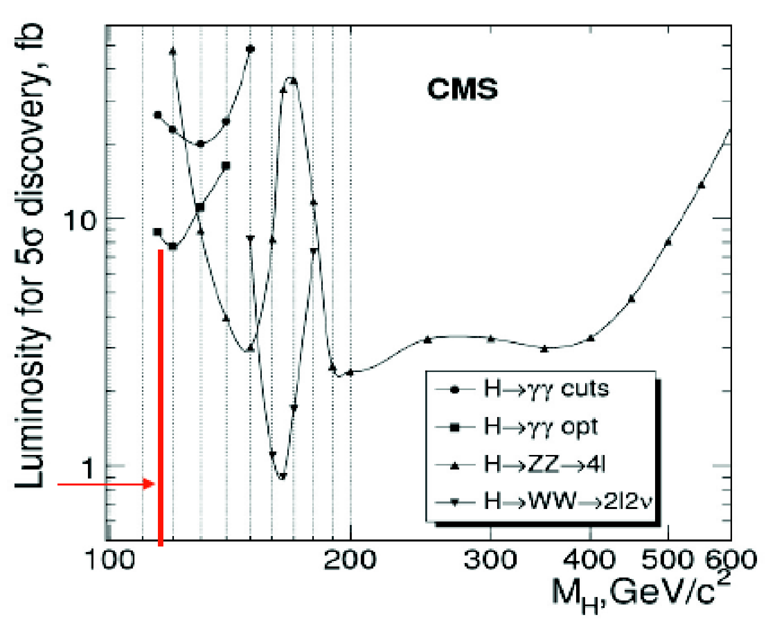
The Photon+X Signature Group

Andrew Askew, Rutgers/FSU
Marat Gataullin, Caltech

Photon + X:

- Not home to a single signal topology, but a host of different analyses with some common challenges:
  - QCD Direct Photons
  - Low mass Higgs->γγ -->
  - Wγ/Zγ Diboson production
  - Graviton signals: High mass diphoton resonanaces, photon plus missing E_T
  - GMSB SUSY/UED: diphoton plus missing E_T
  - Hidden valleys: long lived particles decaying to photons, and more…



So that's a serious array of analyses:

- Since this is a family of analyses, united by one kind of object, it behooves us to make sure that the point of commonality is well understood.
- We try to tackle those issues particular to photons:
  - Thus our main points of contact with CMS are the ECAL DPG, eγ POG, and then the appropriate physics groups for the analyses (Exotica recently added it's own Photon + X subgroup).
  - We don't replace any of these groups. We provide a forum for concentrating on photon issues and sharing experience. Most presentations from our group get refined and then shared at the larger CMS level.

A Young Group:

- Marat actually had to remind me that this group is only 1.5 years old (we've come a long way).
- A lot of investment went towards forming the tools/methods needed for startup photon identification:

Revision **1.1** - (view) (download) (annotate) - [select for diffs]
Thu Apr 17 19:41:42 2008 UTC (15 months, 2 weeks ago) by *askew*
Branch: MAIN

```
First set of files, DOES NOT WORK YET.  Need to add CFG files, test running,
replace the isolation calculation with getting the proper product from the
event, all of which are coming SOON.
```

Photon Identification selection criteria and software, Y. Gershtein, A. Askew

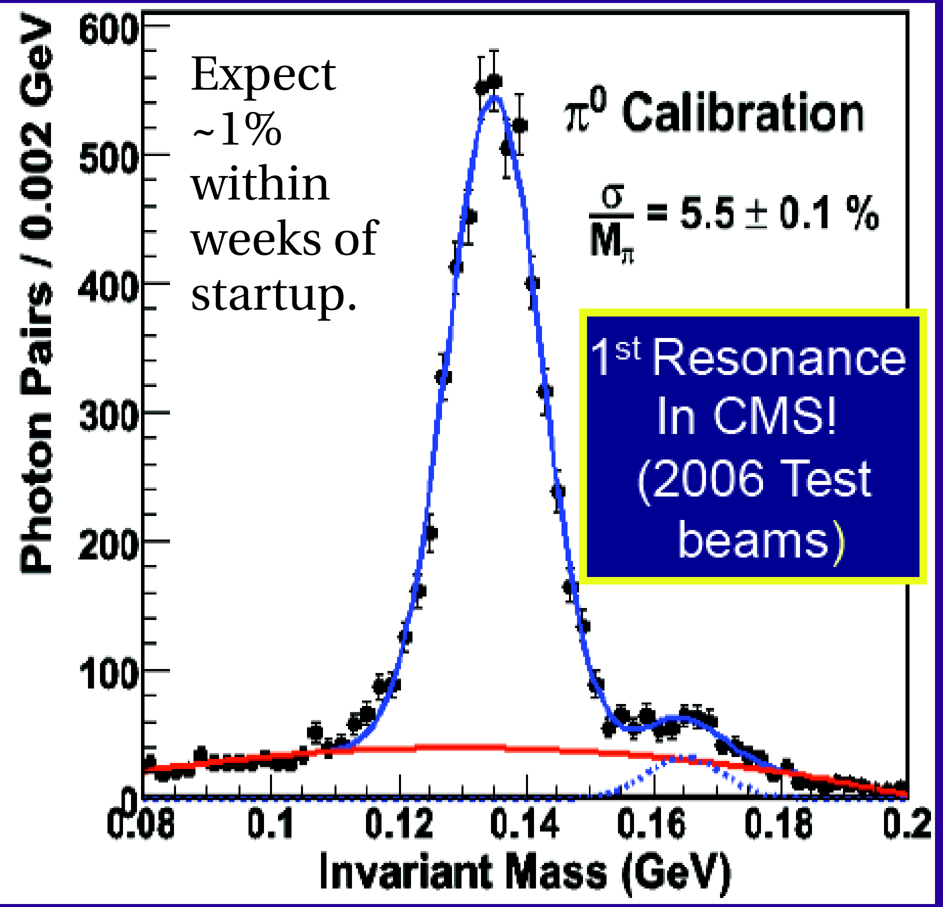
- A year ago, we lacked, among other things, any form of photon analysis software. We've gone from these first versions to a functional set of photon software for CMSSW_3_1.

This work is happening here:

- I'll take you through specifically the work that's being done in this group.
  - Tools and documentation of these studies are in various stages of completion.
- Then I'll highlight some of the analyses that have been approved using this work (you'll hear more in depth about some analysis from Selda and Vanessa).

Calibration:

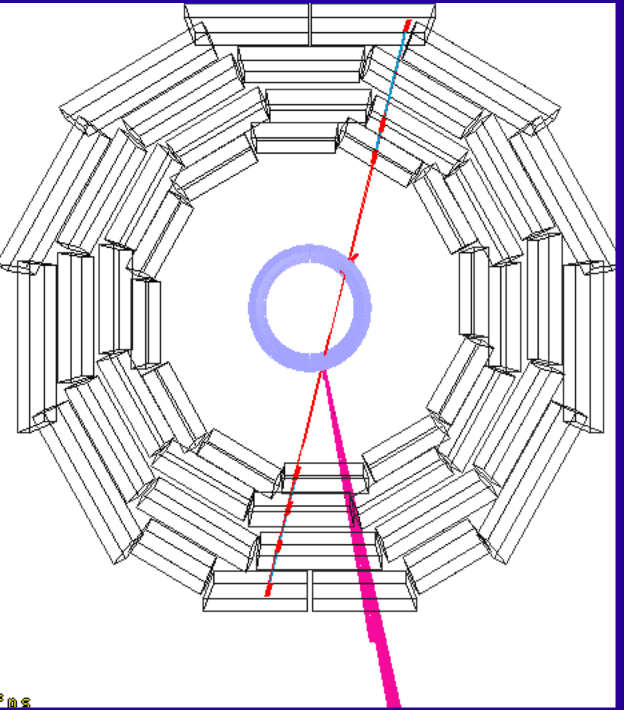
- It's absolutely worth mentioning that algorithms mean nothing without a well calibrated detector.
- A number of our members are veterans of the testbeams, and supporters of the ECAL calibration effort.
- Good contact with DPG leaders, such as G. Franzoni (see Monday's ECAL tutorial).

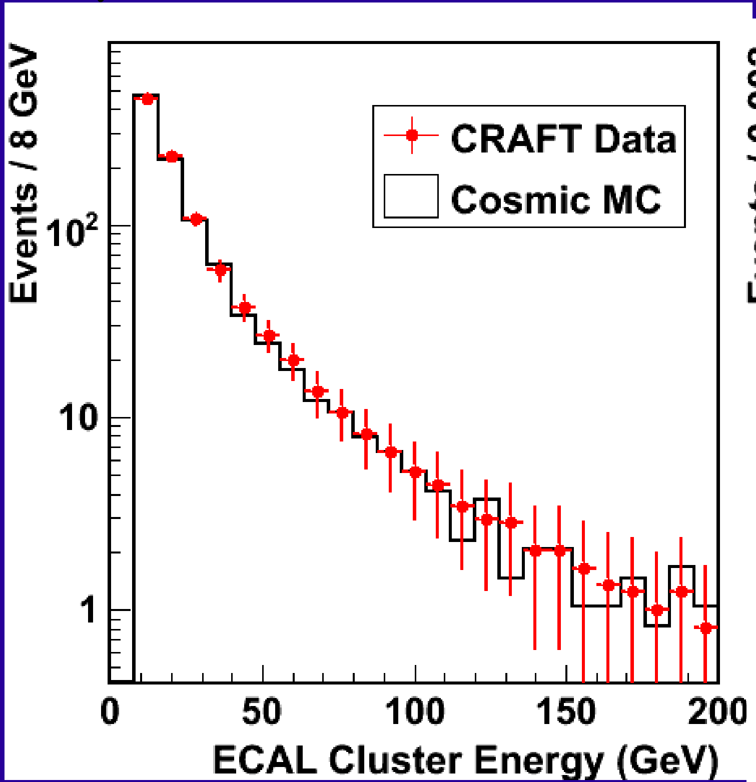


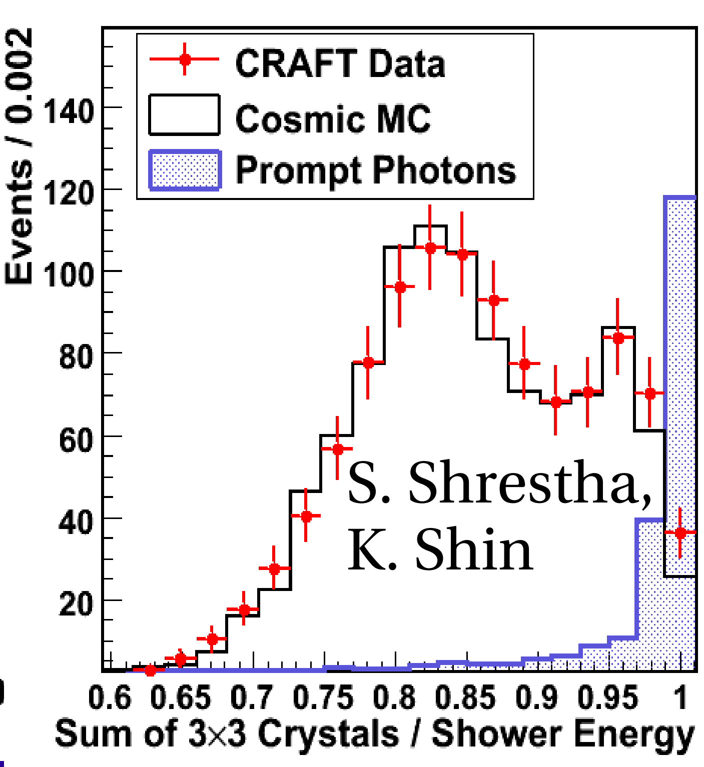
M. Gataulin is ECAL calibration and monitoring coordinator

Cosmic Photons:

Cosmic runs have produced a sample of 10K high-energy photons (E(γ)>10 GeV). Our studies of photon shower-shapes gives us some more confidence in our detector simulation (one of first such studies in CMS). Cosmic tagger developed to reject cosmic photons (main bkgd) for future searches for in the γ+MET channel.



