Photon+X at the LPC: Summary
Jterm III, January 16 2009

Marat Gataullin (Caltech)

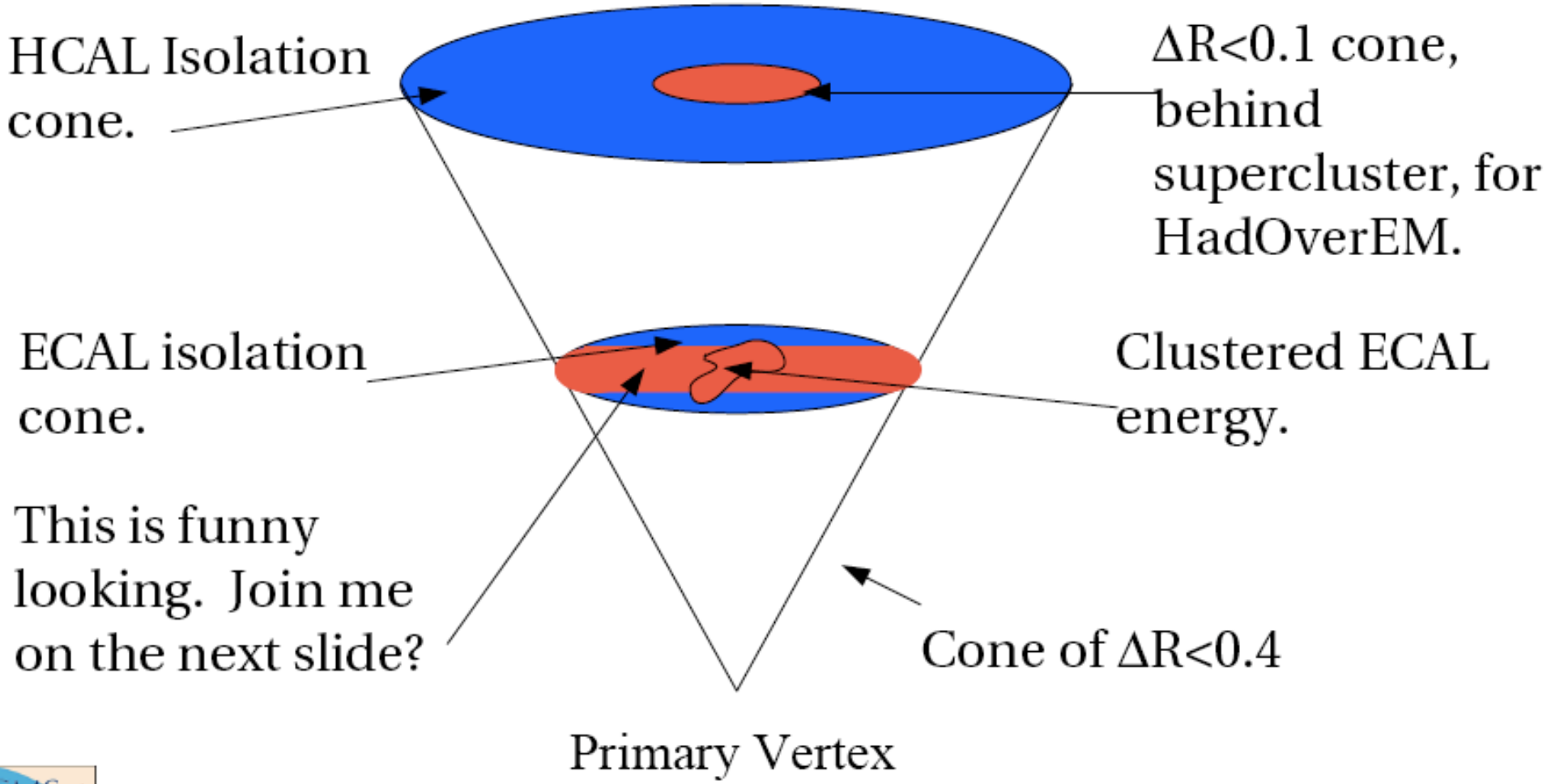
Yuri Gershtein (Rutgers)

on behalf of Photon+X

Snapshot

- We started only a year ago: 1st meeting 01/17/2008
- Main focus remains on the development of the photon ID software and data-driven methods for estimating backgrounds from jets/electrons/cosmics/beam halo
  - The photon ID toolbox in CMSSW was largely developed in our group (A. Askew and Yuri)
- Detector Commissioning Work
  - Cosmic and beam halo studies
  - First meaningful results with the beam data!
- Physics with photons
  - Plenty of early interesting analyses:
    GMSB SUSY, RS Gravitons, W/Z+γ; QCD with diphotons and γ+jets, Higgs, LED in γ+MET, excited leptons. See also Yuri's photon+X introduction on Wed.

Anatomy of reco::Photon



Excellent Photon Tutorial by Andrew Askew on Tuesday

Available on CMS information server

CMS NOTE 2008/00

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

Note in preparation.

Author list is not the full list of people in our group!

23 July 200

Photon Identification for CMS Startup

A. Askew, O. Atramentov, Y. Gershtein,

Florida State University, Tallahassee, FL.

A. Debenedetti,

University of Minnesota, Minneapolis, MN.

M. Gataullin, V. Litvin, J. Veverka,

California Institute of Technology, Pasadena, CA.

C. Kopecky, T. Miceli, J. Stilley, M. Tripathi

University of California at Davis, Davis, CA.

V. Gaultney,

Florida International University, Miami, FL.

S. Shrestha,

Kansas State University, Manhattan, KS.

M. Anderson,

University of Wisconsin, Madison, WI.

J. Lamb

University of California at Santa Barbara, Santa Barbara, CA.

M. Mozer

IIHE, Brussels, Belguim.

N. Marinelli

University of Notre Dame, Notre Dame, IN

Abstract

This note defines the methods by which the identification of photons may be verified from data on start up. This verification includes measurement of the photon efficiency, as well as methods for obtaining photon purity. Backgrounds to photons from jets and electrons are discussed, and an example set of "vanilla" photon identification requirements are presented.

Contents

Photon ID: Tag and Probe

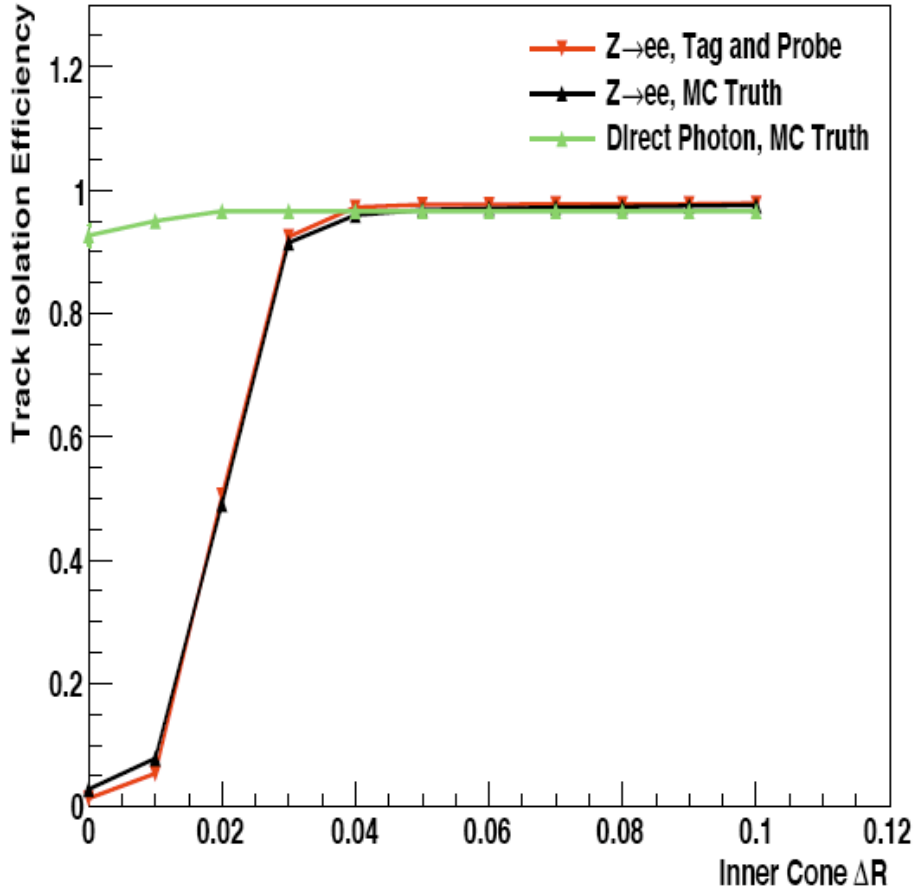
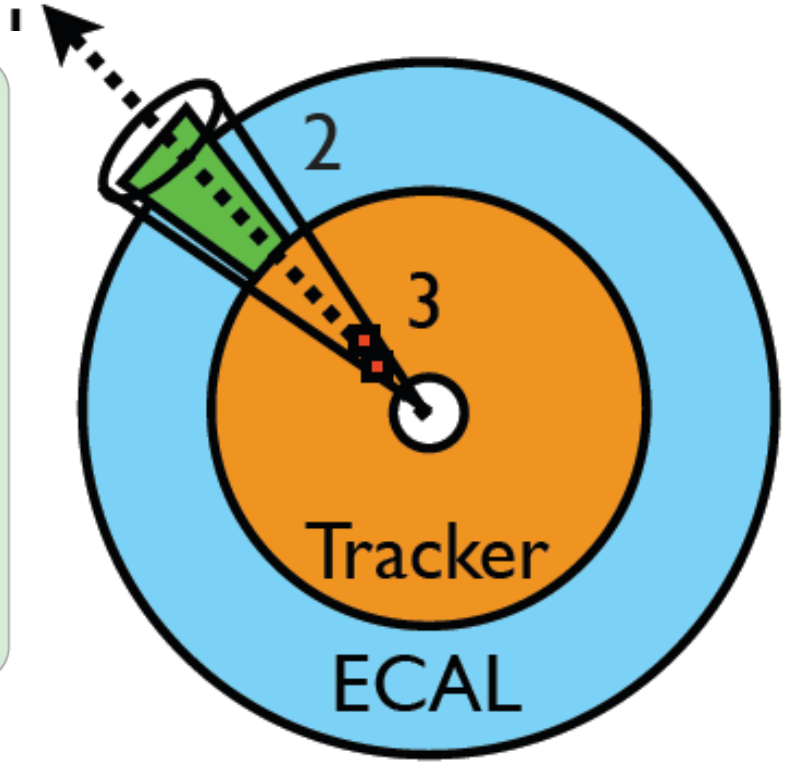


Figure 6: Efficiency of requiring that the sum of track p_T in a hollow cone is smaller than 5 GeV as a function of the inner cone radius. The efficiency of the tag-and-probe method on Monte Carlo electrons is shown in red. The efficiency of the Monte Carlo truth electrons is shown in black. The Monte Carlo truth efficiency for photons is shown in green.

