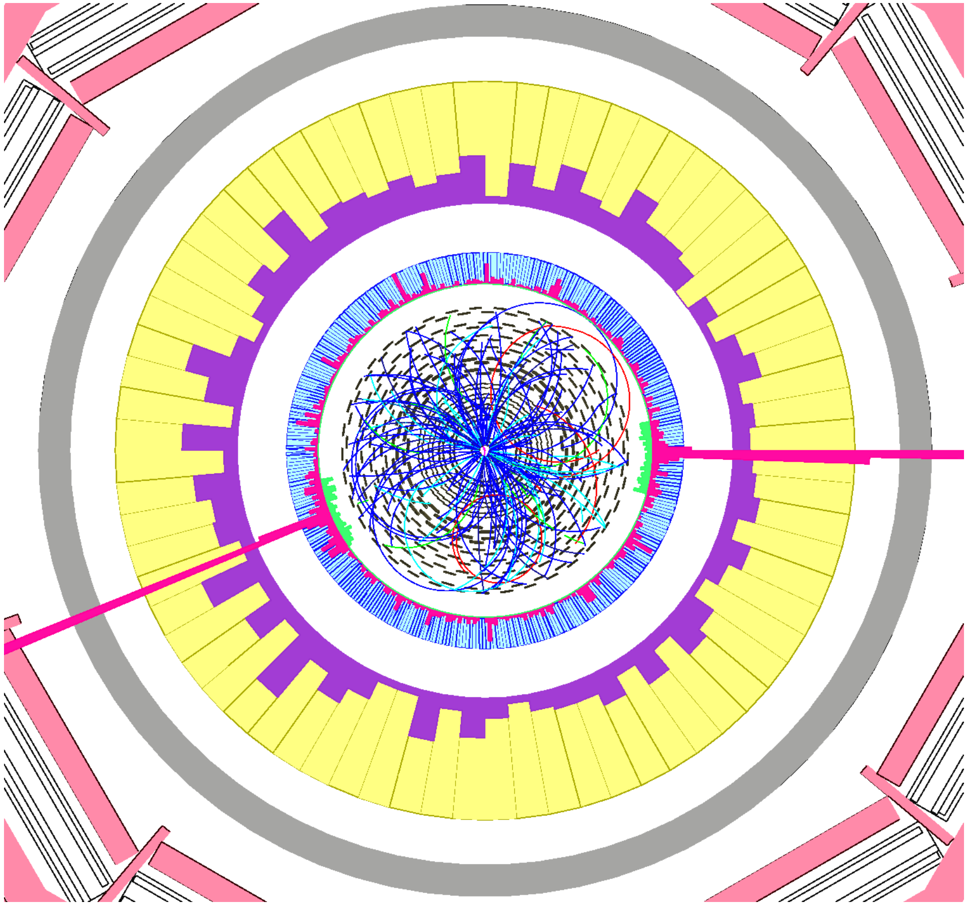
Photons

Andrew Askew

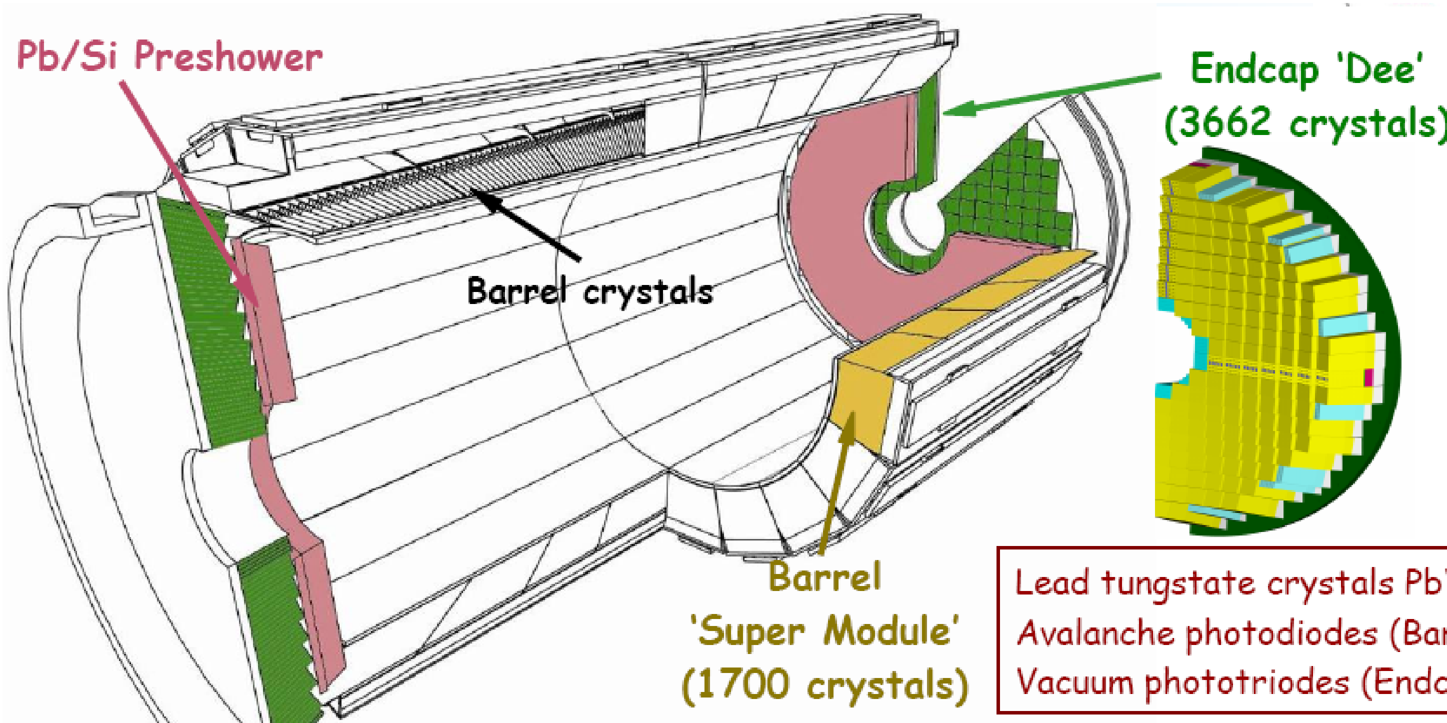
Rutgers University



Introducing the Problem:

- Finding photons is difficult.
- Three major backgrounds:
  - Jets (which fragment into π^0 and other neutrals). Veritable sea of "fake" photons.
  - Electrons (which don't have tracks).
  - Cosmics and Beam halo muons (which undergo bremsstrahlung in the ECAL).
- Complicating this is that there is comparitively little information to use.
- I will try to outline what information is available, and how we use it to deal with the three main backgrounds.

To start off: the ECAL



Toyoko gave an excellent ECAL101 yesterday.

Lead tungstate crystals $PbWO_4$
Avalanche photodiodes (Barrel)
Vacuum phototriodes (Endcaps)

Barrel: $|\eta| < 1.48$
36 Super Modules
61200 crystals (2 x 2 x 23 cm^3)

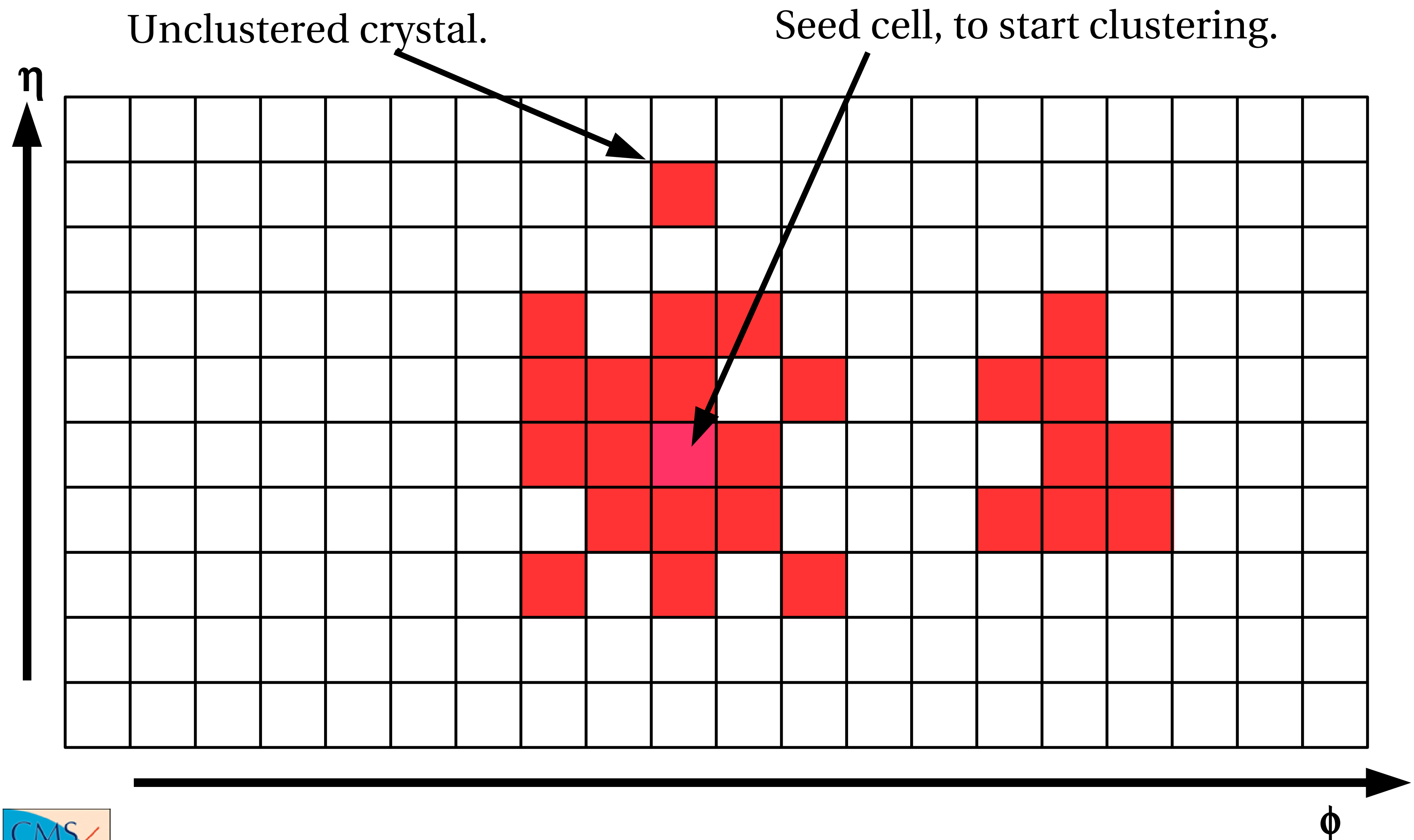
Endcaps: $1.48 < |\eta| < 3.0$
4 Dees
14648 crystals (3 x 3 x 22 cm^3)

- Photons are non-redundant: The only information you have about them will come from the ECAL (and preshower in EE).

