IHEP/IPNL collaboration project on the CMS physics analysis

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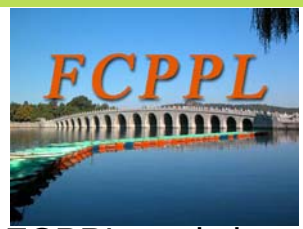
3rd FCPPL Workshop

April 7-9, 2010



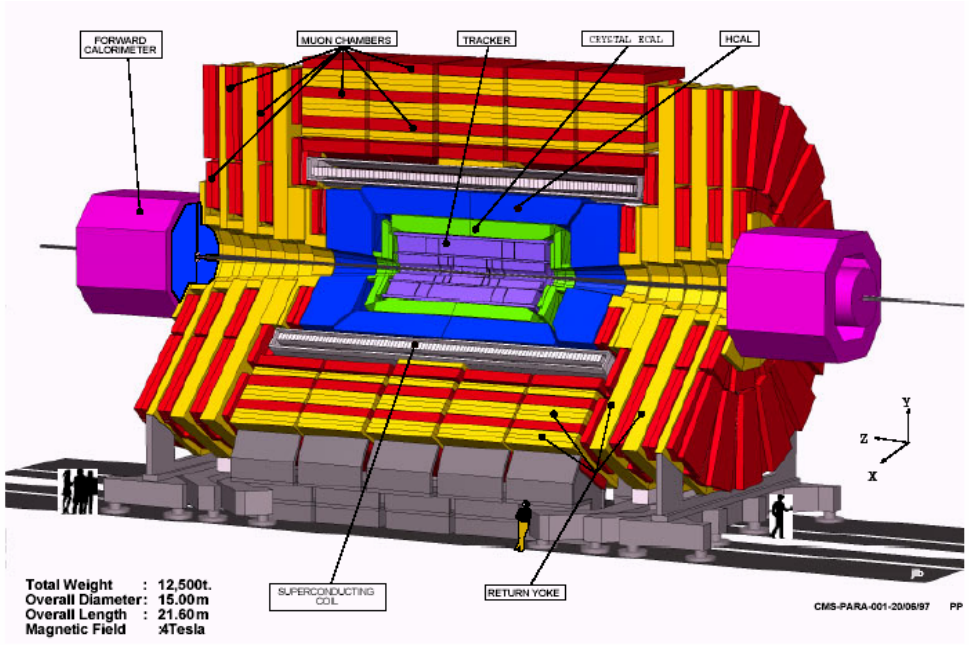
Outline

- Some results from CMS with the LHC collisions 2009
- The CMS groups of IPN Lyon and of IHEP
- A brief **history** of our collaboration up to now
- **IN2P3-IPNL/IHEP project on CMS: mainly on the Photon studies**
  - **Photon Energy Corrections and Calibration with $Z \rightarrow \mu\mu\gamma$**
  - **"Infrastructure" for $H \rightarrow \gamma\gamma$ analysis**: γ/π^0 discrimination of converted and unconverted photons; Impact of higher-order calculations on kinematical observables in 2gamma processes; Activitives on the DQM and 2009 october exercise; etc.
  - **Related work on Monte Carlo description of photons**: QED Matrix Element/Parton Shower photon 'matching' status
  - **MC/Data comparision** on the photon candidates
  - **Other activities**
- Future plans and conclusion
- Acknowledgements

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

LHC collisions

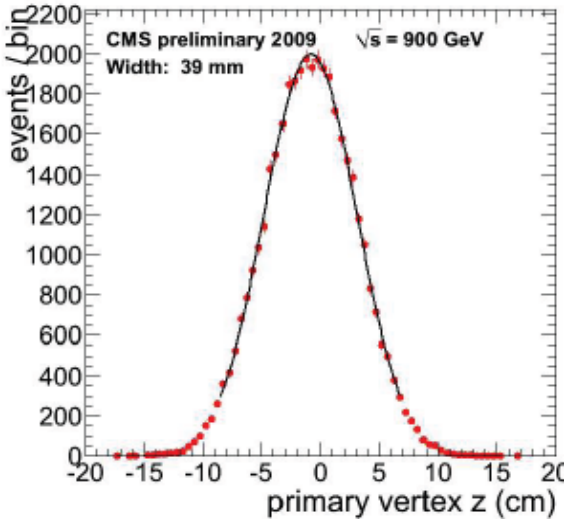
◆ Exciting on the LHC collisions at 900GeV, 2.36TeV from the end of 2009 and now 7TeV.

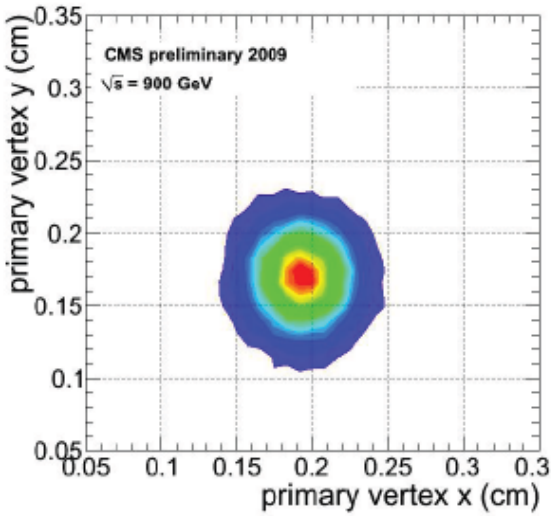


◆ CMS approved plots with the collision at 900GeV and 2.36TeV (the end of 2009).
(Approved DPG Commissioning results to be shown at conferences)