Alternative Method for Electron Rejection

Pixel Seeds

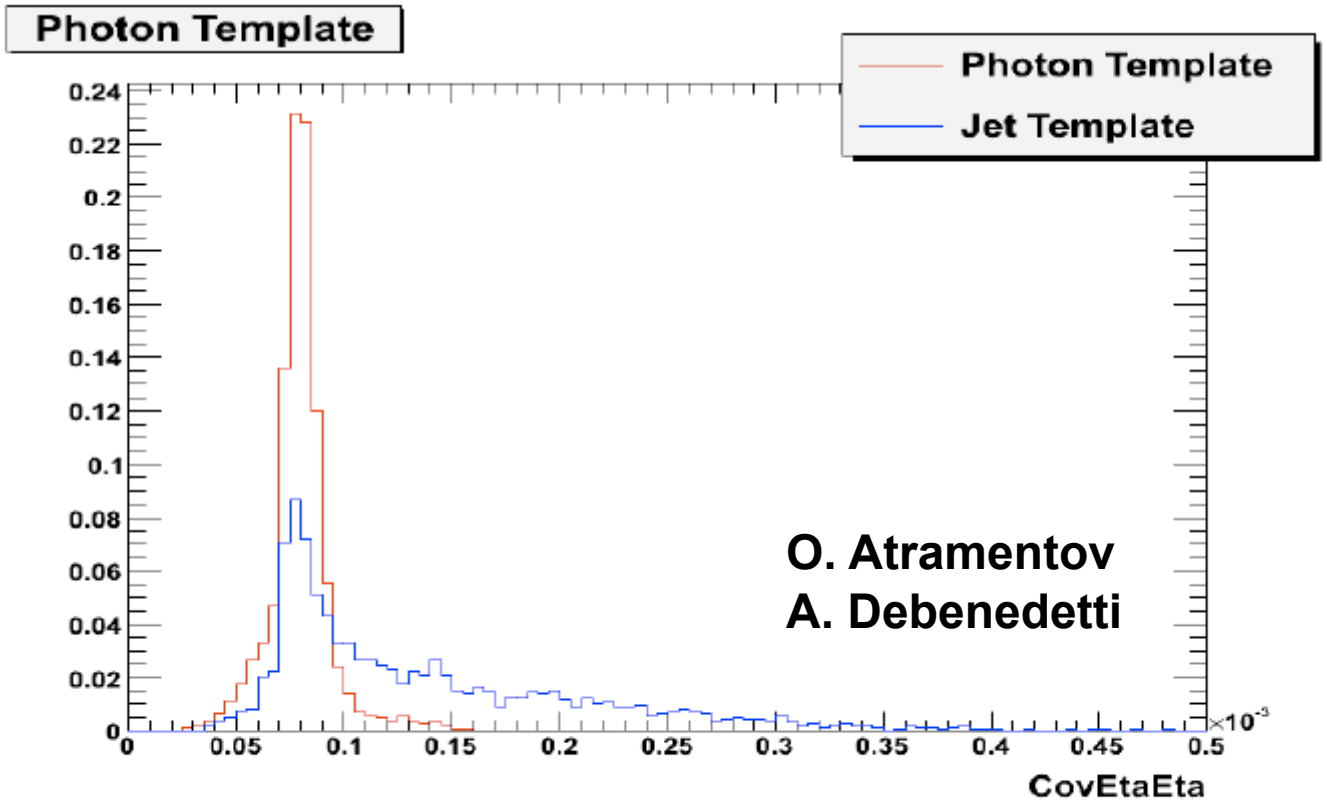
- Search in silicon pixel detectors along both possible curves for first pixel hit
- A more constrained search locates the second pixel hit



This method may help avoid complications due to photon conversions. First results are promising: 95% of electrons are rejected (Carley Kopecky).

Template Method to Estimate Jet Fake Rate

Data-driven approach for estimate the jet-fake contamination.
Effectively used in our on-going physics analysis.

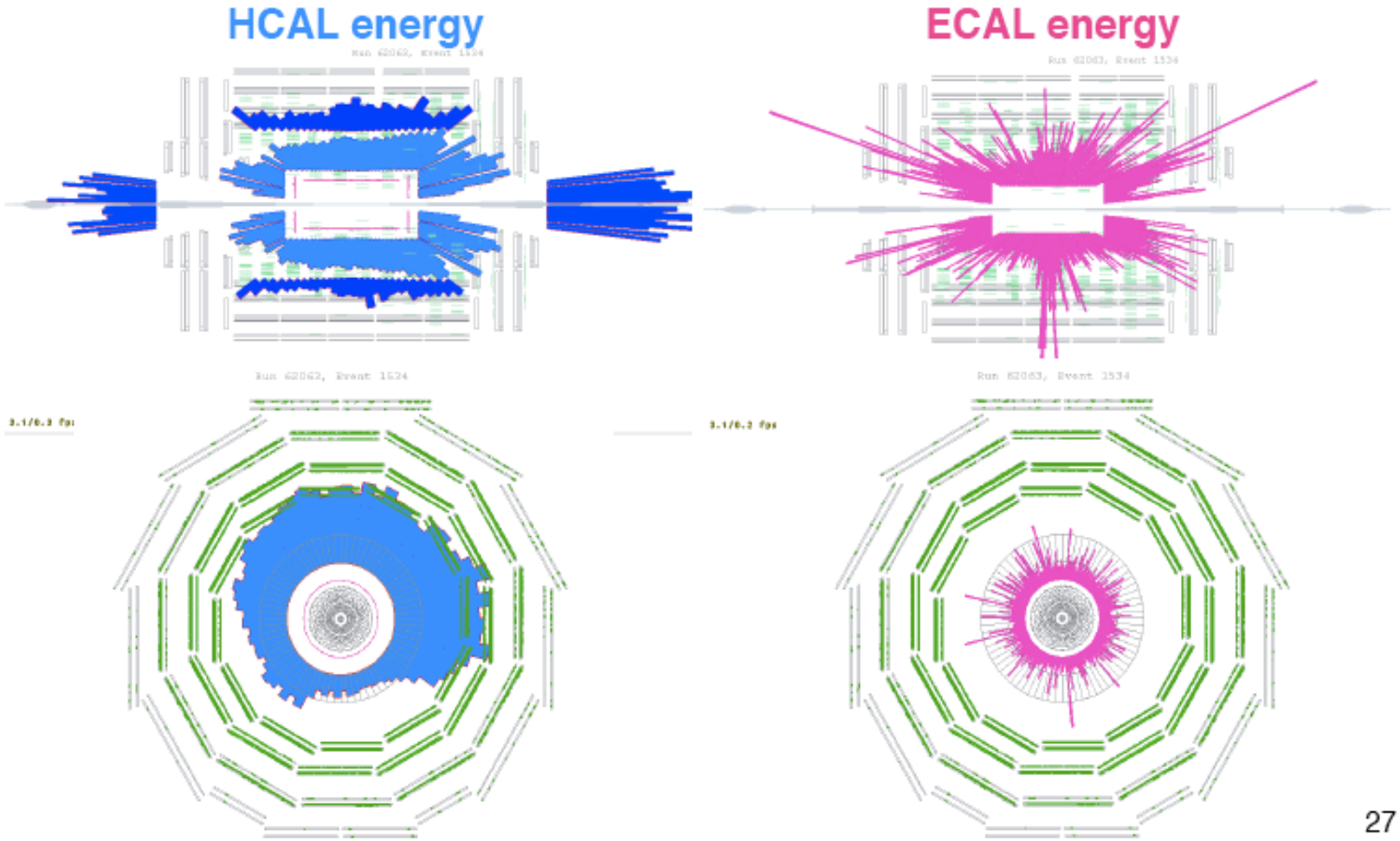


The template Variable in jets compared to it in photons

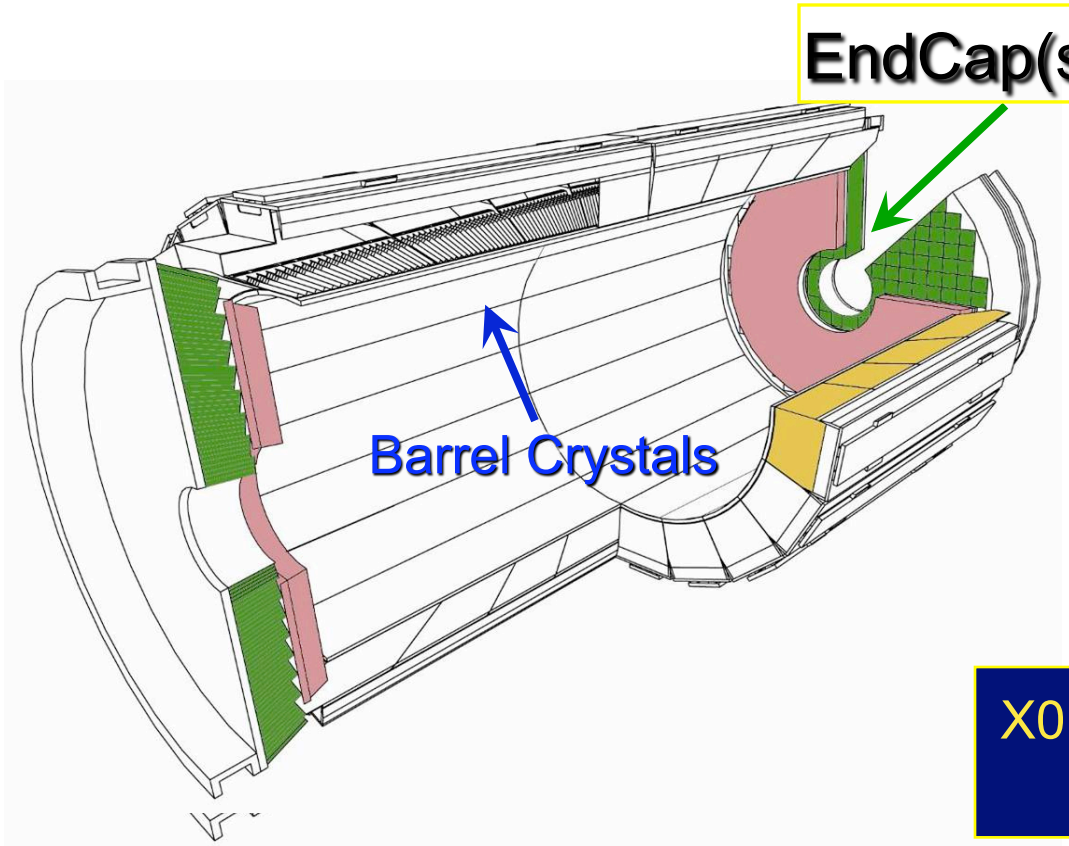
Excellent ECAL Tutorial by Toyoko Orimoto on Monday