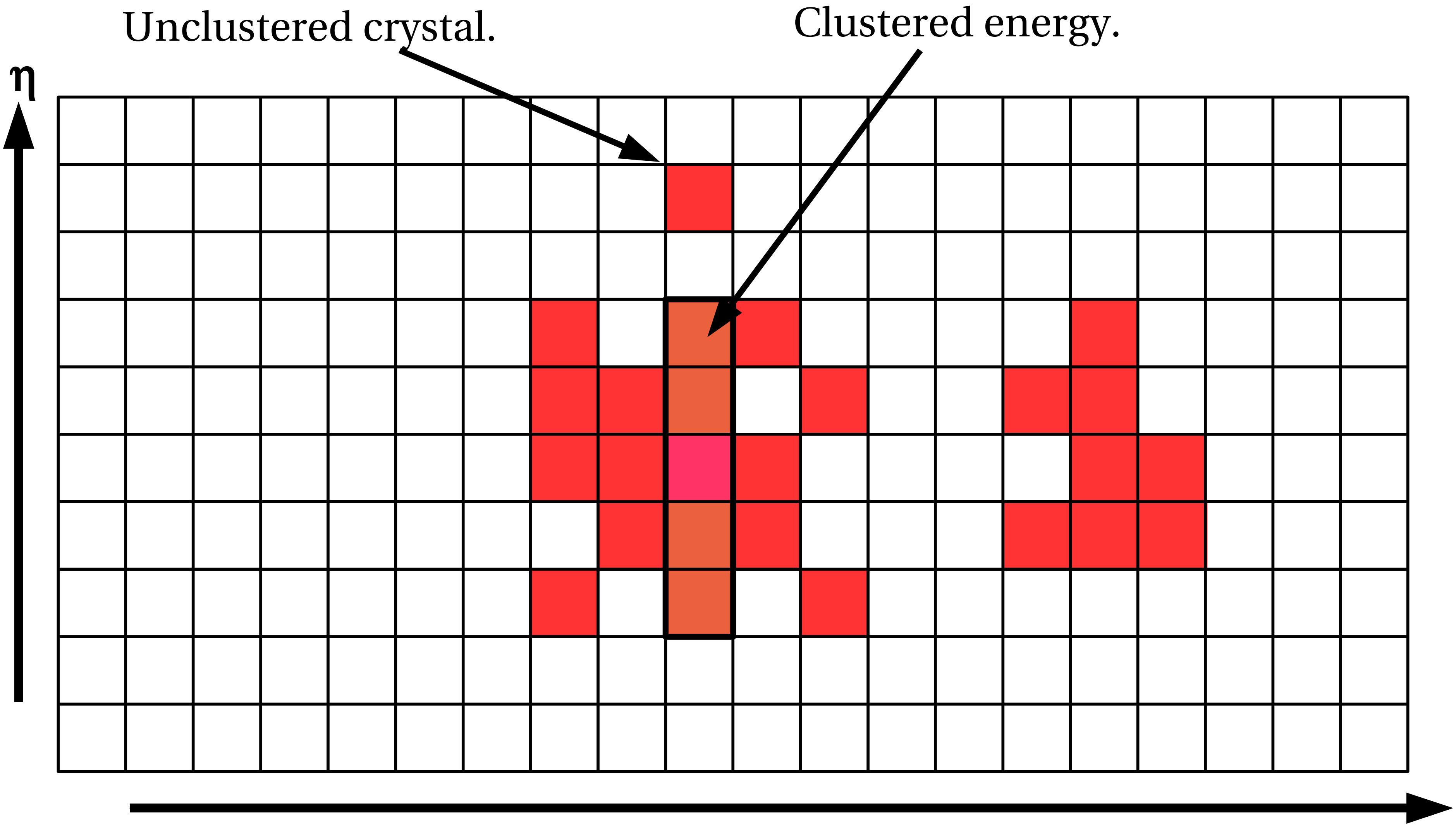
Clustering and Superclusters:

- So we start with crystals which register as having deposits of energy.
- In order to form physics objects, we cluster these crystals together. In order to make sure all of the energy is gathered up, we use 'supercluster' algorithms which are capable of making clusters of clusters (e.g. gather up energy for electrons which brem, and photons which convert).
  - Different algorithms used for barrel and endcap.
- I'll show a couple of slides to aid in visualizing this. I am leaving some subtleties out, if you want to know more specifics, just ask.

EB Clustering (same for e/γ):

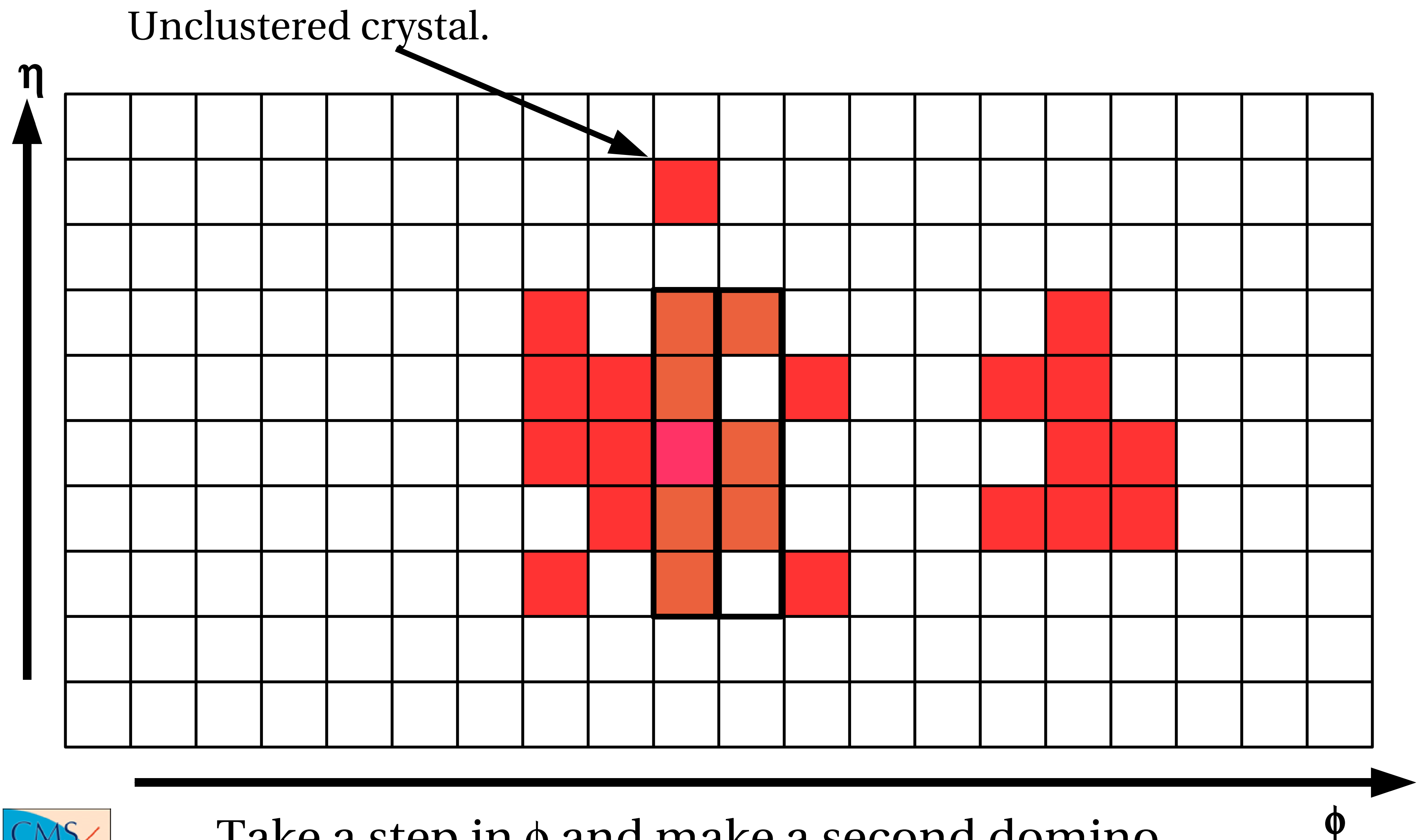


EB Clustering (same for e/γ):



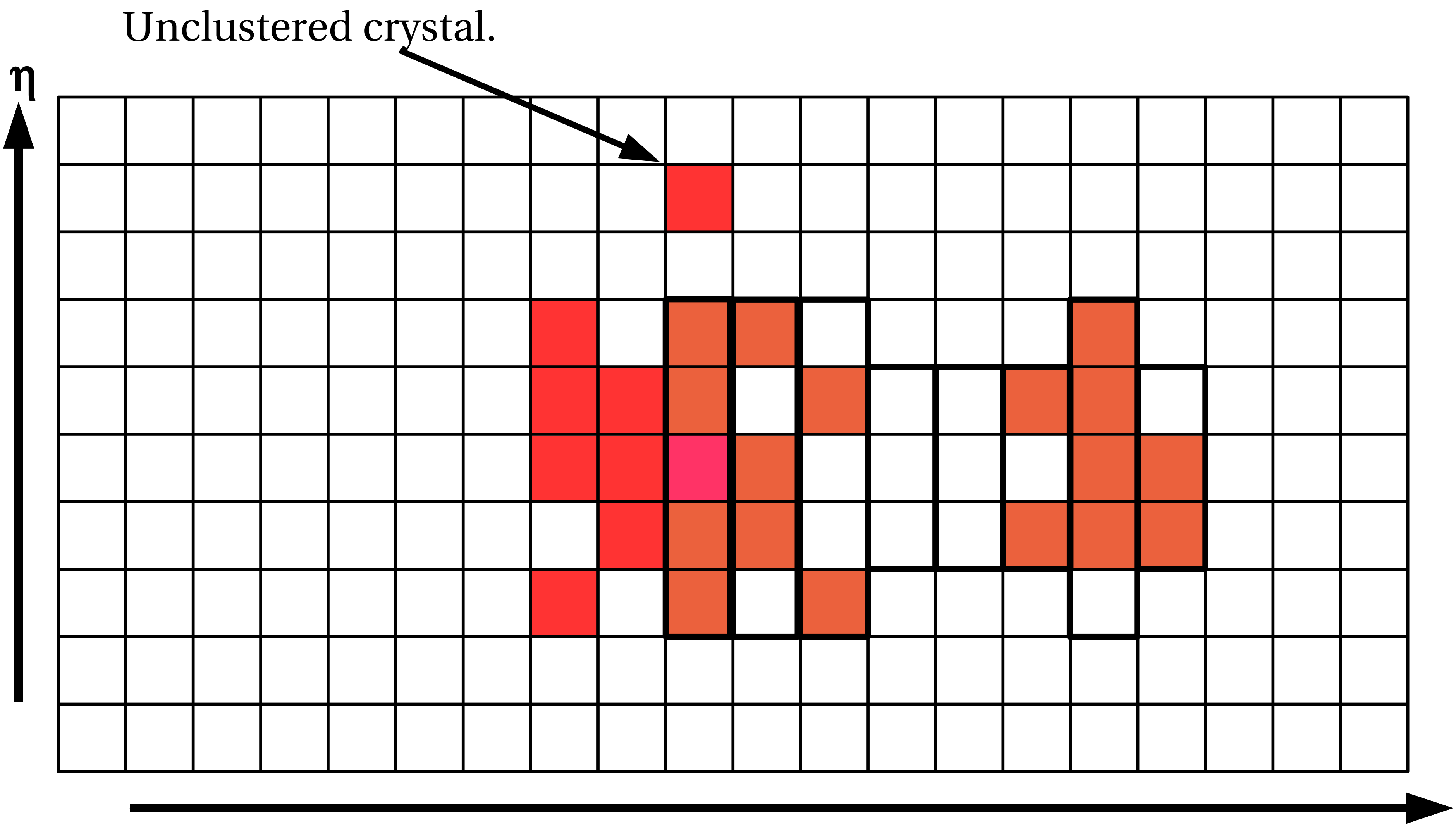
A 1x5 domino about seed cell.

