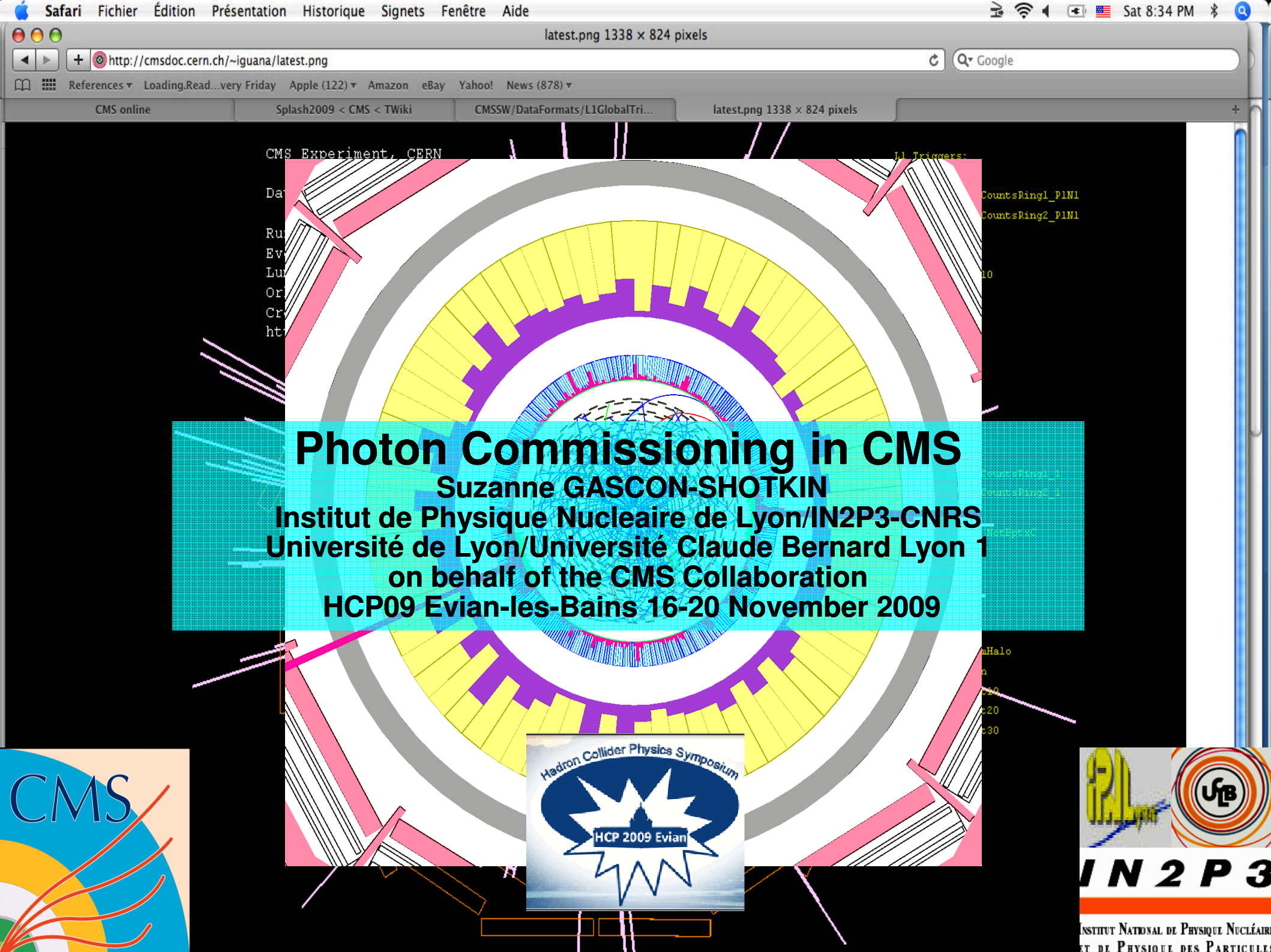
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CMS online
Splash2009 < CMS < TWiki
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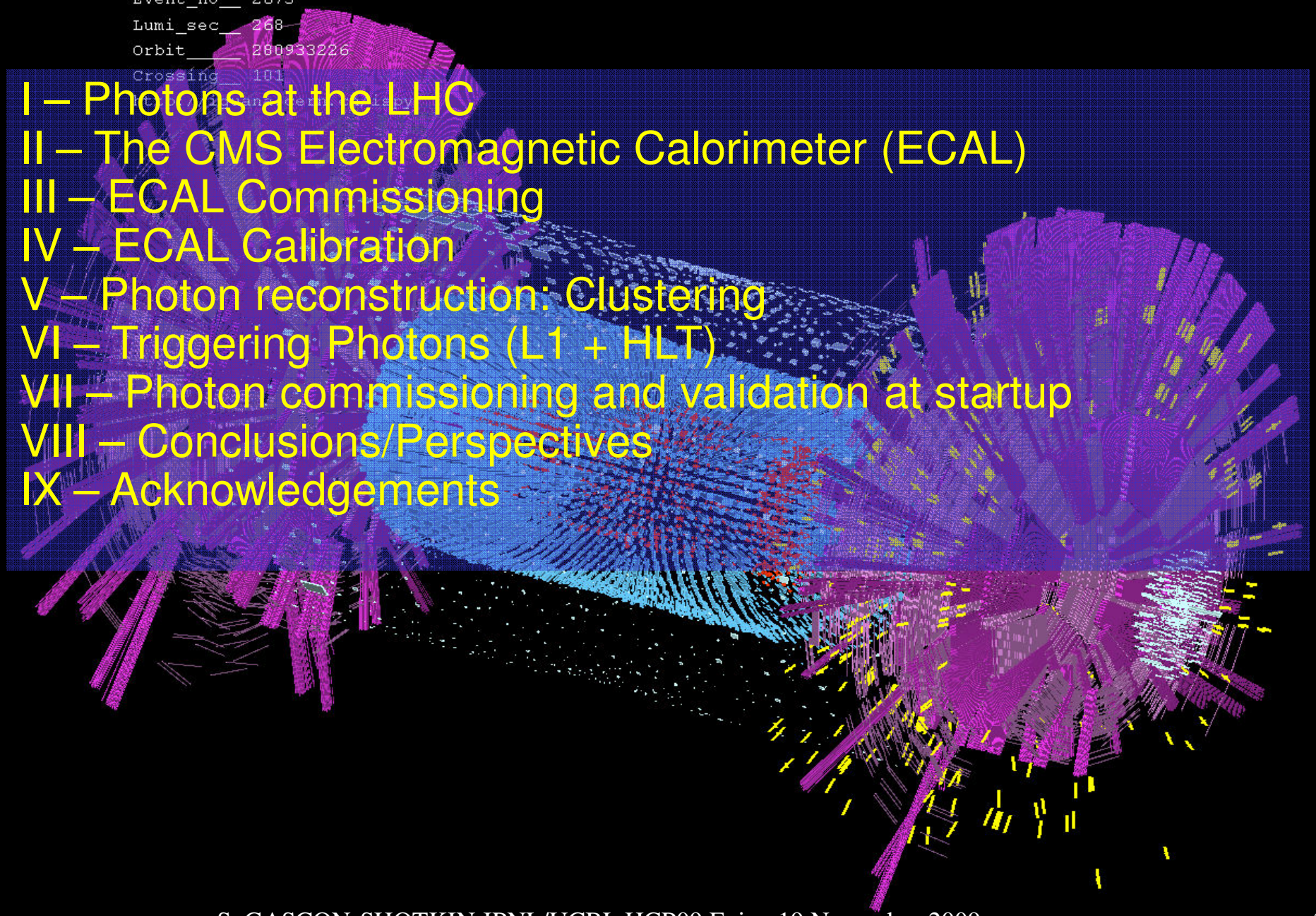
CMS Experiment, CERN
L1 Triggers:
CountsRing1_PlN1
CountsRing2_PlN1
Photon Commissioning in CMS
Suzanne GASCON-SHOTKIN
Institut de Physique Nucleaire de Lyon/IN2P3-CNRS
Université de Lyon/Université Claude Bernard Lyon 1
on behalf of the CMS Collaboration
HCP09 Evian-les-Bains 16-20 November 2009
Hadron Collider Physics Symposium
HCP 2009 Evian
CMS
IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE

Outline

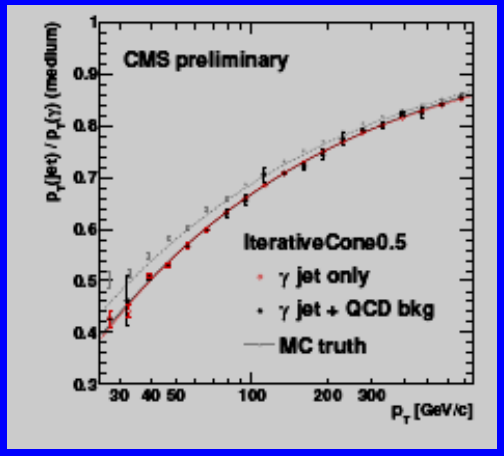


I – Photons at the LHC
II – The CMS Electromagnetic Calorimeter (ECAL)
III – ECAL Commissioning
IV – ECAL Calibration
V – Photon reconstruction: Clustering
VI – Triggering Photons (L1 + HLT)
VII – Photon commissioning and validation at startup
VIII – Conclusions/Perspectives
IX – Acknowledgements

Photons at the LHC

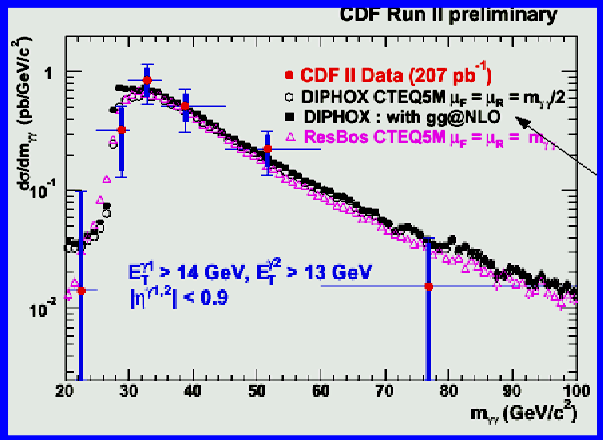
10 pb-1 | 100 pb-1 | 1000 pb-1 | 5000 pb-1

σ (γ + X)
JES via γ + jet



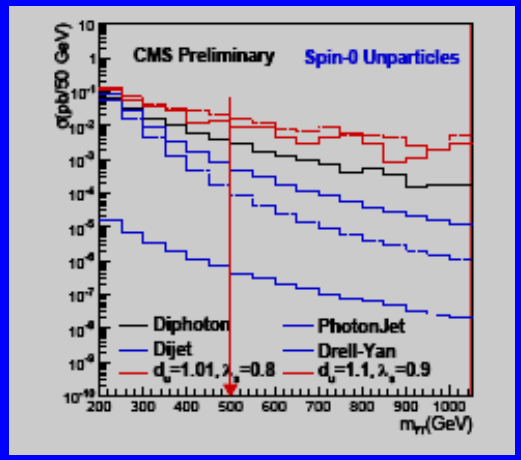
Efficiencies, purities, isolation
Et_γ >20 GeV

σ (γγ + X)



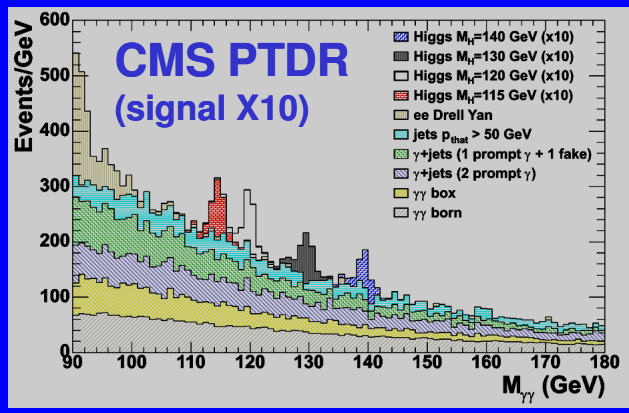
Efficiencies, purities
Et_γ > 10 GeV

NP Searches
(LED, R-S G→ γγ…)



