

# SDA-1: Event generators and Higgs Physics at LHC

Report of FY2007 activities  
and FY2008 R&D plan

Y. Kurihara  
(KEK)

15/May/2008, FJPPL workshop @ Paris



# Members

French Group			Japanese Group		
Name	Title	Affiliation	Name	Title	Affiliation
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J. F. Marchand	PhD				
I. Wingerter-Seez	Dr.	CNRS			
Denis Perret-Gallix	Dr.	CNRS			



# Activities of SDA-1 in FY2007

## ➤ Collaboration meetings at LAPP

- |  |              |
|--|--------------|
| 10 participants, 5 talks and discussions | 15/Oct./2007 |
| 15 participants, 6 talks and discussions | 21.Jan./2008 |

## ➤ Publications

1. “Six-Photon Amplitude in Scalar QED”, C. Bernicot, J-P. Guillet, JHEP 0801 (2008) 059
2. “Hadronic single inclusive  $k_t$  distributions inside one jet beyond MLLA”, F. Arleo, R. P. Ramos and B. Machet, Phys. Rev. Lett. 100 (2008) 052002
3. “Measuring gluon shadowing with prompt photons at RHIC and LHC”, F. Arleo and T. Gousset, Phys. Lett. B 660 (2008) 181
4. “Quenching of photon and pion spectra at intermediate RHIC energy”, F. Arleo, JHEP 0707 (2007) 032
5. “Initial-state parton shower kinematics for NLO event generators”, S. Odaka, Y. Kurihara, Eur. Phys. J. C51 (2007) 867



# Experimental Studies in SDA1

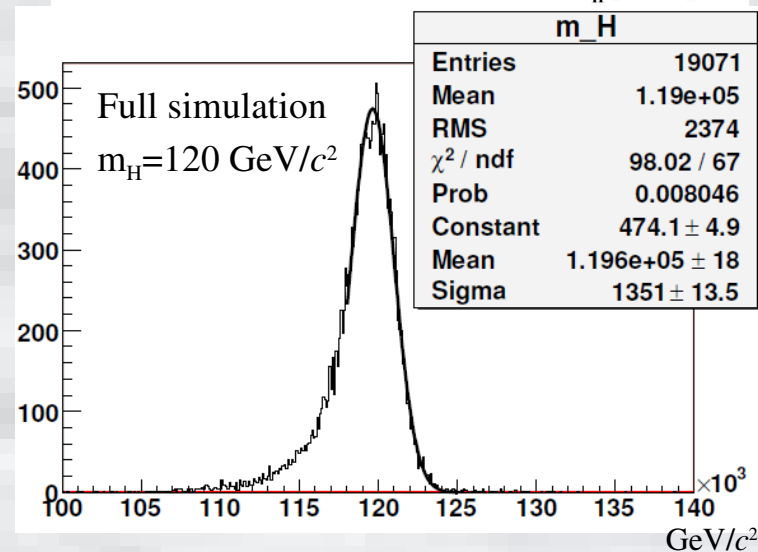
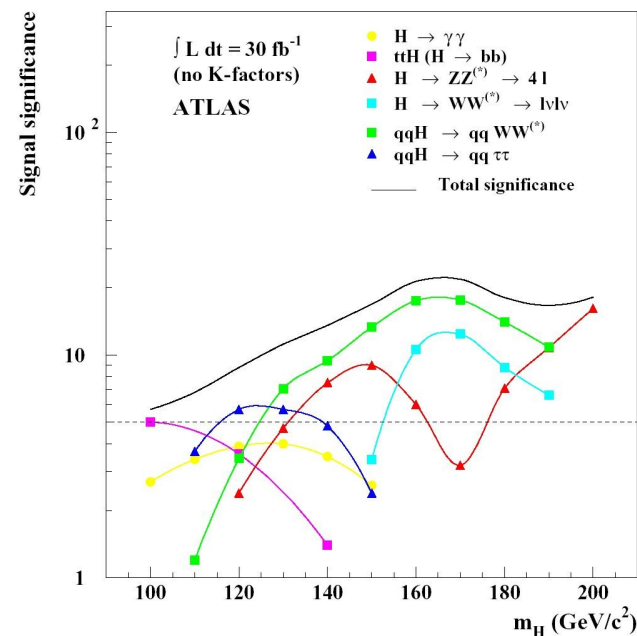
## LAPP-ATLAS & KEK-ATLAS group

