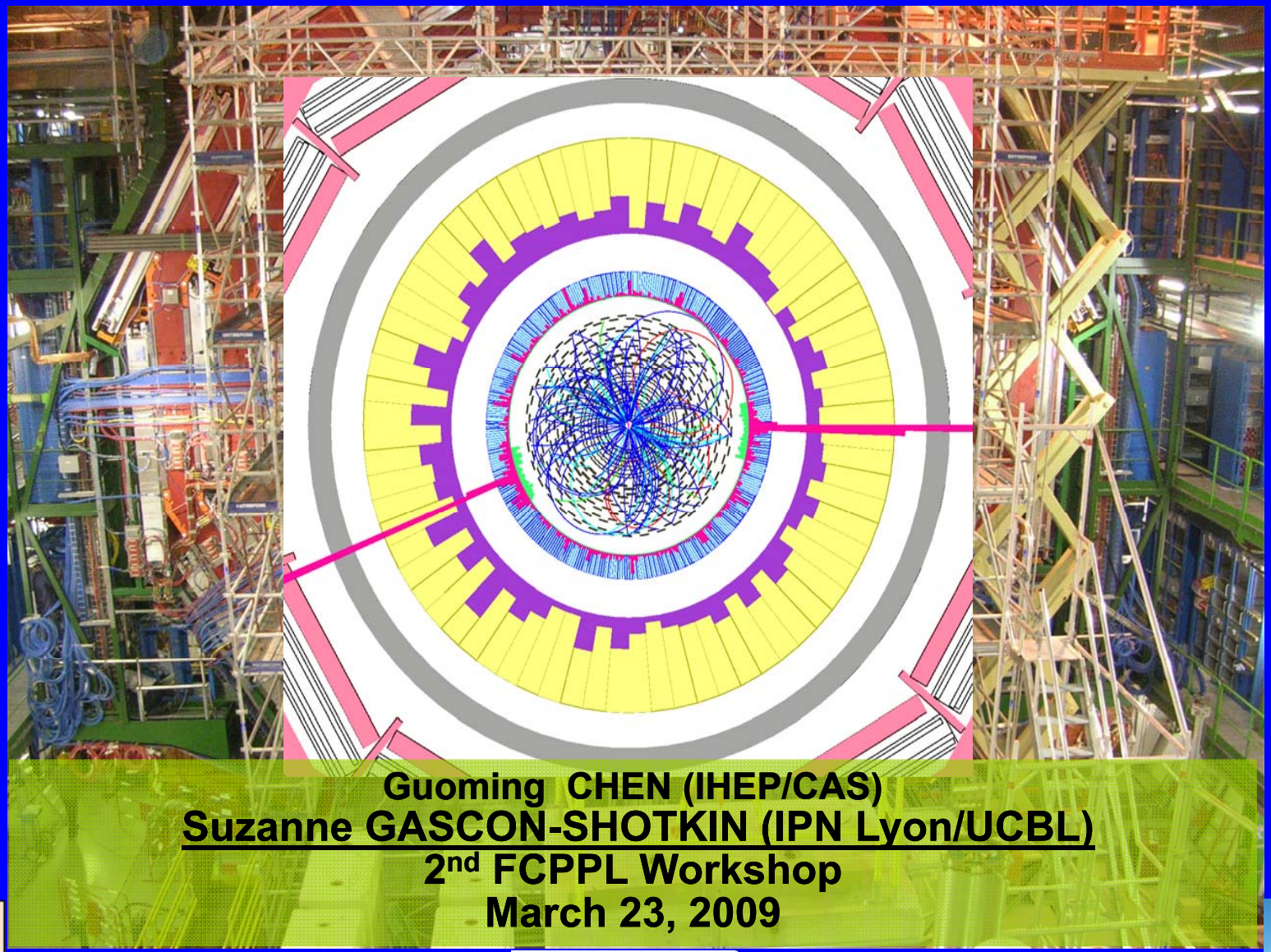
The CMS IN2P3-IPNL/IHEP project : Photon studies for LHC startup physics



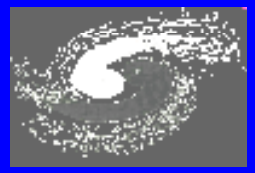
Guoming CHEN (IHEP/CAS)

Suzanne GASCON-SHOTKIN (IPN Lyon/UCBL)

2nd FCPPL Workshop

March 23, 2009

Outline



I – The CMS groups of IHEP and of IPN Lyon
II – A brief history of our collaboration up to now
III – Motivation: The H→γγ search
IV – Photon Calibration and Energy Corrections
V – "Infrastructure" for H→γγ analysis: γ/π^0 discrmination of converted and unconverted photons
VI – H→ γγ analysis: Impact of higher-order calculations on kinematical observables in 2gamma processes (talk by N. CHANON)
VII – Related work on Monte Carlo description of photons: Preparing for QED Matrix Element/Parton Shower photon 'matching' (talk by C. BATY)
VIII – Theory work at IPNL on BSM H→γγ models
IX – Future plans and conclusion
X – Acknowledgements

Note/Apology: In many cases, despite significant progress, results can not yet be shown since not yet formally approved (CMS Rules)

