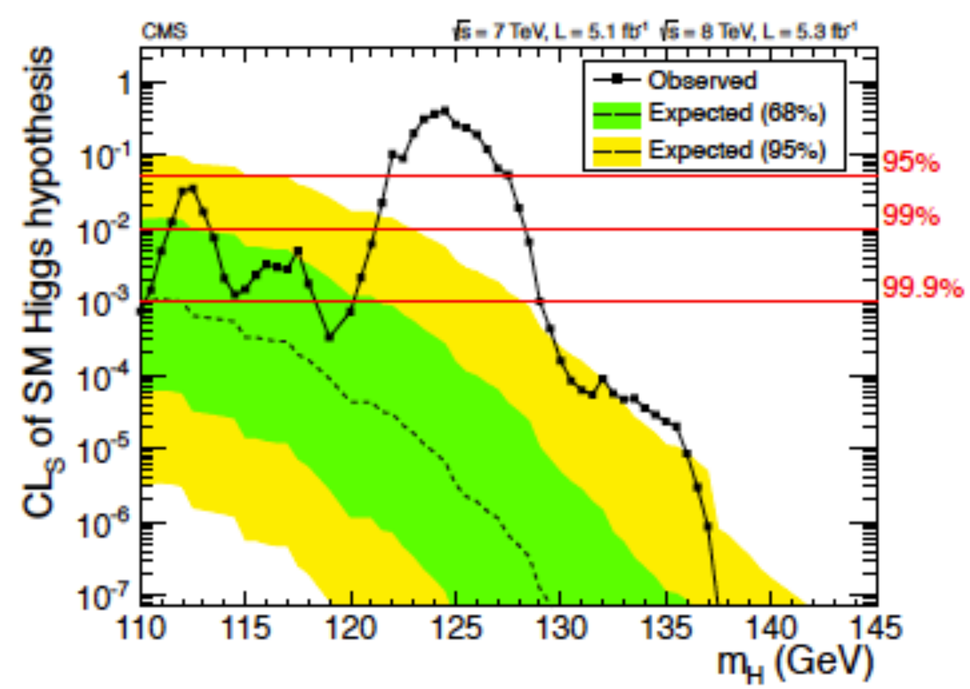
[arXiv: 1207.7214]

The ATLAS Collaboration

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC

[arXiv: 1207.7235]

The CMS Collaboration



Vrije Universiteit Brussel

After one year...

arXiv:1307.1432v1 [hep-ex] 4 Jul 2013

Evidence for the spin-0 nature of the Higgs boson using ATLAS data

The ATLAS Collaboration

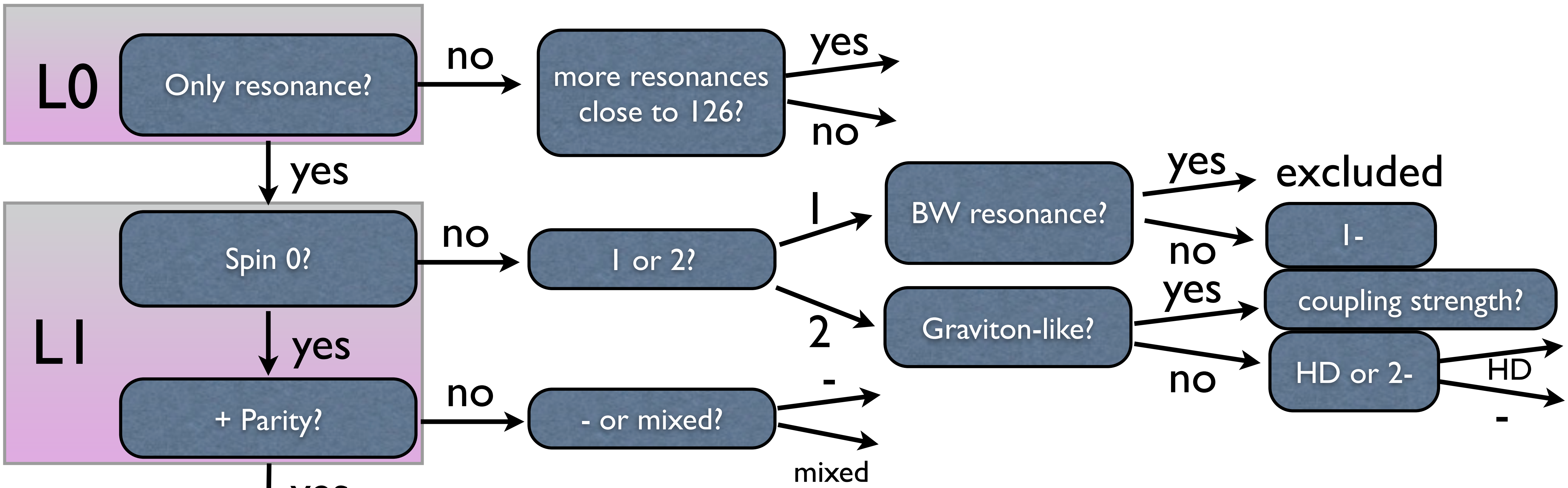
Abstract

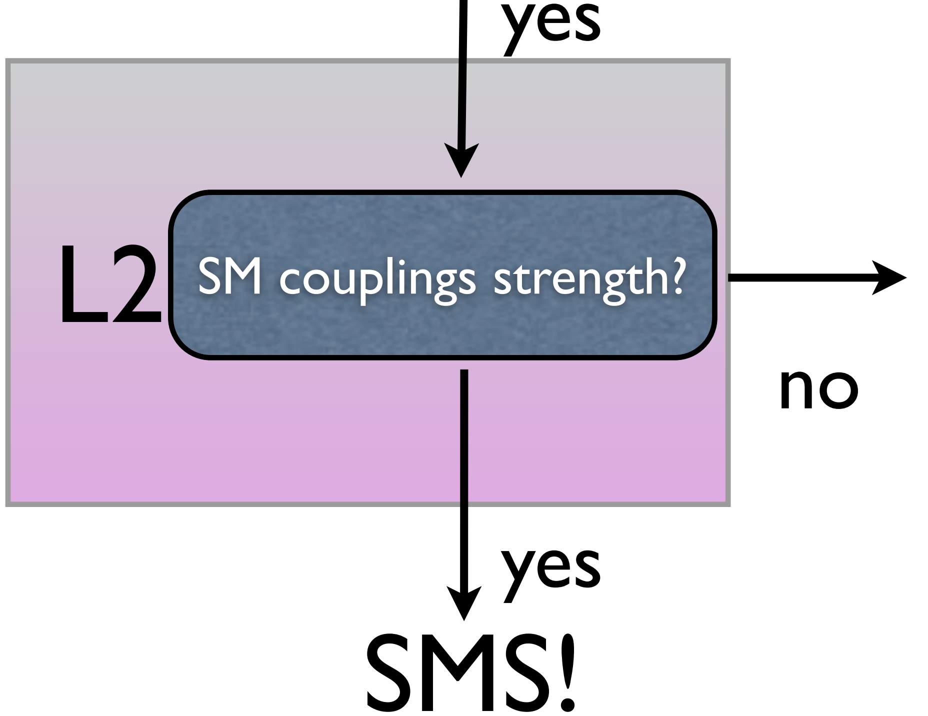
Studies of the spin and parity quantum numbers of the Higgs boson are presented, based on proton–proton collision data collected by the ATLAS experiment at the LHC. The Standard Model spin–parity $J^P = 0^+$ hypothesis is compared with alternative hypotheses using the Higgs boson decays $H \to \gamma\gamma$, $H \to ZZ^* \to 4\ell$ and $H \to WW^* \to \ell\nu\ell\nu$, as well as the combination of these channels. The analysed dataset corresponds to an integrated luminosity of 20.7 fb^{-1} collected at a centre–of–mass energy of $\sqrt{s} = 8$ TeV. For the $H \to ZZ^* \to 4\ell$ decay mode the dataset corresponding to an integrated luminosity of 4.6 fb^{-1} collected at $\sqrt{s} = 7$ TeV is added. The data are compatible with the Standard Model $J^P = 0^+$ quantum numbers for the Higgs boson, whereas all alternative hypotheses studied in this letter, namely some specific $J^P = 0^-, 1^+, 1^-, 2^+$ models, are excluded at confidence levels above 97.8%. This exclusion holds independently of the assumptions on the coupling strengths to the Standard Model particles and in the case of the $J^P = 2^+$ model, of the relative fractions of gluon–fusion and quark–antiquark production of the spin-2 particle. The data thus provide evidence for the spin-0 nature of the Higgs boson, with positive parity being strongly preferred.

Is this the Standard Model scalar boson?

How can we determine the spin/parity nature at the LHC?

Strategy of the Higgs characterization





We provide a complete framework, based on an effective field theory description, that allows to perform characterization studies of the newly discovered boson in all relevant channels in a consistent, systematic and accurate way.

A framework for Higgs characterisation

[arXiv: 1306.6464]

The FeynRules and MadGraph5 framework

FeynRules model
P. de Aquino, K. Mawatari (Vrije U. Brussel)

MadWeight
P. Artoisenet (Nikhef)

aMC@NLO
F. Demartin, F. Maltoni, M. Zaro (UC Louvain)
R. Frederix, S. Frixione (CERN)
P. Torrielli (Zurich)

spin2 in aMC@NLO
M.K. Mandal (Harish-Chandra)
P. Mathews, S. Seth (Saha Inst.)
V. Ravindran (CIT)

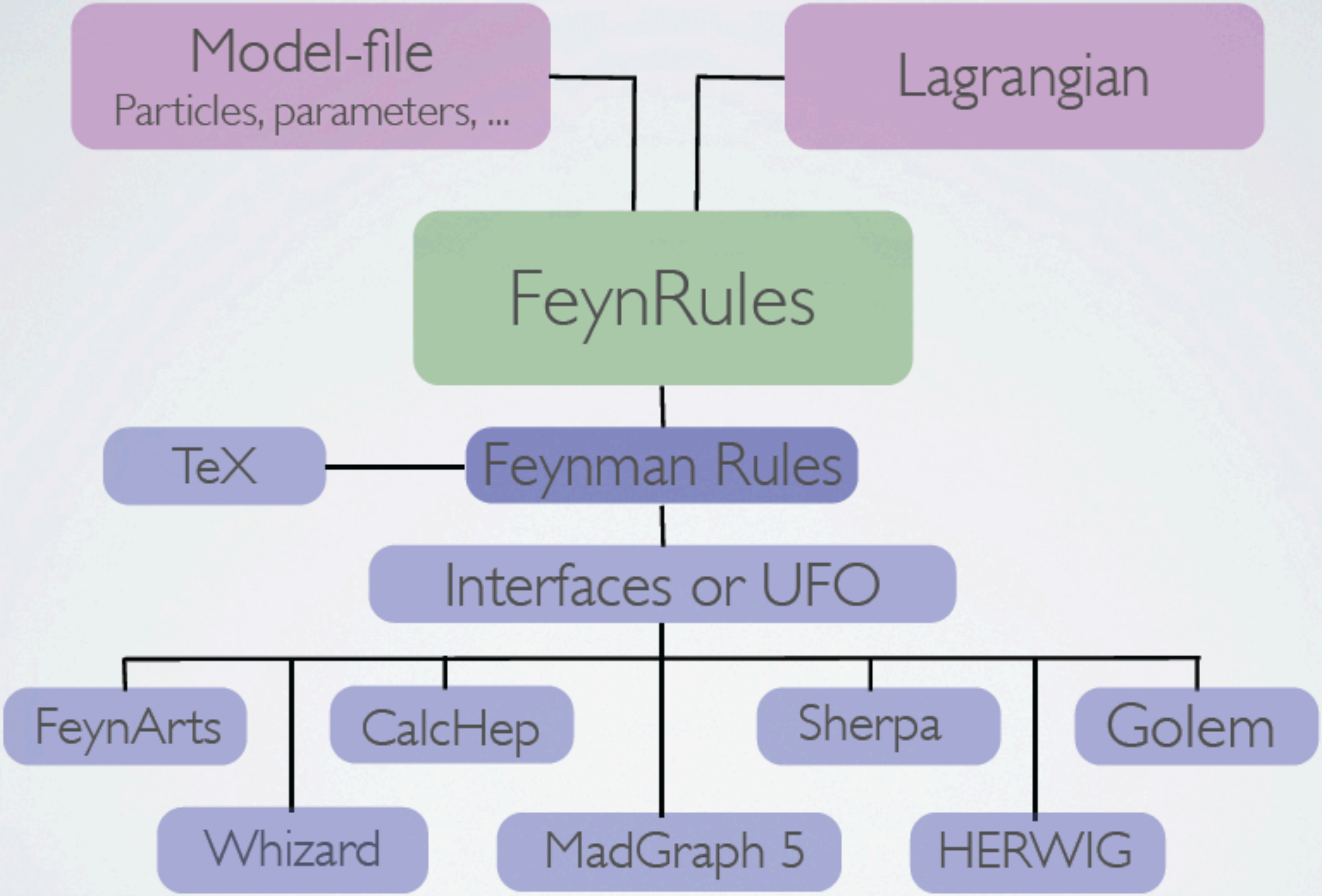
Vrije Universiteit Brussel

Abstract

- We introduce a complete framework, based on an effective field theory approach, that allows one to perform characterisation studies of the boson recently discovered at the LHC, for all the relevant channels and in a consistent, systematic and accurate way.
- The production and decay of such a boson with various spin and parity assignments can be simulated by means of multi-parton, tree-level matrix elements and of NLO QCD calculations, both matched with parton showers.
- Several sample applications are presented which show, in particular, that beyond-leading-order effects in QCD have non-trivial phenomenological implications.

THE FEYNRULES PROJECT

[Christensen, Duhr, Fuks+ many collaborators]



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Higgs Characterisation model in FeynRules

- We implemented an effective Lagrangian featuring bosons
  X(JP=0+,0−,1+,1−,2+)
  in FeynRules (http://feynrules.irmp.ucl.ac.be).
  - Effective field theory approach, valid up to a cutoff scale Λ
  - Only one new bosonic state X(JP) at the EW scale (No other state below the cutoff Λ)
  - Any new physics is described by the lowest dimensional operators.

The parametrization is based on the recent work [Englert, Goncalves-Netto, KM, Plehn (2013)].