- Data analysis for the discovery of Higgs boson decaying to two photons in the ATLAS Experiment at LHC
  - Detailed full simulation studies before LHC turn-on
  - Development of data analysis tools
- Development of NLO event generator for SM  $pp \rightarrow \gamma\gamma + X$  process
  - Understanding of the irreducible SM backgrounds to  $H \rightarrow \gamma\gamma$  signal
  - In collaboration between SDA-1 theorists and experimentalists



# Data Analysis for $H \rightarrow \gamma\gamma$ in LHC-ATLAS Experiment

- The most promising channel for SM Higgs search in low mass region :  $H \rightarrow \gamma\gamma$ 
  - Perform detailed analysis of Monte-Carlo samples fully simulated w/ ATLAS software
  - Studies on high- $p_T$  photon identification, selection cuts and technique to extract signal w/ higher S/B.
- Analysis software/tools developed for  $H \rightarrow \gamma\gamma$ 
  - “HiggsToGamGam” : Analysis package dedicated for  $H \rightarrow \gamma\gamma$  in ATLAS software
  - Photon ID tuning with high efficiency & jet rejection
  - Photon pointing & primary vertex finding
  - Photon-conversion reconstruction
  - Isolation w/ tracks
  - and more...





# Data Analysis for $H \rightarrow \gamma\gamma$ in LHC-ATLAS Experiment

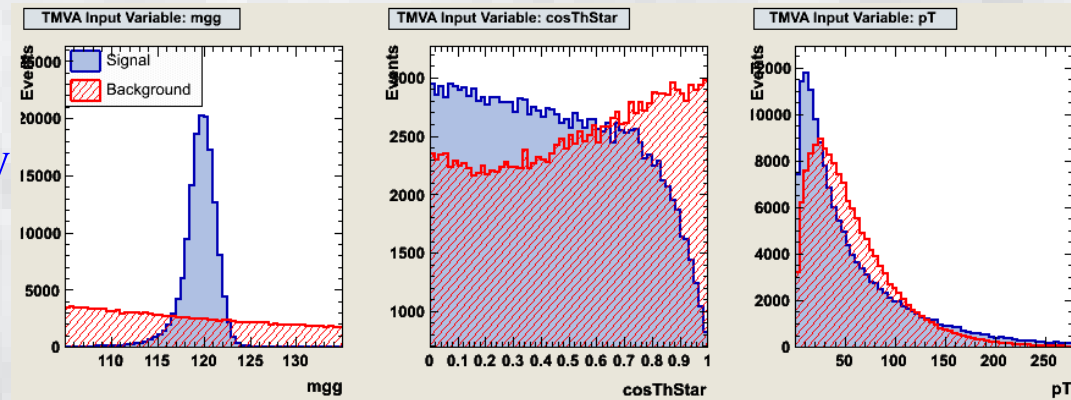
- “Hfitter” : un-binned extended maximum likelihood fitter to extract  $H \rightarrow \gamma\gamma$  signal, for arbitrary number of samples, categories and fit variables

- “Categories” :

- photon  $\eta$ , Higgs production modes

- Fit variables :

- $m_{\gamma\gamma}$ ,  $|\cos\theta^*|$  (Higgs decay angle in the rest frame),  $p_T$ (Higgs) and  $m_{H_{jet}}$



- Fit data with Signal+BG or BG-only models w/ PDF shapes from MC and calculate significance.

- Significant gains from both categories and additional variables.