The CMS groups of IHEP and of IPN Lyon

IHEP Beijing CMS group:

- **Muon endcap chamber construction and commissioning**
- **Current axes of work: J/ψ physics, V',Z' in μ final states, Higgs boson searches incl. anomalous couplings**
- **8 permanent physicists: 1 Research Director, 2 Professors, 4 Associate Professors, 1 Research Scientist**
- **2 Postdocs**
- **7 doctoral students**

IPNL CMS group:

- **Barrel electromagnetic calorimeter and endcap tracker construction and commissioning**
- **Current axes of work: Higgs boson searches, top quark physics, supersymmetry searches, heavy ion physics**
- **13 permanent physicists: 4 Research Directors, 3 Professors, 3 Research Scientists, 2 Junior Research Scientists, 1 Junior Professor**
- **1.5 Postdocs (1 split IPNL/CCIN2P3)**
- **5 Doctoral Students**

A brief history of our collaboration up to now

- January 2006: Agreement to explore possible collaboration on CMS physics analysis after visit of F. LE DIBERDER to IHEP
- July 2006: First visit of IPNL physicists and Director Bernard ILLE to IHEP
- December 2006: Participation and contribution of both teams to organisation of 1st France-China Workshop on LHC physics and Grid computing at IHEP (ancestor of the FCPPL Workshop)
- January-May 2007: IHEP doctoral student **TAO Junquan** at IPNL (funding IN2P3)
- End 2007: PICS proposal (CNRS Programme for International Scientific Collaboration) for collaboration funding for 2008-2010 accepted
- November 2007-May 2008: IHEP doctoral student **ZHANG Zhen** at IPNL (funding FCPPL)
- January 2008: Participation and contribution of both teams to organisation of the 1st FCPPL workshop (Marseille)
- March-August 2009 IHEP: Postdoc **TAO Junquan** at IPNL (funding PICS)
- March 2009: Participation and contribution of both teams to organisation of the 2nd FCPPL workshop (Wuhan)
- End March-beg. June 2009 IPNL doctoral student **Nicolas CHANON** at IHEP (**funding requested FCPPL 2009, not anticipated in PICS proposal**)
- Late 2009 (5 months) IHEP doctoral student **XIAO Hong** at IPNL (PICS/candidate FCPPL-CSC grant)…

Motivation: The H→γγ search

Search for the Higgs Particle

FNAL

Status as of March 2009

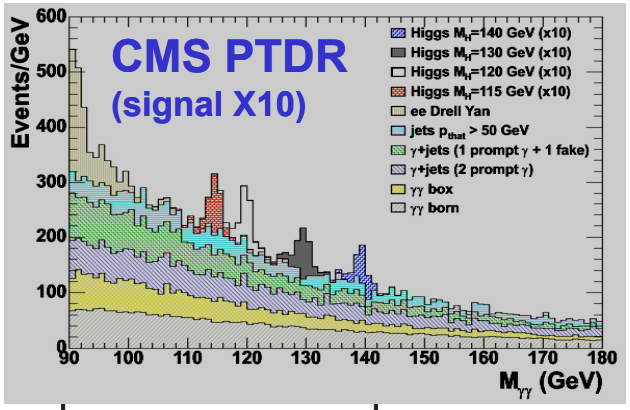
90% confidence level

95% confidence level

Excluded by LEP Experiments 95% confidence level

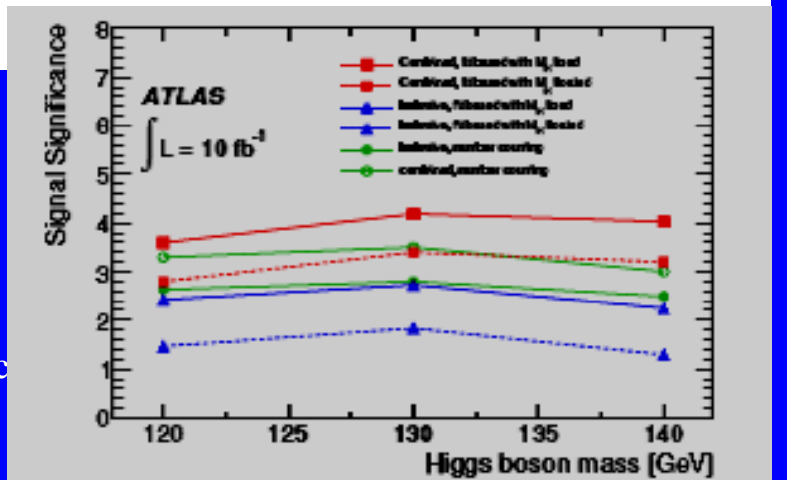
Excluded by Tevatron Experiments

Excluded by Indirect Measurements 95% confidence level



100 114 120 140 160 170 180 185 200 GeV/c^2

Higgs mass values

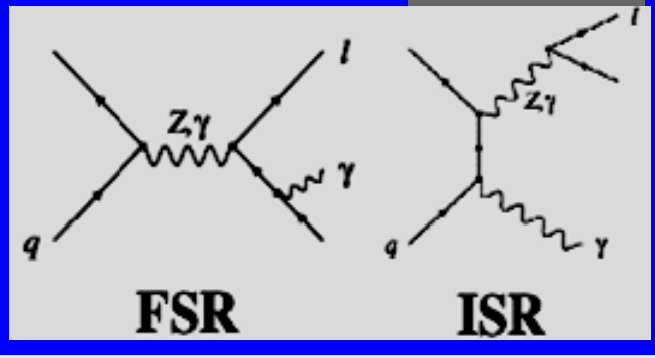


Keep sight of this goal, but put emphasis on detector calibration, photon and analysis 'infrastructure' for the next couple of years

