Anomalous coupling studies

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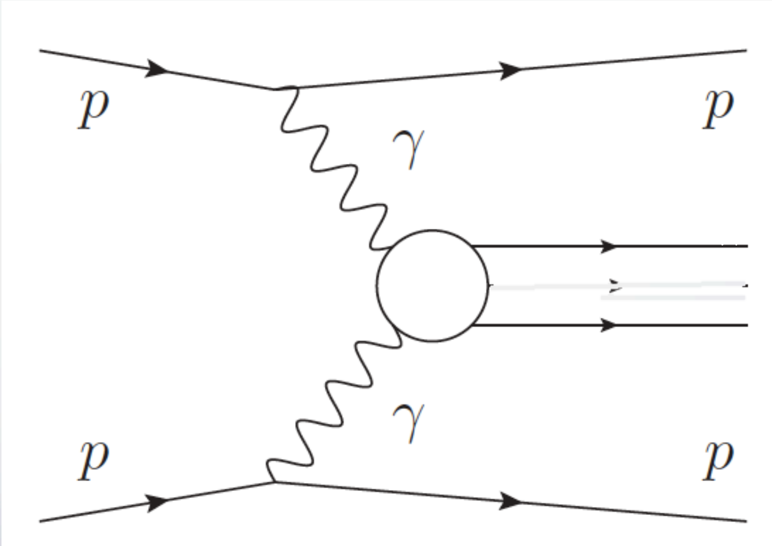
WW and ZZ photon induced processes

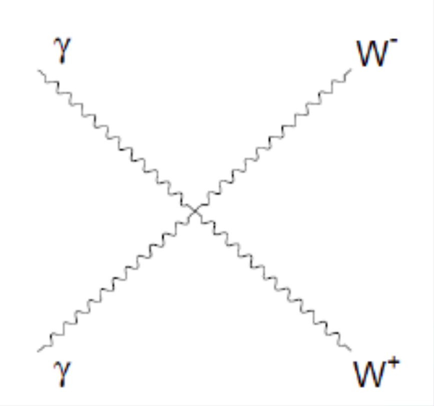
- Study of $pp \rightarrow pWWp$
  - Very clean process: W pair in central detector, intact protons in forward detector.
  - Cross section high and perfectly known (95.6fb QED).
- If $W > 1\text{TeV}$ (cross. sec. = 5.9fb), still high, so it is possible to probe new physics.



WW and ZZ quartic anomalous photon induced processes.

$$\mathcal{L}_6^0 \sim \frac{-e^2}{8}\frac{a_0^W}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\cos^2(\theta_W)}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$\mathcal{L}_6^C \sim \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta) - \frac{e^2}{16\cos^2(\theta_W)}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$



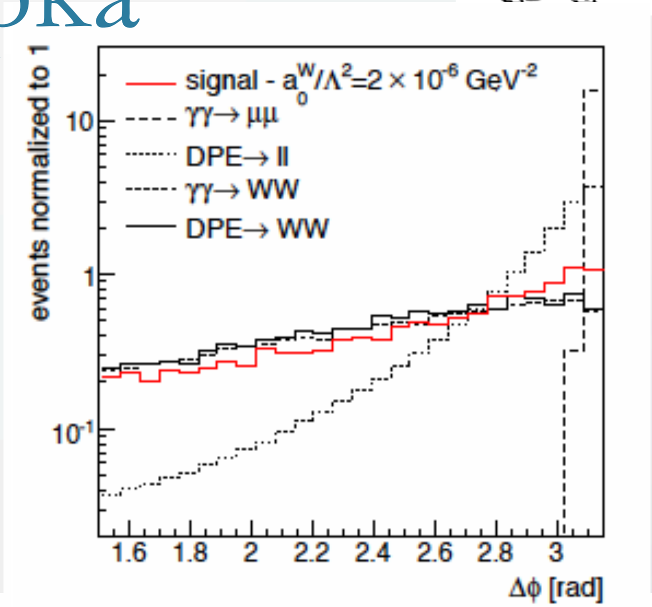
- In addition to standard model measurement, study of anomalous photon coupling [Phys. Rev. D81:074003, 2010 E. Chapon, O. Kepka, C. Royon].
- Anomalous quartic $WW\gamma\gamma$ and $ZZ\gamma\gamma$ coupling are not present in the standard model.
  - They are parameterized by 4 variables a_0^W, a_C^W, a_0^Z, a_C^Z.
  - Present limit on couplings from LEP ~2.10^{-2}.
- Anomalous coupling terms predicted by beyond SM theories: Higgless, extra-dimension. Expected values: few 10^{-6}.