Model (all cuts included)	Signif. Mean	$p$
$m_{\gamma\gamma}$ no cuts	$3.63 \pm 0.07$	
$m_{\gamma\gamma}$ eta cuts	$3.72 \pm 0.07$	0.09
$m_{\gamma\gamma}$ $N_{Jets}$ cuts	$3.86 \pm 0.07$	0.23
$m_{\gamma\gamma}$ eta+ $N_{Jets}$ cuts	$4.36 \pm 0.07$	0.73
$m_{\gamma\gamma} \otimes \cos$	$4.46 \pm 0.07$	0.83
$m_{\gamma\gamma} \otimes p_T$	$4.83 \pm 0.07$	1.20
$m_{\gamma\gamma} \otimes \cos \theta^* \otimes p_T$	$5.05 \pm 0.09$	1.42
$m_{\gamma\gamma} \otimes \cos \theta^* \otimes p_T \otimes m_{HJ}$	$6.04 \pm 0.08$	2.41



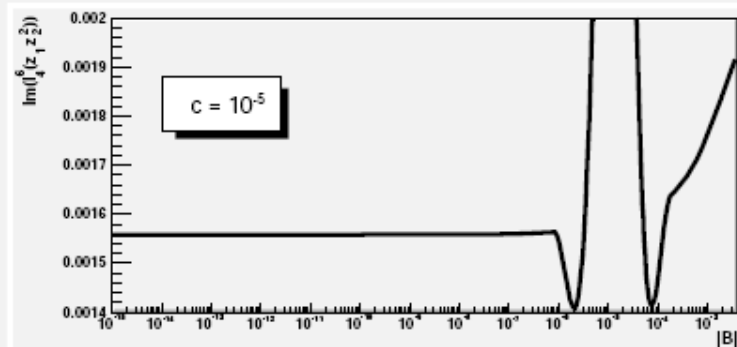
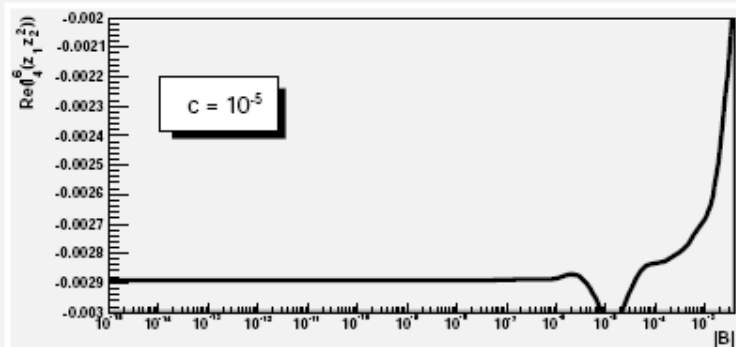
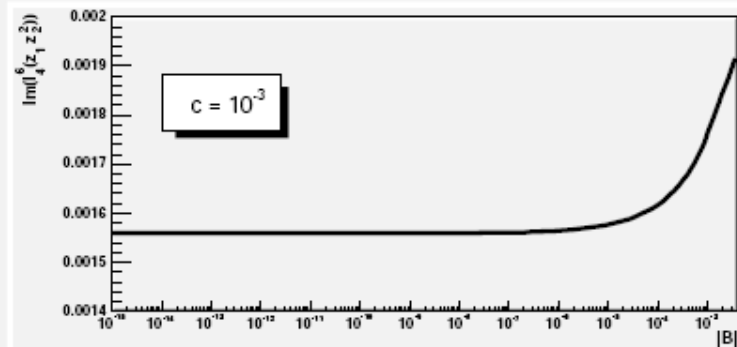
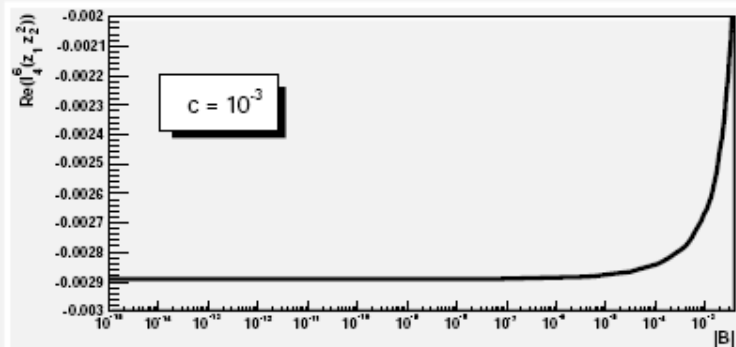
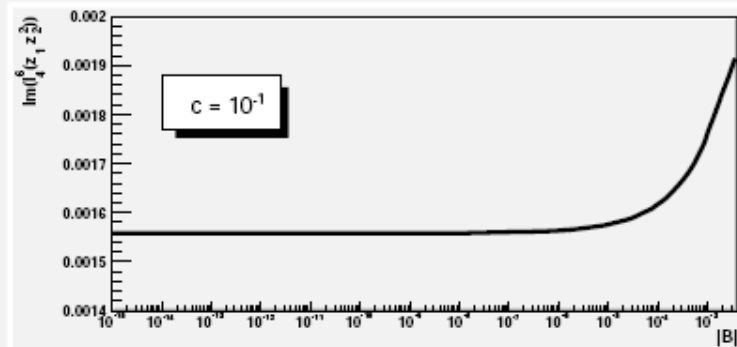
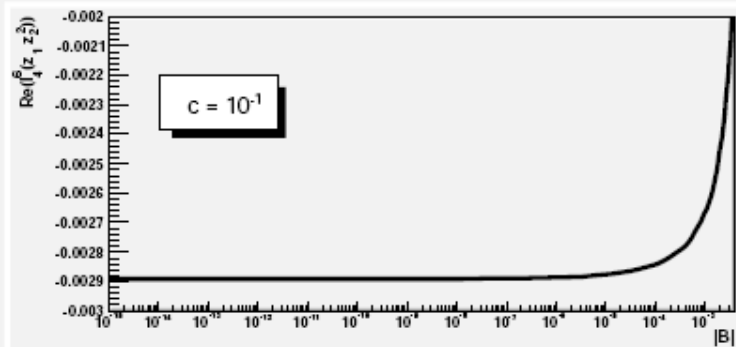
# Status of tools developed at LAPTH

