IPNL/IHEP collaboration project
Photon studies at CMS

Junquan Tao

On behalf of the IPN Lyon and IHEP CMS groups

5th FCPPL Workshop
March 21, 2012

Outline

- A brief history about the collaboration
- Motivation: The H→$\gamma\gamma$ search
- Activities on the photon-related studies
- Summary and Conclusion
- 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: A BRIEF HISTORY OF OUR COLLABORATION

❖ January 2006: Agreement to explore possible collaboration on CMS physics analysis after the visit of F. LE DIBERDER to IHEP

❖ July 2006: First visit of IPNL physicists and Director Bernard ILLE to IHEP

IHEP Beijing ➔ IPN Lyon: (4persons)

- **TAO Junquan (Doctoral Student)—January-May 2007 (IN2P3)**
- **ZHANG Zhen (Doctoral Student)—November 2007-May 2008 (FCPPL)**
- **TAO Junquan (Postdoc)—March-August 2009 (PICS 4162)**
- **XIAO Hong (Doctoral Student)—January-July 2010 (PICS 4162)**
- **FAN Jiawei (Doctoral Student)---April-October 2011 (PICS 4162)**
- **XIAO Hong (Doctoral Student)---June-July 2011 (FCPPL)**

FAN Jiawei (Doctoral Student)—May-Nov. 2012) (**FCPPL 2012 proposal**) + applied for co-phD student (**FCPPL/CSC scholarship 2012**)

IPN Lyon ➔ IHEP Beijing:

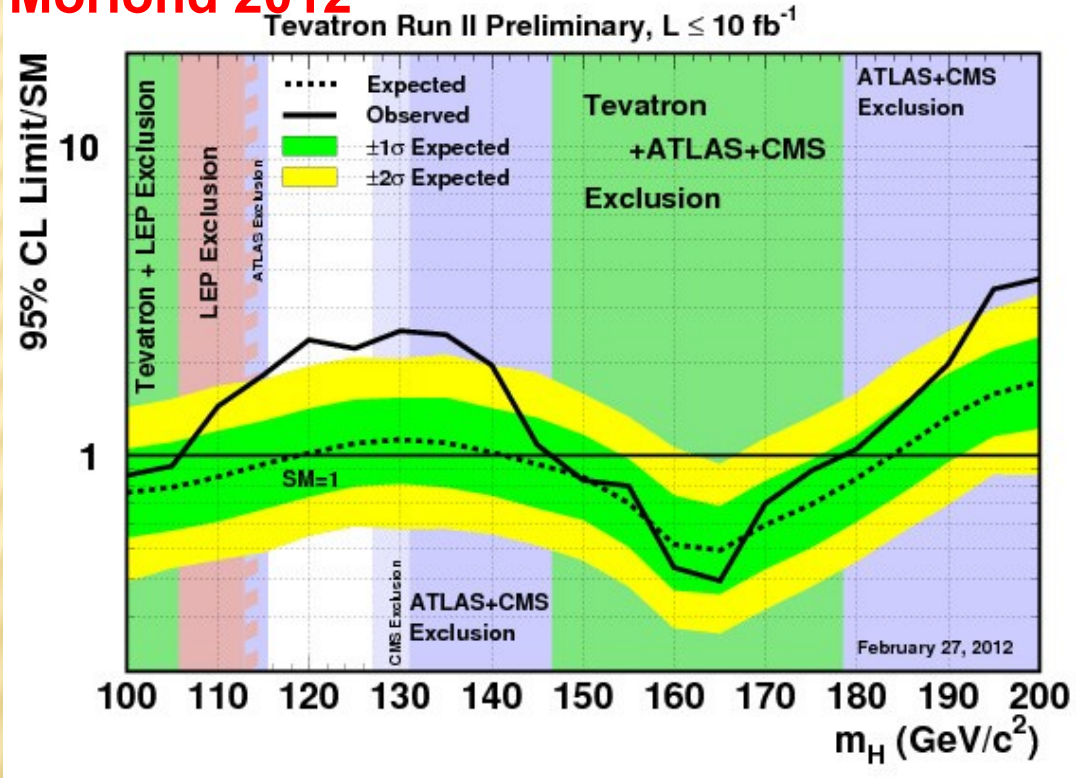
- **Nicolas CHANON (Doctoral Student)—March-May 2009 (FCPPL)**
- **Hugues BRUN (Doctoral Student)—October-December 2010 (FCPPL)**
- **Olivier BONDU (Doctoral Student)–April-May 2011 (FCPPL)**

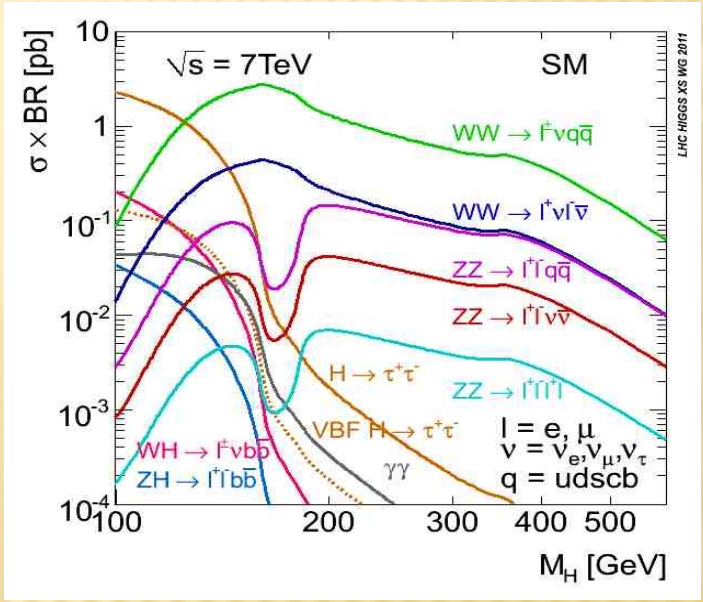
Louis SGANDURRA (Doctoral Student)-Oct-Nov. 2012) (**FCPPL 2012 proposal**)