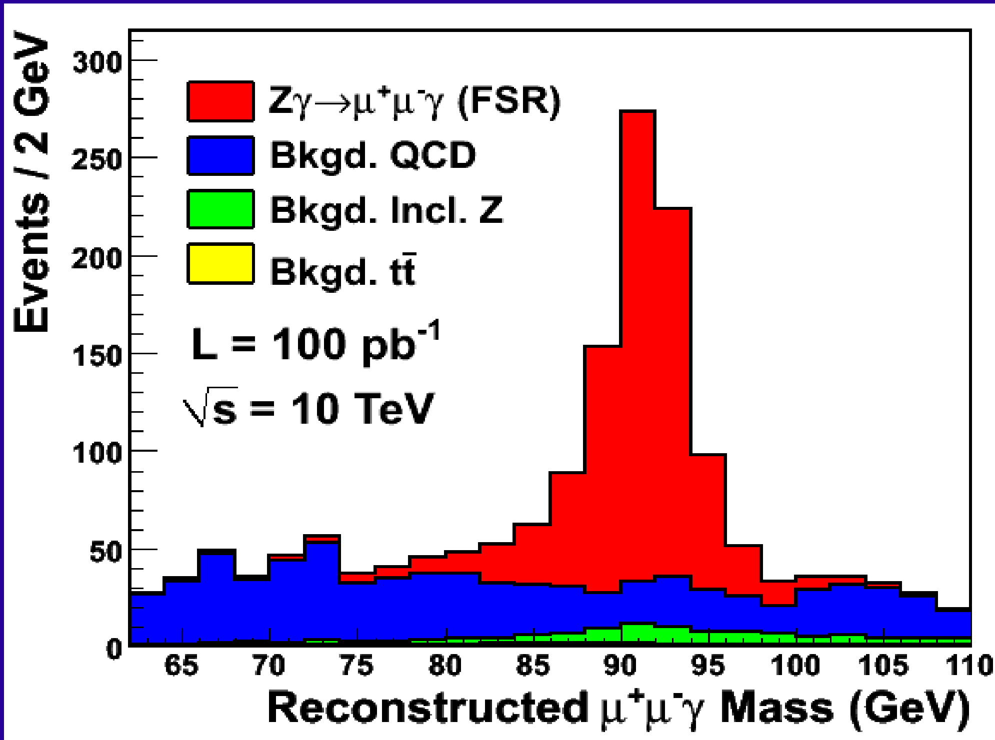




S. Shrestha, K. Shin

Efficiency (real photons):

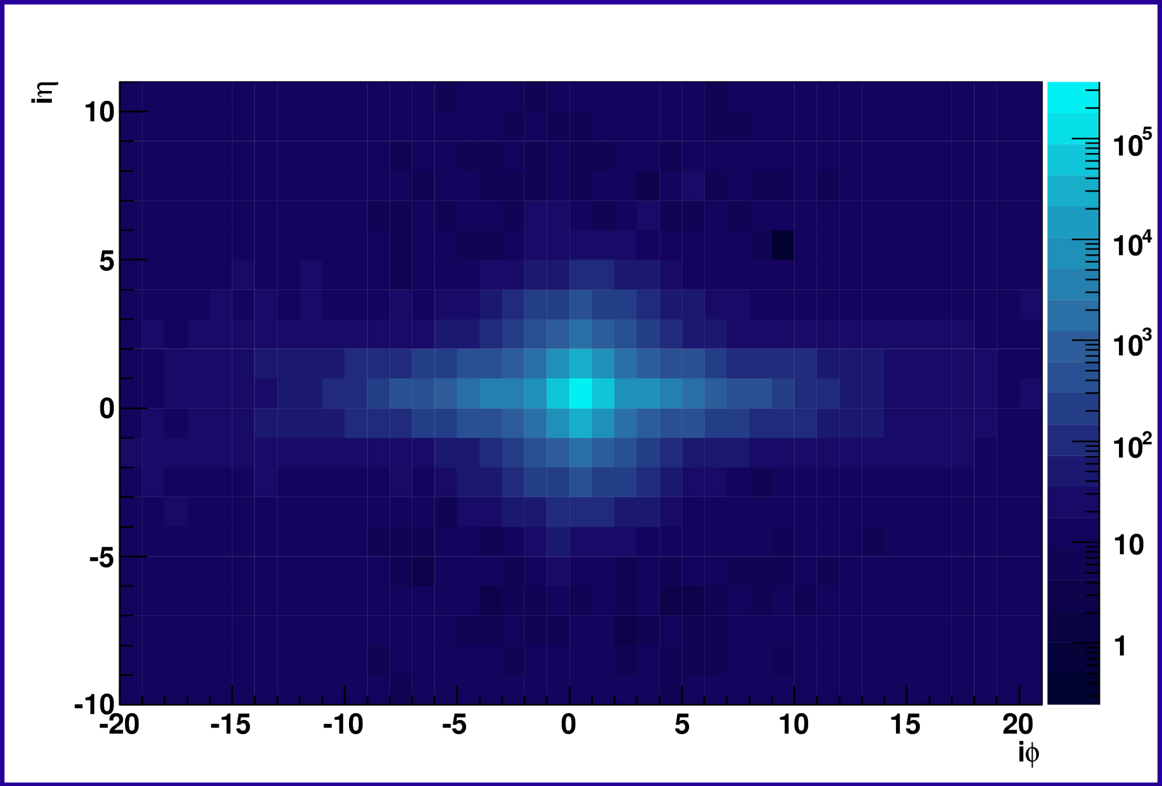
- With startup data, statistics will be limited, but Zγ events provide a vital check on real photons in the data.
- Internal bremsstrahlung: mass of the llγ should still reconstruct to that of the Z, with low backgrounds.



J. Veverka

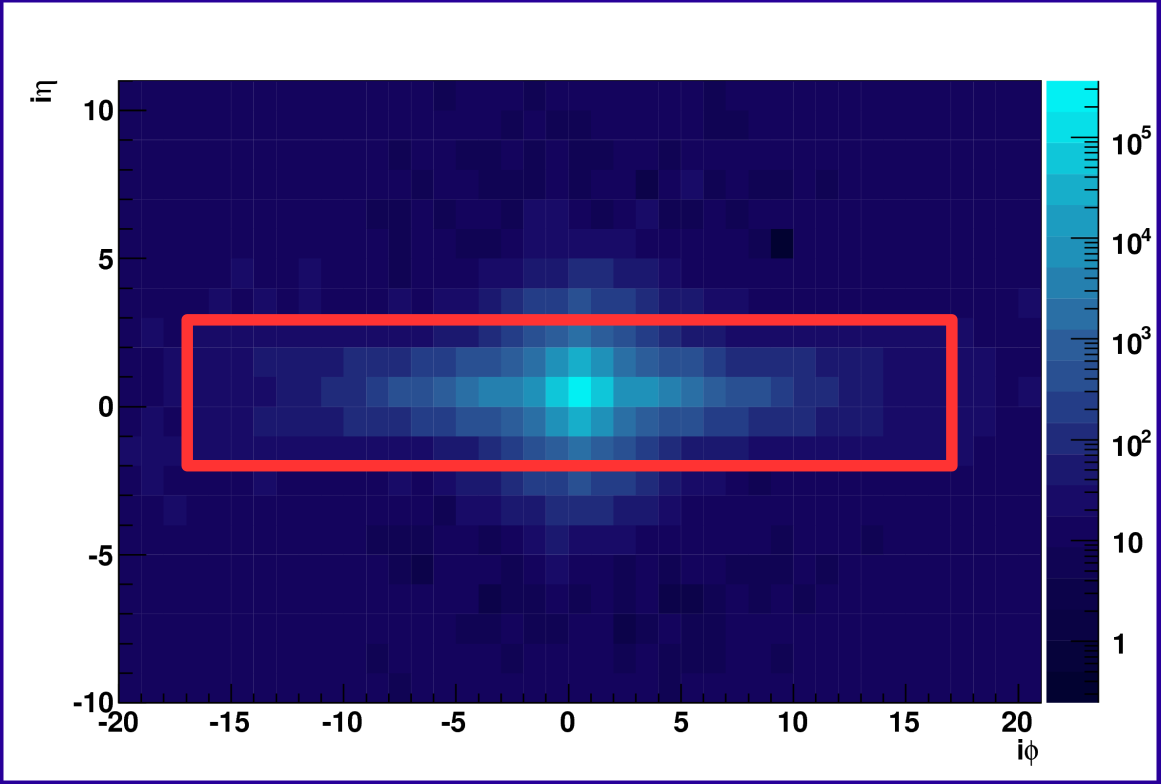
Isolation and Shower Shape:

- This is a kind of profile of the average energy deposition of photons in ECAL.



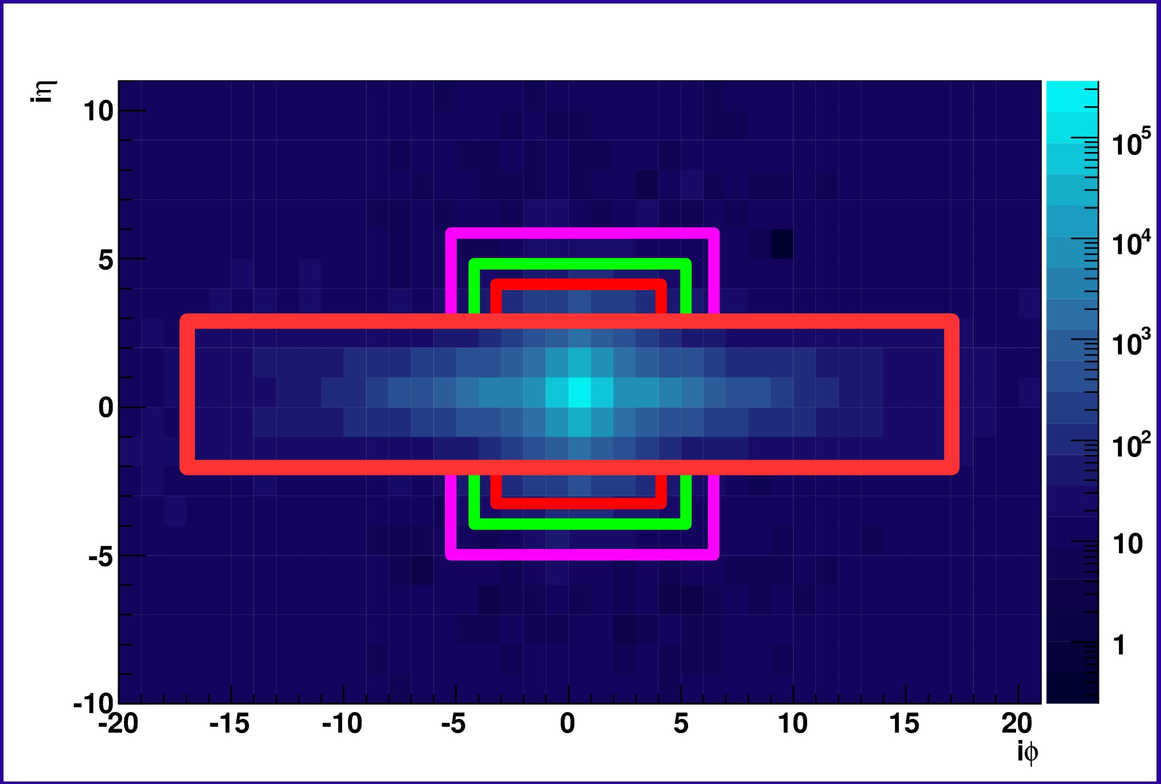
Isolation and Shower Shape:

- This is a kind of profile of the average energy deposition of photons in ECAL.
- The clustering will only operate on what's in the box.
- But there's more information!