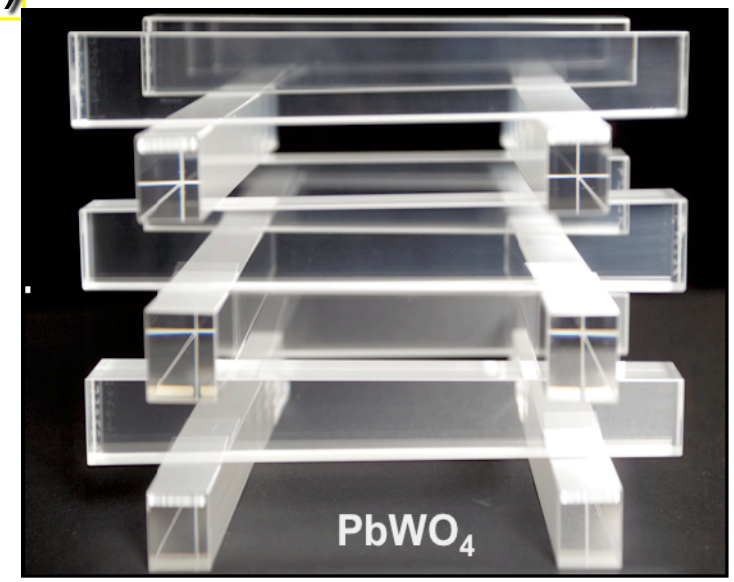
First Beam Data: Splash Events

Beam was sent to collimators ~150m upstream of CMS, creating a fixed target like environment at CMS, ~2×10^9 protons on collimator



CMS ECAL: 76K $PbWO_4$ Crystals, 90 Tons



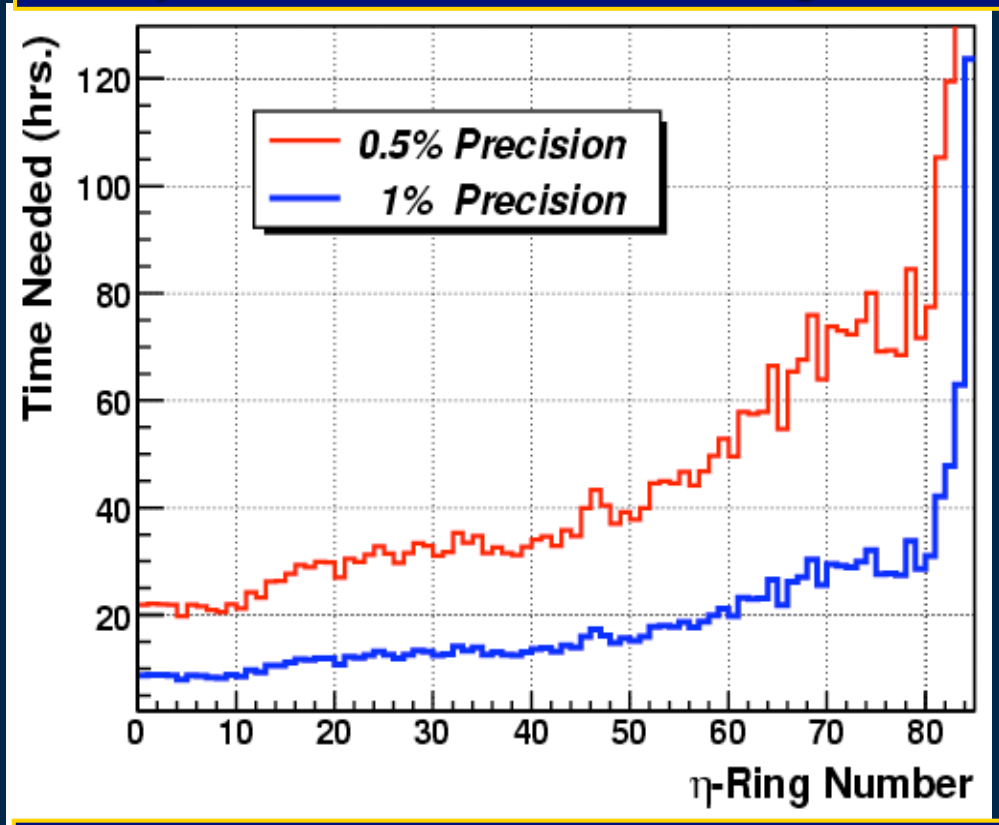


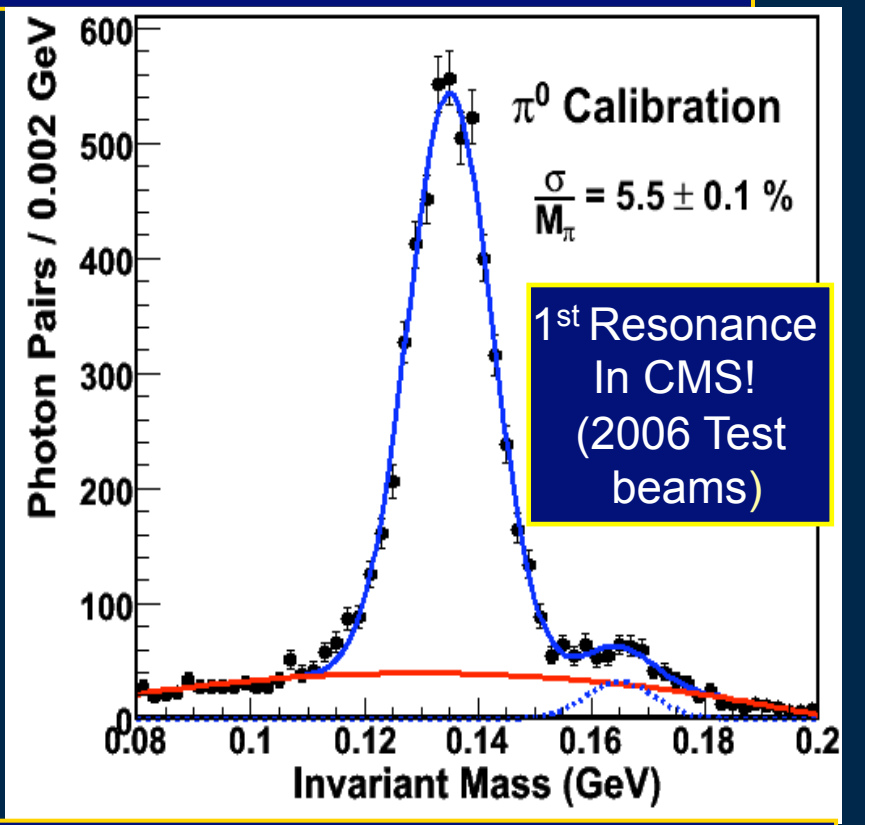
X_0 = 0.89 cm; $R_{Moliere}$ = 2.2 cm;
80% of Light in 25 nsec

Barrel: 61,200 crystals (25.8 X0) 170 φ-rings of 360 ($|\eta| < 1.48$)
Two Endcaps: 7,324 crystals (24.7 X0) Each ($1.48 < |\eta| < 3$)
Test beams: energy resolution of <0.5% (~100 GeV e^-)
Goal: achieve and maintain it in situ at the LHC !

ECAL Calibration With $\pi^0 \rightarrow \gamma\gamma$ Decays

Barrel study: $L=2\times10^{33}$ gives average $\pi^0 \rightarrow \gamma\gamma$ rate of 1.5 kHz or 2,100 π^0/crystal/day with signal-to-background ≈ 2.0.
Only 20 - 80 hours of running needed to calibrate 95% of barrel.