Et_γ >50 GeV
$M_{\gamma\gamma}$> 200 GeV

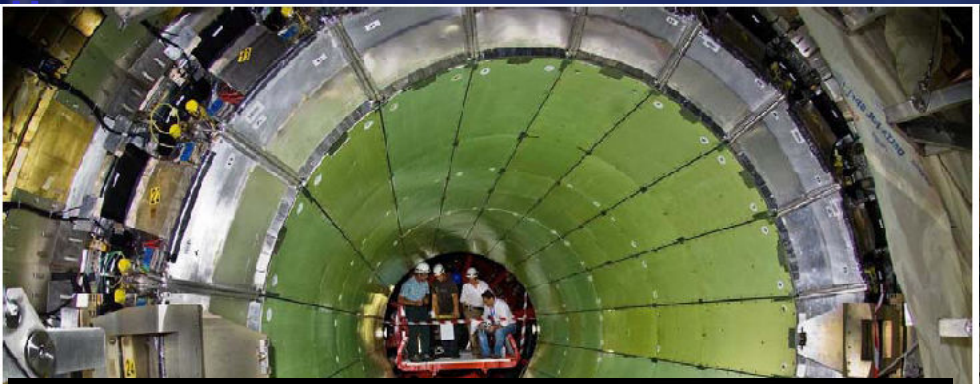
H→ γγ

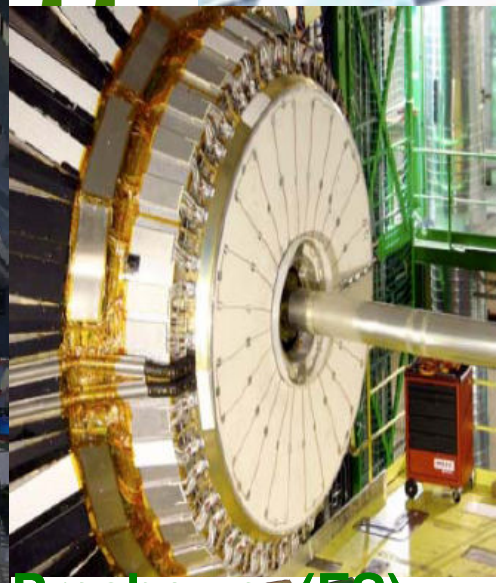


25GeV <Et_γ <100 GeV
m_H =120 GeV,
95% CL Excl. with ~5fb-1
5σ Disc. with <10 fb-1
100 days @ 2 10^{33} $cm^{-2}s^{-1}$

$\sigma(E_\gamma)/E_\gamma$ ~ 0.5%
➔strongest constraint for electromagnetic calorimeter design

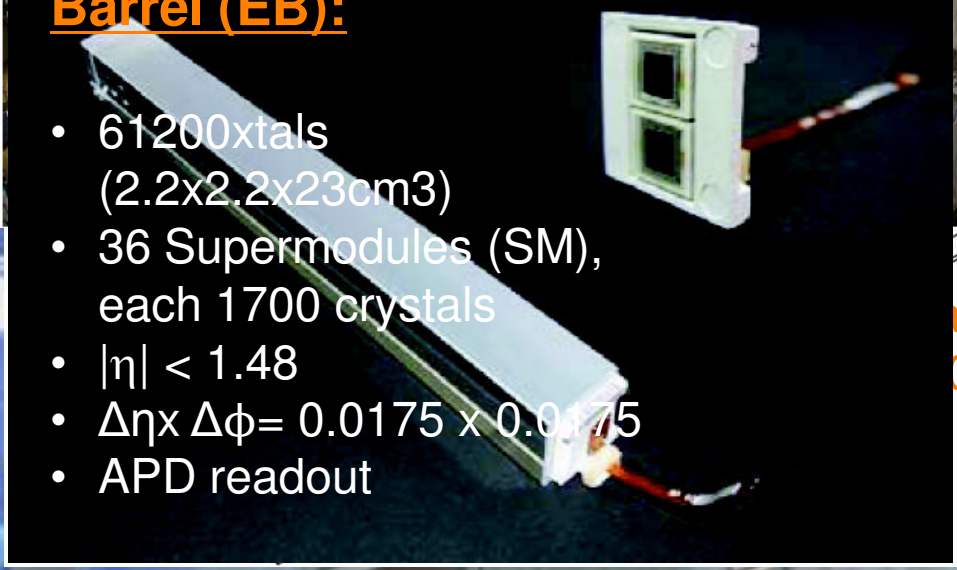
The Electromagnetic Calorimeter (ECAL) of the CMS Experiment





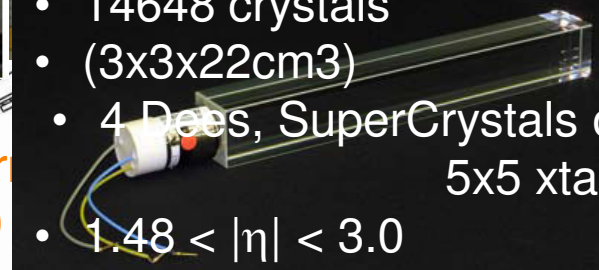
Barrel (EB):

- 61200xtals (2.2x2.2x23cm3)
- 36 Supermodules (SM), each 1700 crystals
- $|\eta| < 1.48$
- $\Delta\eta \times \Delta\phi = 0.0175 \times 0.0175$
- APD readout



Endcap (EE):

- 14648 crystals
- (3x3x22cm3)
- 4 Dees, SuperCrystals of 5x5 xtals
- $1.48 < |\eta| < 3.0$
- $\Delta\eta \times \Delta\phi = 0.01752 \leftrightarrow 0.052$
- VPT readout



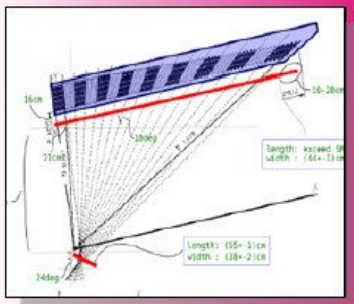
Preshower (ES):

- Pb(2X)-Si(1X)
- 4 Dees
- 4300 Si strips
- $1.65 < |\eta| < 2.6$

Excellent resolution measured in test beam ($\sigma/E < 0.5\%$ at 100 GeV)
Major issues for realization of this performance in situ:
- Intercalibration
- Showering in tracker material

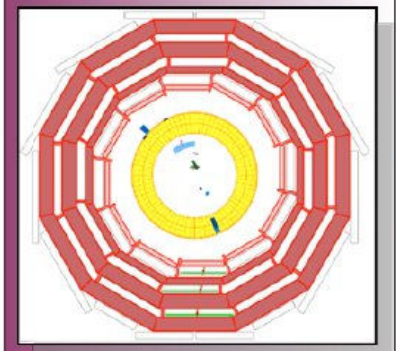
ECAL Installation and Commissioning

2006-2007:
Commissioning & calibration of each SM with cosmics on surface



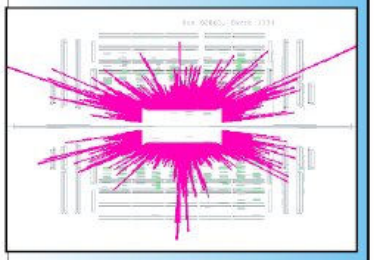
2006:
H4 Test Beam: 9 SM calibrated; H2 Combined Test Beam: ECAL&HCAL

2006:
2 SM tested with B-field on surface (MTCC)

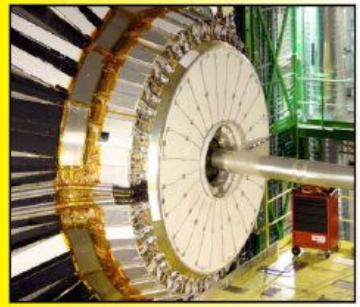


2007:
Individual signoff of each SM during installation in P5; H4 EE Test Beam

2008:
Endcap Installation; Commissioning with cosmics and first beam in-situ



2009:
Installation of Preshower and commissioning of Endcap trigger

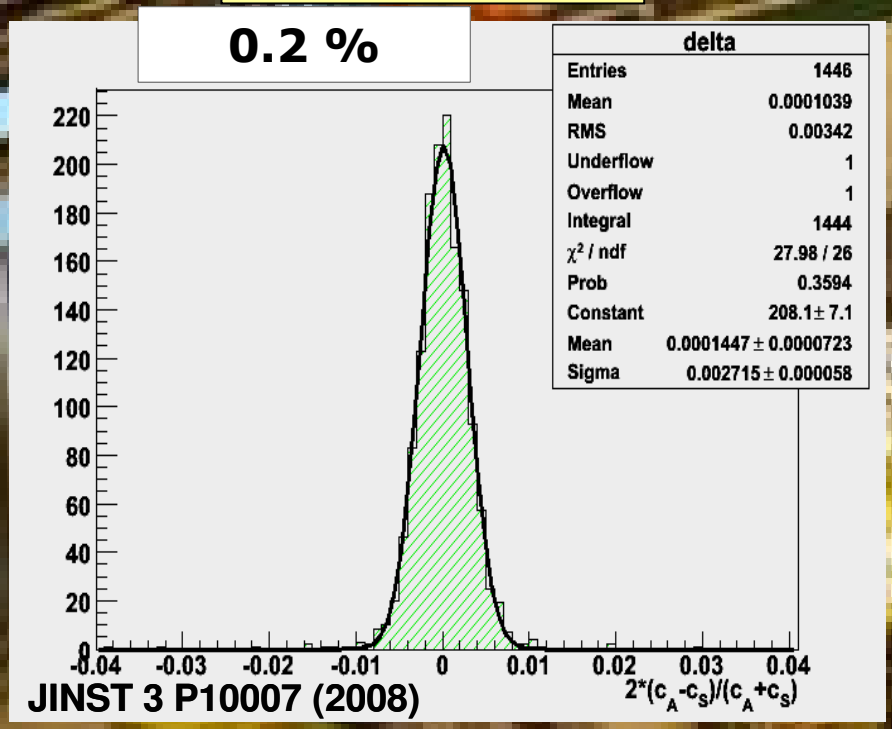


2006 2007 2008 2009

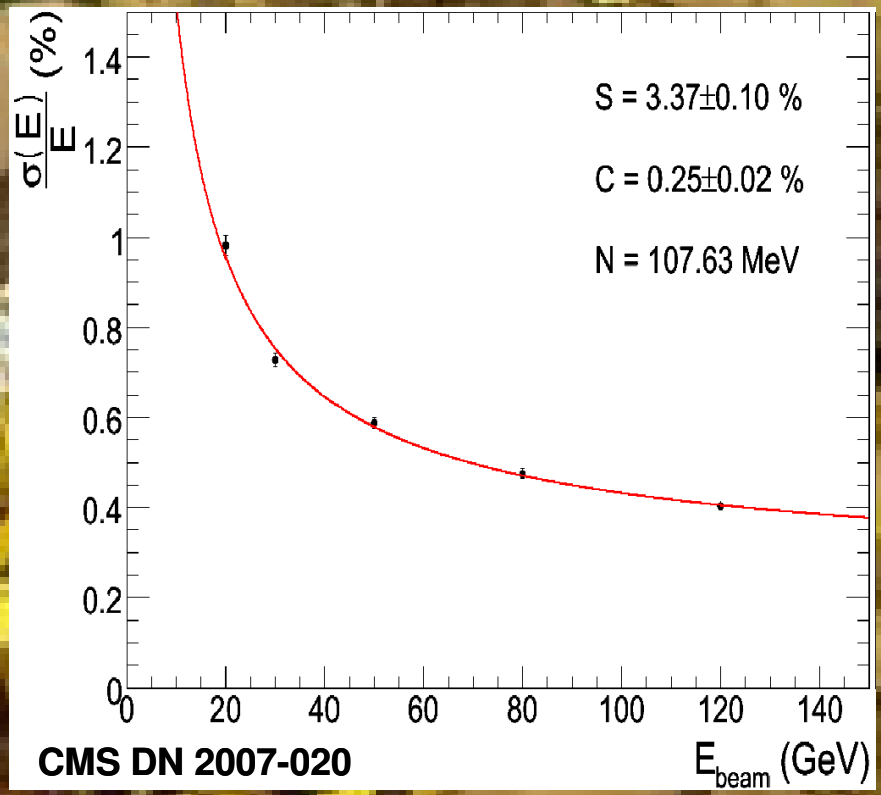
Test beam highlights

Intercalibration with H4 electron beam at CERN (2006): 9/36 Supermodules intercalibrated with electrons @ 120 GeV