(J.Ph Guillet)

## ➤ Golem project

E. Pilon, C. Bernicot, G. Sanguinetti, T. Binoth, G. Heinrich and A. Guffanti  
in collaboration with the GRACE group

- a project to compute one loop QCD amplitudes.
- There is a release which is ready to be put on the web, with a script to install it, a documentation and some demonstration programs
- $c$  : a cut which splits the phase space region where the three/four point functions are evaluated analytically from those where they are evaluated numerically.
- we plot the real and imaginary parts of  $I_4^6(z_1, z_2^2)$  for different values of the cut  $c$  :  $c = 10^{-1}$  ,  $c = 10^{-3}$  and  $c = 10^{-5}$  as a function of  $|B|$  ( $\# \text{ Det}(G)/\text{Det}(S)$ ).







# What is DIPHOX?

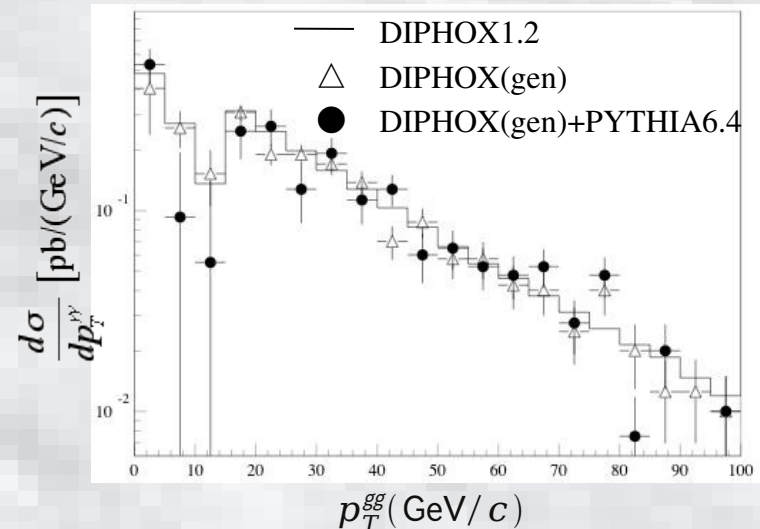
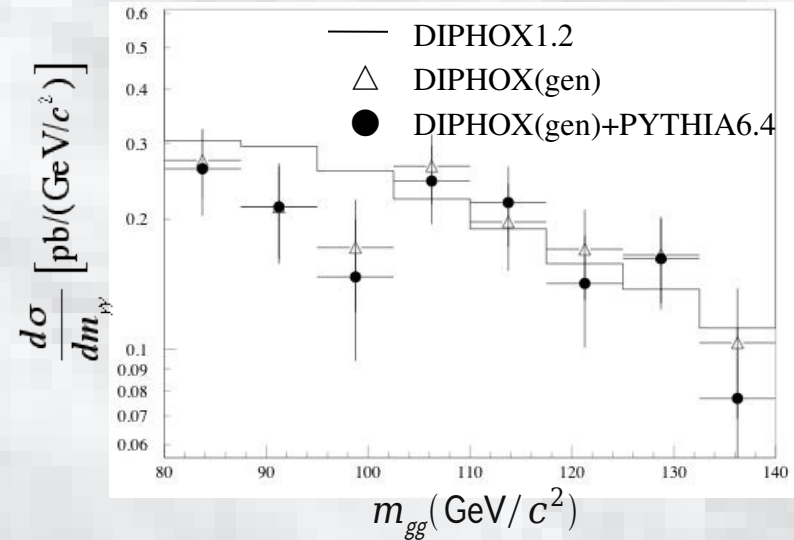
- DIPHOX is a partonic fixed order calculation of  $\gamma\gamma$  pairs (and associated background) in hadronic collisions including  $\alpha_s$  corrections for direct and fragmentation components.
- It is implemented as a Monte Carlo integrator providing distributions are inclusive enough, yet able to account for experimental cuts that can be implemented at the partonic level (cuts on kinematical variables, isolation cuts).



# Development of NLO event generator for

## $pp \rightarrow \gamma + X$ process

- Importance of NLO event generator for SM  $\gamma$  production
  - Irreducible background to  $H \rightarrow \gamma\gamma$
  - NLO event generator greatly helps to understand the background.
- Trial to convert the existing cross-section calculation code (DIPHOX) to an event generator
  - Converted DIPHOX to an event generator (only for “direct” process)
  - Tested against a full simulation chain in ATLAS software
- Developments of new NLO event generator in collaboration with theorists are on going.





## DIPHOX- $\chi$ match

P. Aurenche, F. Arleo, E. Pilon, F. Hautmann, J.Ph Guillet

- separated the divergent and finites terms
- set up Maple programs to generate automatically the different pieces
- set up f90 modules required



# GRACE system

- GRACE can automatically generate FORTRAN codes to calculate NLO-QCD cross sections for any  $2 \rightarrow 2$  processes.
- Extension to  $2 \rightarrow 3$  processes is under way.
- To construct realistic event generators, we have to treat double-countings properly.
- There are two kinds of double-countings.
- $PP \rightarrow \gamma\gamma$  direct processes at NLO are calculated using GRACE.



# PP → $\gamma\gamma$ cross section @ NLO

- $\sqrt{s} = 14 \text{ TeV}$
- PDF: CTEQ5L
- Cuts:  $E_\gamma > 10 \text{ GeV}, 10^\circ < \theta_\gamma < 170^\circ, \theta_{\gamma\gamma} > 10^\circ$