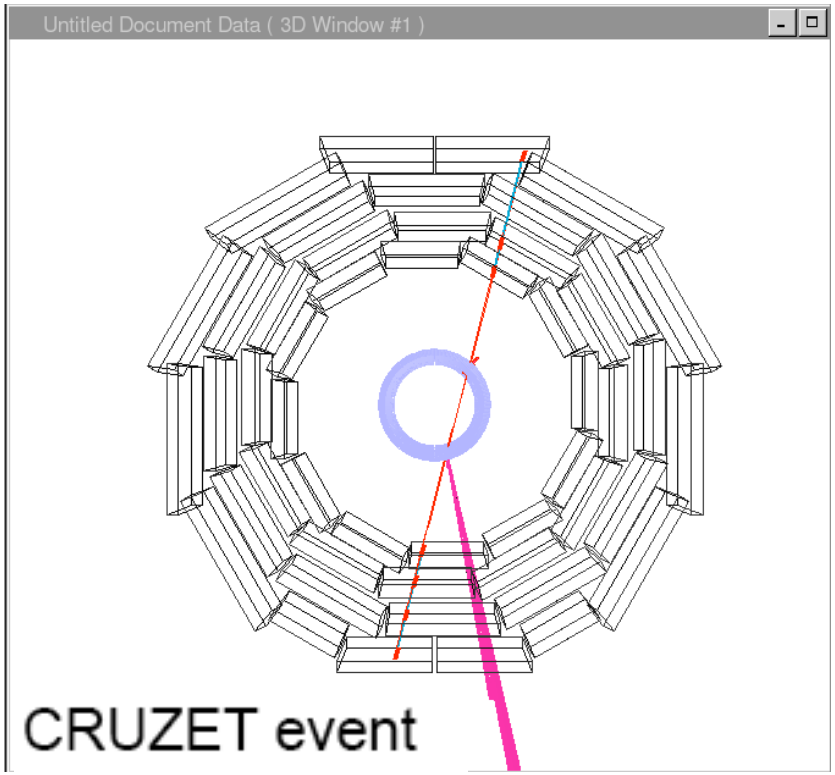


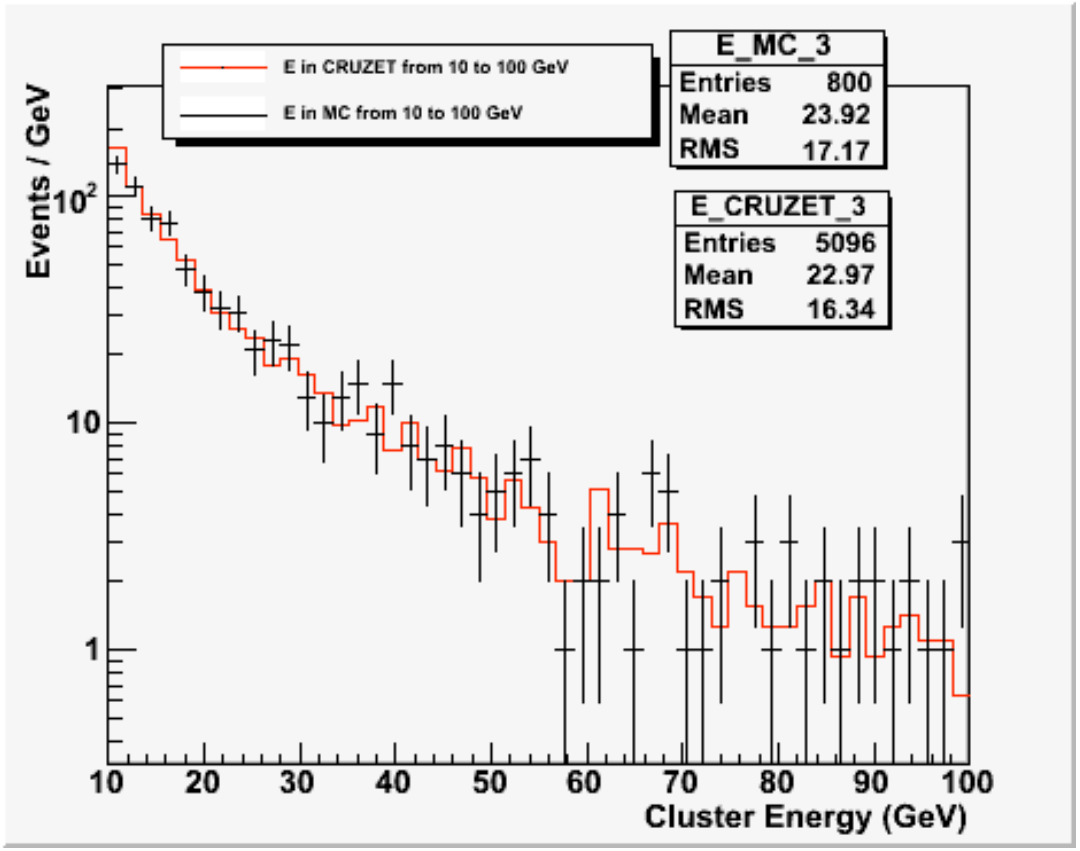


Very useful at startup: 1% Calibration in ~1 Week at $10^{30}cm^{-2}s^{-1}$

Cosmic Photons

CRUZET/CRAFT data provides a direct comparison of data and detector simulation: first results are promising

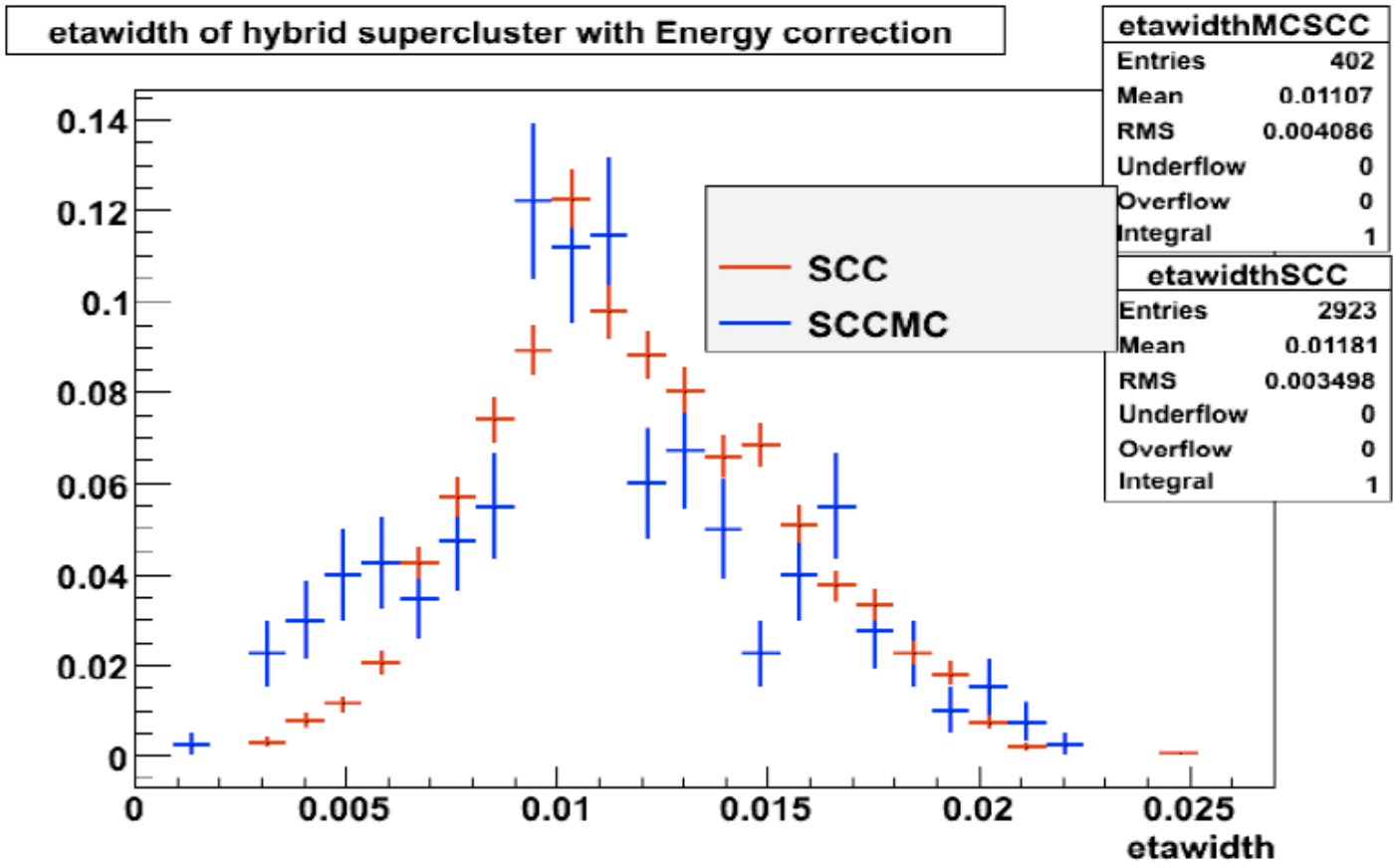




S. Shrestha, K. Shin

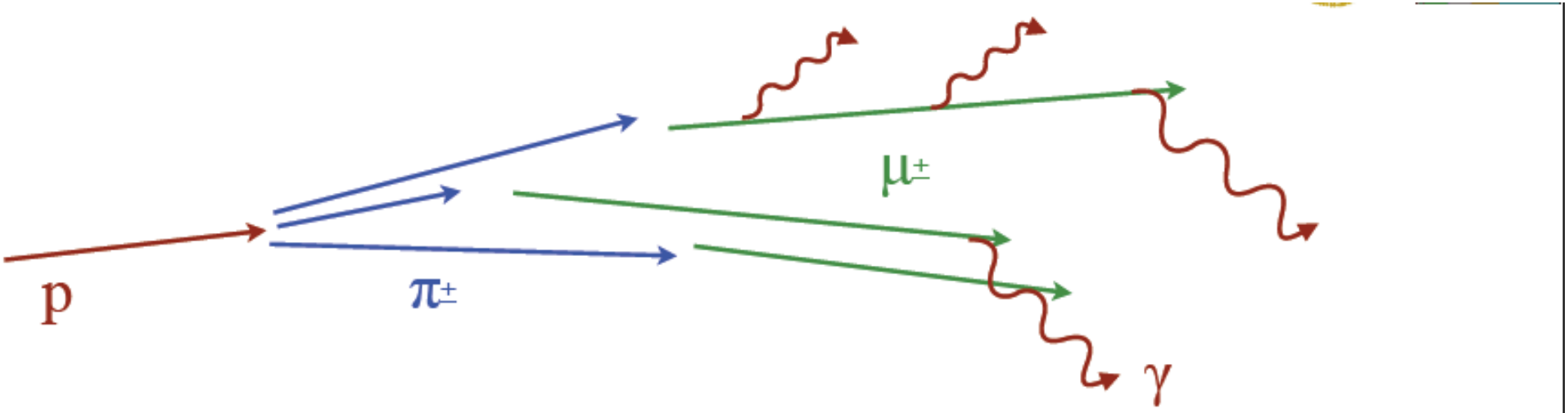
Cosmic Photons

Understanding the shower profile would be important for future cosmic rejection in e.g. LED searches.