Photon calibration & Energy Corrections

« Certified » photons from Z→μμγ (2007-..): (C. BATY, H. BRUN, M. LETHUILLIER, S. GASCON, J. TAO, Z. ZHANG) + CalTech/KSU CMS groups

- Isotropic source of relatively high-pT γ enabling extraction of (~100pb-1) :
  - Photon trigger efficiency
  - Photon energy scale
  - Photon energy correction parametrisation
  - Photon id efficiency
- Complementary with calibration by $\pi^0 \rightarrow \gamma\gamma$
- Validation performed of partly generator-level PTDR1 study in full simulation incorporating most important backrounds (bbar, Z + jets, γ + jets, ttbar)
- Optimisation of selection in progress to combat bbar background via 'far muon' isolation, with hope of increasing signal yields
- Then: Identification et parametrisation of biases (pT, η, …) →correction functions
- – Numerous presentations in CMS workng groups
- Aim for a public CMS note before startup
- Also led to a related study of internal bremsstrahlung photon recovery for H→ZZ*→4leptons (contribution to public CMS Note AN-2008/050 by N. CHANON, S. GASCON)



CMS AN 2005/040, PTDRI

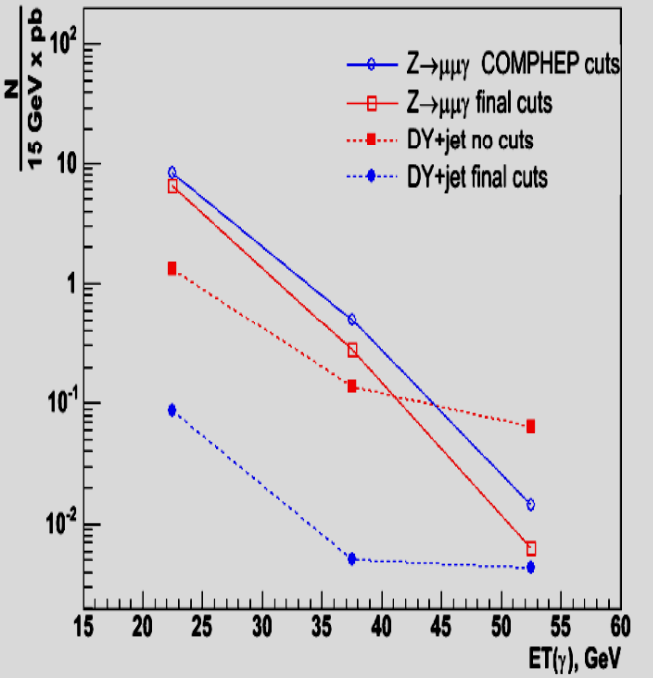


Figure 3: Signal and background yields before and after the cuts on event kinematics

γ/π^0 discrmination of converted and unconverted photons

γ/π^0 discrmination (2008-…): (H. BRUN, G. CHEN, M. LETHUILLIER, S. GASCON, J. TAO, M. YANG, Z. ZHANG)

- For unconverted photons : Try to improve on γ efficiency/ π^0 rejection performance wrt ANN used for the PTDR, use 'L3 method': For each γ candidate,
  - ✓ First fit by the parameterized formula of 1 EM shower
  - ✓ Then fit by the parameterized formulae of 2 EM showers
  - ✓ Compare the χ^2 of the 2 fitting processes.
  - ✓ If the fitted result with 2 EM showers is better, then calculate the invariant mass of the 2 EM showers.
  - ✓ If the invariant mass locates close to the π^0 mass peak, then the shower is a π^0.

Use the following longitudinal and lateral (inspired by AMS) parametrisations:

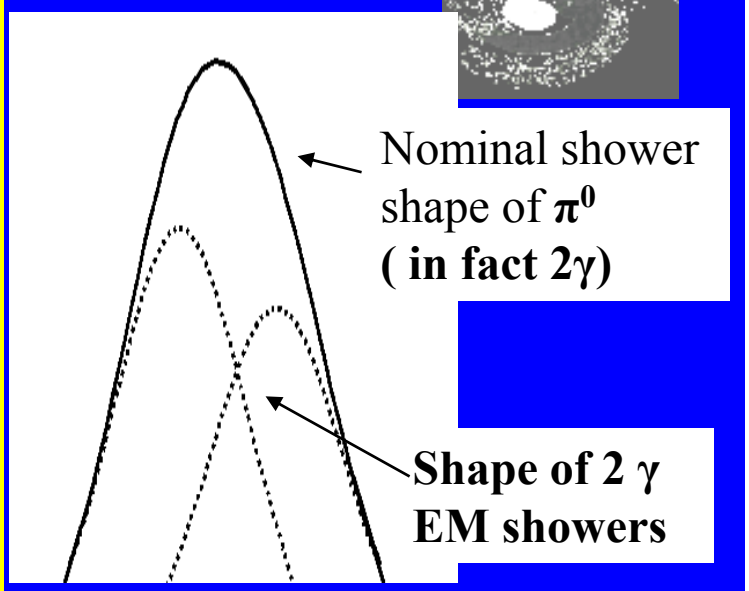
$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)} \qquad f(r) = \frac{6R^2 r}{(r+R)^4}$$