- $\mu_F = \mu_R = S_0$



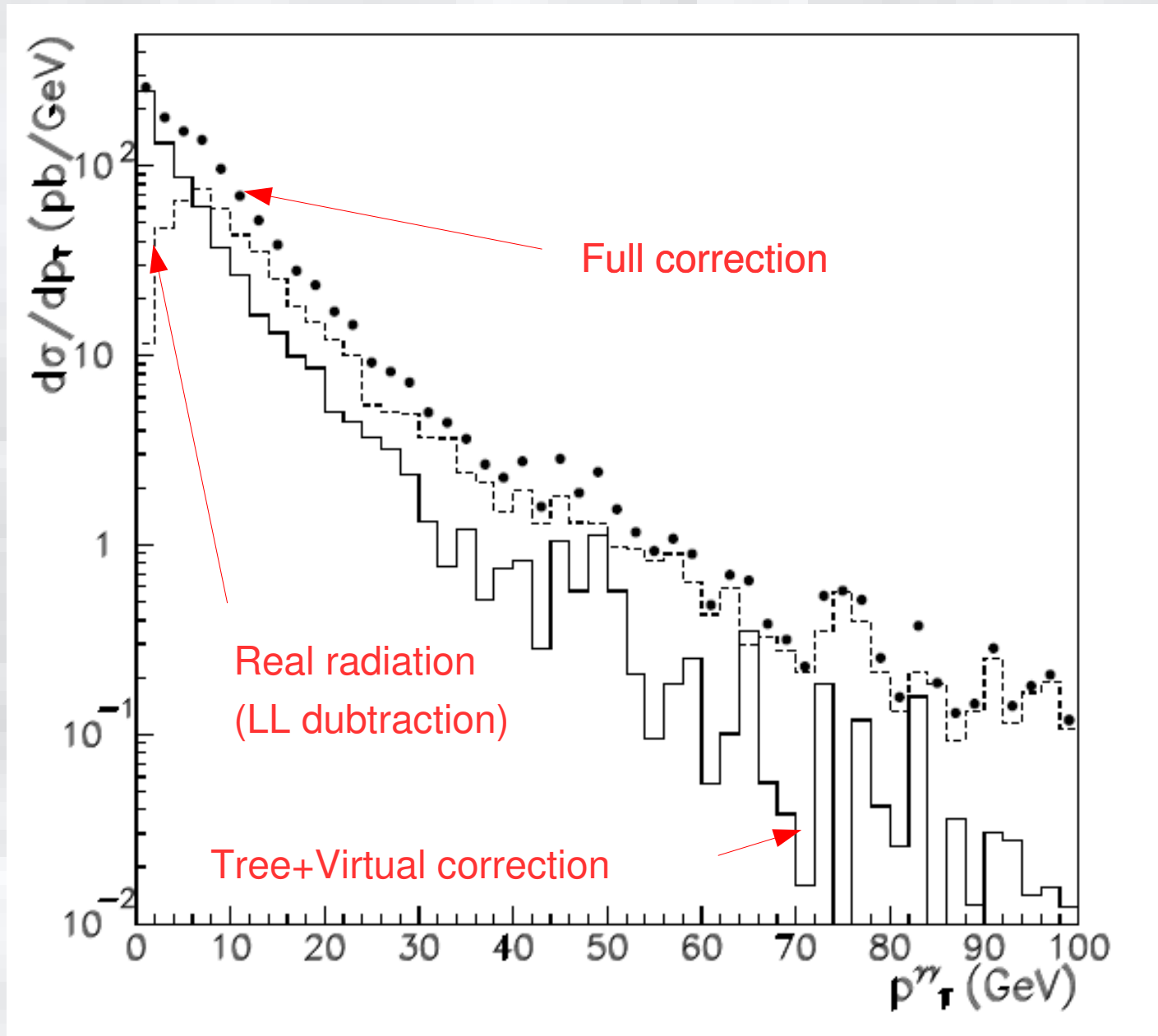
- $\sigma_{\text{tree}} = 7.35 \cdot 10^2 \text{ pb}$