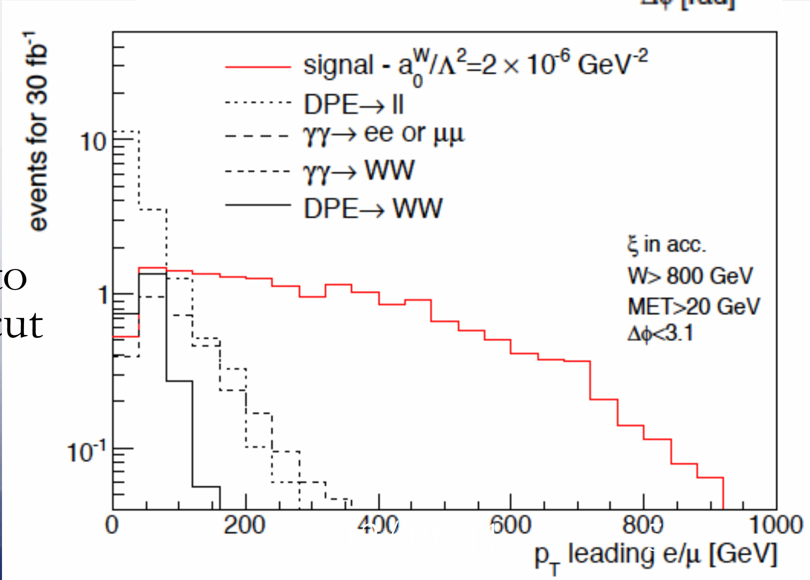
Forward Physics Monte Carlo (FPMC)

- Monte Carlo that implements all diffractive/photon induced processes.
  - Two photon exchange
  - Single diffraction
  - Double pomeron exchange
  - Central exclusive production
- Manual: see M. Boonekamp, A. Dechambre, O. Kepka, V. Juranek, C. Royon, R. Staszewski, M. Rangel, ArXiv:1102.2531, code to be public soon.
- For this study the output of FPMC generator interfaced with the fast simulation of ATLAS detector in the standalone ATLFast++ package.

WWγγ production leptonic case Oldrich Kepka

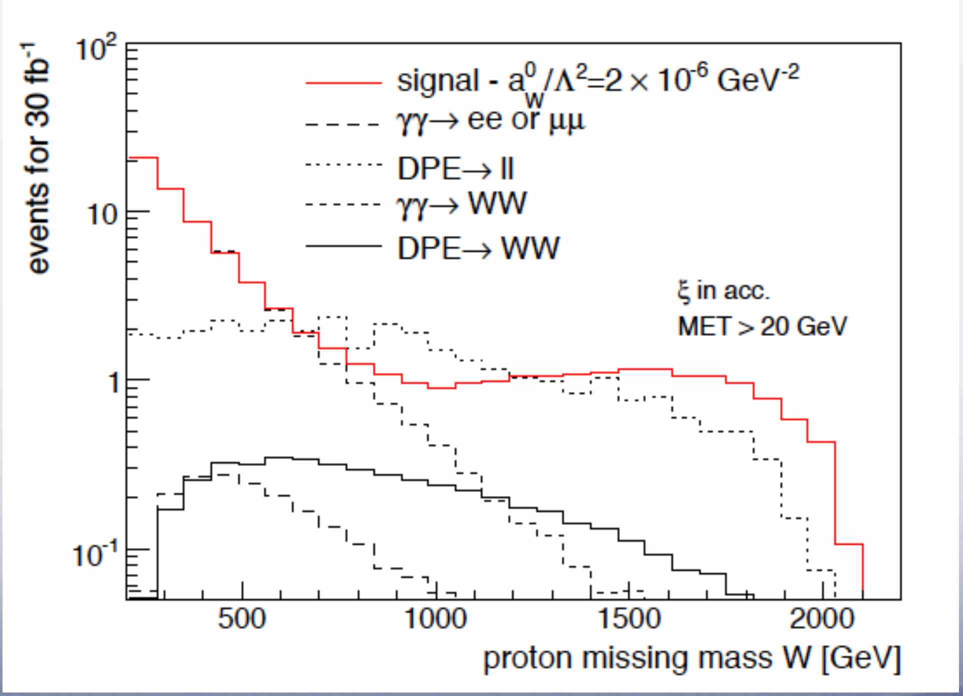
- Signal (red):
  - WW decay in the central detector, protons leave intact at small angles.
- Background (black):
  - SM WW pair production via photon exchange. Removed by cut on high mass.
  - Non diffractive WW production: large energy flow in the forward region. Removed by requesting tagged protons.
  - Dilepton production via photon exchange. Back-to-back leptons. Small cross section for high p_t leptons.
  - Lepton production via double pomeron exchange: activity in the forward region due to pomeron remnants. Removed by missing Et cut and small cross section at high mass.
  - WW via double pomeron exchange: removed by cut on high diffractive mass.