Beam-Halo Photons

Important to study for any searches with MET, e.g. LED in γ+MET



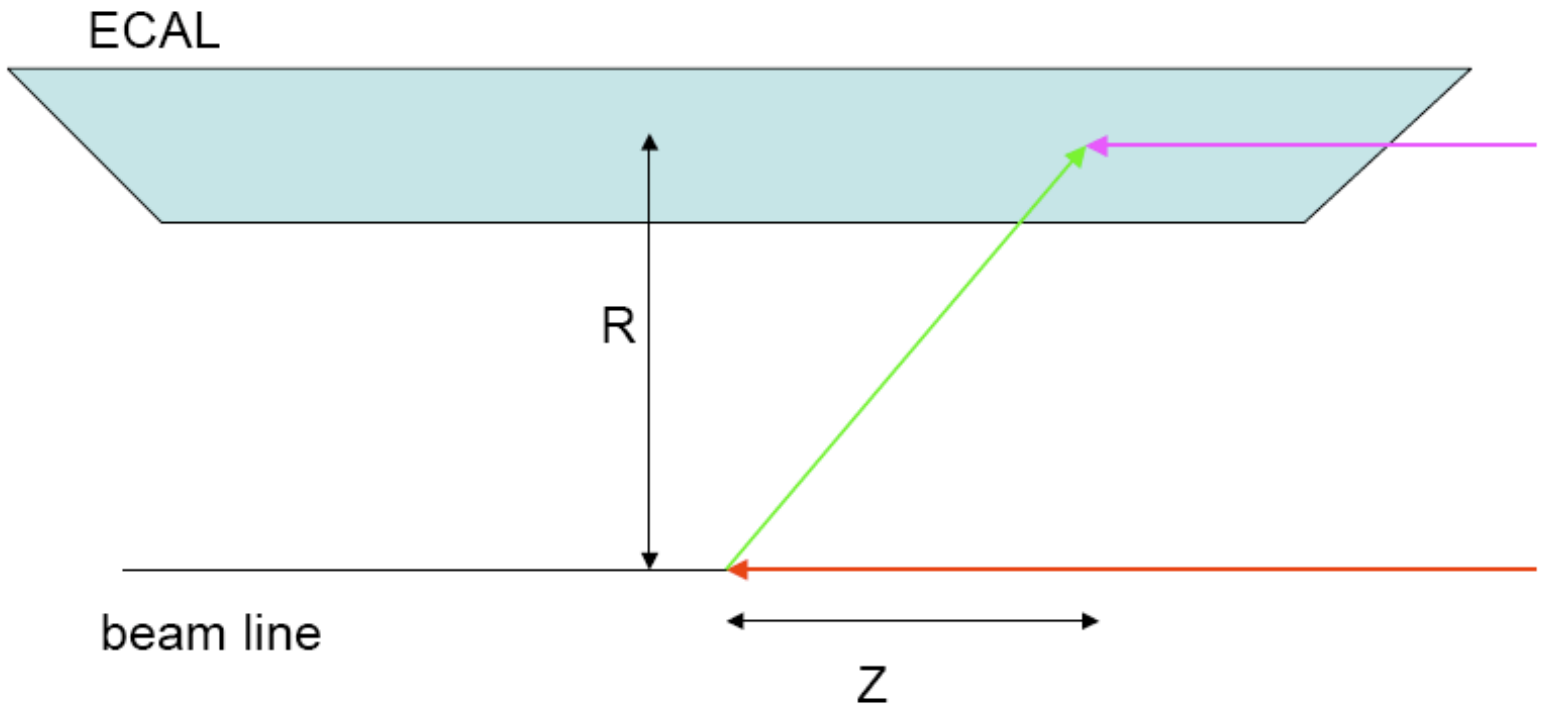
1. Proton interacts with gas/pipe wall, showering to...

2. Pions which decay to...

3. Muons that live long enough to interact with detectors

4. Bremsstrahlung can be confused with interesting, high energy prompt γ!

CMS ECAL Timing



Assume that halo muon (purple) and proton (red) are parallell at each other and have the same z(t). Then the extra time that it takes for the "real" photon (green) to get to the calorimeter is:

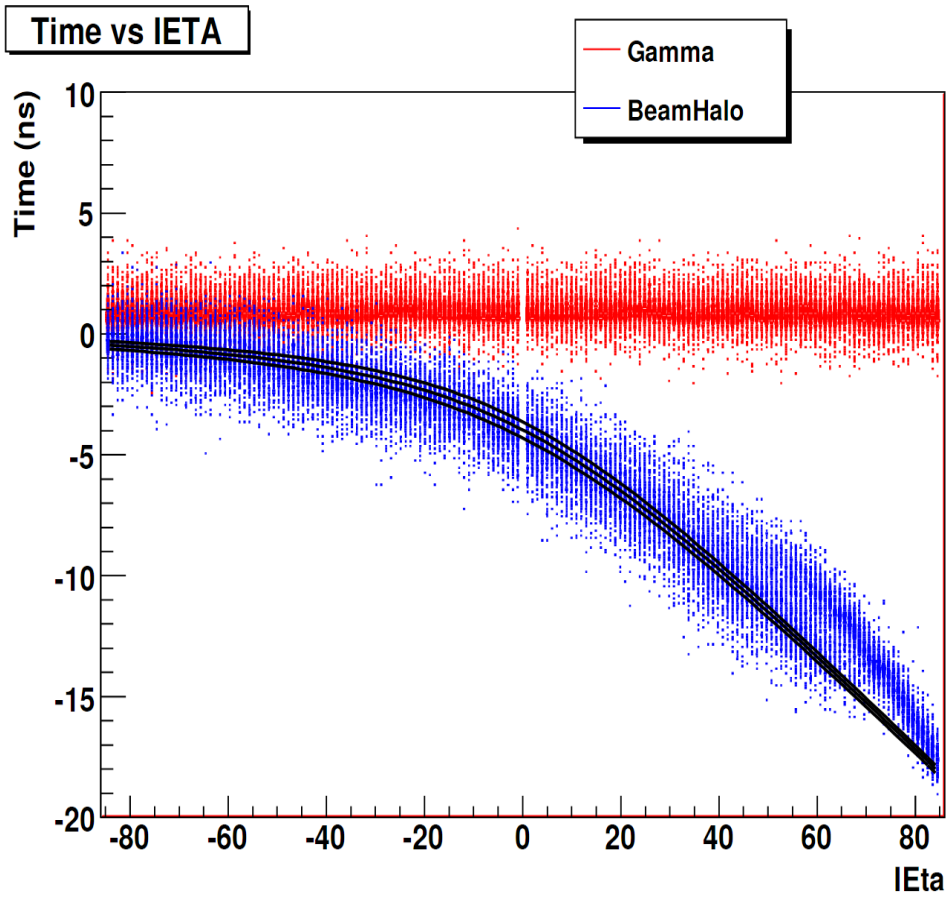
$$\Delta t = (Z + \sqrt{Z^2 + R^2})/c$$

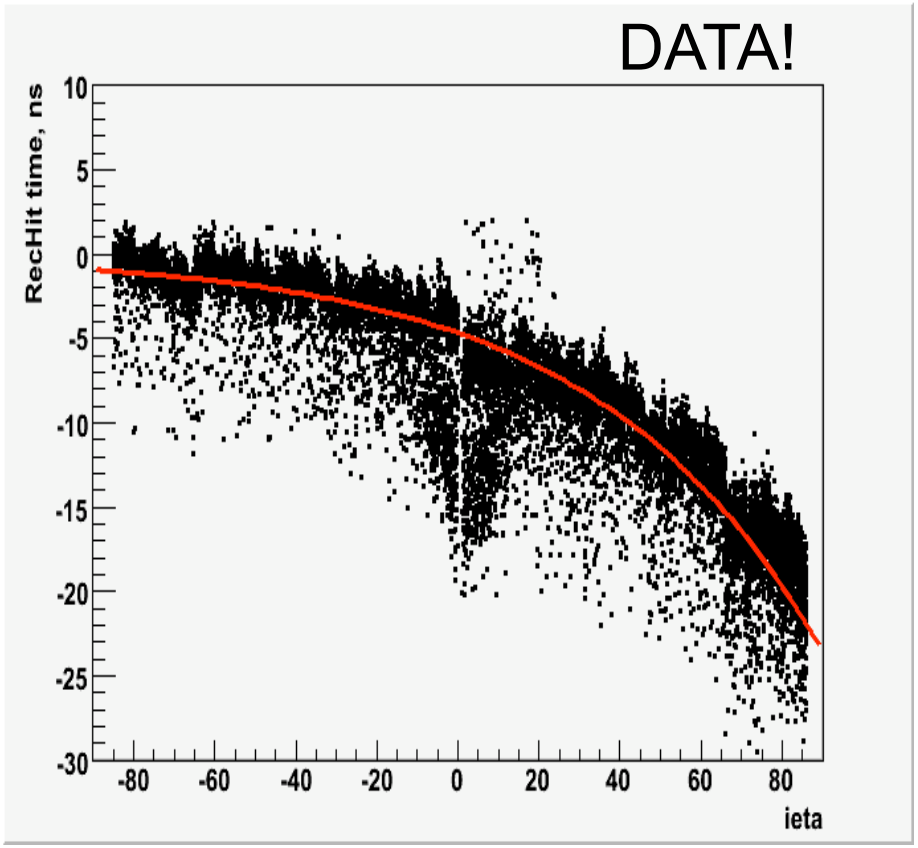
M. Balazs, Yuri

ECAL Timing in Data!

Yuri

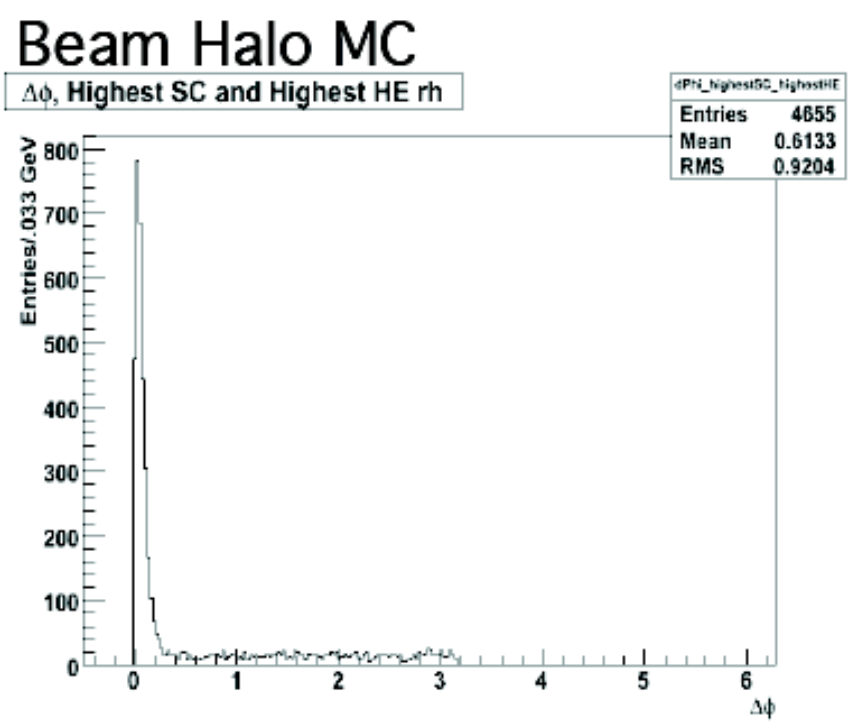
- First Result with the beam data! Good agreement with the MC
- Important for 1) MET searches; 2) searches for long-lived particles. A new algorithm is currently being implemented in CMSSW by A. Ledovskoy and M. Balazs.

