Experimental approach to the effects from SM processes (WW/ZZ) to the Higgs decays/studies

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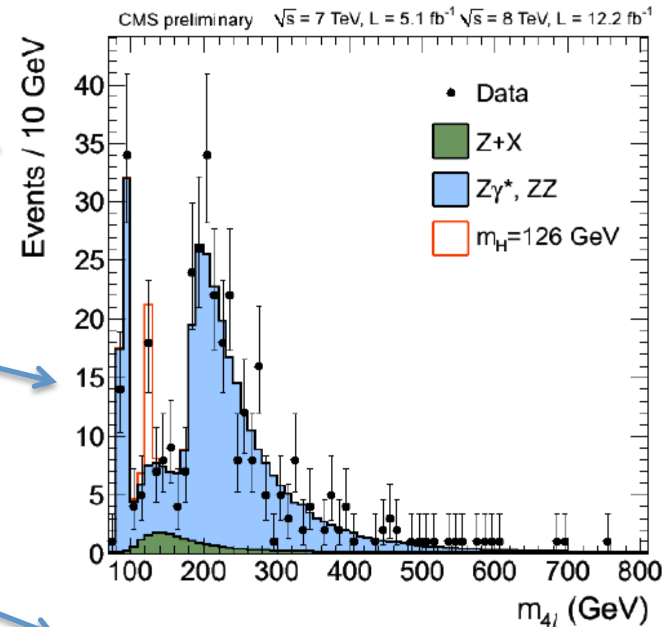
21 November 2012

MC generators and future challenges, a joint ATLAS/CMS/LPCC workshop

H->VV

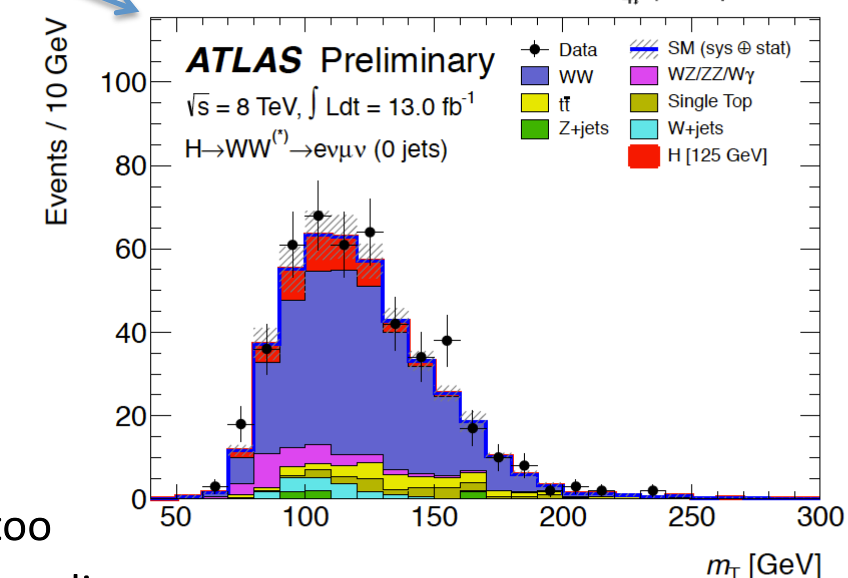
- H->ZZ->4l

  ZZ is main background (also at low mass h125): small uncertainties



- H->WW->lnln

  WW background is main limiting factor (at high H mass $\Delta\phi$ tends to be large)



[Semi-leptonic decays (and H->ZZ->2l2n) mainly limited by V+jets]

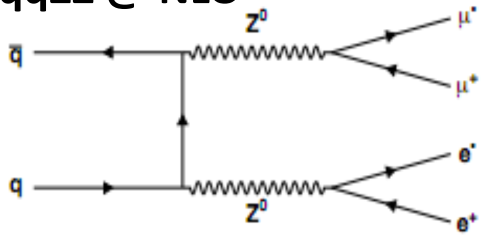
- In all final states at high mass (M_{VV}>400 GeV) large **interference gg->H / gg->VV**

- **Properties:**
  - VV shapes needs to be well under control too
  - good precision on VV+jets needed for VBF studies