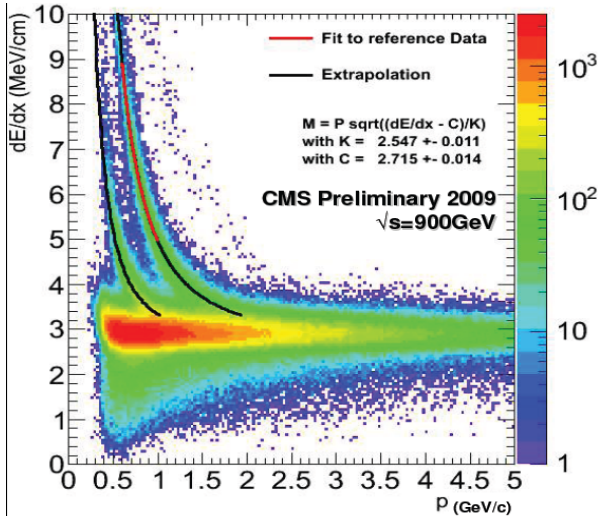
Detector Performance : Tracking

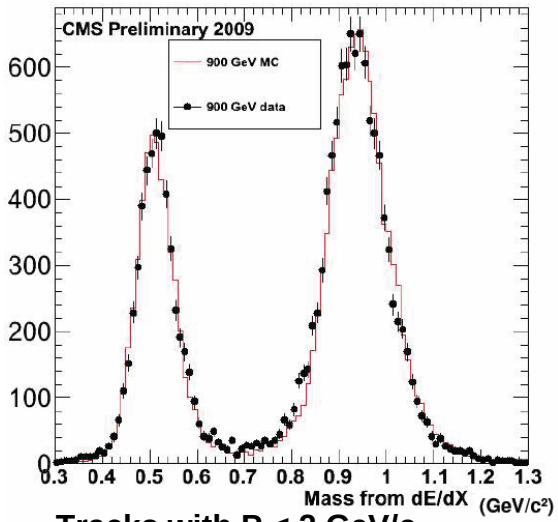
Primary Vertex





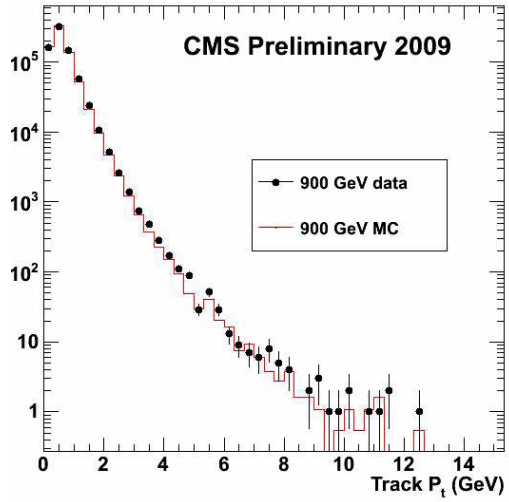
dE/dx

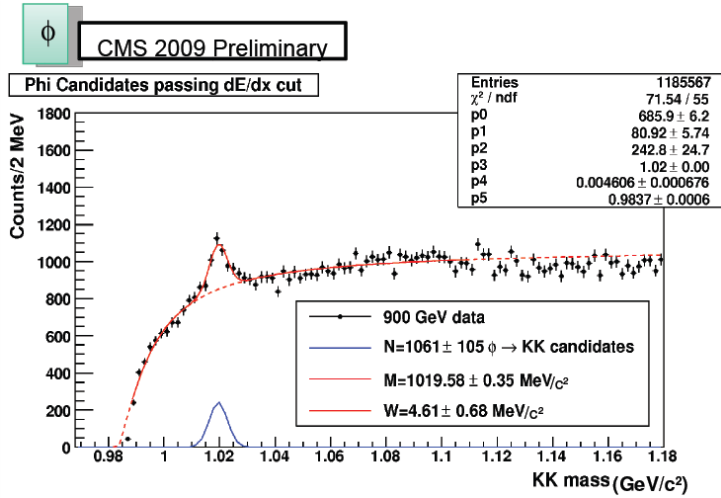




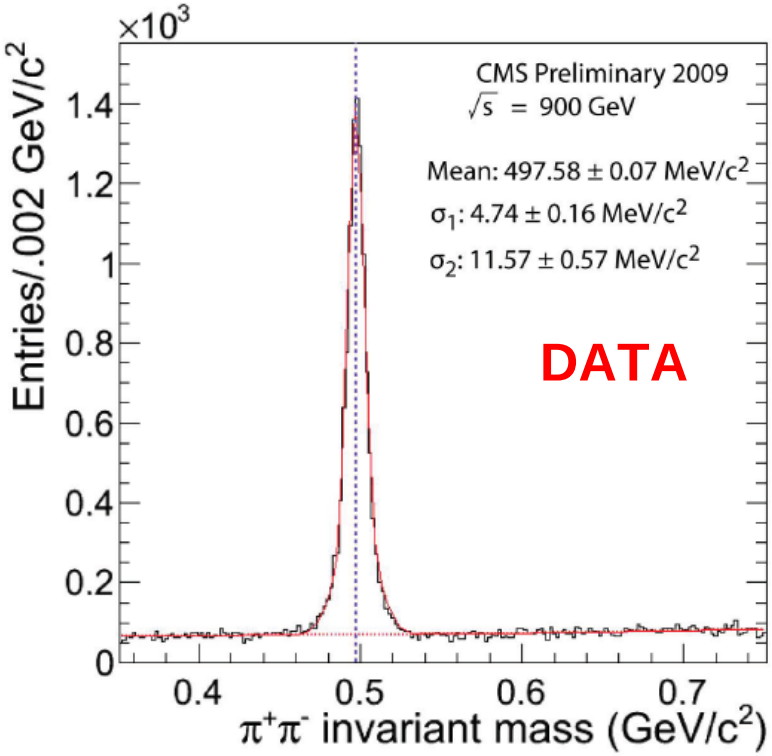
Tracks with P < 2 GeV/c

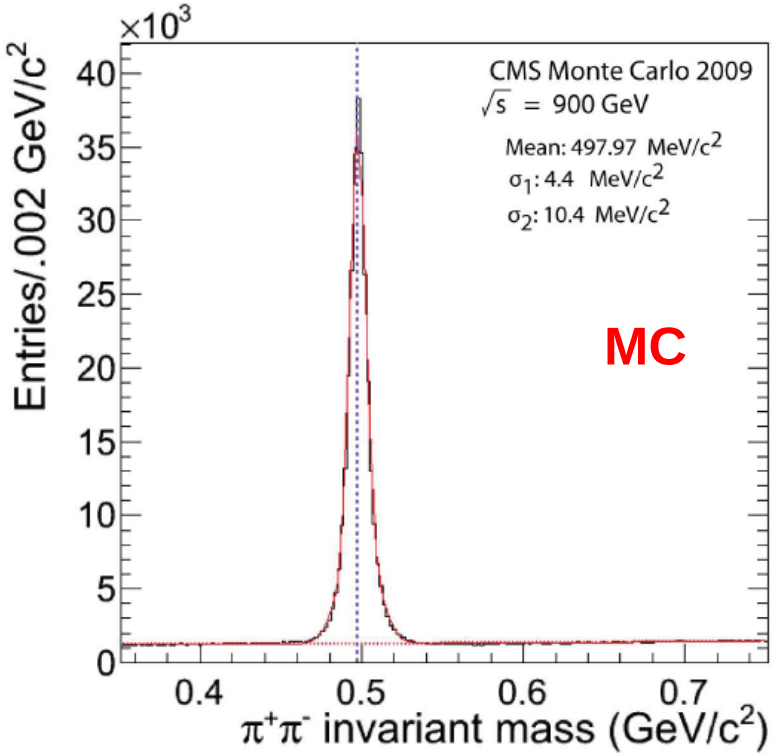
Tracking Pt





K_s

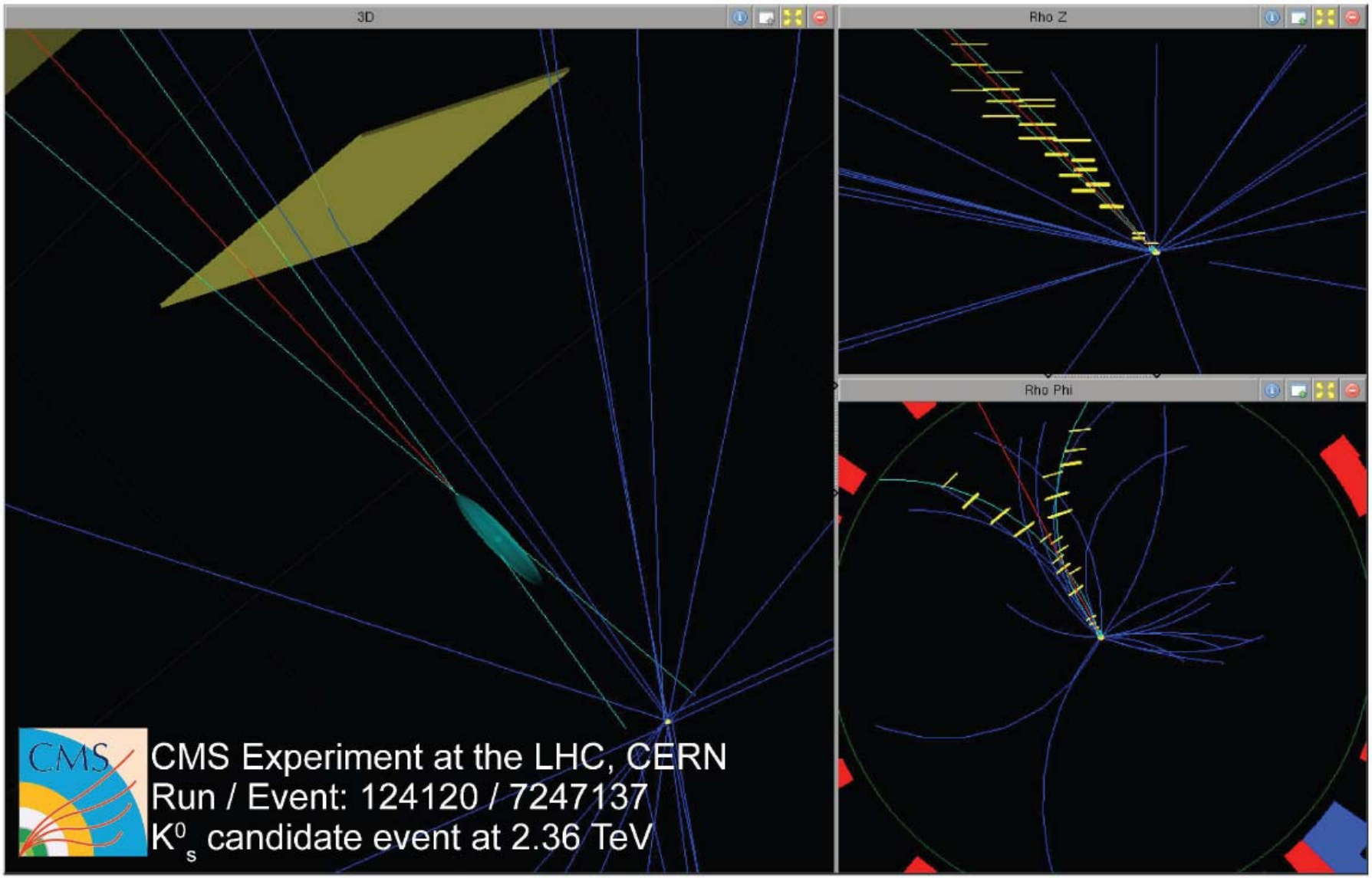




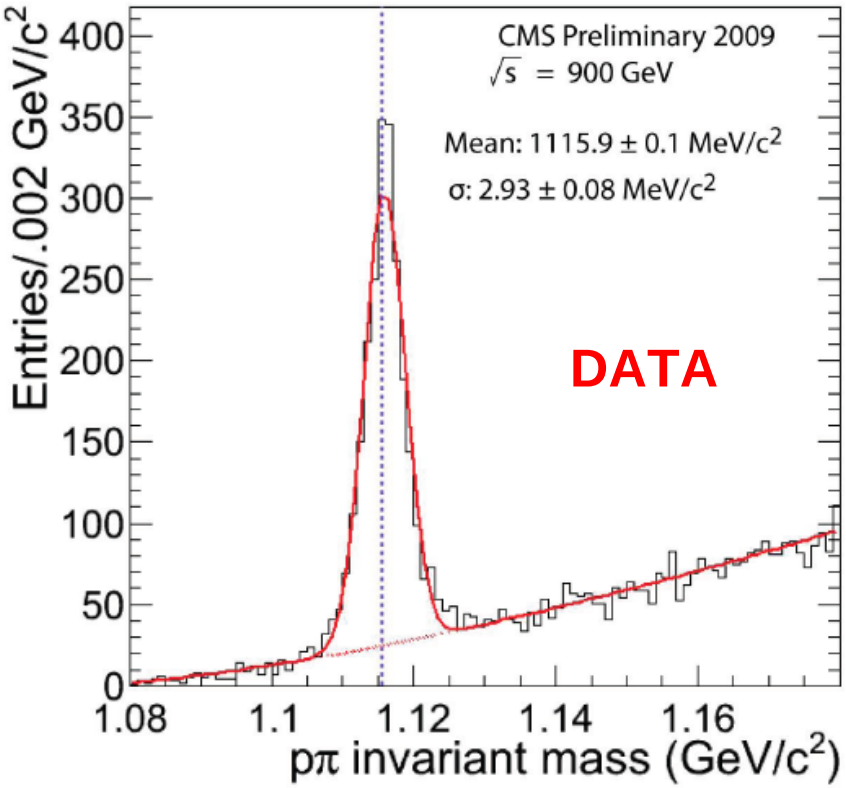
Double Gaussian Fits

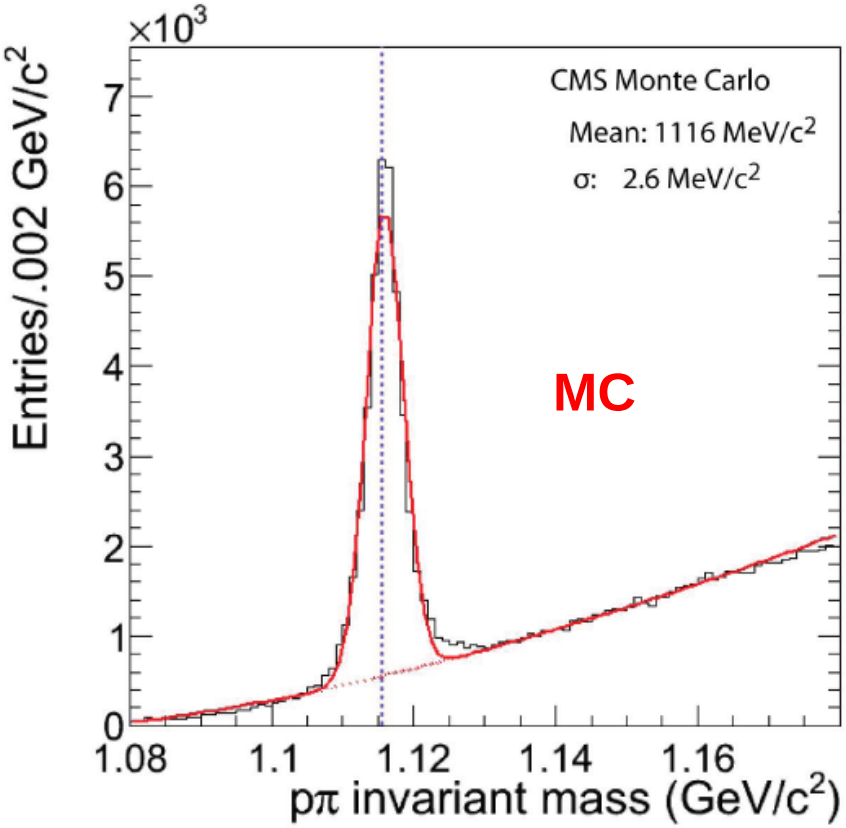
From a sample of ~240k events in runs 123596, 123615, 123732, 124009, 124020, 124022, 124023, 124024, 124027 and 124030