EB Clustering (same for e/γ):



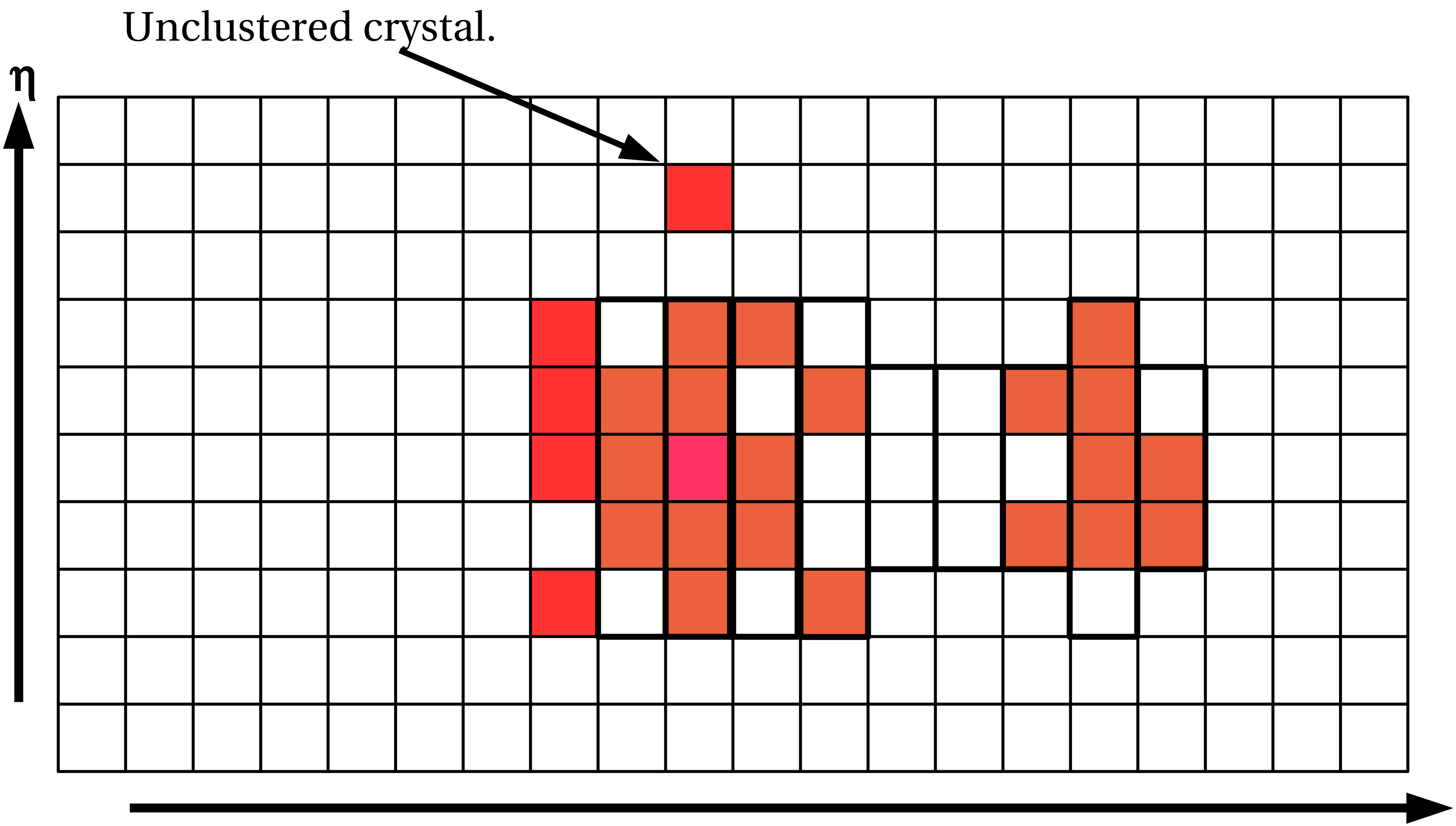
Take a step in ϕ and make a second domino.

EB Clustering (same for e/γ):



Proceed to make more, taking steps in positive ϕ.

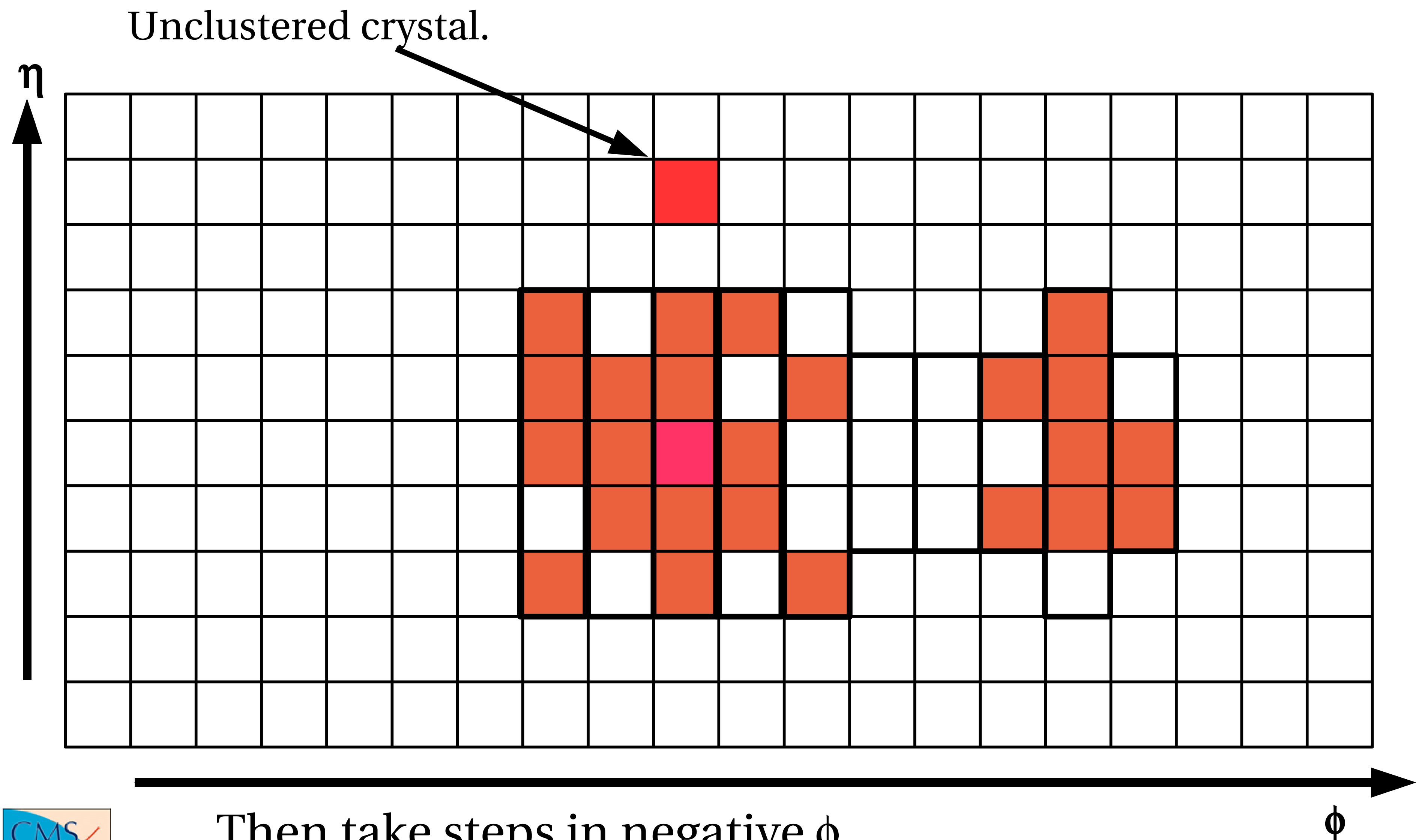
EB Clustering (same for e/γ):



Then take steps in negative ϕ.

