Higher order $\gamma\gamma$ Generator Studies

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23/03/2009 – FCPPL Workshop (Wuhan)

I – Direct Box contributions

II – Complete Direct contributions

III – Direct and fragmentation contributions

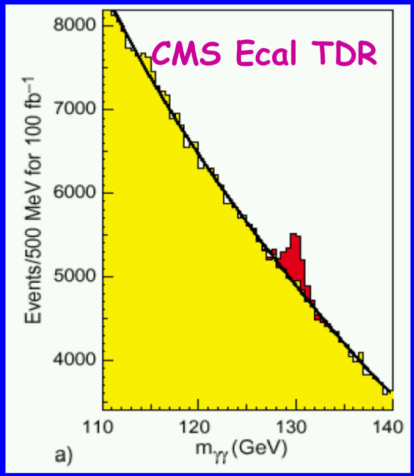
IV – Diphox Born and Gamma2MC Box combination with frag

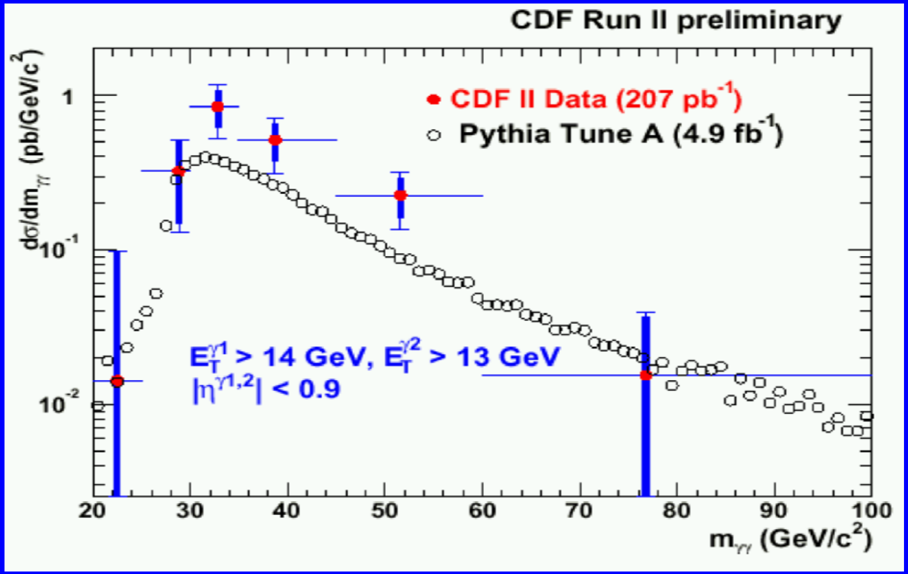
IV – H->$\gamma\gamma$ signal with respect to background

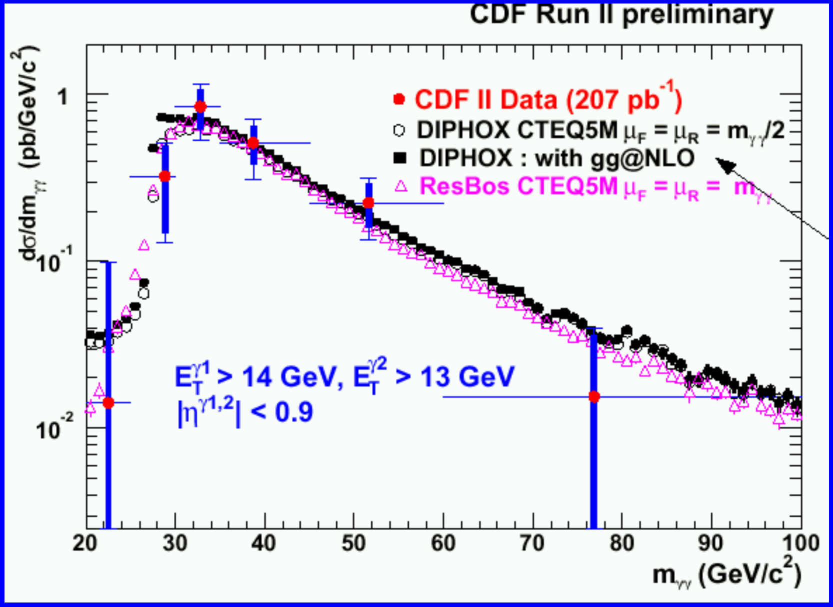
Higher order γγ Generator Studies

Introduction

- The H->γγ searches need the best possible preliminary estimate of the 2 photon background. At generator level, a robust description of γγ + X events can be provided by NLO calculations, like **Diphox** [J.P. Guillet, E. Pilon, T. Binoth] and **Gamma2MC** [Z. Bern, L. Dixon, and C. Schmidt]. For the Higgs signal, **HNNLO** can provide a description at NNLO [S. Catani, M. Grazzini]
- The distributions of variables susceptible to be kinematically sensitive to higher-order effects have to be scrutinized, and confronted with the first data in CMS (as they were at the TevaTron), to increase the discriminating power of the 2 photon analysis and the Higgs to 2 photons analysis.



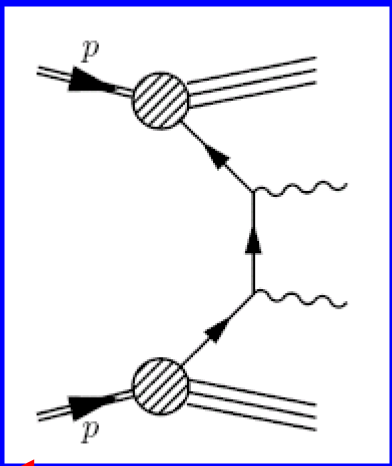


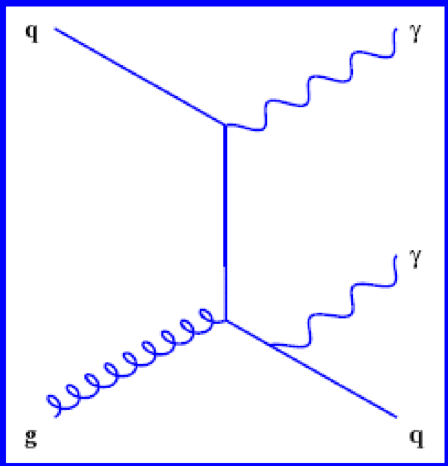


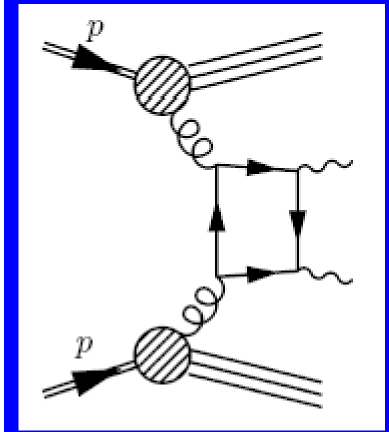
Higher order γγ Generator Studies

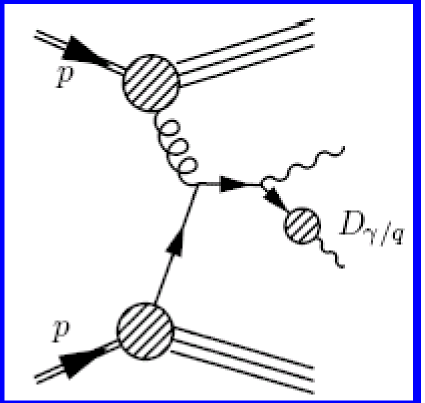
NLO generators of γγ processes

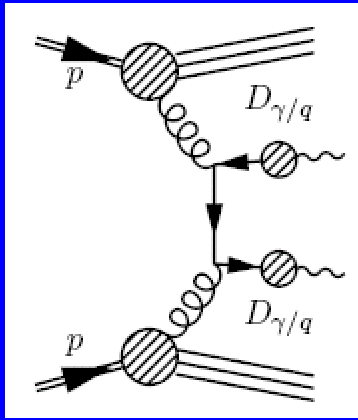
BORN	BREM	BOX	ONE FRAG	TWO FRAG











DIRECT

NLO codes

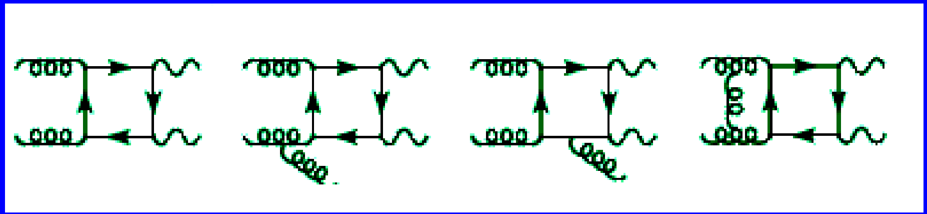
	type of code	Direct	One Frag.	Two Frag.
Aurenche et al.	I/FO	NLO	LO	none
Owens et al.	G/FO	NLO	LO	none
DIPHOX (*)	G/FO	NLO	NLO	NLO
RESBOS	G/SGS	NLO	LO	none

I : Inclusive
G : Generator
FO : Fixed Order
SGS: Soft Gluon Summation

(*) http://wwwlapp.in2p3.fr/lapth/PHOX_FAMILY/main.html

BOX : gamma2MC & Resbos: LO and NLO

Box [already NLO] + corrections [up to N3LO])



Corrections to box

=> The most complete description would seem to be possible with DIPHOX for all contributions but box, interfaced with Gamma2MC for Box

Higher order $\gamma\gamma$ Generator Studies

2 gamma and Higgs analysis

Generators : **Gamma2MC, DIPHOX (2 photons), and HNNLO (H->$\gamma\gamma$)**

For this preliminary study we have considered 2 sets of selection criteria :

2gamma parameters : (Marat et al.)

- pp, 10 TeV
- |eta|<1.442 (barrel only for the moment), pT_γ1>10 GeV, pT_γ2>10 GeV, 40<m_$\gamma\gamma$<1500 GeV
- "HCAL" isolation : sum of hadronic Et < 6 GeV in the barrel inside dR=0.35 around each photon

H->$\gamma\gamma$ PTDR parameters :

- pp, 14 TeV
- |eta|<2.5, pT_γ1>40 GeV, pT_γ2>35 GeV, 40<m_$\gamma\gamma$<1500 GeV
- "HCAL" isolation : sum of hadronic Et < 6 GeV in the barrel inside dR=0.3 around each photon

Higher order γγ Generator Studies

I – Direct Box contributions

Box contributions cross sections

2gCuts	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Box DIPHOX	18.22	-
Direct Box Gamma2MC	17.71	23.25

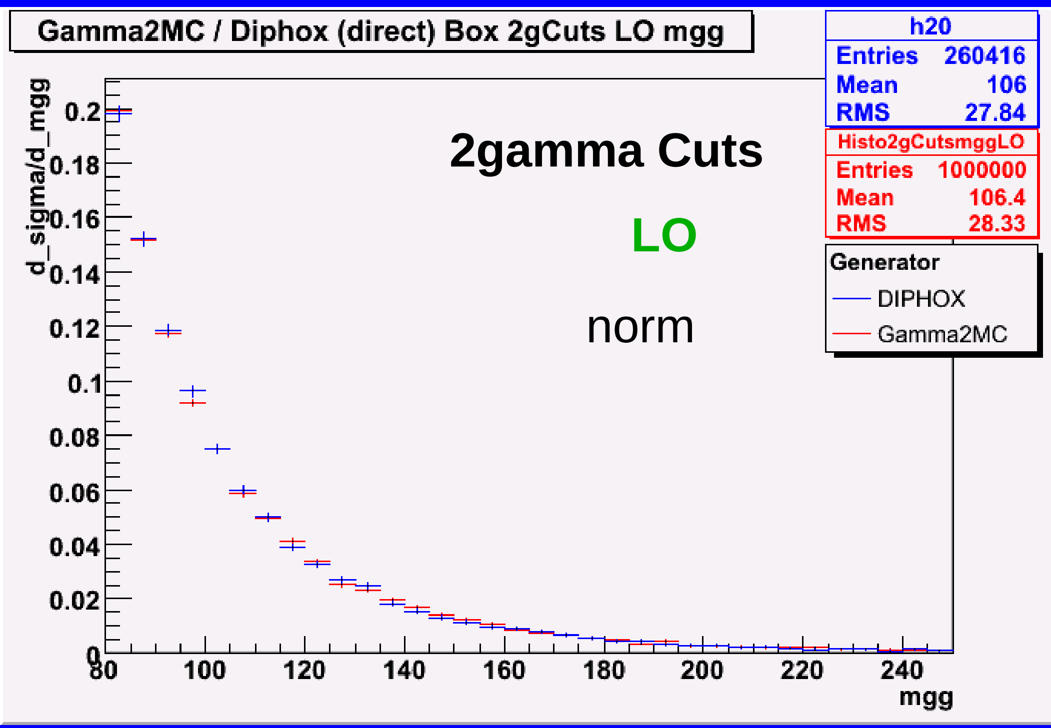
PTDR	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Box DIPHOX	3.24	-
Direct Box Gamma2MC	3.16	5.40

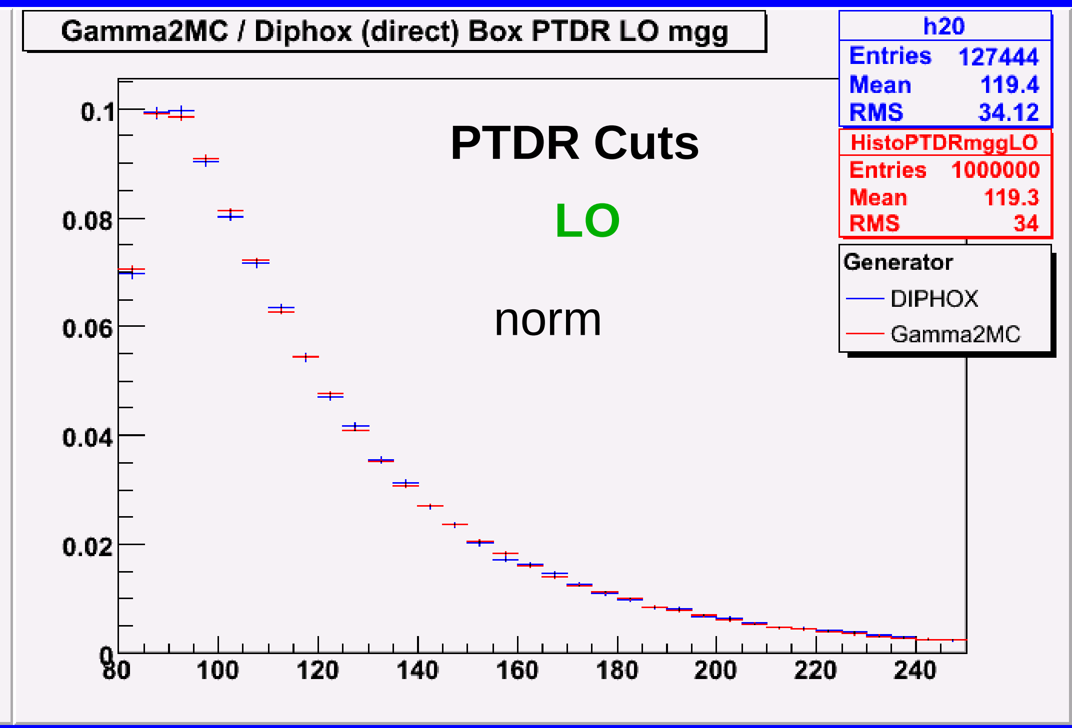
- For LO contribution, Diphox and Gamma2MC have cross sections that agree quite well. The small difference is under investigation (maybe a difference in the loop number in the calculation of the QCD parameter αs)
- Diphox cannot compute the Box contribution at NLO.