$WW\gamma\gamma$ proton missing mass

- Signal appears at high mass
- Anomalous coupling value chosen is 2.10^{-6}



Signal and background for 30fb^{-1}

Background events for 30 fb^{-1}

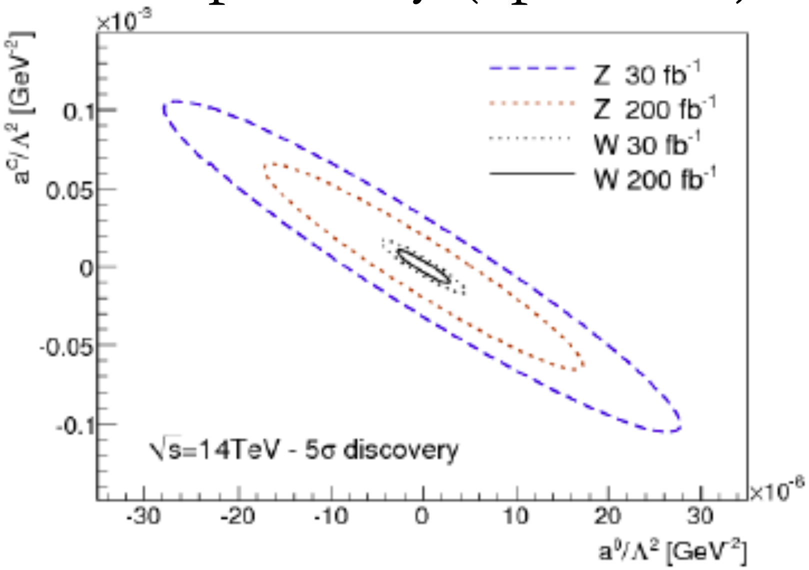
cut / process	$\gamma\gamma \to ll$	$\gamma\gamma \to WW$	DPE$\to ll$	DPE$\to WW$
$p_T^{lep1,2} > 10$ GeV	50619	99	18464	8.8
$0.0015 < \xi < 0.15$	21058	89	11712	6.0
$\not{E}_T > 20$ GeV	14.9	77	36	4.7
$W > 800$ GeV	0.42	3.2	16	2.5
$M_{ll} \notin <80, 100>$	0.42	3.2	13	2.5
$\Delta\phi < 3.13$	0.10	3.2	12	2.5
$p_T^{lep1} > 160$ GeV	0	0.69	0.20	0.024

Signal events for 30 fb^{-1}

cut / couplings (with f.f.)	$\lvert a_0^W/\Lambda^2 \rvert = 5.4 \cdot 10^{-6}$	$\lvert a_C^W/\Lambda^2 \rvert = 20 \cdot 10^{-6}$
$p_T^{lep1,2} > 10$ GeV	202	200
$0.0015 < \xi < 0.15$	116	119
$\not{E}_T > 20$ GeV	104	107
$W > 800$ GeV	24	23
$M_{ll} \notin <80, 100>$	24	23
$\Delta\phi < 3.13$	24	22
$p_T^{lep1} > 160$ GeV	17	16

Reach at LHC

- The anomalous coupling terms can be measured very precisely (up to 10^{-6}) using forward detectors.