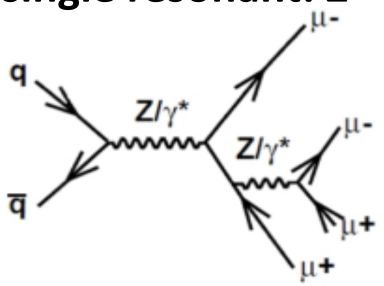
ZZ background

- Extracted from MC: sum of different contributions

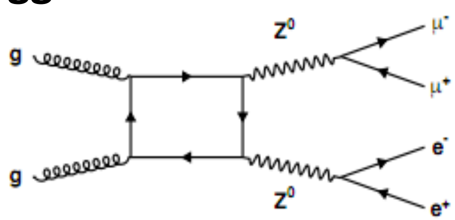
qqZZ @ NLO

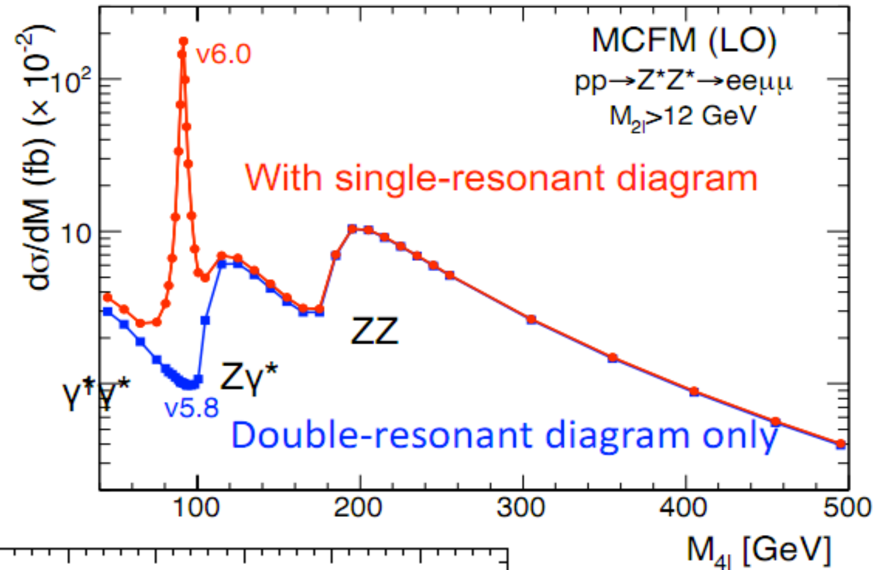


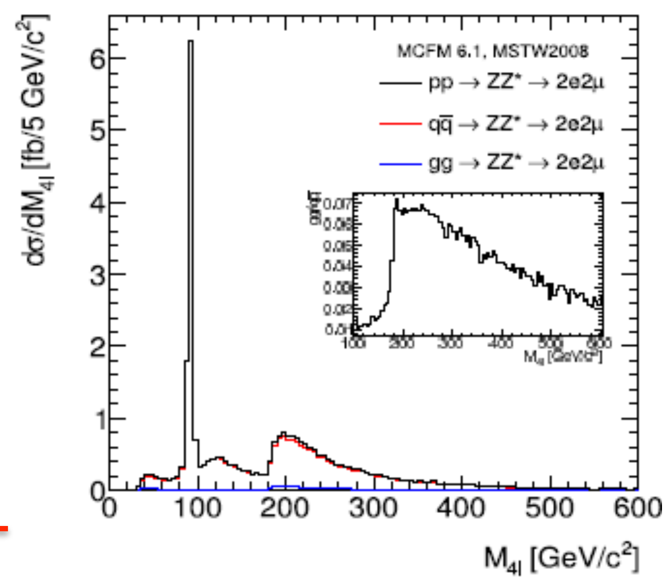
single resonant: Z->4f



gg→ZZ



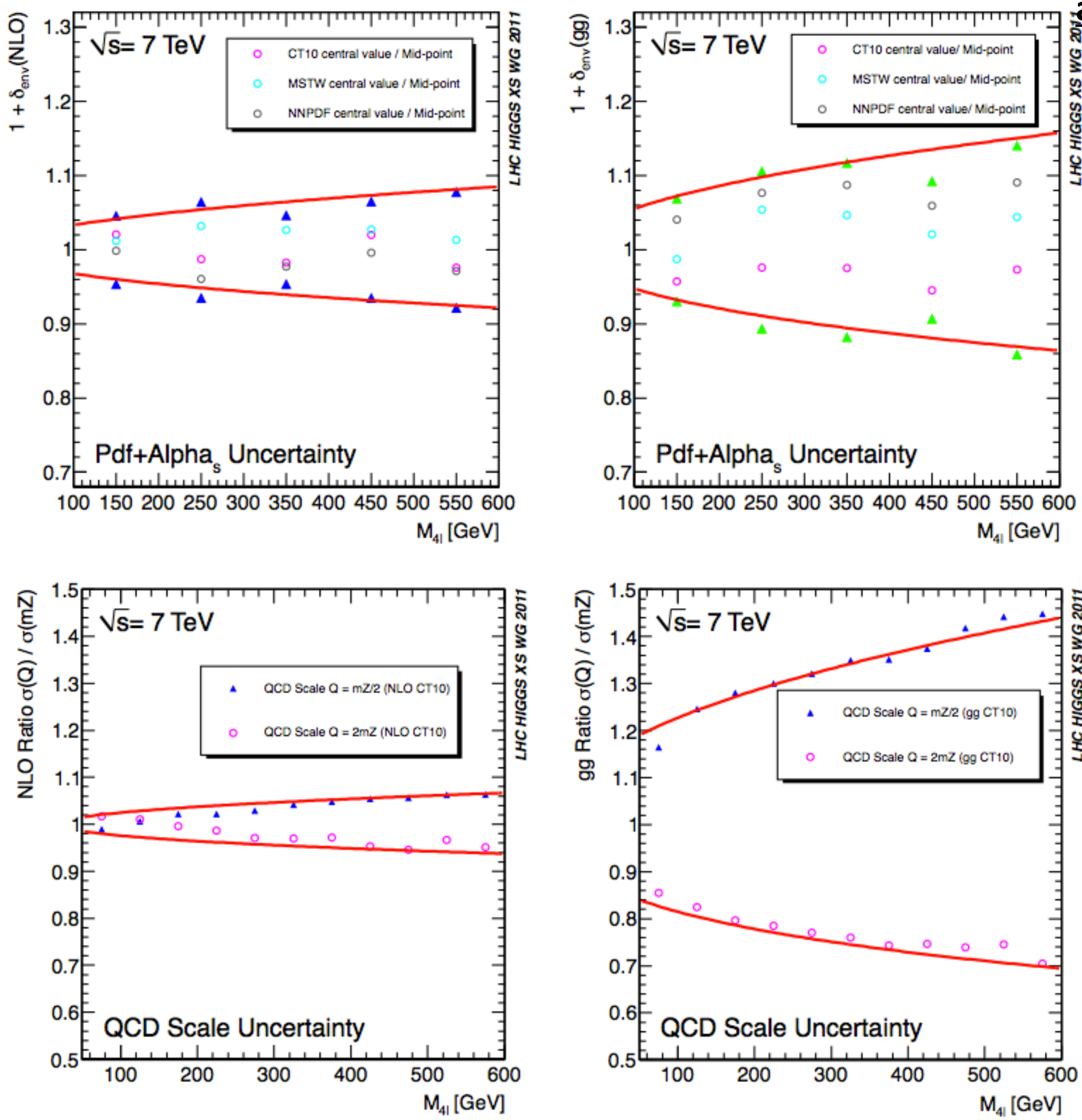




All processes available:
POWHEG (with MCFM) + gg2ZZ
and in MC@NLO

ZZ uncertainties

arXiv:1201.3084



WW background (low H mass)

- At low H mass WW extrapolated from M(ll)>100 or 80 GeV,

$$N_{\mathrm{S.R.}}^{\mathrm{WW0j}} = \alpha_{0\mathrm{j}} N_{\mathrm{C.R.}}^{\mathrm{WW0j}}, \quad N_{\mathrm{S.R.}}^{\mathrm{WW1j}} = \alpha_{1\mathrm{j}} N_{\mathrm{C.R.}}^{\mathrm{WW1j}}.$$

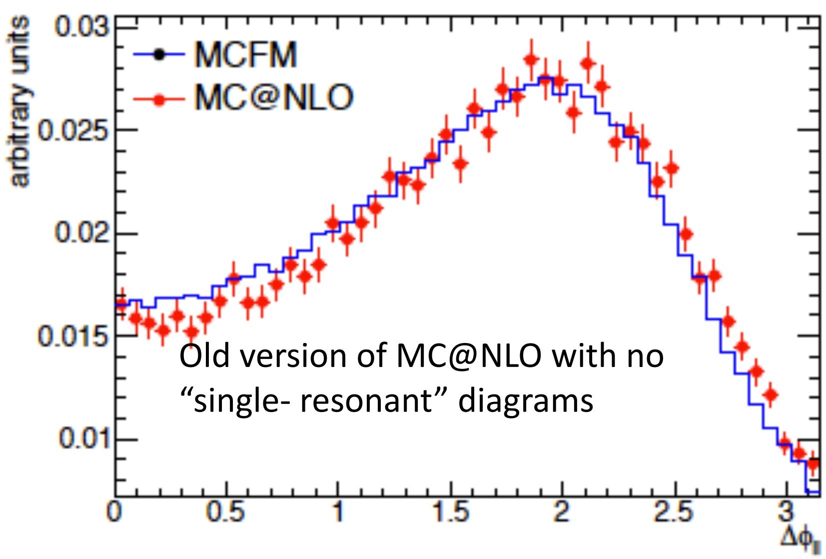
ATLAS-CONF-2012-158 (qq->WW)

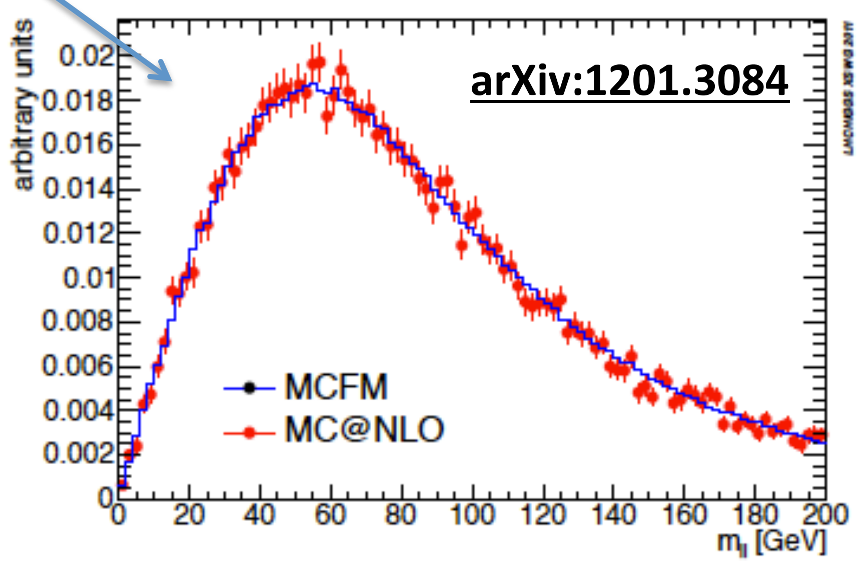
WW background extrapolation uncertainties

	Scale	PDFs	PS/UE	Modelling
α_{WW}^{0j}	2.5%	3.7%	4.5%	3.5%
α_{WW}^{1j}	4%	2.9%	4.5%	3.5%

(gg->WW)

	scale	PDF
α_{WW}^{0j}	6%	4.4%
α_{WW}^{1j}	9%	4.6%





WW background (high H mass)

- Fully evaluated **from MC in different jet bins** (for VBF categorization)

$$N_{0\text{j}}^{\text{WW}} = \sigma_{\geq 0} f_0 A_0, \quad N_{1\text{j}}^{\text{WW}} = \sigma_{\geq 0} f_1 A_1,$$

• exclusive jet counting obtained from inclusive xsecs:

$$f_0 = \frac{\sigma_{\geq 0} - \sigma_{\geq 1}}{\sigma_{\geq 0}}, \quad f_1 = \frac{\sigma_{\geq 1} - \sigma_{\geq 2}}{\sigma_{\geq 0}}.$$

• summary of uncertainties for pt>30 GeV, $|\eta|<4.7$

modeling from MC@NLO / ALPGEN comparison

scale from variation in MC@NLO

$\Delta\sigma_{\geq 0}$ [%]	$\Delta\sigma_{\geq 1}$ [%]	$\Delta\sigma_{\geq 2}$ [%]	$\Delta\sigma_{\geq 3}$ [%]
3	6	42	100

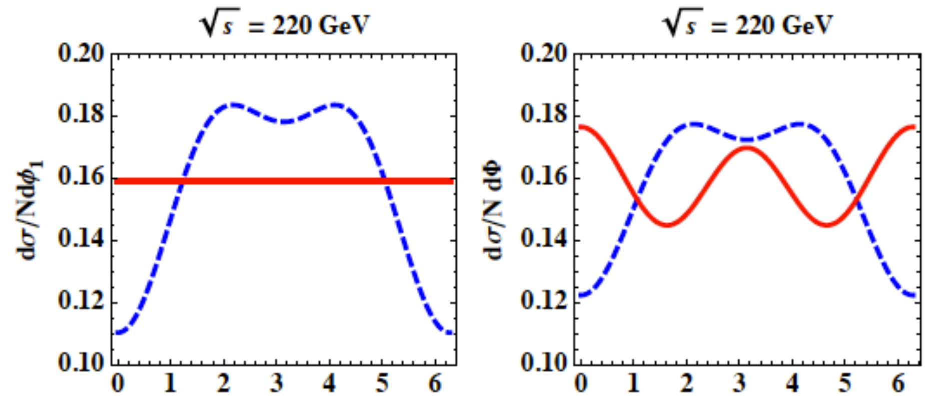
arXiv:1201.3084

ZZ shape (analytical)