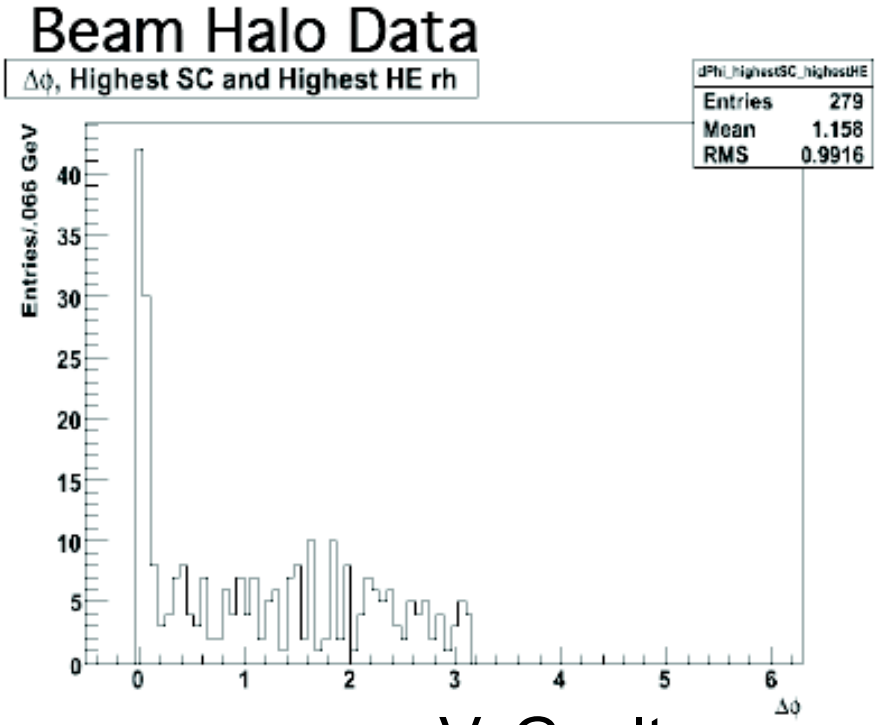




Early Beam Halo Tagging: HE

- Incoming BH muons should pass through HE on the way to passing through EB. The positions of these hits in phi tend to correlate well, both in the BH Monte Carlo, and the BH data we have.

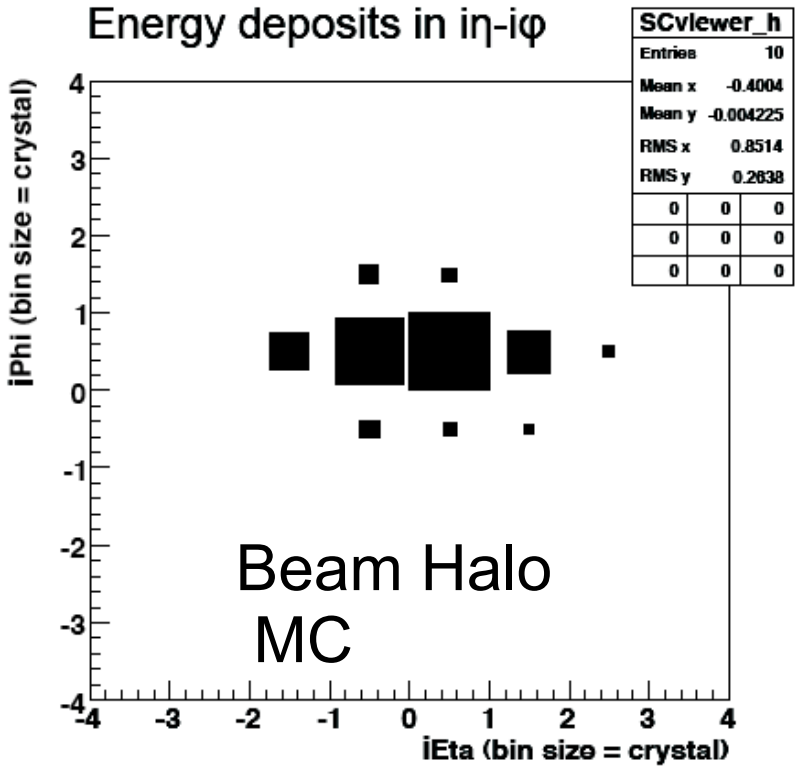


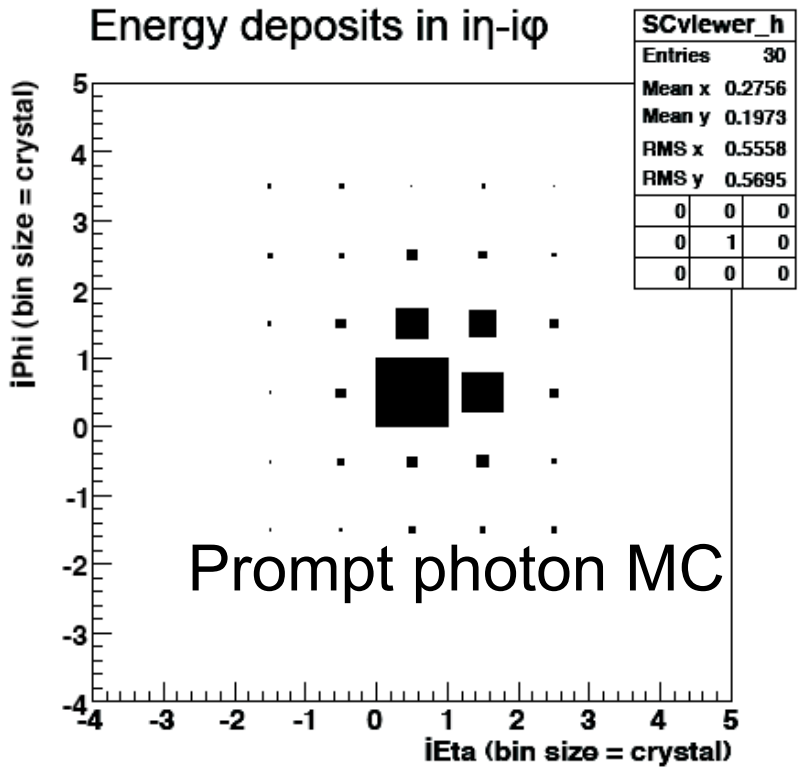


V. Gaultney

Tagging Beam Halo with Shower Shapes

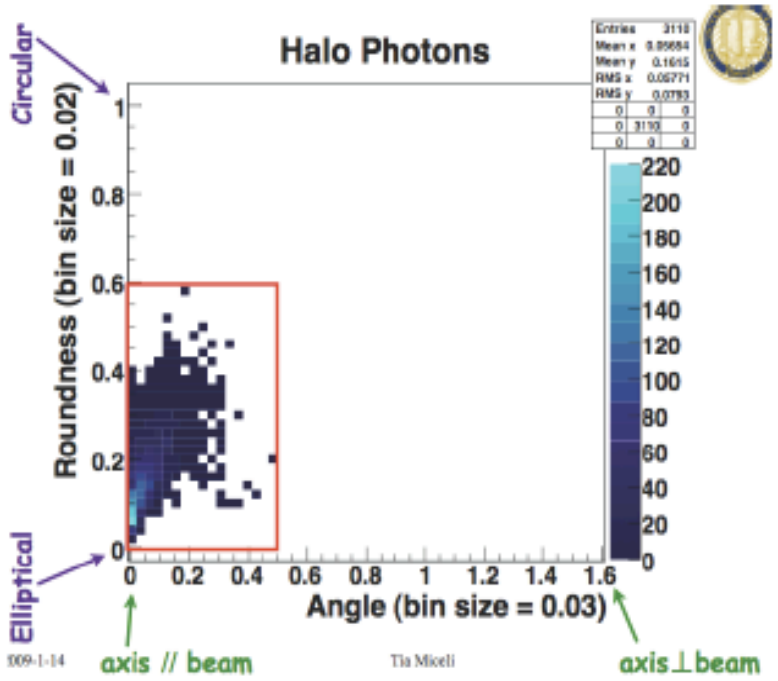
- We know that brem. events from beam halo muons will be "more parallel" to the beam axis.
- This would seem a good way to differentiate these events from prompt photons.