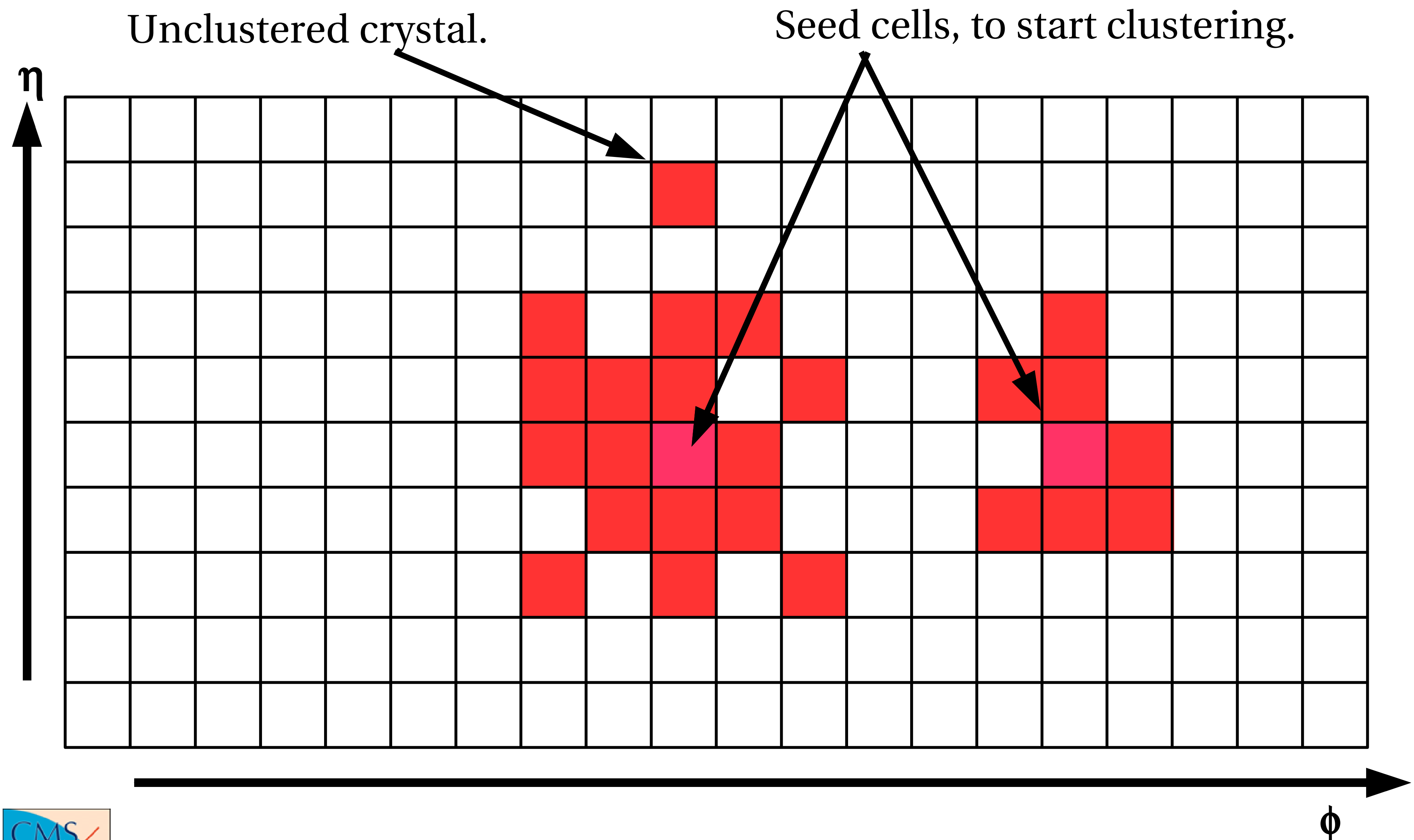
ϕ

EB Clustering (same for e/γ):

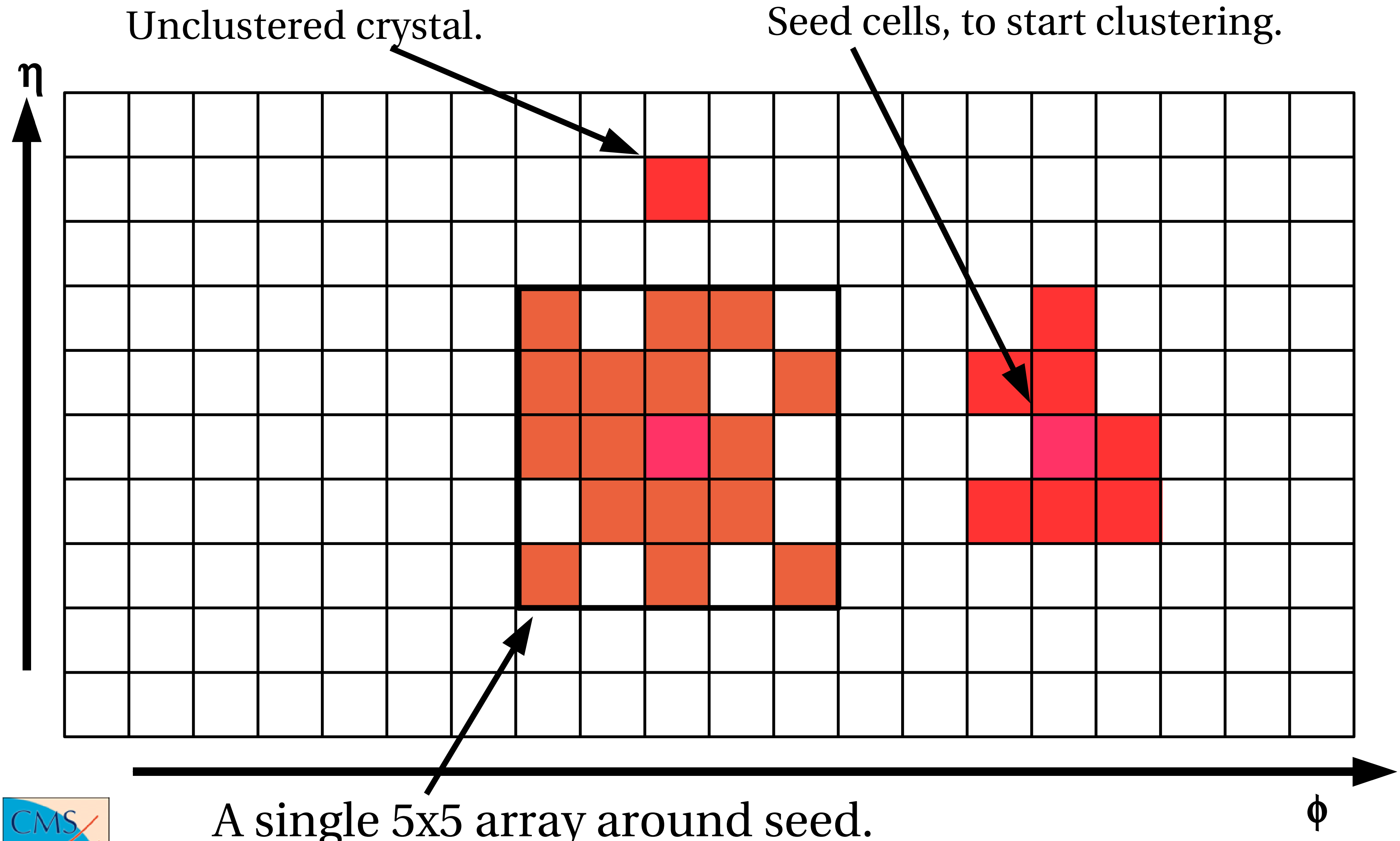


Then take steps in negative ϕ.

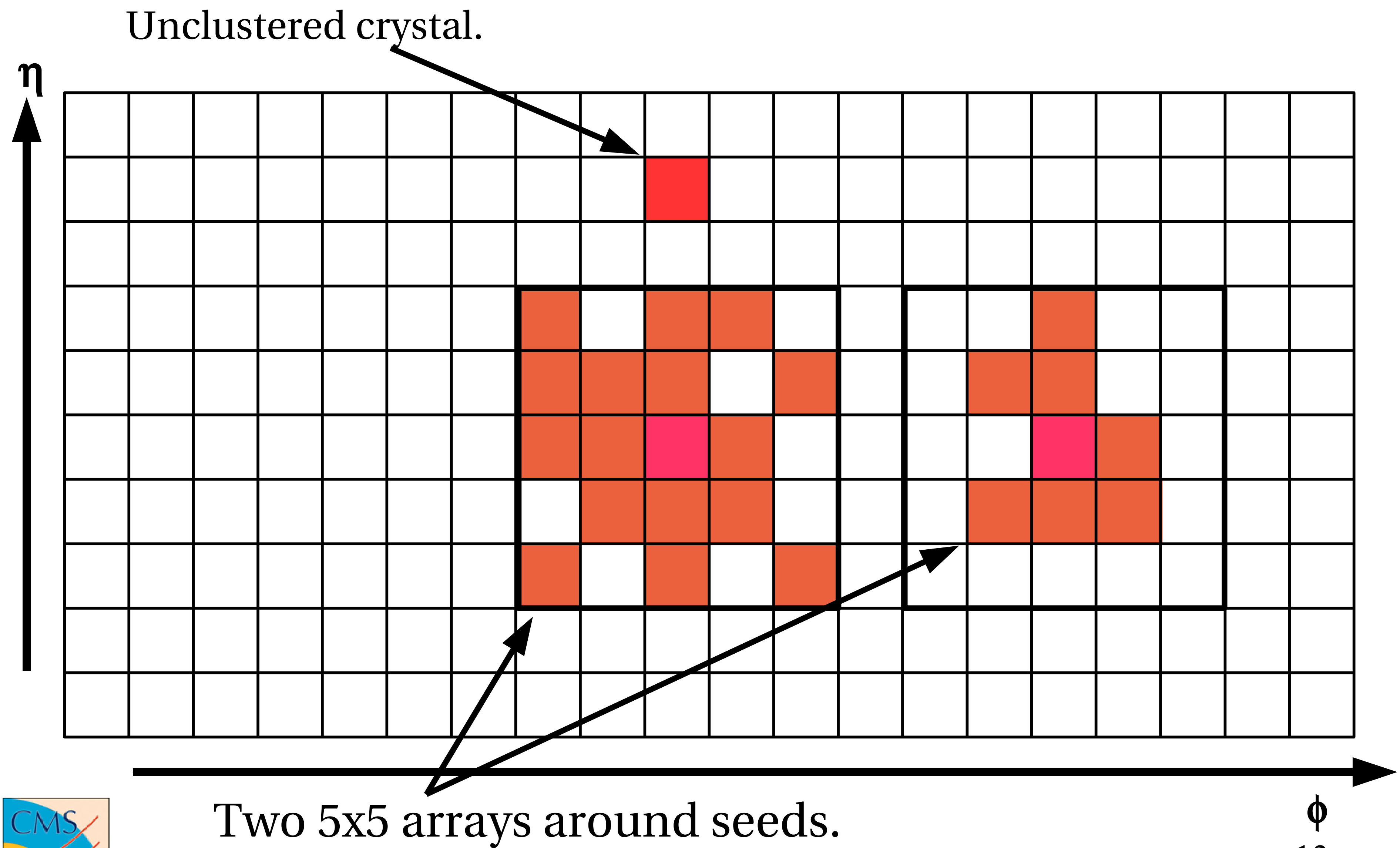
EE Clustering (same for e/γ):