+ participation to the Organising committees of the prototype workshop at IHEP and to the 1st, 2nd, 3rd , 4th and 5th FCPPL workshops

MOTIVATION: THE SM H→γγ SEARCH

Moriond 2012





- For $M_H \lesssim 140$ GeV → $H \to \gamma\gamma$ (BR ~ 10^{-3})
- For $140 \lesssim M_H \lesssim 180$ GeV → $H \to WW^* \to l\nu l\nu$
- $M_H > 2M_Z$ → $H \to ZZ \to 4l$ (gold pleated)

Observed exclusion at 95% CL (Moriond2012):

Tevatron: $100<M_H<106$GeV $147<M_H<179$GeV

CMS: $127.5<M_H<600$GeV

ATLAS: $110<M_H<117.5$GeV **$118.5<M_H<122.5$GeV** $129<M_H<539$GeV

Survive at 95% CL: $117.5<M_H<127.5$GeV excluding $118.5<M_H<122.5$GeV

Activities: photon-related studies

- Photon reconstruction: Clusterisation, Photon Commissioning , Photon Energy Scale and Energy Corrections using $Z \rightarrow \mu\mu\gamma$

- Technique development: Prompt photon and non-prompt photon (γ/π^0) discrimination

- **$\gamma\gamma$+X** Differential Cross-section Measurement

- Impact of **higher-order calculations** on kinematical observables in $\gamma\gamma$ processes , contributed to $H \rightarrow \gamma\gamma$ analysis

Supercluster and Photon Commissioning

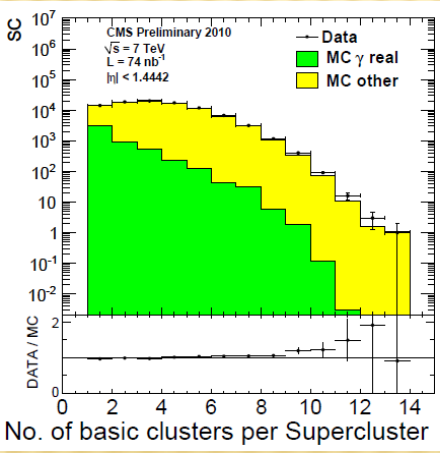
(**2008**-..): (O. BONDU, H. BRUN, M. LETHUILLIER, S. GASCON, J. TAO, H. XIAO, Z. ZHANG)

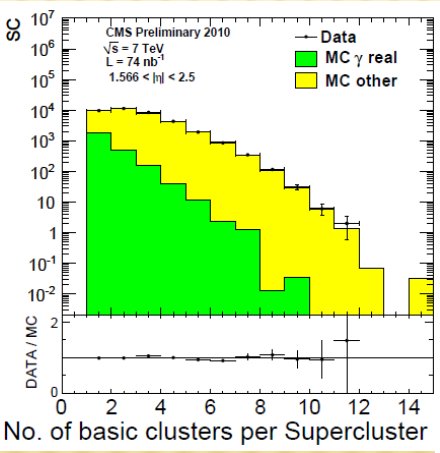
- Check understanding of key observables for photon reconstruction (~80nb-1) :
  - Cluster constituent multiplicites
  - Cluster shapes used to assign energy determination method, to derive energy corrections and photon identification
  - Isolation energies used for photon identification
- **Results made public for ICHEP2010** (EGM-10-001 and EGM-10-005)

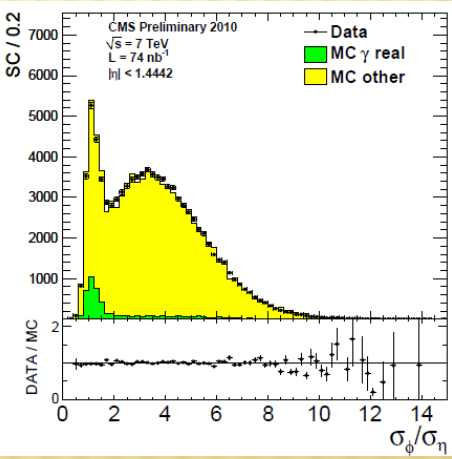
Loose Photon Id

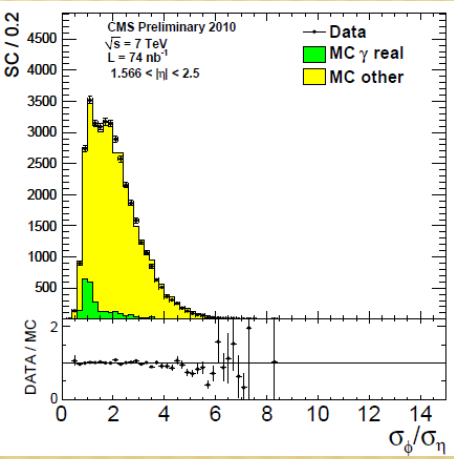
Variable	Barrel	Endcap
pixel seed	require none	
E_T	30 GeV	
Tracker Iso	2.0 GeV	
ECAL Iso	4.2 GeV	
HCAL Iso	2.2 GeV	
H/E	0.05	
$\sigma_{i\eta i\eta}$	0.01	0.03

$$\sigma_\eta = \sum_{i=1}^{n} \sqrt{\frac{E_i}{E_{SC}}(\eta_i - \eta_{SC})^2}$$









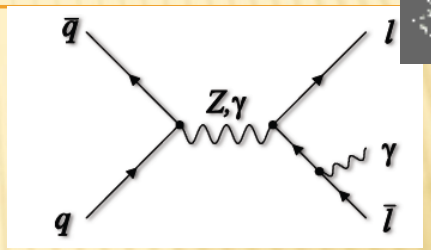
Photon Energy Scale & Photon ID efficiency