K^0_s candidate event at 2.36 TeV



Λ

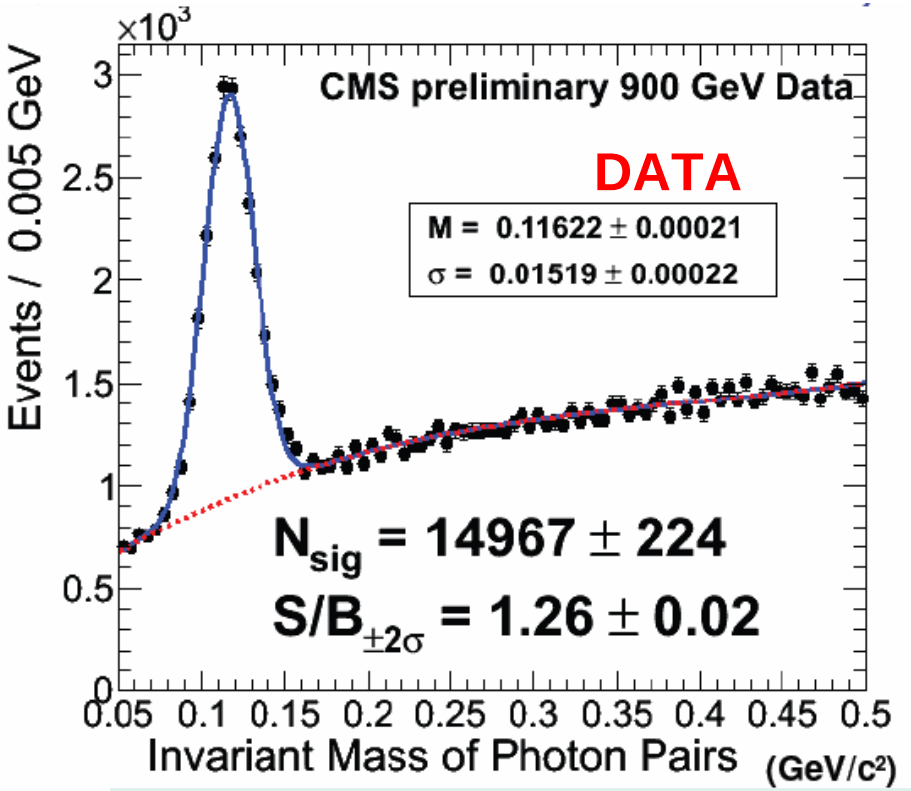


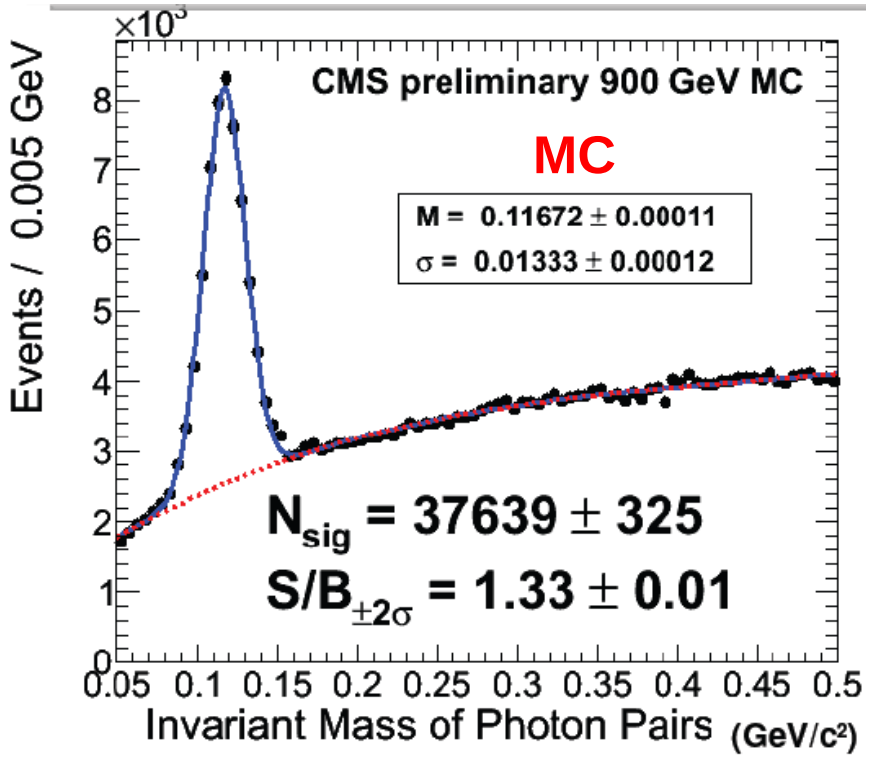


Single Gaussian Fits

From a sample of ~240k events in runs 123596, 123615, 123732, 124009, 124020, 124022, 124023, 124024, 124027 and 124030

First Di-photon Distribution in CMS

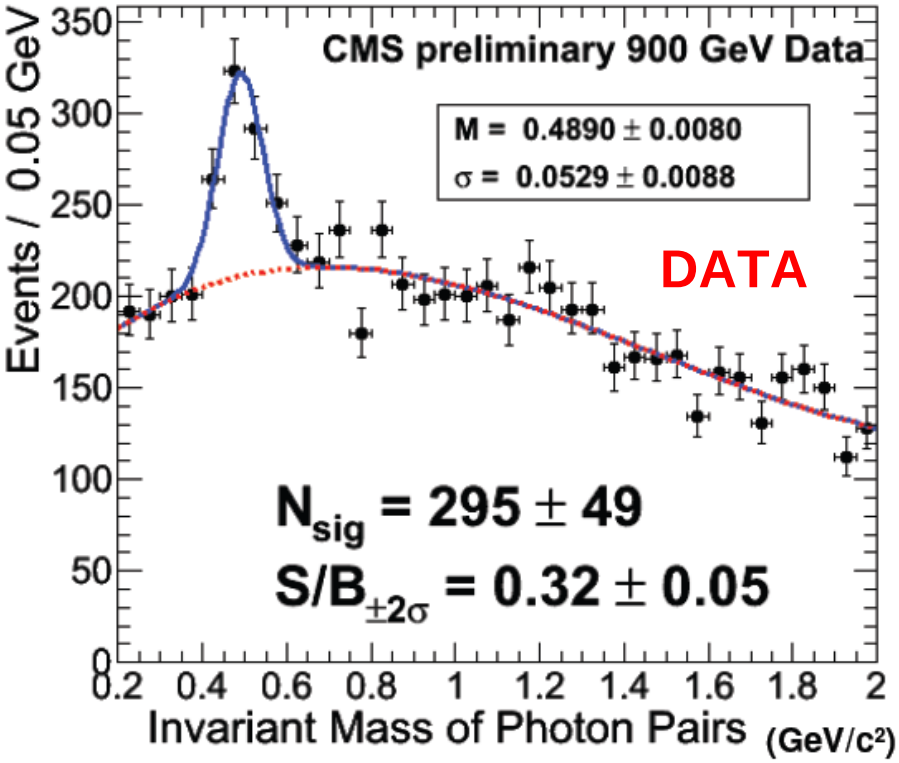


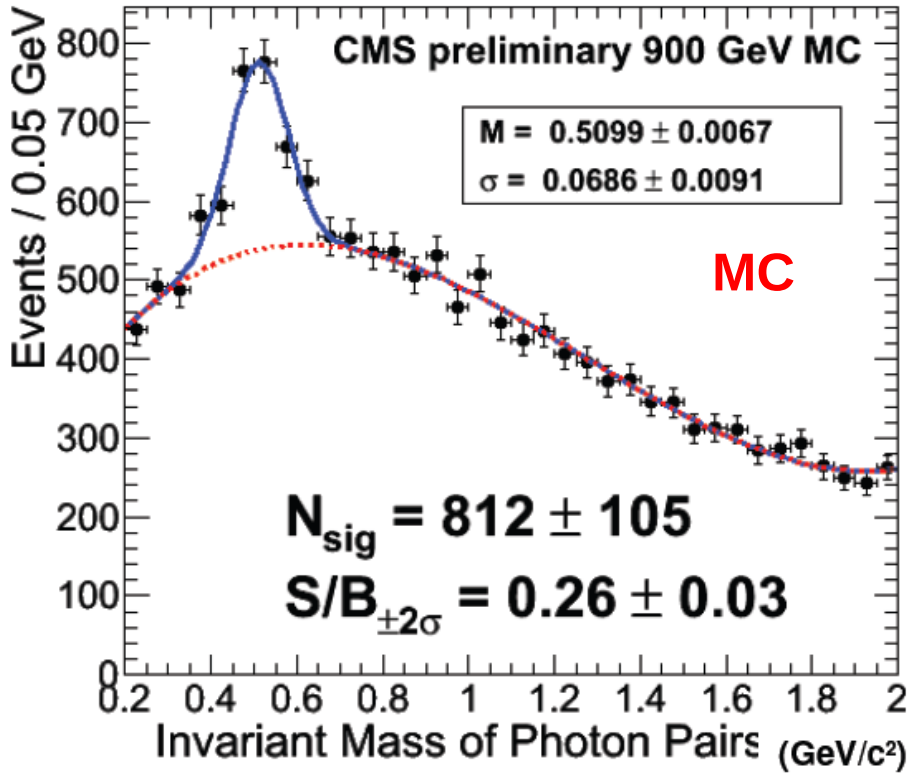


- **Data and MC comparison (uncorrected distributions)**
- Almost identical S/B, mass and width compatible
- M(π^0) is low in both data and MC - Mostly due to the readout threshold (100 MeV/Crystal) and conversions

π^0 in ECAL Barrel

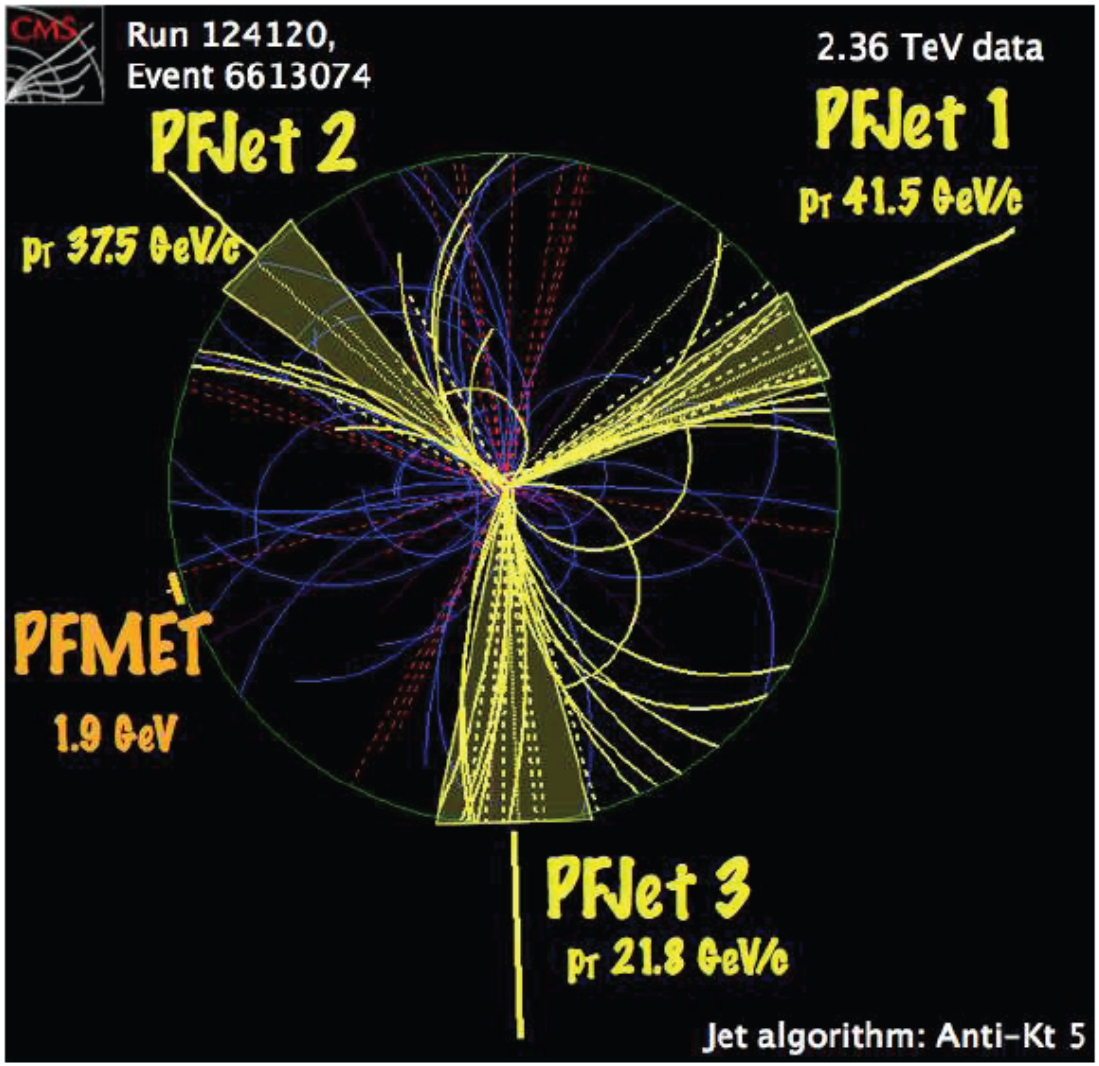
η Yield in ECAL Barrel





- Mass and width compatible with MC
- η yield scale as expected (π^0 candle)
  - $N(\eta) / N(\pi^0) = 0.020 \pm 0.003$ DATA
  - $N(\eta) / N(\pi^0) = 0.021 \pm 0.003$ MC

Multi jet event @ 2.36 TeV



PFJets with (uncorrected) p_T > 20 GeV/c

Particle inside the jet:

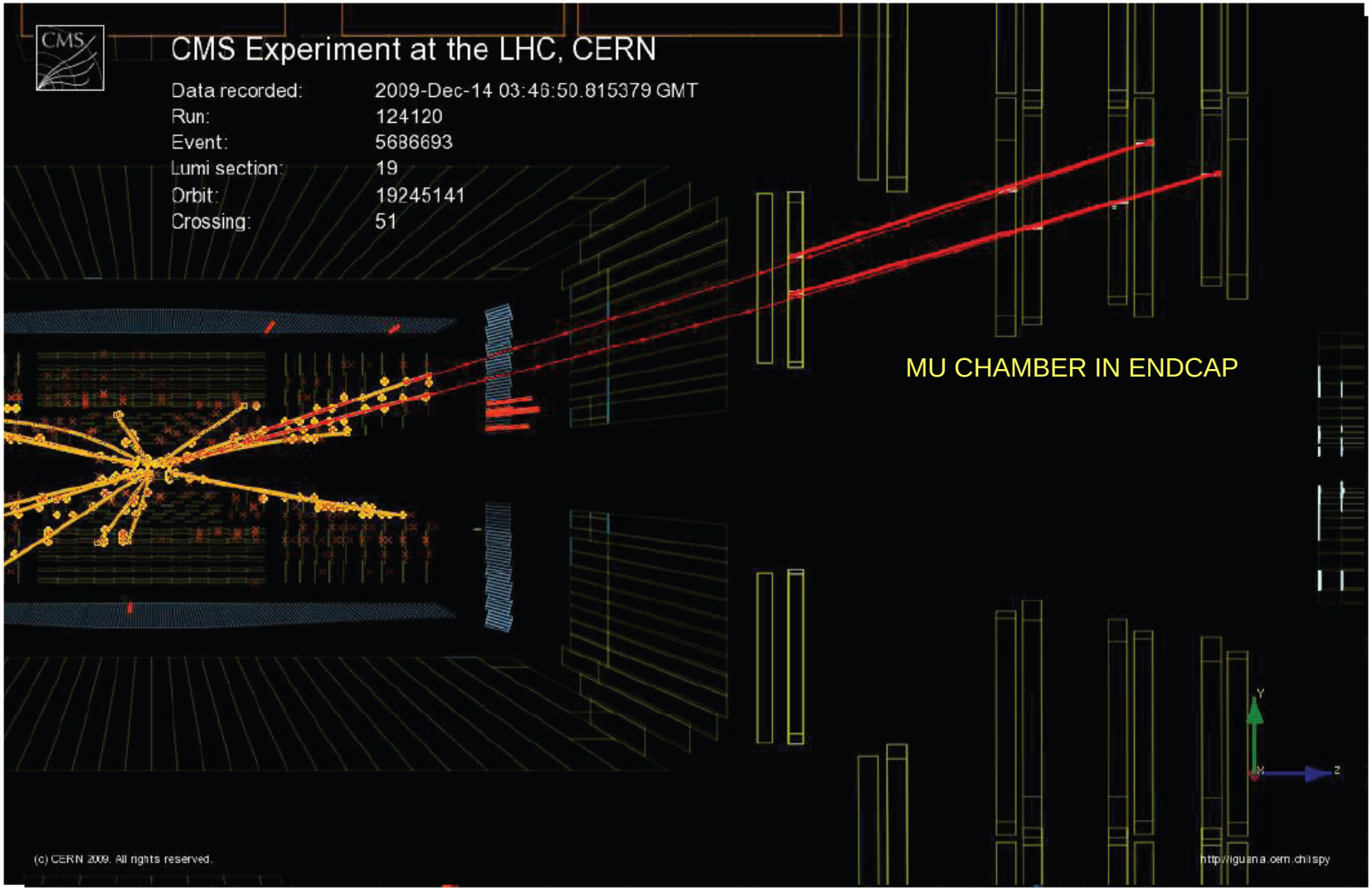
- Charged hadrons
- Photons
- Neutral hadrons

Particles outside the jet:

- Charged hadrons
- Photons
- Neutral hadrons

PFMET (1.9 GeV)

Muons: A Dimuon Event at 2.36 TeV



$p_T(\mu_1)$ = 3.6 GeV/c, $p_T(\mu_2)$ = 2.6 GeV/c, $m(\mu\mu)$= 3.03 GeV/c^2

Detector Performance from 2009 collisions

- The detector has produced some amazing results from the relatively small 2009 data set.

- Amazing consistent between the Real Data and MC simulation, thanks to all the contributions to the software developing.

CMS group at IPN Lyon

- **Current composition of the group:**
  - **14 permanent physicists**

    4 Research Directors

    (M. Bedjidian (Heavy Ions), D.Contardo, J. Fay, B. Ille [Laboratory Director]**)**

    3 Professors

    (P. Depasse, H. El Mamouni, S. Gascon-Shotkin**),**

    3 Research Scientists

    (R. Chierici**,** M. Lethuillier, S. Viret**),**

    3 Junior Research Scientist (G. Boudoul, D. Boumediene, V. Sordini**),**

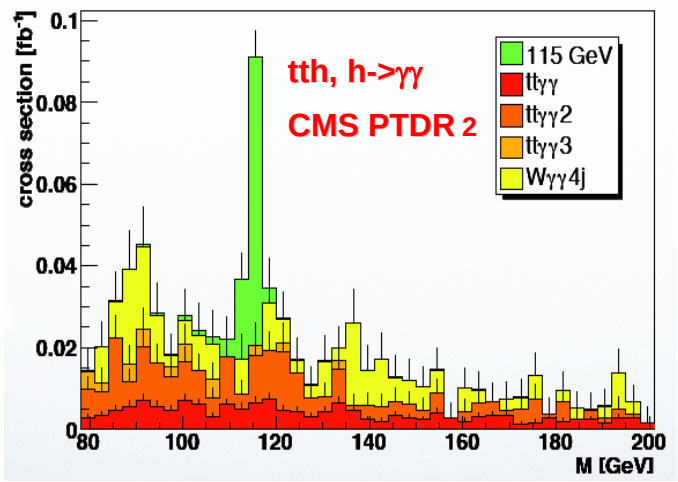
    1 Junior Professor (S. Perriès **)**
  - **3 Postdocs** (A. Falkiewicz, C. Baty (ATER), S. Tosi)
  - **6 Doctoral Students** (Th. LeGrand, N. Chanon, H. Brun,Y. Tschudi, O. Bondu, N. Beaupere) and **1 Visit Doctoral Student** (Hong Xiao from IHEP)

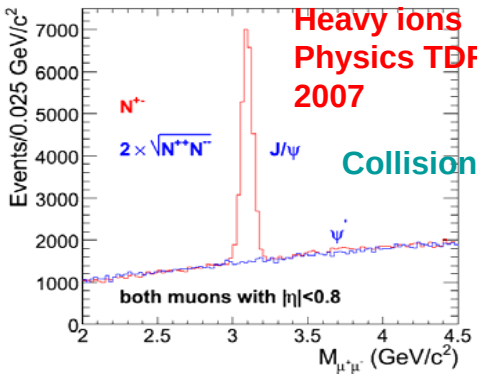
CMS activities at IPNL

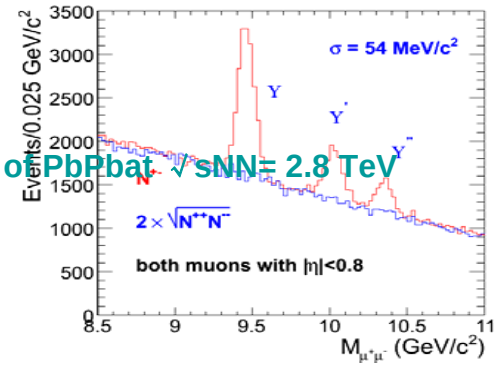
- **Barrel electromagnetic calorimeter and endcap tracker construction and commissioning**

- **Current axes of work:**

  - **Higgs boson searches**
    - ✓ Associated ttbarH production with H→γγ
    - ✓ WH/ZH with H→γγ channel
    - ✓ H→ZZ*→4l
  - **top quark physics**
  - **supersymmetry searches**
  - **heavy ion physics**







CMS group at IHEP

- **Current composition of the group:**
  - **8 permanent physicists:**

    1 Research Director

    H.S. Chen

    2 Professors

    G.M. Chen, C.H. Jiang

    2 Associated Professors

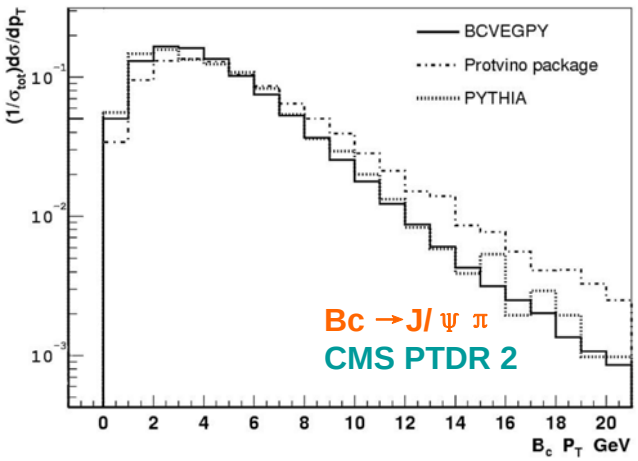
    M. Yang, J.G. Bian

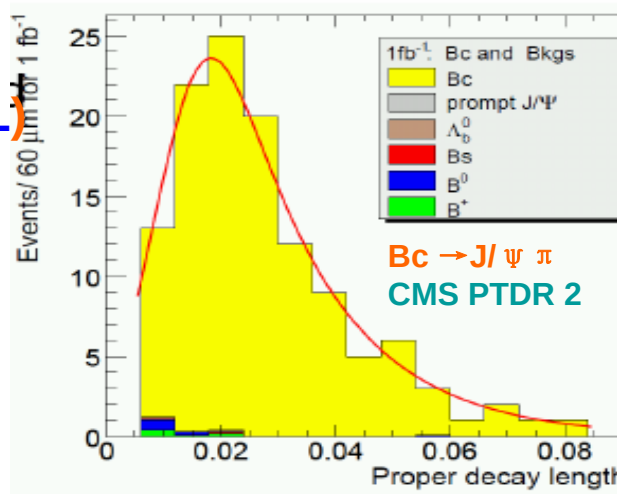
    3 Research Scientists

    X.W. Meng, Z. Wang, Z.H. Li
  - **2 Postdocs (J. Tao, Z. X. Zhang)**
  - **5 Doctoral Students (J. Wang, Z.C. Tang, J.J. Zang, M. Xu, J. W. Fan) and 2 Visit Doctoral Students (X.Y. Wang from Chongqing Univ., J. Wang from GUCAS)**

CMS activities at IHEP

- **Muon endcap chamber construction and commissioning**
- **Current axes of work:**
  - **J/ψ physics:**
    - Inclusive b → J/ψ → μ μ production
    - B+ → J/ψ K+ production
    - Bc → J/ψ π & Bc → J/ψ μ ν
    - Prompt double J/ψ production
    - ψ(2s) measument with ψ(2S) → J/ψ π + π -
  - **Higgs boson searches**
    - HWW anomalous coupling measurement
    - Inclusive/exclusive(VBF) H→γγ search (with **IPNL**)
    - Higgs search with qqH→ZZ→ μ μ ν ν
    - Higgs search with H→ τ τ (with **PKU**)
  - **V',Z' with μ in the final states**
    - V' →ZW → μ μ μ ν search
    - Z' → μ μ search (with **Florida Uni.**)
  - **ttbar cross section measurement** with ttbar->2W+2b->mu+nu+2j+2b (with **Fermilab**)





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)

A brief history of our collaboration up to now (cont.)