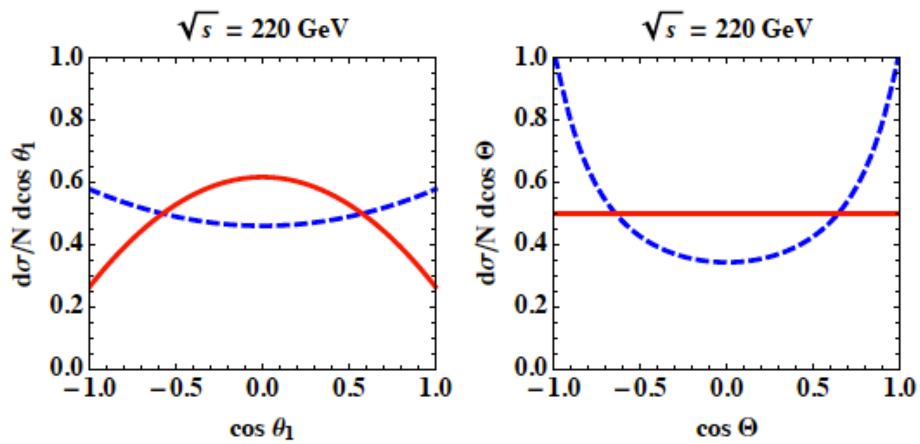
❑ **Matrix Element analysis for H->ZZ search and for spin-parity measurement** (soon in WW)

-> needs analytical background for "MELA":

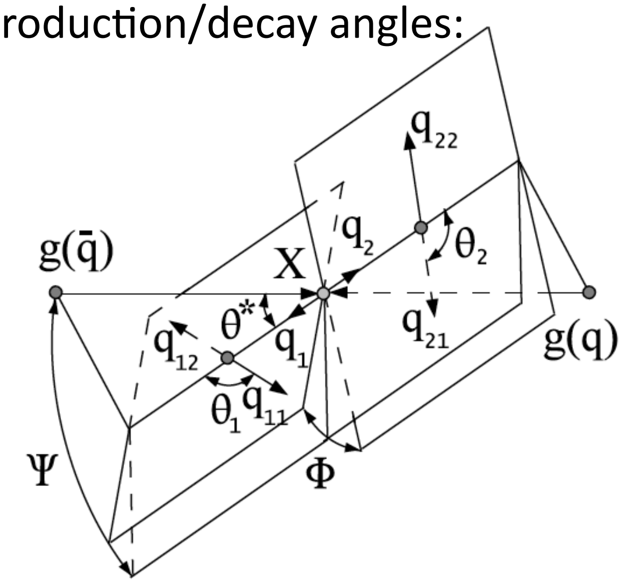
- **above threshold (MZZ>2*MZ)**



ϕ_1 ZZ background, H signal Φ



analytical computation of production/decay angles:



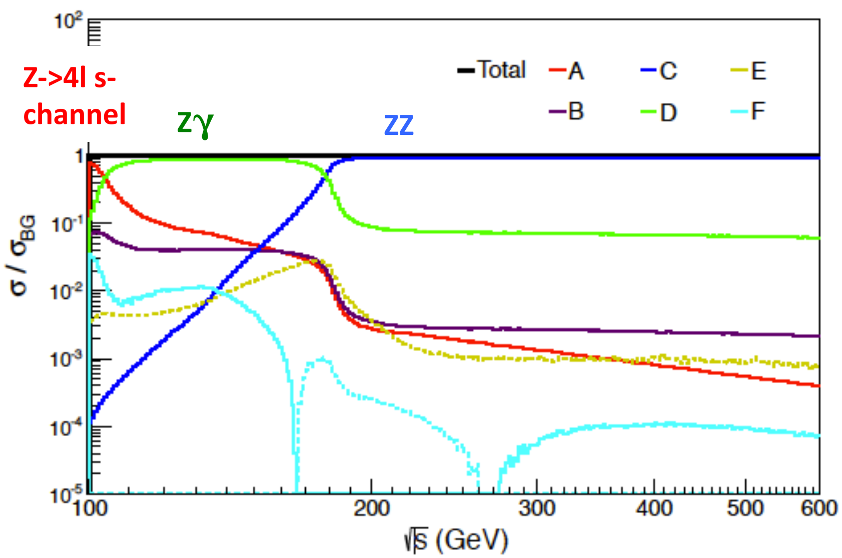
(arXiv 1208.4018)

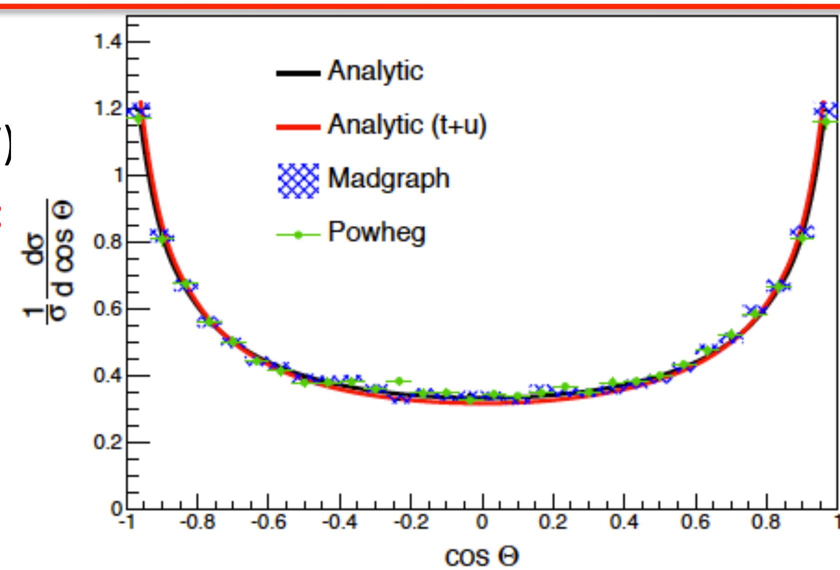
ZZ shape (analytical)

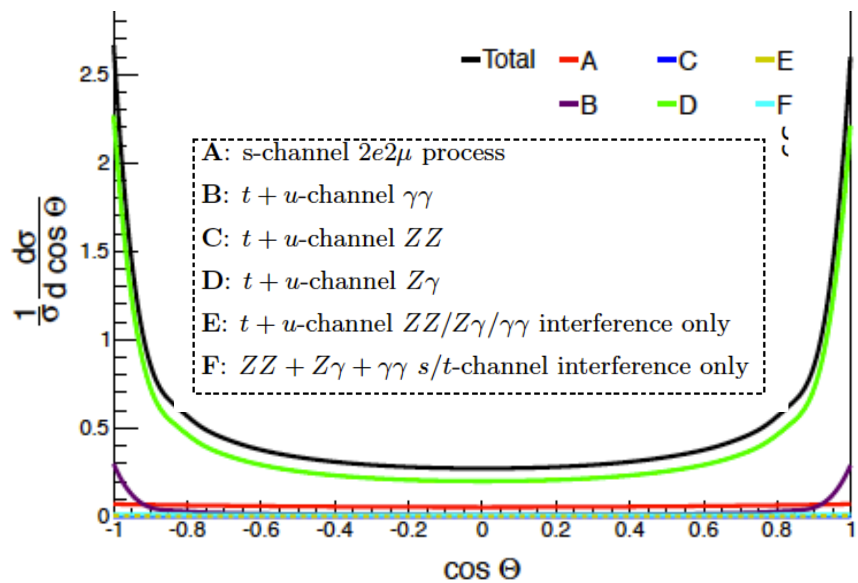
❑ **Matrix Element analysis for H->ZZ search and for spin-parity measurement** (soon in WW)

-> needs analytical background for "MELA":

- **below threshold (NEW!!)**







(arXiv 1211.1959)