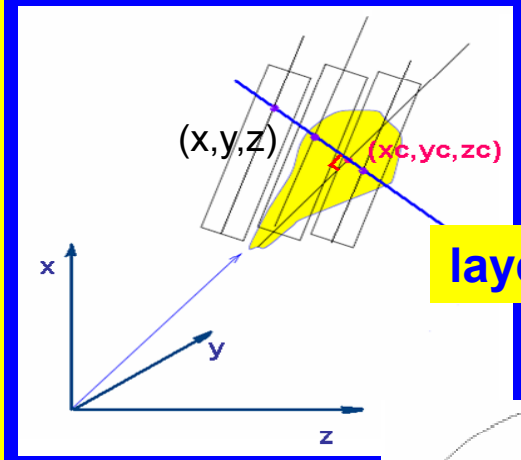
- For converted photons: Try to improve on γ efficiency/ π^0 rejection performance wrt likelihood method used for PTDR. Combine new kinematic variables with some from reconstructed conversion tracks, explore several multivariate optimisation techniques.

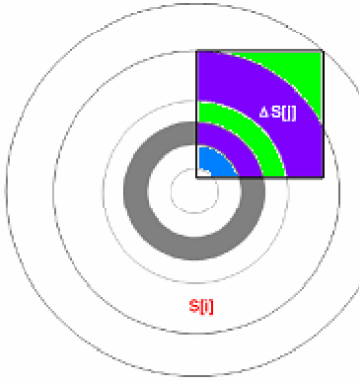
Some improvement possible, still under study

– Several presentations in CMS workng groups

- Contribute to planned study (200pb-1) for a public CMS note







H→γγ analysis: Impact of higher-order calculations on kinematical observables in 2γ processes

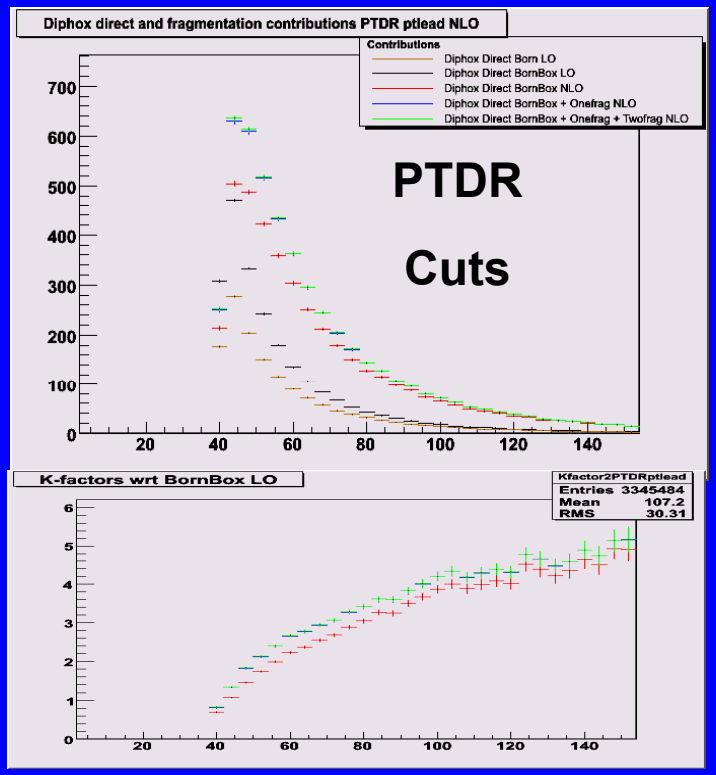
(2007-…): (N. CHANON, M. LETHUILLIER, S. GASCON)

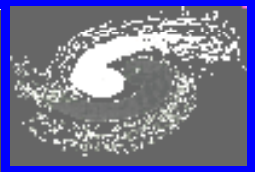
- Incorporate kinematic implications of >LO calculations on analysis observables (pt_2γ, $\Delta\phi$_2γ , m_2γ, cos θ*...). Collaboration avec théoriciens LAPTH/IPNL/INFN et américains.