Intercalibration reproducibility



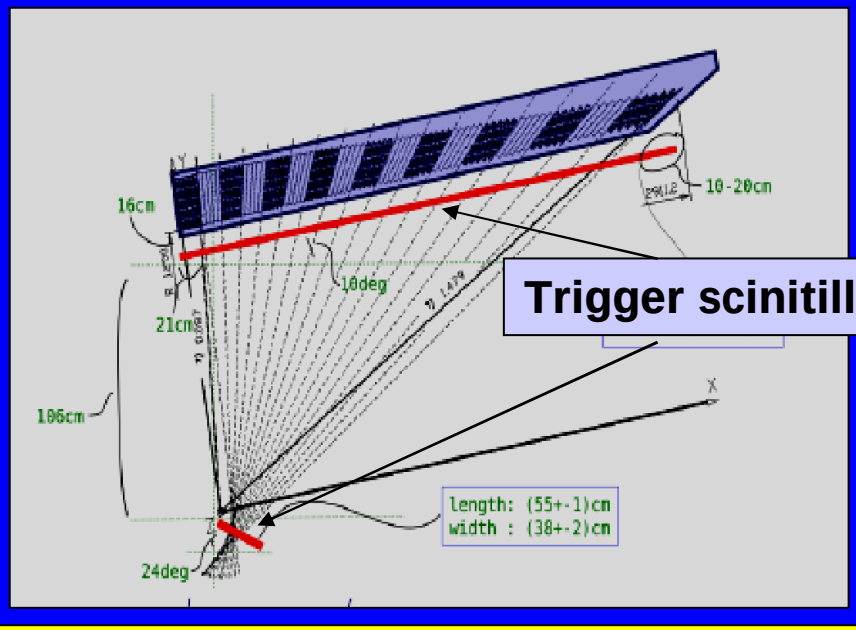
Energy Resolution, 3x3 crystals



Precalibration with beam, 9/36 SM: Precision: 0.2%

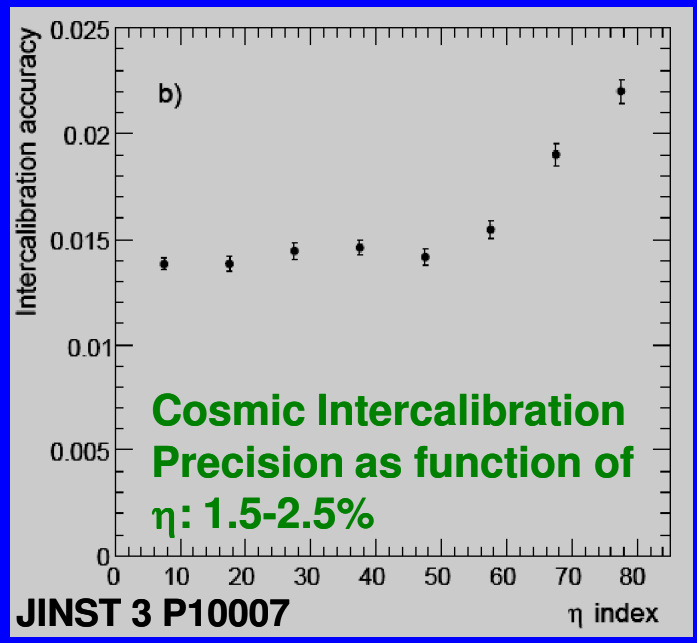
$$\frac{\sigma}{E} = \frac{3.37\%}{\sqrt{E}} \oplus \frac{108}{E}\,MeV \oplus 0.25\%$$

Cosmics pre-calibration on surface

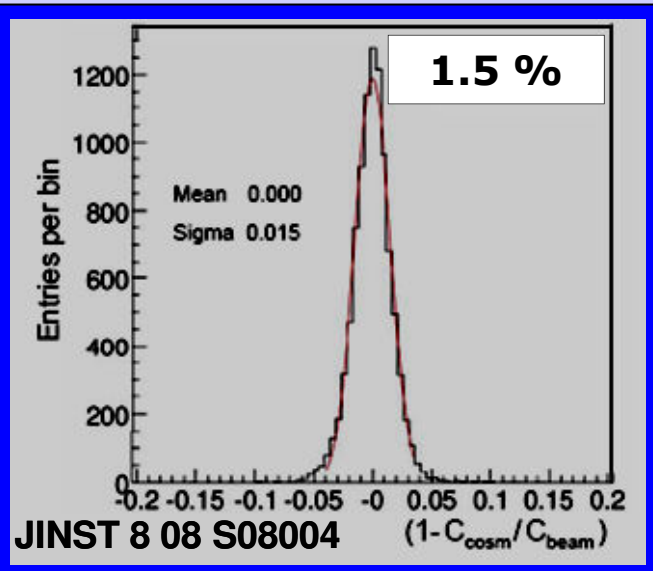


Each supermodule exposed to cosmics for at least 1 week (2006-2007)

- **Supermodule inclined 10°**
- **Increased APD gain (x4)**
- **~ 5 million triggers/SM**
- **~ 500 <selected events/ crystal>**



Cosmic and beam intercalibration: agreement @ 1.5%

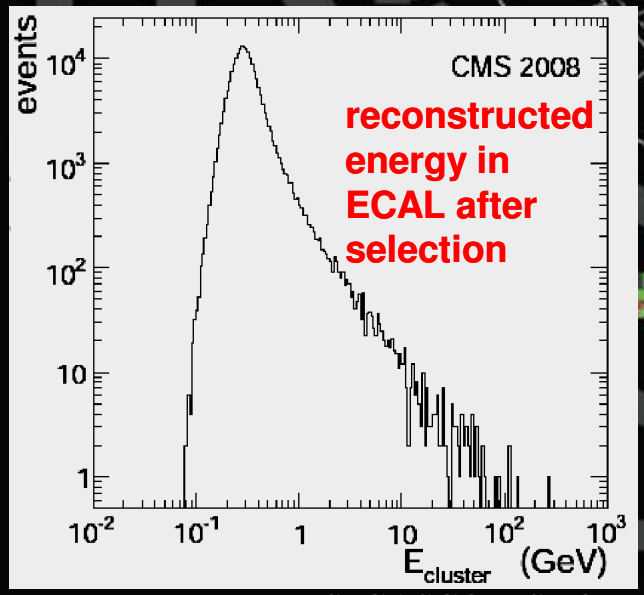


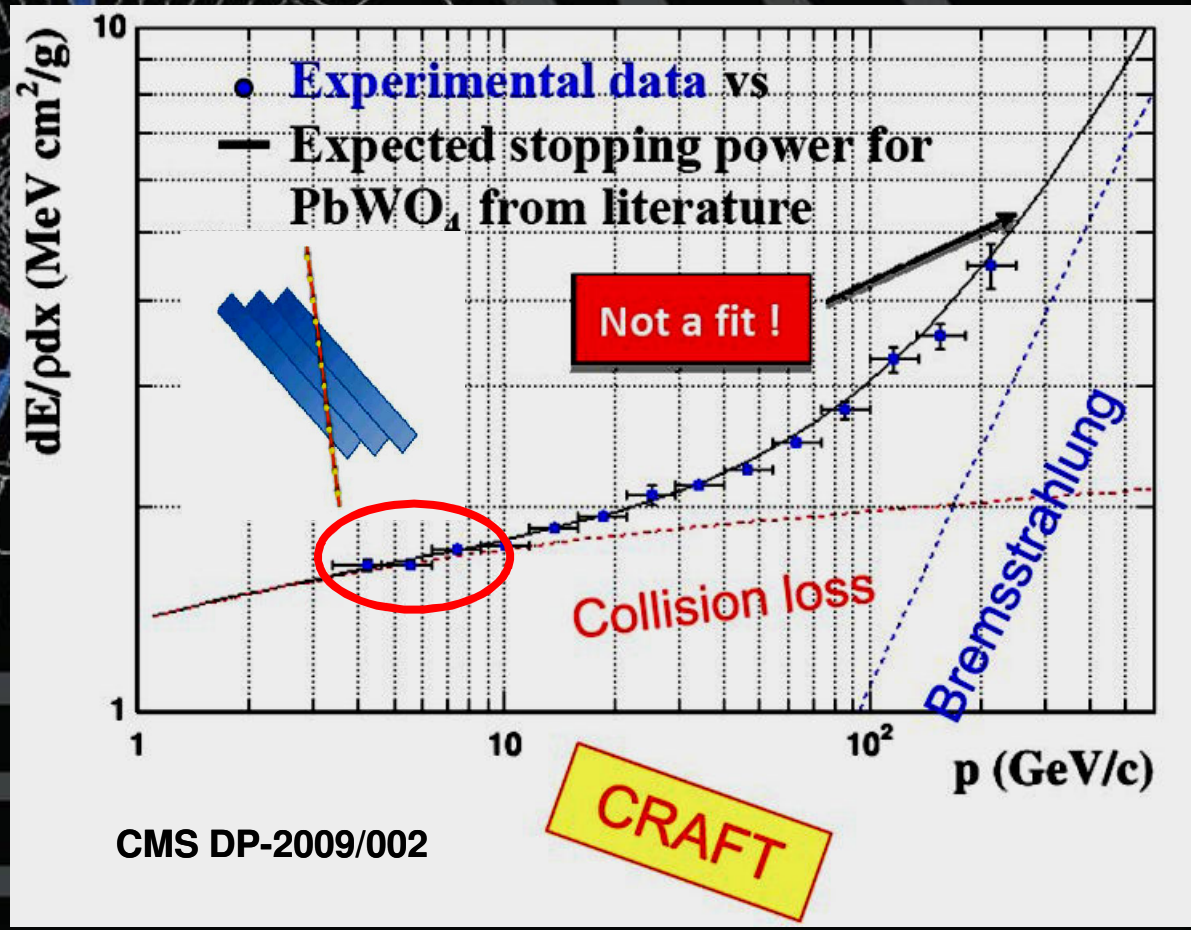
In situ commissioning prior to LHC startup

Measurement of stopping power dE/ρdx of cosmic muons traversing ECAL vs muon momentum (CRAFT ['Cosmic Run at Full Tesla'] 2008)

- Events for dE/dx selected to be loosely pointing: d0<1m, |dz|<1m
- dE: energy from ECAL, in regime dominated by collision losses
- dx: length traversed in ECAL crystals
- Muon Momentum measured by silicon tracker

Agreement with theoretical curve➔Global energy scale (ADC counts/GeV) set with 120 GeV electrons in test beam validated in the sub-GeV (~ 300 MeV) region