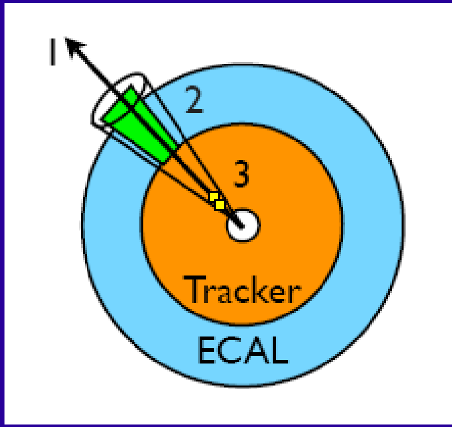
Isolation and Shower Shape:

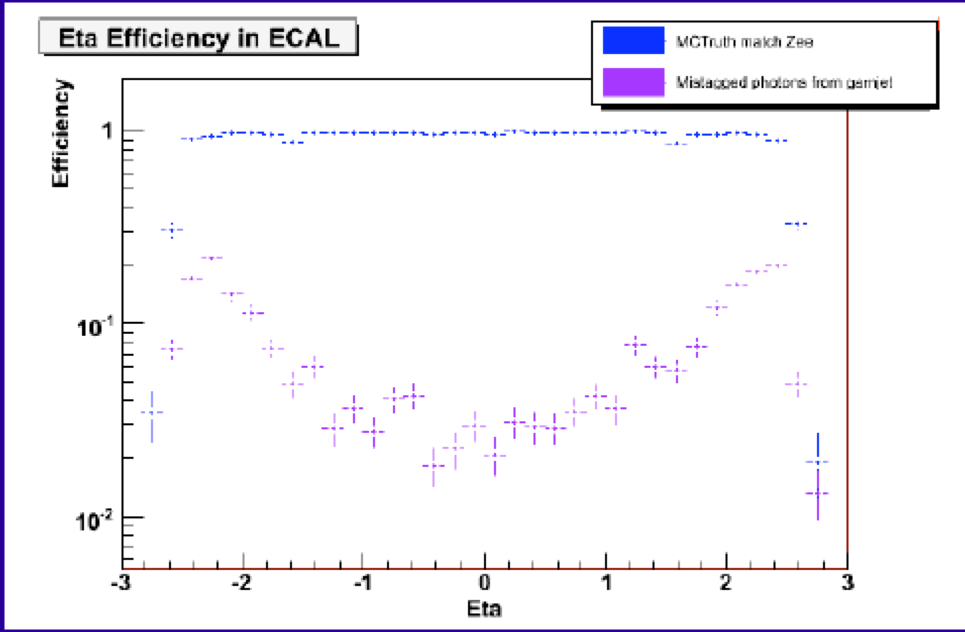
- This is a kind of profile of the average energy deposition of photons in ECAL.
- The clustering will only operate on what's in the box.
- But there's more information! Change isolation to use more position information?



Electron Veto:

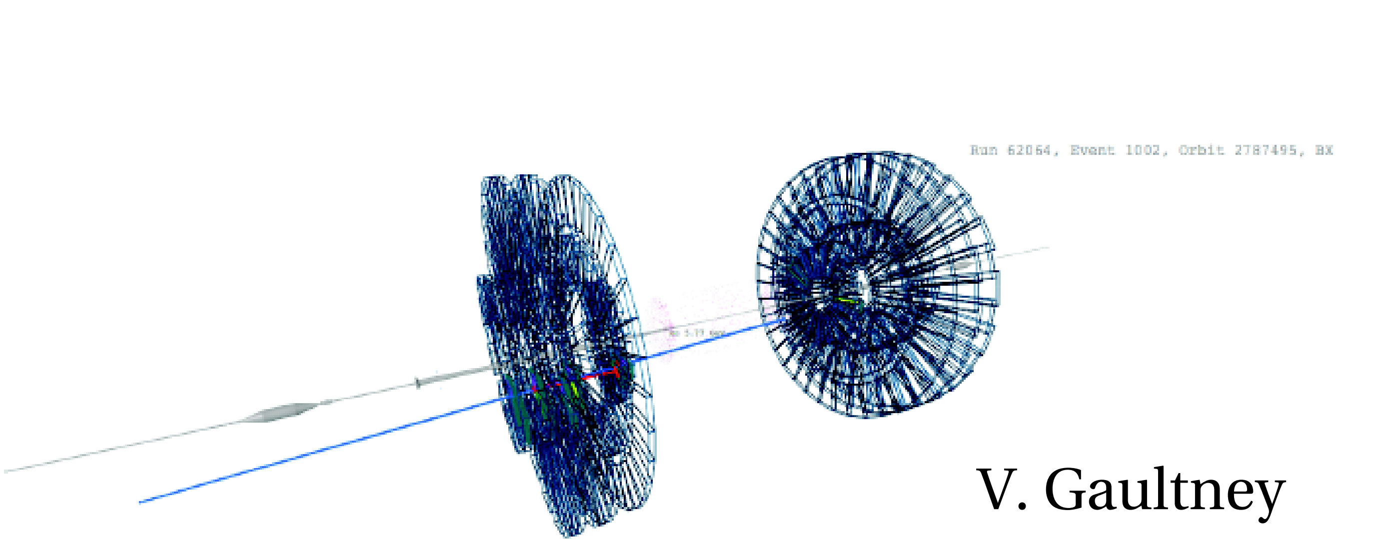
- Since by construction the track isolation should have similar efficiency for electrons, we discriminate between e/γ using pixel seeds.
  - Uncertainty due to material, but only pixel material.
  - Inefficiency almost entirely due to conversions.





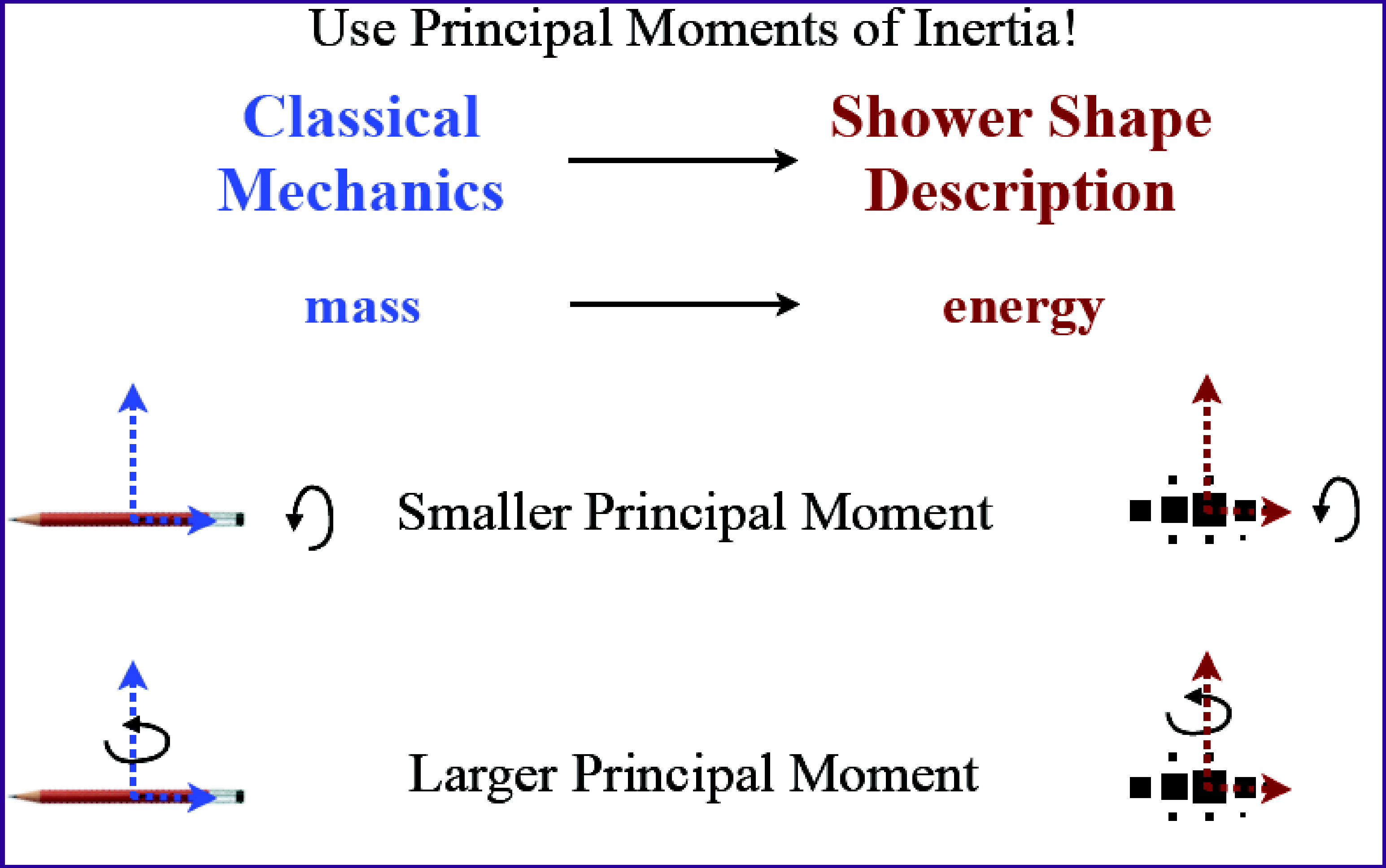
C. Kopecky

Beam Halo Tagging:



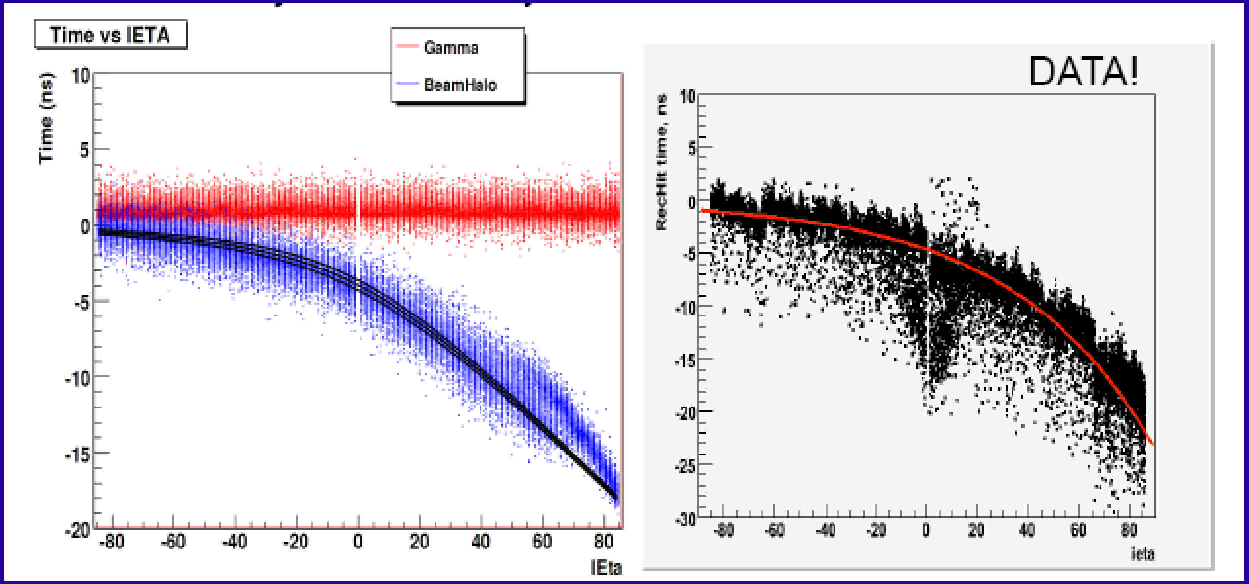
- First, build an independent method of identifying that a beam halo muon has produced a brem photon in ECAL. Such as the above, using hits in the HE to signal the passage of the muon.
- Use the correlation between the ϕ of the HE hits to the energy deposition in ECAL.

Beam Halo Shower Shapes:



T. Miceli

ECAL Timing:

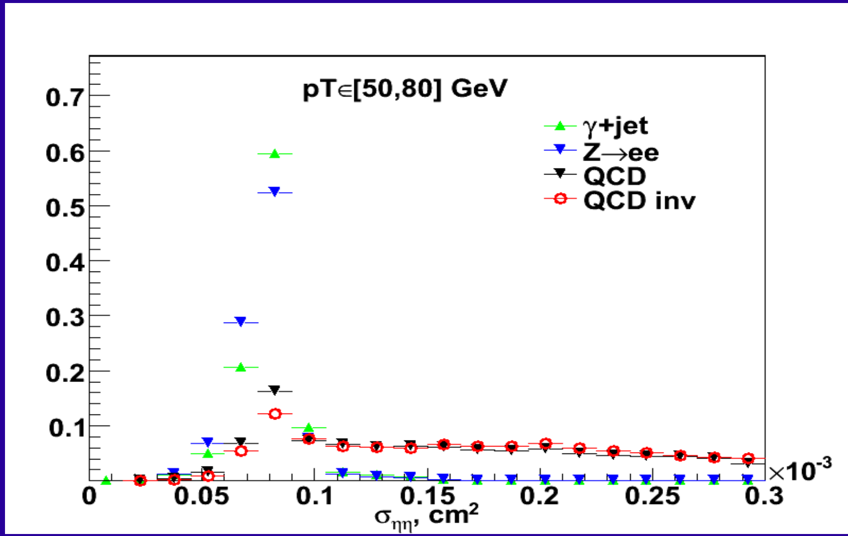


M. Balazs,
Y. Gershtein

- The actual time profile of the energy deposition in the ECAL may prove to be the best discriminator against out of time backgrounds (cosmics and beam halo).