Higher order γγ Generator Studies

I – Direct Box contributions

Mgg : gamma-gamma invariant mass





Higher order γγ Generator Studies

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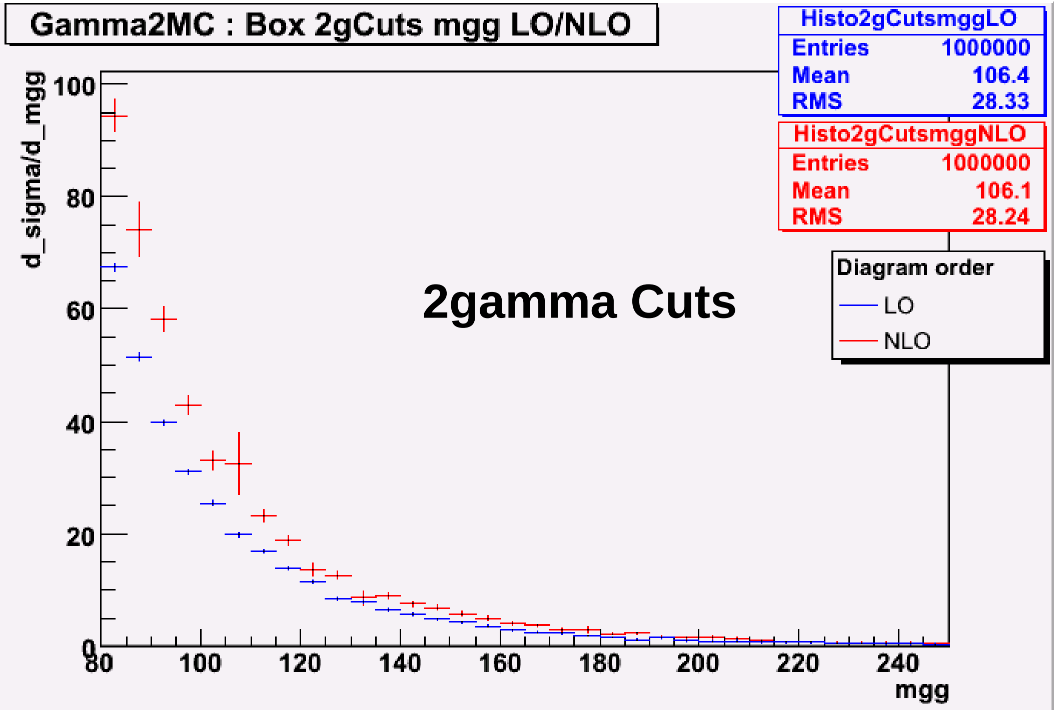
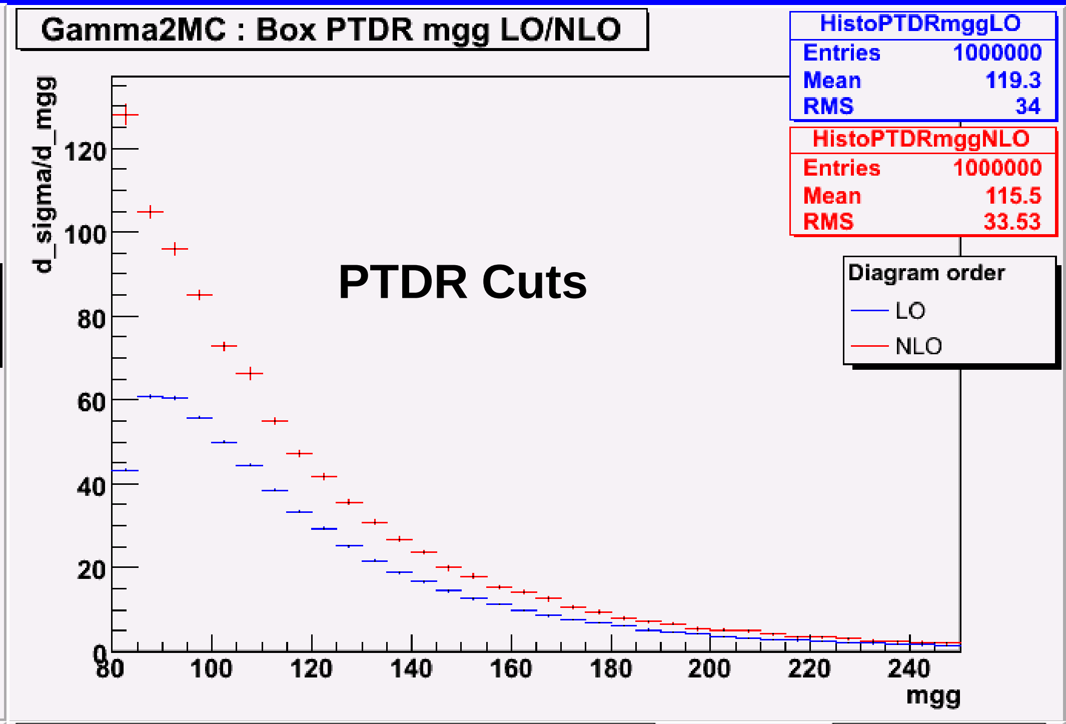
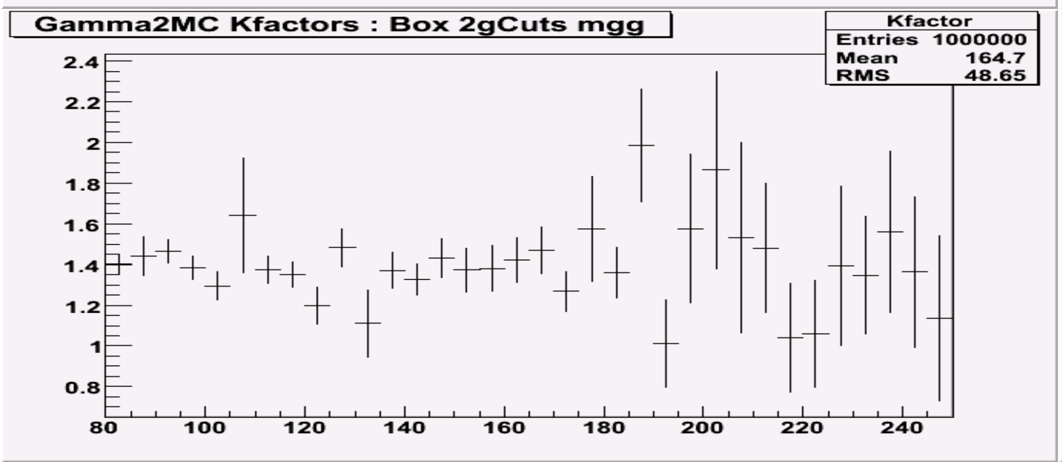
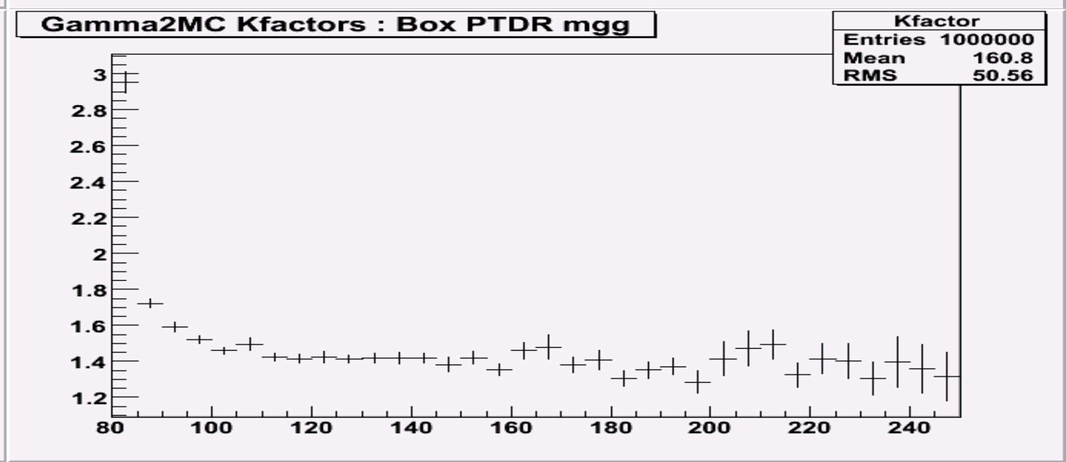








Higher order $\gamma\gamma$ Generator Studies

II – Complete Direct contributions

Born+Box contributions cross sections

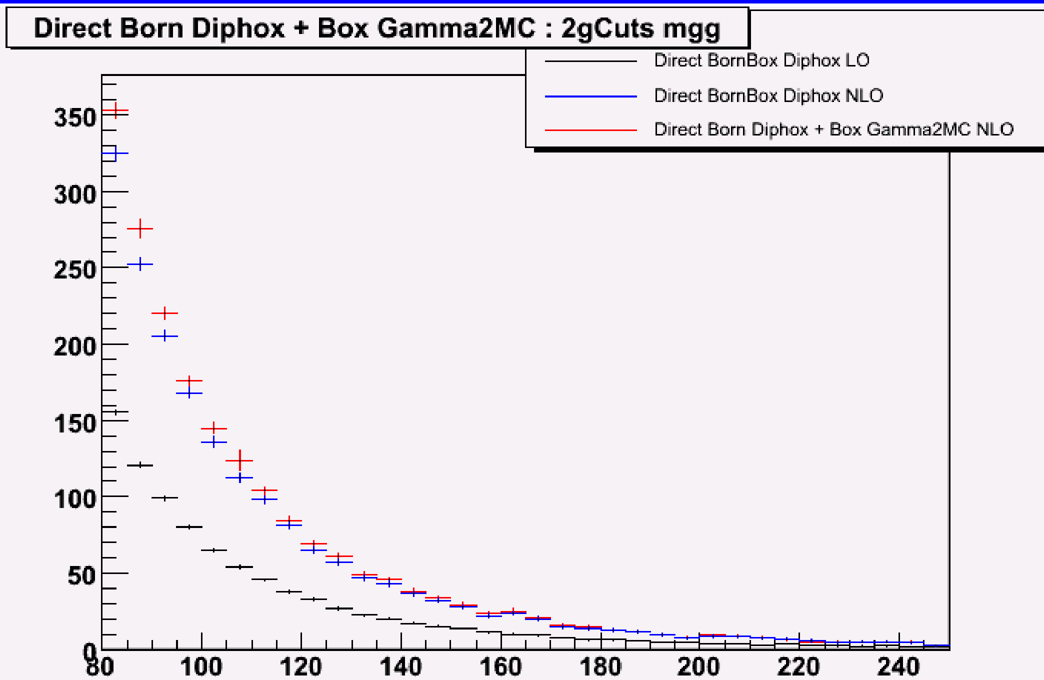
2gCuts	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Born DIPHOX	16.78	46.79
Direct BornBox DIPHOX	34.99	65.00
Direct Born DIPHOX + Box Gamma2MC	34.49	70.04
PTDR	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Born DIPHOX	5.86	14.39
Direct BornBox DIPHOX	9.11	16.93
Direct Born DIPHOX + Box Gamma2MC	9.03	19.79

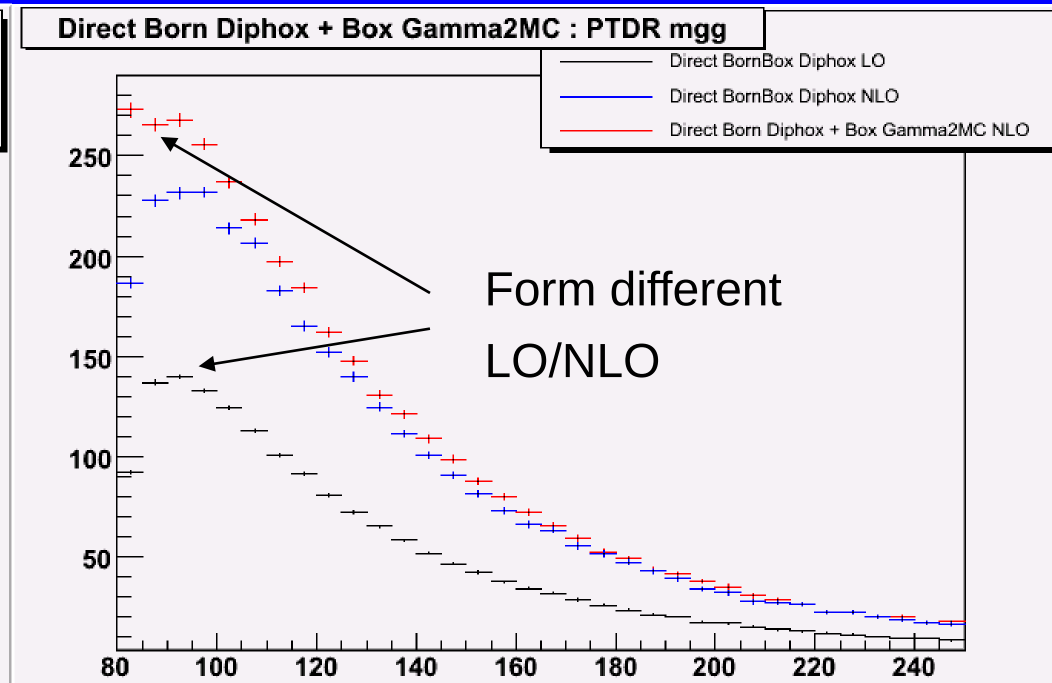
At NLO, the process Born DIPHOX + Box Gamma2MC has a bigger cross section than the BornBox DIPHOX (~8% more for 2 photon cuts, ~16% more for the Higgs PTDR curs), which is not surprising considering the importance of the corrections to box taken into account by Gamma2MC and not by DIPHOX.