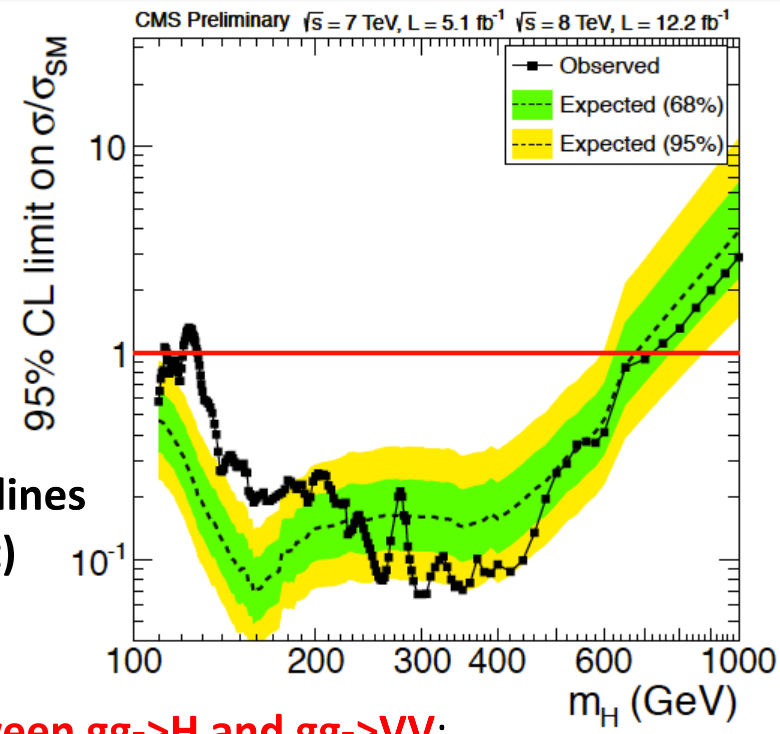
Heavy Higgs search and interference

- h125 smells like SM-Higgs but alternative interpretation possible ("Higgs impostor")

  -> firm statement will be possible only with precise measurement of VV-scattering

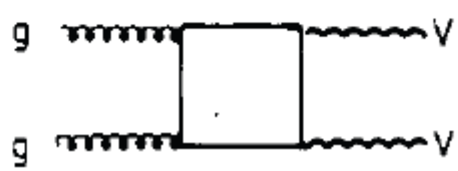
- BSM extensions with Higgs mass splitting, composite models -> heavy resonance

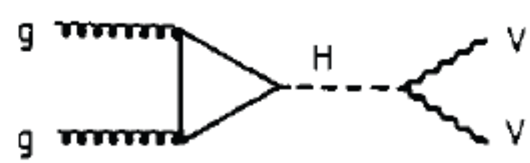
- **Pure SM-like search for now, theoretical guidelines needed for a more general (model-independent) search at high mass (see later)**



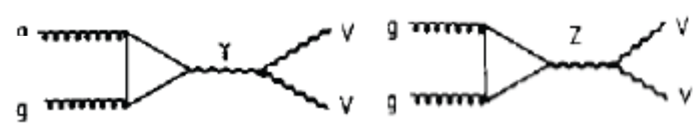
- At high mass **large interference expected between gg->H and gg->VV**:

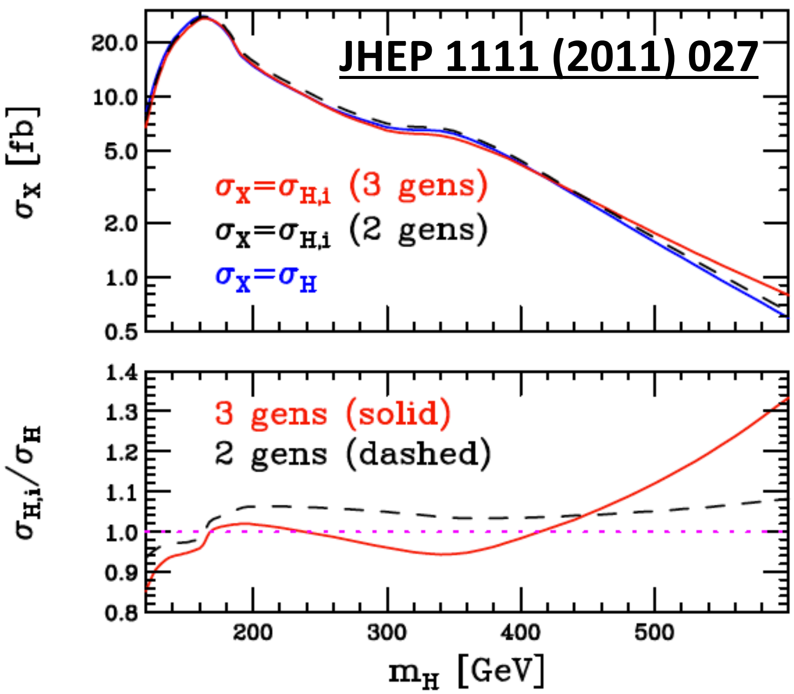
$$\sigma_B \longrightarrow |\mathcal{A}_{\rm box}|^2 \ ,$$
$$\sigma_H \longrightarrow |\mathcal{A}_{\rm Higgs}|^2 \ ,$$
$$\sigma_i \longrightarrow 2{\rm Re}\left(\mathcal{A}_{\rm Higgs}\mathcal{A}^*_{\rm box}\right) \ ,$$
$$\sigma_{H,i} = \sigma_H + \sigma_i \ .$$





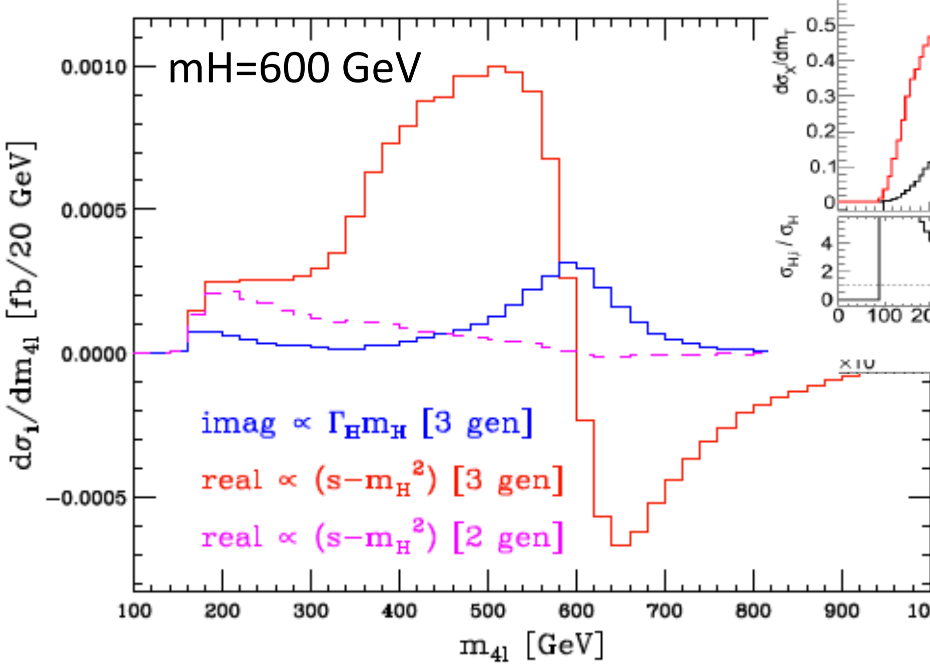
only gg->WW:

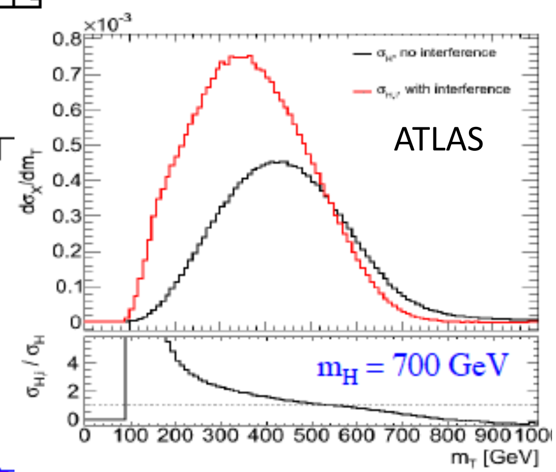


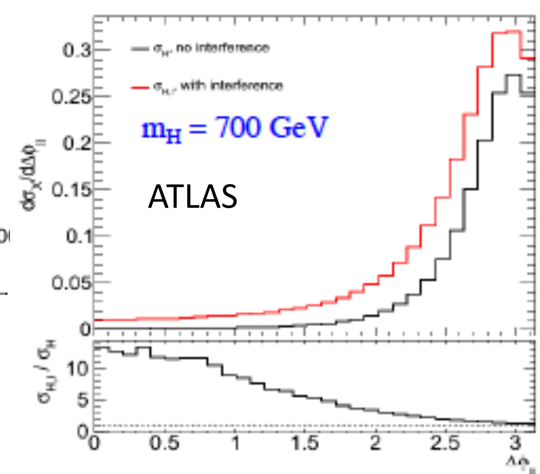


How important is interference?