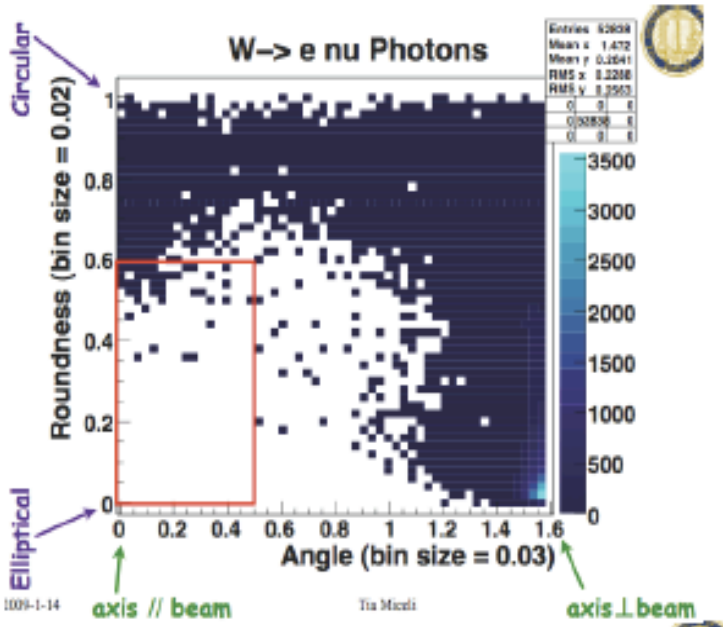


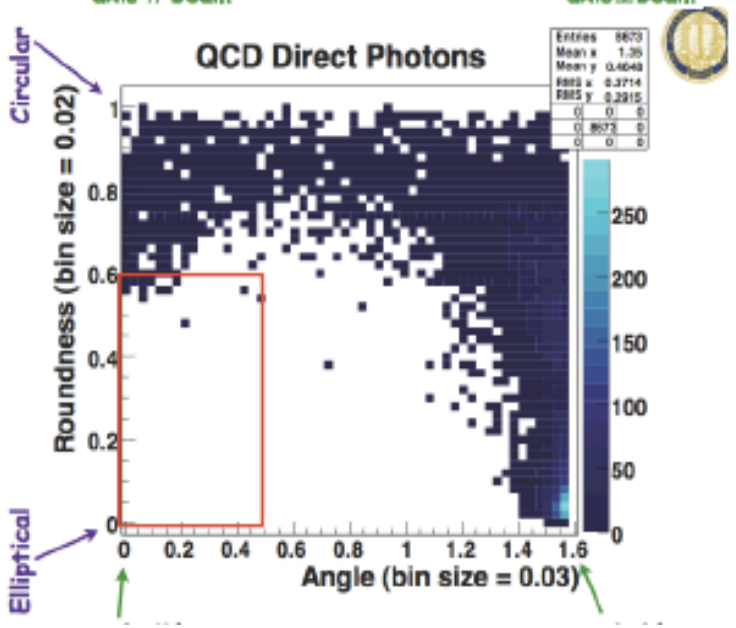


Tia Miceli

Roundness v.s. Direction







Quite promising for beam halo
-need to try this on cosmics as well
-need to try this on non-pointing signals

Photon Triggers

- Currently 13 HLT Paths related to photons:

For high mass di-γ(or e) resonances (like RS G*->γγ).

1) HLT_EM80
2) HLT_EM200

For single γ processes (like γ+jet), at L=2E32. Tight Isolation, will reject γ that convert early in tracker

3) HLT_IsoPhoton30_L1I
4) HLT_IsoPhoton40_L1R

For single γ processes at lower luminosities

5) HLT_IsoPhoton10_L1R
6) HLT_IsoPhoton15_L1R
7) HLT_IsoPhoton20_L1R
8) HLT_IsoPhoton25_L1R

No isolation, they are the loosest possible paths requiring just a SuperCluster above E_T threshold

9) HLT_Photon15_L1R
10) HLT_Photon25_L1R

For double γ processes (like h->γγ). Lower threshold & isolation (will not reject early conversions)

11) HLT_DoubleIsoPhoton20_L1I
12) HLT_DoubleIsoPhoton20_L1R

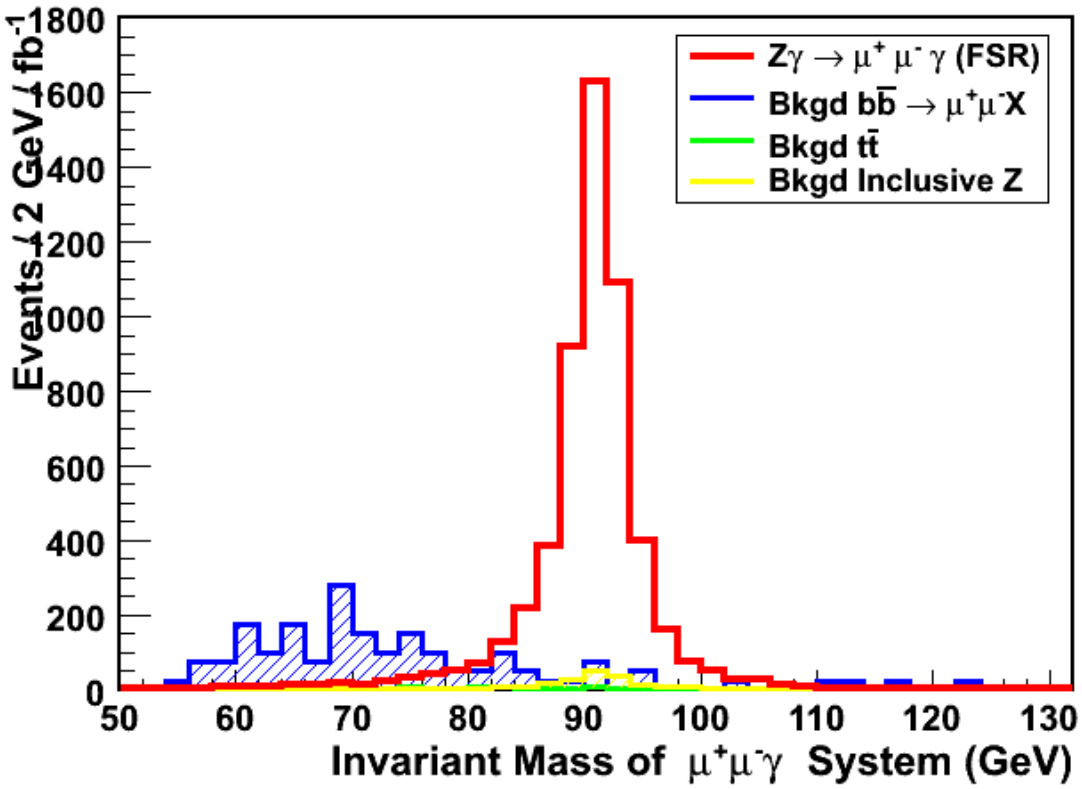
For diffractive physics

13) HLT_DoublePhoton10_Exclusive

6

Excellent Photon Trigger Tutorial by Mike Anderson in the parallel session. We were involved in the preparations for trigger reviews.

Z + γ, Z→ll: The Only « Photon » Candle at the LHC

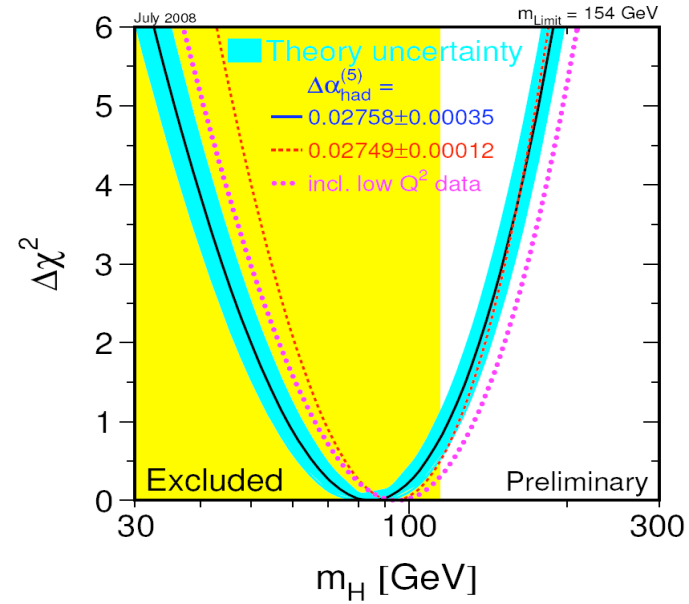


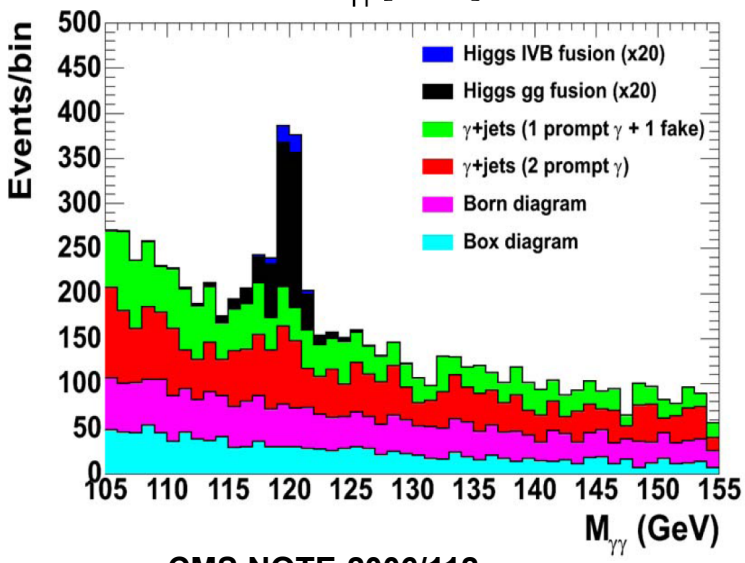
Jan Veverka

- The purity in the 2sigma mass window is 93%
- Total yield: ~10K events per 1/fb: observable with ~10 pb-1
- Will be used for an efficient Photon ID tuning
- **W + γ is also being investigated**

Di-Photons: Higgs

- Light Higgs decays mostly in bbar, which is unobservable at the LHC (too much background, even in associated W/Z production), and in $\tau\tau$ which is quite challenging
  - Liight Higgs should be sought with light!
- SM light Higgs would show up after a few years worth of data is accumulated, but SM extensions (e.g. fermiophobic Higgs) predict much higher yields - suitable for the early searches
- Recent developments: results from TDR neural network based analysis have been replicated using a decision bagging methoc (Yousi Ma). At the startup: study QCD diphoton production.