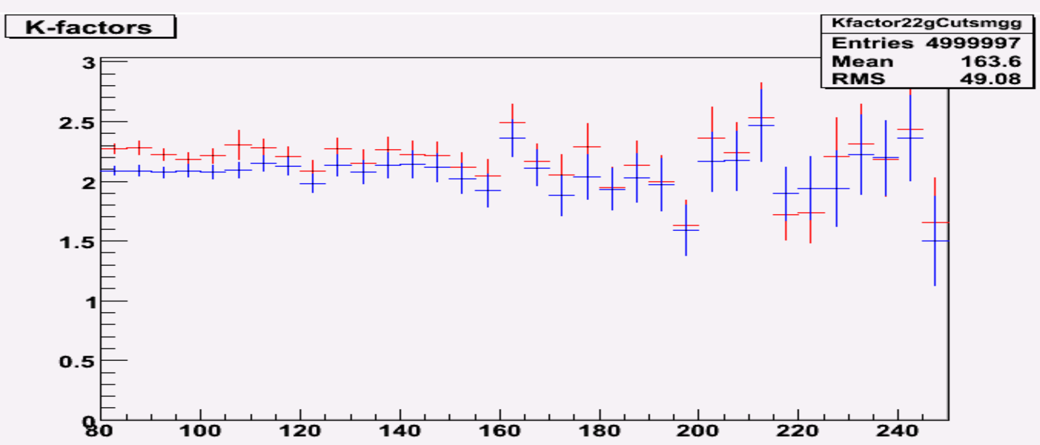
Higher order γγ Generator Studies

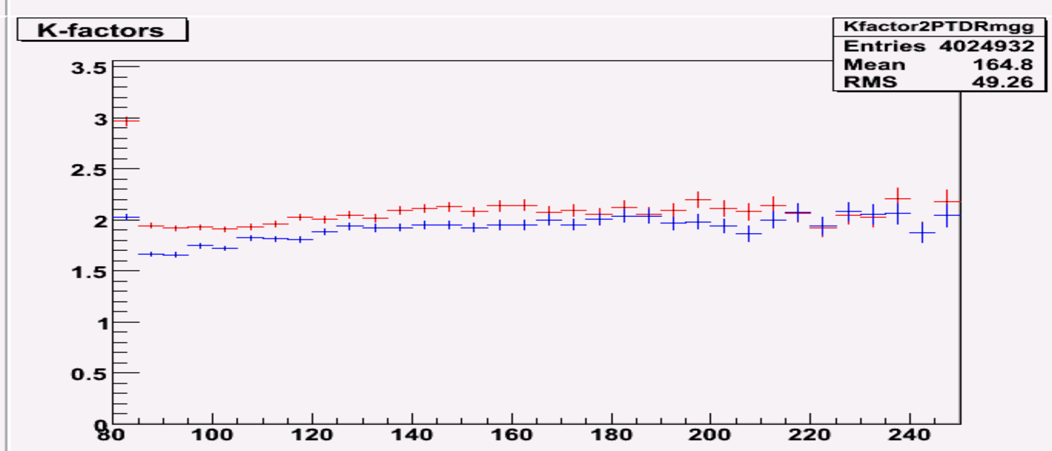
II – Complete Direct contributions

Mgg : gamma-gamma invariant mass









Higher order $\gamma\gamma$ Generator Studies

III – Direct and fragmentation contributions

2gCuts	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Born DIPHOX	16.78	46.79
Direct BornBox DIPHOX	34.99	65.00
Direct Born DIPHOX + Box Gamma2MC	34.49	70.04
Onefrag DIPHOX	10.04	20.06
Twofrag DIPHOX	0.58	1.50
Direct BornBox DIPHOX + Onefrag + Twofrag	45.61	86.56
Direct Born DIPHOX + Box Gamma2MC + Onefrag + Twofrag	45.11	91.60

PTDR	σ_{LO} (pb)	σ_{NLO} (pb)
Direct Born DIPHOX	5.86	14.39
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Onefrag DIPHOX	1.56	3.10
Twofrag DIPHOX	0.03	0.10
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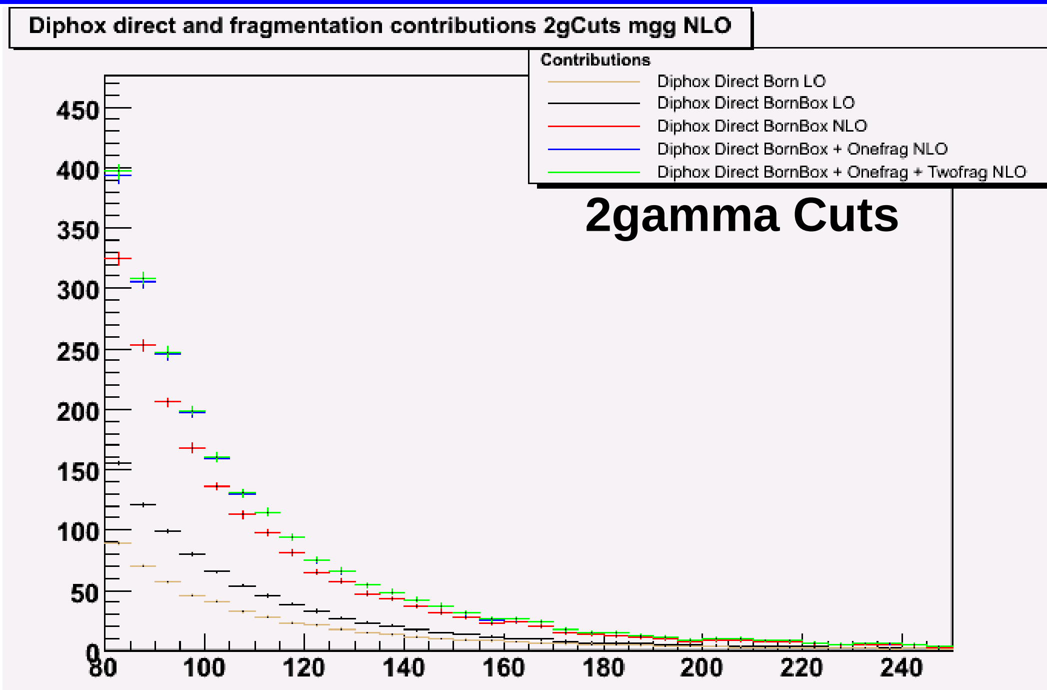
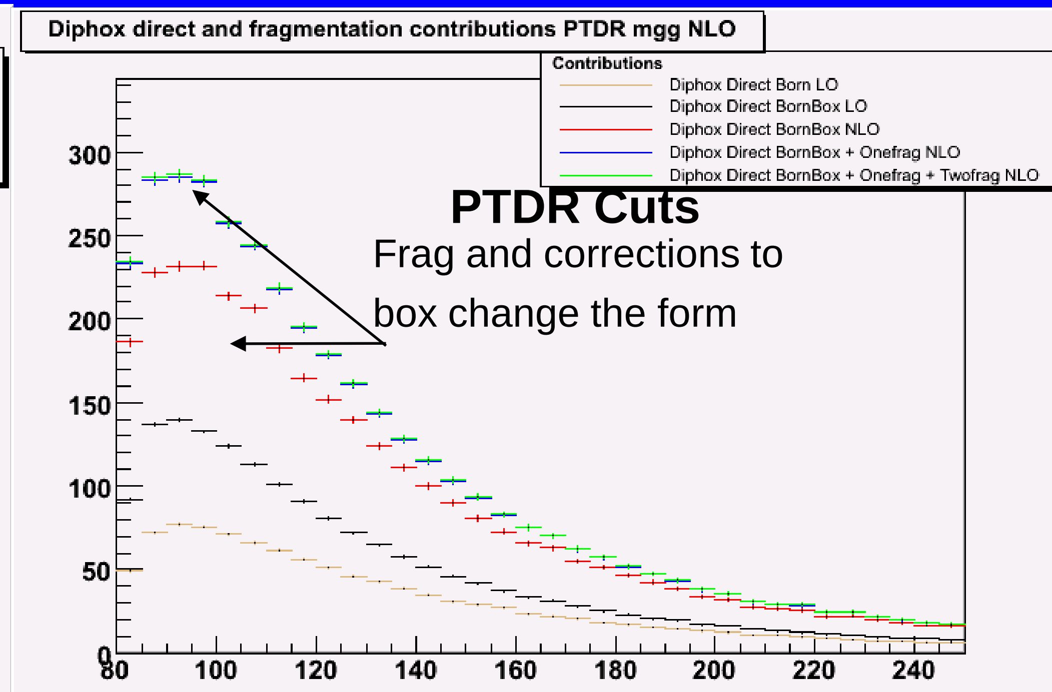
Direct Born DIPHOX + Box Gamma2MC + Onefrag + Twofrag	10.62	22.99

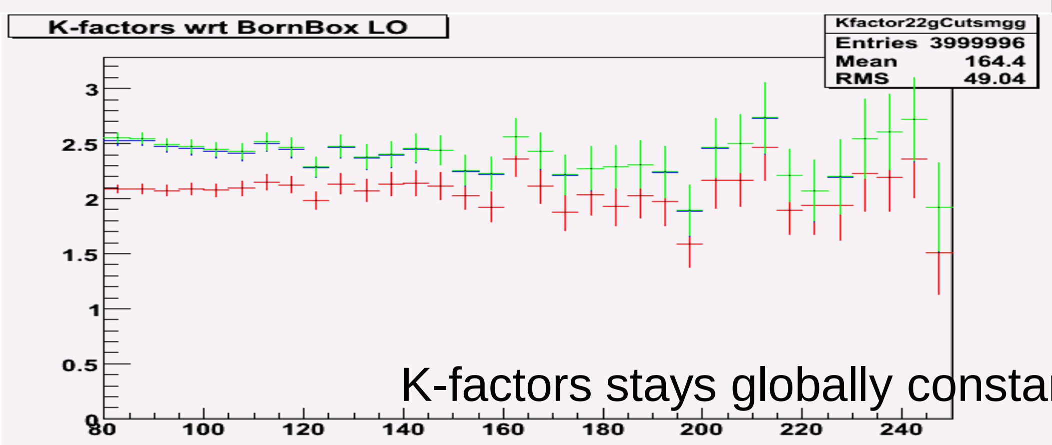
Higher order $\gamma\gamma$ Generator Studies

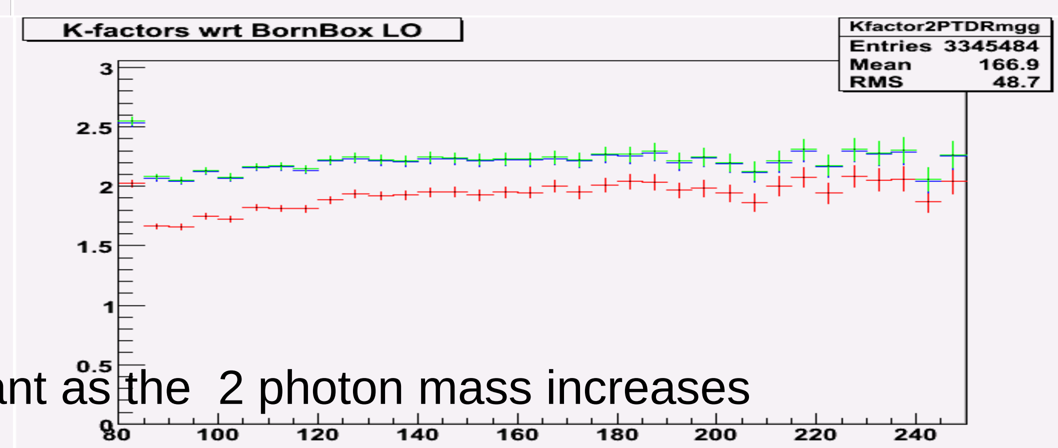
III – Direct and fragmentation contributions