« Certified » photons from Z→μμγ FSR (**2007**-..): (C. BATY, O. BONDU, H. BRUN, M. LETHUILLIER, S. GASCON, L. SGANDURRA, J. TAO, Z. ZHANG)

- Isotropic source of relatively **high-pT** γ enabling extraction of
  - **Photon energy scale**
  - **Photon id efficiency: electron veto efficiency**
  - Photon energy correction (2011 data)
  - Photon trigger efficiency

photon energy scale was used to estimate systematic error for **:**

- first Measurement of the Wγ and Zγ inclusive cross-sections with 2010 dataset (**EWK-10-008, Phys. Lett. B 701 (2011) 535555**)
- Vgamma analysis with 2011 data (**EWK-11-009, Preapproved in CMS**)

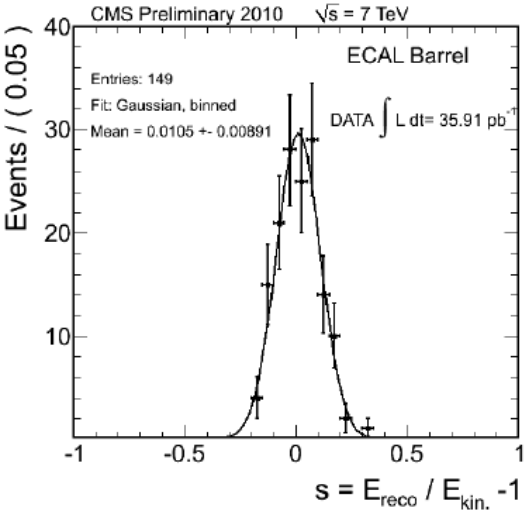


Category	ϵ_{data} (%)	ϵ_{MC} (%)	$\epsilon_{data}/\epsilon_{MC}$
All cuts except electron rejection (from $Z \to ee$)			
1	91.77±0.14	92.43±0.07	0.993±0.002
2	72.67±0.43	71.89±0.08	1.011±0.007
3	80.33±0.47	80.04±0.18	1.004±0.008
4	57.80±1.26	55.09±0.15	1.049±0.025
Electron rejection cut (from $Z \to \mu\mu\gamma$)			
1	$99.78^{+0.13}_{-0.16}$	$99.59^{+0.13}_{-0.17}$	$1.002^{+0.002}_{-0.002}$
2	$98.77^{+0.59}_{-0.73}$	$97.70^{+0.32}_{-0.37}$	$1.011^{+0.007}_{-0.008}$
3	$99.32^{+0.51}_{-1.02}$	$99.29^{+0.30}_{-0.42}$	$1.000^{+0.006}_{-0.011}$
4	$93.0^{+2.1}_{-2.3}$	$93.34^{+0.79}_{-0.86}$	$0.996^{+0.024}_{-0.027}$

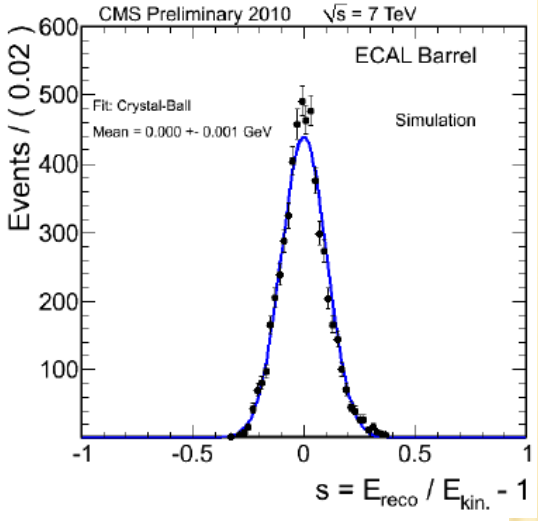
Electron veto efficiency was used in the H→γγ analysis (HIG-11-010, HIG-11-021, HIG-11-033 and submitted to Physics Letters B arXiv:1202.1487, HIG-12-001, HIG-12-002)

Photon Energy Scale with Z→μμγ FSR

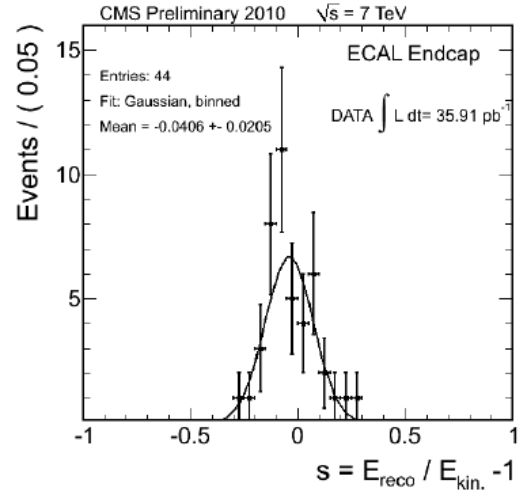
Data



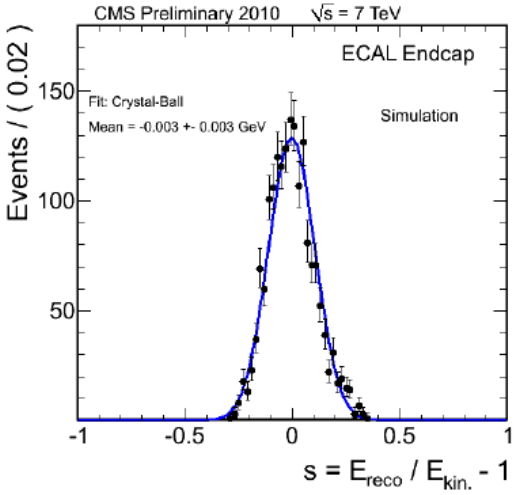
Monte Carlo



Data



Monte Carlo



public document CMS DPS -2011/008

$$s = \frac{E^{\gamma}_{measured}}{E^{\gamma}_{expected}} - 1$$

$$s = \frac{m^2_{\mu\mu\gamma} - m^2_{\mu\mu}}{m^2_{Z^0} - m^2_{\mu\mu}} - 1$$

Photon scale agrees with expectations at the 1% level in EB, ~3% in EE with 2010 data