- 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**)

- January-July 2010 IHEP doctoral student **XIAO Hong** at IPNL (PICS/candidate FCPPL-CSC grant)

- April 2010: Participation and contribution of both teams to organisation of the 3rd FCPPL workshop (Lyon)

- Fall 2010 IPNL doctoral student **Hugues BRUN** at IHEP and late 2010 IHEP doctoral student **FAN Jiawei** at IPNL …

Motivation: The H→γγ search

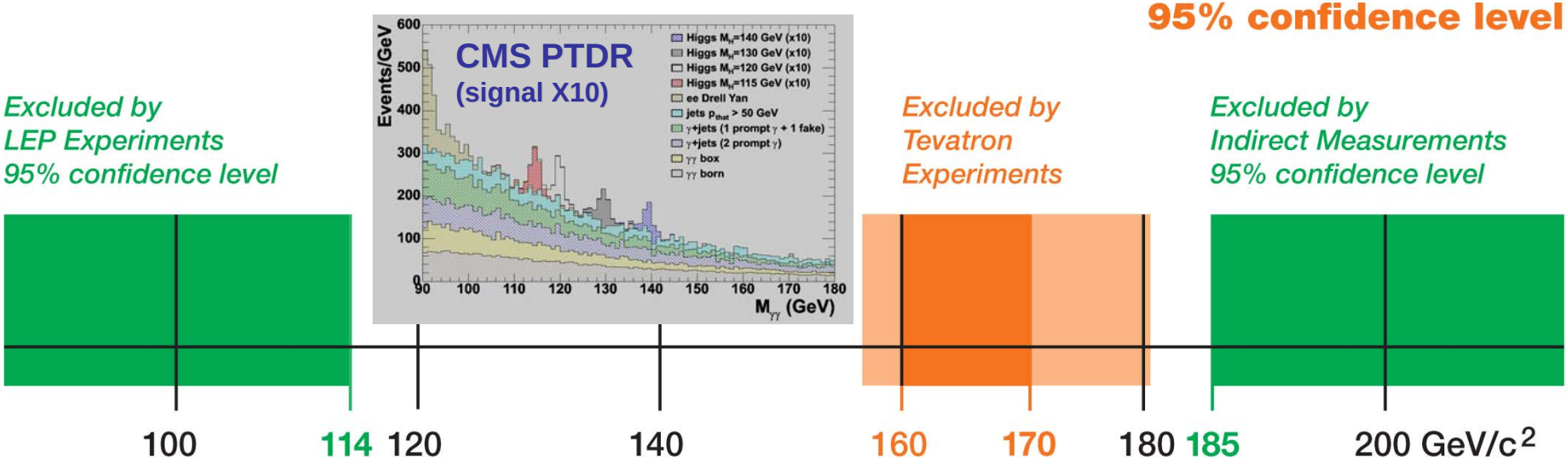
Search for the Higgs Particle

FNAL

Status as of March 2009

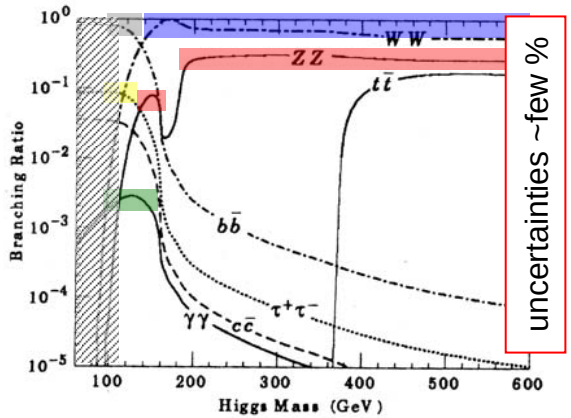
90% confidence level

95% confidence level



Higgs mass values

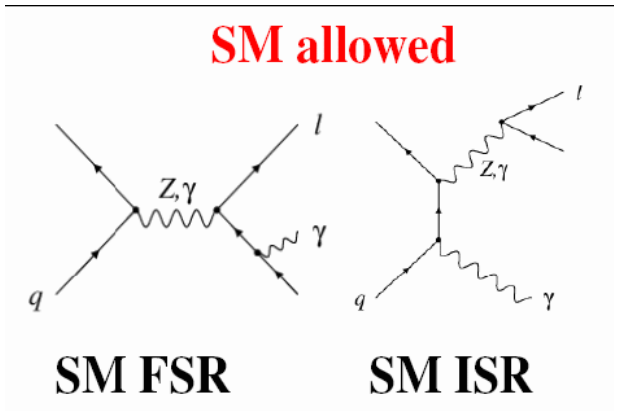
Keep sight of this goal, but put emphasis on detector calibration, photon and 'infrastructure' analysis for the next couple of years.



- For $M_H \lesssim 140$ GeV → $H \to \gamma\gamma$ (BR $\sim 10^{-3}$)
- 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)

A Good chance for the collaboration on the photon related studies !

Photon Energy Corrections & Calibration



➢ **The energy correction of rec. photons can be performanced with the correction functions based on R9, R19, η and ϕ.**

➢ « 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 (~100pb^{-1}) , used for Photon trigger efficiency, Photon energy scale, Photon energy correction parametrisation and Photon id efficiency

- Complementary with calibration by $\pi^0 \rightarrow \gamma\gamma$

- Then: Identification Et parametrisation of biases (pT, η, …) →correction functions

– Numerous presentations in CMS working groups

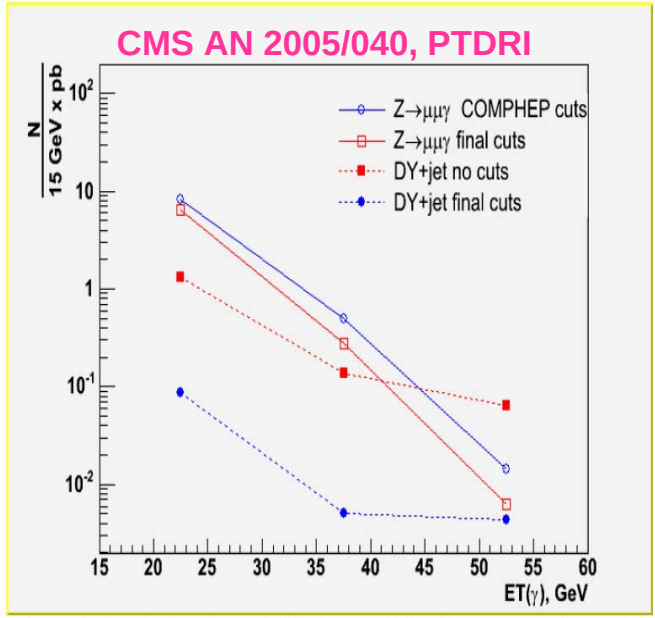


Figure 3: Signal and background yields before and after the cuts on event kinematics

γ/π^0 discrmination of converted and unconverted photons

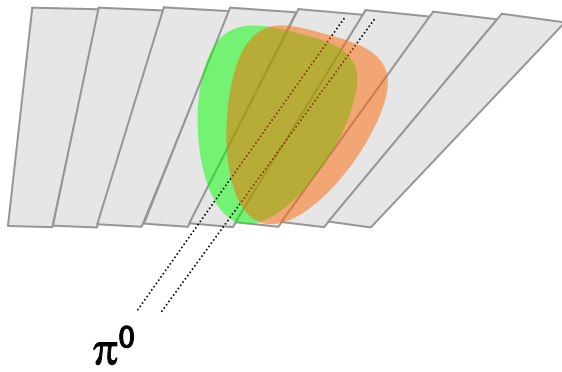
γ/π^0 discrmination (2008-…): (N. ChANON, G. CHEN, M. LETHUILLIER, S. GASCON, J. TAO, M. YANG, Z. ZHANG)

- For unconverted photons : Try to improve on γ efficiency / π^0 rejection performance wrt ANN used in the PTDR, using the parametric shower shape method (same as the 'L3 method'). Based on the difference of shower parameters, ~10% improvement on the p0 rejection can be obtained for the interesting PT region of H→γ analysis (PT 35GeV~75TeV) if keeping 90% signal efficiency.

-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. Improved results can be obtained.

-**After the application of the γ/ π^0 discrmination in the H→$\gamma\gamma$ analysis, improved significance can be obtained for the signal.**

– Several presentations in CMS working groups



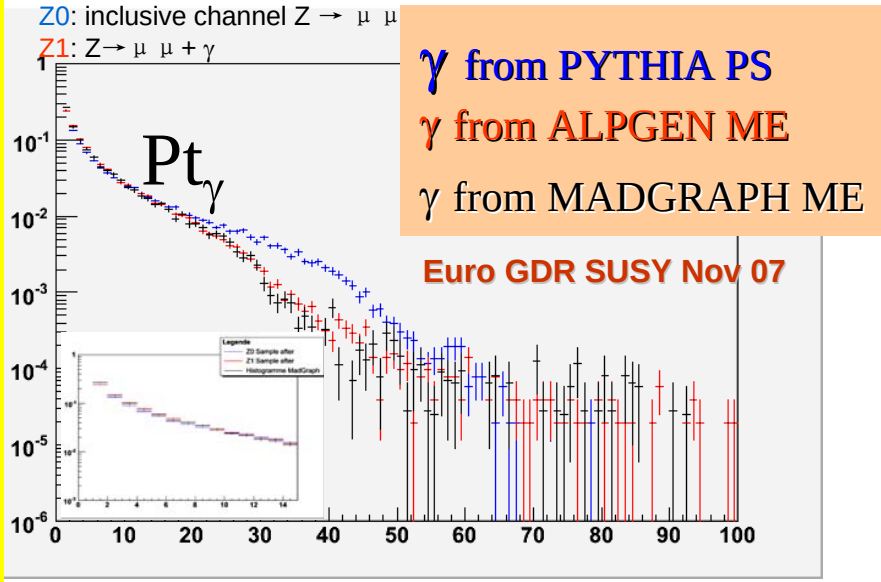
QED Matrix Element/Parton Shower photon 'matching'

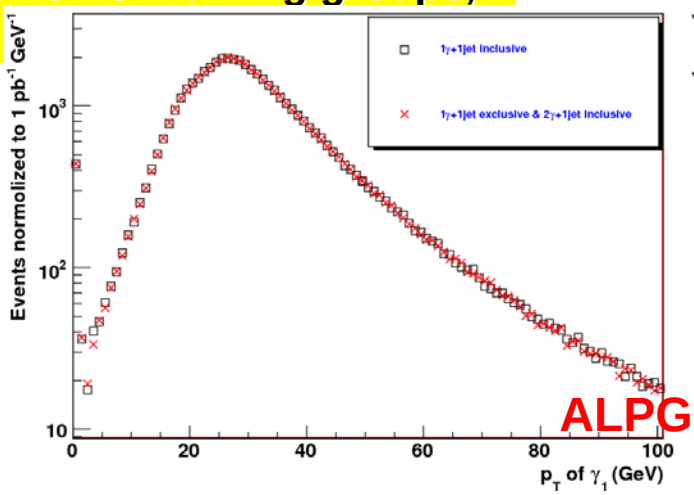
(2007-…): (C. BATY, M. LETHUILLIER, S. GASCON, J.TAO)

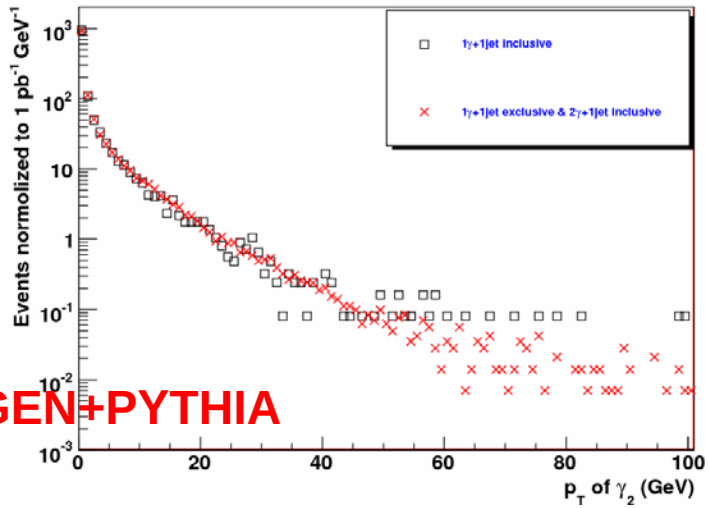
-Collaboration with the authors of ALPGEN (CERN/INFN): Towards an algorithm permitting co-existence of Matrix Element and Parton Shower γ without double-counting. Inspired by existing procedure for jets.