Mgg : gamma-gamma invariant mass







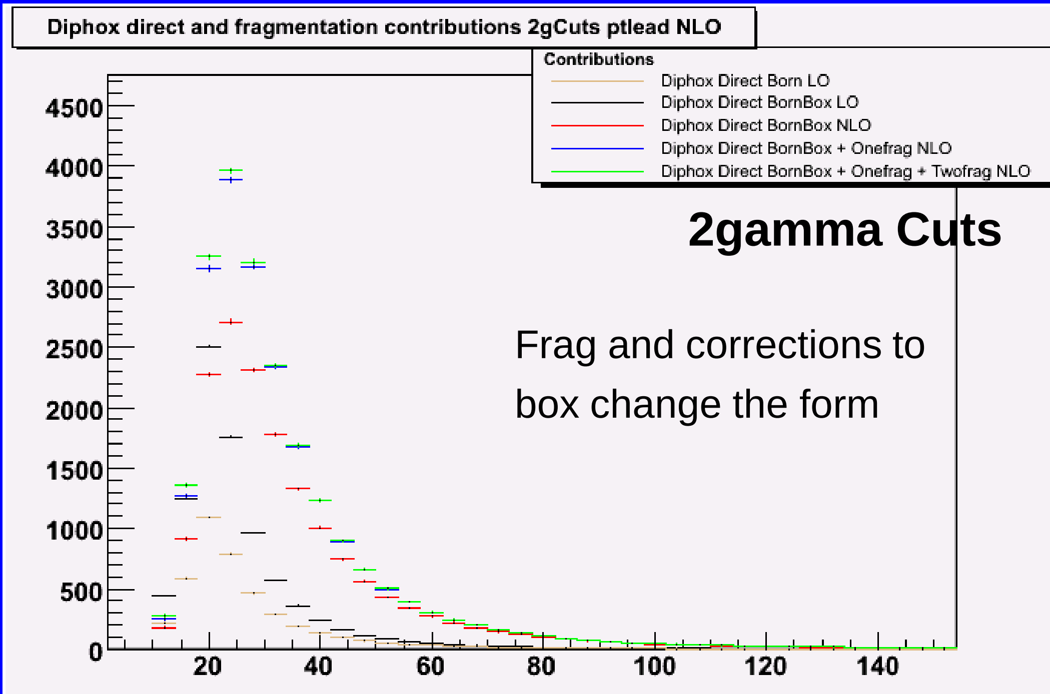


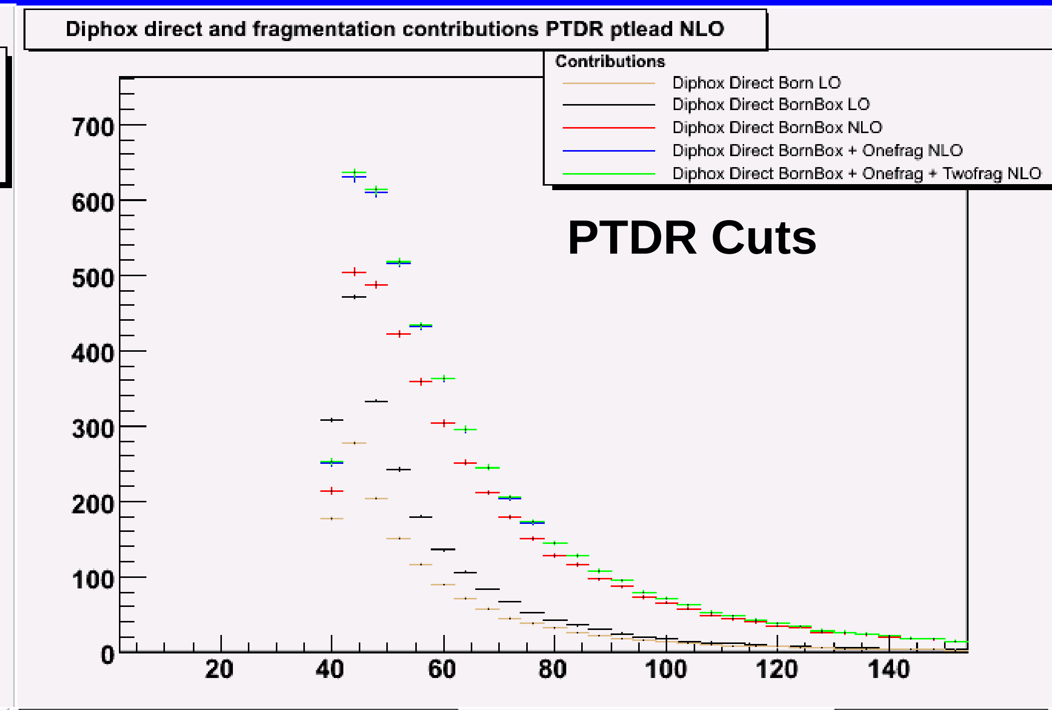
K-factors stays globally constant as the 2 photon mass increases

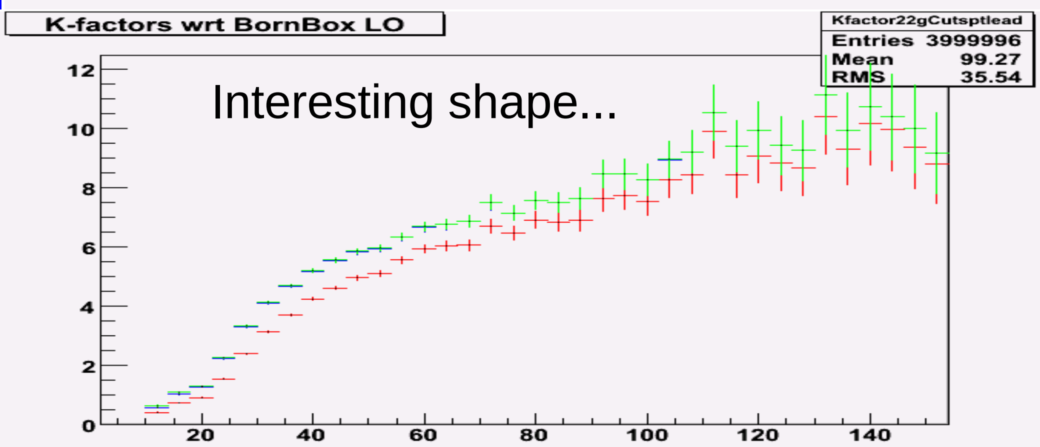
Higher order γγ Generator Studies

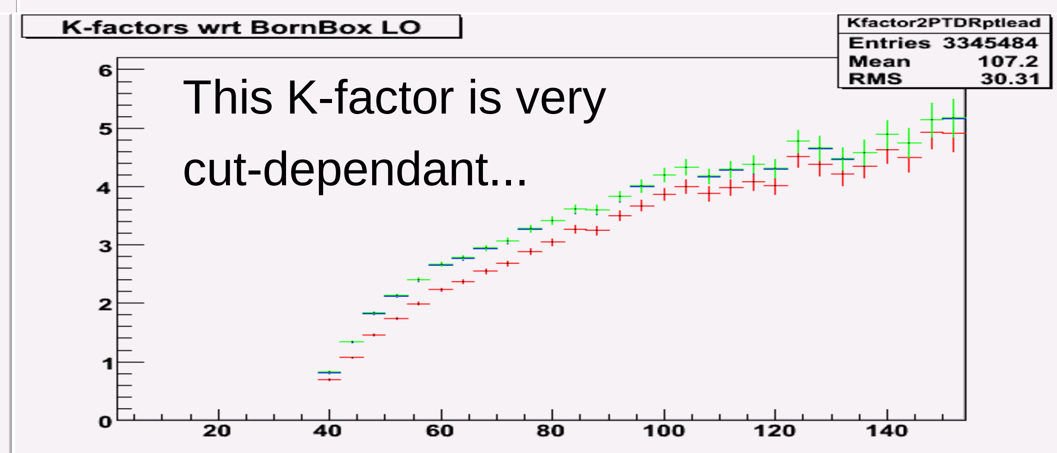
III – Direct and fragmentation contributions

PtLead : transverse momentum of the leading photon









Higher order γγ Generator Studies

IV – Diphox Born and Gamma2MC Box combination with frag

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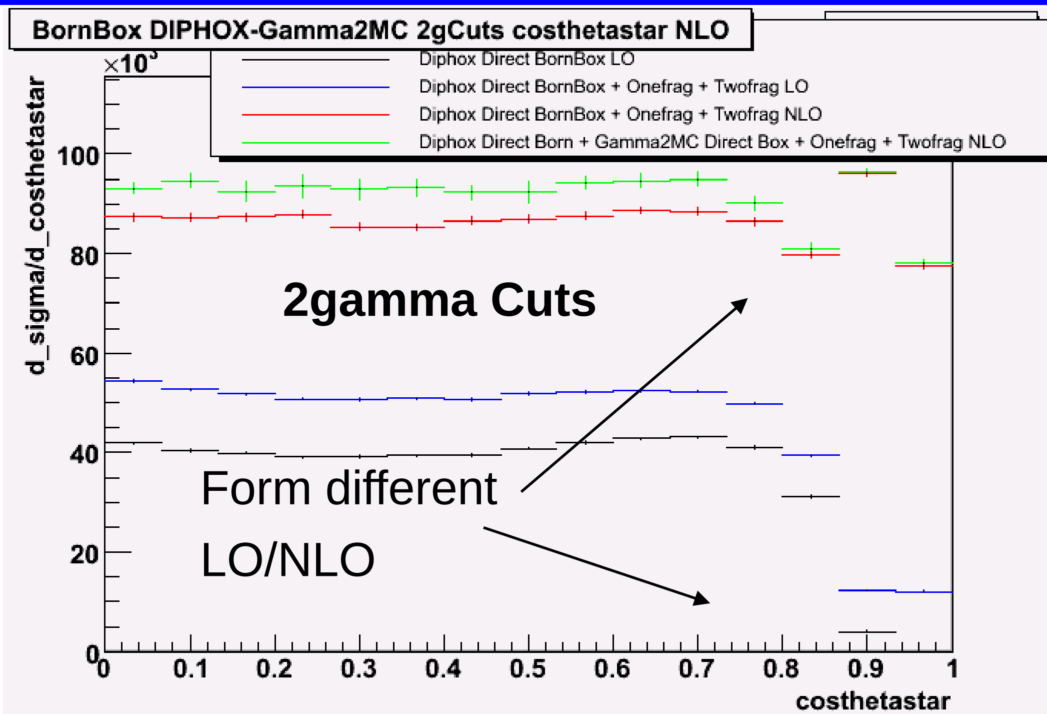
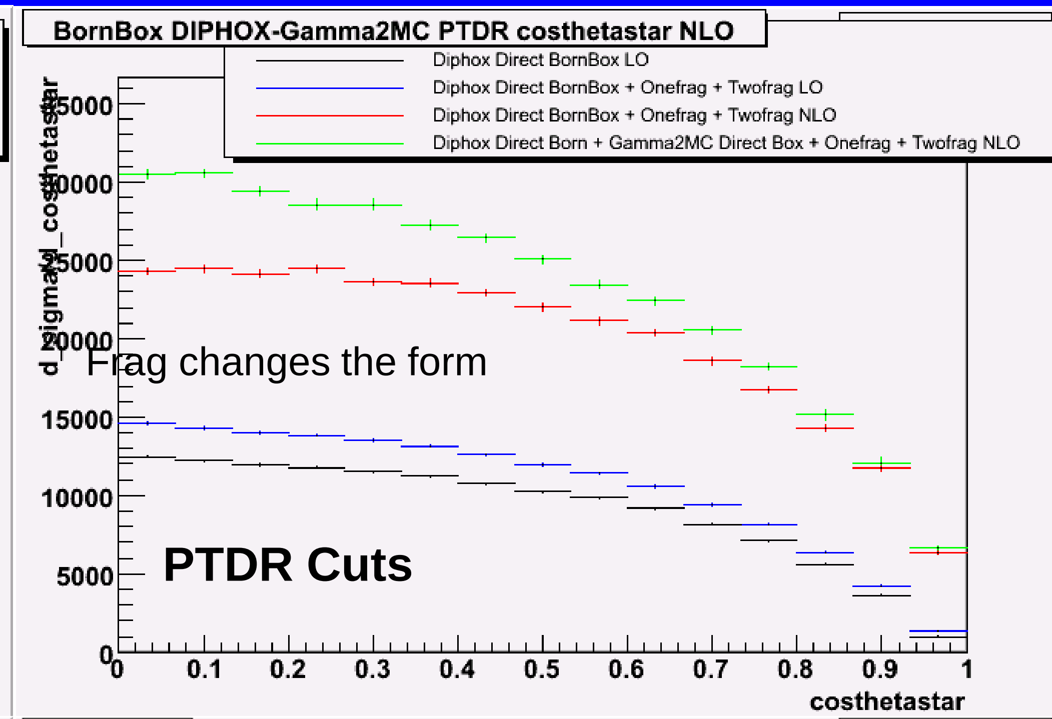
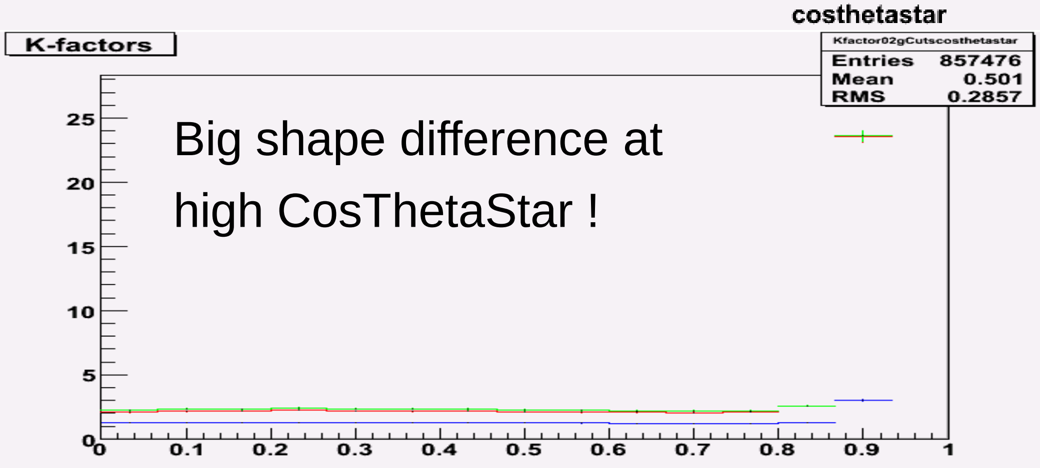
Higher order γγ Generator Studies