See more details from Olivier Bondu's presentation tomorrow

γ/π^0 discrimination

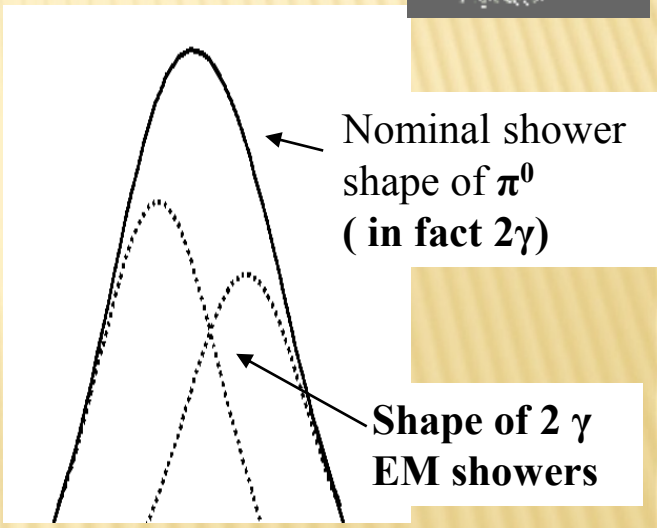
γ/π^0 discrmination (2008-…): (H. BRUN, N. CHANON, G. CHEN, M. LETHUILLIER, S. GASCON, J. TAO, M. YANG, Z. ZHANG, H. Xiao) for both converted and non-converted photons

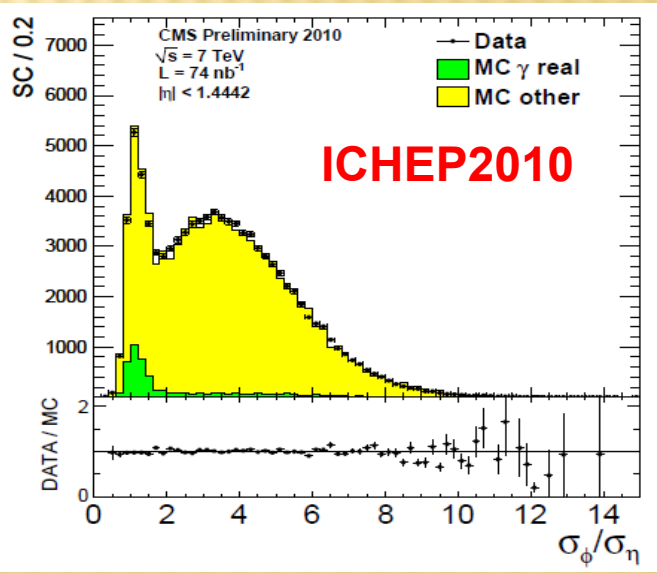
Exploit particular cluster and shower shape observables proper to our crystal calorimeter, in a MLP NN

-For a 'tighter' photon Id than current cutbased Id based on isolation

-For the measurement of the SM backgrounds to H→γγ : γγ + X and γ + X (**see next**)

-For direct application to MVA analysis for the H→γγ search still a major challenge to this analysis for us.





γγ+ X DIFFERENTIAL σ MEASUREMENT

γγ + X differential cross-section measurement (2010-…): (H. BRUN, N. CHANON, G. CHEN, M. LETHUILLIER, S. GASCON, J. TAO, H. XIAO, J. FAN)

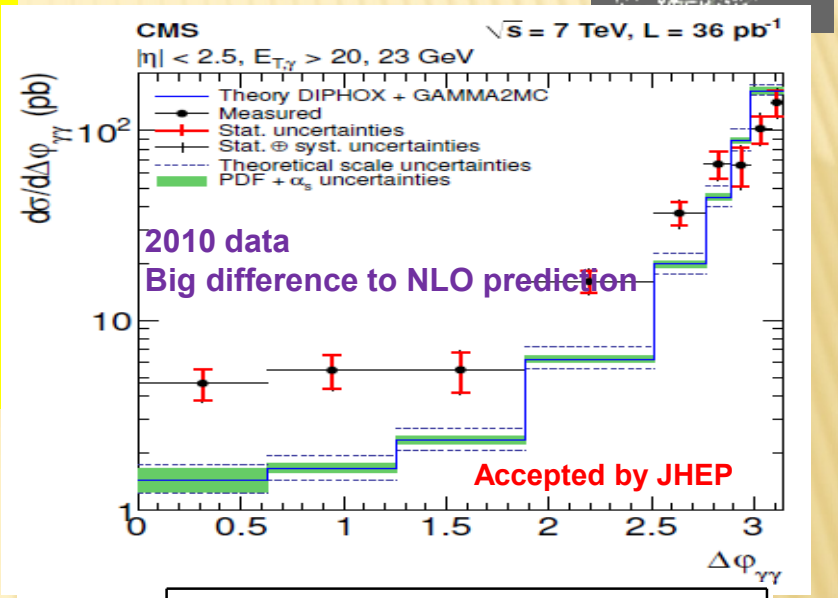
- Use a data-driven 'template' method along the lines of the CMS γ + X cross-section measurement