QCD Background fitting:

- Once one builds up the quantities to be used for analysis, one can determine the purity by template fitting (Z->ee for signal, background with inverted isolation).
- Very useful for analyses (γ+j) which do not have nice mass peaks.



O. Atramentov,
A. DeBenedetti

Putting this all together:

- I said we'd made a sizable investment in infrastructure, tools, studies.
- In this last round of approvals we started putting our tools to work:
  - Efficiency measurements
  - Background estimates
  - Data-like exercise, blind to the MC truth

GMSB Diphotons:

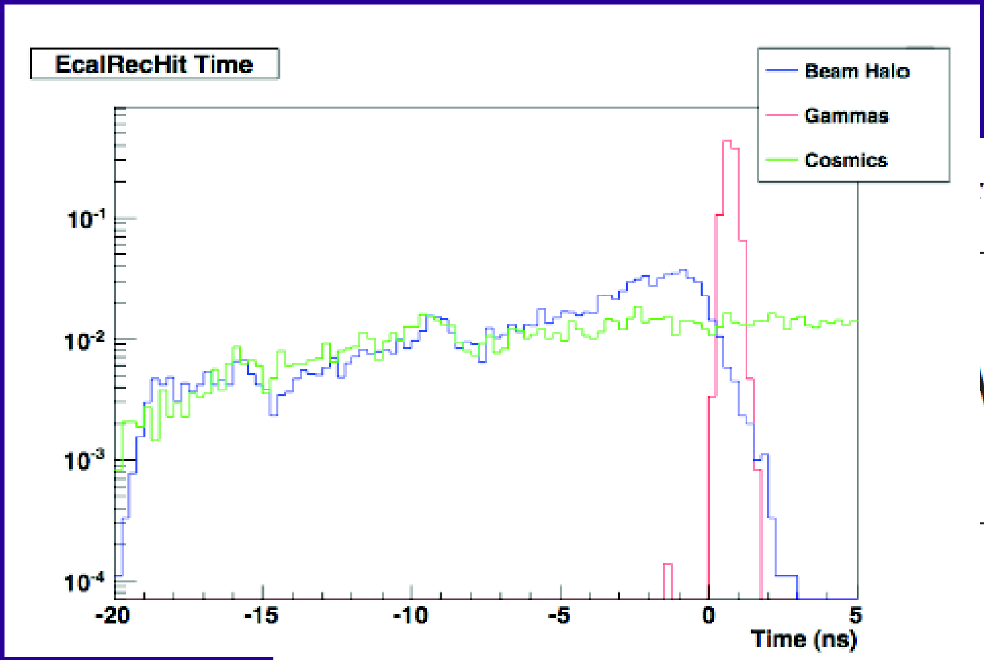
Available on the CERN CDS information server **CMS PAS SUS-09-004**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2009/07/02

Data-Driven Background Estimates for SUSY Di-Photon Searches

GMSB Diphotons:



ver CMS PAS SUS-09-004

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2009/07/02

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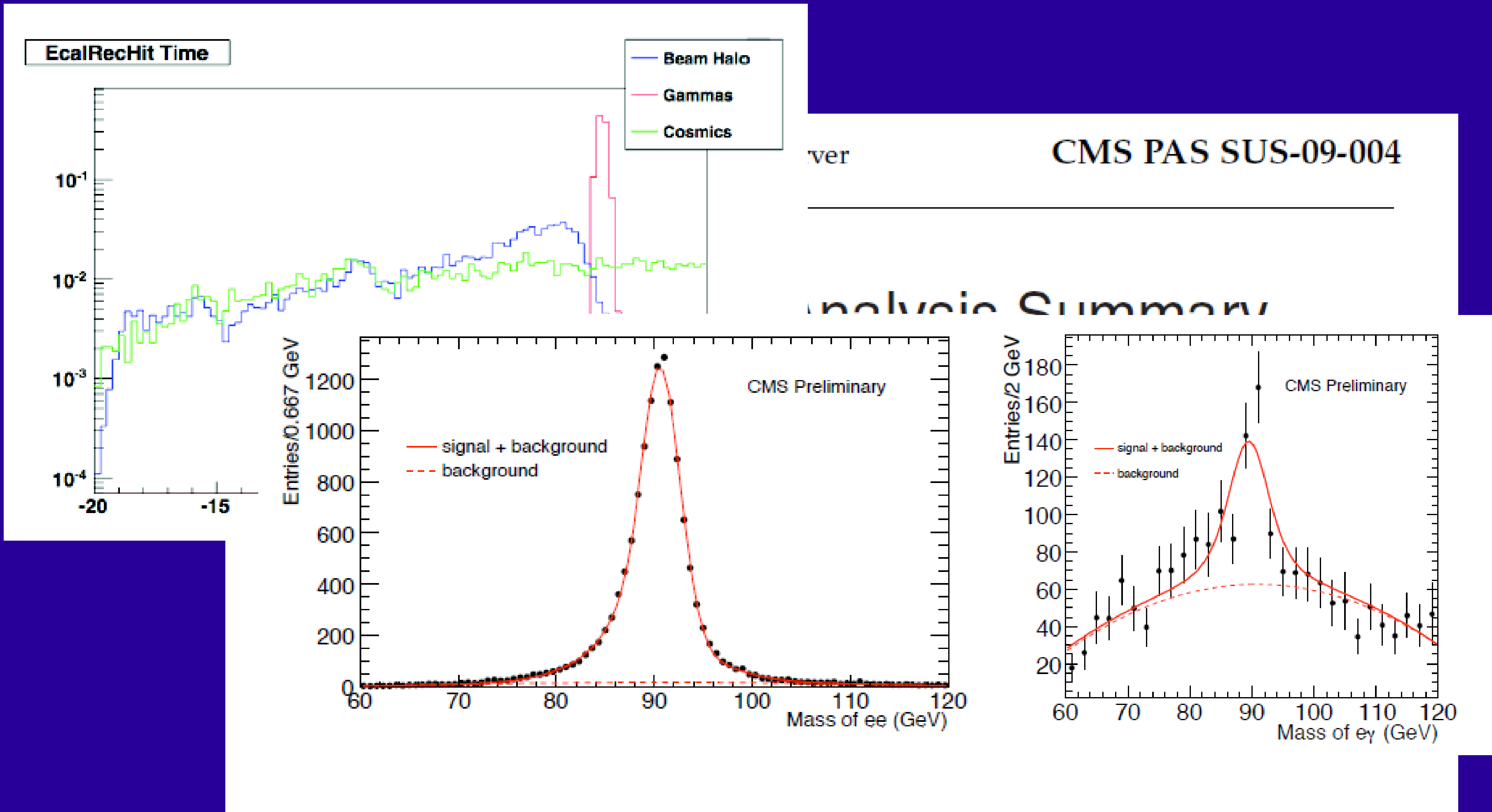
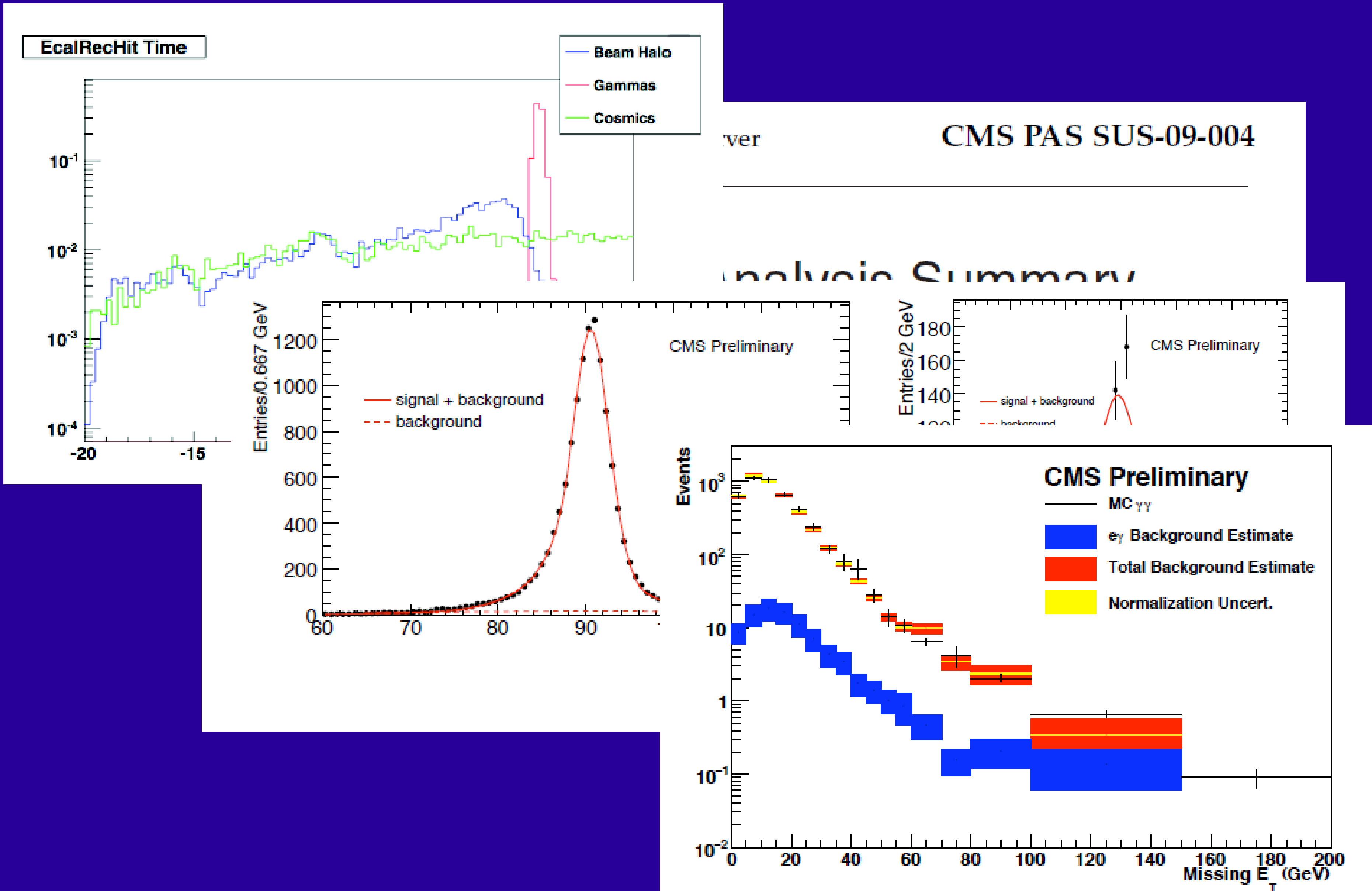


GMSB Diphotons:



Exotica Diphoton Searches:

Available on the CERN CDS information server **CMS PAS EXO-09-009**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2009/07/09

Search for Randall-Sundrum Gravitons in the Diphoton Final State

Available on the CERN CDS information server **CMS PAS EXO-09-011**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2009/07/07

Search for Scalar and Tensor Unparticles in the Diphoton Final State

Available on the CERN CDS information server **CMS PAS EXO-09-004**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2009/07/02

Search for Large Extra Dimensions in the Diphoton Final State

How to join?

- Regular bi-weekly meetings, every other Tuesday 1-3pm FNAL time.
- Next meeting is on August 11th.
- Active contributions from Rutgers, Caltech, UC Davis, FIU, Virginia, 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/

  askew@fnal.gov, marat@caltech.edu

This is the tip of the iceberg. If you're interested in Photon physics with CMS: this is the place to be.