- Very large constructive effect above 400 GeV
- Distortion of M_{WW} shape
  - -> constructive/destructive below/above mH
  - -> effect on mT and $\Delta\phi$ shape

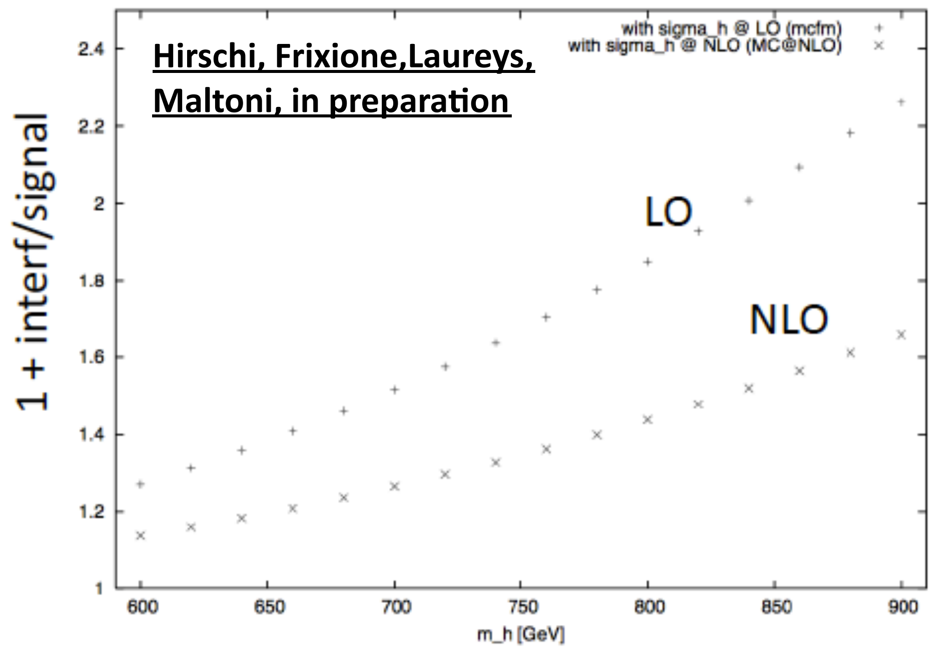




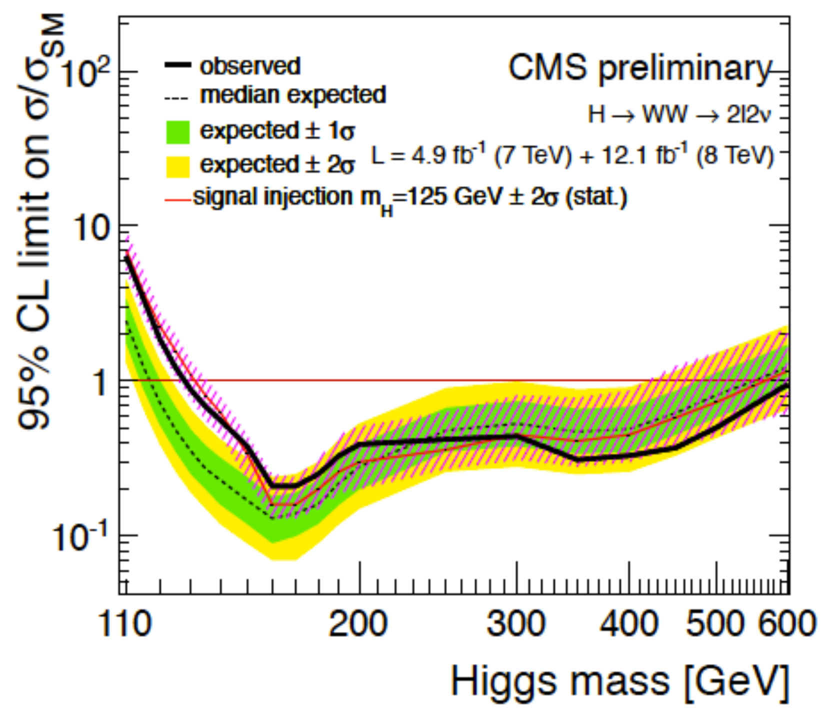


HCP results: WW -> lνlν

- Correction from MC@NLO and 100% uncertainty



(nothing magic in the scaling LO->NLO signal xsec increase but interference always at LO)

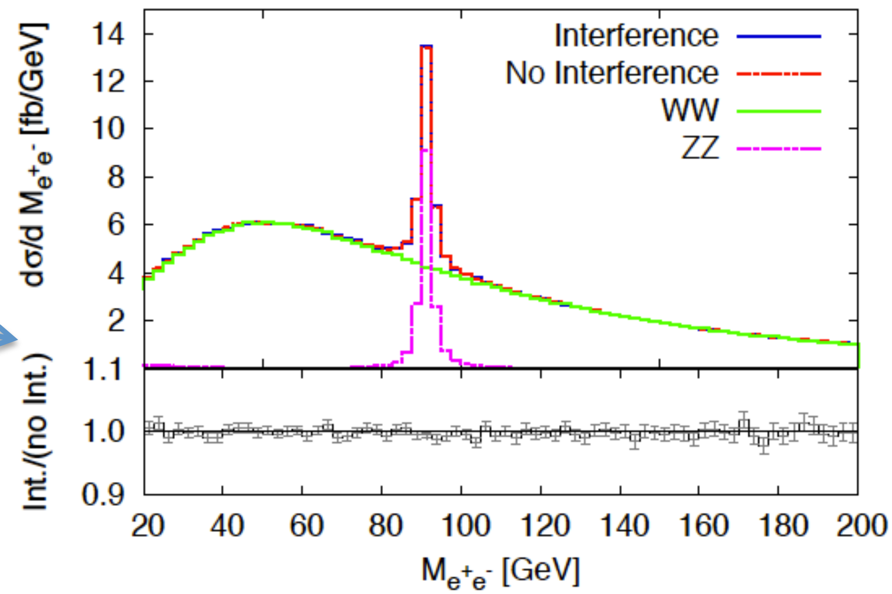


- No shape corrections yet, subleading effect

ZZ->2l2ν

- qq->WW and qq->ZZ interference **negligible**

arXiv 1107.5051



- H->ZZ->2l2n **interference with ggZZ and ggWW studied**

mT>325 GeV, MET>110 GeV, |M_ll-M_Z| < 15 GeV

MH = 600 GeV	ZZ only	(S+B+I)/(S+B) ~ 1.047
	WW+ZZ	(S+B+I)/(S+B) ~ 1.05
MH = 1 TeV	ZZ only	(S+B+I)/(S+B) ~ 1.12
	WW+ZZ	(S+B+I)/(S+B) ~ 1.14

N.Kauer, in preparation

ZZ contribution dominates (with these cuts)