Effective Lagrangian -- spin0

- allows one to recover the SM case easily.
- includes all possible interactions that are generated by gauge-invariant D6 operators above the EW scale
- includes 0- state couplings typical of SUSY or of generic 2HDM
- allows CP-mixing between 0+ and 0− states

parameter	reference value	description
Λ [GeV]	10^3	cutoff scale
$c_\alpha (\equiv \cos\alpha)$	1	mixing between 0^+ and 0^-
κ_i	0 , 1	dimensionless coupling parameter

$g_{Xyy'} \times v$	ff	ZZ/WW	$\gamma\gamma$	$Z\gamma$	gg
H	m_f	$2m^2_{Z/W}$	$47\alpha_{EM}/18\pi$	$C(94\cos^2\theta_W - 13)/9\pi$	$-\alpha_s/3\pi$
A	m_f	0	$-4\alpha_{EM}/3\pi$	$-2C(8\cos^2\theta_W - 5)/3\pi$	$-\alpha_s/2\pi$

Effective Lagrangian -- spin0

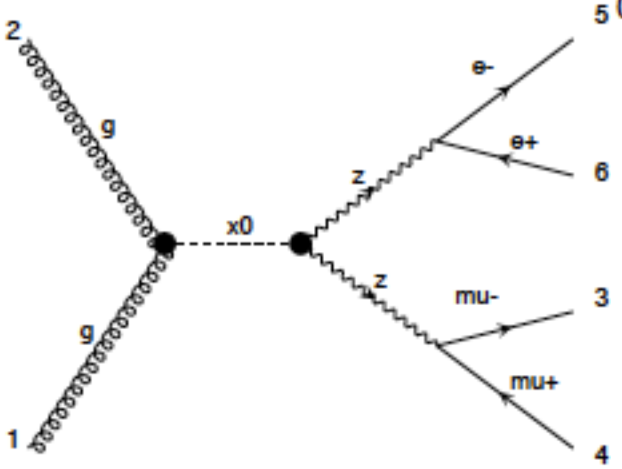
$$\mathcal{L}_0^f = -\sum_{f=t,b,\tau} \bar{\psi}_f \big(c_\alpha \kappa_{Hff} g_{Hff} + i s_\alpha \kappa_{Aff} g_{Aff}\, \gamma_5 \big) \psi_f X_0$$

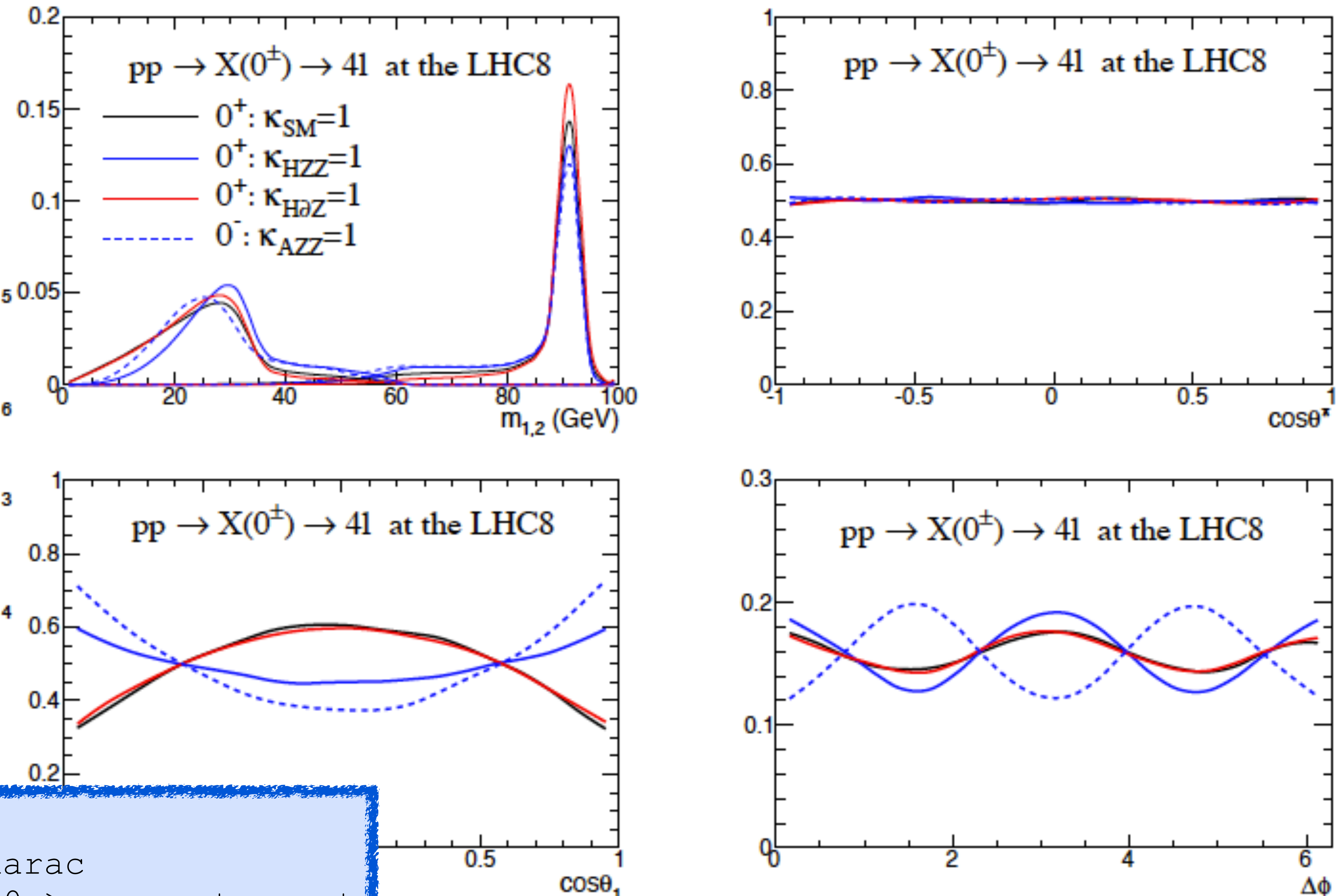
$$\begin{aligned}
\mathcal{L}_0^V = \Big\{ & c_\alpha \kappa_{\rm SM} \big[\tfrac{1}{2} g_{HZZ}\, Z_\mu Z^\mu + g_{HWW}\, W_\mu^+ W^{-\mu} \big] \\
& - \frac{1}{4} \big[c_\alpha \kappa_{H\gamma\gamma} g_{H\gamma\gamma}\, A_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{A\gamma\gamma} g_{A\gamma\gamma}\, A_{\mu\nu} \widetilde{A}^{\mu\nu} \big] \\
& - \frac{1}{2} \big[c_\alpha \kappa_{HZ\gamma} g_{HZ\gamma}\, Z_{\mu\nu} A^{\mu\nu} + s_\alpha \kappa_{AZ\gamma} g_{AZ\gamma}\, Z_{\mu\nu} \widetilde{A}^{\mu\nu} \big] \\
& - \frac{1}{4} \big[c_\alpha \kappa_{Hgg} g_{Hgg}\, G^a_{\mu\nu} G^{a,\mu\nu} + s_\alpha \kappa_{Agg} g_{Agg}\, G^a_{\mu\nu} \widetilde{G}^{a,\mu\nu} \big] \\
& - \frac{1}{4} \frac{1}{\Lambda} \big[c_\alpha \kappa_{HZZ}\, Z_{\mu\nu} Z^{\mu\nu} + s_\alpha \kappa_{AZZ}\, Z_{\mu\nu} \widetilde{Z}^{\mu\nu} \big] \\
& - \frac{1}{2} \frac{1}{\Lambda} \big[c_\alpha \kappa_{HWW}\, W^+_{\mu\nu} W^{-\mu\nu} + s_\alpha \kappa_{AWW}\, W^+_{\mu\nu} \widetilde{W}^{-\mu\nu} \big] \\
& - \frac{1}{\Lambda} c_\alpha \big[\kappa_{H\partial\gamma}\, Z_\nu \partial_\mu A^{\mu\nu} + \kappa_{H\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} + \kappa_{H\partial W}\, \big(W_\nu^+ \partial_\mu W^{-\mu\nu} + h.c. \big) \big] \Big\} X_0
\end{aligned}$$

$$V_{\mu\nu} = \partial_\mu V_\nu - \partial_\nu V_\mu \quad (V = A, Z, W^\pm),$$
$$G^a_{\mu\nu} = \partial_\mu G^a_\nu - \partial_\nu G^a_\mu + g_s f^{abc} G^b_\mu G^c_\nu ,$$
$$\widetilde{V}_{\mu\nu} = \frac{1}{2} \epsilon_{\mu\nu\rho\sigma} V^{\rho\sigma}$$

```
######################################
## INFORMATION FOR FRBLOCK
######################################
Block FRBlock
    1 1.000000e+03 # Lambda
    2 1.000000e+00 # ca
    3 1.000000e+00 # kSM
    4 1.000000e+00 # kHtt
    5 1.000000e+00 # kAtt
    6 1.000000e+00 # kHbb
    7 1.000000e+00 # kAbb
    8 1.000000e+00 # kHll
    9 1.000000e+00 # kAll
   10 1.000000e+00 # kHaa
   11 1.000000e+00 # kAaa
   12 1.000000e+00 # kHza
   13 1.000000e+00 # kAza
   14 1.000000e+00 # kHgg
   15 1.000000e+00 # kAgg
   16 0.000000e+00 # kHzz
   17 0.000000e+00 # kAzz
   18 0.000000e+00 # kHww
   19 0.000000e+00 # kAww
   20 0.000000e+00 # kHda
   21 0.000000e+00 # kHdz
   22 0.000000e+00 # kHdw
```

Mass and angular distributions -- spin0






```
./bin/mg5
>import model HiggsCharac
>generate p p > x0, x0 > mu- mu+ e- e+
>output
>launch
```

Effective Lagrangian -- spin1

- The most general interactions at the lowest canonical dimension:

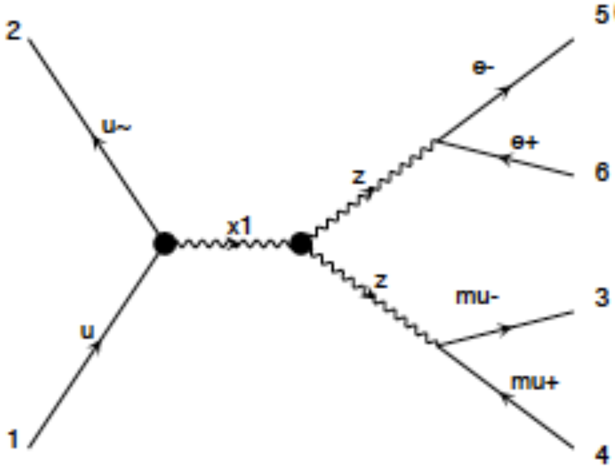
$$\mathcal{L}_1^f = \sum_{f=q,\ell} \bar{\psi}_f \gamma_\mu (\kappa_{f_a} a_f - \kappa_{f_b} b_f \gamma_5) \psi_f X_1^\mu$$

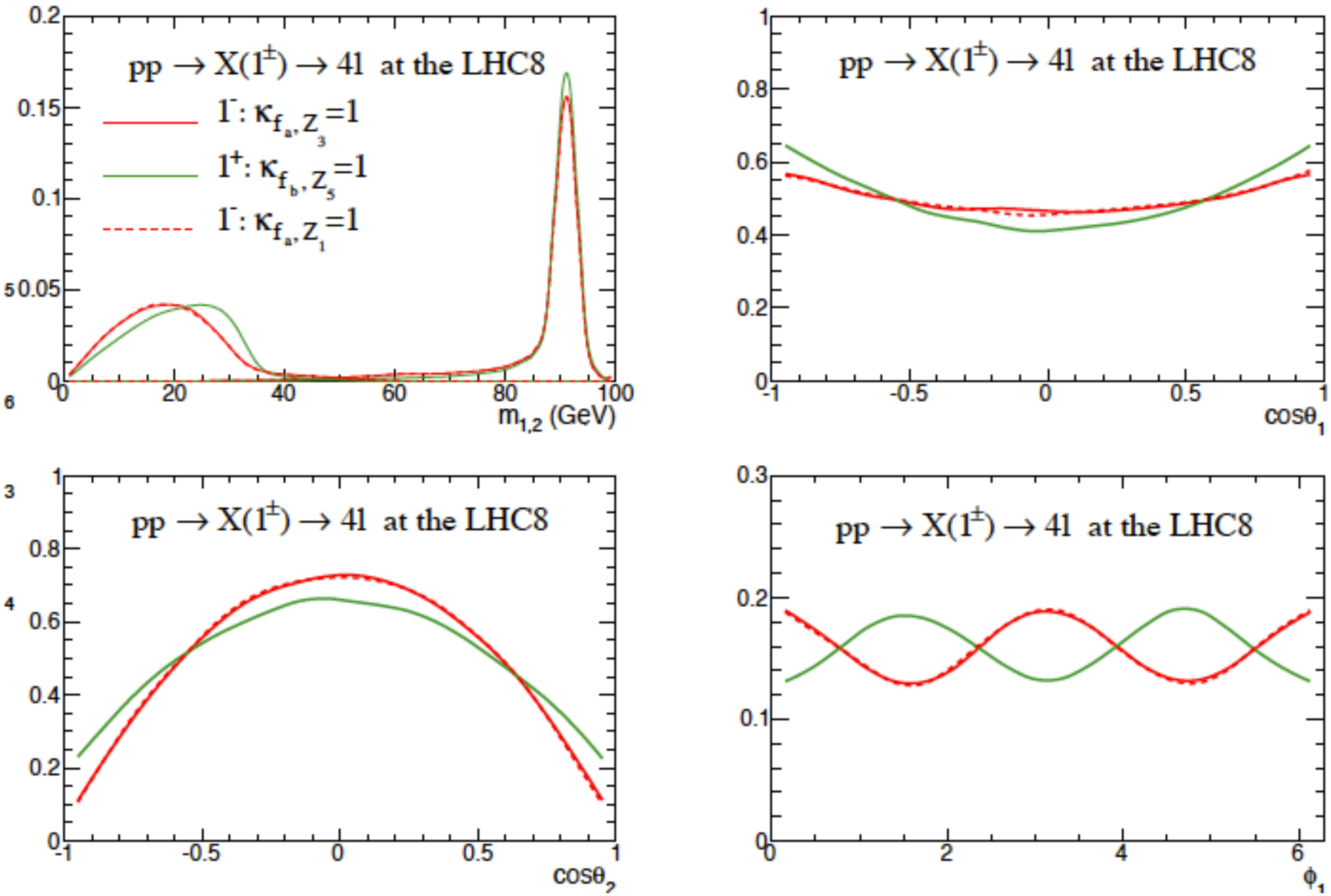
$$\begin{aligned}\mathcal{L}_1^W = & i\kappa_{W_1} g_{WWZ} (W^+_{\mu\nu} W^{-\mu} - W^-_{\mu\nu} W^{+\mu}) X_1^\nu + i\kappa_{W_2} g_{WWZ} W^+_\mu W^-_\nu X_1^{\mu\nu} \\ & - \kappa_{W_3} W^+_\mu W^-_\nu (\partial^\mu X_1^\nu + \partial^\nu X_1^\mu) \\ & + i\kappa_{W_4} W^+_\mu W^-_\nu \widetilde{X}_1^{\mu\nu} - \kappa_{W_5} \epsilon_{\mu\nu\rho\sigma} [W^{+\mu} (\partial^\rho W^{-\nu}) - (\partial^\rho W^{+\mu}) W^{-\nu}] X_1^\sigma\end{aligned}$$

$$\mathcal{L}_1^Z = -\kappa_{Z_1} Z_{\mu\nu} Z^\mu X_1^\nu - \kappa_{Z_3} X_1^\mu (\partial^\nu Z_\mu) Z_\nu - \kappa_{Z_5} \epsilon_{\mu\nu\rho\sigma} X_1^\mu Z^\nu (\partial^\rho Z^\sigma)$$