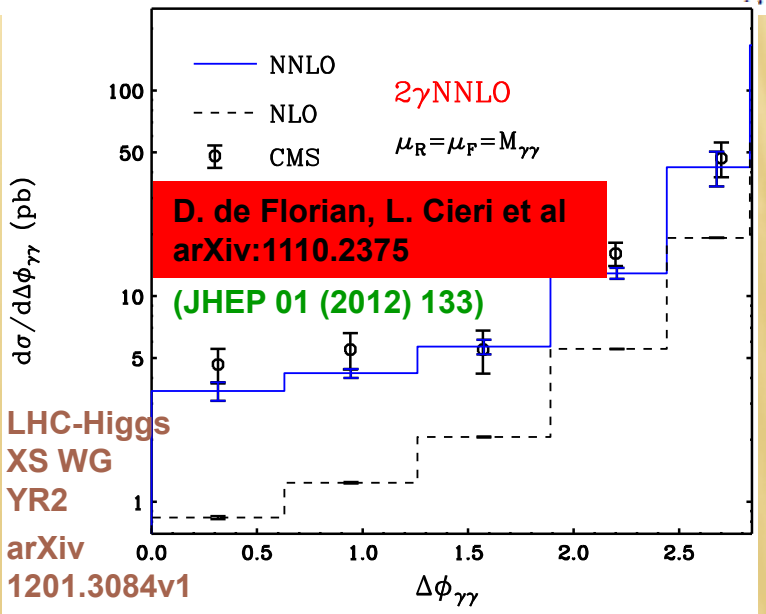
- Compare to pQCD predictions

✓ **2010 data** analysis , work together with the CEA saclay group **"**the modified ECAL isolation method": Observables binning, trigger efficiency , reconstruction efficiency and so on.

✓ Trying again with NN template (from γ/π^0 discrmination)method (and other templates) for **2011 data** analysis (Hong Xiao)

✓ **NNLO**: 2gammaNNLO



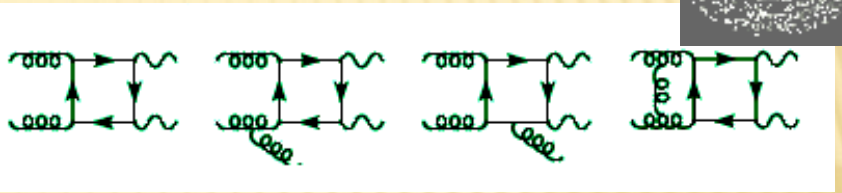


H→γγ analysis: Impact of higher-order calculations on kinematical observables in 2γ processes

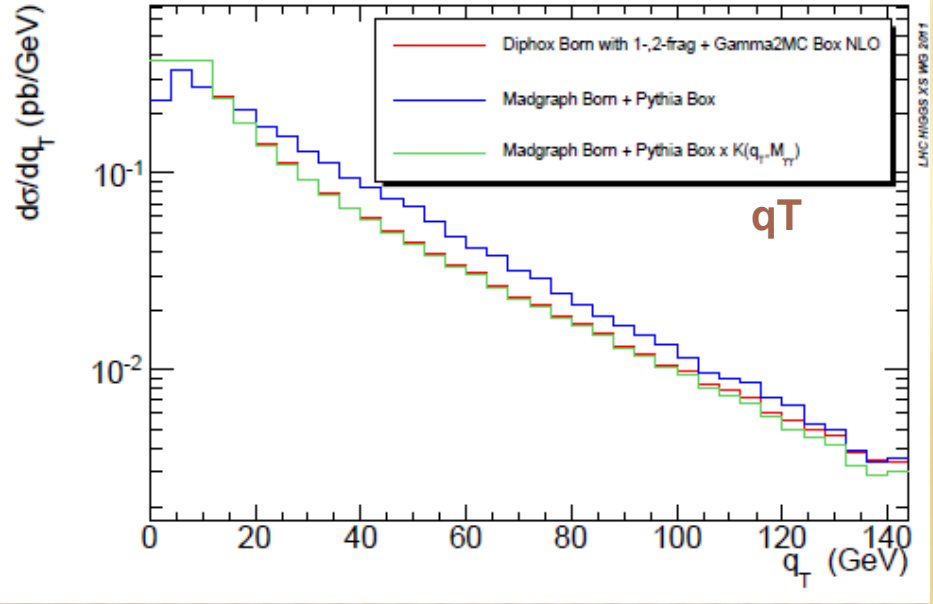
(2007-…): (O. BONDU, N. CHANON, M. LETHUILLIER, S. GASCON, J. Tao, Y. Shen)

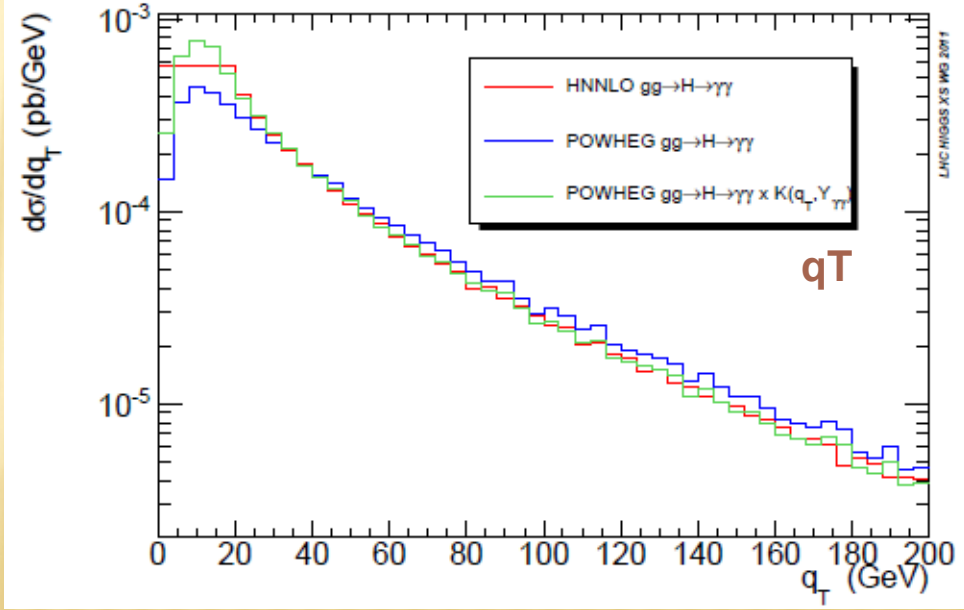
- Implemented **doubly-differential reweighting scheme** with dynamical **k-factors** (NLO/LO) for H→γγ signal and diphoton background