Work on-going to include this corrections with 100% uncertainty up to 1 TeV

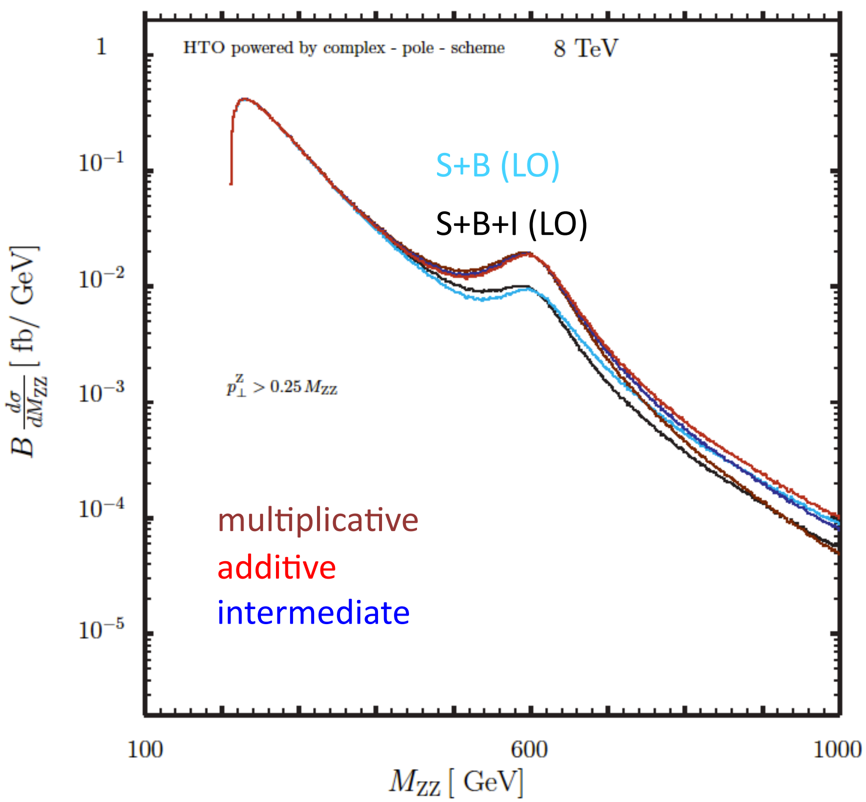
One step forward: lineshape correction

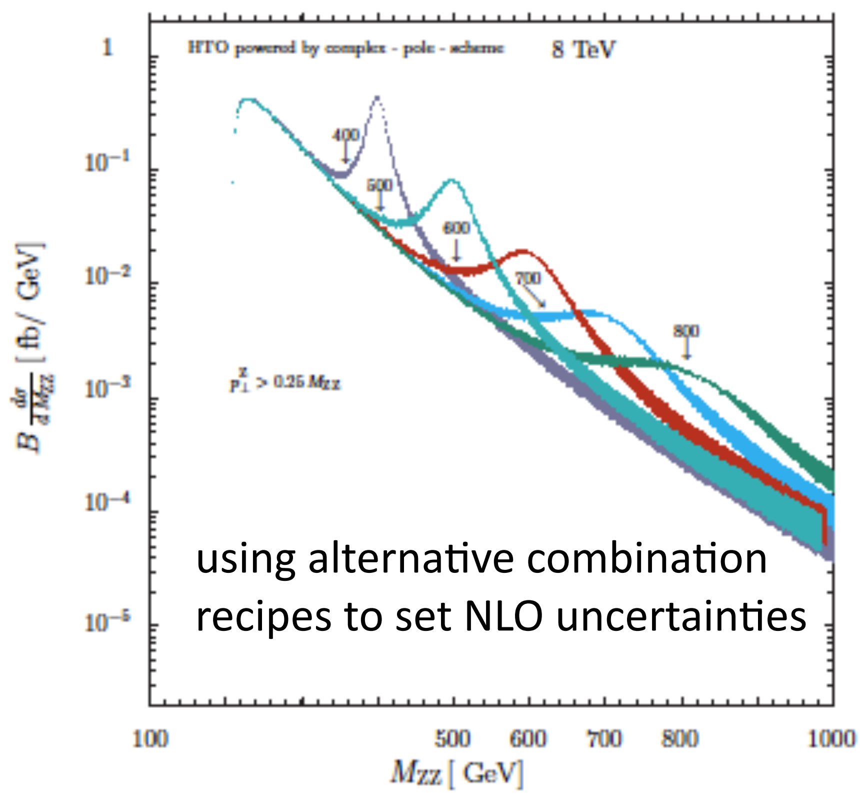
- **Interference known at LO only, while signal at NNLO -> how to combine?**

$K = S_{NNLO} / S_{LO}$

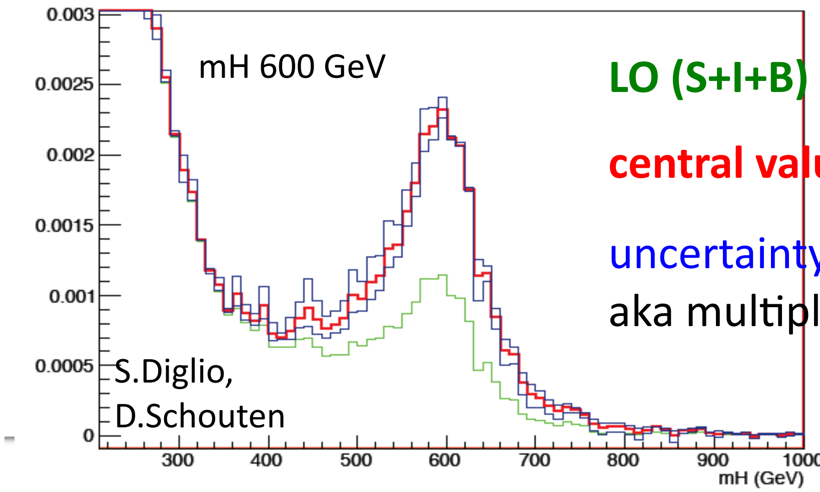
- same K-factor: (S+I)*K + B (multiplicative, upper limit on norm.)
- no rescaling for I: S*K + I + B (additive, lower limit on norm.)
- modified K' with only gg initiated: S*K + I*K' + B (intermediate, reference value)

arXiv:1206.3824





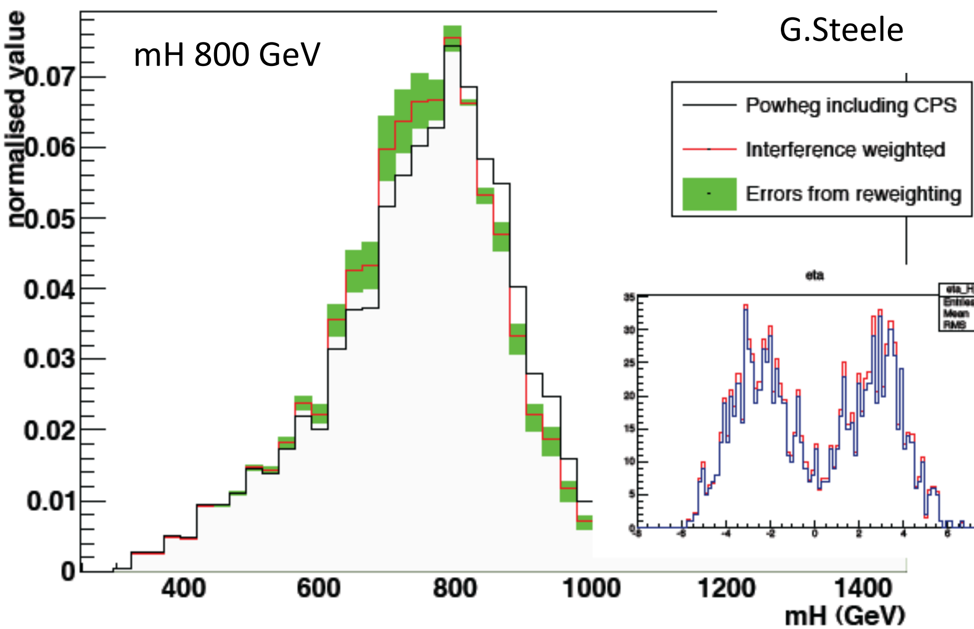
Example of reweighting: WW->lνlν

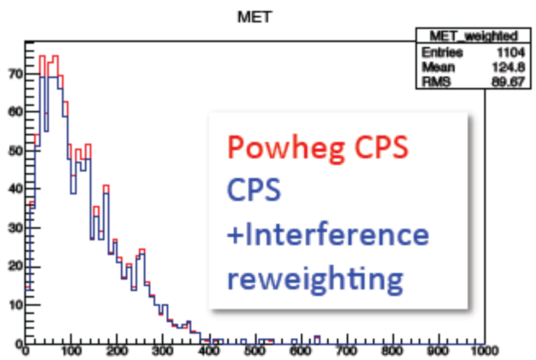


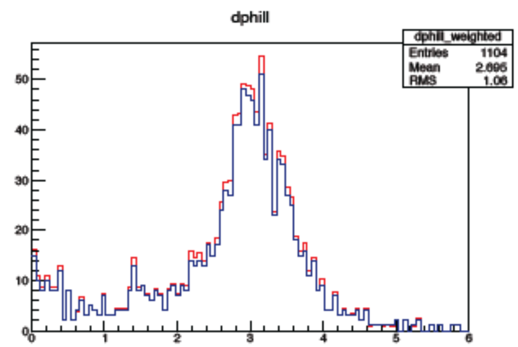
LO (S+I+B) from gg2VV

central value = (S*K + I*K’ + B) aka intermediate

uncertainty band = (S*K + I*K + B) – (S*K + I +B)
aka multiplicative - additive





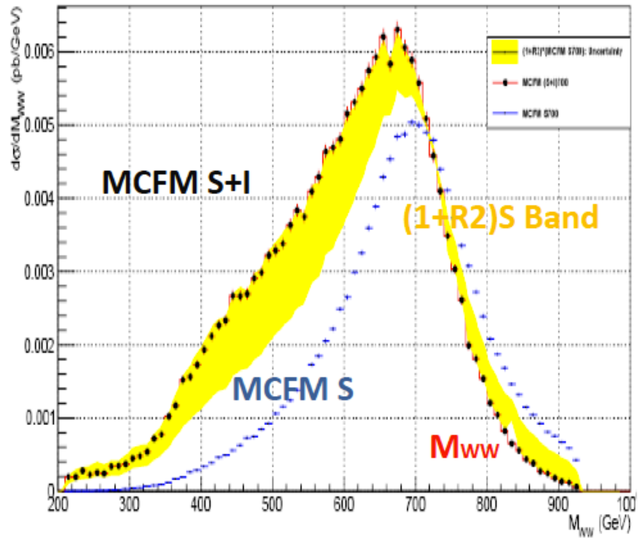


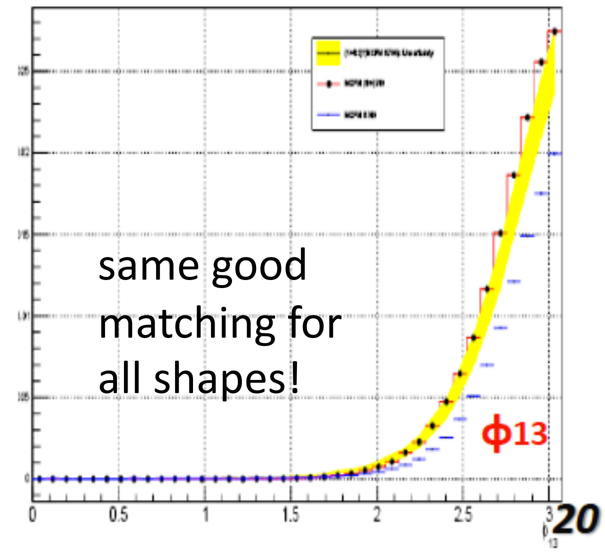
WW->lνjj

- ❑ WW: is the **reweighting on the mass shape** enough to catch the distortion of kinematics due to interference ?