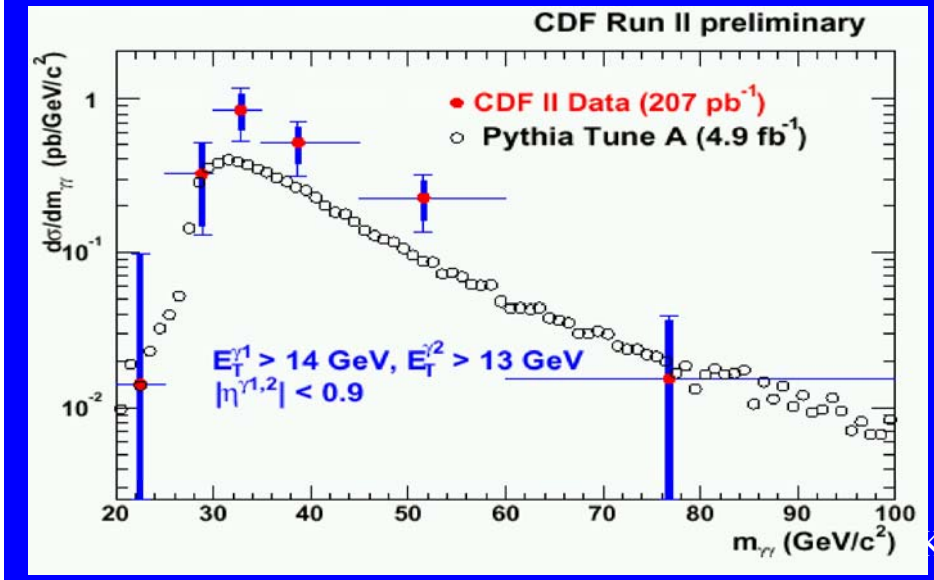
- – Several presentations in CMS workng groups

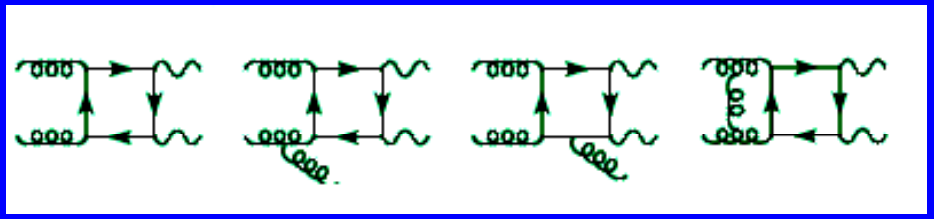
- Contribute to planned study (200pb-1) for a public CMS note before startup

See talk by N. CHANON immediately following!









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
Onefrag DIPHOX	1.56	3.10
Twofrag DIPHOX	0.03	0.10
Direct BornBox DIPHOX + Onefrag + Twofrag	10.71	20.13
Direct Born DIPHOX + Box Gamma2MC + Onefrag + Twofrag	10.62	22.99

Preparing for QED Matrix Element/Parton Shower photon 'matching'

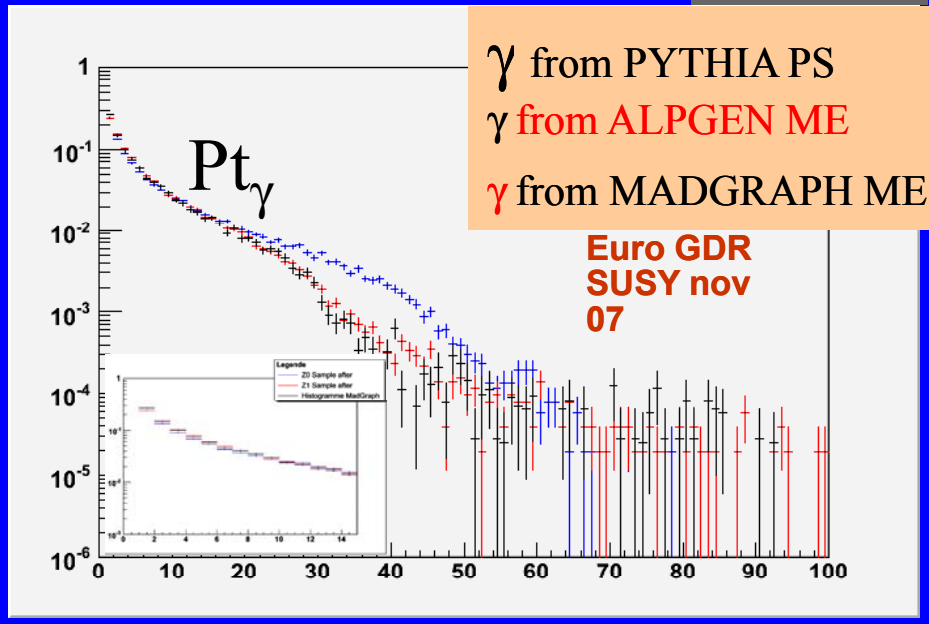
(2007-…): (C. BATY, M. LETHUILLIER, S. GASCON, J.TAO)

- Collaboration with the authors of ALPGEN (CERN/INFN): Towards an algorithm permitting co-existence of Matrix Element and Parton Shower γ without double-counting. Inspired by existing procedure for jets.

– Several presentations in CMS workng groups, also at Euro/GDR SUSY.