- Parity conservation implies that
  - for X_1- $\quad \kappa_{f_b} = \kappa_{V_4} = \kappa_{V_5} = 0$
  - for X_1+ $\quad \kappa_{f_a} = \kappa_{V_1} = \kappa_{V_2} = \kappa_{V_3} = 0$

Mass and angular distributions -- spin1





Effective Lagrangian -- spin2

- via the energy-momentum tensor of the SM fields, starting from D5:

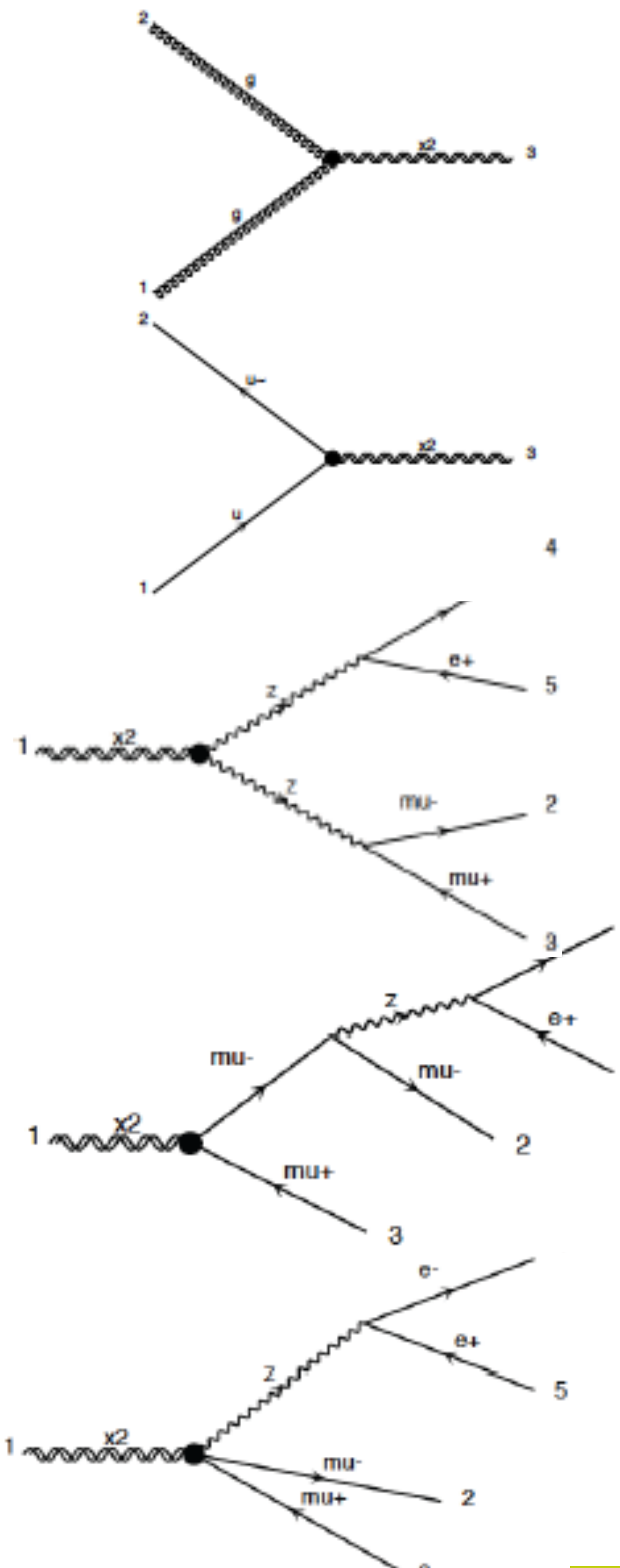
$$\mathcal{L}_2^f = -\frac{1}{\Lambda}\sum_{f=q,\ell} \kappa_f T^f_{\mu\nu} X_2^{\mu\nu}$$

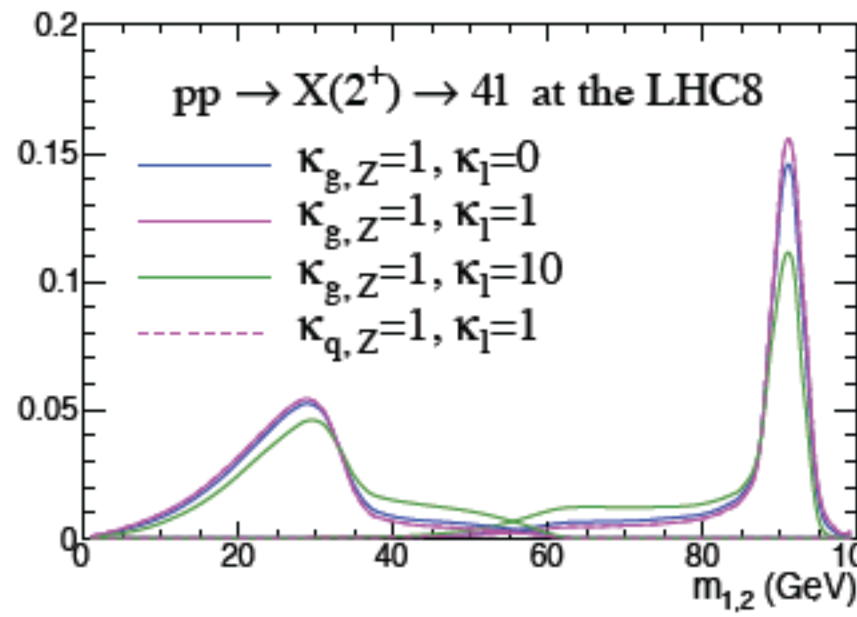
$$\mathcal{L}_2^V = -\frac{1}{\Lambda}\sum_{V=Z,W,\gamma,g} \kappa_V T^V_{\mu\nu} X_2^{\mu\nu}$$

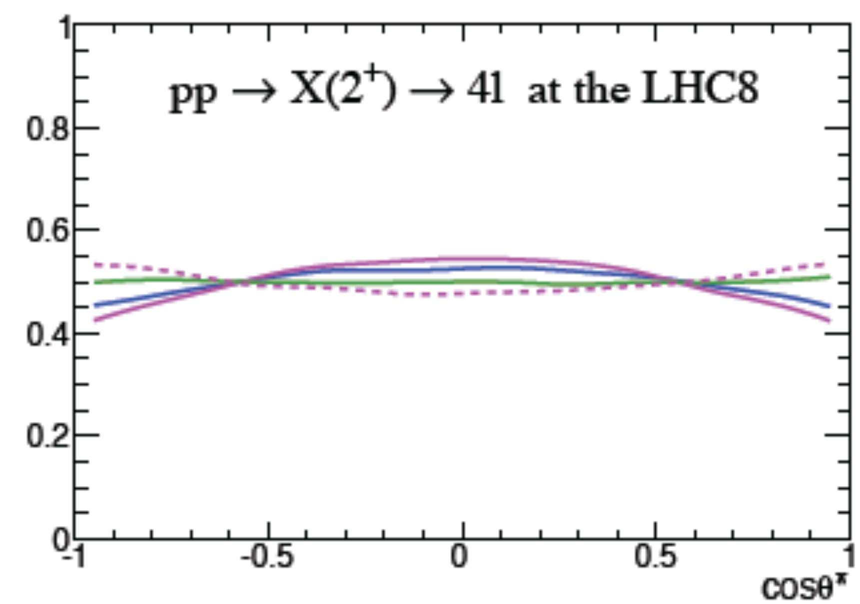
  - The E-M tensor for QED:

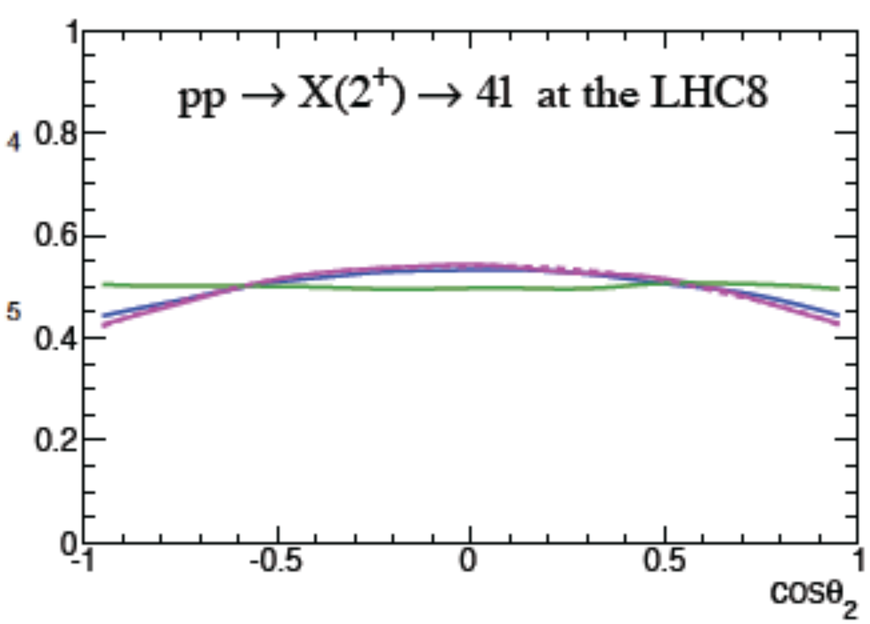
$$\begin{aligned}
T^f_{\mu\nu} = &- g_{\mu\nu}\Big[\bar\psi_f(i\gamma^\rho D_\rho - m_f)\psi_f - \frac{1}{2}\partial^\rho(\bar\psi_f i\gamma_\rho\psi_f)\Big] \\
&+ \Big[\frac{1}{2}\bar\psi_f i\gamma_\mu D_\nu\psi_f - \frac{1}{4}\partial_\mu(\bar\psi_f i\gamma_\nu\psi_f) + (\mu\leftrightarrow\nu)\Big]\,, \\
T^\gamma_{\mu\nu} = &- g_{\mu\nu}\Big[-\frac{1}{4}A^{\rho\sigma}A_{\rho\sigma} + \partial^\rho\partial^\sigma A_\sigma A_\rho + \frac{1}{2}(\partial^\rho A_\rho)^2\Big] \\
&- A_\mu^{\ \rho}A_{\nu\rho} + \partial_\mu\partial^\rho A_\rho A_\nu + \partial_\nu\partial^\rho A_\rho A_\mu\,,
\end{aligned}$$