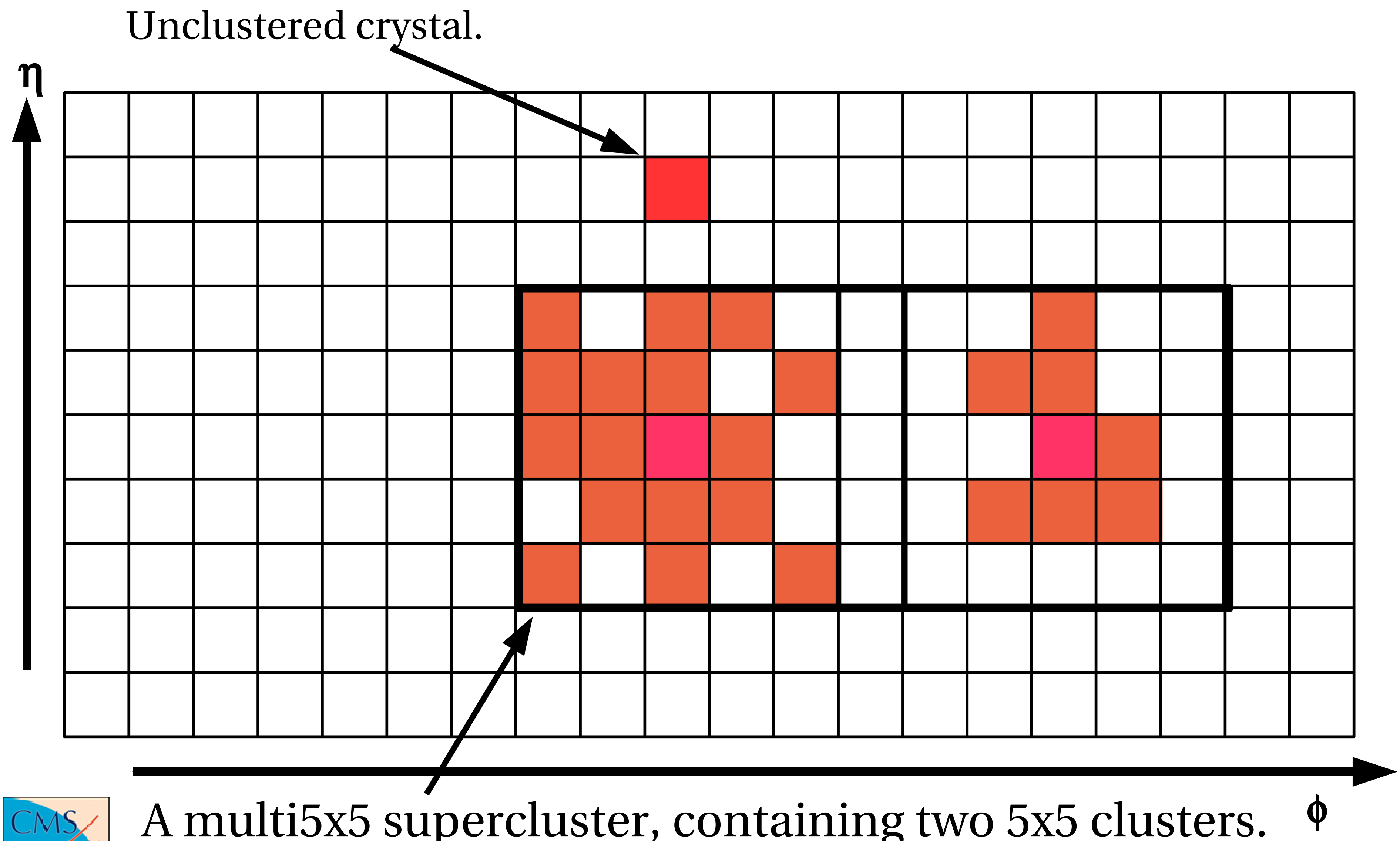
EE Clustering (same for e/γ):



EE Clustering (same for e/γ):



EE Clustering (same for e/γ):

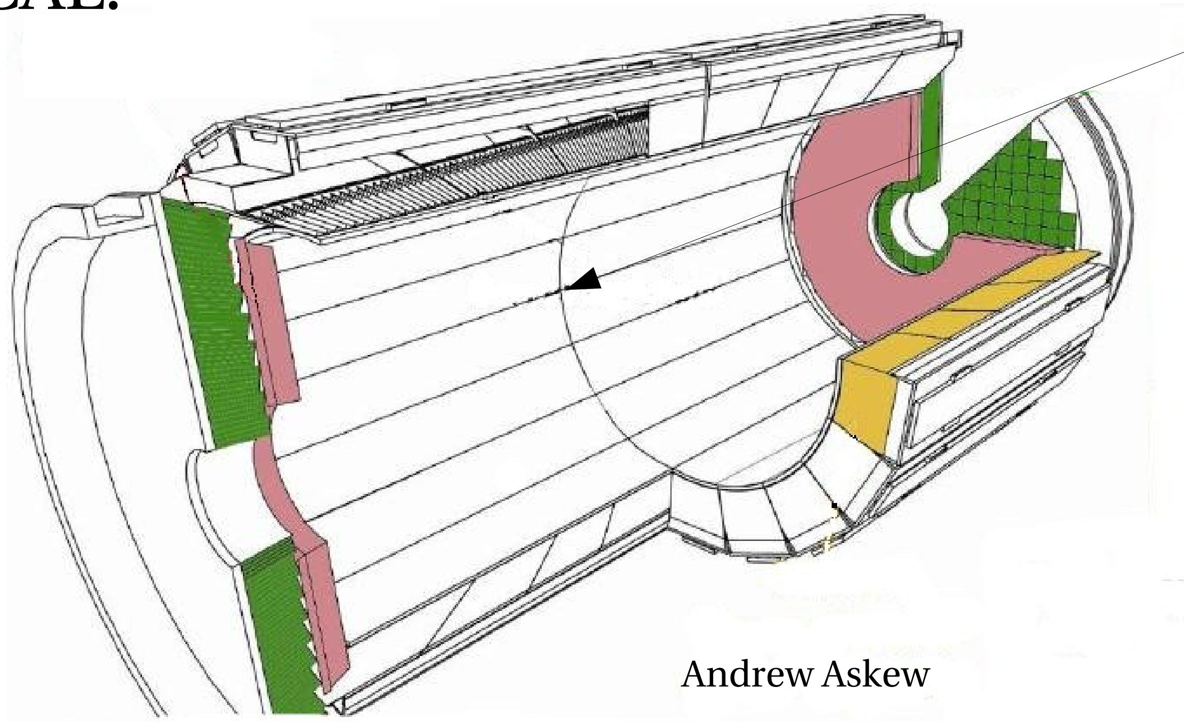


Energy Corrections:

- After clustering, an η-dependent correction is applied to the clustered energy. This is meant to compensate for the additional losses due to interactions in the material, and leakage, and is performed for electrons and photons.
- Energy-weighted widths in η and ϕ are calculated and stored in correctedSuperClusters (widths are used in the calculation of correction).
- After these energy corrections are made, we're left with logical depositions in the ECAL, which have η, ϕ, and a corrected E_T.

Fiducial Flags:

- There are small boundaries (gaps) between the supermodules in ϕ, and there are internal gaps inside each supermodule in η.
- These affect both the amount of energy that is measured, and the amount of energy that 'leaks' into HCAL.



All of these little lines are boundaries between supermodules.

Fiducial Flags:

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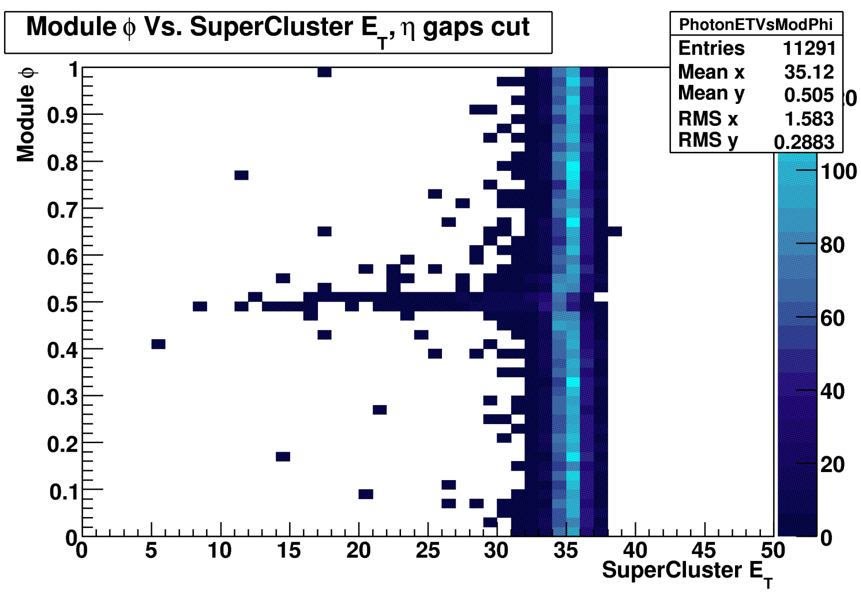
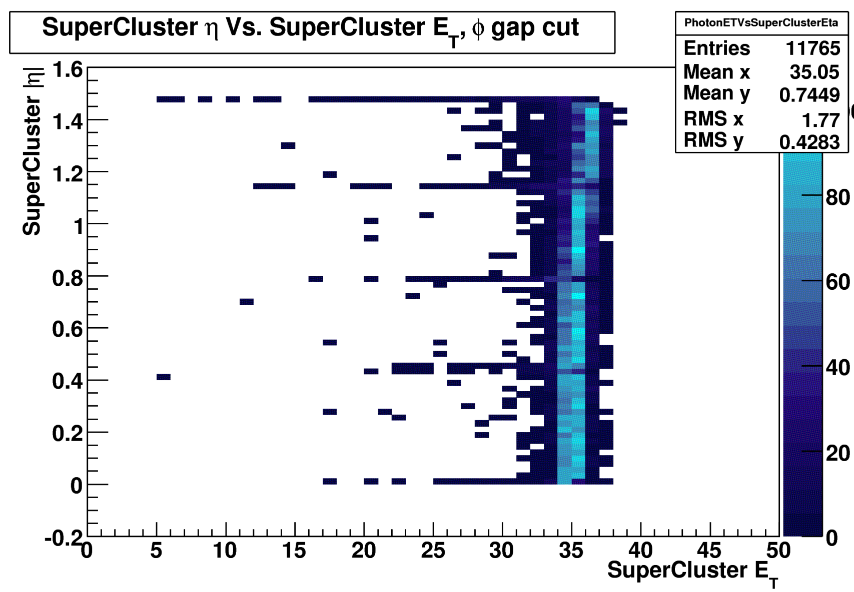
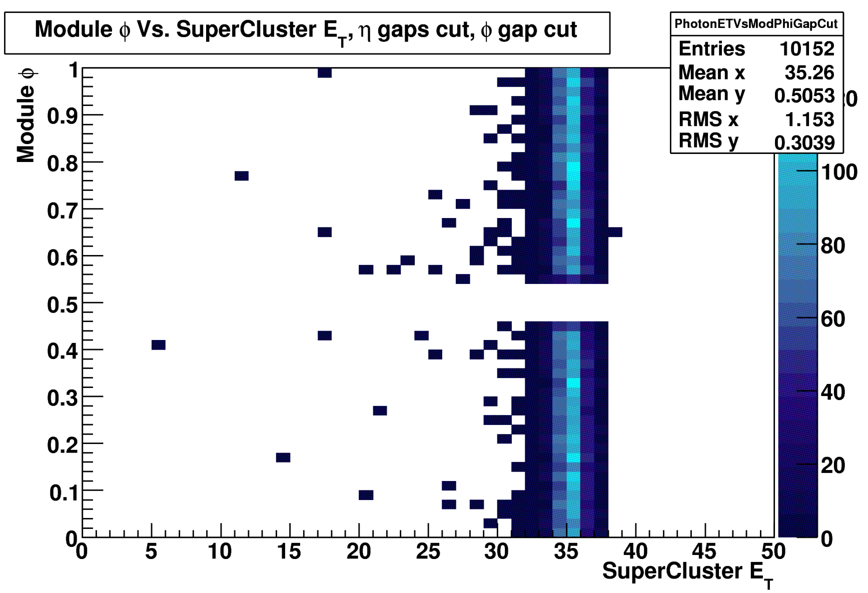
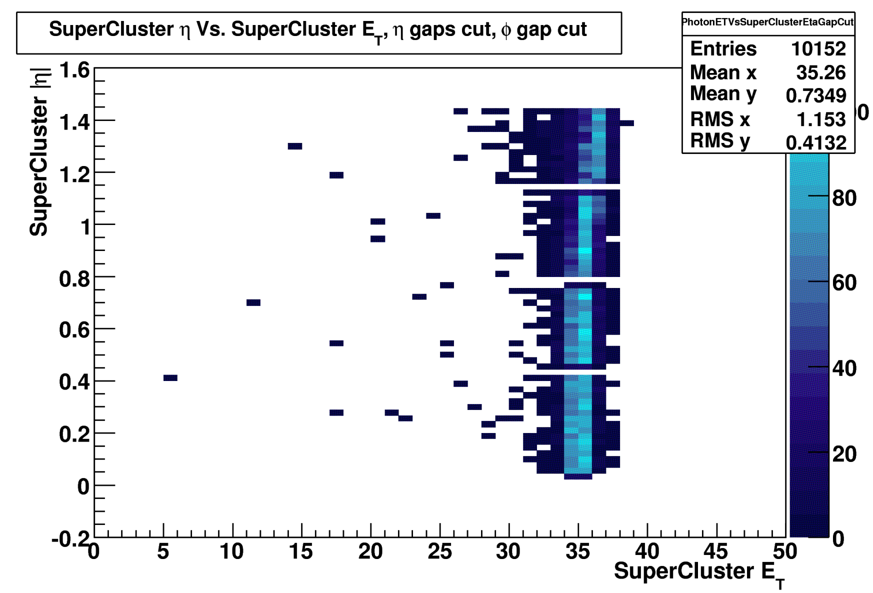