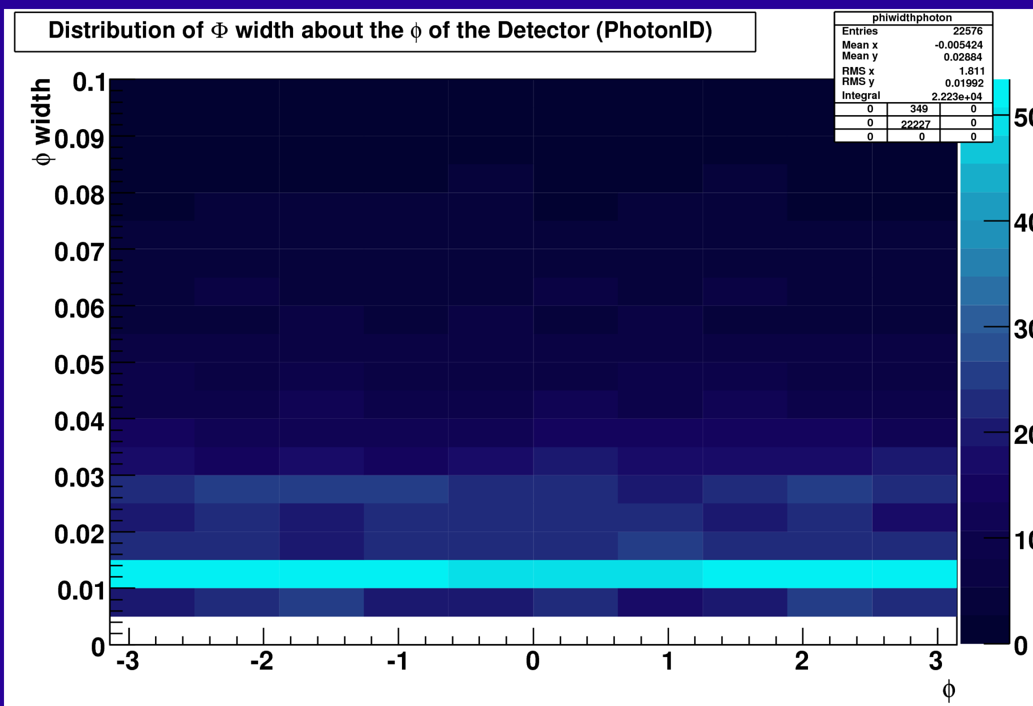
Summary:

- There's a lot of physics with photons:
  - A lot that can also be done with EARLY data.
  - Say if someone wanted to…do a thesis?
- We've been developing tools, and creating the infrastructure, and plotting out how to make these early measurements.
  - Want to be an expert? No better way than to get involved.

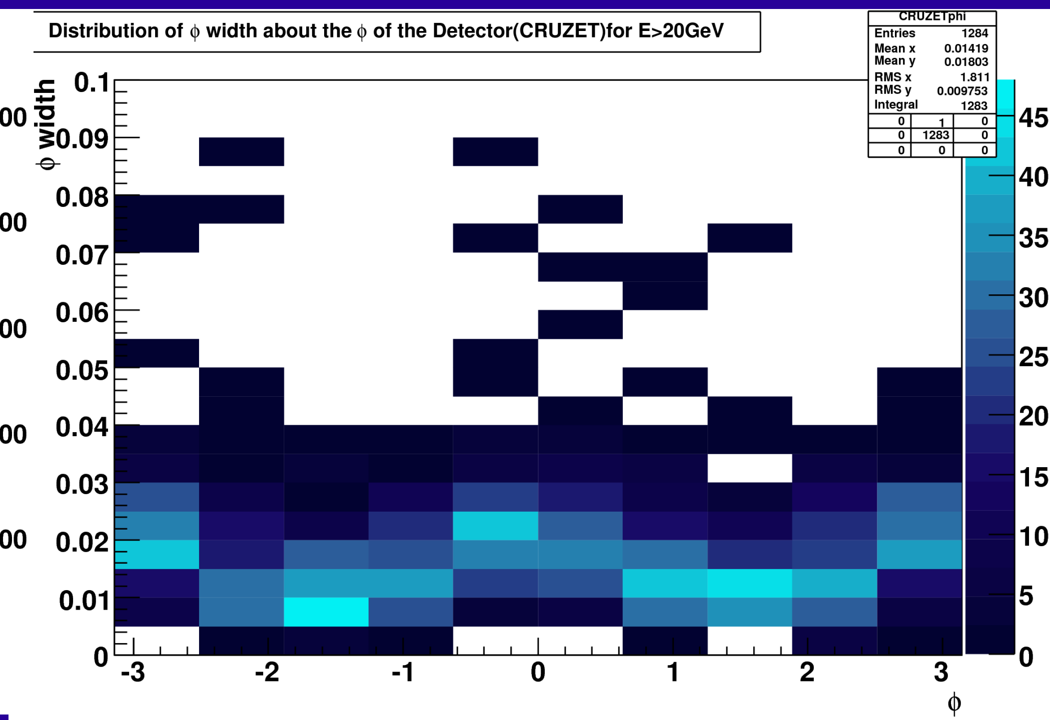
BACKUPS

Cosmic shapes:

- Since most cosmics are passing vertically through the detector, their shape ends up being elongated in that direction. Use of this to discriminate against cosmics is under study.



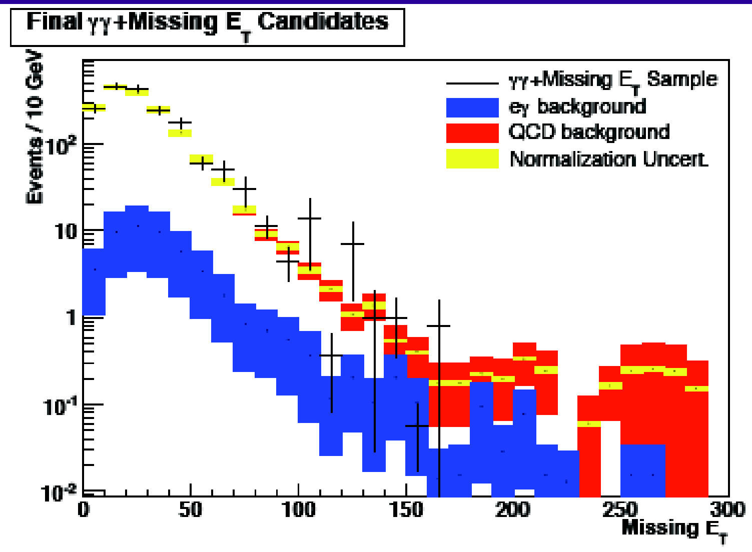
Prompt γ Monte Carlo, ϕ-width

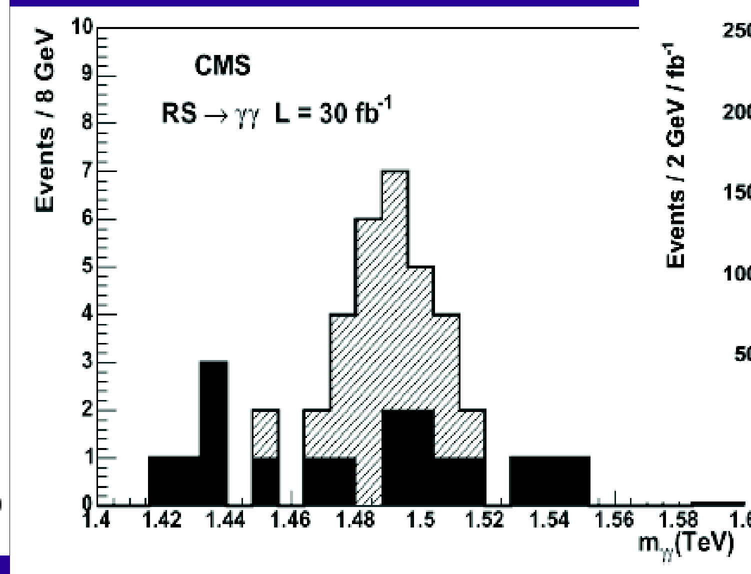


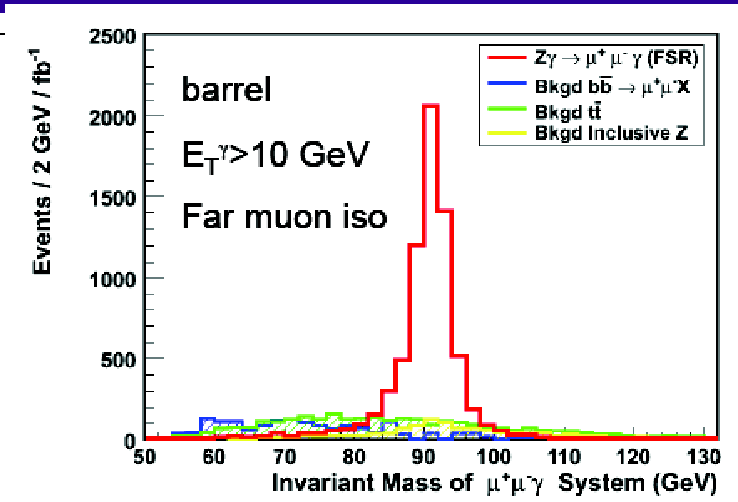
CRUZET Data, ϕ-width

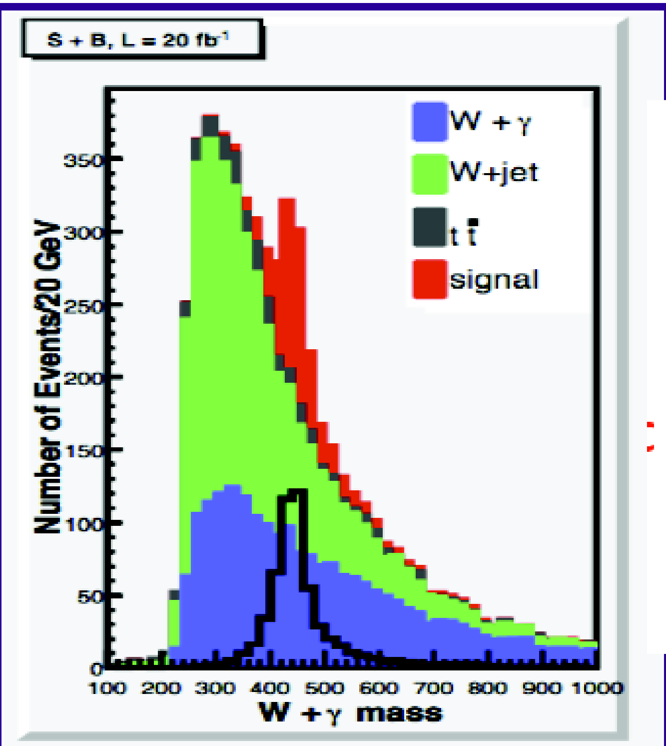
S. Shrestha

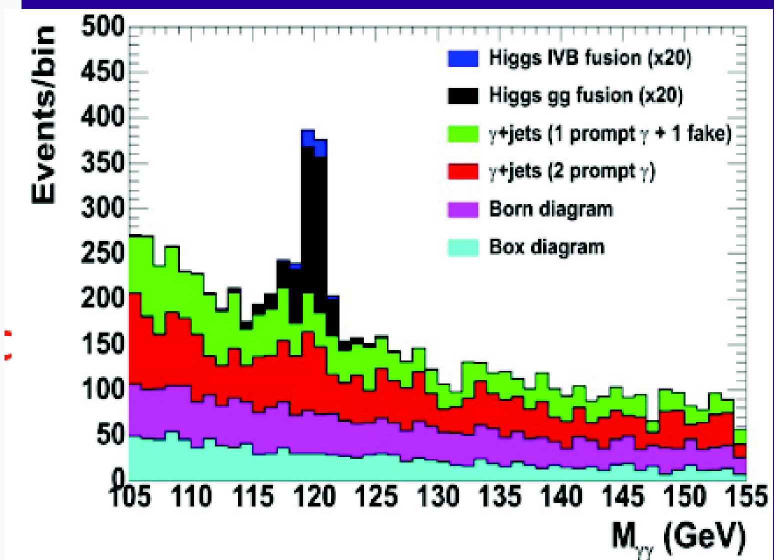
Photon + X:

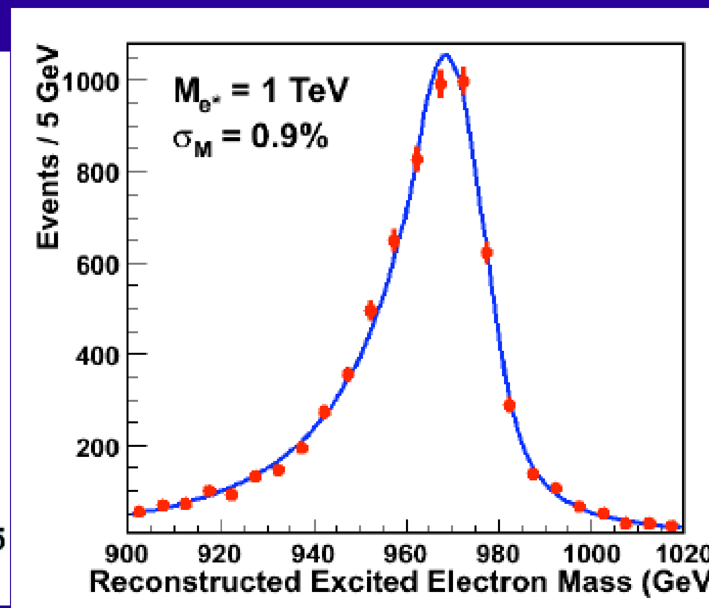








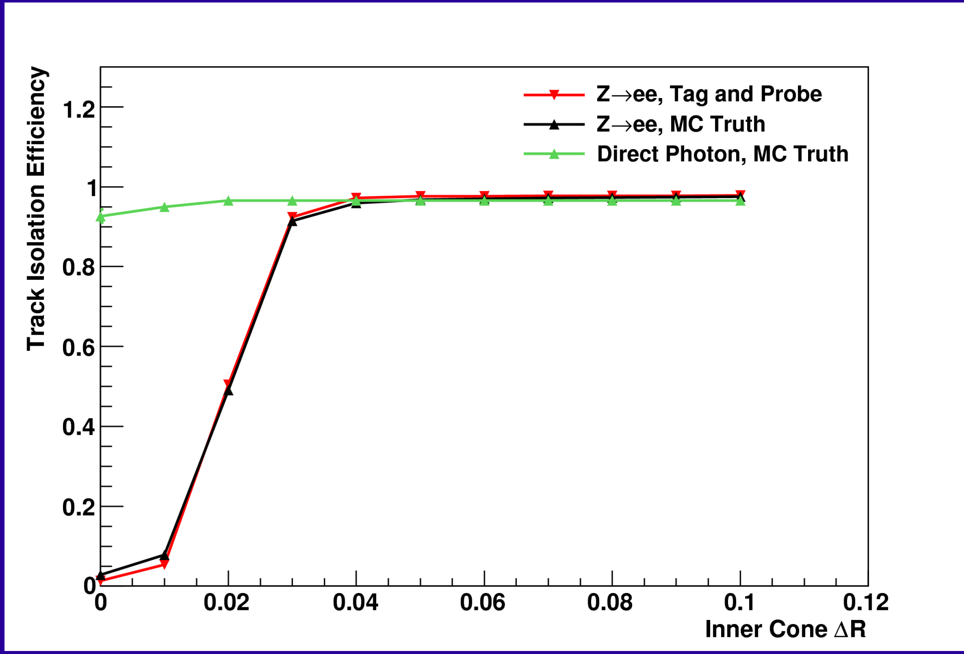




A quick sampler platter.

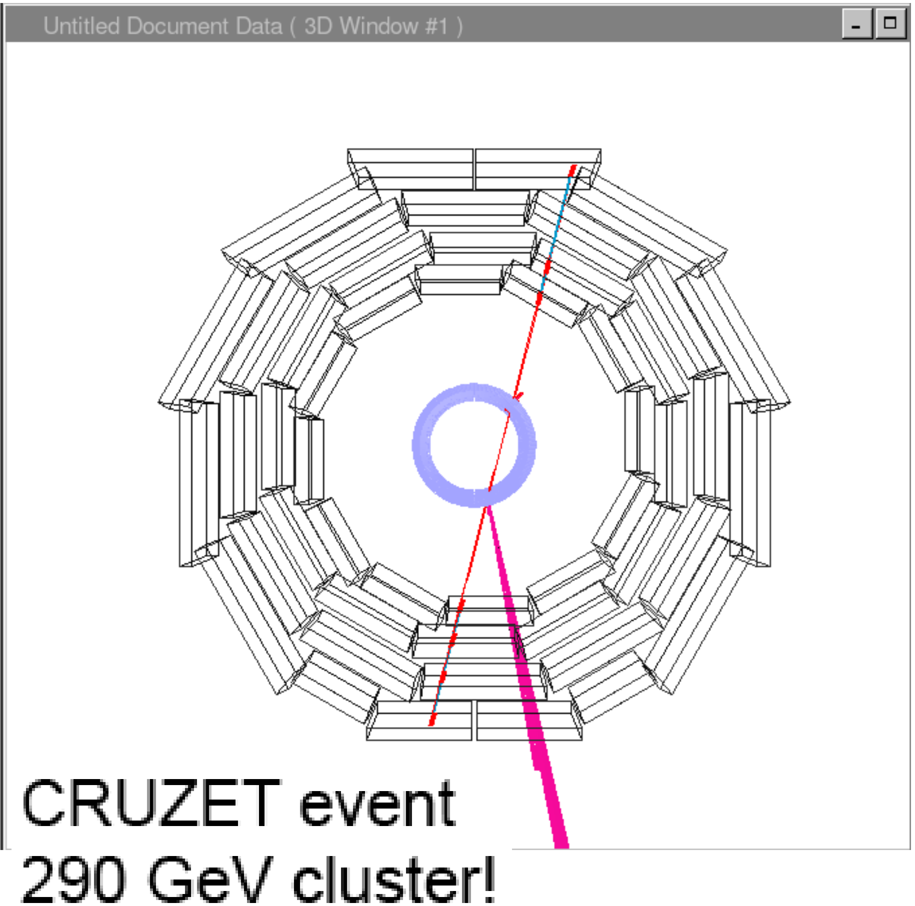
Isolation:

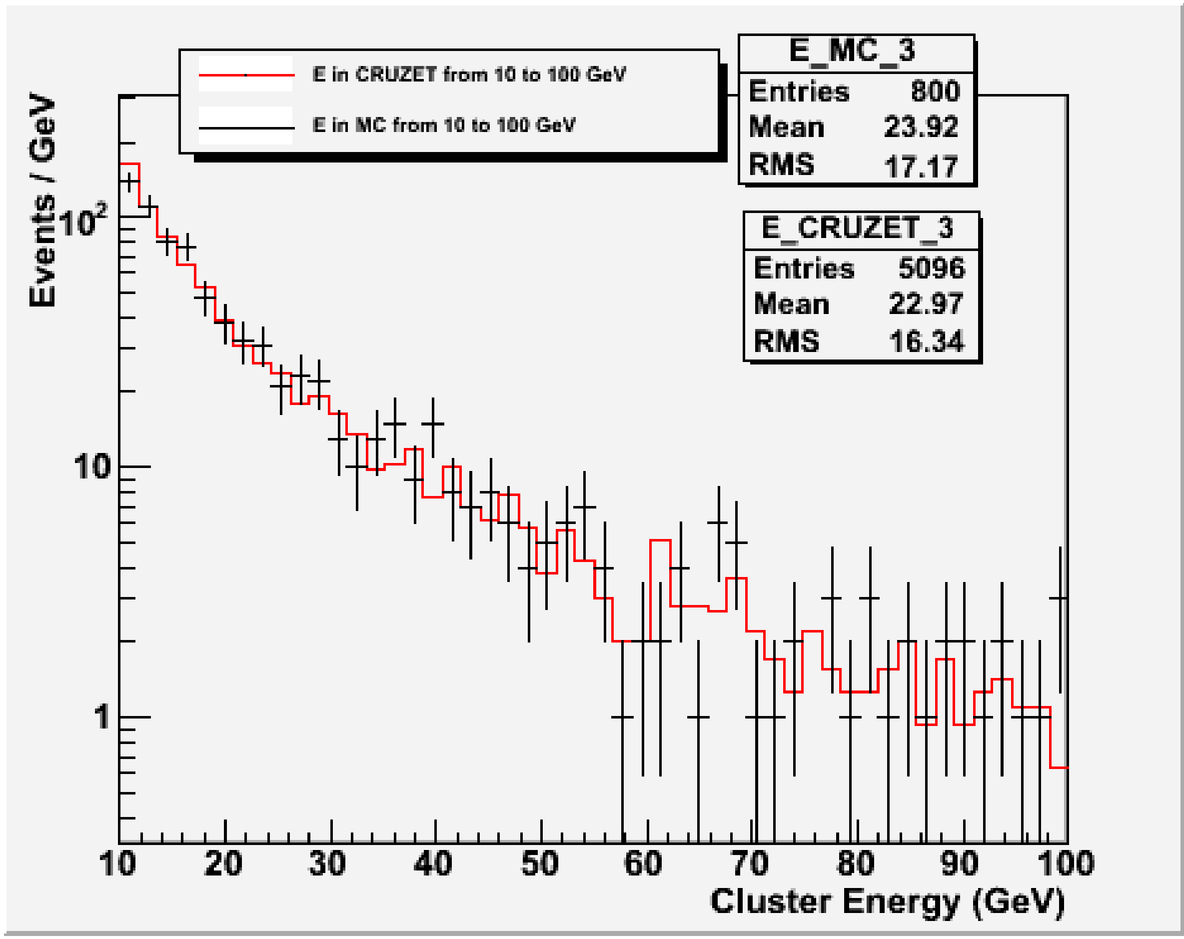
- Hollow cone track isolation, allows for checking of photon efficiency with electrons, and is less sensitive to material interactions.
- Set the inner cone size properly, and this similarity is acheived.



Cosmic Photons

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





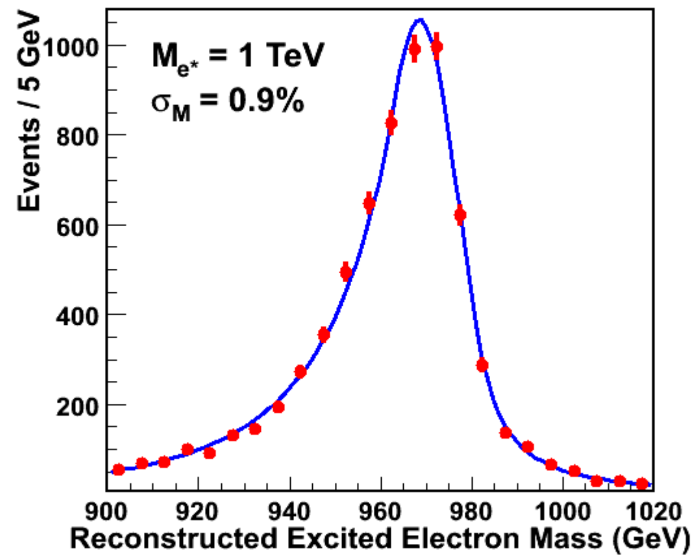
S. Shrestha, K. Shin

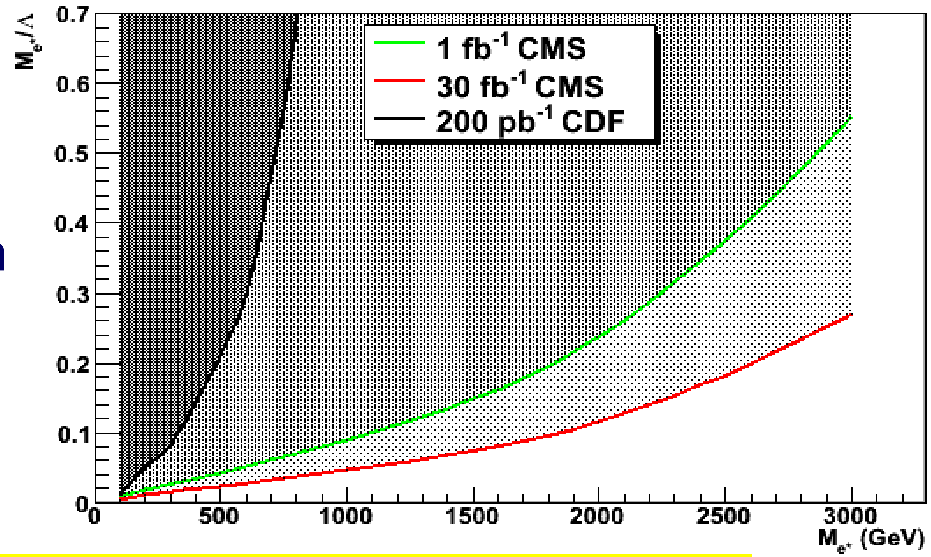
Search for Compositeness: Excited Electrons