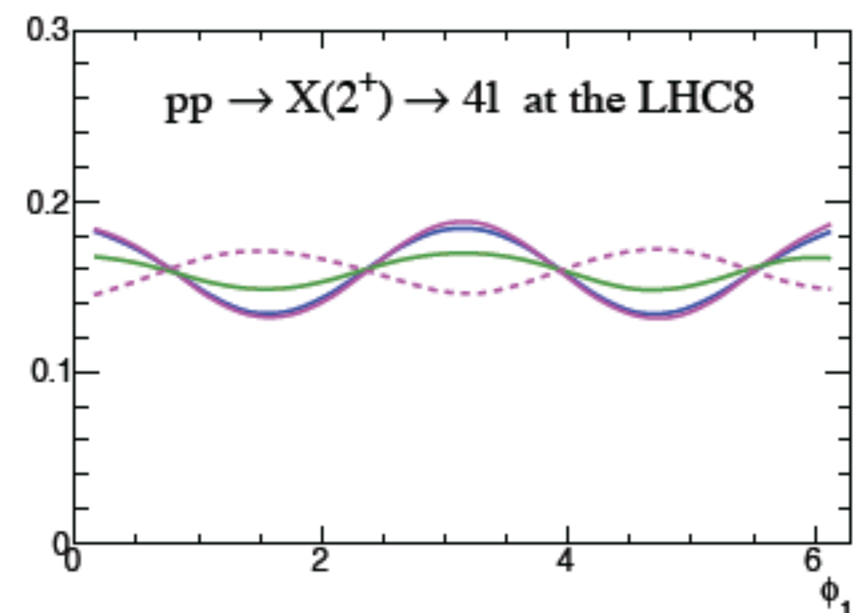
Mass and angular distributions -- spin2

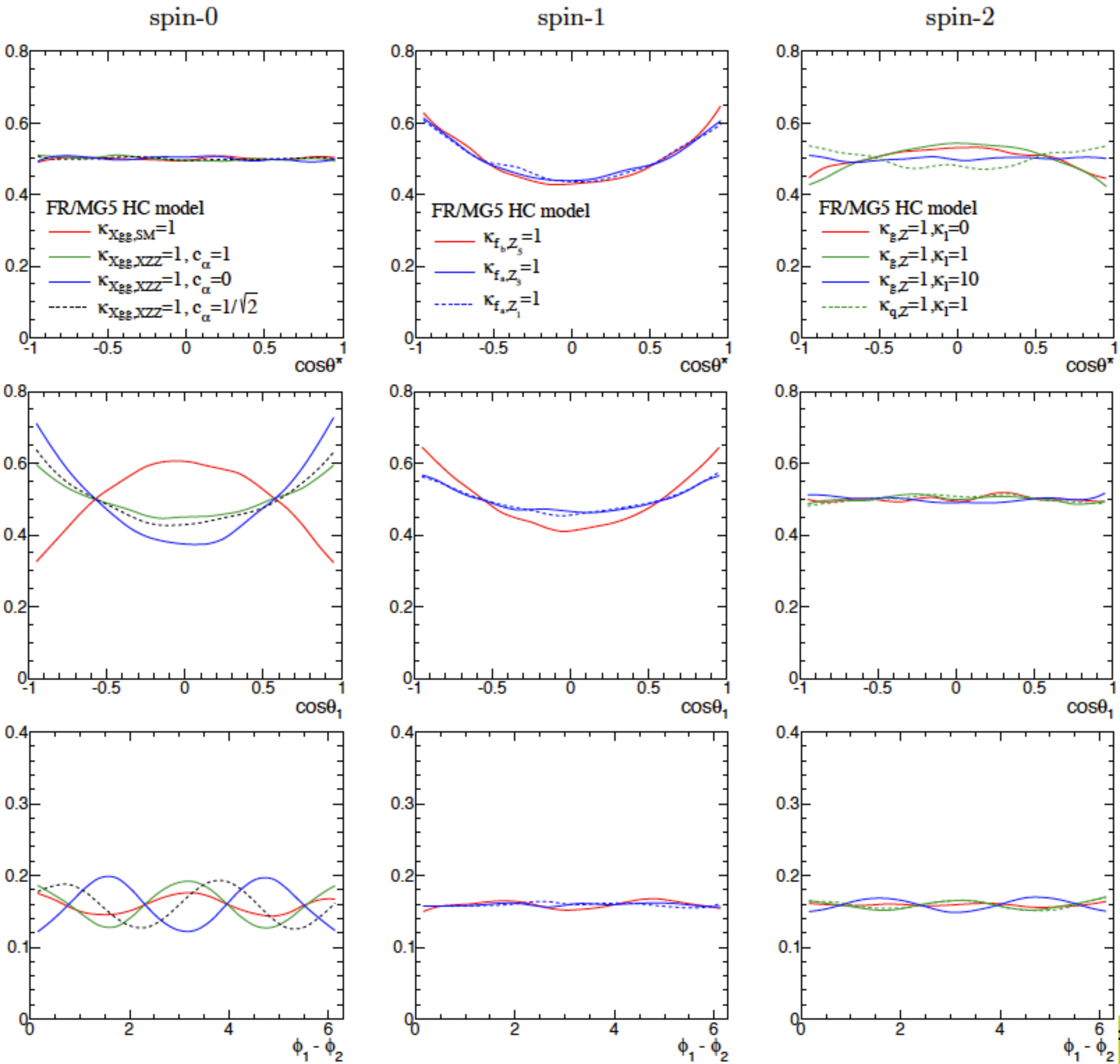








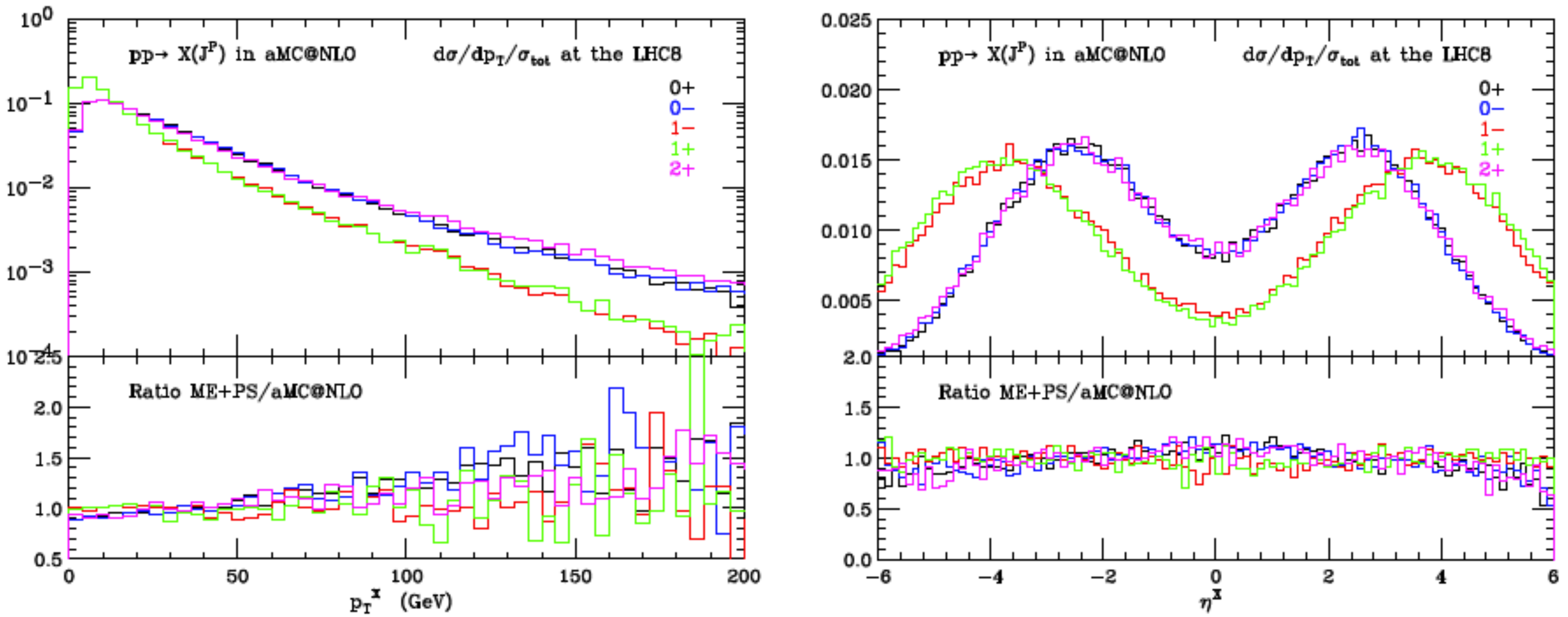




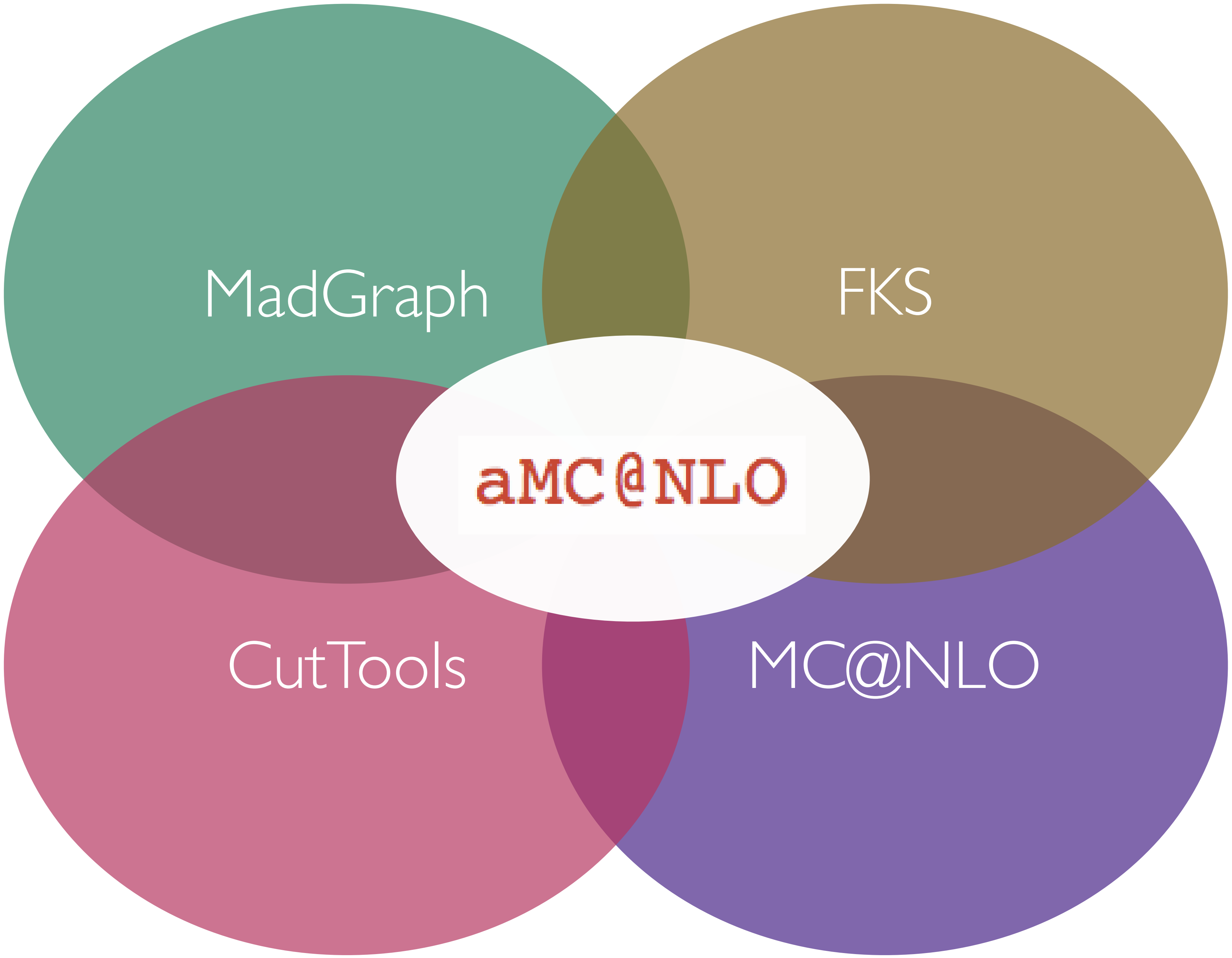
spin-0
spin-1
spin-2
FR/MG5 HC model
$\kappa_{X_{gg,SM}}=1$
$\kappa_{X_{gg},XZZ}=1, c_\alpha=1$
$\kappa_{X_{gg},XZZ}=1, c_\alpha=0$
$\kappa_{X_{gg},XZZ}=1, c_\alpha=1/\sqrt{2}$
$\kappa_{f_b,Z_S}=1$
$\kappa_{f_a,Z_S}=1$
$\kappa_{f_a,Z_1}=1$
$\kappa_{g,Z}=1, \kappa_1=0$
$\kappa_{g,Z}=1, \kappa_1=1$
$\kappa_{g,Z}=1, \kappa_1=10$
$\kappa_{q,Z}=1, \kappa_1=1$
$\cos\theta^*$
$\cos\theta_1$
$\phi_1 - \phi_2$

Higher order effects in QCD

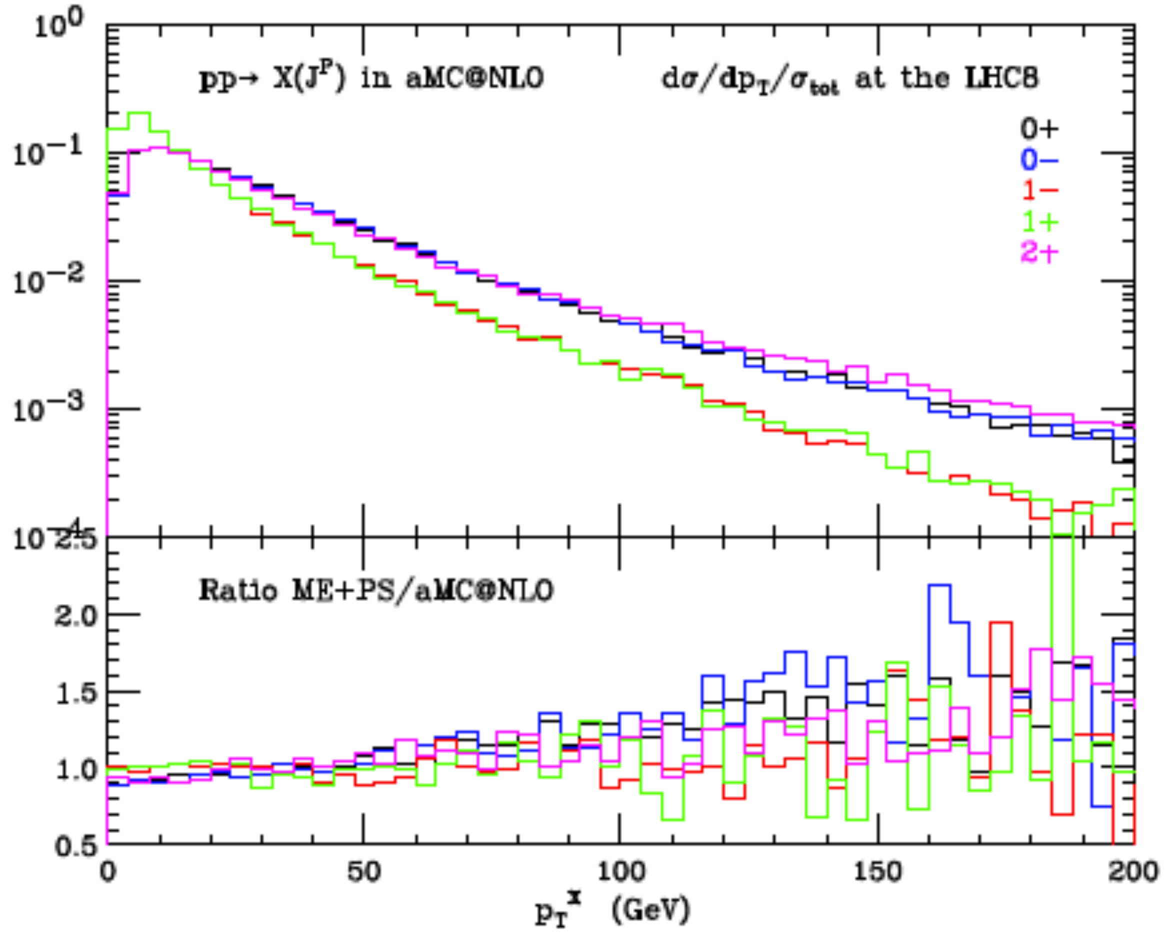
- The LO predictions can be systematically improved by including the effects due to the emission of QCD partons.
  - LO Matrix-Element/Parton-Shower merging [ME+PS]
  - full-NLO matrix element with parton-shower [aMC@NLO]