- $\sigma_{\text{tree+virtual}} = 1.32 \cdot 10^3 \text{ pb}$

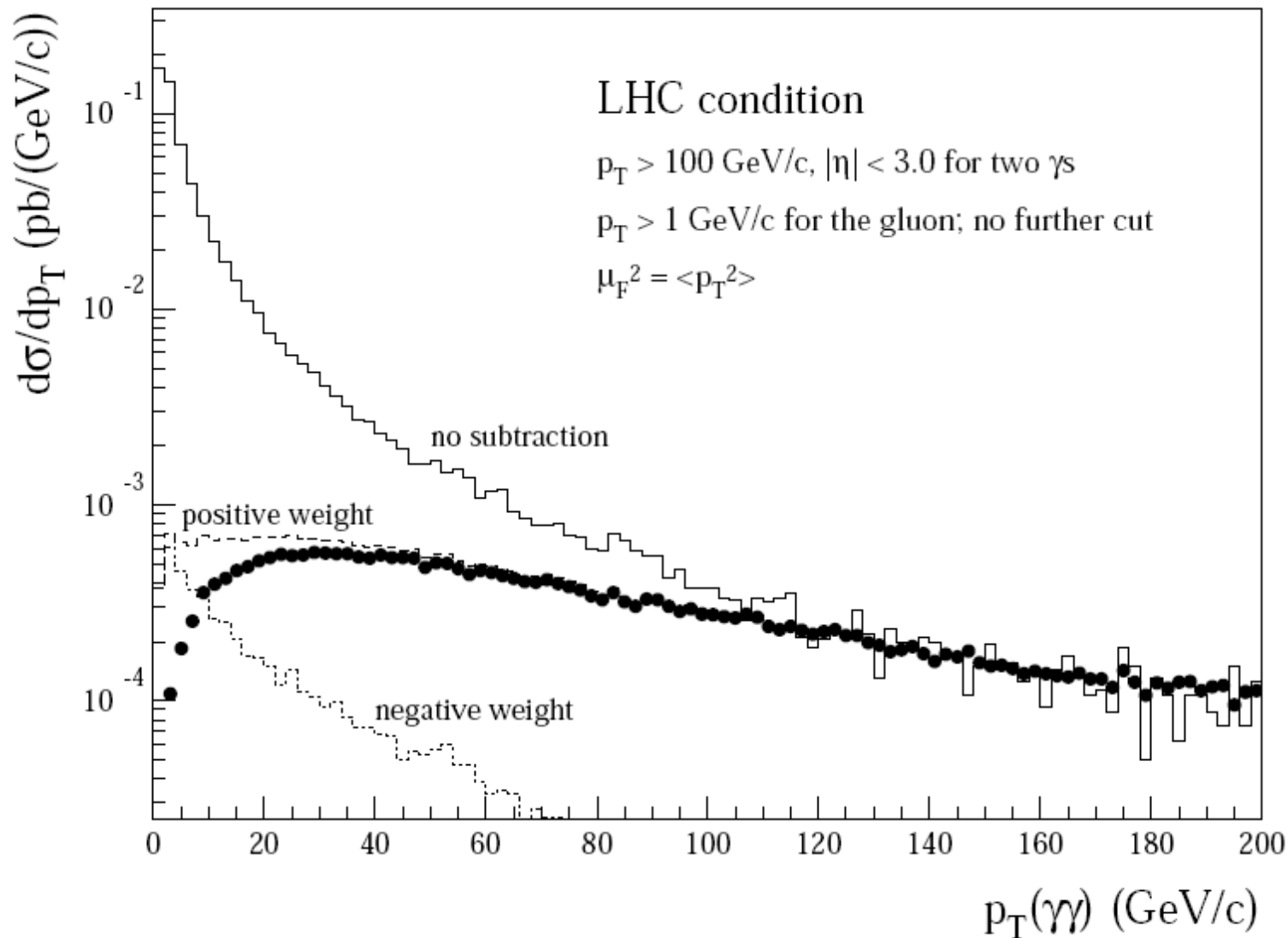
- $\sigma_{\text{real radiation}} = 9.32 \cdot 10^2 \text{ pb}$

IR cancellation  $1/\epsilon_{\text{IR}}^2, 1/\epsilon_{\text{IR}} \quad O(10^{-10})$