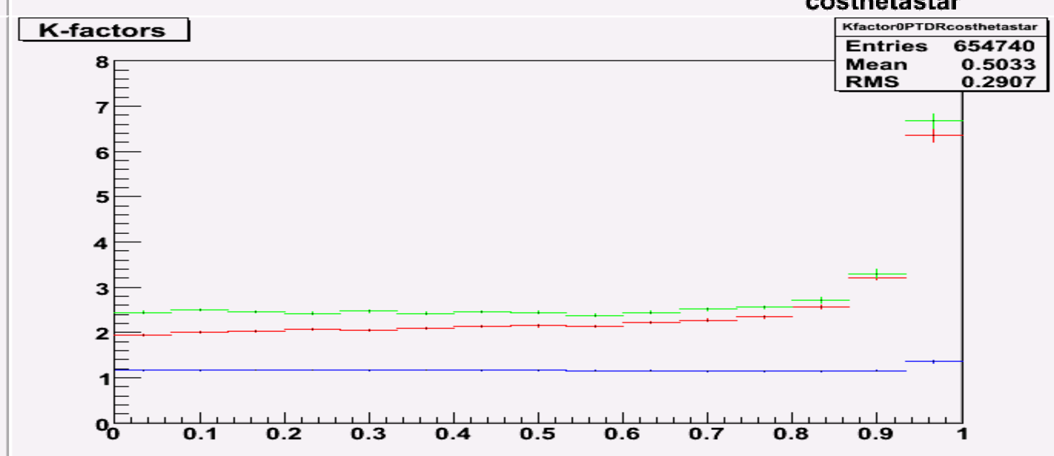
IV – Diphox Born and Gamma2MC Box combination with frag

CosThetaStar





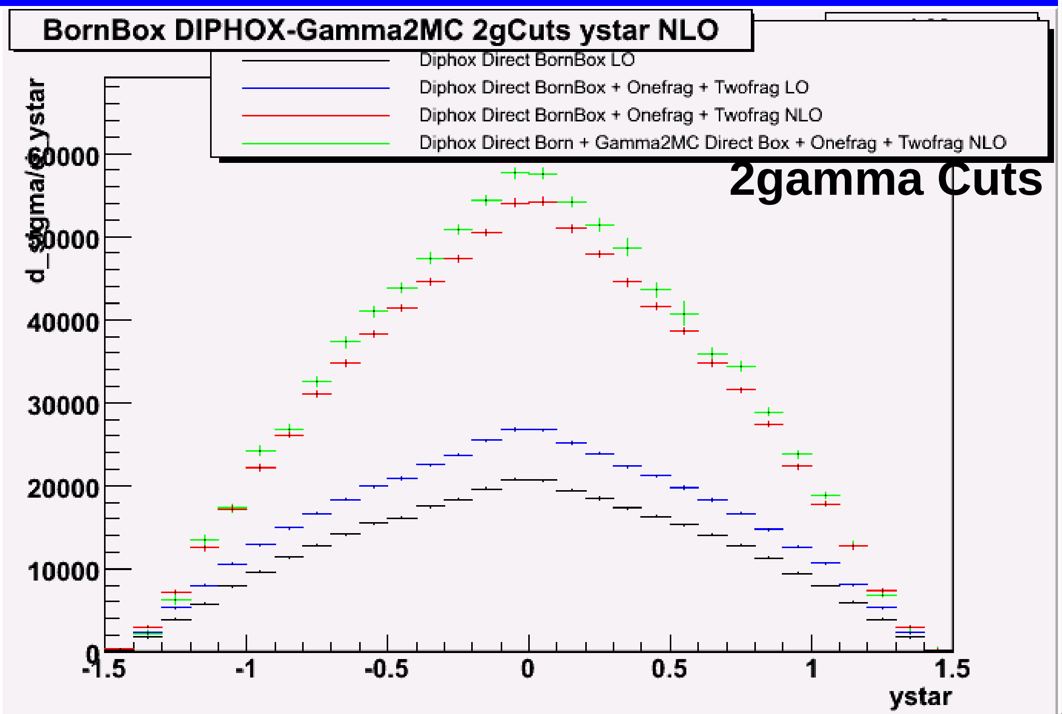


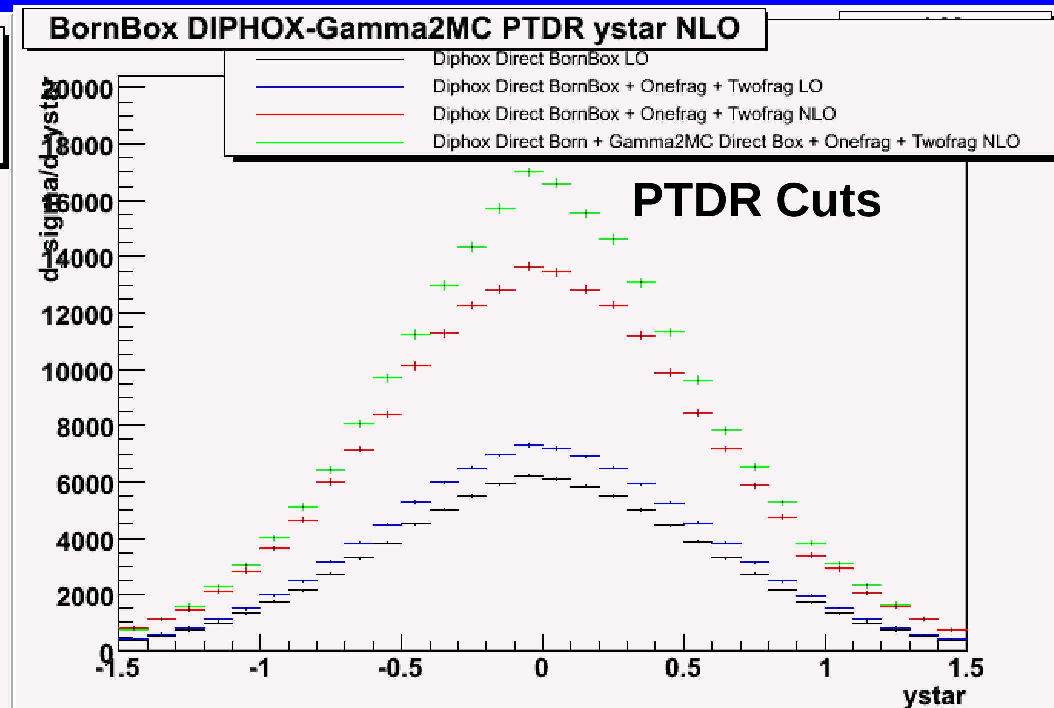


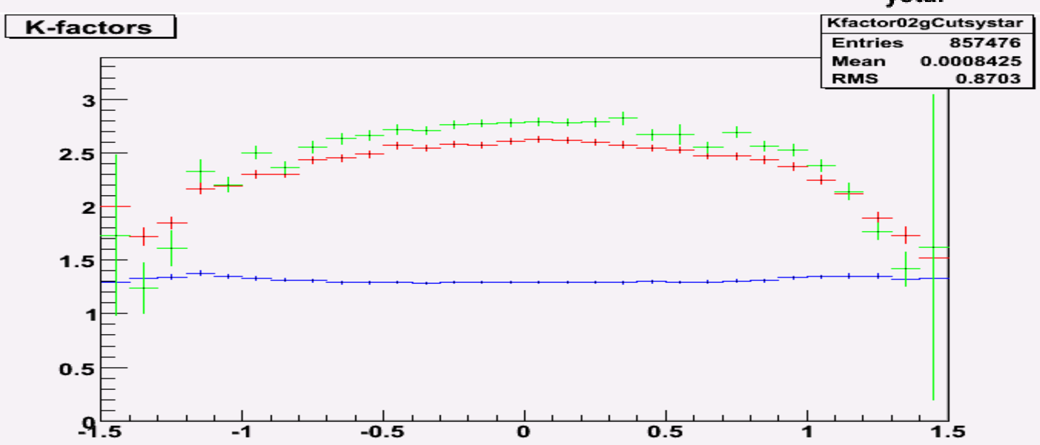
Higher order $\gamma\gamma$ Generator Studies

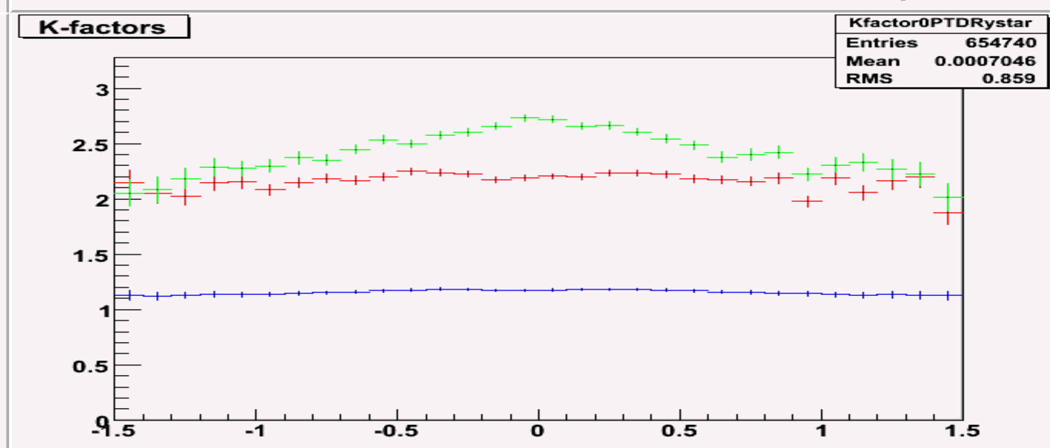
IV – Diphox Born and Gamma2MC Box combination with frag

Ystar : $(\eta 1-\eta 2)/2$









Higher order γγ Generator Studies

V – H->γγ signal

Background : Direct Born Diphox + direct Box Gamma2MC + 1 Frag + 2 Frag

Signal : H->γγ mH=120 GeV HNNLO

Signal / Background Cross-sections

Signal cross-sections :

mH = 120 2gamma cuts LO : 7.47 +/- 0.00 fb

mH = 120 2gamma NLO : 17.49 +/- 0.01 fb

mH = 120 2gamma cuts NNLO : 23.91 +/- 0.20 fb

mH = 120 PTDR cuts LO : 20.24 +/- 0.00 fb

mH = 120 PTDR cuts NLO : 46.06 +/- 0.02 fb

mH = 120 PTDR cuts NNLO : 58.93 +/- 0.49 fb

Background cross-section :

2gamma cuts Bkgd LO : 45.11 *pb*

2gamma Bkgd NLO : 91.60 *pb*

PTDR cuts Bkgd LO : 10,62 *pb*

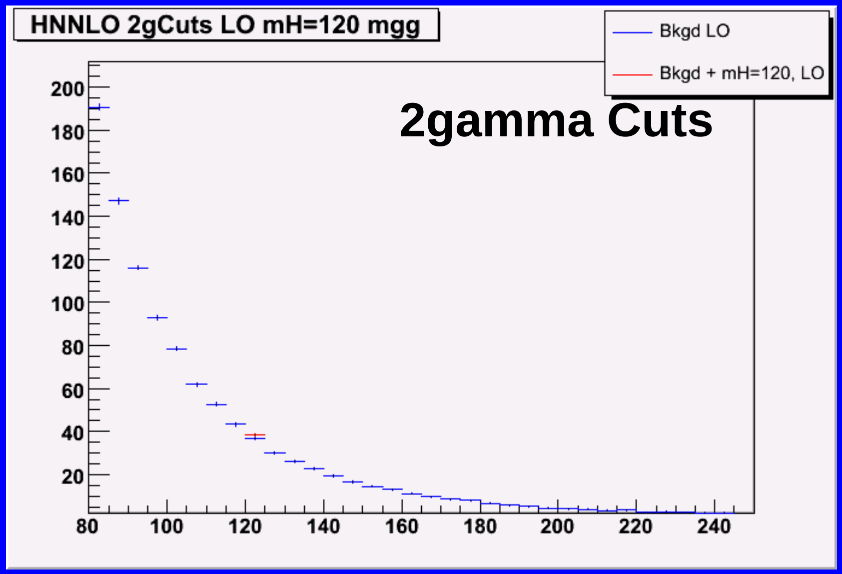
PTDR cuts Bkgd NLO : 20,13 *pb*

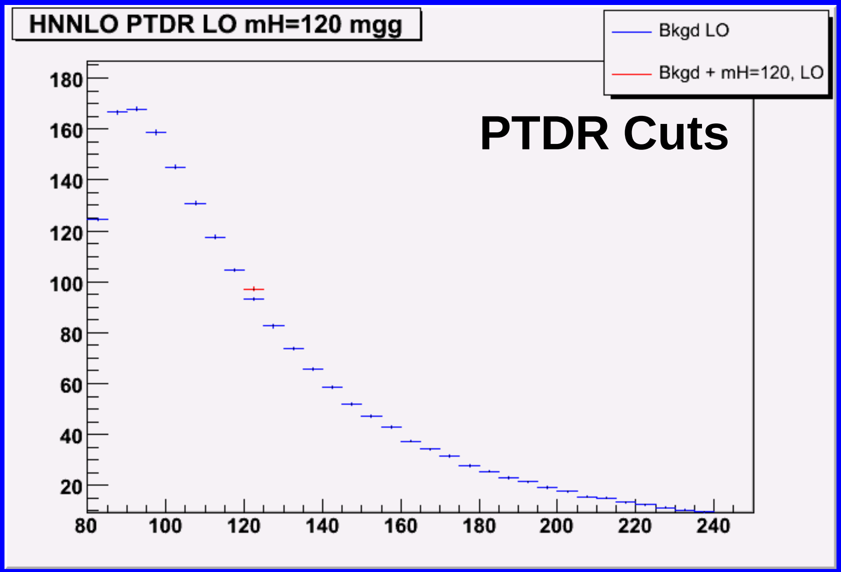
=> Corrections increase the ratio signal/bkgd.