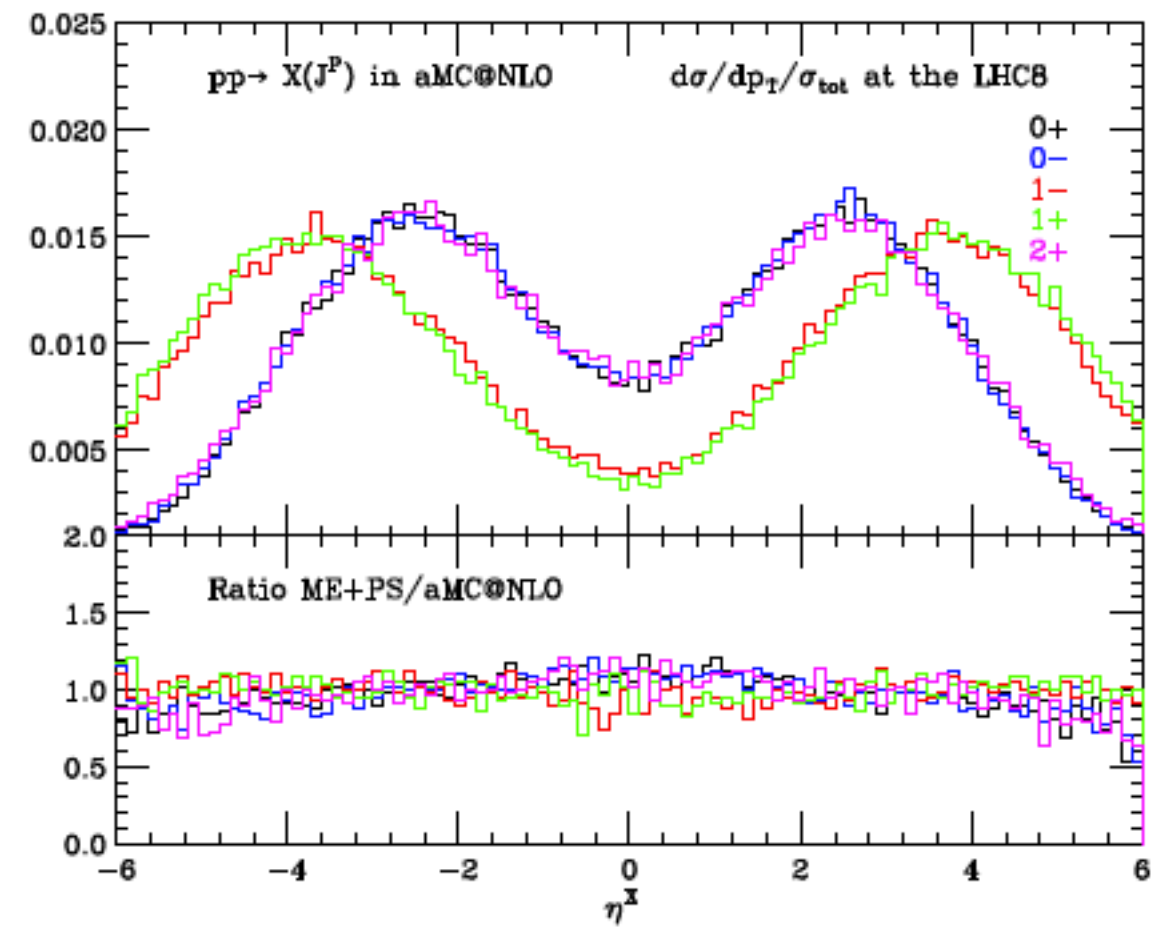


aMC@NLO



Higher order effects in QCD





matched sample harder
than aMC@NLO at large pt
(as it should)

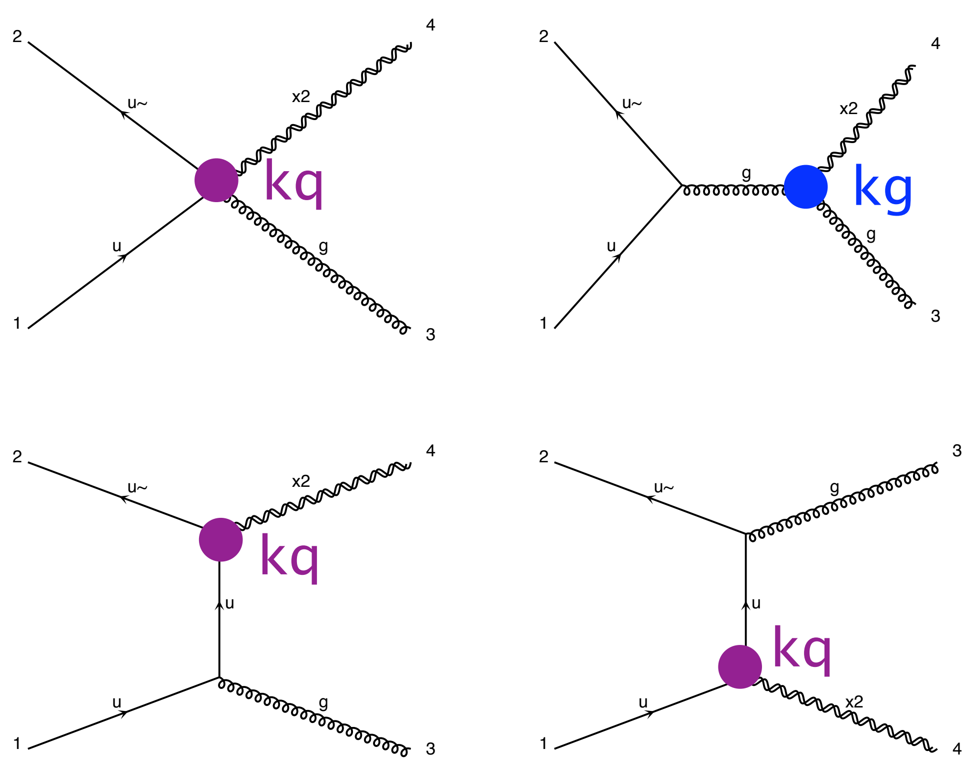
different shapes due
to different initial state

excellent agreement between
ME+PS and aMC@NLO

Higher order effects in QCD

unitarity-violating behavior of models with a spin-2 state

$$\mathcal{L} = -\frac{1}{\Lambda}\kappa_q T^q_{\mu\nu} X_2^{\mu\nu} - \frac{1}{\Lambda}\kappa_g T^g_{\mu\nu} X_2^{\mu\nu}$$



$$|\mathcal{M}|^2 \propto s/\Lambda^2 \quad \text{for } \kappa_q = \kappa_g$$

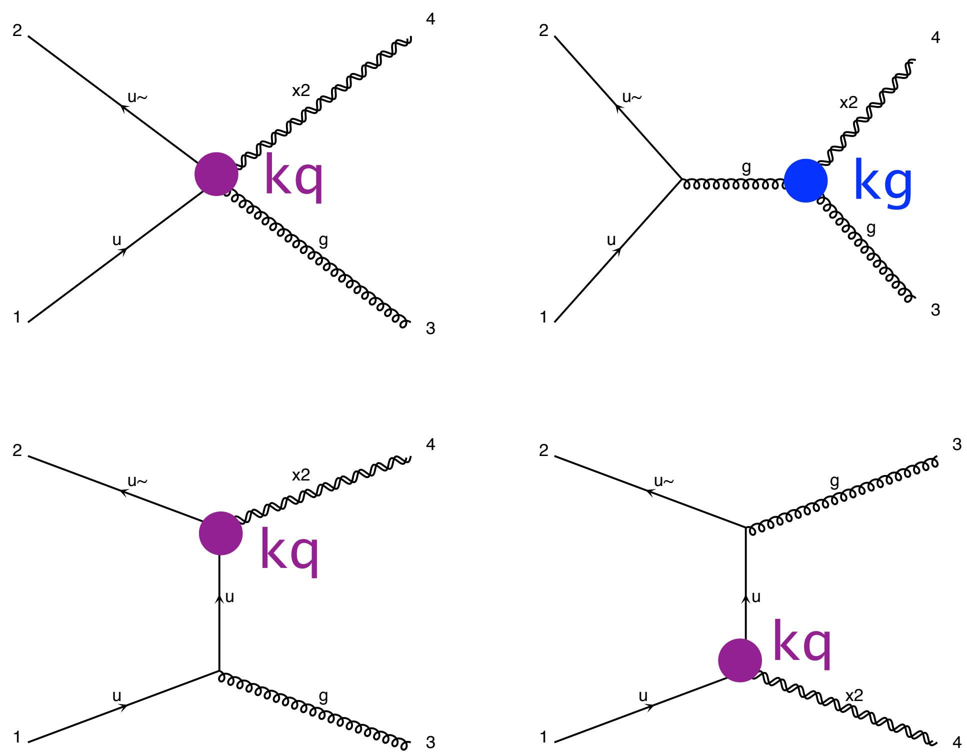
$$|\mathcal{M}|^2 \propto s^3/m^4\Lambda^2 \quad \text{for } \kappa_q \neq \kappa_g$$

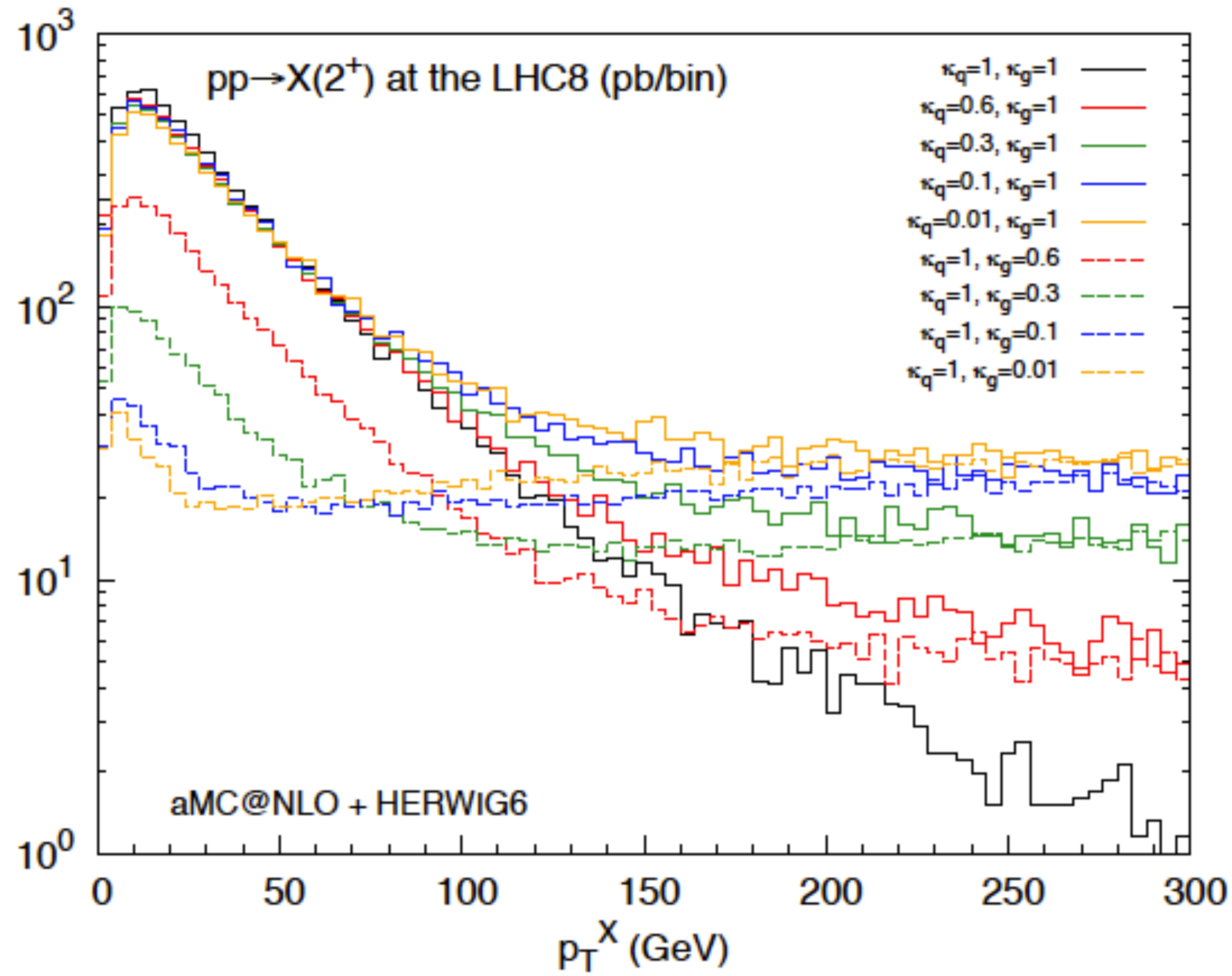
$$|\mathcal{M}|^2 = \frac{N}{\Lambda^2 s\,t\,u\,m^4}\Big\{3\kappa_g^2 m^4\left[2m^4 - 2m^2(t+u) + t^2 + u^2\right]\left[m^4 - m^2(t+u) + 4tu\right]$$
$$+ (\kappa_q - \kappa_g)\,6\,\kappa_g m^4 s\left[m^6 + m^2 s(s+2u) - 2su(s+u)\right]$$
$$+ (\kappa_q - \kappa_g)^2 s\big[6m^{10} - 6m^8(t+u) + 3m^6(t^2+u^2) - 12m^4 tu(t+u)$$
$$+ 2m^2 tu(t^2 + 12tu + u^2) - 2tu(t^3 + t^2u + tu^2 + u^3)\big]\Big\}, \quad (4.2)$$

Higher order effects in QCD

unitarity-violating behavior of models with a spin-2 state

$$\mathcal{L} = -\frac{1}{\Lambda}\kappa_q T^q_{\mu\nu} X_2^{\mu\nu} - \frac{1}{\Lambda}\kappa_g T^g_{\mu\nu} X_2^{\mu\nu}$$