- For some special physics channel analysis, it can be fixed with proper selection of the QED parameters, exclusive or inclusive. For general case, further study will be needed.

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







ALPGEN+PYTHIA

Black rectangle : 1jet +1photon qed-inclusive samples

Red cross: 1jet+1photon qed-exclusive + 1jet+2photons qed-inclusive samples

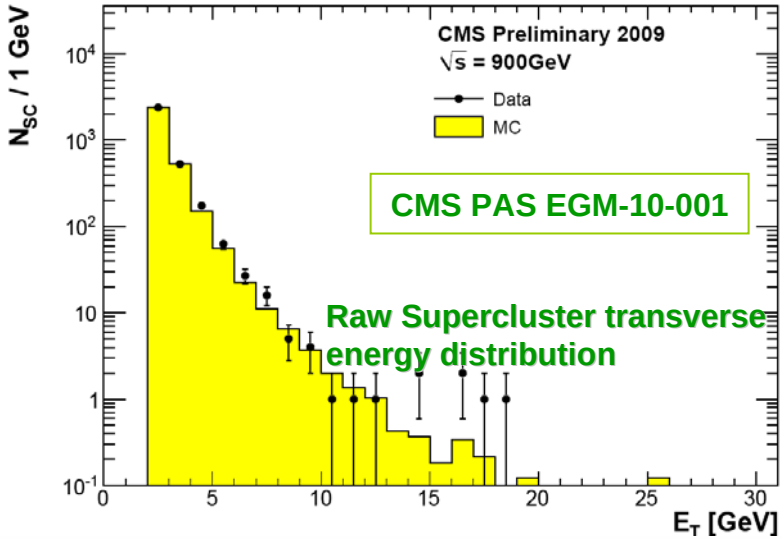
Comparison of SuperCluster in MC/Data

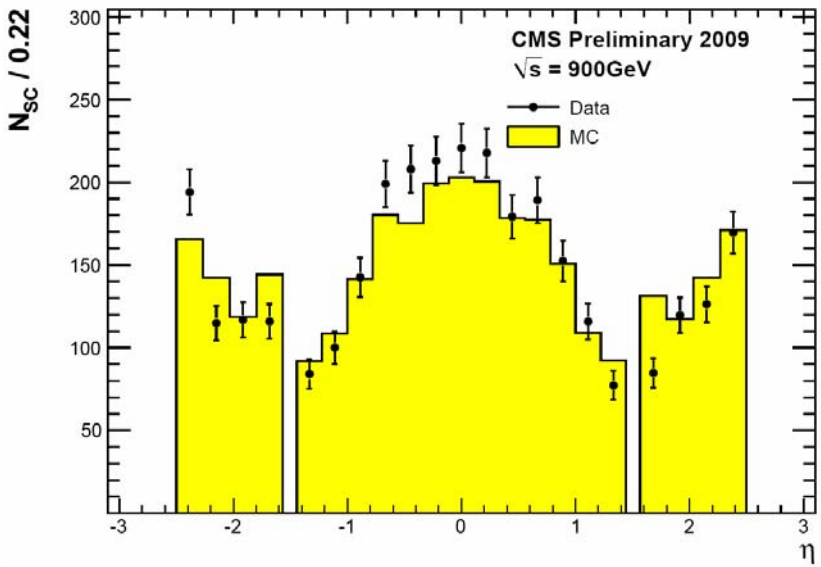
(2009-…): (M. LETHUILLIER, S. GASCON, H. Xiao)

- The data at 900GeV and 2.36 TeV from Nov. 2009, and now 7TeV , are available

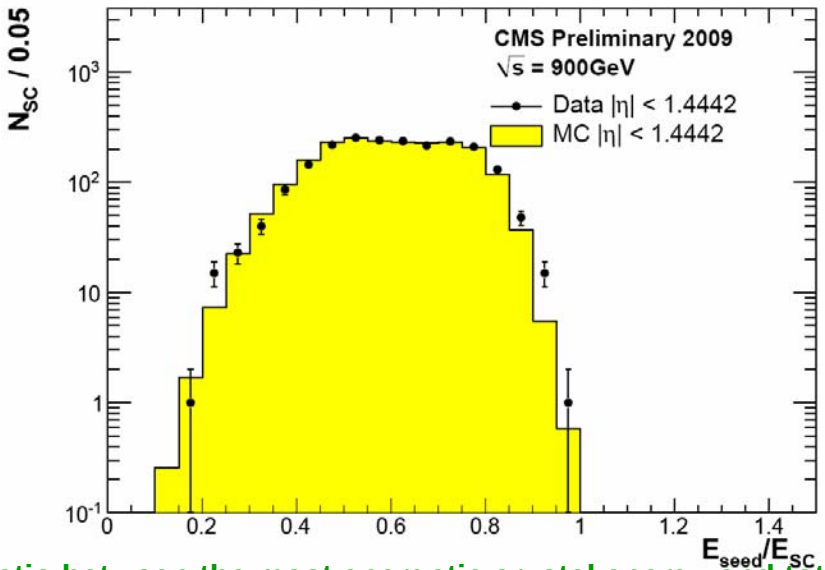
- Cross check with other groups on the Spectra, Shapes and Isolations of **SuperCluster**

-Hong Xiao's presentation detailedly





Pseudorapidity distribution of the superclusters



Ratio between the most energetic crystal energy and total supercluster energy for the barrel case

Other activities of IPNL-IHEP

- **ECAL Single Dead Channel correction**

The parametric EM shower profile method can be used for dead channel correction in ECAL crystals (not the seed crystal).

- **H→γγ Data Quality Monitor on PVT(Physics Validation Team) Report**
  - To monitor the **variables** related to the **Higgs2GaGa** analysis, both for the MC samples and the ral data samples: m_2γ, pt_2 γ, eta_2 γ, cos(theta*)…..
  - Check the pre-production samples (10%~20% full production) before full production.
  - For the real data, can give simply and fast cut-base analysis results
- **Collabration on H→γγ** October Exercise 2009
  - Check the plots in different energy based on the same analysis codes
  - IHEP analyzed the 7TeV samples in Beijing (J. Tao, H. Xiao)
  - IPNL analyzed the 10TeV samples in Lyon (A. Falkiewicz , S. Gascon)
- **Full Sim. /Fast Sim. Comparisons**: Focus on the **photon shower shape** & **isolation variables**.

- Etc.

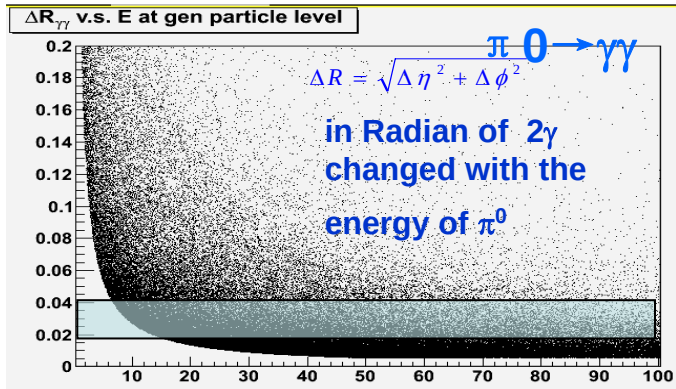
Photon Calibration strategy with the data at IHEP

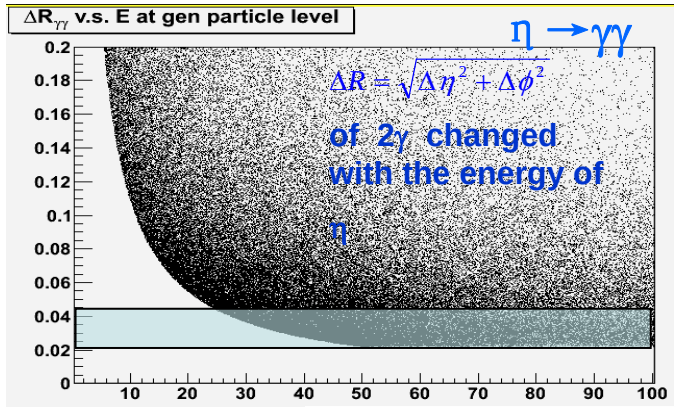
- With collisions, 2010 is THE YEAR for calibration activities.

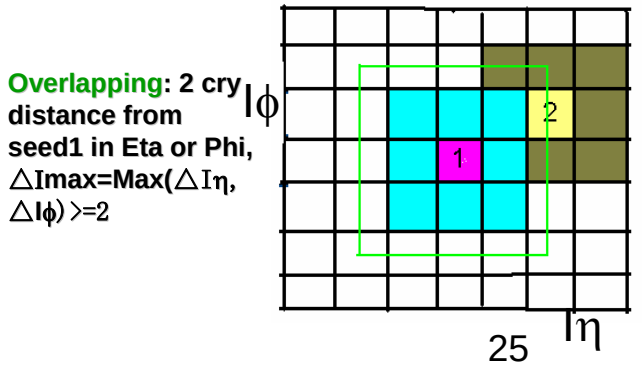
- ECAL calibration with $\pi^0 \rightarrow \gamma\gamma$ and $\eta \rightarrow \gamma\gamma$ at the startup.

- Cluster of γ candidates based on 3x3 crystals array, if the energy is higher, there will be overlapping between 2 γ candidates, considering the size of crystal ~0.0174× 0.0174 Radian in η-ϕ geometry.

- We will contribute to solve the shower overlapping problem in the higher energy region. The parametric shower shape profile method can be used for such purpose.

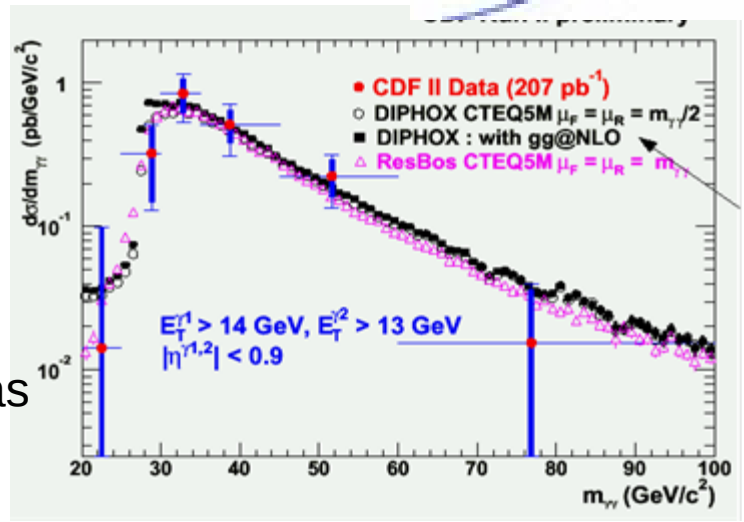


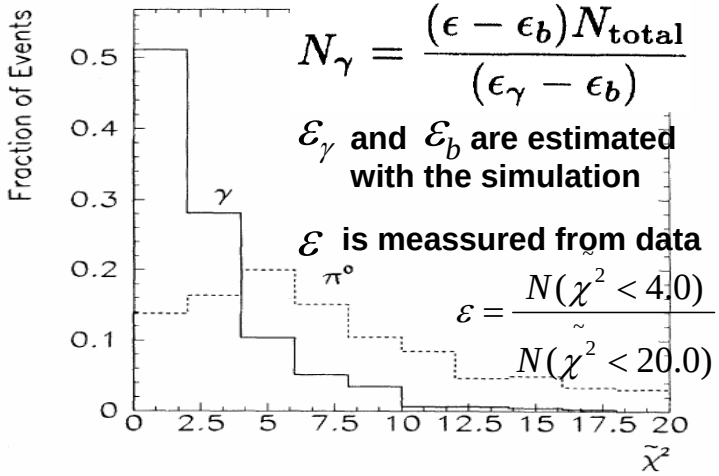




Contribution to Di-photons in CMS

- σ (γ γ + X) CDF published with 200pb^{-1} (hep-ex/0412050)
- Due to higher cross section, CMS will have equivalent statistics with ~10pb^{-1}.
- The decision of the number of "TRUE" photons exclude the backgroud from neutral mesons such as π^0 and η that decay to multiple photons, is a very inportant point. **(**photon purity problem**)**
- The parametric shower shape profile method as in CDF analysis will contribute a lot on this topic for the unconverted photon case. **(IHEP)**
- "Template method" trying with the outputs of Neural Network with γ/π0 discrmination analysis. **(IPNL)**





$$N_\gamma = \frac{(\epsilon - \epsilon_b)N_{\text{total}}}{(\epsilon_\gamma - \epsilon_b)}$$

$\mathcal{E}_\gamma$ and $\mathcal{E}_b$ are estimated with the simulation

$\mathcal{E}$ is meassured from data

$$\varepsilon = \frac{N(\tilde{\chi}^2 < 4.0)}{N(\tilde{\chi}^2 < 20.0)}$$

FIG. 3. Simulated $\tilde{\chi}^2$ distributions for 15 GeV/c photons (solid) and π^0's (dashed).