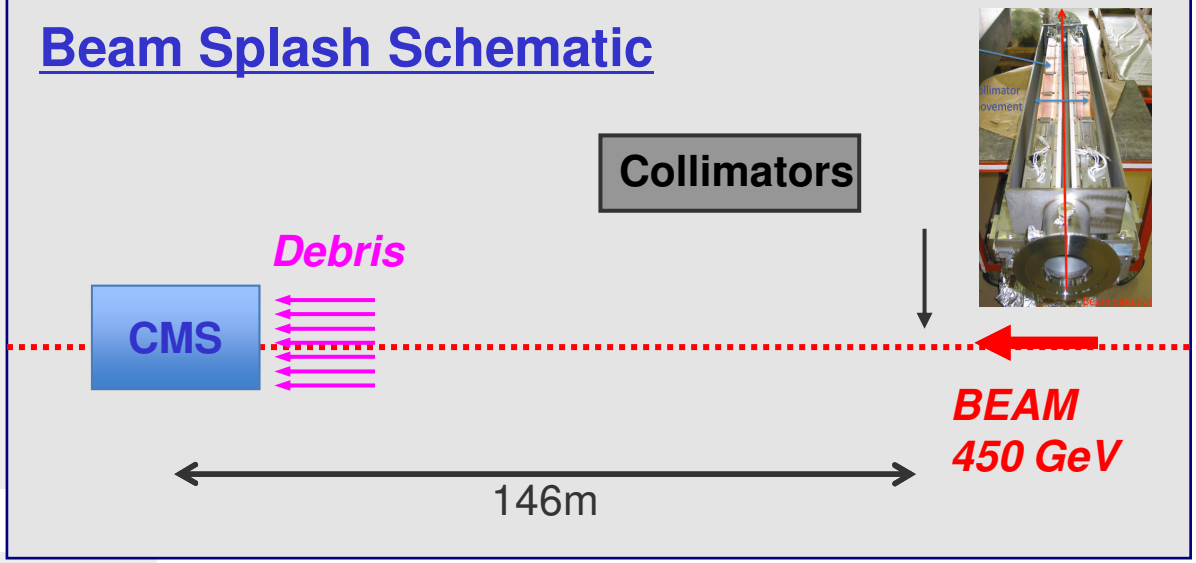


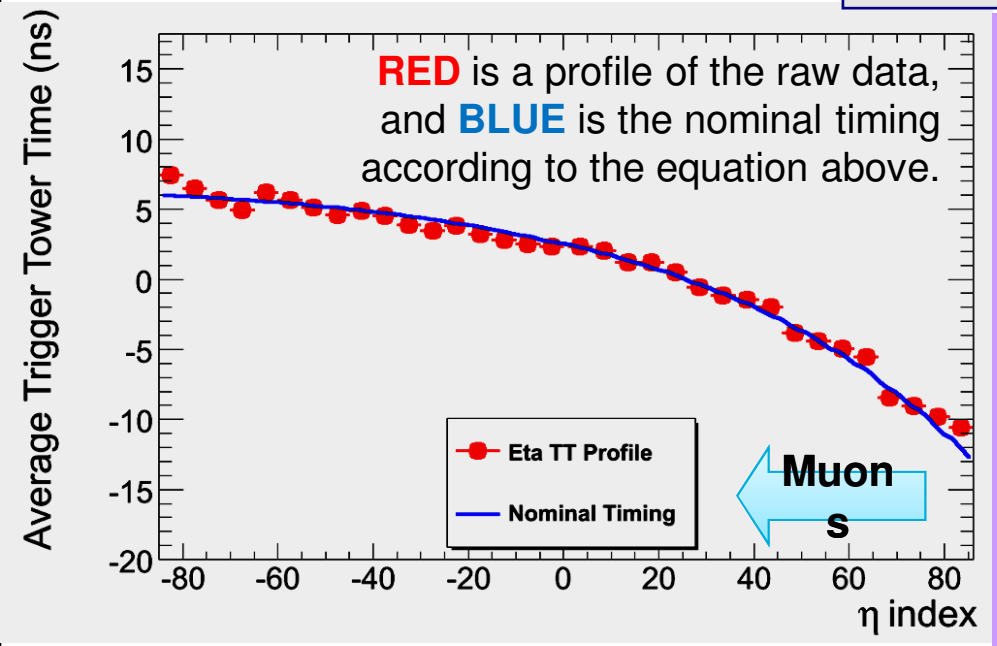
Beam Splash events in 2008 and 2009: ECAL time Synchronization

Beam splash events provide a source of synchronous hits throughout detector, allowing to internally synchronize ECAL

$$\Delta t = \Delta t_{Readout} + \Delta t_{PlaneWave}$$
$$= (\sqrt{x^2 + y^2 + z^2} - R \pm z)/c$$

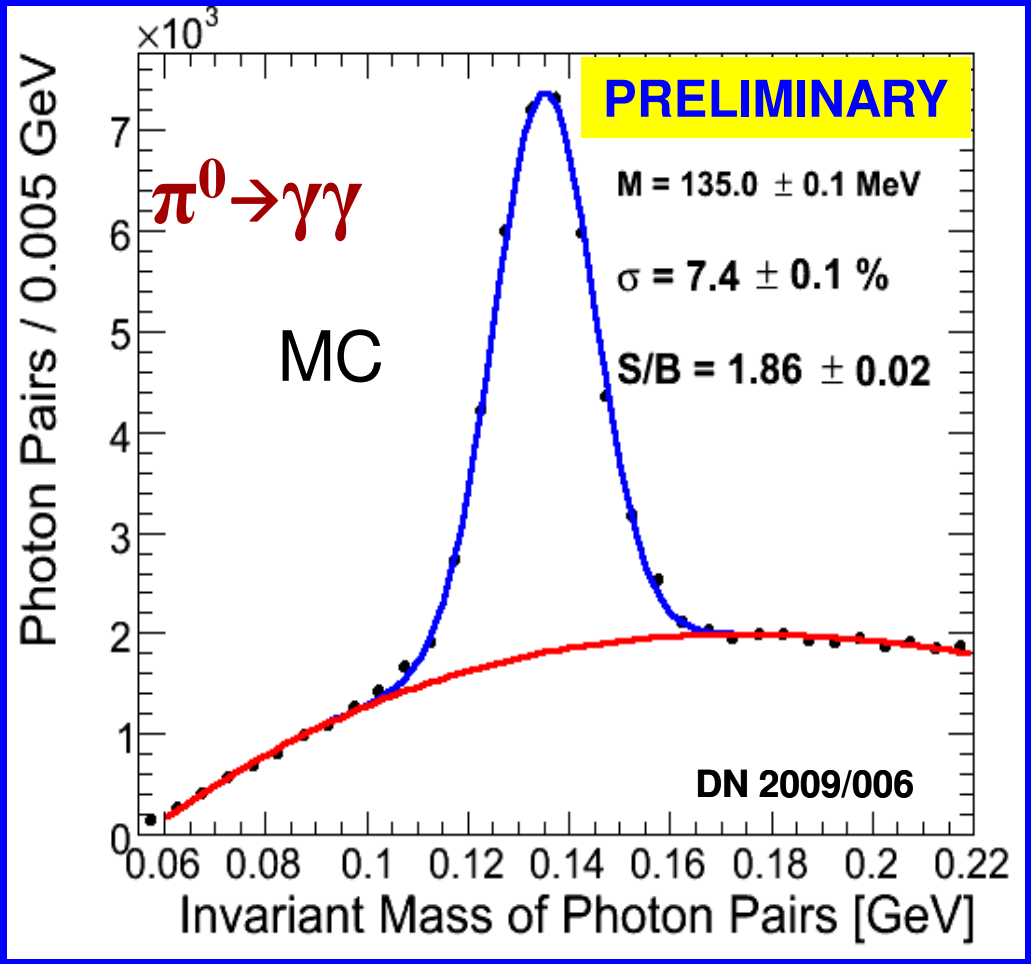
Beam Splash Schematic

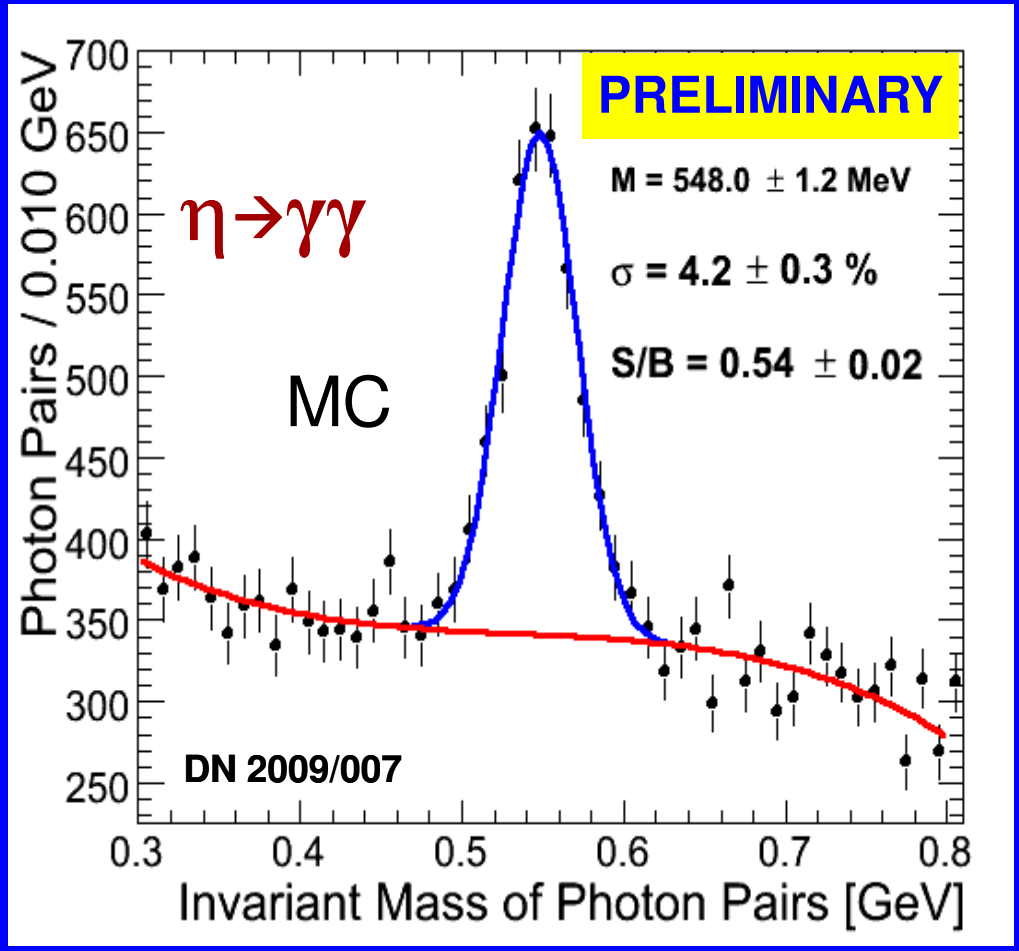




- Observed pattern is due to pre-synchronization obtained with laser light
- Synchronizarion of each single channel measured with splashes at **better than 1ns**
- Synchronization from beam splashes will be start-up condition; better precision w/ LHC data