Q.Li Heavy Higgs meeting @ HxsecWG

https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=212297

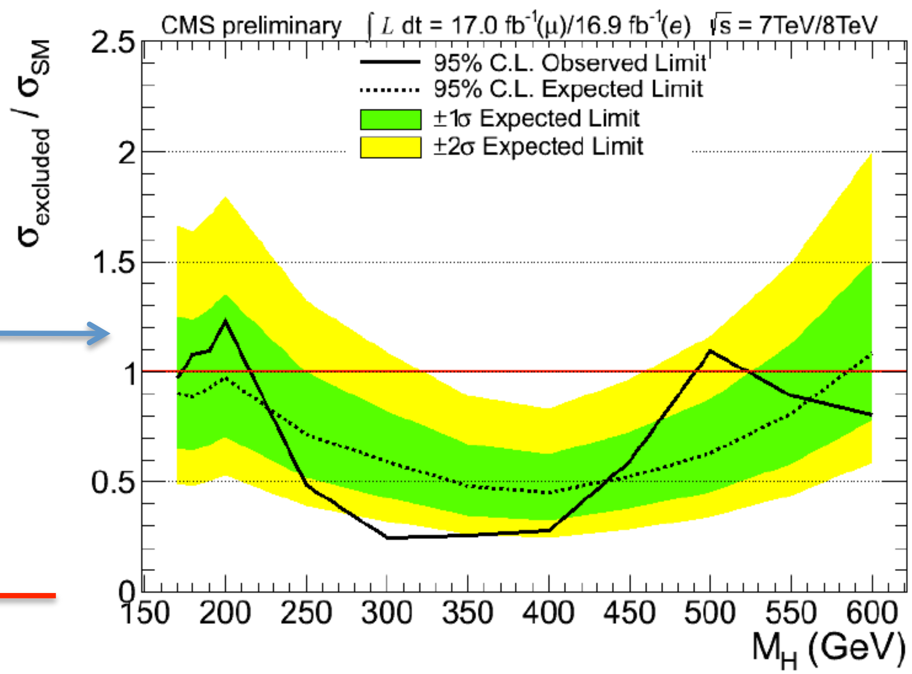




Yes! Additive reweighting match full MCFM S+I

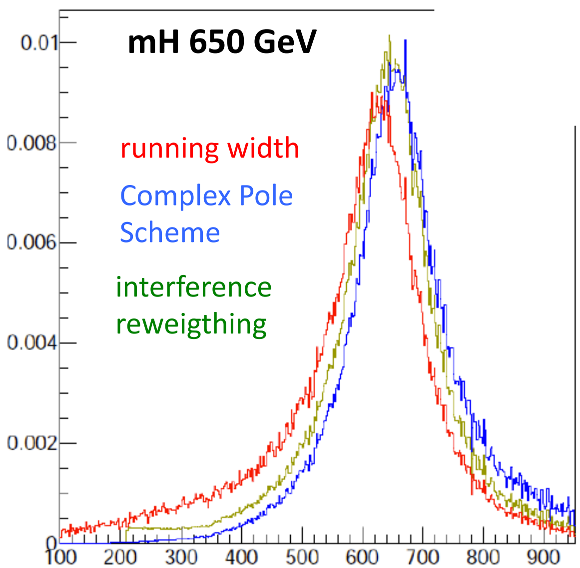
MCFM reweigthed to match **intermediate +/- additive multiplicative**

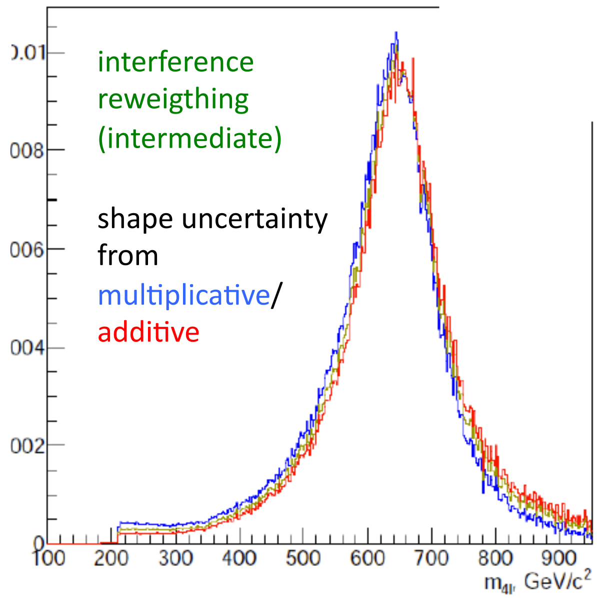
- ❑ Recipe applied for HCP results in lνjj channel (can be pursued up to 1 TeV)

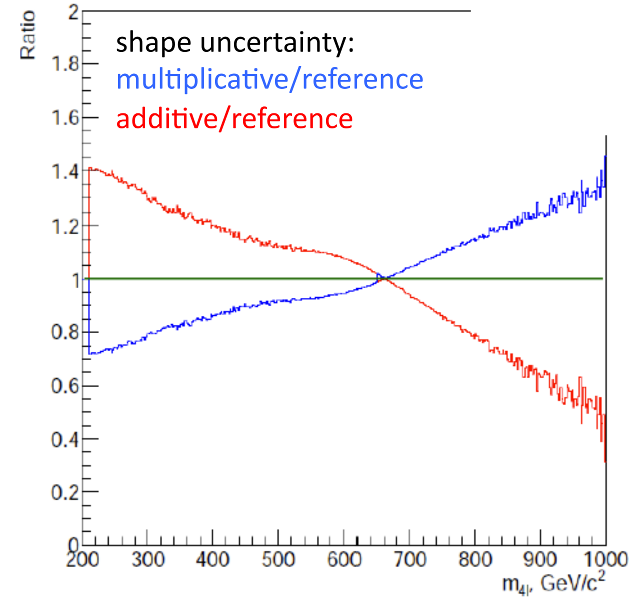


ZZ->4l/2l2q interference

C. Tongguang







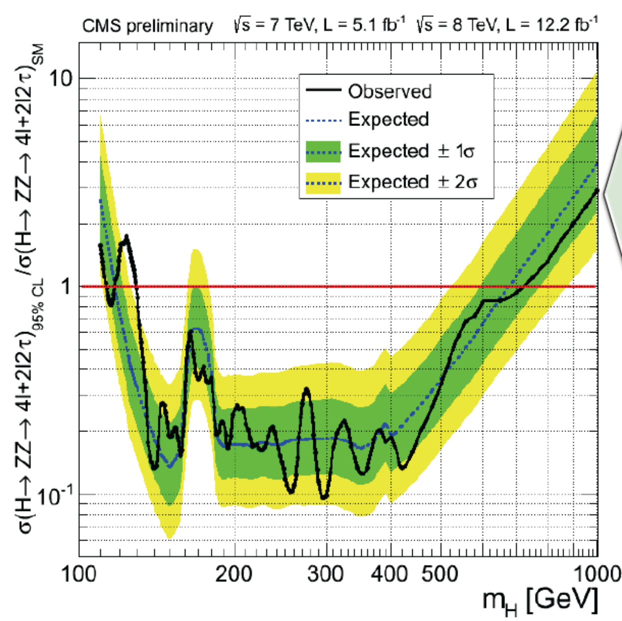
- In ZZ final states, where we can reconstruct mZZ, **interference does not affect the normalization!**

  4l (500 GeV) : S+B / (S+B+I) < few %

  arXiv:1201.1667

- HCP results H->4l:

  first exclusion up to 720 GeV !