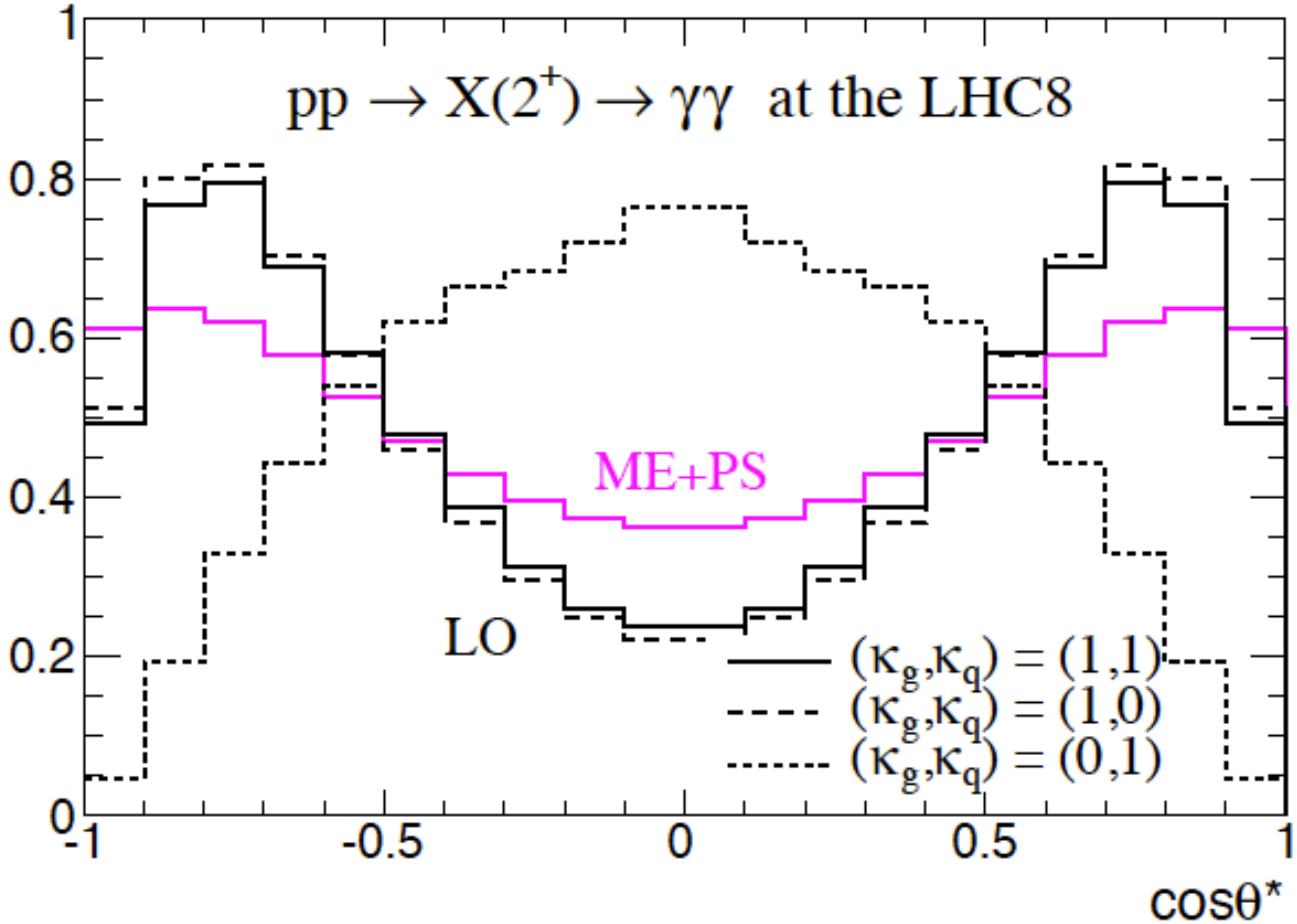




- A model with non-universal couplings dramatically changes the pT(X) spectrum.

Higher order effects in QCD

on spin observables for a spin-2 state



$$\frac{d\sigma(gg)}{d\cos\theta^*} \propto |d^2_{22}(\theta^*)|^2 + |d^2_{2-2}(\theta^*)|^2 = \frac{1}{8}(1 + 6\cos^2\theta^* + \cos^4\theta^*)\,,$$

$$\frac{d\sigma(q\bar{q})}{d\cos\theta^*} \propto |d^2_{12}(\theta^*)|^2 + |d^2_{1-2}(\theta^*)|^2 = \frac{1}{2}(1 - \cos^4\theta^*)\,.$$

How can we get the spin/parity information?

1. $X \to \gamma\gamma$
2. $X \to VV^* \to 4l$
3. $pp \to jjX$
4. $pp \to VX$
5. $X \to \tau\tau$

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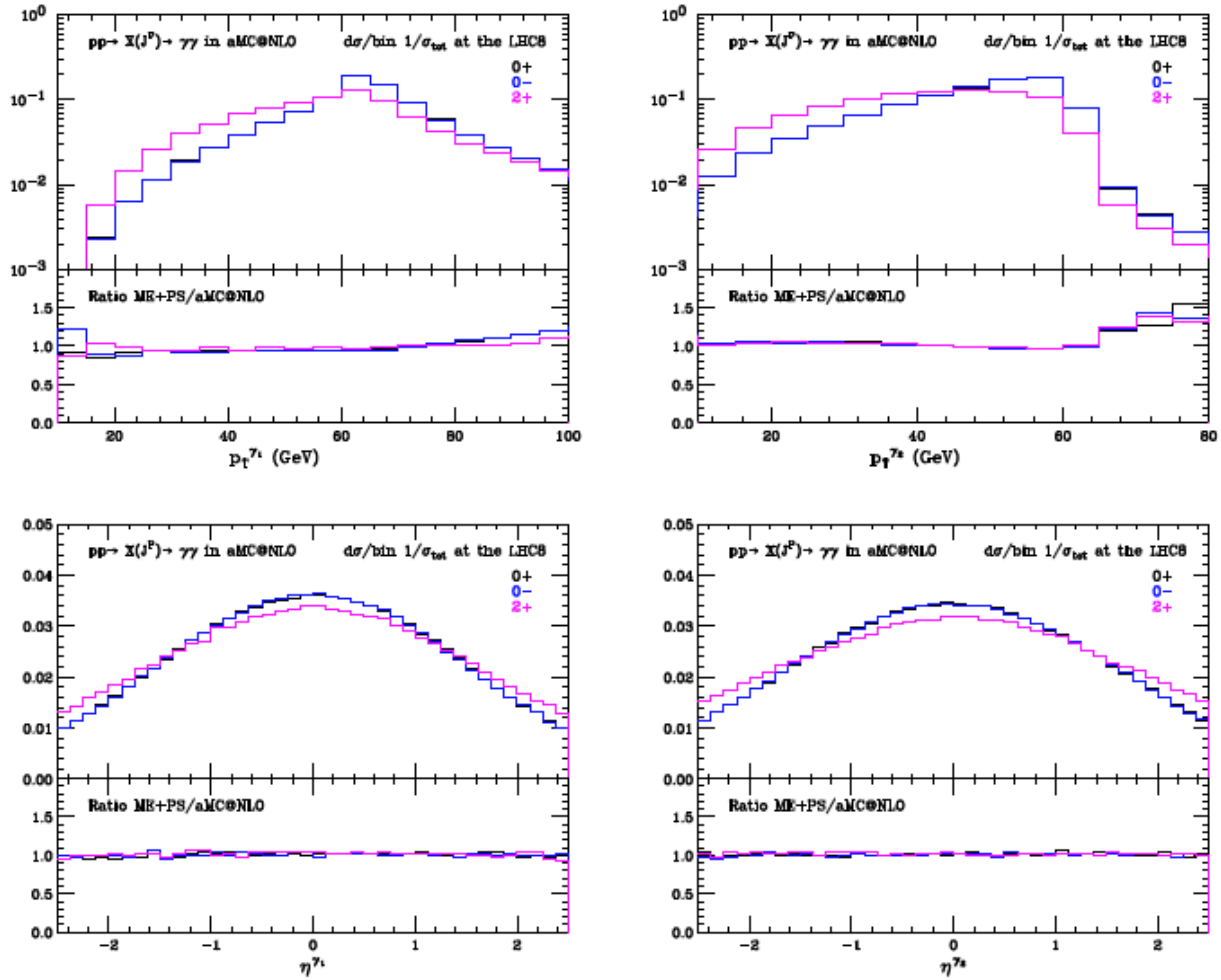
Spin/parity determination
1. X→γγ



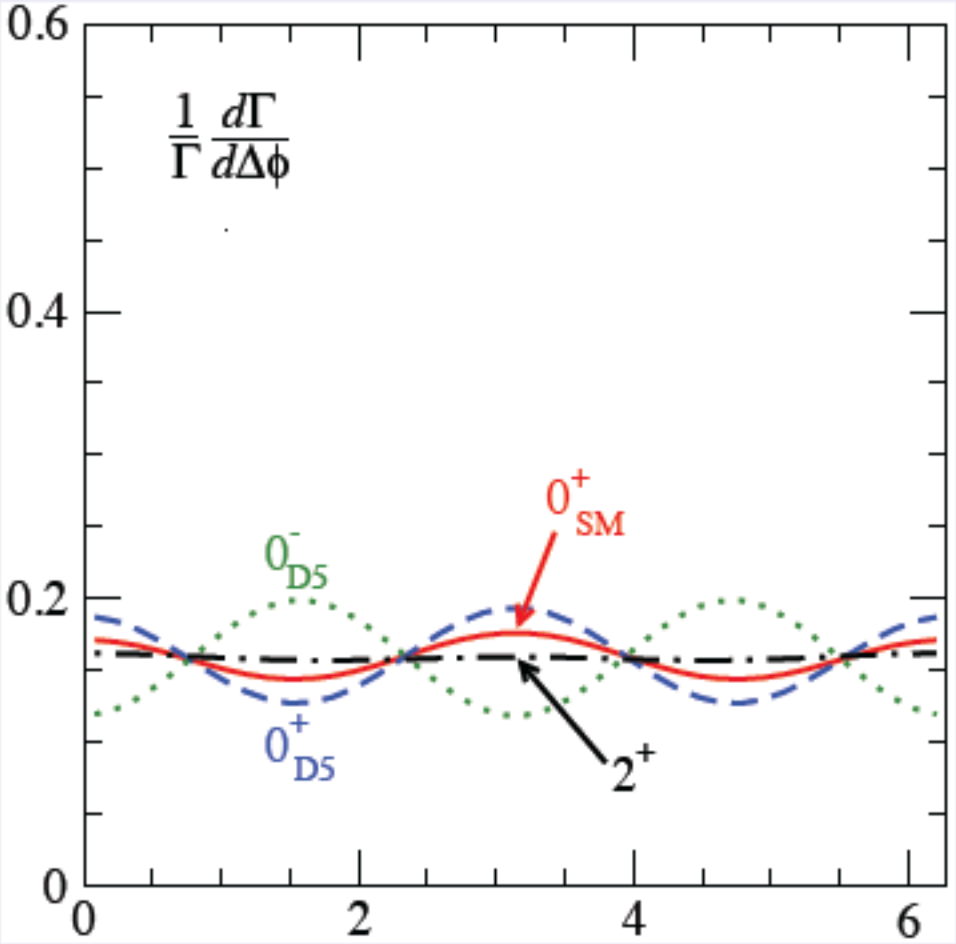
Spin/parity determination
2. X→VV*→4l

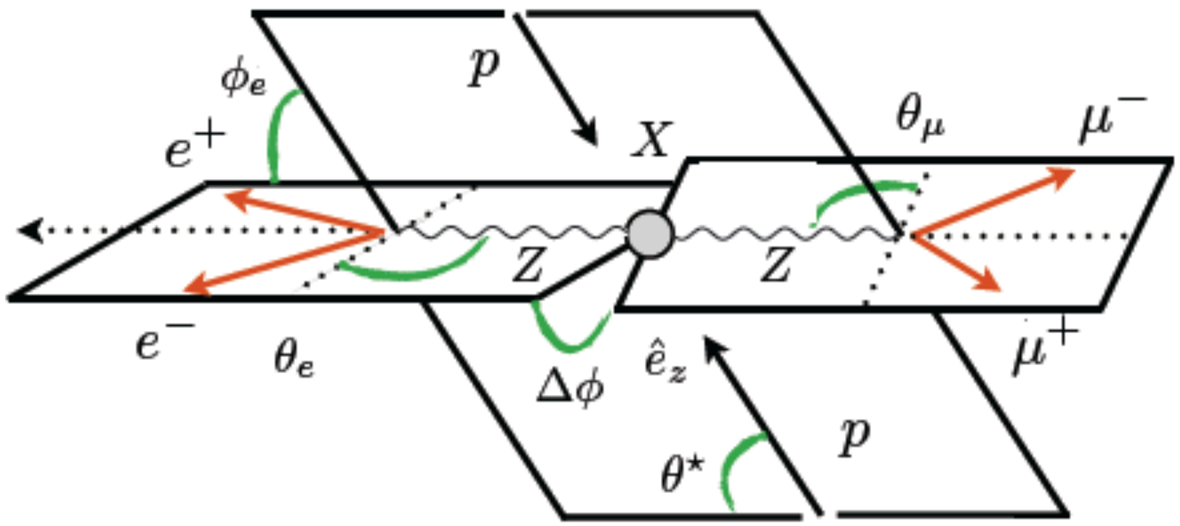
[Dell'Aquilla, Nelson, PRD(1986)]
[Choi, Miller, Mühlleitner, Zerwas, PLB(2003)]
[Gao et al, PRD(2010)] ...

[Bolognesi et al, PRD(2012)]

$$\mathcal{L}_{0^+_{\rm SM}} = g_{0^+_{\rm SM}} V_\mu V^\mu X_0$$
$$\mathcal{L}_{0^+_{\rm D5}} = g_{0^+_{\rm D5}} V_{\mu\nu} V^{\mu\nu} X_0$$
$$\mathcal{L}_{0^-_{\rm D5}} = g_{0^-_{\rm D5}} V_{\mu\nu} \widetilde{V}^{\mu\nu} X_0$$

$X \to ZZ^* \to 4\ell$





$d\sigma/d\Delta\phi \sim$ const. for $0^+_{\rm SM}$, $\quad d\sigma/d\Delta\phi \sim 1 \pm A\cos 2\Delta\phi$ for $0^\pm_{\rm D5}$.