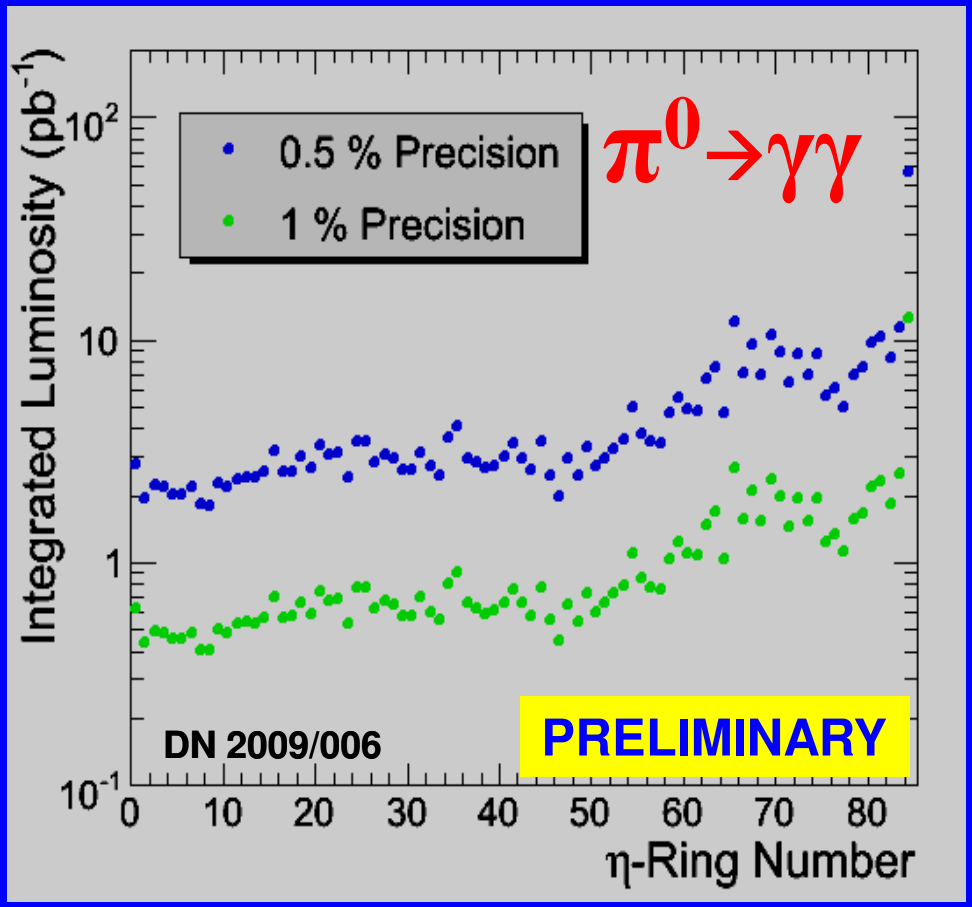
ECAL intercalibration with π0 and η->γγ

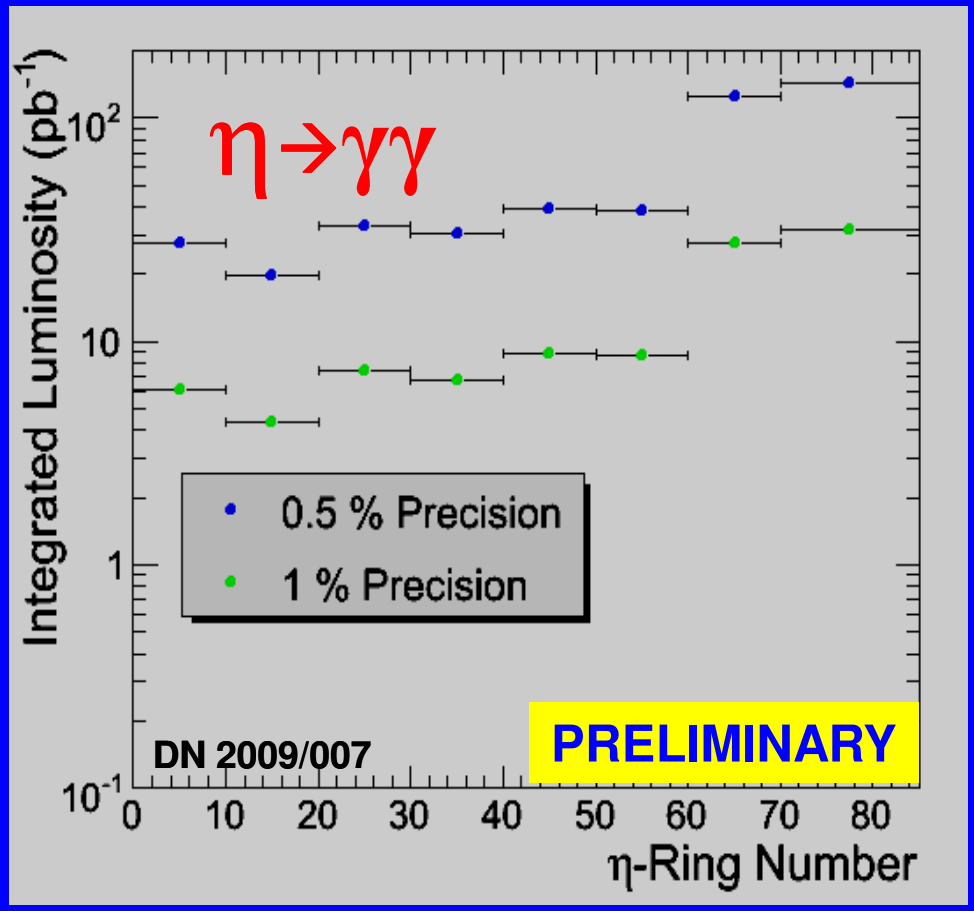




- We expect to observe clean signal peaks for both resonances
- Average photon energies are ~ 2.7 GeV and 4.7 GeV for $\pi^0 \rightarrow \gamma\gamma$ and $\eta \rightarrow \gamma\gamma$ decays
- For low-luminosity L=2x10^{30}cm^{-2}s^{-1} , ~100 Hz useful $\pi^0 \rightarrow \gamma\gamma$, and ~6 Hz $\eta \rightarrow \gamma\gamma$ decays with dedicated HLT stream.

ECAL intercalibration with π0 and η->γγ: Performance



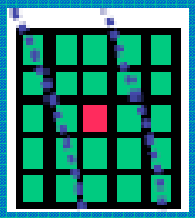


- For the low-luminosity scenario of $L=2x10^{30}cm^{-2}s^{-1}$, assume 1-2 pb^{-1} data taking / day
- Extending this procedure to Endcaps seems promising

Photon reconstruction: Clustering

Unconverted photons

5x5 matrix

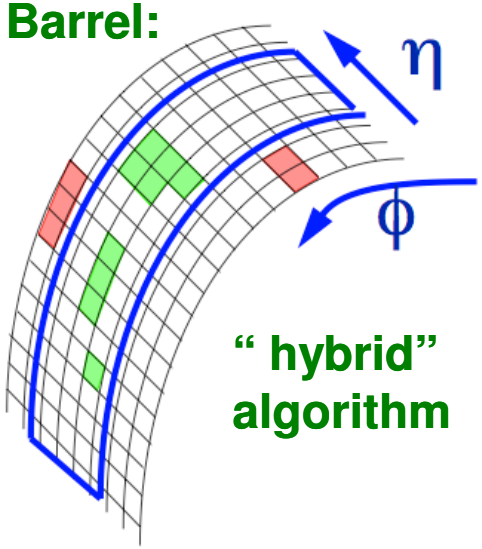


Contains 96.5% (97.5%) of unconverted photon energy in Barrel (Endcaps)

Gives best energy estimate

Converted photons

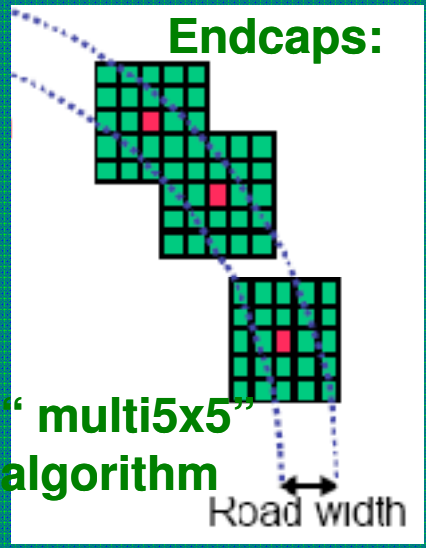
Barrel:



" hybrid" algorithm

"Super-Cluster" (SC):

Endcaps:

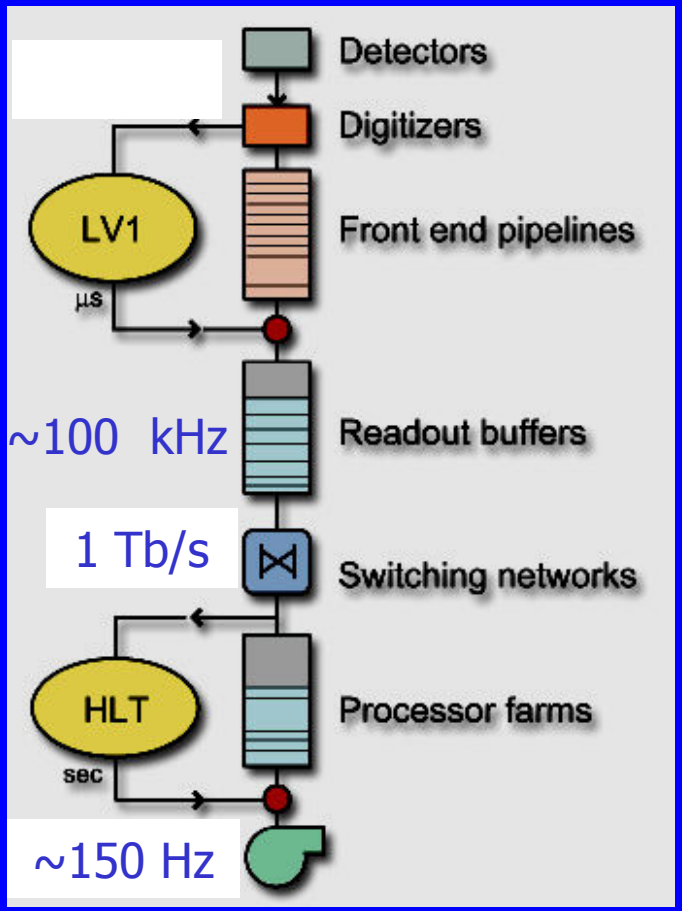


" multi5x5" algorithm

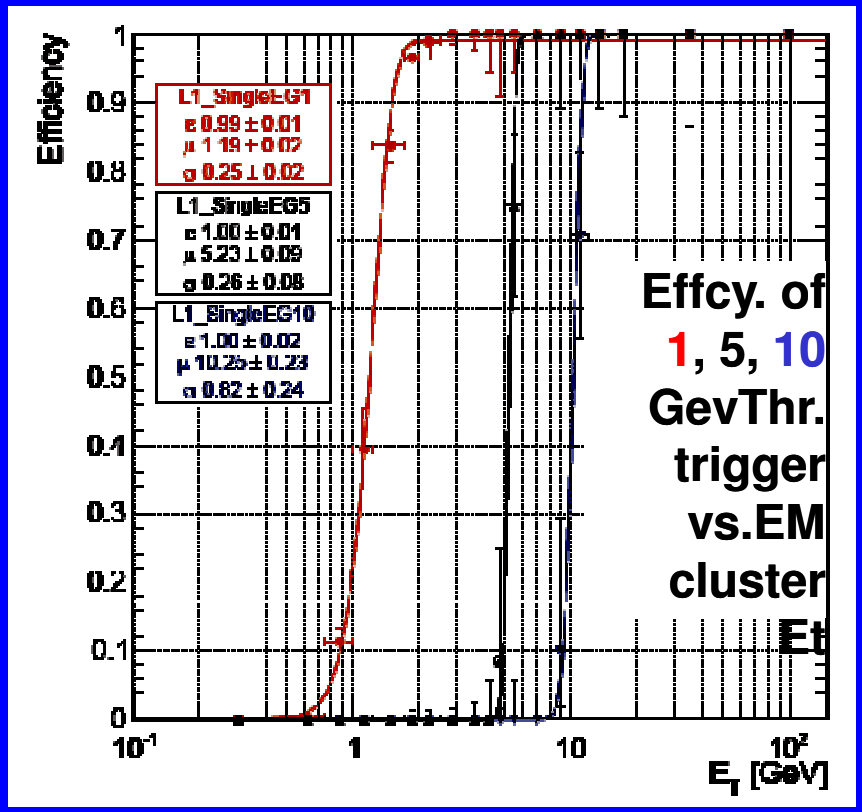
Form Super-clusters of clusters along φ(bending direction) to recover energy from conversions in the tracker

In the endcaps, add also the energy deposited in the preshower detector

Triggering Photons (L1 + HLT)



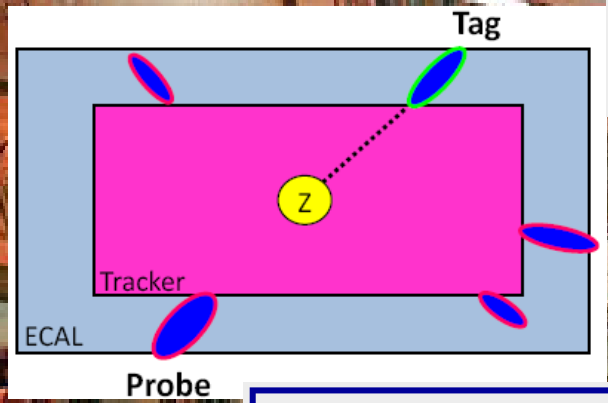
L1 eγ efficiency turn-on curve (CRAFT09)



Measurement using muon brems in crystals, requiring muon associated with ECAL e.m. cluster, Muon-triggered events.