Fiducial Flags:

- Thus we flag these regions, either to be dealt with separately, or excluded.
- These plots are just the same as before, but wil the flagged regions excluded.
- Use Z->ee and tracks to study in data.



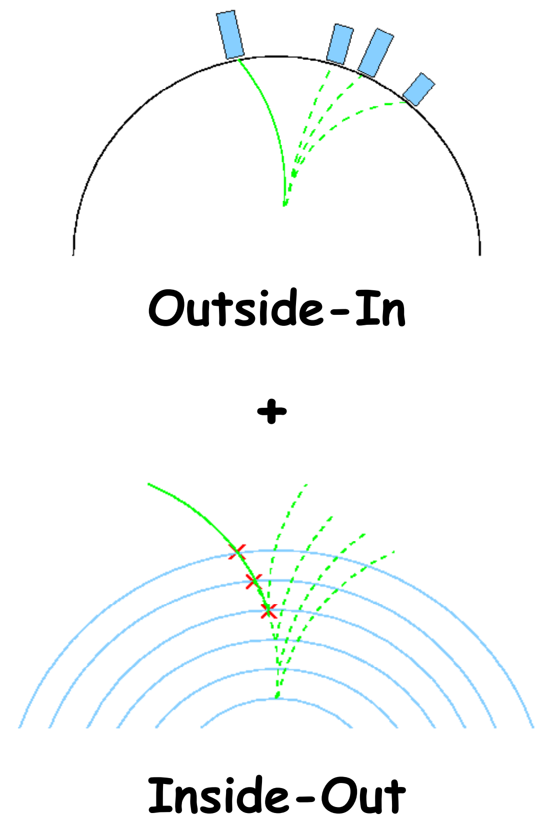


Conversions (I):

- After clustering, there is a dedicated algorithm for starting from ECAL clusters and attempting to reconstruct conversion tracks.
  - This really deserves it's own talk.
- Software-wise, there is an associated Conversion object that contains information about the tracks, a vertex (if available), and what clusters were used. This is associated to a Photon object
- My one slide description of what is done is next.

Conversions (II):

- Start with path based on center of detector and subcluster E_T.
- Find sets of hits in the outermost layers of tracker which are consistent. Begin tracking inward using this hit set.
- When track ends, look outward from last hit, searching for a cluster in a ϕ window. If such a cluster exists, begin tracking outward.
- Then attempt fitting the vertex.



e/γ POG Conversion Subgroup

Photon objects (software):

- To Become A Photon In the Software:
  - You must have a deposition of energy in the ECAL (a SuperCluster).
  - You must pass an E_T threshold (currently set at 10 GeV).
  - You must pass some minimal, and efficient isolation cuts, which are based only on ECAL/HCAL quantities.
- Which means:
  - A.) All real photons should have Photon objects.
  - B.) All real electrons should have Photon objects.
  - C.) A LOT of jets will have Photon objects.

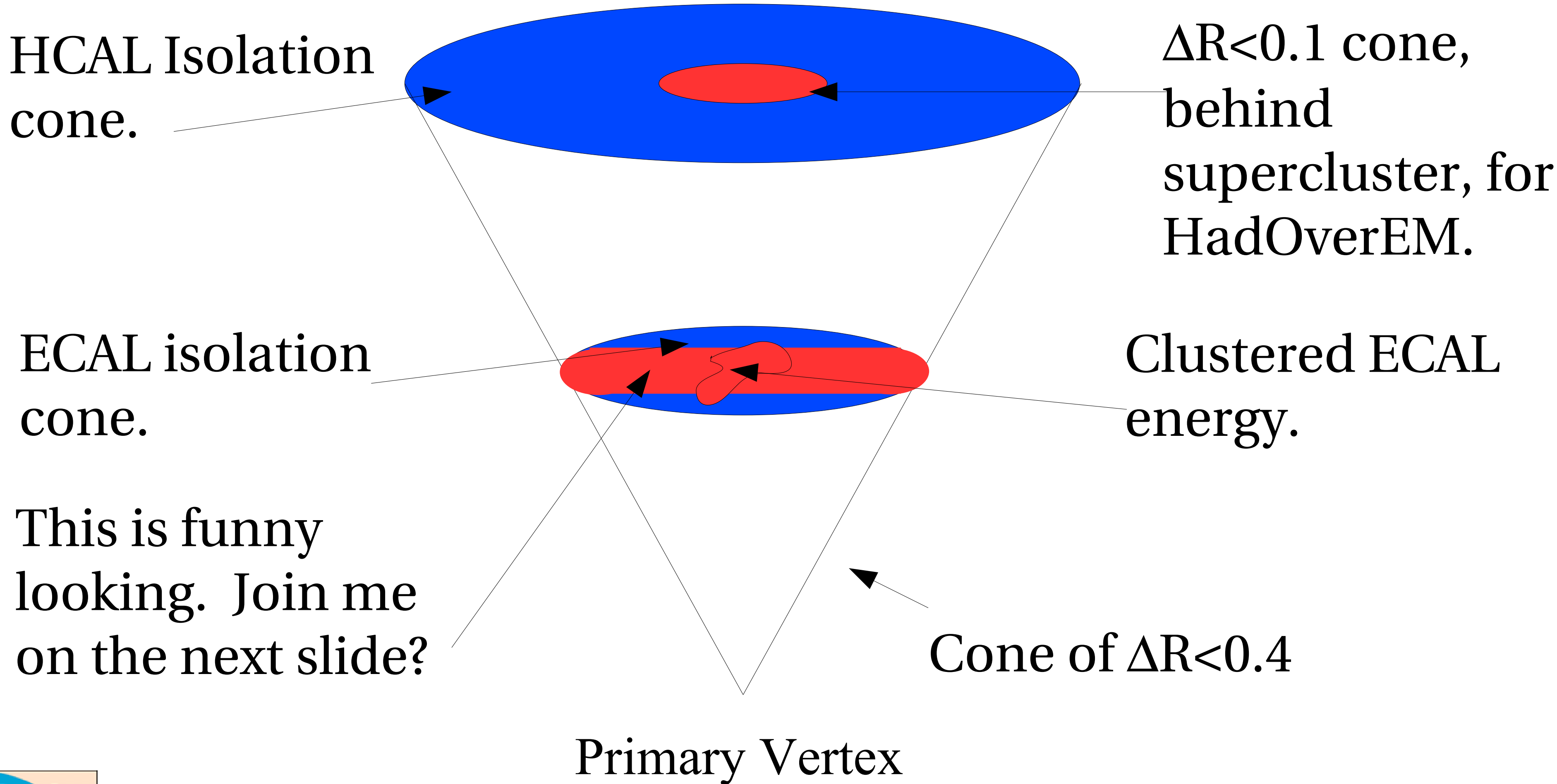
Dealing with this:

- Three major backgrounds:
  - Jets: Discriminate against via **isolation** (ECAL, HCAL, Tracks). Largest background.
  - Electrons: Discriminate against via **pixel seed** veto. Size of this background very dependent on final state.
  - Cosmics and Beam halo muons (which undergo bremsstrahlung): Discriminate against mainly via **shower shape**. Appears with missing E_T, since brem is not balanced. Difficult: random appearance during data taking.
- All require **DATA** solutions.

Isolation:

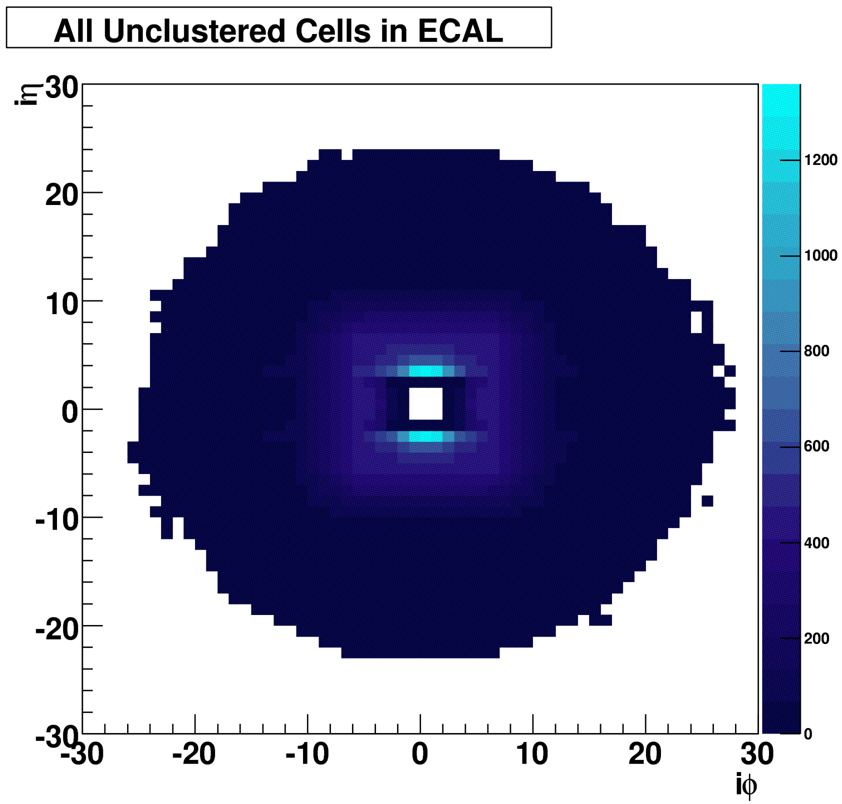
- I already said we apply a loose preselection, based on calorimeter quantities.
- In order to put this in context, I need to define:
  - HadOverEM: Hadronic Energy in the HCAL tower directly behind the supercluster, divided by the energy of the SuperCluster.
  - HCAL Isolation: Energy in the HCAL in a $\Delta R < 0.4$-0.1 hollow cone (excludes the tower used for HadOverEM).
  - ECAL Isolation: Unclustered energy in a region surrounding the SuperCluster.