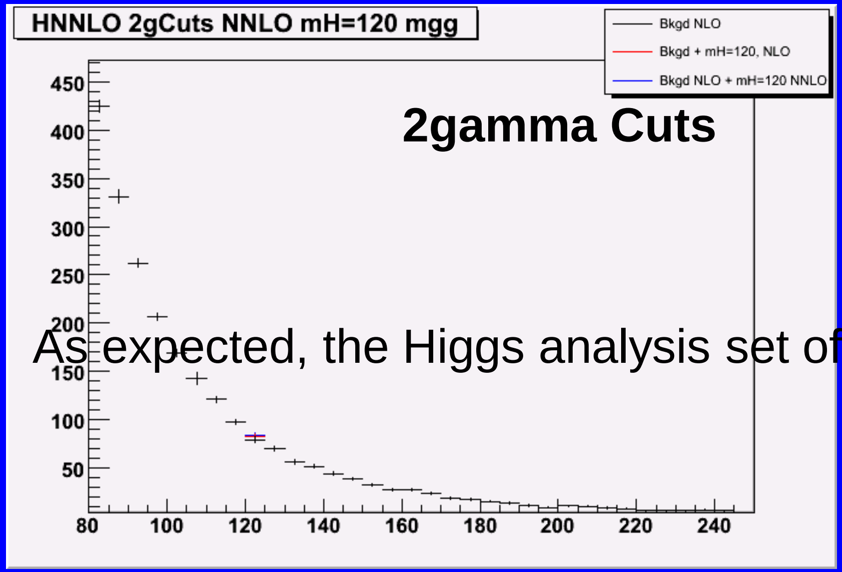
Higher order γγ Generator Studies

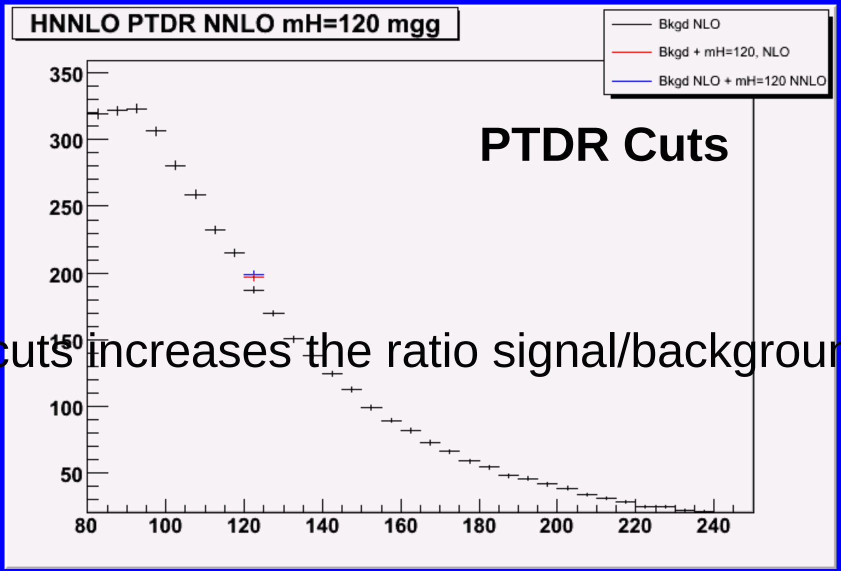
V – H->γγ signal

Mgg : gamma-gamma invariant mass







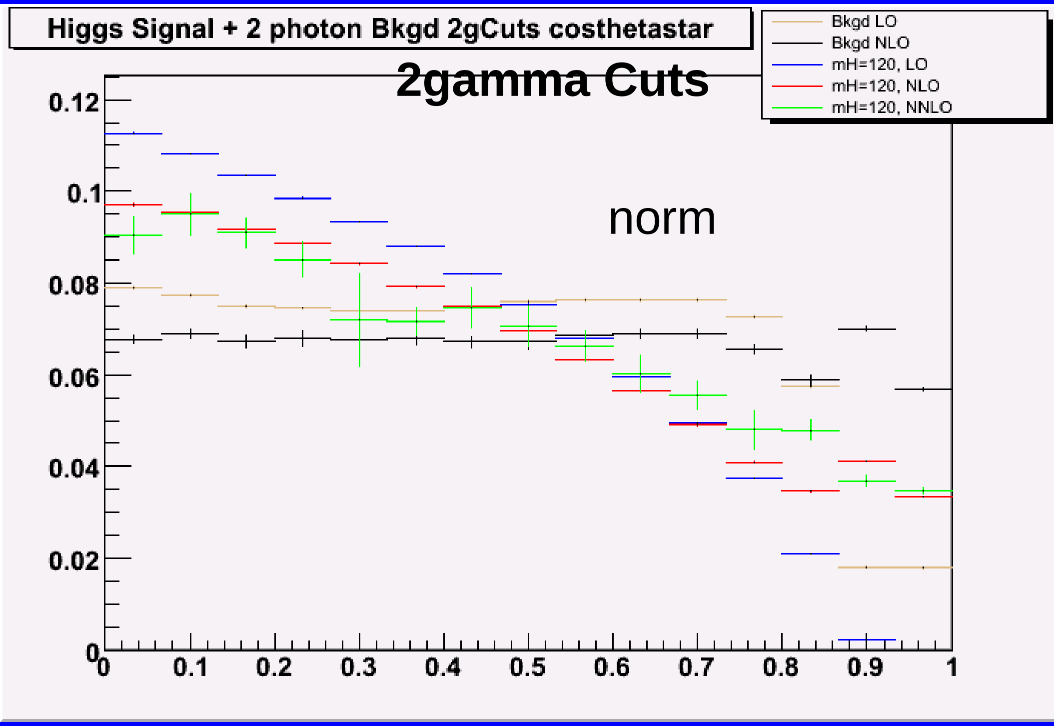


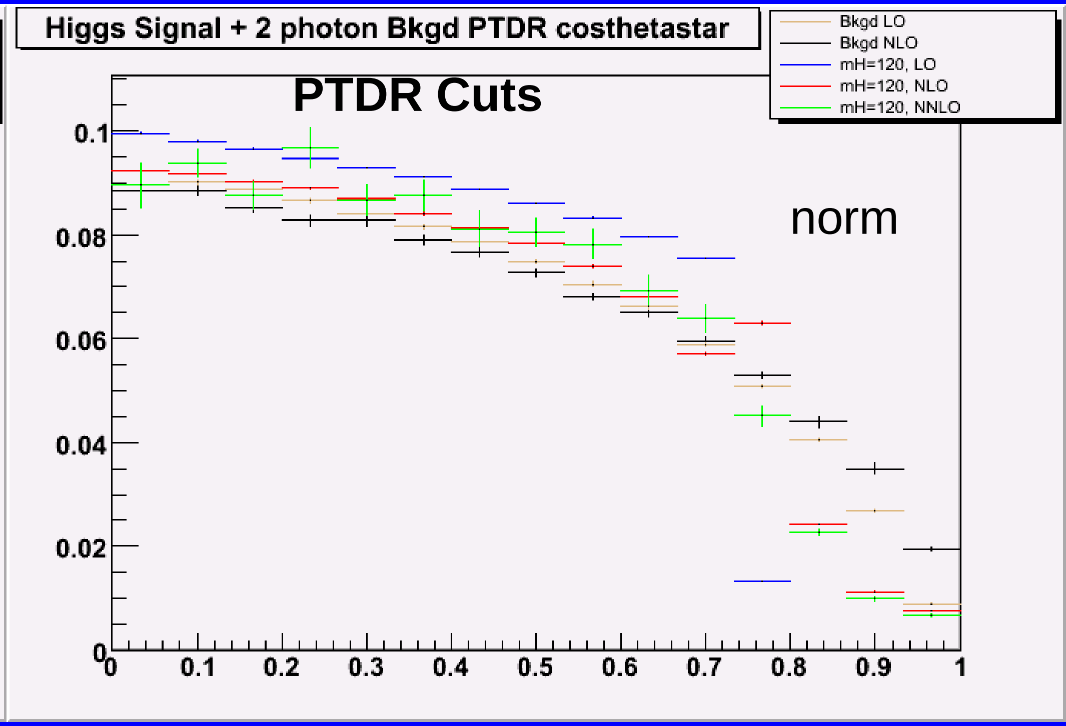
As expected, the Higgs analysis set of cuts increases the ratio signal/background.

Higher order γγ Generator Studies

V – H->γγ signal

CosThetaStar



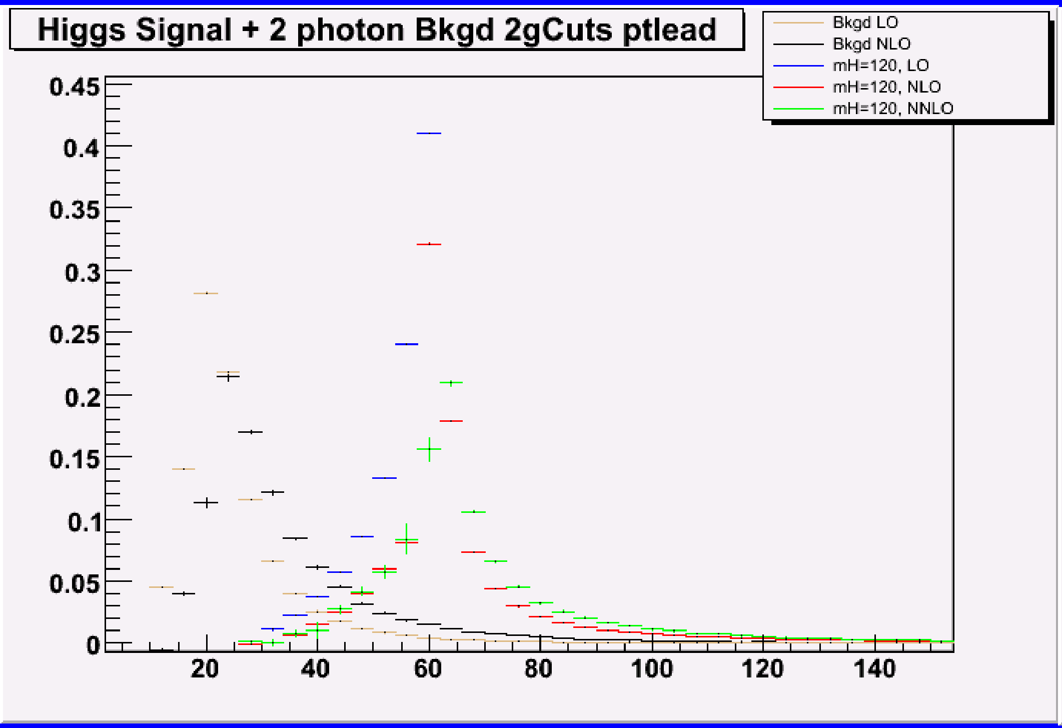


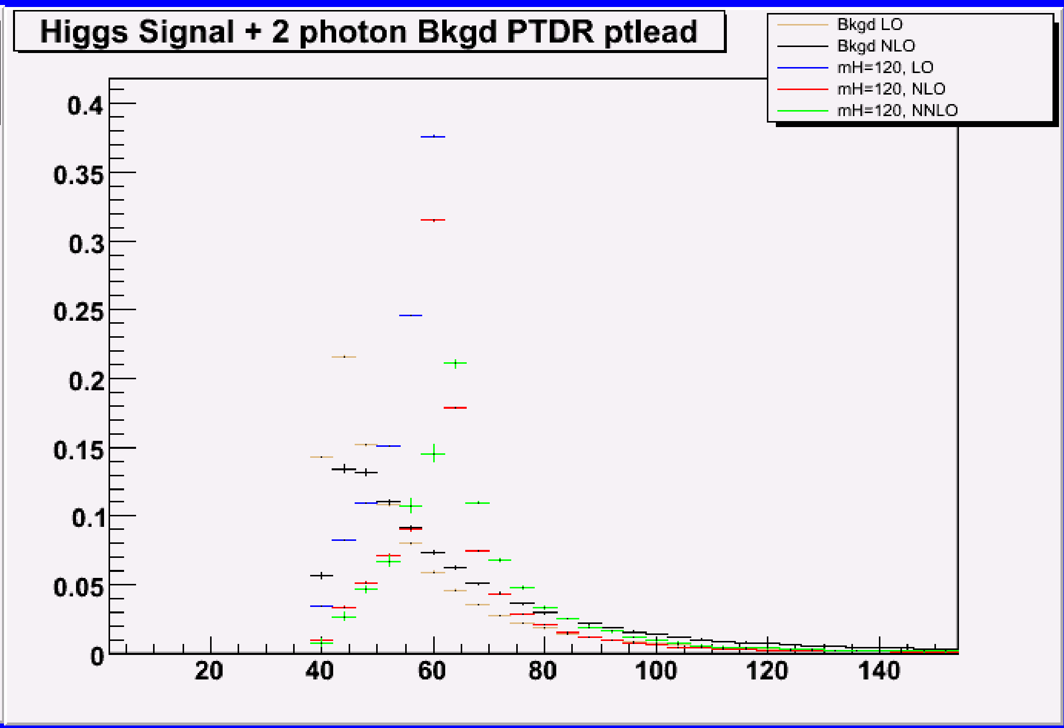
Globally, signal CosThetaStar decreases faster than the background, constantly for the 2 photon analysis, and rapidly at high costhetastar for the higgs analysis.