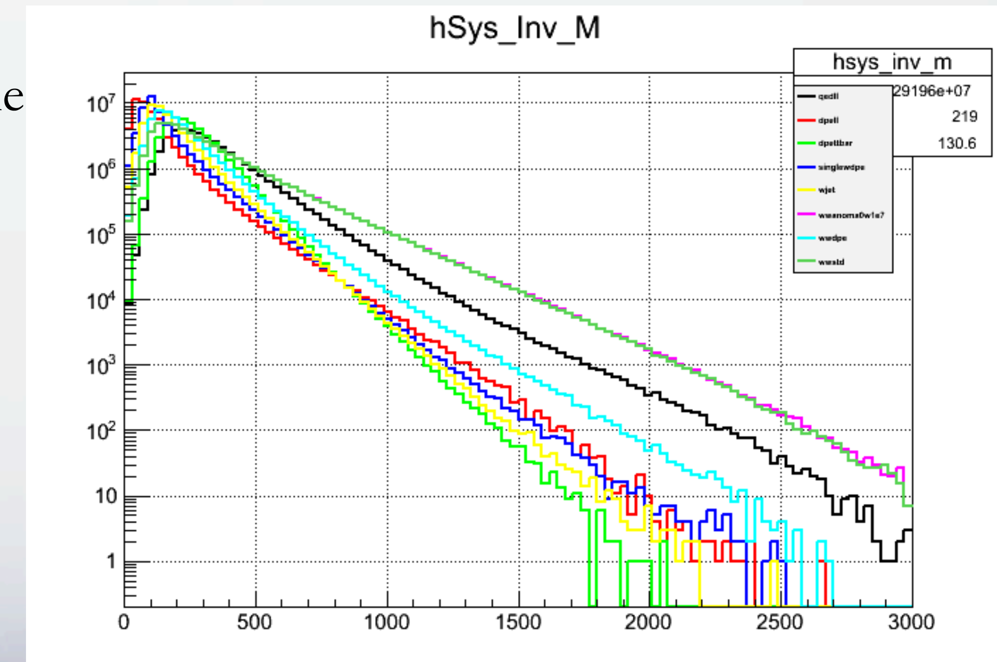


Couplings	OPAL limits $[\mathrm{GeV}^{-2}]$	Sensitivity @ $\mathcal{L} = 30\ (200)\ \mathrm{fb}^{-1}$ 5σ	95% CL
a_0^W/Λ^2	[-0.020, 0.020]	$5.4\ 10^{-6}$ $(2.7\ 10^{-6})$	$2.6\ 10^{-6}$ $(1.4\ 10^{-6})$
a_C^W/Λ^2	[-0.052, 0.037]	$2.0\ 10^{-5}$ $(9.6\ 10^{-6})$	$9.4\ 10^{-6}$ $(5.2\ 10^{-6})$
a_0^Z/Λ^2	[-0.007, 0.023]	$1.4\ 10^{-5}$ $(5.5\ 10^{-6})$	$6.4\ 10^{-6}$ $(2.5\ 10^{-6})$
a_C^Z/Λ^2	[-0.029, 0.029]	$5.2\ 10^{-5}$ $(2.0\ 10^{-5})$	$2.4\ 10^{-5}$ $(9.2\ 10^{-6})$

- Improvement over previous LEP measurement by 4 orders of magnitude with 30/200fb^{-1} at LHC. And 2 orders of mag. better than standard studies at the LHC (methods by studying $pp \rightarrow l^{\pm}\nu\gamma\gamma$ [P. J. Bell, ArXiV:0907.5299]).
- Reaching the values in Higgsless and extra dimension models.

The semi-leptonic studies

- In addition to Olda's work we considered the WW pair decaying into l+jets
  - Looking for 2 intact protons in the forward detector
  - 1 lepton and 2 jets in th central detector
- In forward detectors: intact protons at relatively high mass.
- In central detector: high invariant mass lepton+dijet
- Dijet from a single W



The background

- Diffractive
  - pp → pWWp Standard model
  - pp → pWWp By double pomeron exchange
  - pp → pWjet p
  - pp → pWp Single W by DPE
  - pp → pttbar p Double pomeron exchange
  - pp → p*ll* p Dileptons by DPE
- Pile up
  - Single top
  - Drell Yann
  - Ttbar
  - Diboson WW WZ ZZ
  - W+jet Z+jet

The analysis @ 1e-7 wo pike-up

Cuts	Signal	Background
No cuts	2744	1254974
AFP cut	2471	899034
Number of lepton and jets cut	515	12819
High pt cut on lepton or dijet system	22	116
Dijet mass cut	18	34
System inv mass cut	8	10

Full simulation

- Done by Olda for the leptonic case. Same sensitivity is reached.
- For the semi-leptonic case:
  - Cut on the generator level:
    - AFP
    - 1<lepton 2<jets (how hard is that?)
    - 250Gev<lep_pt || 150Gev<jet_pt (possible?)
  - Which signals can we reuse from Olda's? where can we find them?
  - What are the strategies for the cuts to remove pile-up (not include tracks inside jets).

Conclusion

- Full simulation starting.
- Still hard to manage to work on chip & analysis at the same time
- Simulation about timing requirements to be done and included in thesis work

Conclusion

- Gain 4 orders of magnitude in quartic anomalous coupling, reaching values predicted by Higgsless, extra-dimension models, in the leptonic channel. Can we do better including the semi-leptonic?
- Analysis redone in ATLAS using full simulation of signal, background and pileup (Diboson, single top, ttbar, W+jet, etc). Sensitivity found to be similar to ATLFast studies shown in this talk.