- Contributing to LHC-Higgs-XS working group (cut-dependent k-factors)



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





LHC-Higgs XS WG YR2 arXiv 1201.3084v1

Photon-related analysis 2012

- **2012 LHC running** will be at **8TeV, L~15 fb^{-1}**

- **$\gamma\gamma$ final status physics analyses**

  $\sigma(\gamma\gamma$+X) measurement

  - Differential cross section: more observa
  - Ratio of cross section 8TeV/7TeV
  - Doubly differential measurement

  H->$\gamma\gamma$ improvements

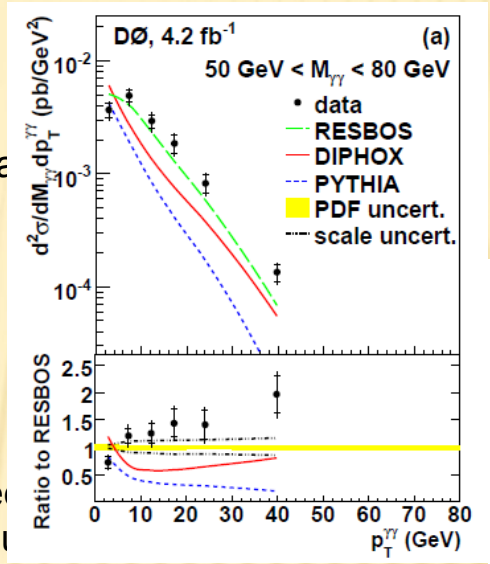
  - Any benefits of PF Photons ?
  - Isolation improvements in PhotonID
  - Shower shapes NN in PhotonID
  - continue work with theorists on improve

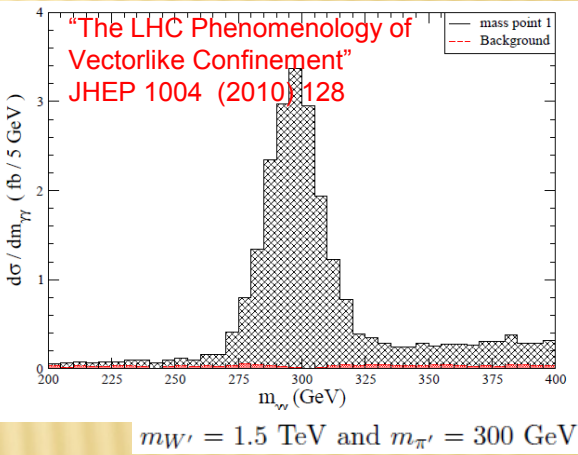
  direct photon spectrum predictions and their u

  the Hgg search …

  Any new resonance? (W$'^{\pm}$->$\pi'^{\pm}\pi'^{0}$, π'^{0} ->$\gamma\gamma$)

  - Need higher PT/E photon studies





- **Zγ final status physics analyses**

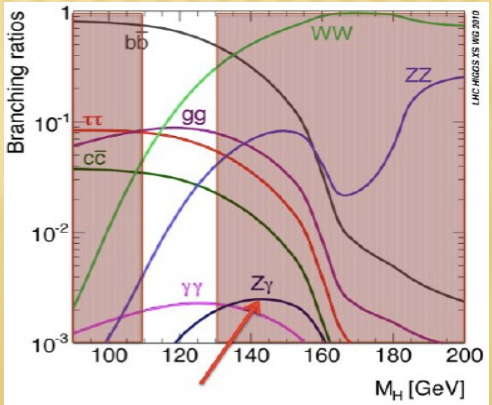
  Z->$\mu\mu\gamma$ More statistics of purity high pT photon source for photonID

  …

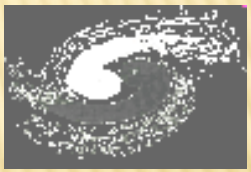
  H->Zγ (MC study by Zhen Zhang (2008), now Yuqiao Shen):

  - Similar production method to H->$\gamma\gamma$
  - Not included in 2011 Higgs Search

  New resonance? (W$'^{\pm}$->$\pi'^{\pm}\pi'^{0}$, π'^{0} ->Zγ)



Summary and Conclusions



- We continue to make good progress in direct photon measurements, photon "infrastructure" (photon commissioning and reconstruction, calibration and identification) and in the H→γγ search through our cooperation efforts, which have continued to expand

- We look forward to continue our efforts, which make good use of our groups' complementarities

- Almost all this photon-related work is now contributed by both of our groups ➔ more and more common activities

Acknowledgements

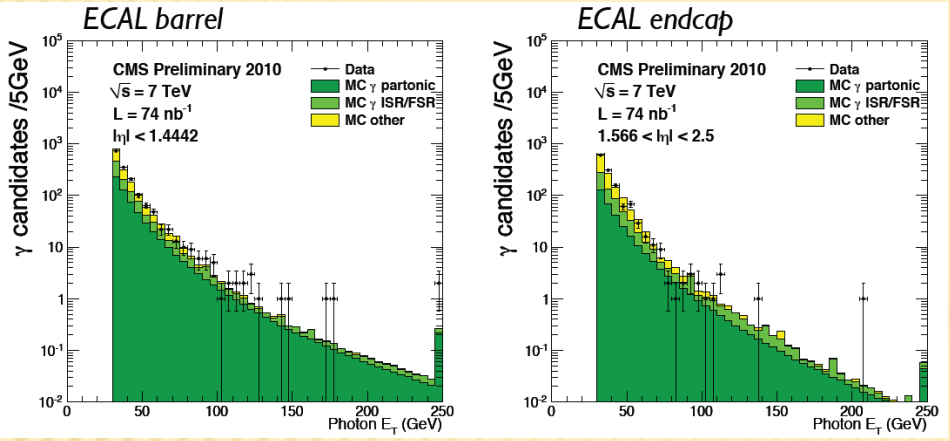
Many thanks to:

- **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 organizing committee of this workshop for the wonderful hospitality and working environment**

Thanks Merci 谢谢

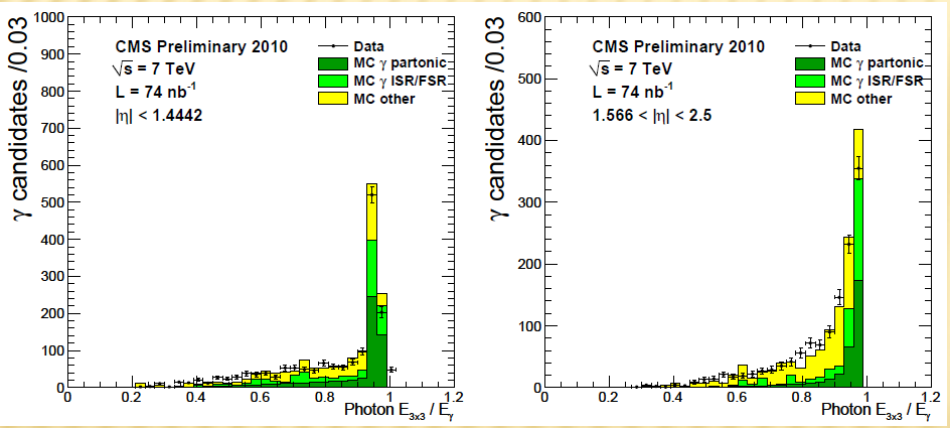
Backup

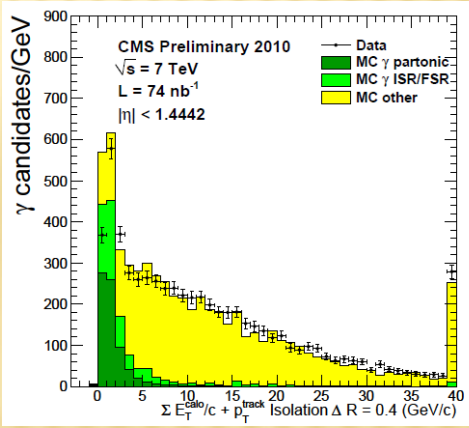
Photon Commissioning

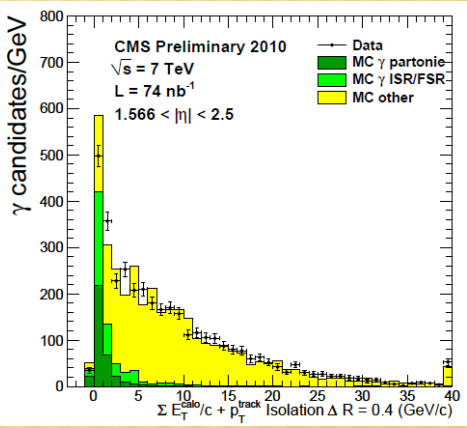


Loose Photon Id

Variable	Barrel	Endcap
pixel seed	require none	
E_T	30 GeV	
Tracker Iso	2.0 GeV	
ECAL Iso	4.2 GeV	
HCAL Iso	2.2 GeV	
H/E	0.05	
$\sigma_{i\eta i\eta}$	0.01	0.03

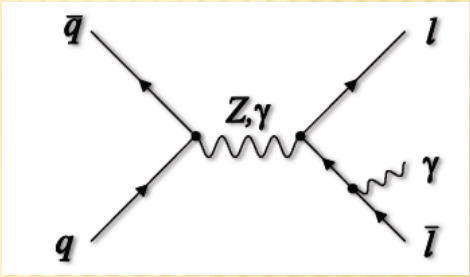






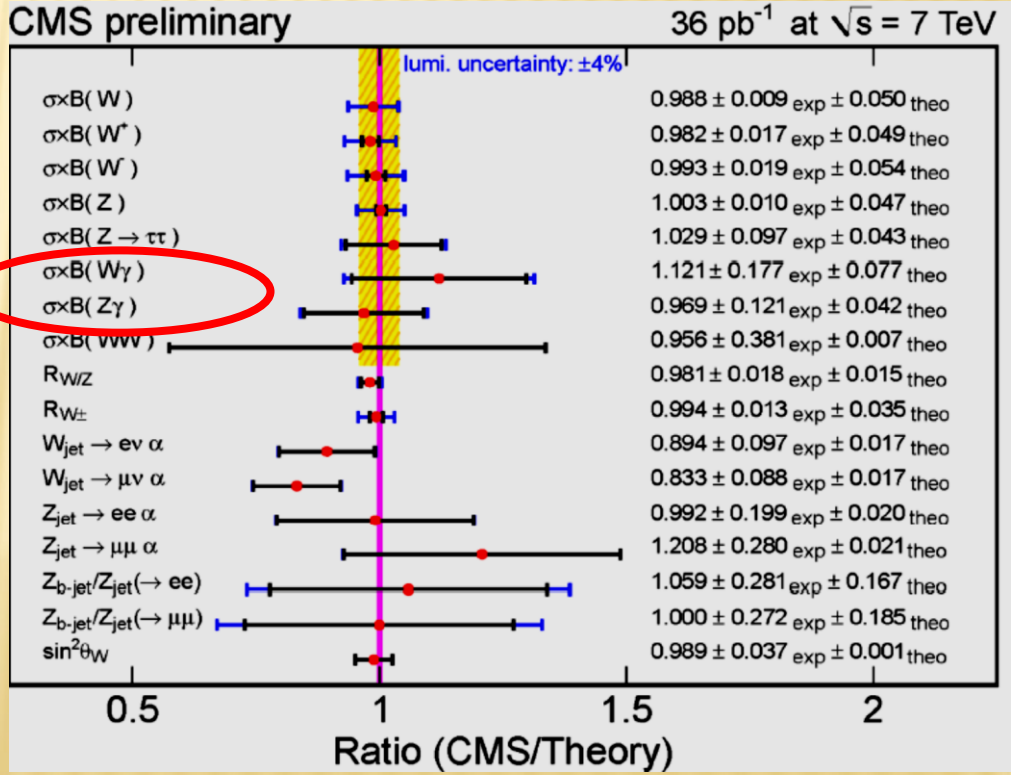
Photon Energy Scale Measurement input to Wγ, Zγ cross-section Measurements