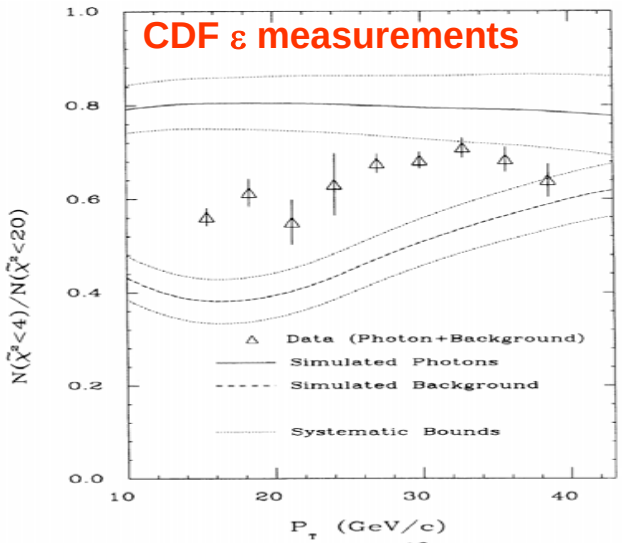


FIG. 23. Signal and background $\tilde{\chi}^2$ efficiencies for the profile method. Also shown are the total systematic uncertainties on these efficiencies, and the measured efficiency of the data as a function of photon P_t.

Conclusions

- **We have made tight collabration on the photon studies based on the MC simulation analysis.**

- **We continue to make good progress in $H\rightarrow\gamma\gamma$ and photon infrastructure through our cooperation efforts, which have continued to expand.**

- **We look forward to continuing our efforts, especially on the real data analysis based on the task force of Egamma objects, QCD-photon analysis and $H\rightarrow\gamma\gamma$ analysis, which make good use of our groups' complementarities**

Acknowledgements

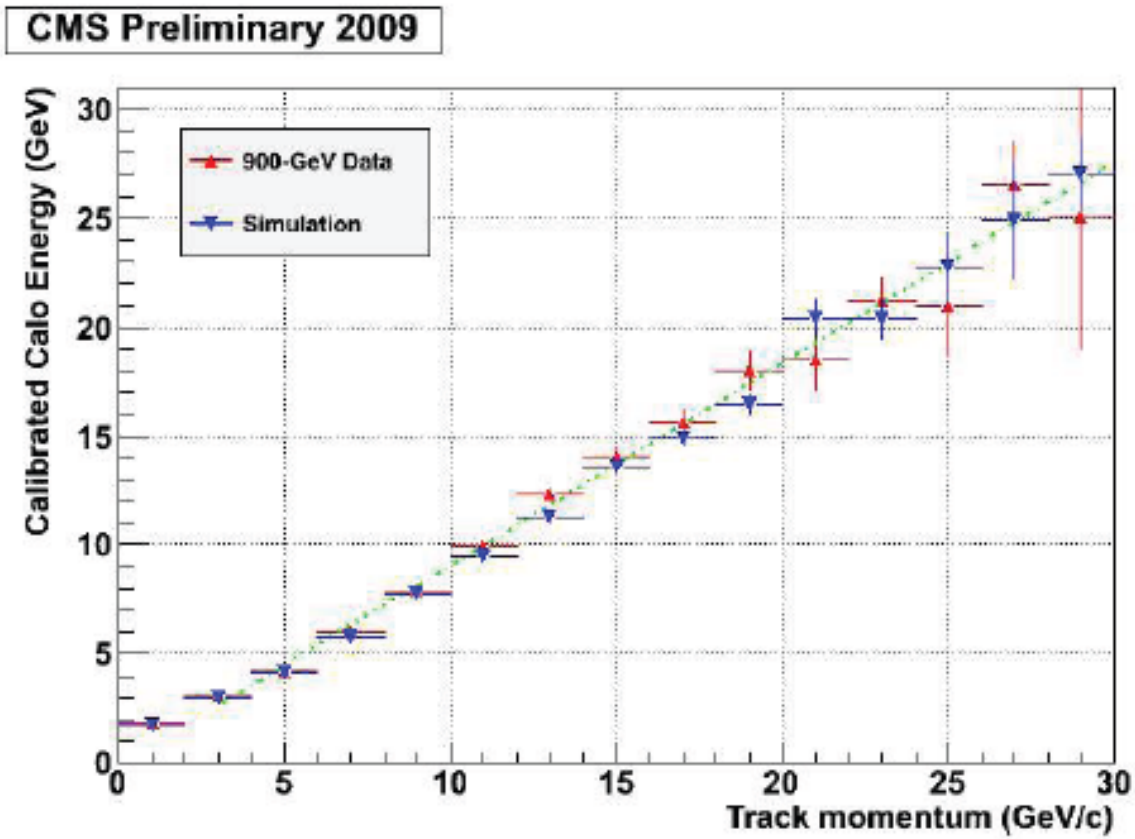
Thanks to:

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

Thanks *Merci* 谢谢

Backup

Charged hadron response



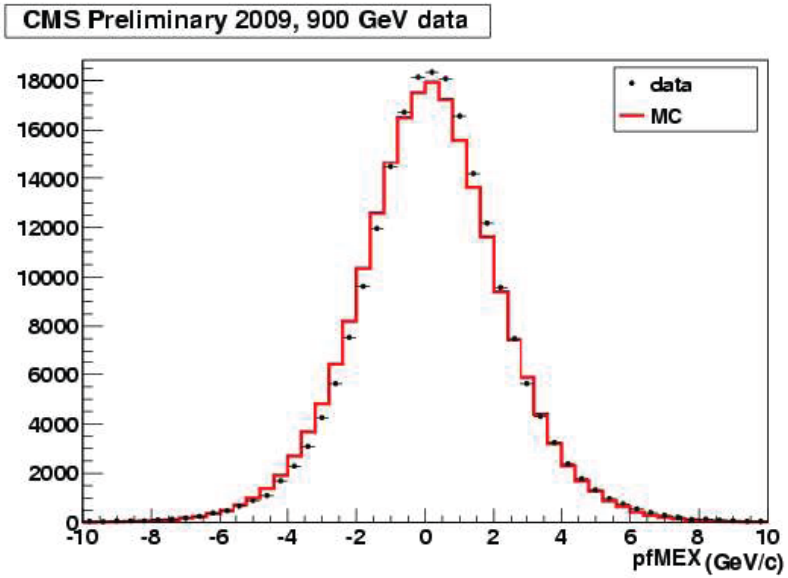
Selections:

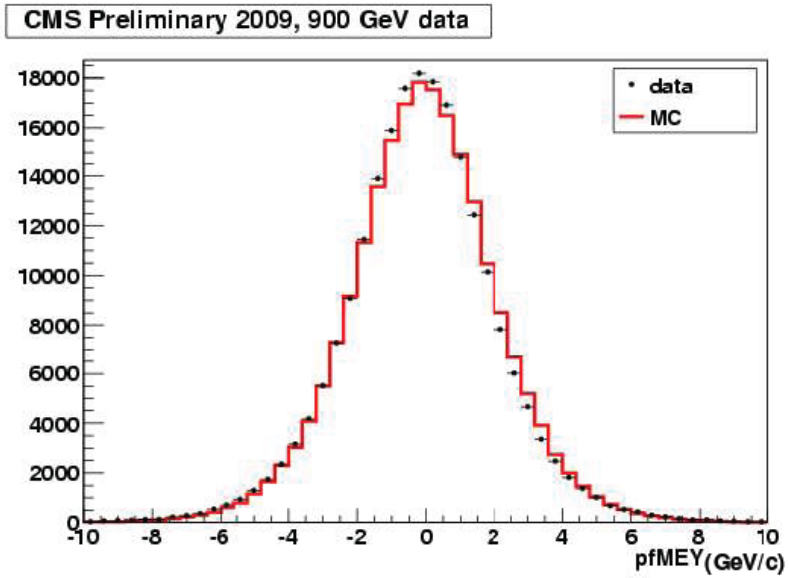
- track p_T > 1 GeV/c and |η| < 2.4
- nHits > 14 and nPixelHits > 1
- only one track in the corresponding "PFBlock"
- Something in the HCAL linked to the track

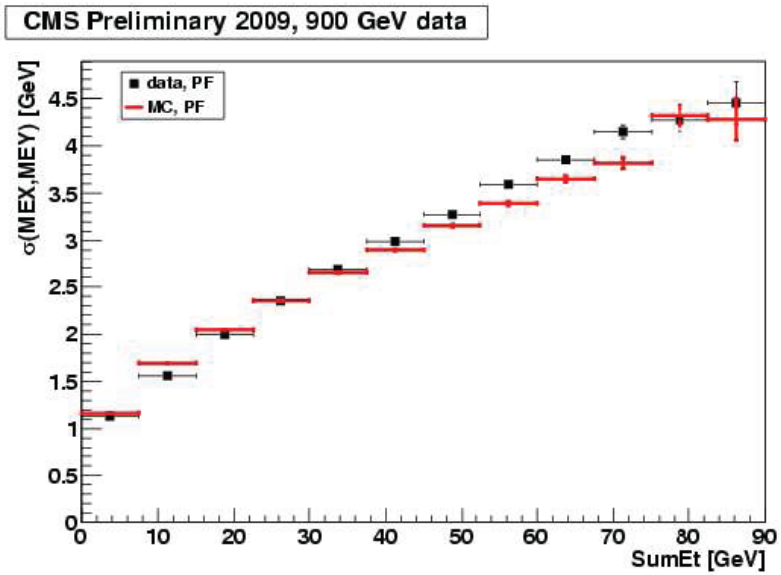
Linear fit to the data above 3 GeV

MC based calibration is validated

Particle Flow MET







Note: In plot at left σ (MEX,MEY) corresponds to a Gaussian fit to a histogram containing MEX and MEY. Thus one has 2 entries per event and σ corresponds to the resolution on one coordinate of MET only.