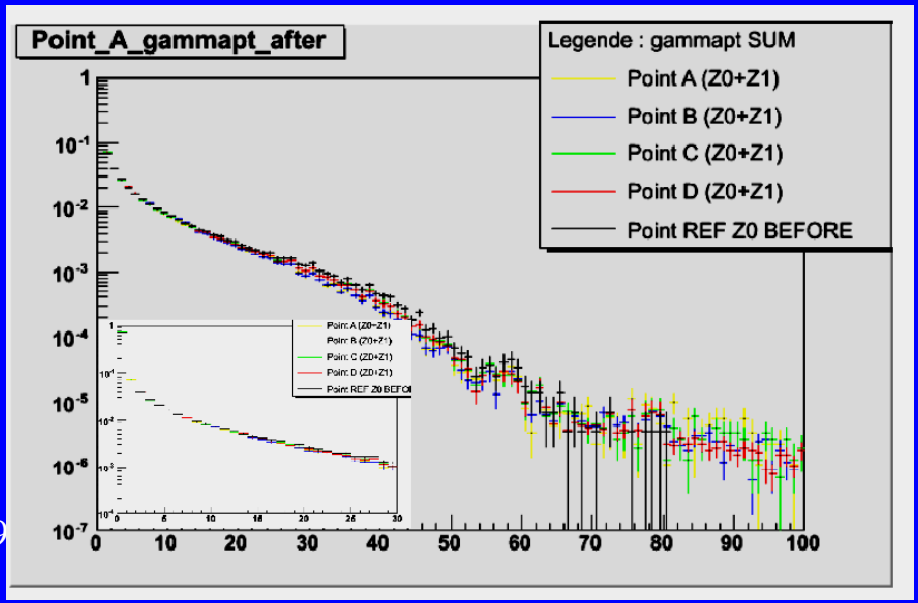
- Implementation in ALPGEN currently being tested by authors

- See talk by C. BATY immediately following!



Point	Z_0
A	3.832 %
B	1.214 %
C	2.067 %
D	0.684 %

Events rejected
double-counted in abs



Higgs boson to two photons beyond the Standard Model

Giacomo Cacciapaglia, Aldo Deandrea and Jérémie Llodra-Perez

E-print : arXiv:0901.0927 [hep-ph]

Email: deandrea@ipnl.in2p3.fr, g.cacciapaglia@ipnl.in2p3.fr

Amplitudes and Couplings to the Higgs

For SM, masses proportional to the Higgs VEV

For New Physics

Mass of NP not necessarily proportional to Higgs VEV

Small correction from EW breaking

Definition of A_{NP} :

Spin and mass taken into account in the standard amplitudes for fermions, vector bosons and scalars $A_{F,W,S}$

Coupling effects contained in the pre-factor

$$y^{NP}_{hff} = \frac{\partial m_f}{\partial v} \quad and \quad y^{NP}_{hWW} = \frac{\partial m^2_W}{\partial v}$$

$$A_{NP} = \frac{v}{m_{NP}} \frac{\partial m_{NP}}{\partial v} A_{F,S,W}$$

Model-independent parameterization

Normalization of new contributions to the top's one.

SM-like Higgs sector and tree level structure assumed

Only 2 parameters in this case

$$\Gamma_{\gamma\gamma} = \frac{G_F \alpha^2 m_H^3}{128\sqrt{2}\pi^3} \left| A_W(\tau_W) + 3\left(\frac{2}{3}\right)^2 A_F(\tau_{top})\left[1+\kappa_{\gamma\gamma}\right] + \ldots \right|^2$$

$$\Gamma_{gg} = \frac{G_F \alpha_s^2 m_H^3}{36\sqrt{2}\pi^3} \left| \frac{3}{4} A_F(\tau_{top})\left[1+\kappa_{gg}\right] + \ldots \right|^2 \quad where \quad \tau_x = \frac{m_H^2}{4m_x^2}$$

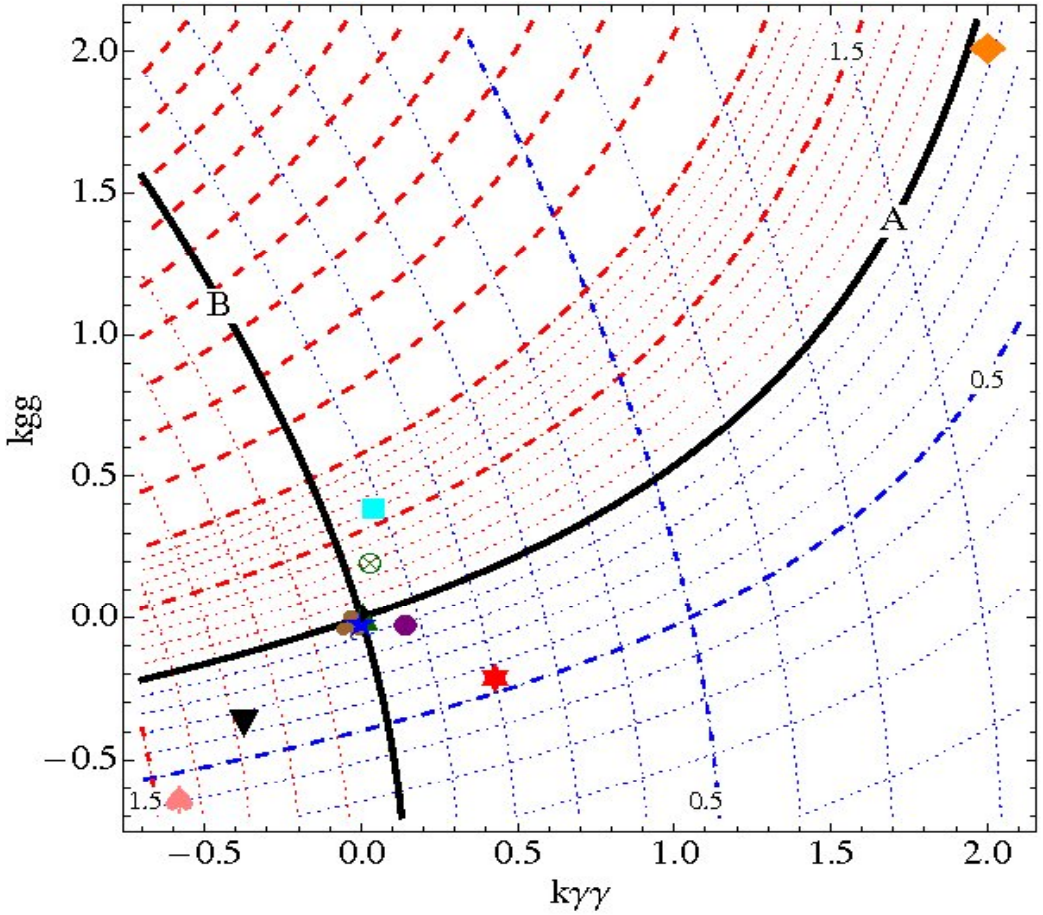
$$\kappa_{\gamma\gamma} = \sum_{NP} \frac{3}{4} N_c Q_{NP}^2 \frac{v}{m_{NP}} \frac{\partial m_{NP}}{\partial v} \frac{A_{F,S,W}(\tau_{NP})}{A_F(\tau_{top})}$$