$$\sigma = \frac{N_{\text{Observed}} - N_{\text{Background}}}{A \cdot \epsilon_{\text{MC}} \cdot \rho_{\text{eff}} \cdot \mathcal{L}}$$



Source	Systematic uncertainty	$e\nu\gamma$ Effect on $\mathcal{F} = A \cdot \epsilon_{MC}$	$\mu\nu\gamma$ Effect on $\mathcal{F} = A \cdot \epsilon_{MC}$
Electron energy scale	2% (EB), 3% (EE)	2.3%	n/a
Electron energy resolution	5%	0.3%	n/a
Muon p_T scale	1%	n/a	1.0%
Muon p_T resolution	1%	n/a	0.2%
Photon energy scale	2% (EB), 9% (EE)	4.5%	4.2 %
Photon energy resolution	5%	0.4%	0.7%
Pileup		2.7%	2.3%
PDF		2.0%	2.0%
Total uncertainty on $\mathcal{F} = A \cdot \epsilon_{MC}$		6.1%	5.2%

Source	Systematic uncertainty	$ee\gamma$ Effect on $\mathcal{F}$	$\mu\mu\gamma$ Effect on $\mathcal{F}$
Electron energy scale	2% (EB), 3% (EE)	2.8%	n/a
Electron energy resolution	5%	0.5%	n/a
Muon p_T scale	1%	n/a	1.5%
Muon p_T resolution	1%	n/a	0.7%
Photon energy scale	2% (EB), 9% (EE)	3.7%	3.0%
Photon energy resolution	5%	1.7%	1.4%
Pileup		2.3%	1.8%
PDF		2.0%	2.0%
Total uncertainty on $A \cdot \epsilon_{MC}$		5.8%	4.6%



See more details from Olivier Bondu's presentation tomorrow

Theoretical Predictions

DIPHOX V1.3 **LHAPDF-compatible**
Binoth, Guillet, Pilon, Werlen, hep-ph/9911340, 2000

RESBOS LHAPDF-compatible
Balazs, Berger, Mrenna, Yuan, hep-ph/9712471, 1997

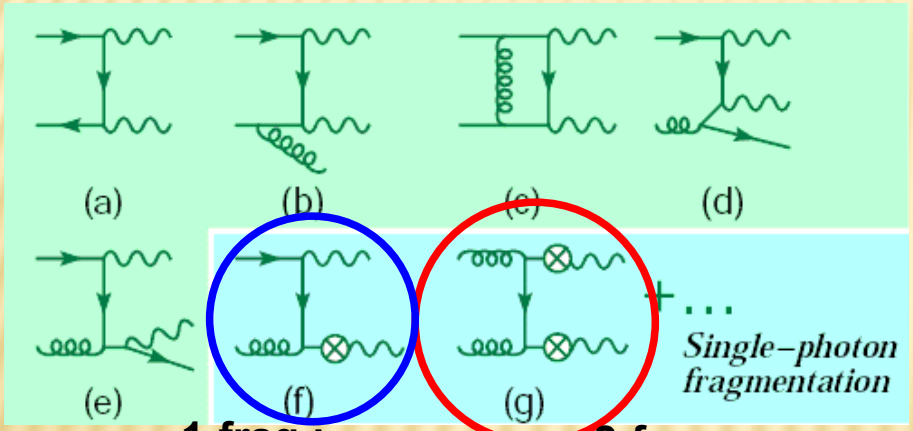
gamma2MC, NLO
Now LHAPDF-compatible!
Bern, Dixon, Schmidt, hep-ph/0211216, 2002

FIXED ORDER : NLO

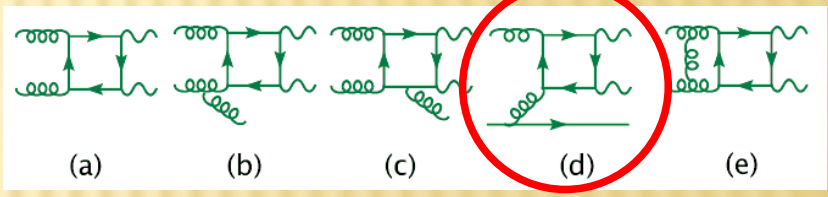
NLO with NNLL Resummation

FIXED ORDER : NLO

BORN + FRAG (and NLO corrections)



BOX (and NLO corrections)



Resbos only

1-frag :
- LO, effectively in Resbos
- NLO in Diphox

2-frag :
DIPHOX only (NLO)

DIPHOX+gamma2MC contains the most complete NLO treatment -> 2010 analysis
ResBos for 2011 data analysis, 2gammaNNLO?

Any news will be from Workshop on Photon Physics and Simulation at Hadron Colliders", Paris, 30 March 2012