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

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

- 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

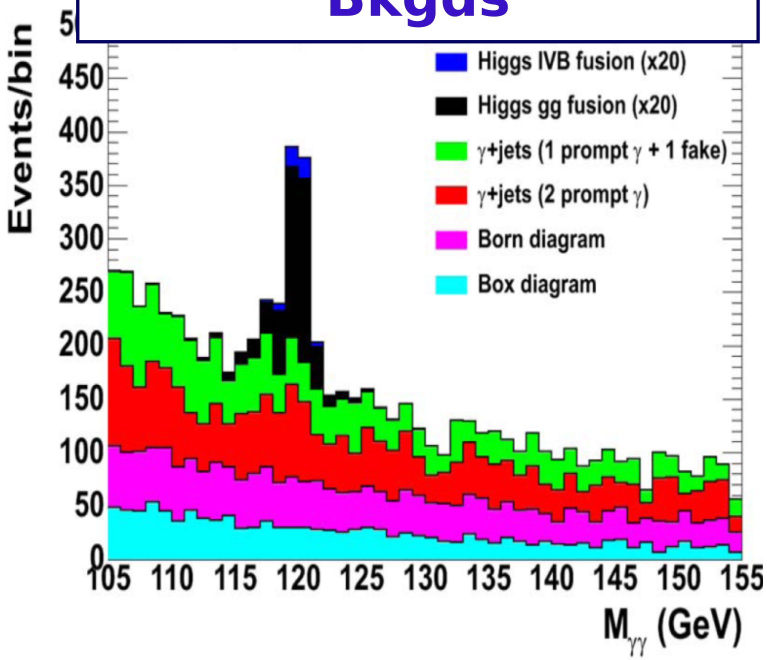
Optimized H→γγ Analysis – Decision Trees and Categories (Log-Likelihood)

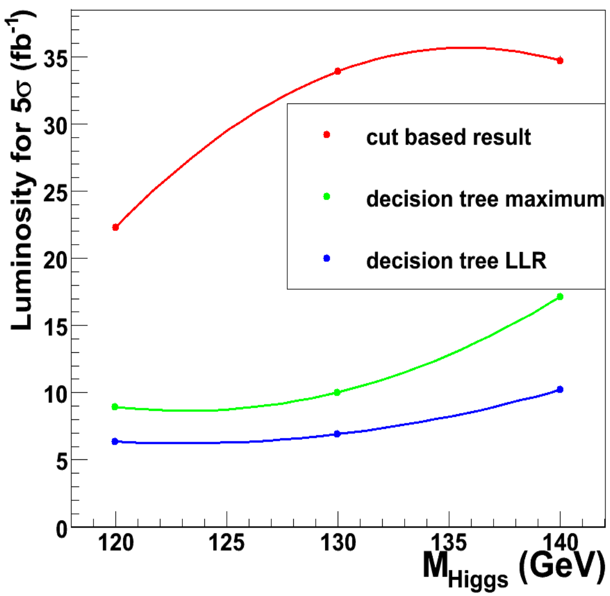
Luminosity for 5σ Discovery

Y. Ma, 2009

Elwk Fit 4/09
M_{top} = 173.4 ± 1.3 GeV
M_W(LEP2) = 80.383 ± 0.030 GeV
M_H < 163 [191] GeV (95% CL)

Higgs Signal and Bkgds

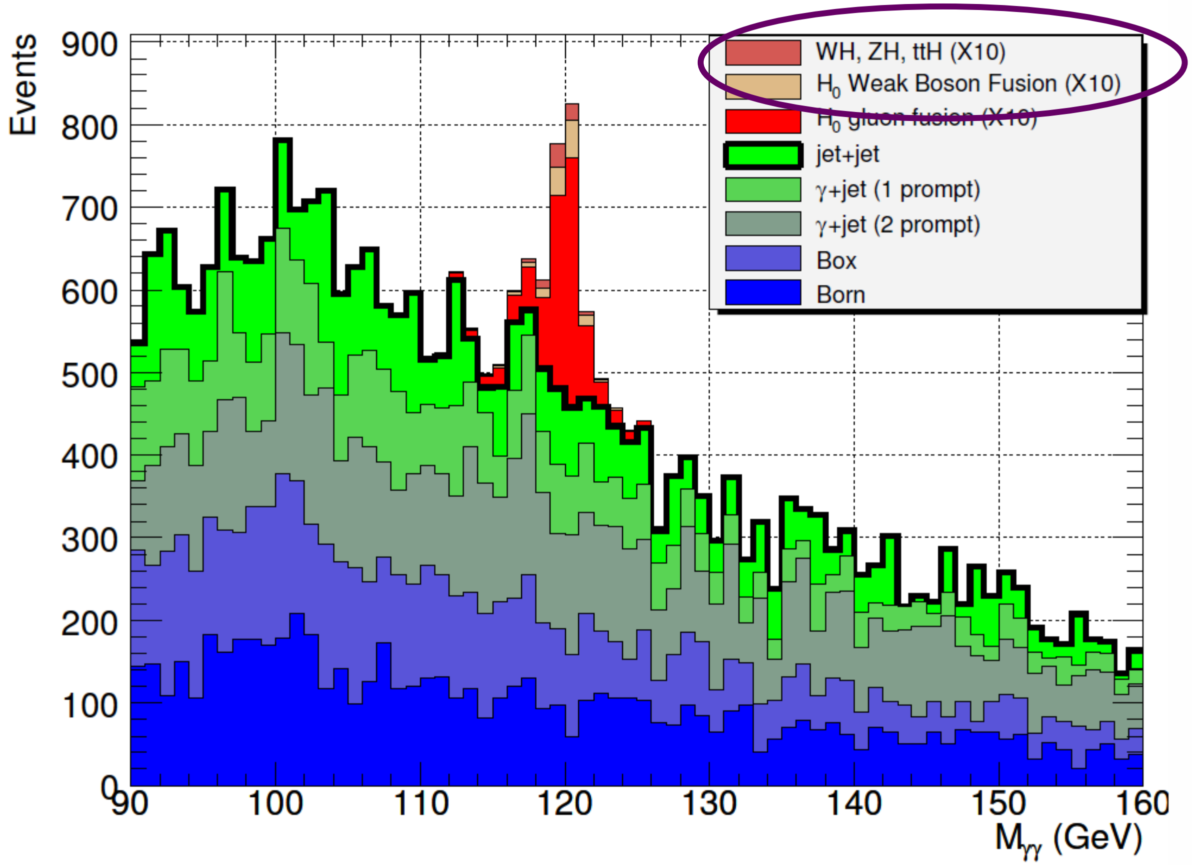


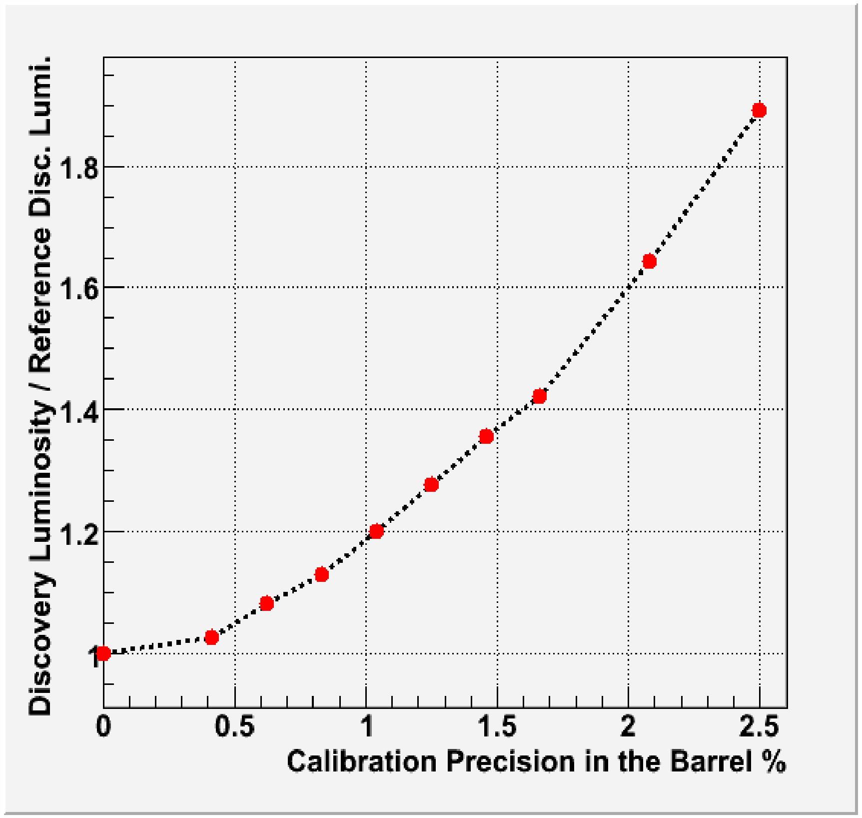


- **Keys:** Clean Photon ID, 0.7% Mass Resolution, Precise Calibration
- **Multivariate:** nearly double significance compared to cut based
- **Next Steps:** Optimize Signal/Background Separation, Including Higher Order Bgd. Calculations (with Dubinin); ECAL Calib. Effects

ECAL Calibration: Higgs Hunting

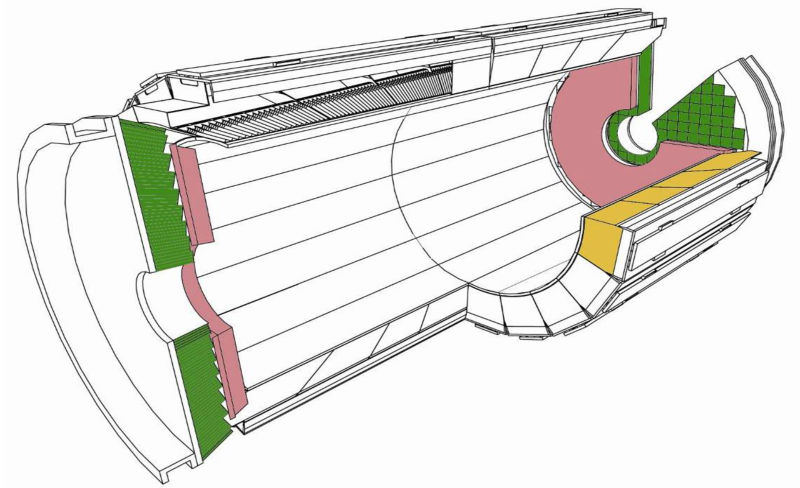
- Achieving a precise in situ crystal-by-crystal calibration and monitoring! of the ECAL will be crucial for the H $\gamma\gamma$ search.
- But also very important for other searches for new diphoton and dielectron resonances, which can appear quite soon (e.g. RS gravitons, Z')





CMS ECAL Calibration Overview

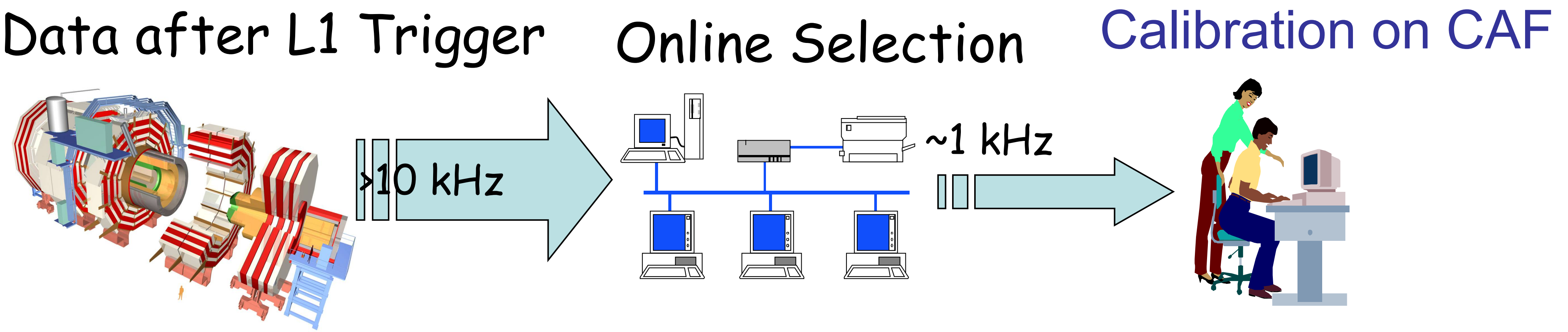
- Our PWO crystal electromagnetic calorimeter is the first high-precision ECAL at a hadron collider
- Barrel: $|\eta| < 1.48$
  - → 36 Super Modules 61200 crystals
- Two Endcaps: $1.48 < |\eta| < 3.0$
  - → 4 Dee's 14648 crystals



- Long-term calibration (and monitoring) goal: attain and maintain in situ the design energy resolution of 0.5% (as achieved in test beams)
- This year: starting with a ~1.5% precalibration precision in the barrel achieve ~1-2% stable calibration precision that would be suitable for early physics, e.g. with Z and W decays.
- In the endcaps the goal is to go from ~10% precalibration to a precision of a few %.