CMS NOTE-2006/112

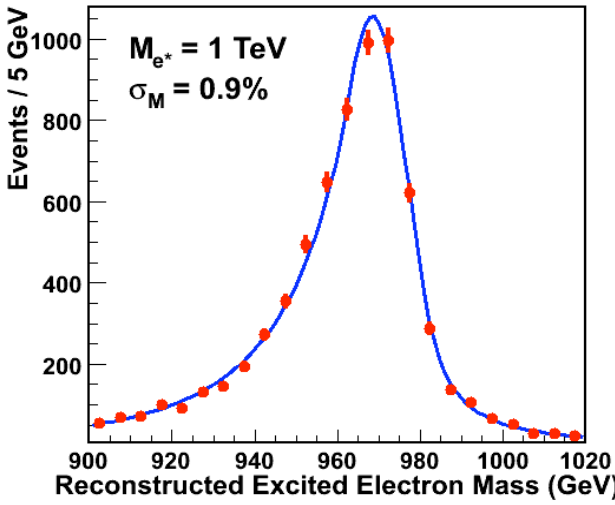
Search for Compositeness: Excited Electrons

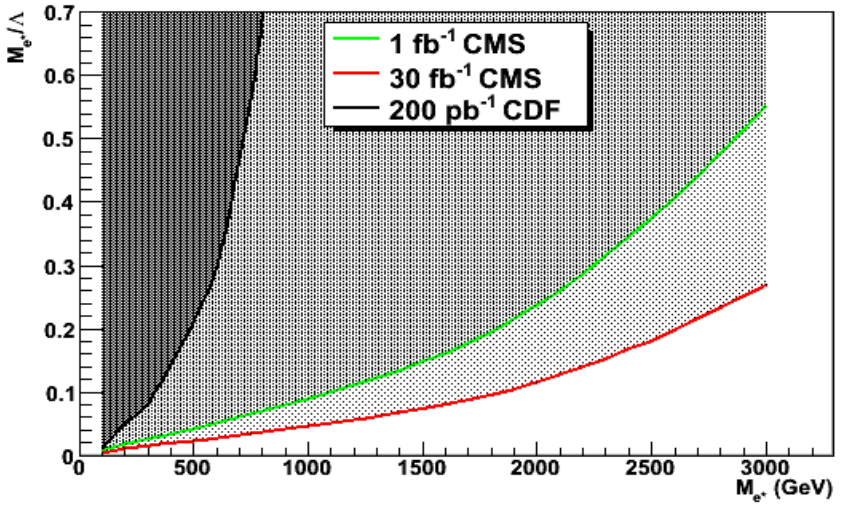
- Compositeness: a natural explanation of the fermionic generations of matter
- Excited electrons would be produced copiously at the LHC:

$$q\bar{q} \rightarrow e^{*}e^{+} \rightarrow e^{+}e^{-}\gamma$$

- The backgrounds Z+γ and Z+jets are completely suppressed and selection efficiency is > 70% for the entire range of excited electron masses (precise CMS ECAL)
- First such study in CMS: work done by a Caltech undergrad last summer.

Andy Yen, Y. Yang



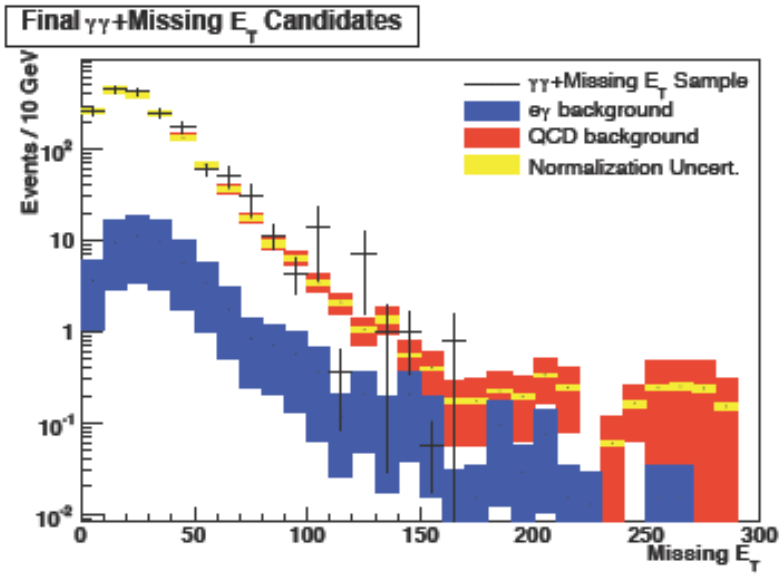


1 fb^{-1} reach: M(e*)=1 TeV and compositeness scale 10 TeV

Di-Photons: with MET

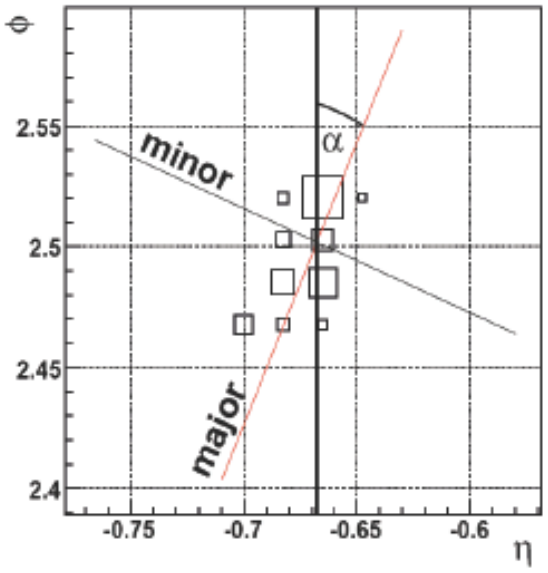
- "standard" gauge-mediated SUSY channel
- MET is hard, but this is the easiest channel with MET
  - getting rid of instrumental tails is hard, but one can measure the tails well in data ($\gamma\gamma$+MET was the first DØ Run II paper that used calorimeter)

$$p\bar{p} \rightarrow gauginos \rightarrow \chi_1^0\chi_1^0 + X \rightarrow$$
$$\rightarrow \gamma\gamma + \tilde{G}\tilde{G} + X$$



χ_1^0 can be long-lived: off pointing photons!

Need special tricks to identify, like elongated showers



Available on CMS information server

CMS AN -2009/001

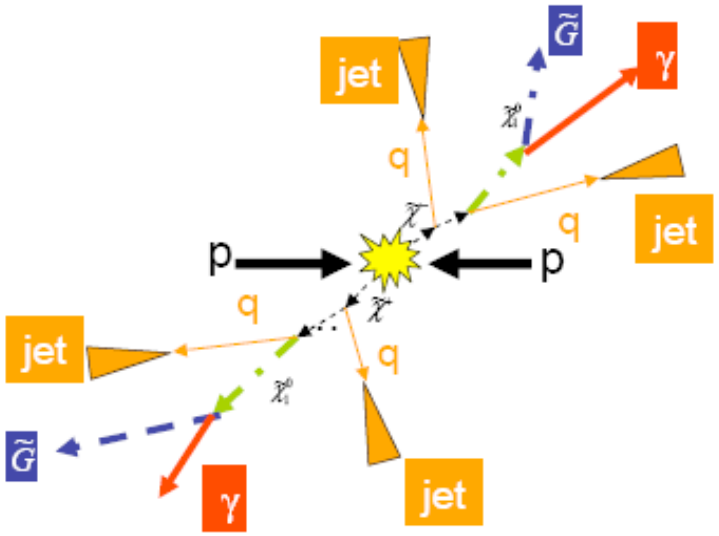
The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only

08 January 2009

Understanding Missing Transverse Energy in Di-Photon Events for Exotica Searches



A. Askew, Y. Gershtein,

Rutgers University, Piscataway, NJ.

G. Hanson, R. Stringer,

University of California, Riverside, CA.

B. Heyburn, U. Nauenberg, S. Zang,

University of Colorado, Boulder, CO.

D. Del Re, S. Rahatlou,

ersita di Roma I "La Sapienza" , Rome, Italy.

M. Balazs, B. Cox,

University of Virginia, Charlottesville, VA.

Many excellent talks in our parallel session.
Several mini-tutorials for beginners.

Wednesday 14 January 2009

top

10:30	Opening Remarks (05')	Marat and Yuri
10:35	photon triggers (20')	Mike Anderson
10:55	Photon pixel match and Electron-Photon mid-ID (20')	Carley Kopecky
11:15	W+gamma (20')	Oleksiy Atramentov
11:35	Z+gamma (20')	Jan Verveka
11:55	ECAL Operation in situ at the LHC and First Results from Cosmics (20')	Marat Gataulin
12:15	lunch (1h15')	
13:30	ECAL timing (20')	Michael Balazs
13:50	Using Shower Shape to Discriminate Beam Halo Photons (20') (Slides)	Tia Miceli
14:10	ECAL-HCAL correlations for beam halo photons (20')	Vanessa Gaultney
14:30	GMSB SUSY (20') (Slides)	Yuri Gershtein
14:50	Searches for Excited Leptons (15')	Andy Yen
15:05	higgs->gamma gamma (20')	Yousi Ma

Halo muons will have high energies and be plentiful enough at the LHC to Bremsstrahlung in the CMS ECAL. These Brems contaminate the prompt photon collection. I present discriminating shower shape variables for halo events vs prompt events. I also discuss how to determine this contamination fraction using a data-only method (no Monte Carlo required).

Summary (1)

- Many Exciting opportunities
  - Early publishable analyses are now the main focus:
    Z+gamma: SM and Exotica;
    Inclusive Di-Photon & Single-photon;
    Searches for Di-Photon resonances and GMSB type signatures.
    We try to cover (most of) these analyses!
  - Photon ID and purity tools have been steadily improving
- Plenty of early physics with photons: a few of PhD thesis topics to choose from
- The collaborative effort is now very good
  - We are carving a relatively narrow scope so that our meeting can become a forum where nitty-gritty problems of on-going analyses can be discussed - and solved
  - Students/postdocs new to CMS are always welcome:
    the amount of work is still staggering and we are undermanned
- A very good rapport with the ECAL PFG/DPG/POG, and EWK/ Exotica/QCD groups exists; we are taking advantage of that.

How to Join

- Regular be-weekly meetings with ~10 participants.
  Every other Tuesday, 1-3 pm CDT, Sunrise/EVO
  http://indico.cern.ch/categoryDisplay.py?categId=1747
- Next meeting is on January 27
- Active contributions from Rutgers, Caltech, UC Davis, FIU Virginia, Wisconsin, Univ. of Minnesota, KSU, FNAL.
- Talk to us (and to CMS DPG/PAG/POG conveners!)
  - Students/postdocs new to CMS are always welcome

Mailing list: lpc_diphoton@fnal.gov

Web: http://www.uscms.org/uscms_at_work/physics/lpc/organization/topologies/diphotons/

gershtein@physics.rutgers.edu marat@caltech.edu

If you like Photons in CMS: this is the place to be.

Thanks to the LPC for supporting this effort.