Higher order γγ Generator Studies

V – H->γγ signal

PtLead : transverse momentum of the leading photon



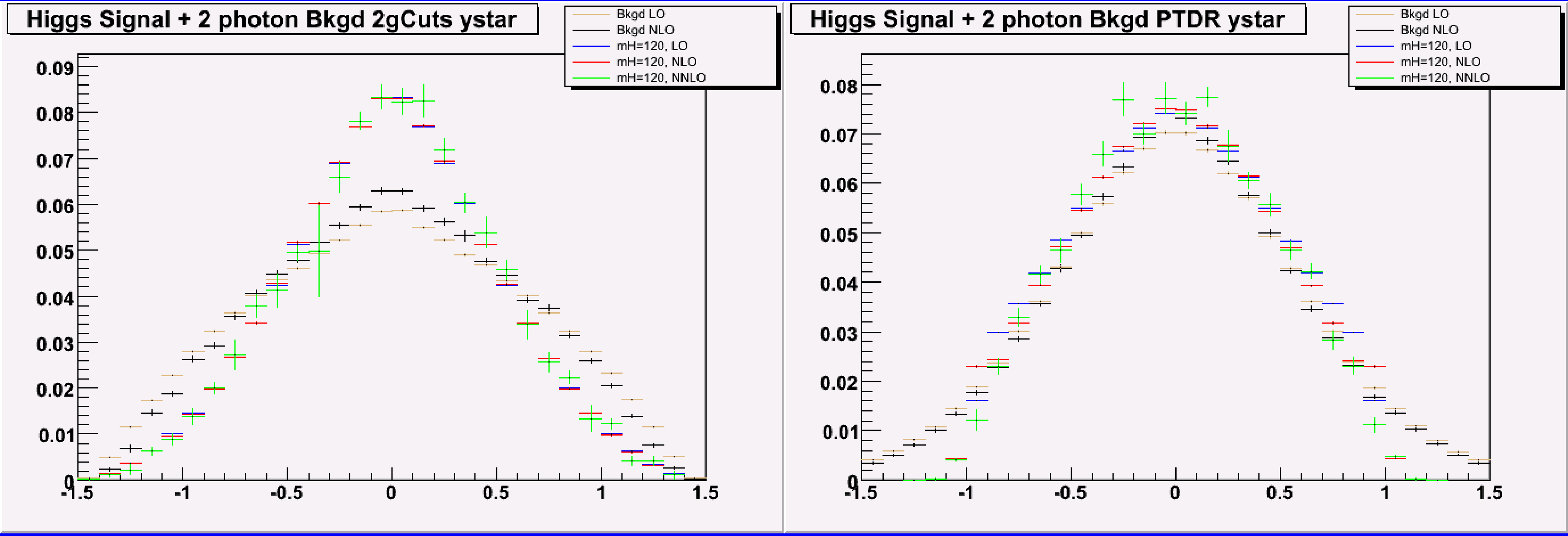


The cut at 40 GeV for the leading photon is very useful in the Higgs analysis.

Higher order γγ Generator Studies

V – H->γγ signal

Ystar : (η1-η2)/2



NLO and NNLO signal more centred on zero

Higher order $\gamma\gamma$ Generator Studies

Conclusions and future plans

- Diphox does not compute the NLO Box contribution, whereas Gamma2MC does. Gamma2MC corrections to Box are important, especially for $M_{\gamma\gamma}<120$ GeV
- The fragmentation contributions are not negligible (~20 pb in a process of ~90 pb for the 2 photon analysis), and not included in ResBos.
- It's inaccurate to reweight simply LO distributions with K-factors independent of the variables.

Perspectives :

- New MadGraph and MC@NLO samples are becoming available. Compare them and PYTHIA born and box contributions to DIPHOX/Gamma2MC.
- Reweighting of $\gamma\gamma$ LO ME key distributions with gamma2MC for the NLO Box plus DIPHOX for all other direct and fragmentation diagrams. Cross-check with Resbos.
- Continue to compare the H->$\gamma\gamma$ distributions with the Born+Box NLO distributions to see if some variables could be more discriminating than at LO.
- Investigate the issue of isolation cone saturation at reconstructed vs generated level.

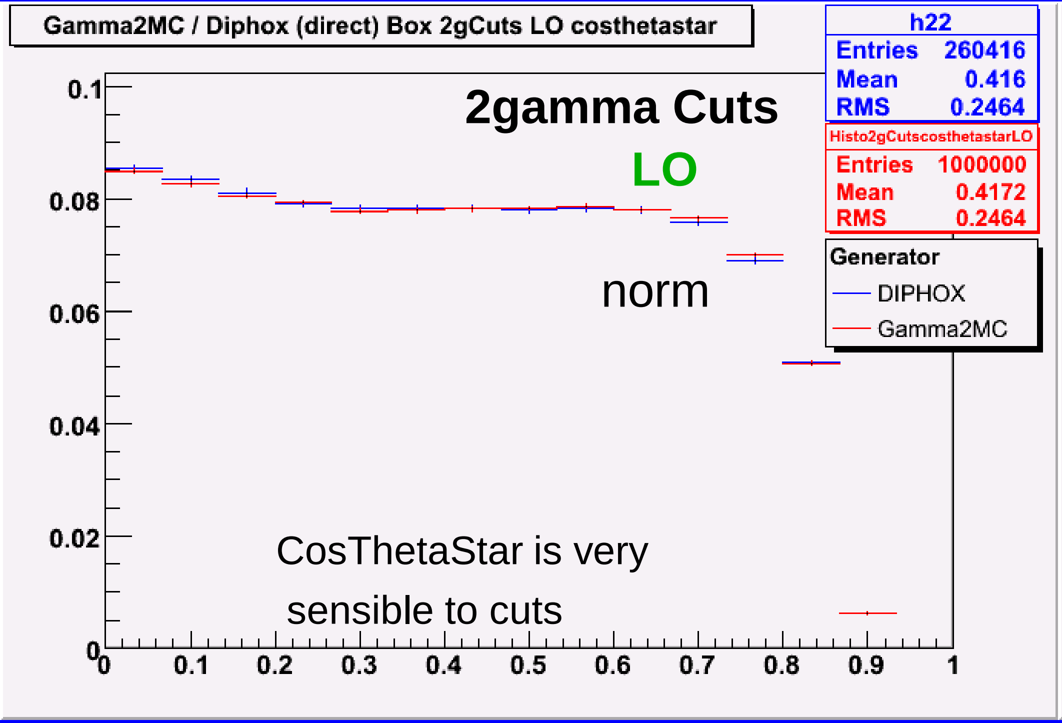
Thanks to the FCPPL organisation to allow us to go in Wuhan,
and Guoming Chen who invited me to work at IHEP the next months

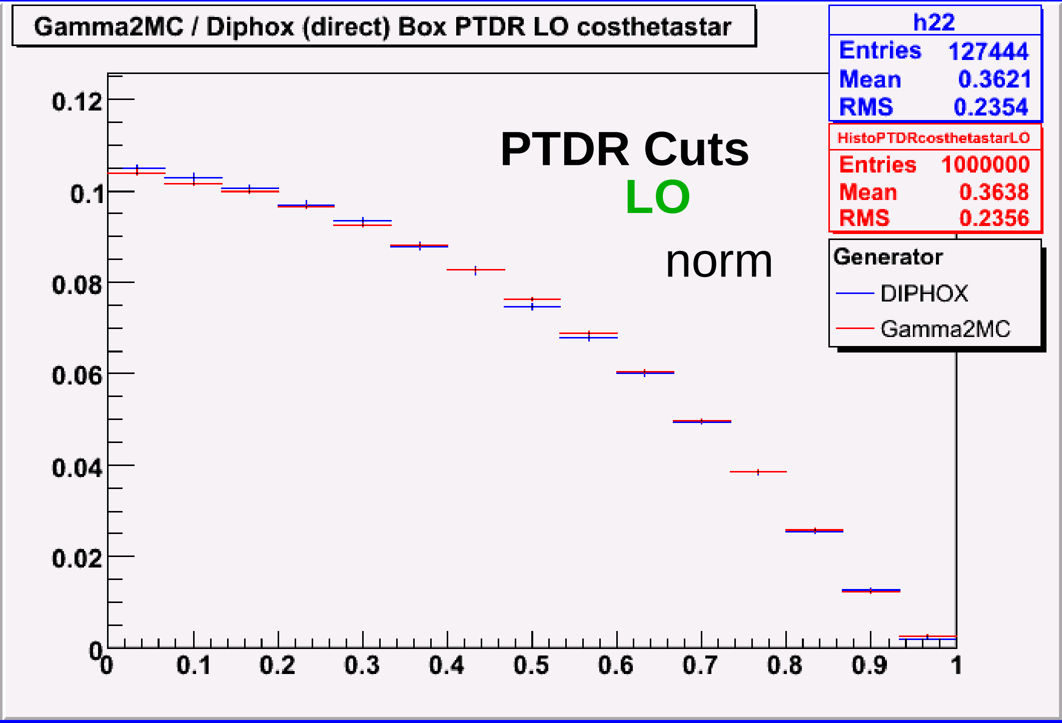
BACK-UP SLIDES

Higher order γγ Generator Studies

I – Direct Box contributions

CosThetaStar : Cosinus of the angle between the diphoton system and one of the photon, in the center of mass of the diphoton system.