	Strategy	Time	Precision
→	Mean energy deposited by jet triggers independent of ϕ at fixed η (after correction for Tracker material)	few hours	~2-3%
→	Neutral pion mass peak: @ 2×10^{33} cm^{-2} s^{-1}	few days	≤1%
	Z→ ee: absolute calibration	100 pb^{-1}	< 1%
	W→ eν: E/p measurement	5-10 fb^{-1}	0.5%

ECAL AlCaRaw Calibration Concept



Both $\pi^0 \rightarrow \gamma\gamma$ (Caltech with Rome) and φ-invariance AlCaRaw streams use events accepted by Level 1 triggers in order to accumulate millions of events for a quick channel-to channel calibration.

Information from only 20-30 “useful” rechits is stored for each accepted event.

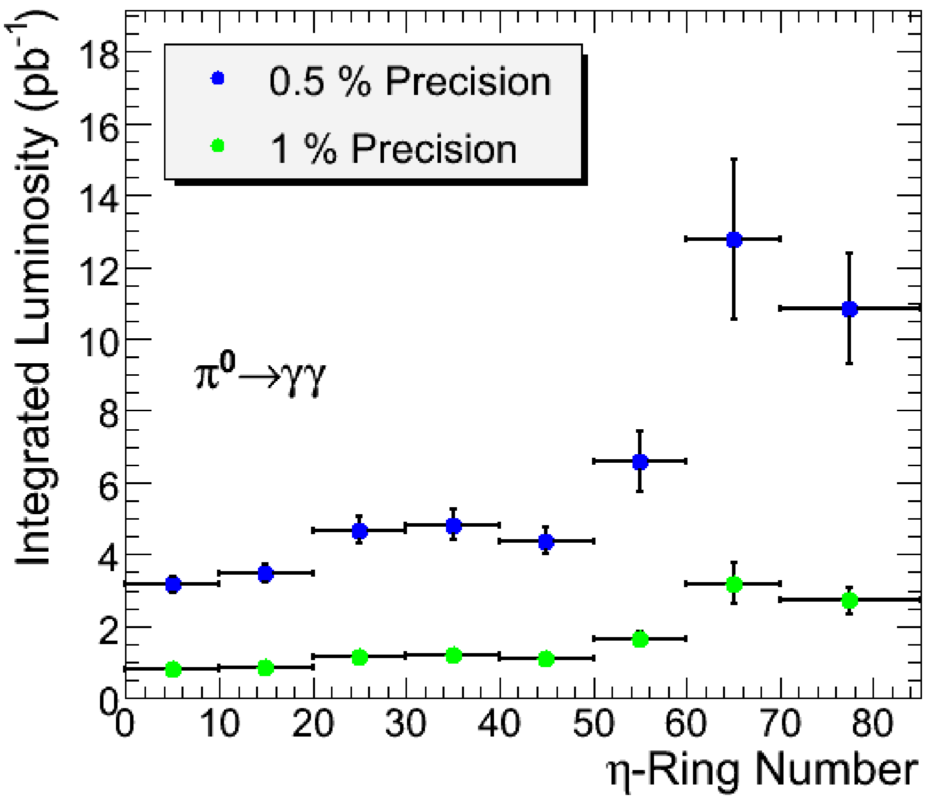
The output rate to CAF is close to 1kHz per stream.

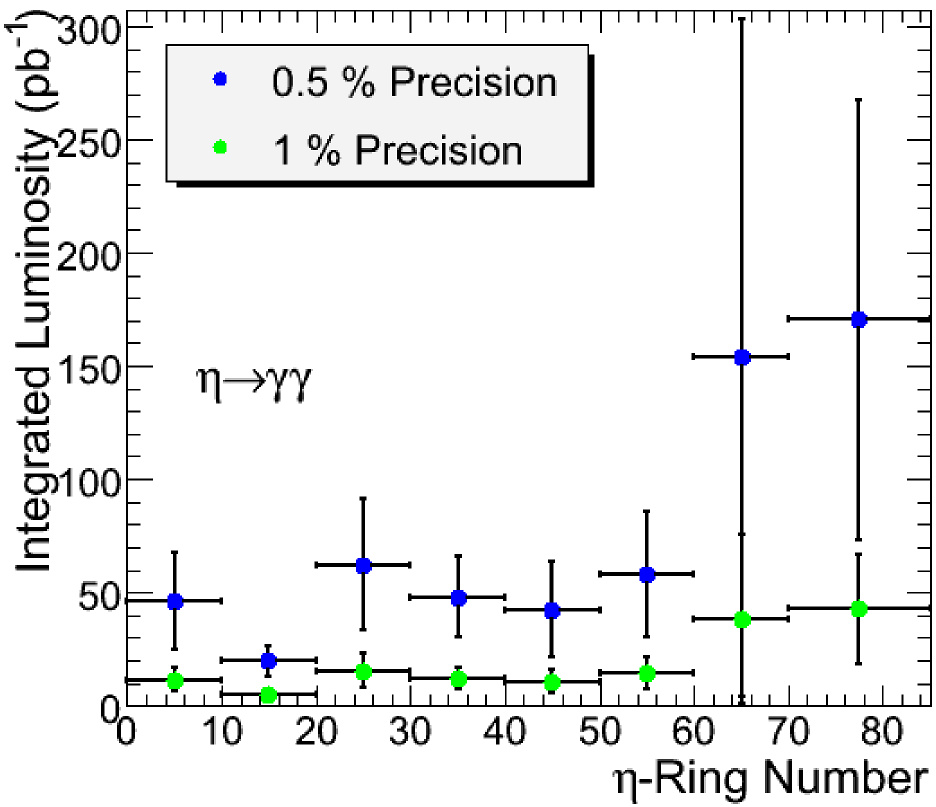
Calibration constants then derived on CAF within a few hours.

Projected π^0 Calibration Performance

The π rate at 1E31 is translated into time needed to achieve a 1% accuracy: 30 to 50 hours of continuous data-taking needed to calibrate 95% of the barrel; about twice as long in the endcaps.

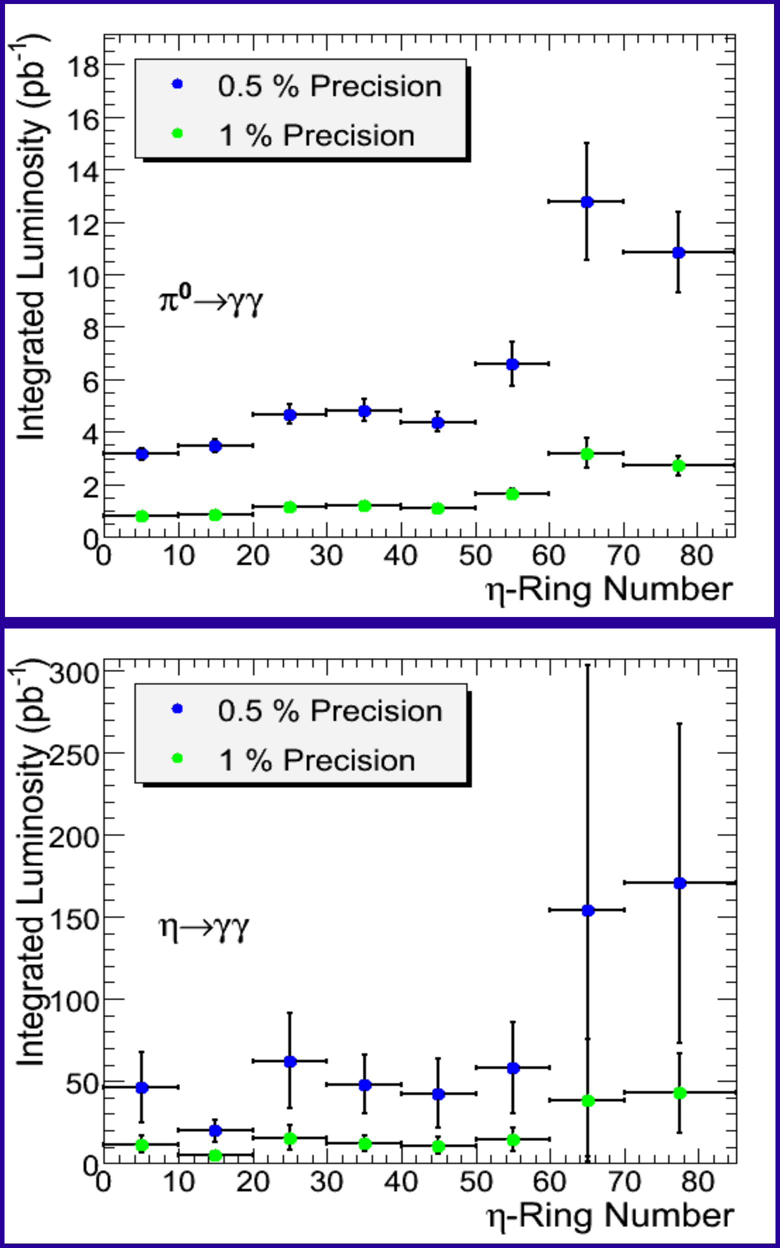
Dependence on instantaneous luminosity is mild: at 2E30 menu the effective rate was only about 1.6 times lower.





Calibration:

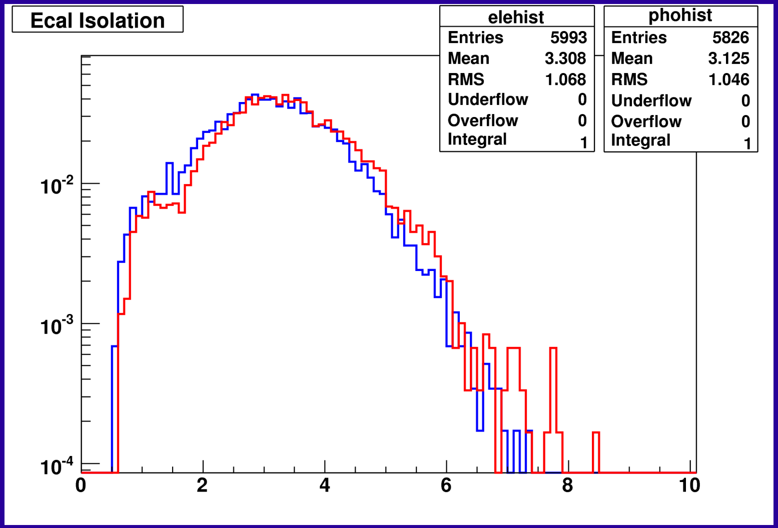
- It's absolutely worth mentioning that algorithms mean nothing without a well calibrated detector.
- Streams for calibration are established, available and approved.



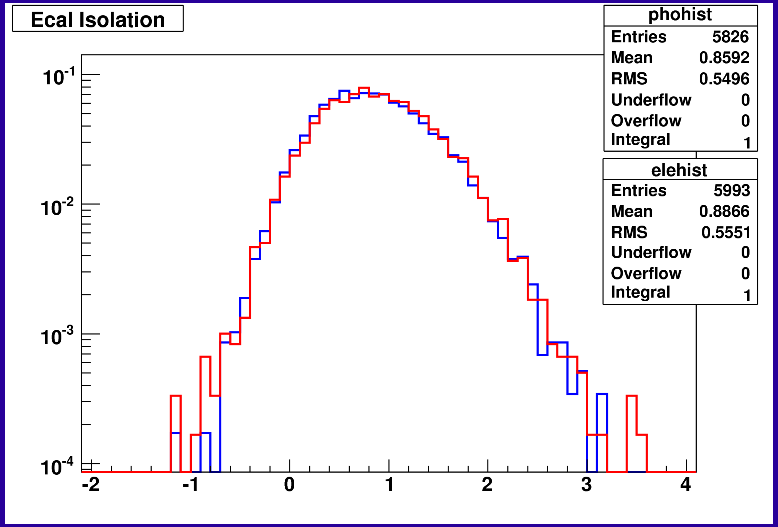
M. Gataulin is ECAL calibration and monitoring coordinator

Efficiency (startup):

- For startup efficiencies, the only handle on verifying photon quantities will be through electrons, which is why we have concentrated on forming the photon quantities to be as similar as possible between electrons and photons.



Threshold $E_T > X$



Threshold $|E_T|> X$