- L1 at $10^{31}cm^{-2}s^{-1}$: Unprescaled at pT=25 GeV with no isolation
- Loose startup HLT photon selection: Require one supercluster with no isolation and Et > 30 - 40 GeV depending on luminosity (L <~ 10 32 cm-2s-1)
- HLT photon rate at $10^{31}cm^{-2}s^{-1}$: 23 Hz

Commissioning/validation with first and early data

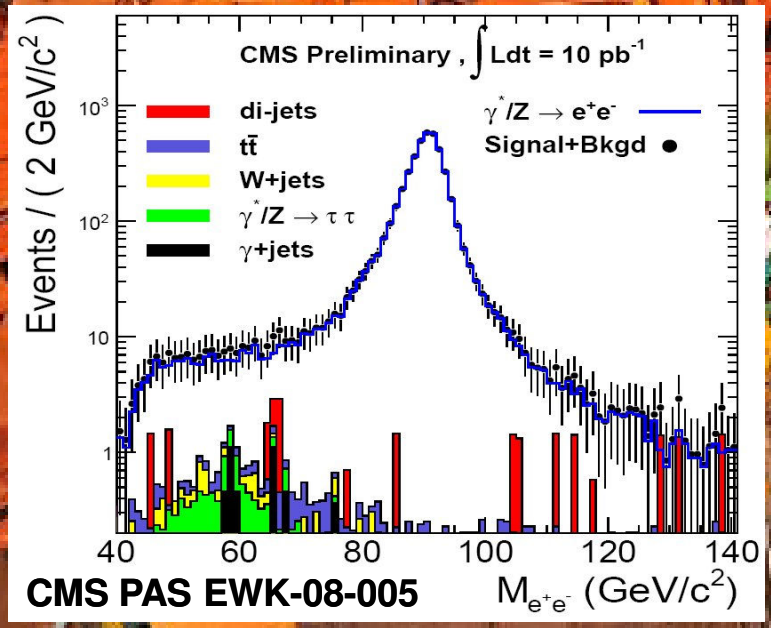


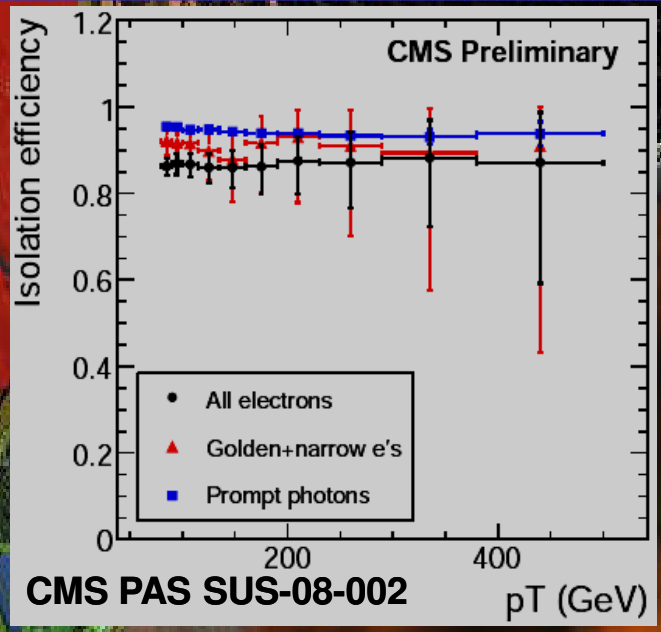
Tag:
Passes stringent electron identification criteria

Probe:
Passes a set of identification criteria depending on the efficiency under study

Exploit similarities between electrons and photons.
Before 100pb-1: Use 'Tag and Probe' method with Z→e+e- (large sample of pure unbiased electrons) to measure efficiencies: Trigger, Photon ID, Photon selection, isolation…

Then correct photon MC prediction for relative difference between electron data and MC.
From 100pb-1 on: Use Z→μμγ





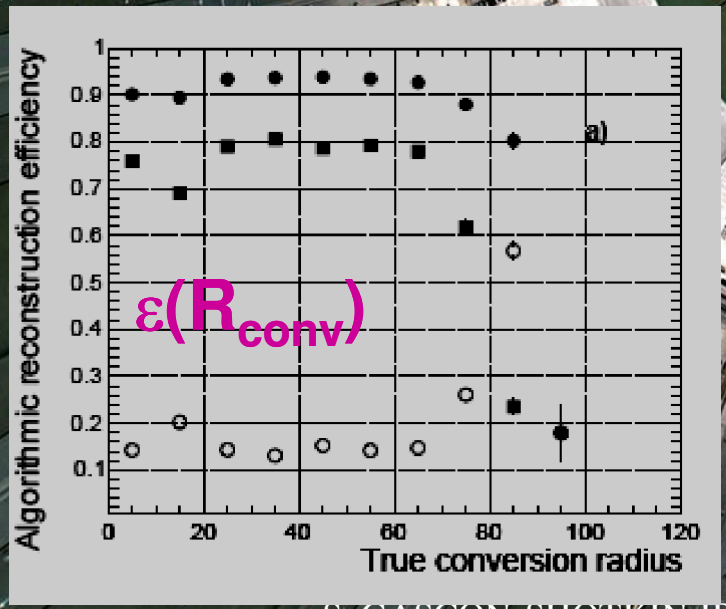
Photon energy scale initially from Z->ee, later verified with Z->μμγ

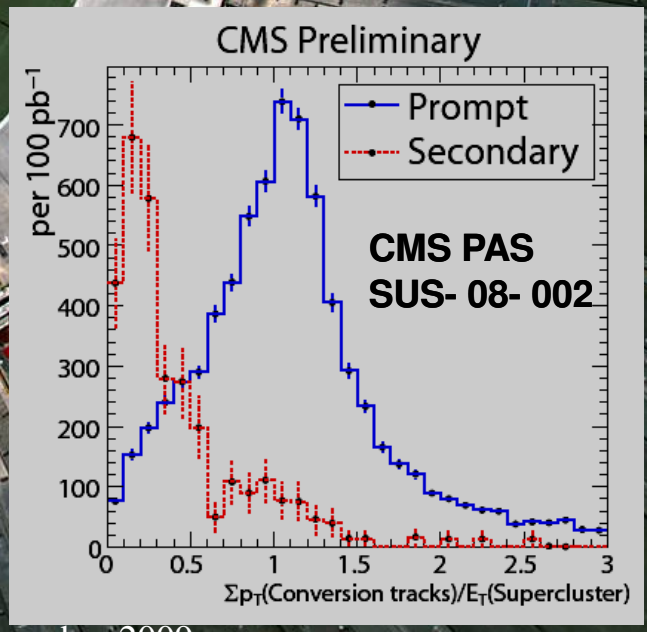
Photon purity measurement

- Early cross-section measurements (for example, γ + jets) require estimations of photon purity
- Photon purity as a function of ET and η can be measured with early data. One possibility is to use templates of signal and BG estimated from data using reconstructed photon conversions

Dedicated track-finding algorithm:
Uses inward ECAL SC-seeded track-finding to iteratively determine conversion vertex (R_{conv})

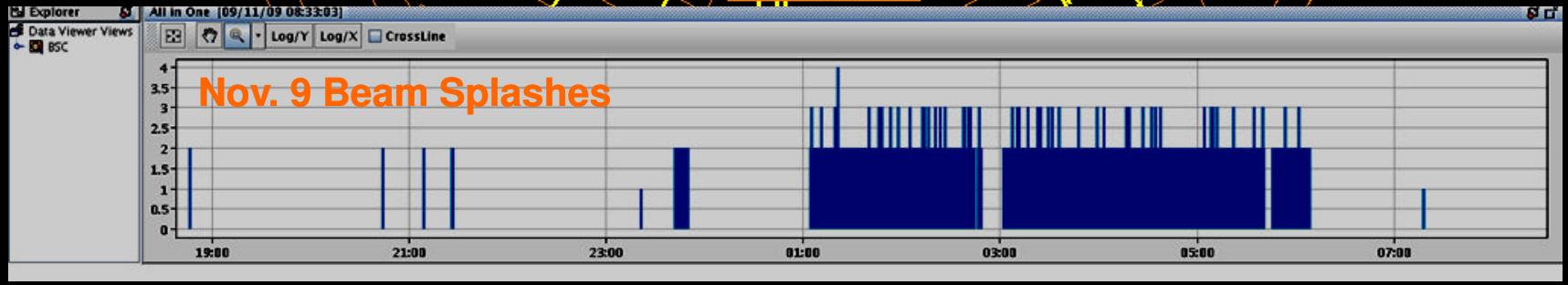
Application:
Σp_T (tracks)/ E_T (SC) to help estimate QCD background to γ + jets, with 100pb-1





Conclusions/Perspectives

- The commissioning of photons in CMS stands on the solid foundation of intensive ECAL precalibration and calibration efforts in test beam, with cosmic rays and with 'Beam Splashes', over the last several years.
- Procedures for further calibration *in situ*, and for the extraction with data of results important for physics analyses (photon energy scale, selection efficiencies, purities…) have been developed and extensively tested.
- Once data is here, the following will be among the major challenges we will face:
  - comparison of measurements for electrons and photons
  - tuning of isolation criteria
  - measurement of photon purity after selection
- We are ready to begin!

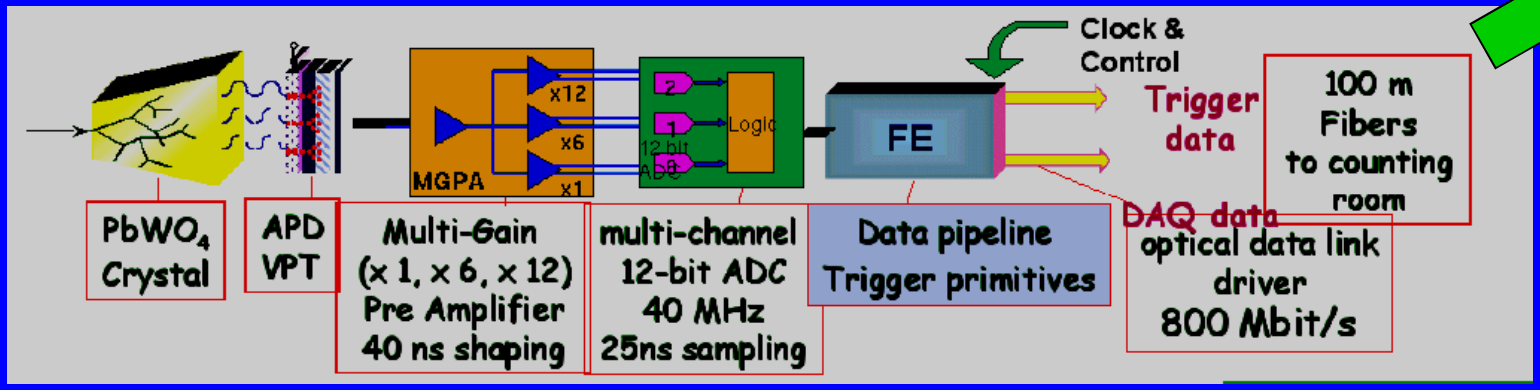


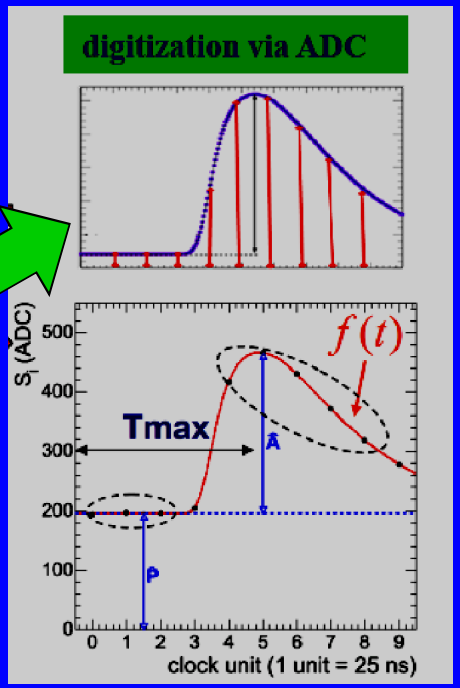
Acknowledgements

- S. Argiro, C. Biino, M. Felcini, G. Franzoni, Y. Gershtein, T. Maaki, M. Malberti, Y. Maravin, N. Marinelli, P. Meridiani, T. Orimoto, M. Pieri, C. Seez, W. Smith, T. Taberelli de Fatis, P. Vanlaer, …
- The members of the CMS ECAL Collaboration and the CMS e/γ Physics Object Group
- To the organising committees of the Symposium and the beautiful city of Evian-les-Bains