Empirical formula to parameterize the EM shower shape

- We combined the longitudinal formula and lateral formula of EM shower to get the empirical 3-dimentional formula. The lateral formula was obtained from the ECAL study of AMS (Alpha Magnetic Spectrometer) experiment.
- The longitudinal profile of EM shower can be well described by a Gamma-distribution:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

where *t* is the shower depth. *E0* is the Energy. *a* and *b* are parameters

- The following formula was used to describe the lateral profile:

$$f(r) = \frac{6R^2 r}{(r+R)^4} \qquad f(r)dr = \frac{3}{\pi}\frac{R^2}{(r+R)^4} \cdot rdr \int_0^{2\pi} d\theta$$

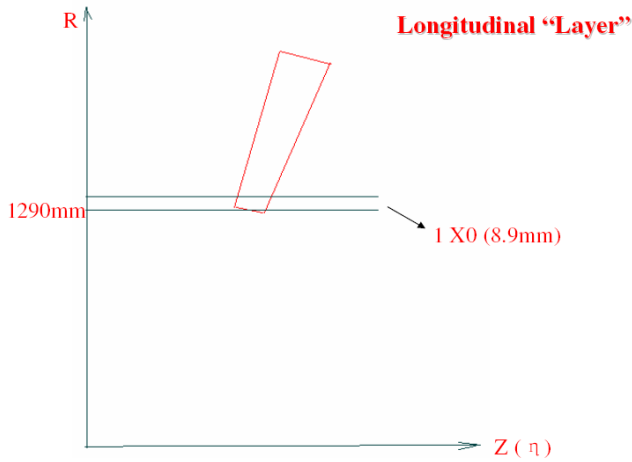
where *r* is the distance of a crystal to the COG (centre of gravity), and *R* is a parameter.

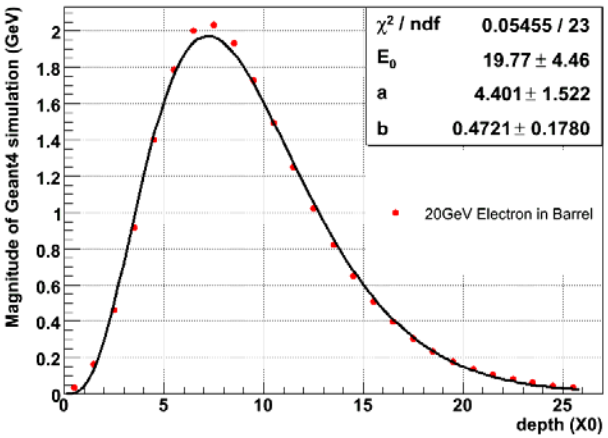
- The longitudinal profile was validated from the CMS Geant4 simulation samples.
- For the whole empirical formula (Longitudinal + Lateral), the electron data of ECAL test beam 2006 were used for validation.

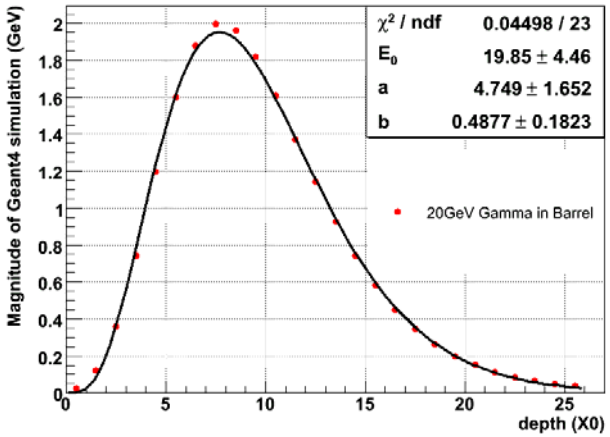
EM Showers -- Longitudinal profile

Determine longitudinal profile from CMS Geant4 Simulation

- Along the R(=√x2+y2) direction, from R=1290mm, about 26 layers are split in G4 Sim, with each layer about 1X0 .
- Simulation samples of single particles in SW167 with incident point: η =0.05, φ =0.22.
- Using "EcalSimHitsValidProducer" in the CMSSW/Validation package
- ~2000 evts/sample to see the average distribution



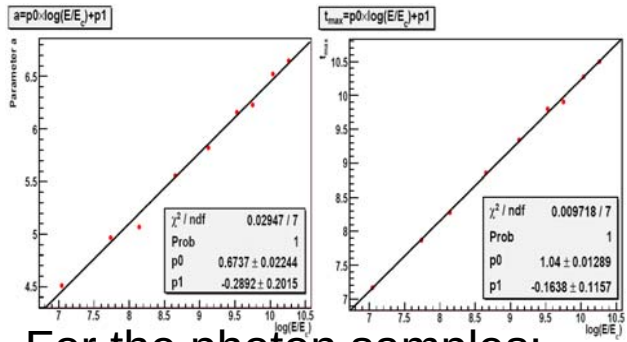




20GeV Electron longitudinal profile fitted by the Gamma-distribution

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

20GeV Gamma longitudinal profile fitted by the Gamma-distribution



For the photon samples:

$$a = 0.67 \times \log \frac{E}{E_c} - 0.29$$

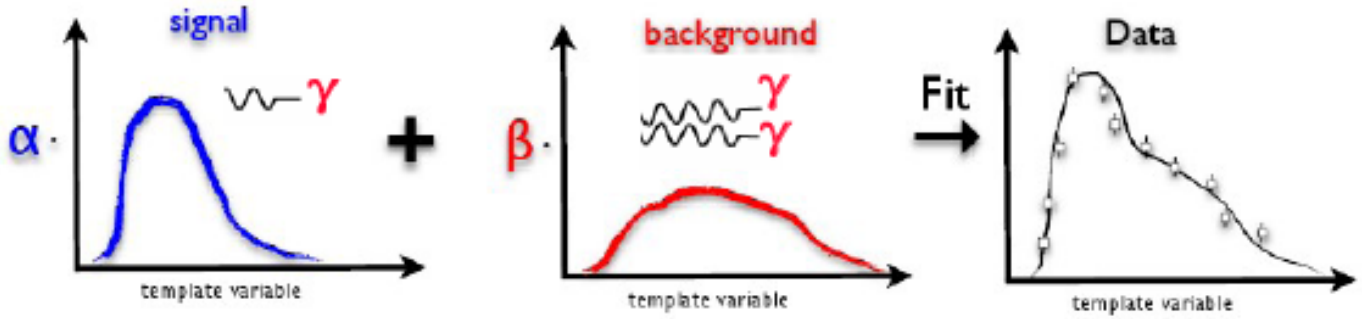
$$t_{max} = 1.04 \times \log \frac{E}{E_c} - 0.16$$

$$t_{max} = \frac{a-1}{b}$$

E: incident energy
Ec: critical energy

Template method

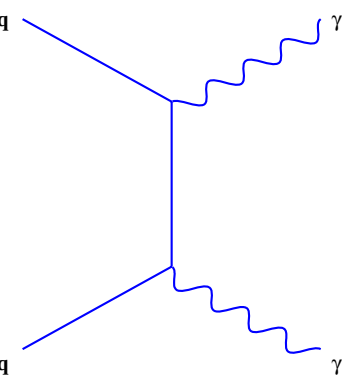
- How to determine the true content of photons?
  - Find a variable to discriminate signal and background
  - Determine signal and background content in data by fitting the distribution



- Use cluster shape (σ^2_{η}) as discriminating variable
- **Data-driven** method to obtain templates:
  - Photons: use electrons from **Z→ee**
  - Jets: use **non-isolated** photon candidates (5GeV/c<TrackIso<10GeV/c)

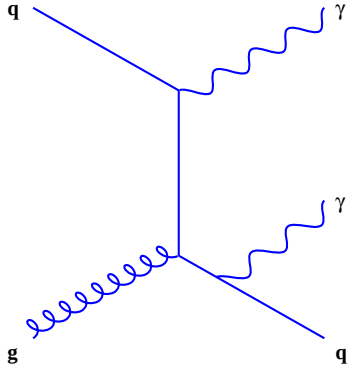
γγ processes and their description/calculation I

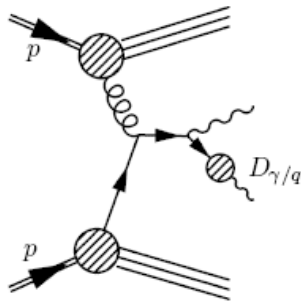
Born

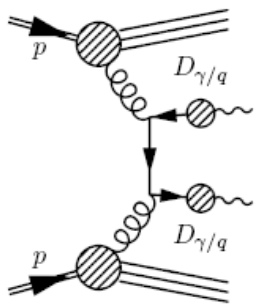


γ+j,j→π⁰

Brem + Fragmentation

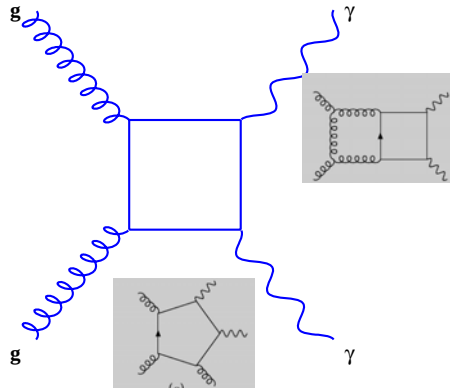






j+j,jj→π⁰+π⁰

Box: gg-> γγ



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

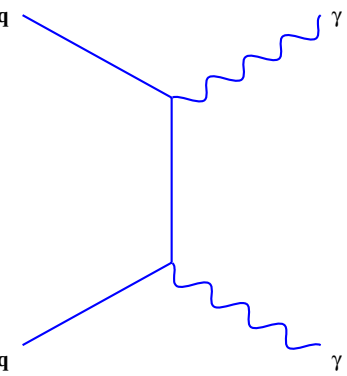
LO Codes: 'PS': PYTHIA (Sjostrand..)
Herwig
'ME': ALPGEN (Mangano..)
MadGraph (Stelzer...)
...

Binoth,Guillet, Pilon
Balazs, Nevski, Yuan

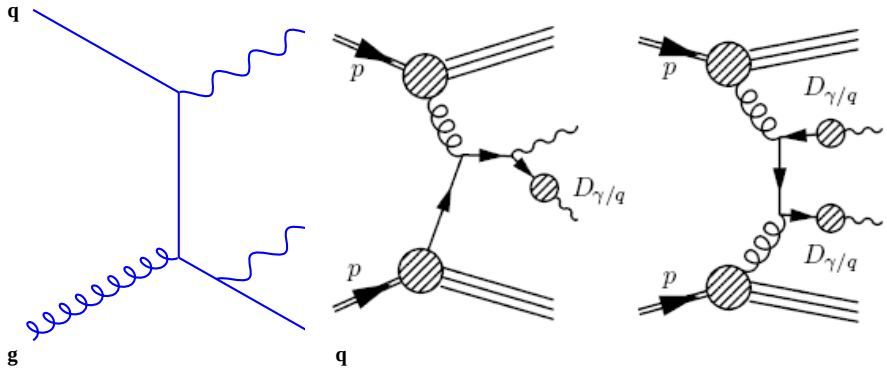
+ gamma2MC
(Bern, Dixon, Schmidt)
+ NLOjet++ (Nagy) + …

$\gamma\gamma$ processes and their description/calculation II

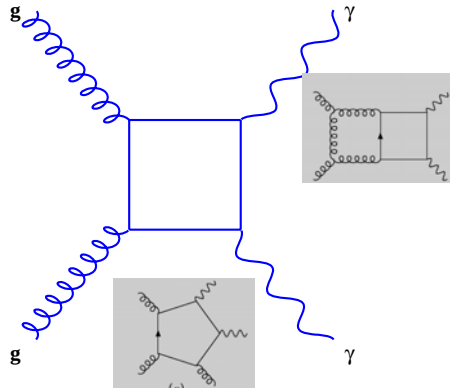
Born



Brem + Fragmentation



Box: gg-> $\gamma\gamma$



PYTHIA : qq->$\gamma\gamma$ with ISR

DIPHOX: LO: qq->$\gamma\gamma$,
NLO: qq->$\gamma\gamma$g + virtual gluon

Resbos

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

gamma2MC & Resbos: LO and NLO

γ+j,j→π^0

PYTHIA : qg->γq with γ + π^0 signature. ISR/FSR; no mult. int.

DIPHOX: qg->γq at NLO with q->π^0 fragmentation

j+j,jj→π^0+π^0

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

DIPHOX: NLO 2->2 with g, q->π^0 fragmentation