Spin/parity determination X→4l vs. VBF

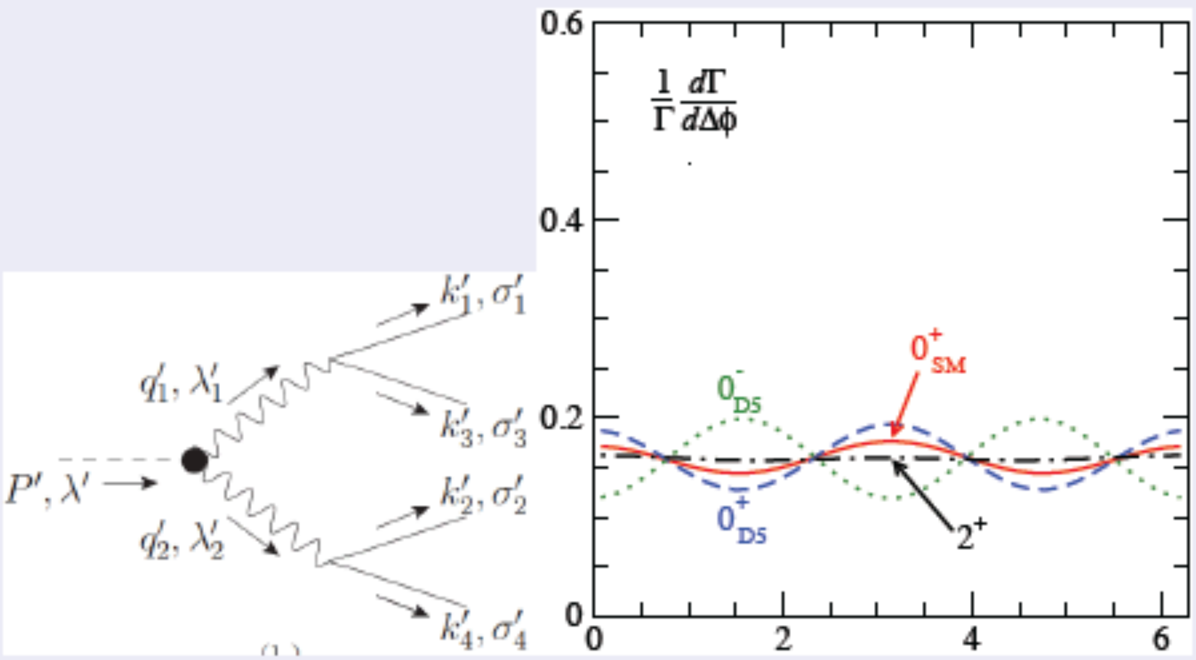
[Choi, Miller, Mühlleitner, Zerwas, PLB(2003)]
[Gao et al, PRD(2010)] ...

[Bolognesi et al, PRD(2012)]

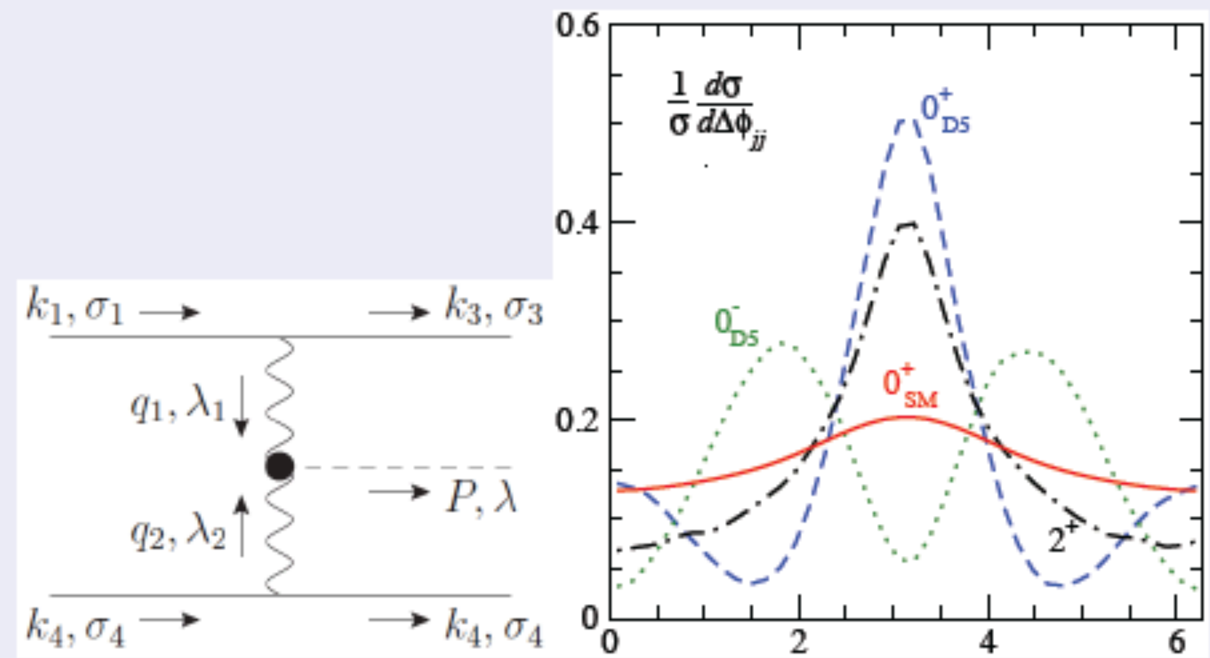
[Plehn, Rainwater, Zeppenfeld, PRL(2002)]
[Hagiwara, Li, KM, JHEP(2009)] ...

[Englert, Goncalves-Netto, KM, Plehn, JHEP(2013)]

$X \to ZZ^* \to 4\ell$



Vector boson fusion (VBF)



$$d\sigma/d\Delta\phi \sim \text{const. for } 0^+_{\rm SM}, \quad d\sigma/d\Delta\phi \sim 1 \pm A\cos 2\Delta\phi \text{ for } 0^\pm_{\rm D5}.$$

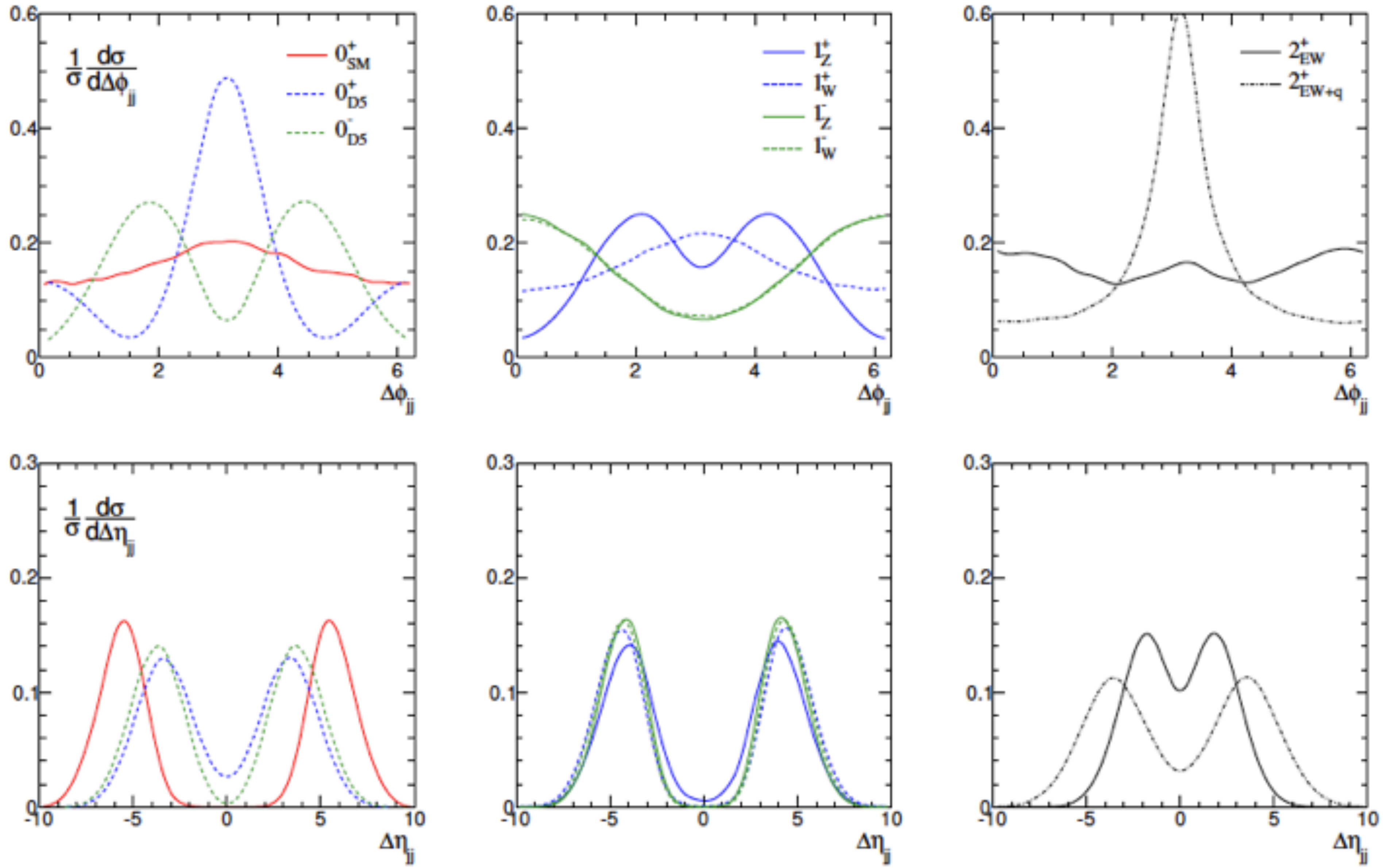
Nontrivial azimuthal angle correlations of the decay planes ($X \to ZZ$) and the jets (VBF) can be explained as the quantum interference among different helicity states of the intermediate vector-bosons.

Spin/parity determination
3. pp→jjX

di-jet correlations

Englert, Goncalves-Netto, KM, Plehn (2013)

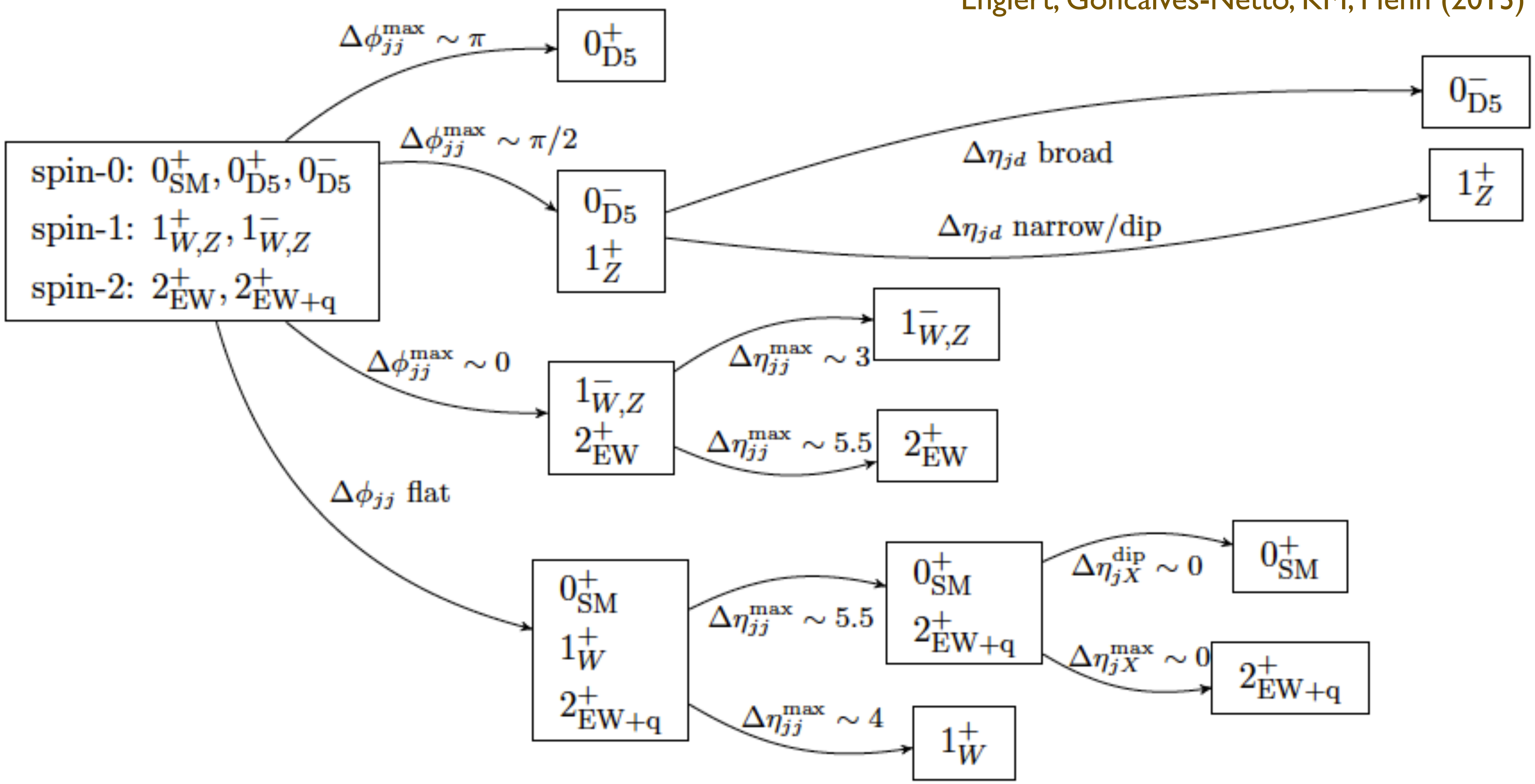
spin-0 spin-1 spin-2



Δη as well as ΔΦ are the powerful observables.

Obs-by-obs based strategy in VBF

Englert, Goncalves-Netto, KM, Plehn (2013)



The di-jet correlations are the most decisive, in particular to separate the different scalar coupling structures.