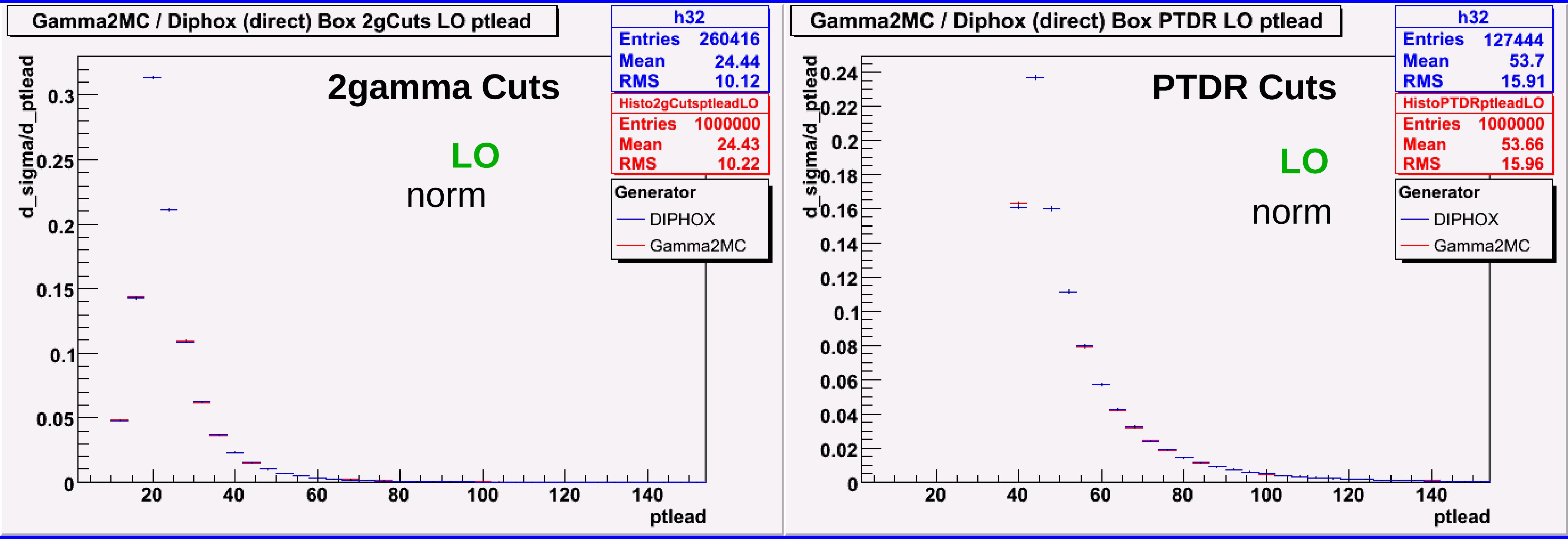




Higher order γγ Generator Studies

I – Direct Box contributions

PtLead : transverse momentum of the leading photon



Higher order γγ Generator Studies

I – Direct Box contributions

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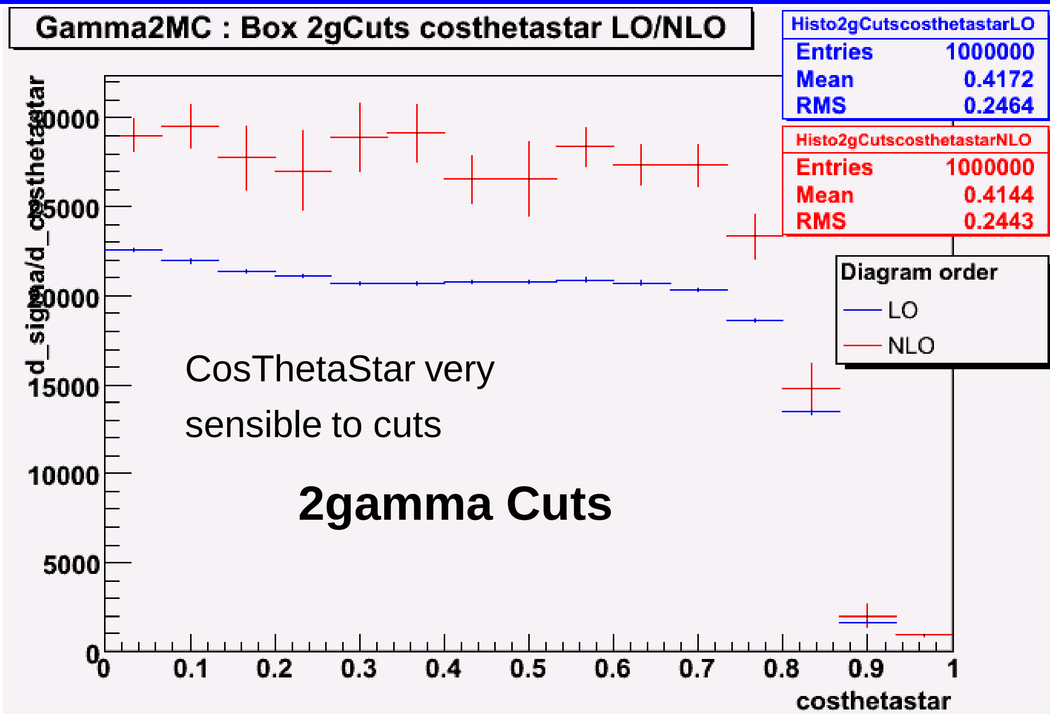
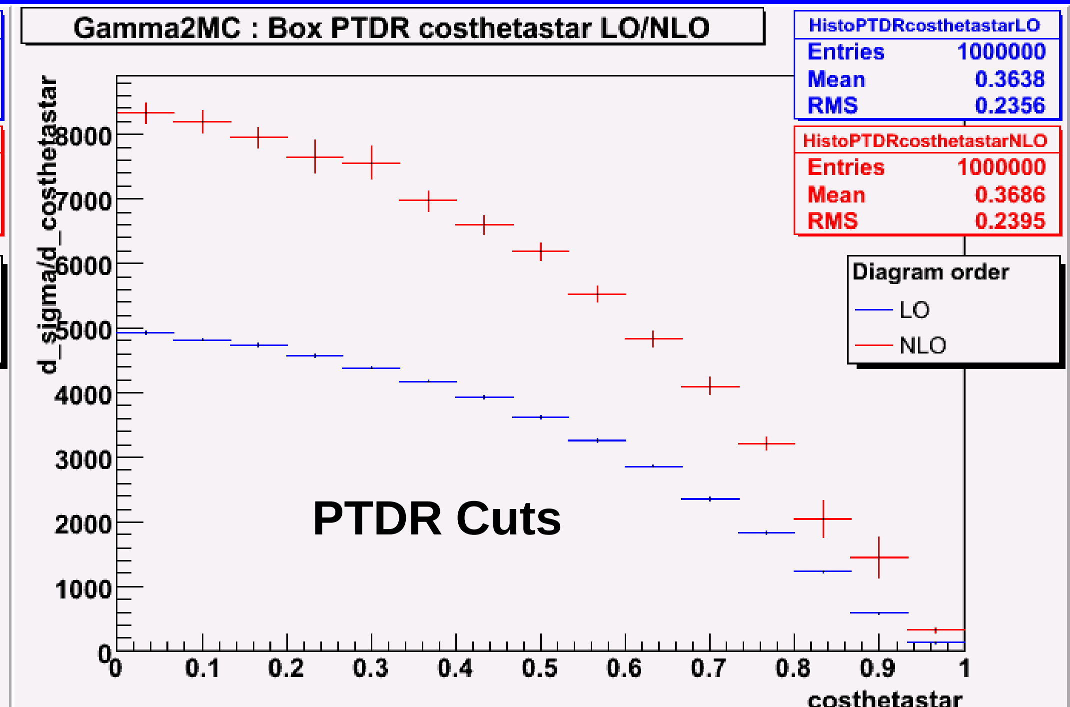
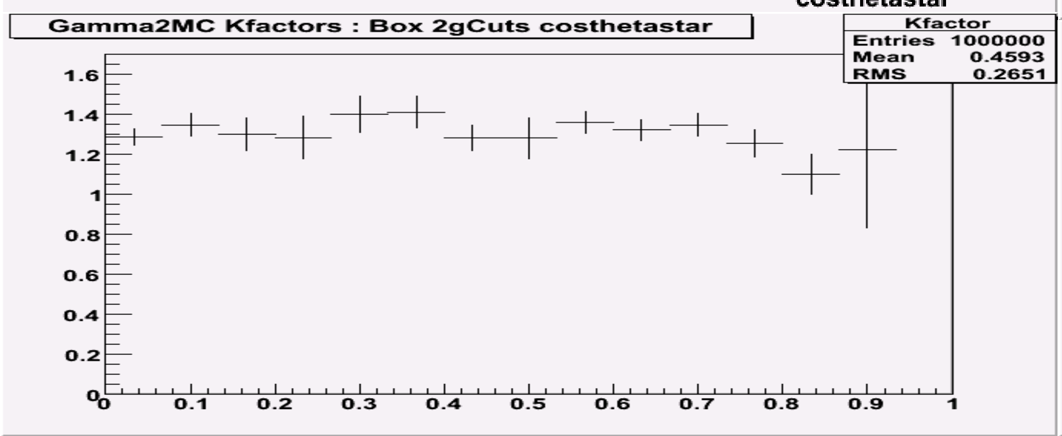
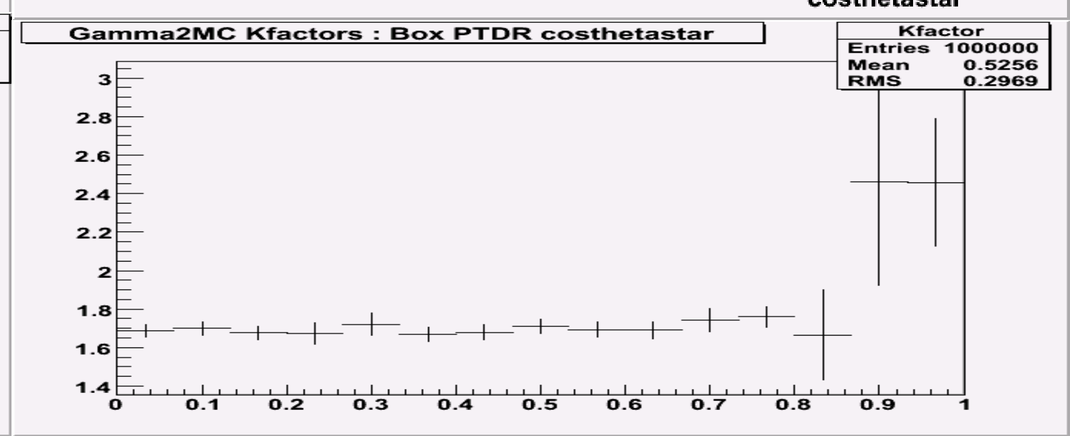




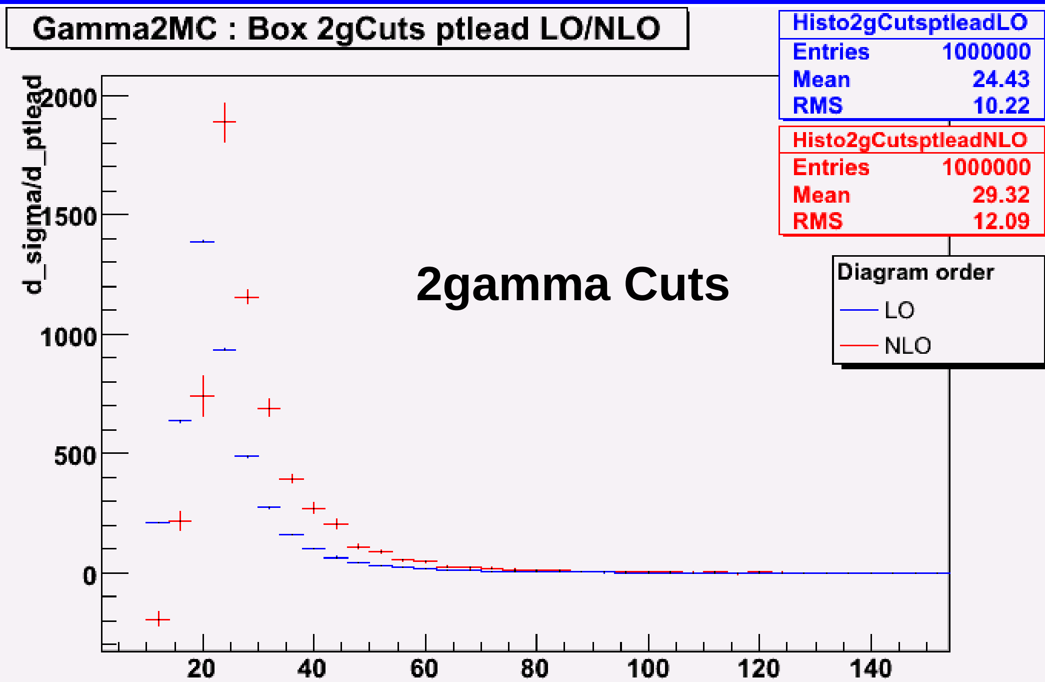


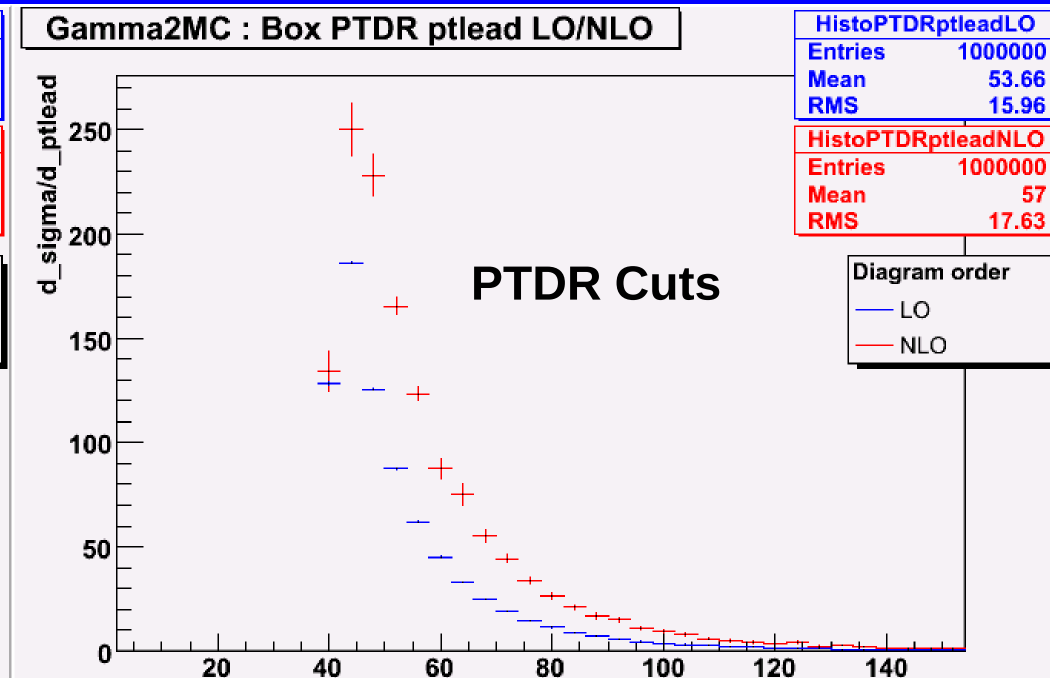


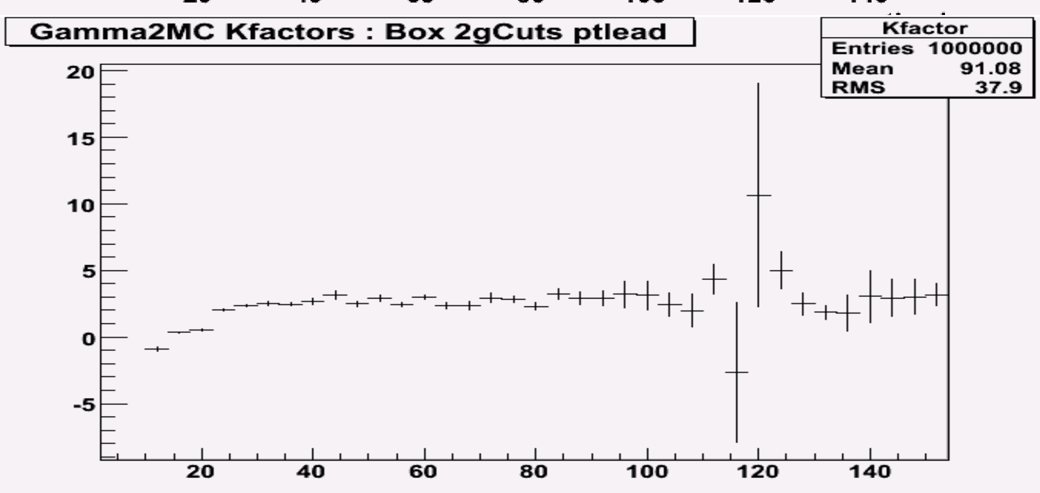
Higher order γγ Generator Studies

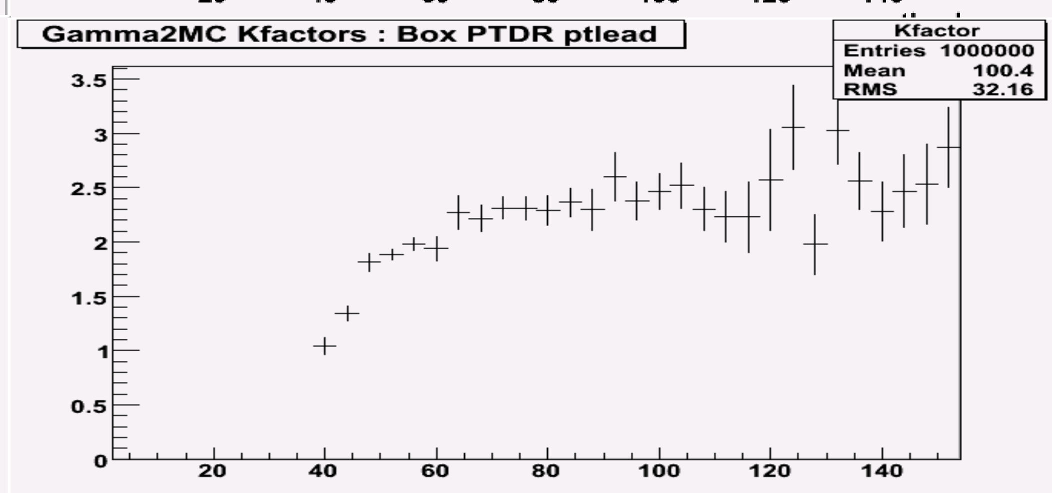
I – Direct Box contributions

PtLead : transverse momentum of the leading photon









Higher order $\gamma\gamma$ Generator Studies

III – Direct and fragmentation contributions

Ystar : $(\eta 1-\eta 2)/2$