BACKUP

The CMS ECAL Readout Electronics



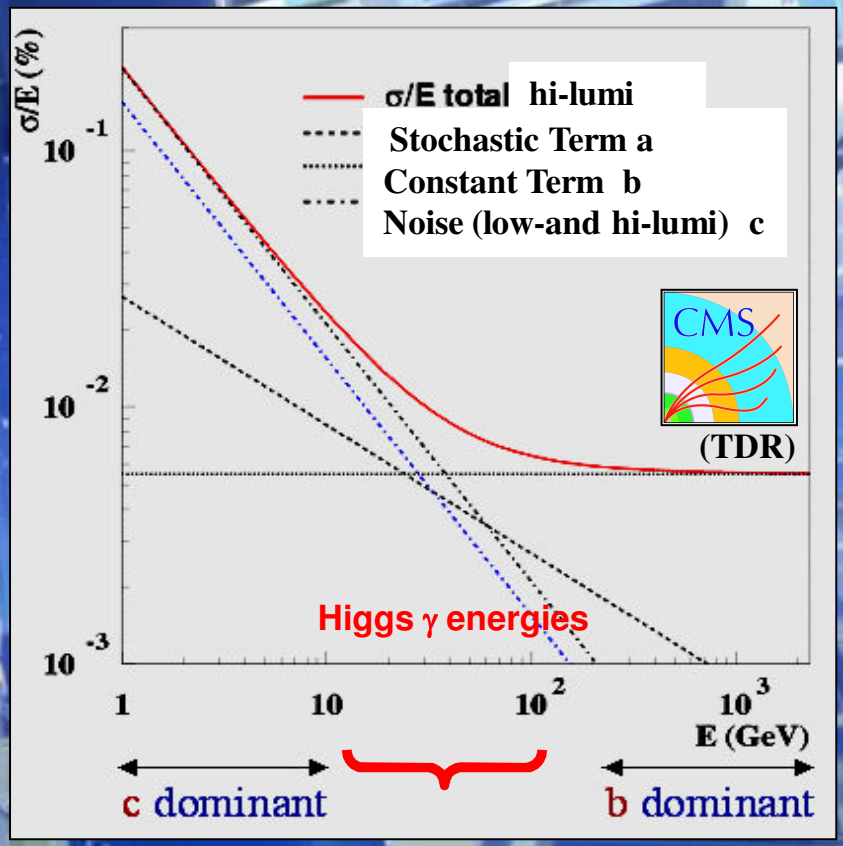


ECAL Energy Resolution

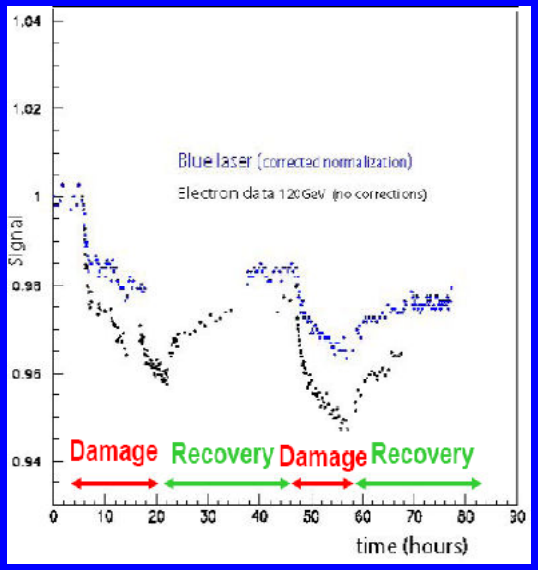
$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$

- 'Stochastic': Shower and sample fluctuations, transverse leakage, photostatistics
- 'Constant': Calibration, LY non-uniformity, rear leakage
- 'Noise': Electronic noise, radiation-induced I_{dark}, pileup

- Relative importance of the 3 terms for the different use cases:



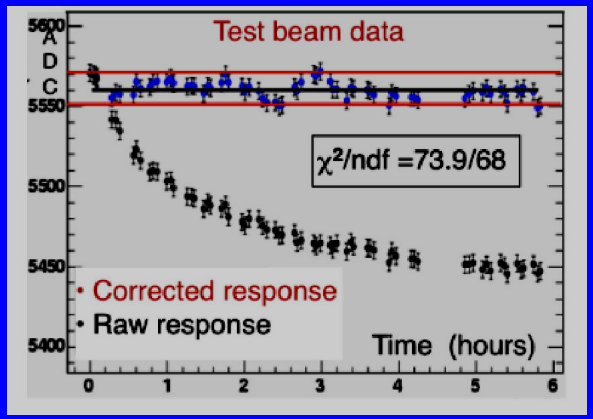
Test beam highlights [2]

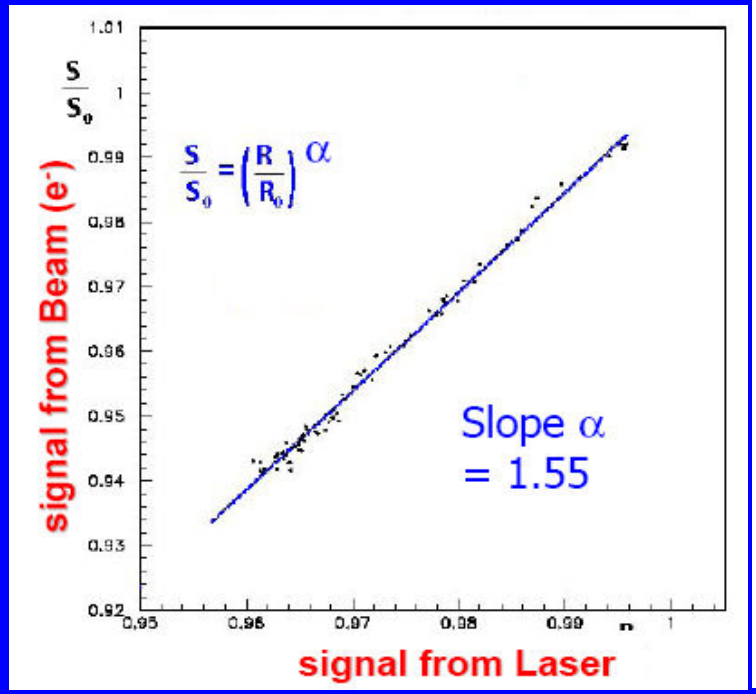


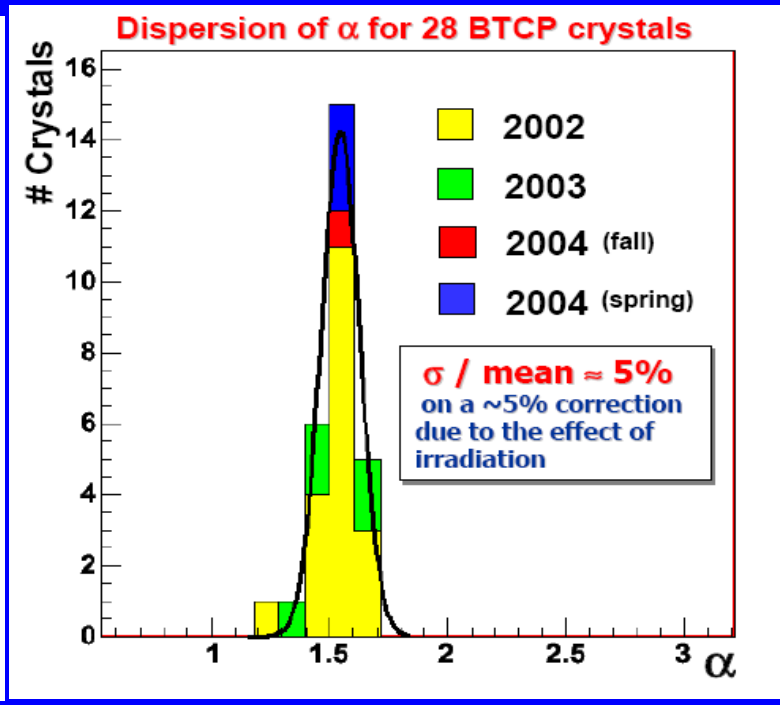
Measured on several irradiation/recovery cycles relation between transparency change and variation of scintillation signal

Small dispersion of the α parameter, allow to use a constant for each producer and crystal type (barrel/endcap)

Validation of continual correction of calibration constants via laser monitoring of crystal transparency losses due to irradiation