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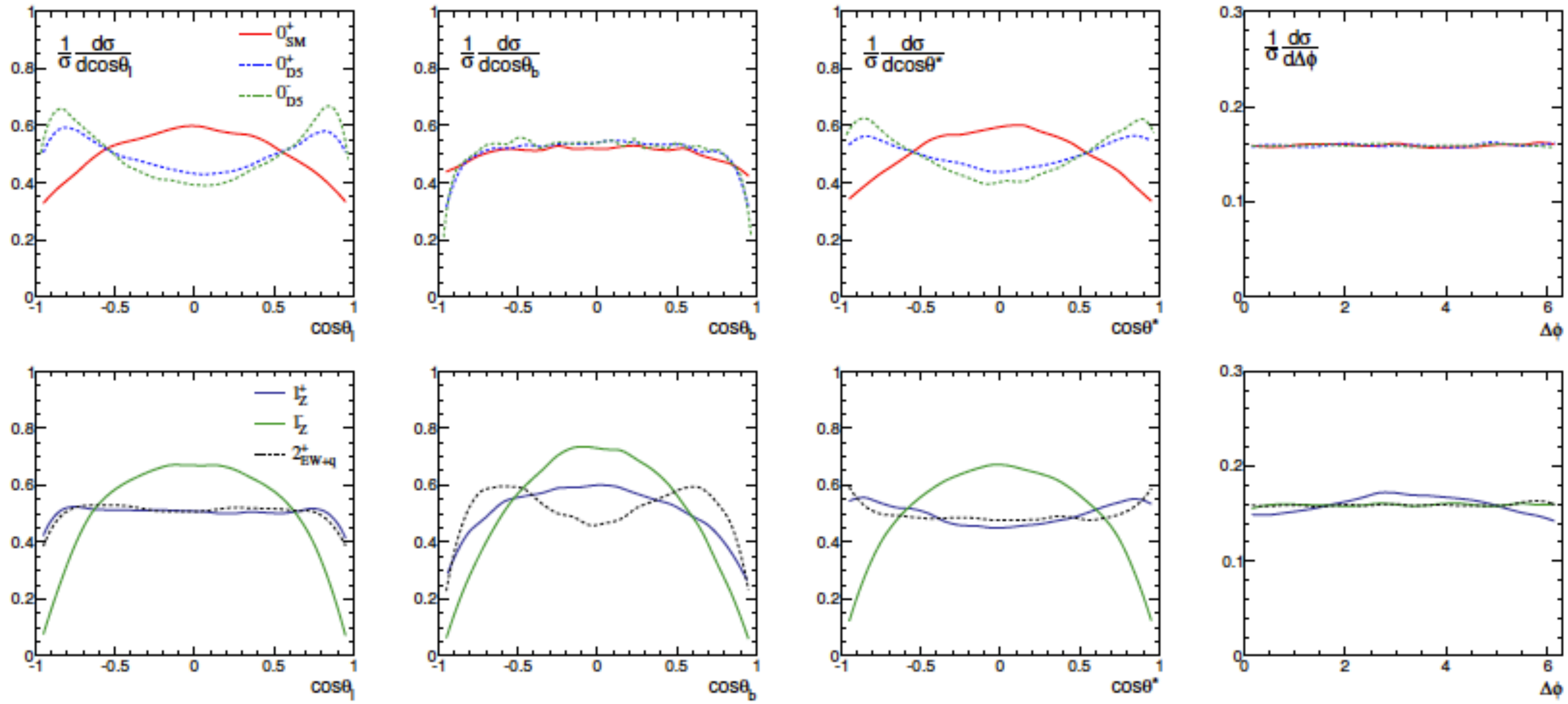
Spin/parity determination
4. pp→ZX

Englert, Goncalves-Netto, KM, Plehn (2013)



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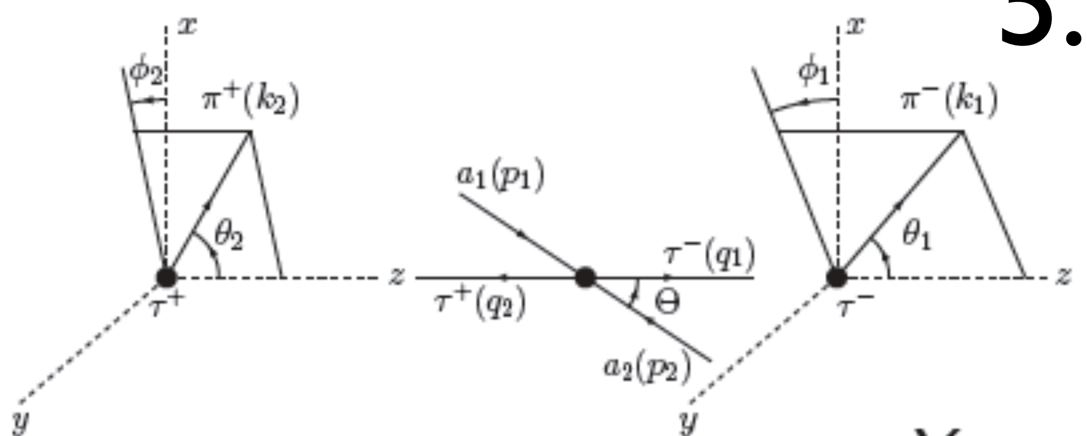
Spin/parity determination
5. X→ττ

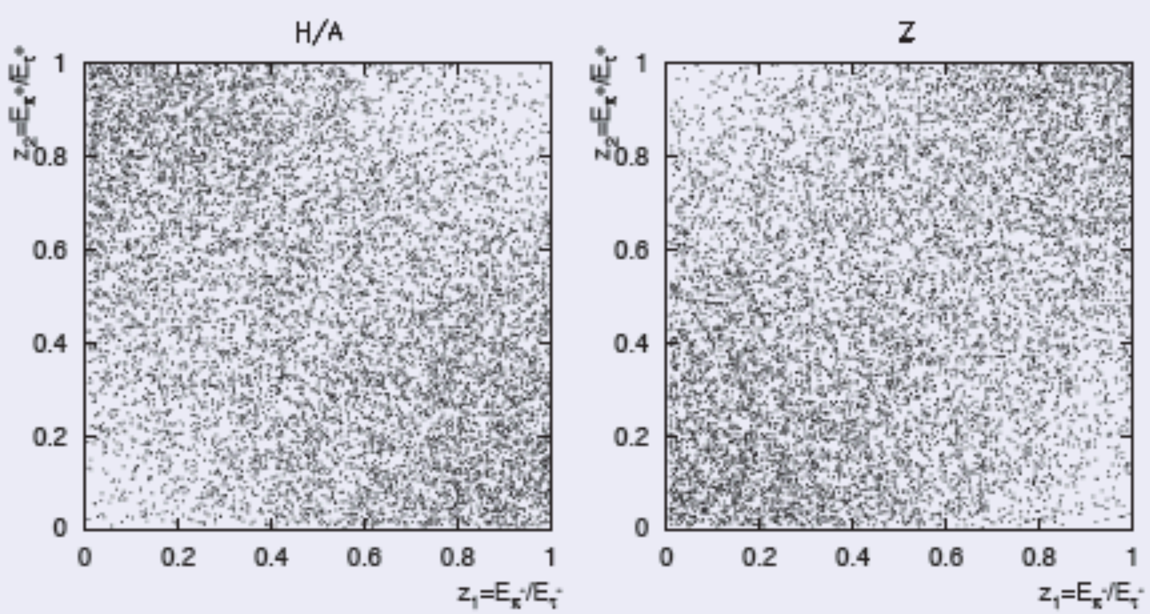


[Bullock, Hagiwara, Martin, NPB(1993)]
[Krämer, Kühn, Stong, Zerwas, ZPC(1994)]
[Pierzchala, Richter-Was, Was, Worek, APPB(2001,2002,...)]

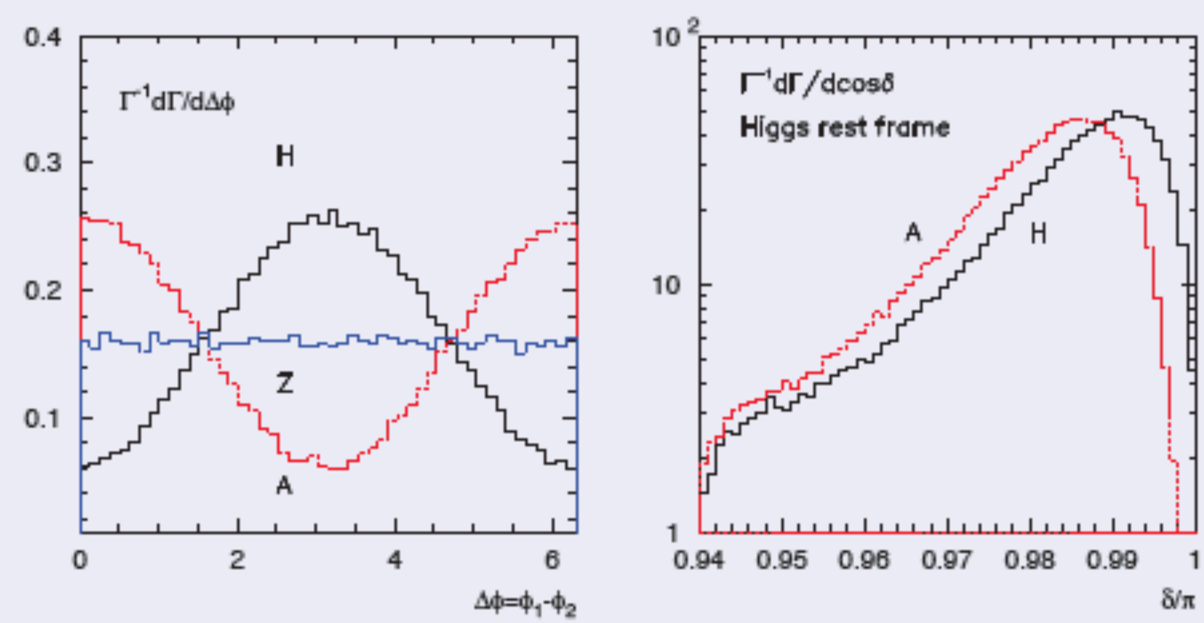
[Hagiwara, Li, KM, Nakamura, 1212.6247]

$$pp \to X \to \tau^+\tau^- \to \pi^+\pi^-\nu_\tau\bar{\nu}_\tau$$

Longitudinal spin (helicity) effect



Transverse spin effect



$$d^2\Gamma/dz_1dz_2 \sim 1 \mp z_1z_2 \text{ for spin-0/1}, \quad d\Gamma/d\Delta\phi \sim 1 \mp A\cos\Delta\phi \text{ for } 0^\pm$$

τ could be a spin/parity analyzer!

TauDecay

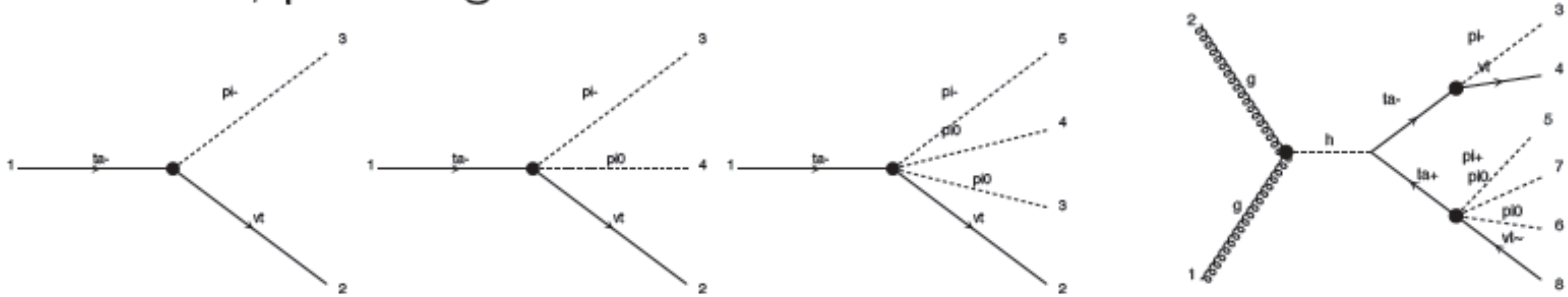
a library to simulate polarized tau decays via FeynRules/MadGraph5

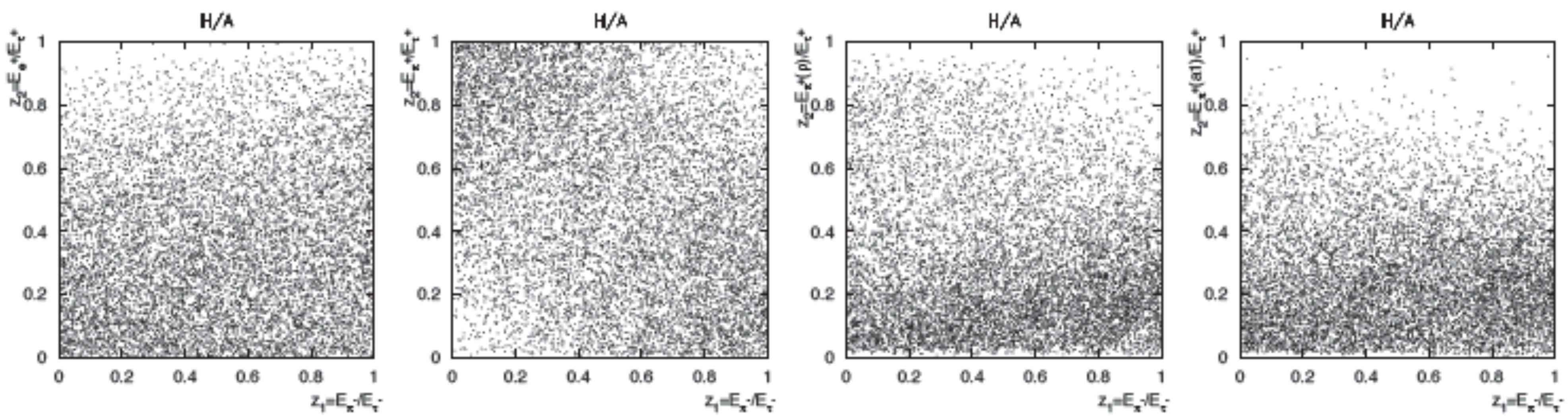
We implemented the effective Lagrangians [Hagiwara, Li, KM, Nakamura, 1212.6247]

$$\mathcal{L}_\pi = \sqrt{2} G_F f_\pi \cos\theta_C \, \bar{\tau}\gamma^\mu P_L \nu_\tau \, \partial_\mu \pi^- + h.c.$$

$$\mathcal{L}_\rho = 2 G_F \cos\theta_C F_\rho(Q^2) \, \bar{\tau}\gamma^\mu P_L \nu_\tau \, (\pi^0 \partial_\mu \pi^- - \pi^- \partial_\mu \pi^0) + h.c.$$

into FeynRules, providing the model file for MadGraph5.





Full spin correlations for any kinds of new physics models can be generated for free.

Outlook

- After the discovery of a Higgs-like resonance at the LHC, the main focus of the analyses now is the determination of the Higgs Lagrangian.
- This includes
  - the structure of the operators, linked to the spin/parity of the 'Higgs' boson.
  - an independent measurement of the coupling strength.
- Our FR/MG5 Higgs Characterization model is ready for the spin/parity study of the recently-discovered boson.