$$\kappa_{gg} = \sum_{NP} \frac{4}{3} C_c(r_{NP}) \frac{v}{m_{NP}} \frac{\partial m_{NP}}{\partial v} \frac{A_{F,S,W}(\tau_{NP})}{A_F(\tau_{top})}$$

Easy to take into account a more general situation

The $\kappa_{\gamma\gamma}$-κ_{gg} parameter space for LHC

Many points insensitive to details. Clear predictions!



4th generation (♦)

SUSY in the MSSM golden region (♣)

Simplest Little Higgs model (▲)

Littlest Higgs ( )

Univ. Extra Dimension ( )

Minimal Comp. Higgs (●)

Brane Higgs with flavor : In flat space (▼) In warped space(♠)

Other particle theory subjects....

We seek active collaboration in particle theory on

Phenomenology beyond the standard model

- Interplay of flavour measurements and LHC
- Effective lagrangian approach

Model building

- Constrained extra dimensions and cosmology
- Gauge-Higgs models
- Strong electroweak sector

- **Contact us : deandrea@ipnl.in2p3.fr, g.cacciapaglia@ipnl.in2p3.fr**

X – Future Plans and Conclusions

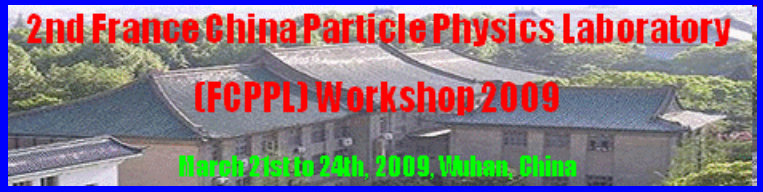
- We continue to make good progress in H→γγ and photon infrastructure through our cooperation efforts, which have continued to expand
- We look forward to continuing our efforts, which make good use of our groups' complementarities
- Awaiting PICS notification for 2009

X – Acknowledgements

Thanks to:

- F. Le Diberder and Chen Hesheng for their initiatives in helping us get our collaboration efforts started
- To the IN2P3/CNRS and IHEP-CAS for helping us to continue, and in particular to the FCPPL directorate and steering committee
- To the local organising committee of this workshop for the wonderful hospitality and working environment

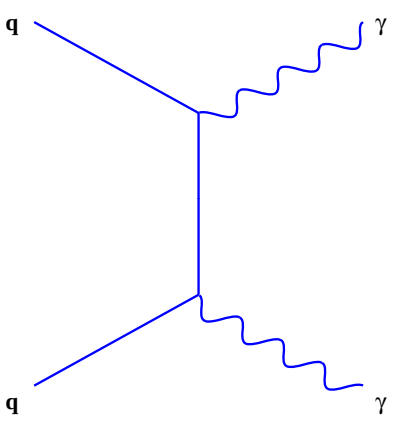
谢谢

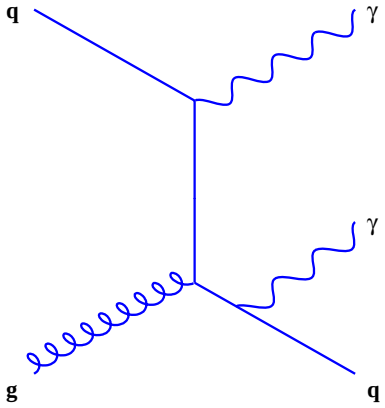


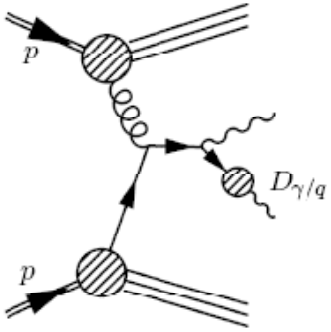
Backup

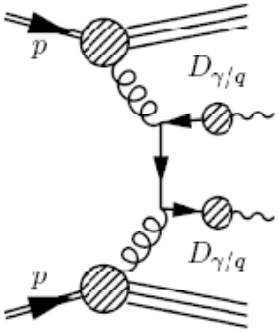
γγ processes and their description/calculation I