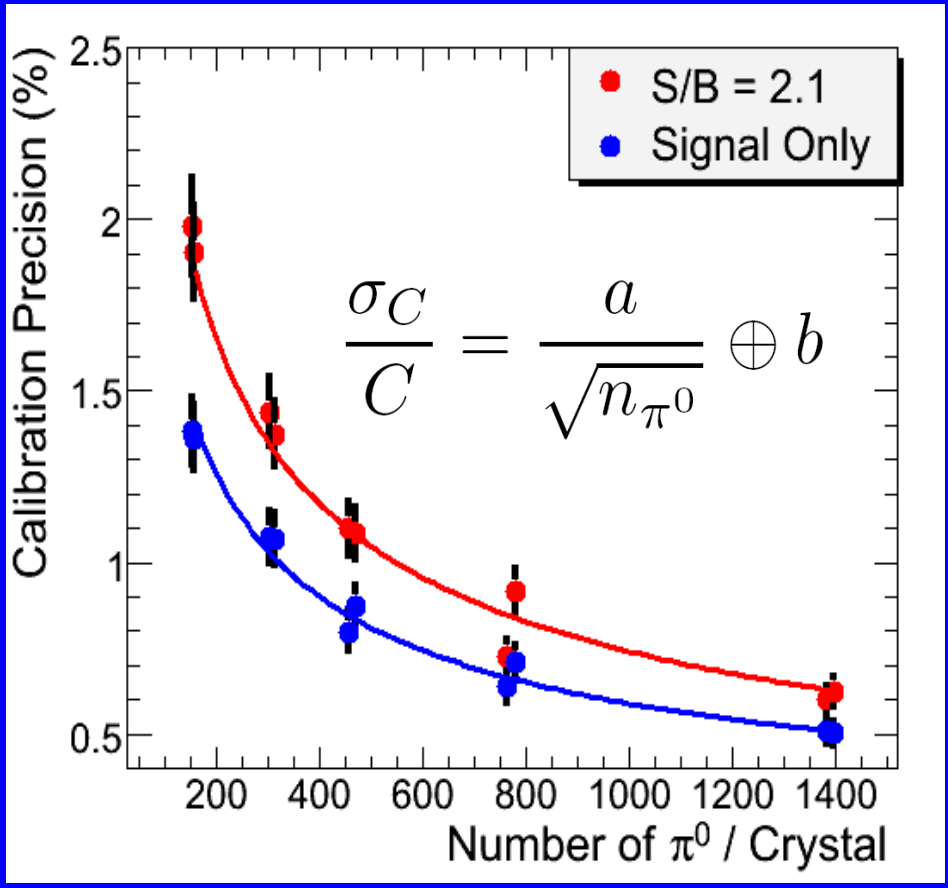






Intercalibration Results

The dependence of calibration precision on number of collectedπ0

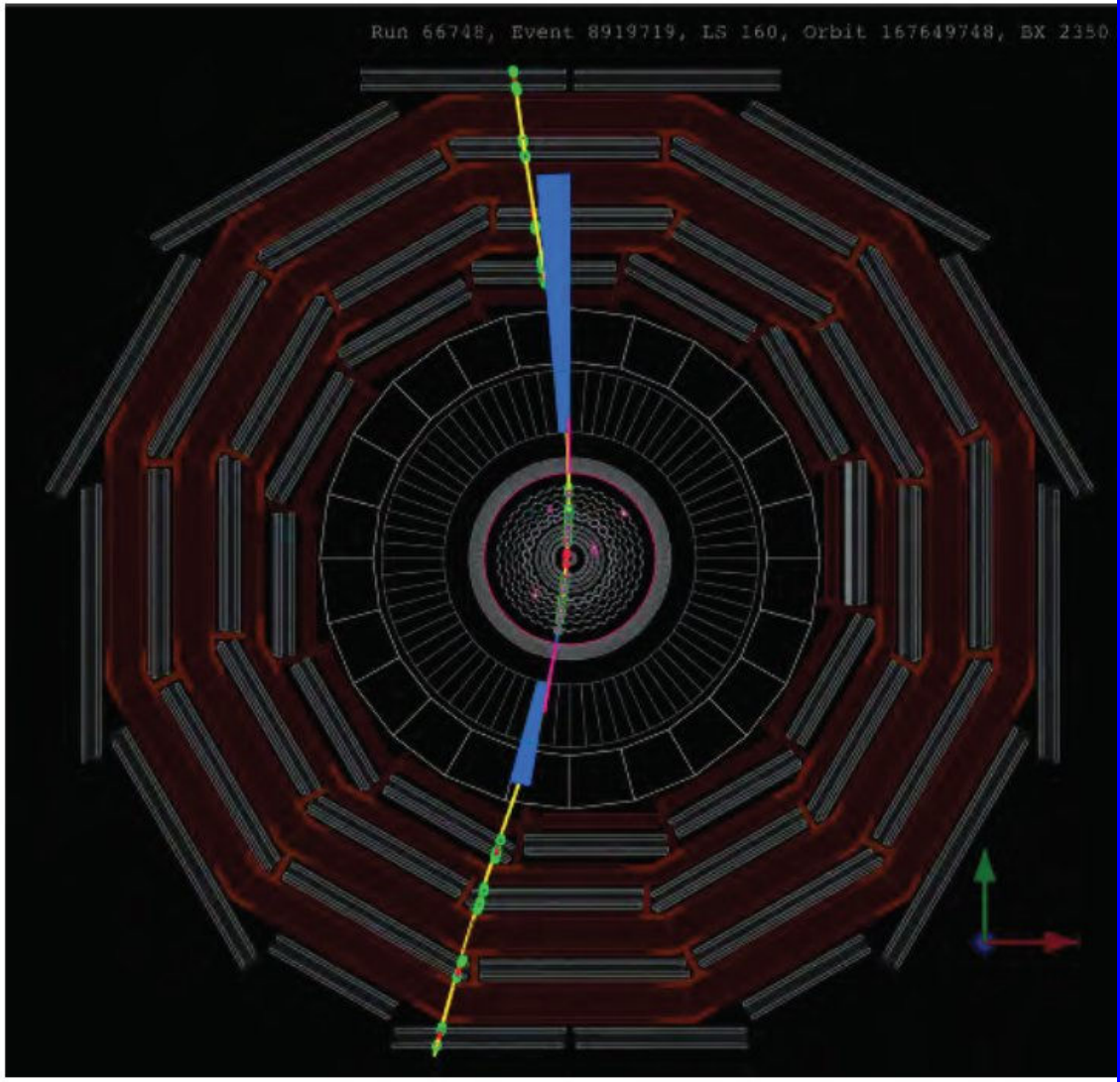


As expected, the spread of $\pi^0 \to \gamma\gamma$ peak positions on individual crystals has strong correlation with the inter-calibration precision.

CRAFT – Cosmic Run At 4 T*

- Ran CMS continuously for 6 weeks (Oct – Nov '08) to gain operational experience, stability of infrastructure.
- Collected ~300M cosmic events.
- About 400 TB of data distributed widely.
- Efficiency ~ 70% (24/7)
- First analyses of these data used s/w release intended for 2008 data-taking & LHC grid infrastructure.
- Re-reconstruction & analyses with more advanced versions of the release

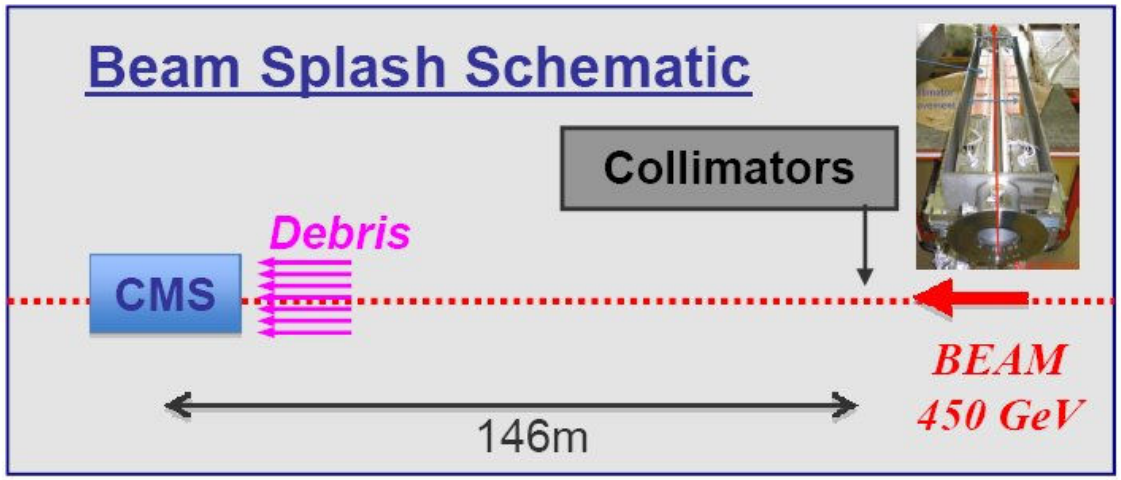
*operating field of CMS is 3.8T

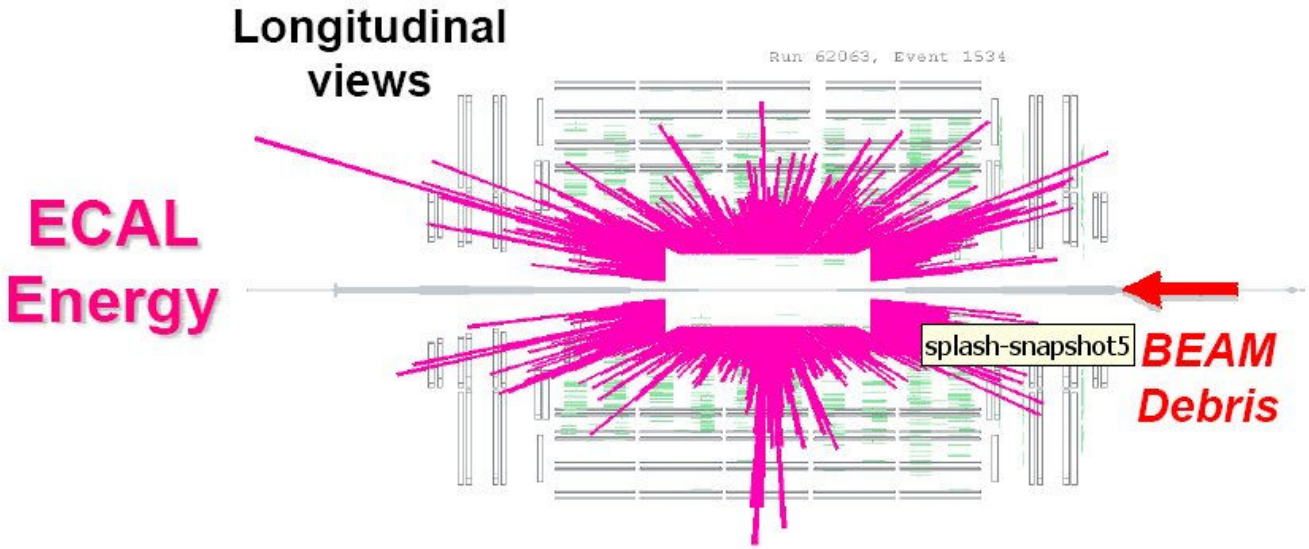


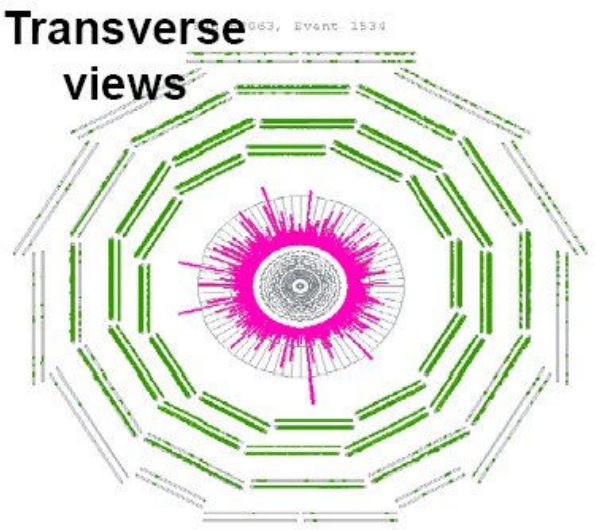
Beam Splash events – 2008 and 2009

Beam Splash Events: Single beam shots of 2×10^9 protons onto closed collimators 150m upstream of CMS

A "wave" or "splash" of secondary particles passed through CMS, depositing a huge amount of energy

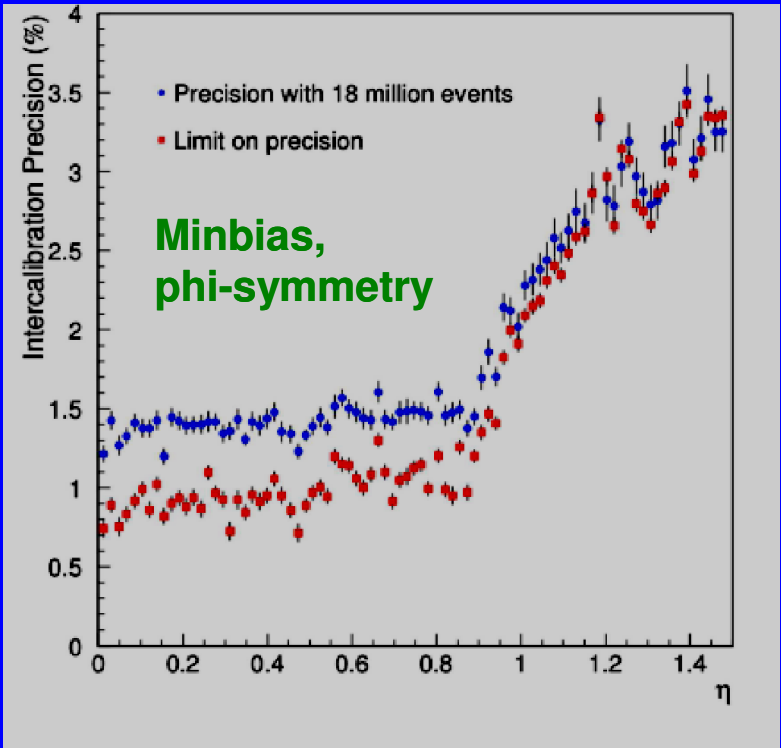


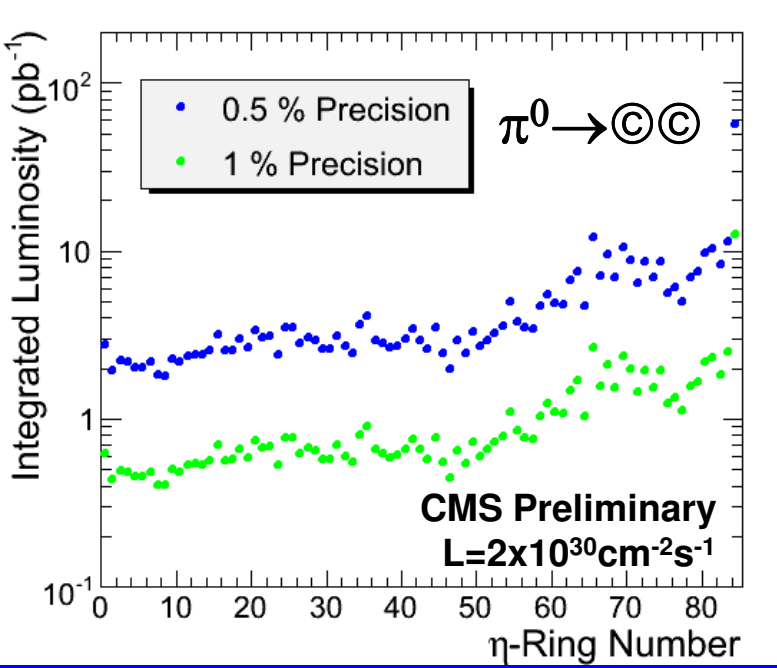




VI – ECAL Calibration: Physics events

Strategy	Time	Precision
ϕ **symmetry**: use invariance of mean energy deposited by jets at fixed η	Few hours	~ 2-3%
$\pi^0 \rightarrow \gamma\gamma$: mass peak @ low luminosity	Few weeks	<= 1%
Z→ee: absolute energy calibration	100 pb^{-1}	< 1%





Event rates at the LHC, Nominal Luminosity