Moving to BSM benchmarks

- **SM-like approach**: σ_S -> $\sigma_S+\sigma_I$ strictly valid only for signal strength = 1 (ie, exact SM assumption)

  When far from σ_S^{SM}, interference treatment not justified
  but this is true for the whole analysis, full SM-like assumption (eg: $\Delta\phi$ cut efficiency in H->WW)

- **Alternatives:**
  - **assume h125 to be "THE" SM Higgs boson -> search for something additional**

    not good either: we want to search for models (eg, Higgs mass splitting, Composite models) where h125 only carries part of the VV couplings (not the exact SM case)

    (+ models where h125 is something completely different)

  - Higgs Cross Section Working Group is working to prepare **guidelines for BSM benchmarks for heavy resonances:**

    multidimensional scan (eg: xsec vs mH' vs H' width), compatible with h125 given his **measured** VV couplings

Conclusions and plans

- ❑ **Good control of WW, ZZ backgrounds from MC**

  -> VV+jets is the next step for VV scattering studies (pretty large uncertainties now)

- ❑ Problem of interference S/B at high mass:

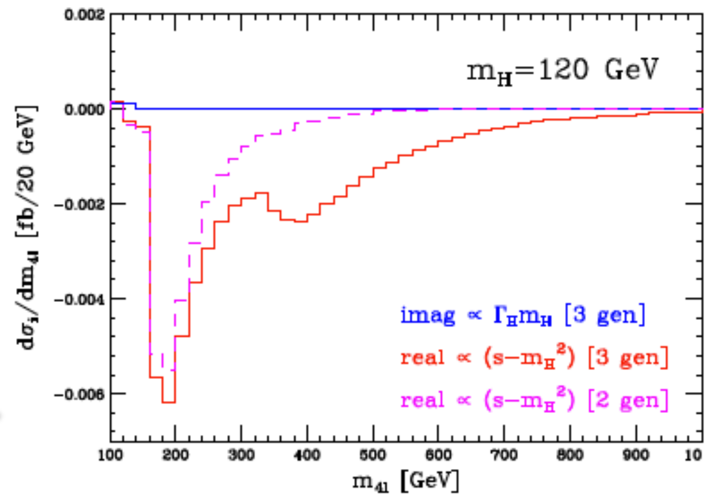
  - **LO** results available
  - **reweighting procedure** with large uncertainties applied to match with S_{NNLO}

- ❑ Move **from pure SM-like search -> to BSM benchmarks**

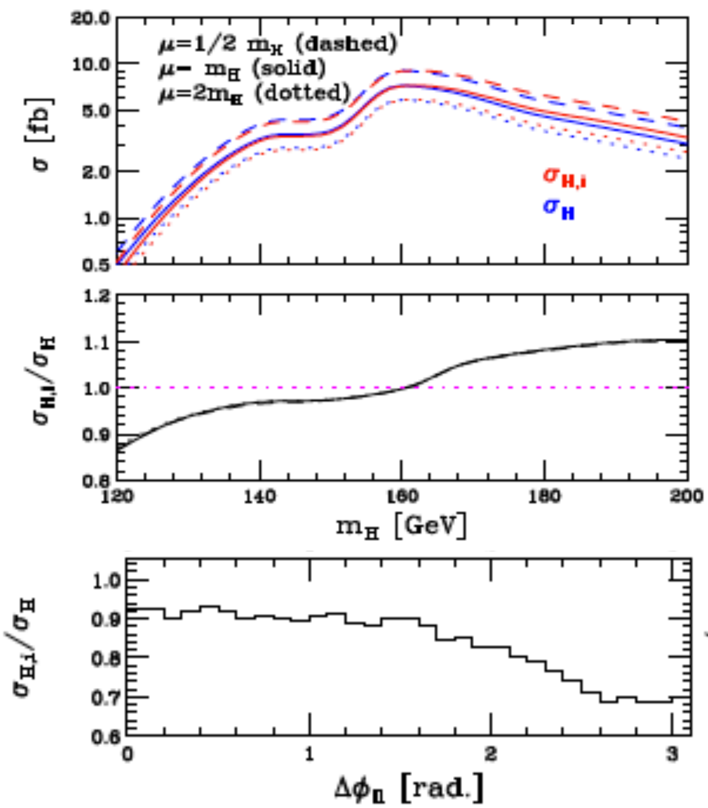
  - multidimensional scan for model-independent search: theoretical input needed

Interference at low mass and mT cut

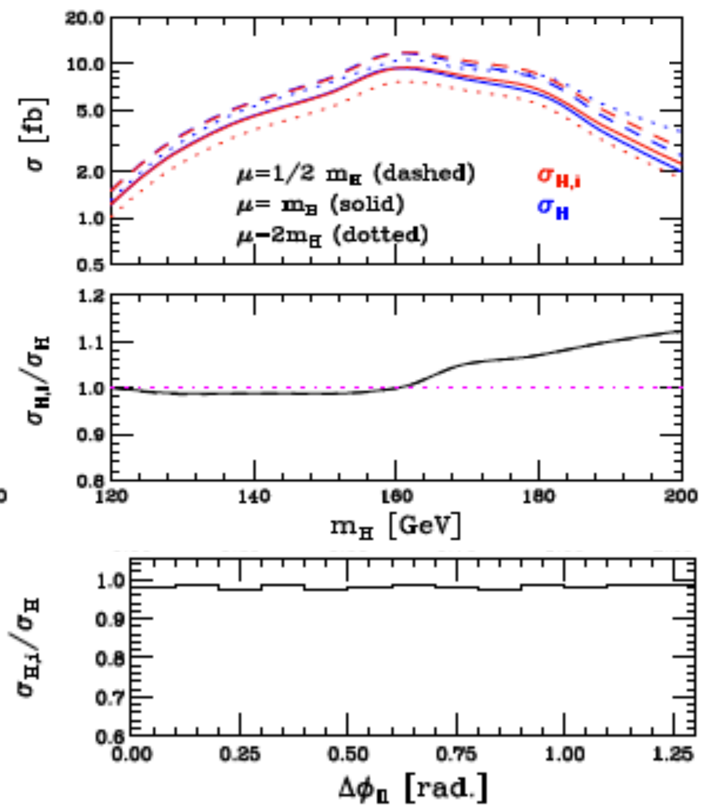
Campbell, Ellis, Williams 2011



without MT cut



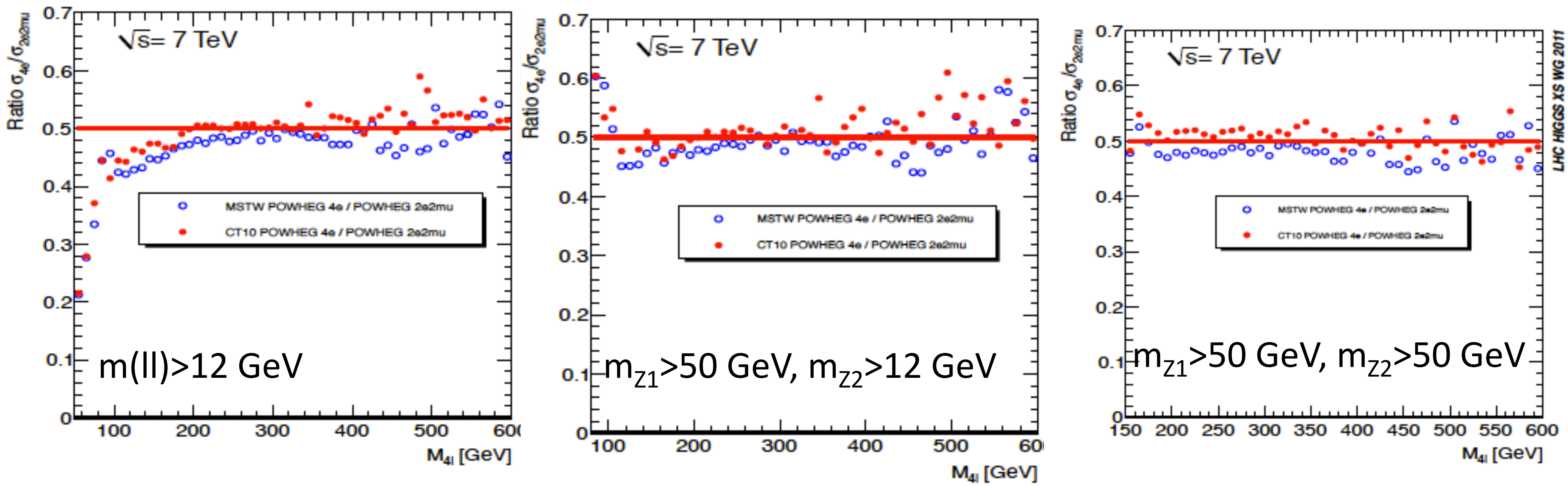
with MT cut: 0.75*mH < mT < mH



arXiv:1201.3084

ZZ background (2)

- Interference between same flavour Z decays: ratio ZZ->4e / ZZ->2e2m



-> affects m4l and Z mass shapes (angles)