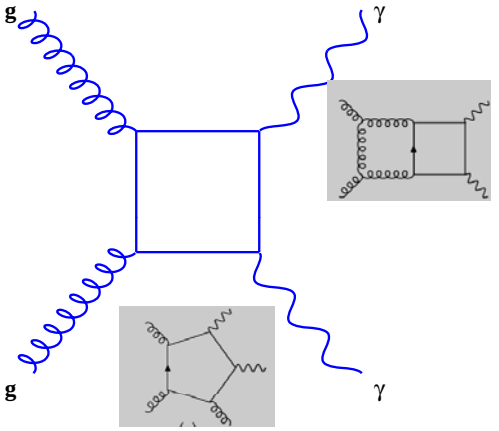
Born **Brem + Fragmentation** **Box: gg-> γγ**











Aussi, γ+j,j→π^0 et j+j,jj→π^0+π^0

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

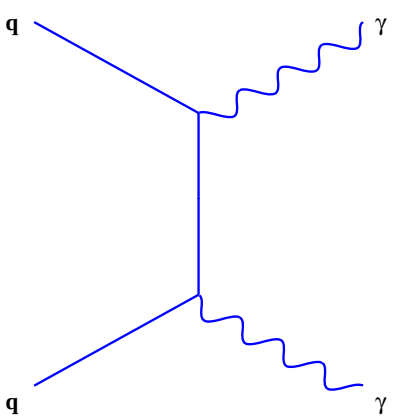
LO Codes: 'PS': PYTHIA (Sjostrand..)
Herwig
'ME': ALPGEN (Mangano..)
MadGraph (Stelzer...)
...

Binoth,Guillet, Pilon
Balazs, Nevski, Yuan

+ gamma2MC
(Bern, Dixon, Schmidt)
+ NLOjet++ (Nagy) + …

γγ processes and their description/calculation II

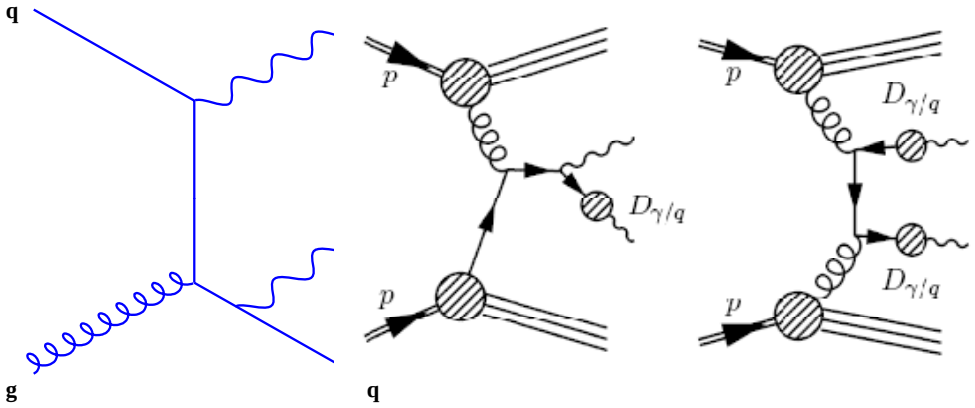
Born



PYTHIA : qq->γγ with ISR
DIPHOX: LO: qq->γγ, NLO: qq->γγg + virtual gluon
Resbos

γ+j,j→π⁰

Brem + Fragmentation

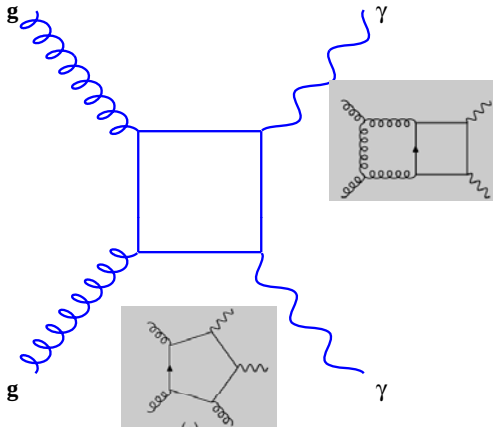


PYTHIA : qg->γq, qq->γg with the second prompt photon selected. ISR/FSR
DIPHOX: qg->γq (q->γq' brem.), qg->γq (q->γ fragmentation) qq->γg (g->γ fragmentation)
Resbos

PYTHIA : qg->γq with γ + π⁰ signature. ISR/FSR; no mult. int.

DIPHOX: qg->γq at NLO with q->π⁰ fragmentation

Box: gg-> γγ



gamma2MC & Resbos: LO and NLO

j+j,jj→π⁰+π⁰

PYTHIA : MSEL=1 2->2 processes. ISR/FSR, Mult. int. ON

DIPHOX: NLO 2->2 with g, q->π⁰ fragmentation