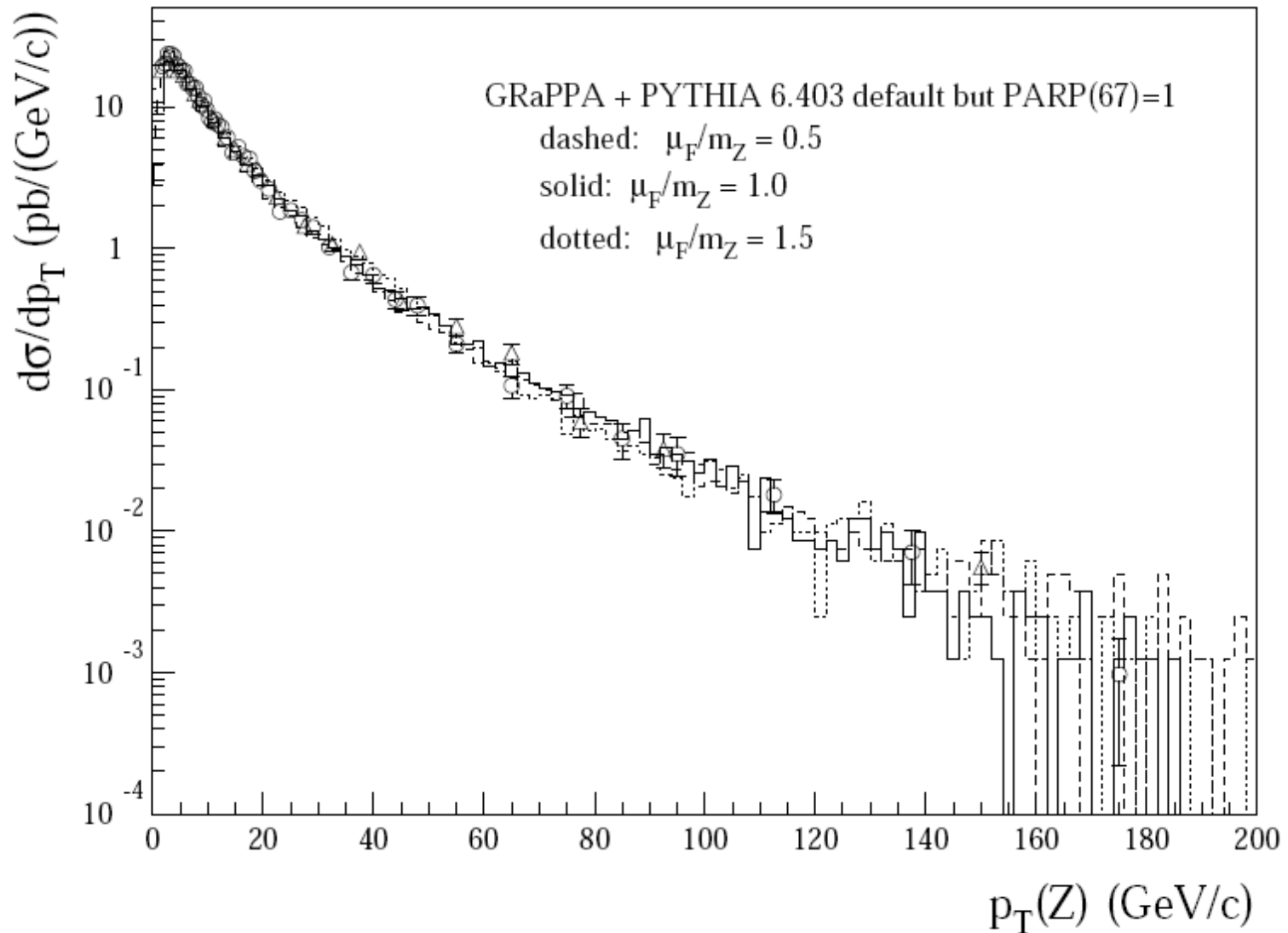
# Transverse momentum distribution of $\gamma$



# LLL subtraction for $q\bar{q} \rightarrow \gamma\gamma g$



# Z( $\rightarrow e^+e^-$ ) production at Tevatron Run 1







# Plan of SDA1 Experimental Studies in 2008

- The LHC is expected to be turned on around the end of July in 2008.
  - The first collision at 10 TeV is expected around the end of September.
  - The analysis of the real data will be carried out for the SDA1 physics cases.
- On-going activities will be continued and developed further for the real data analysis.
  - Analysis software developments for  $H \rightarrow \gamma\gamma$  search
  - Studies on photon identification
  - $pp \rightarrow \gamma\gamma + X$  cross-section measurement in view of  $H \rightarrow \gamma\gamma$  search
  - Development of NLO event generator in collaboration with SDA1 theorists and application to the data analysis



# Plan of SDA1 Theoretical Studies in 2008

- **DIPHOX**

- build a fixed order NLO program for the direct using DIPHOX- $\chi$  match method
- build a LO program with parton shower.

- **GRACE**

- Implement  $pp \rightarrow \gamma \gamma$  (NLO) process in GR@PPA system.