Anatomy of Photon



ECAL Isolation:

- ECAL Isolation: Based on sum of RecHits in a cone about the SuperCluster direction. A 'slice' in η excludes the clustered energy, and an inner cone excludes the real energy which is not clustered.

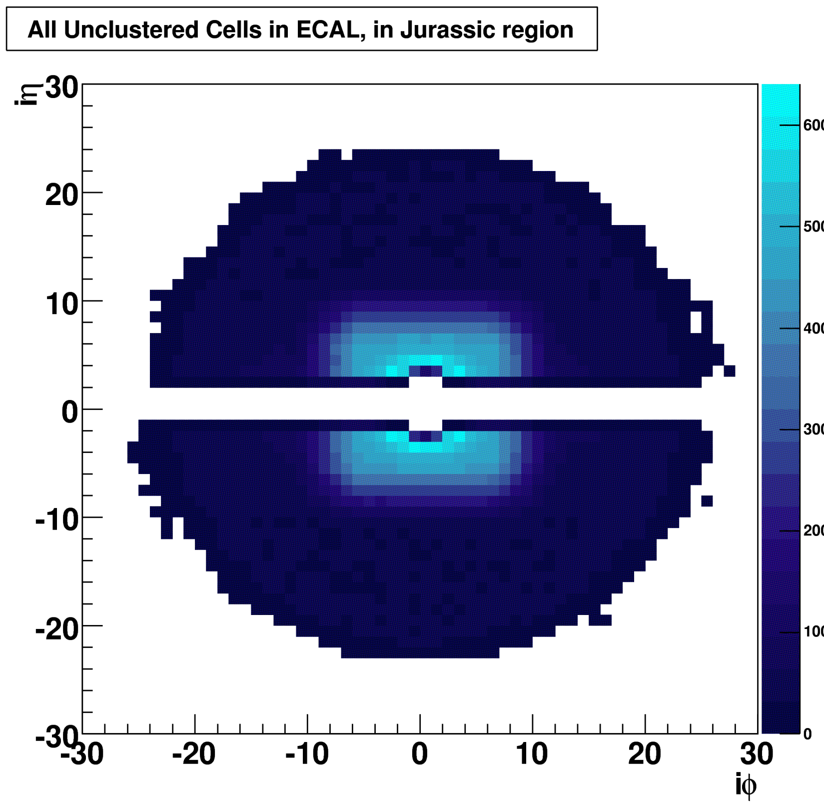


Without inner cone and strip. All clustered cells excluded.

ECAL Isolation:

- ECAL Isolation: Based on sum of RecHits in a cone about the SuperCluster direction. A 'slice' in η excludes the clustered energy, and an inner cone excludes the real energy which is not clustered.

With inner cone and strip. All clustered cells excluded.

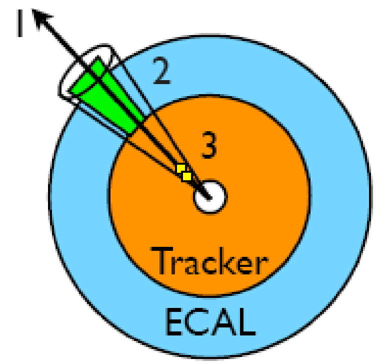


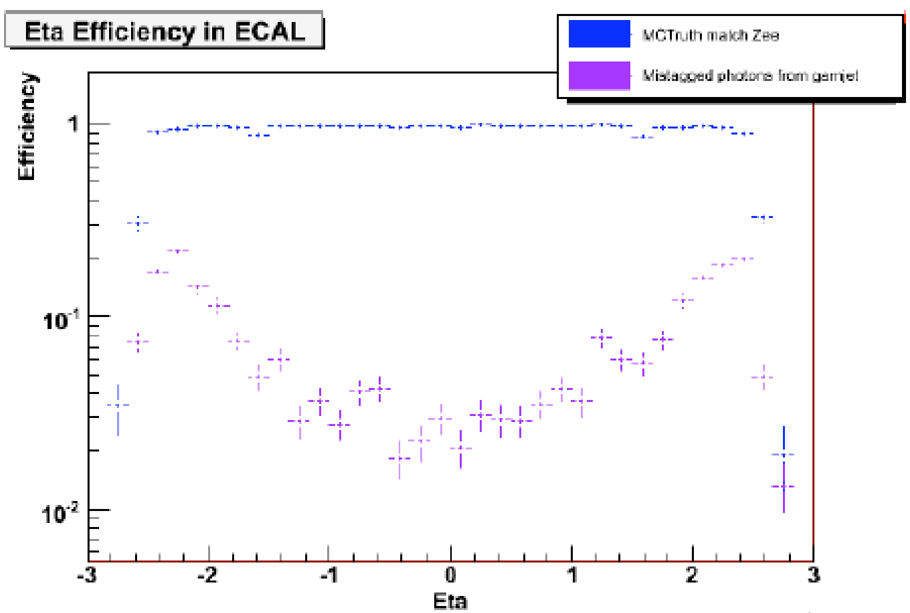
Jets: More Isolation

- ECAL Isolation, HCAL isolation, and HadOverEM all have very modest cuts at preselection (just meant to pare down the collection). Optimal cuts will depend on the analysis you're doing.
- Track isolation: Values for the sum of p_T of tracks, and the number of tracks are provided for hollow cone (0.4-0.04, and 0.3-0.04), and for solid cones (0.4, 0.3). The hollow cone track isolation is constructed to be **insensitive to conversions** and **efficient for electrons**.
- Electrons provide our earliest handle for probing how these quantities behave in real data.

Electrons: Pixel Seed Veto

- Starting from SuperCluster E_T and position, we search for pixel hits which are consistent with an electron track.
- Veto-ing on this pixel match in the case of photons, is sensitive to conversion efficiency, but only to very early conversions.

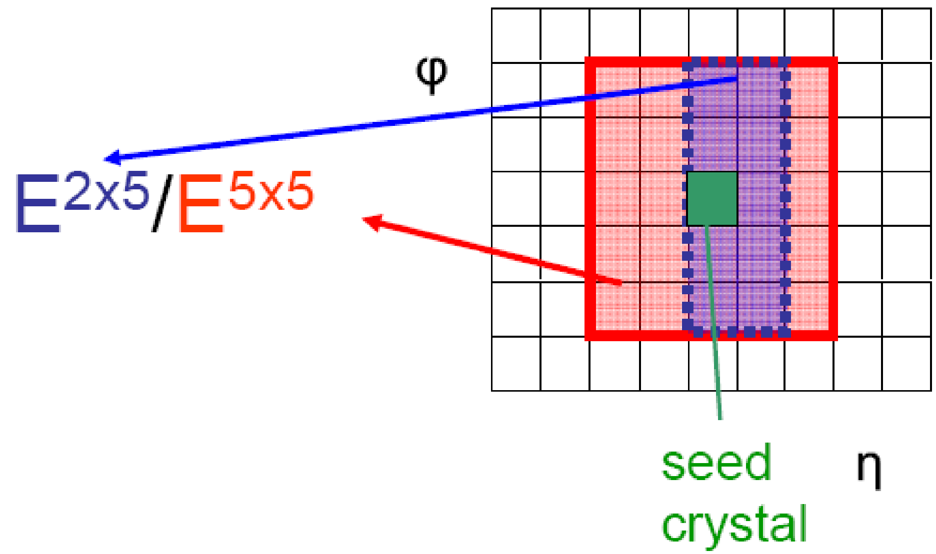


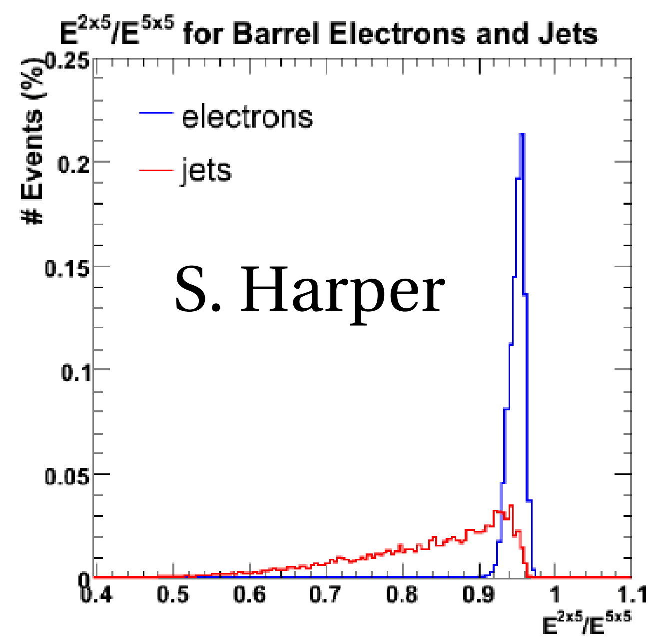


C. Kopecky

Shower Shape:

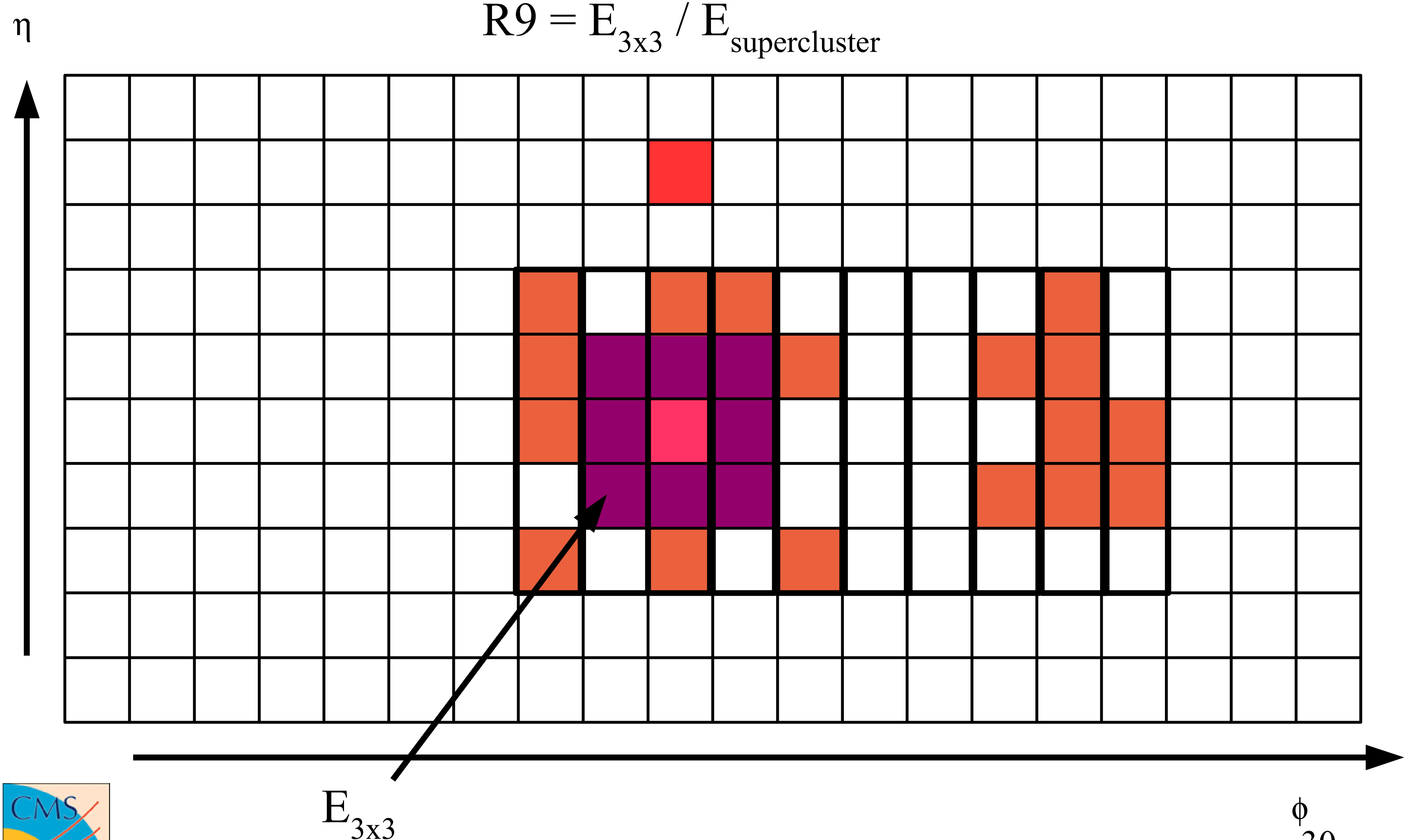
- For 3_0, several different shower shape quantities are stored in the reco::Photon:
  - $\sigma_{\eta\eta}$: Width of the central 5x5 crystal array in η.
  - e1x5, e2x5: These are ratios of the highest 1x5 and 2x5 dominoes to the 5x5 energy.
  - R9: Ratio of inner 3x3 to supercluster energy.





R9:

$$R9 = E_{3x3} / E_{supercluster}$$



Andrew Askew

Sidebar: R9 and the Photon

- R9 effectively encapsulates how spread the cluster is in ϕ. Thus it is sensitive to conversions.
- E_T, η, ϕ: Calculated differently depending on R9.
  - If R9 < = 0.93: Use the energy and position of the correctedSuperCluster. Assumed to be likely a conversion.
  - If R9 > 0.93: Use energy in 5x5 array of crystals, and recalculate position based on only these crystals. Assumed to be likely an uncoverted photon.

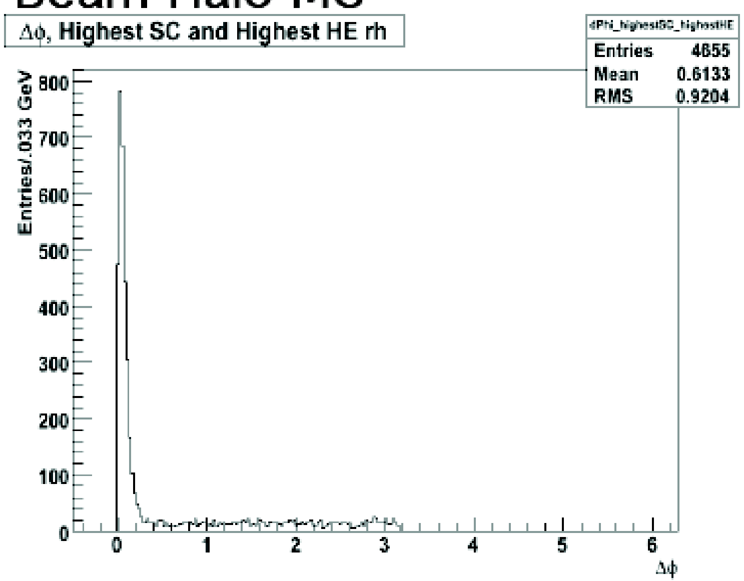
Beam Halo and Cosmics:

- Random backgrounds, difficult to predict except from data. We plan to follow mainly the same prescription for each:
  - A.) Determine a criteria through which we may identify (tag) some subset of events in data as BH or cosmics.
  - B.) Determine a shower shape quantity sensitive to the difference between signal and these backgrounds.
  - C.) Statistically determine the fraction of each in the final candidates.

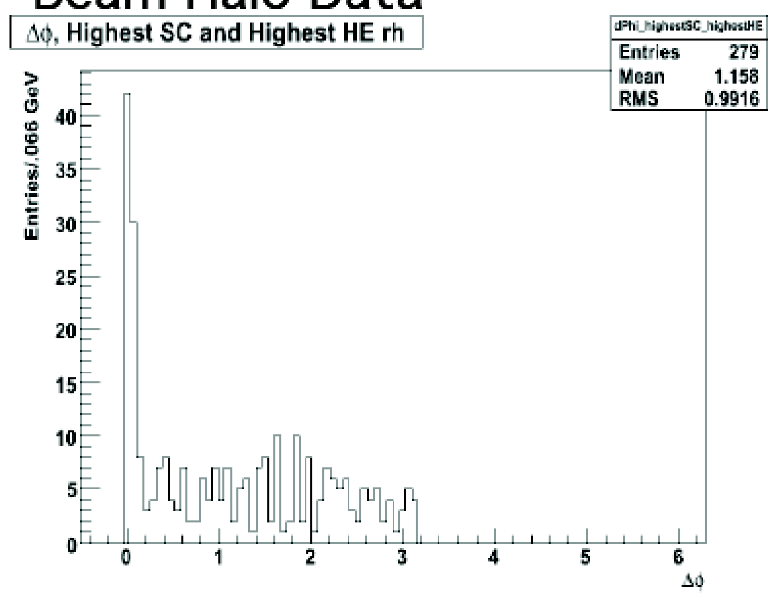
Early Beam Halo Tagging: HE

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

Beam Halo MC



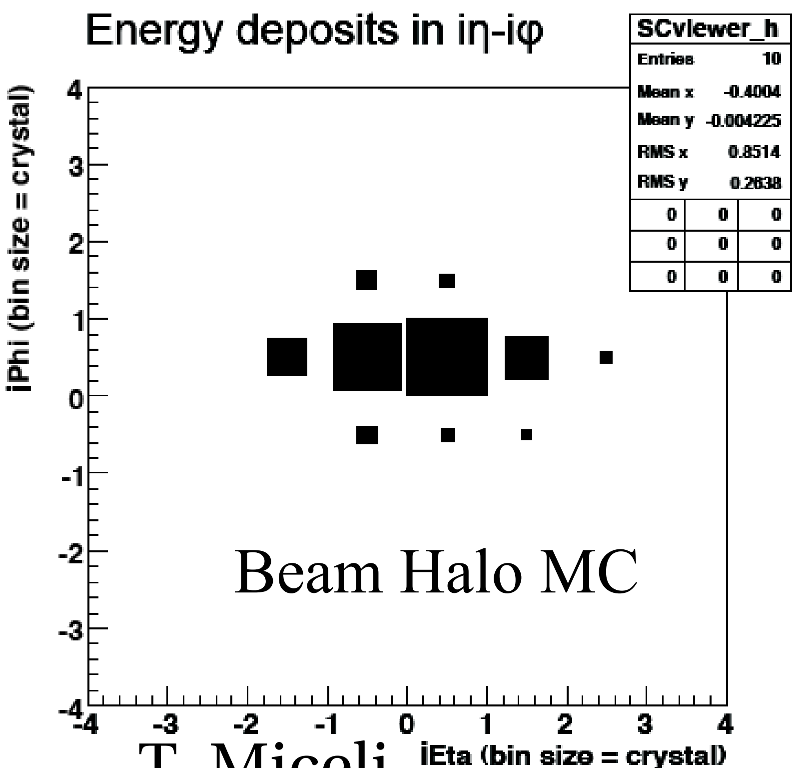
Beam Halo Data

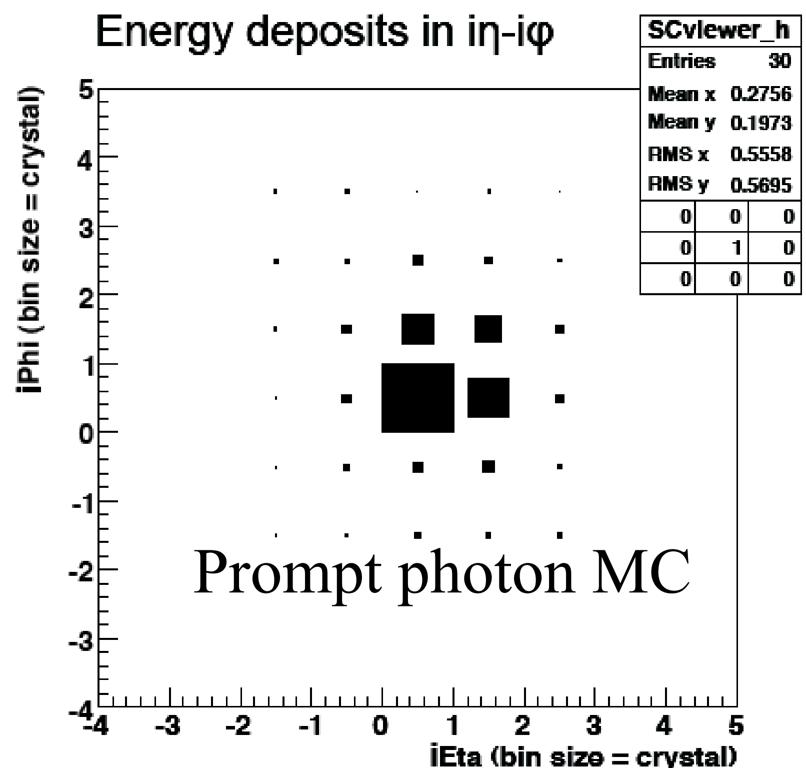


V. Gaultney

Possible expansion: Beam Halo

- We know that brem. events from beam halo muons will develop more along η.
- This would seem a good way to differentiate these events from prompt photons.

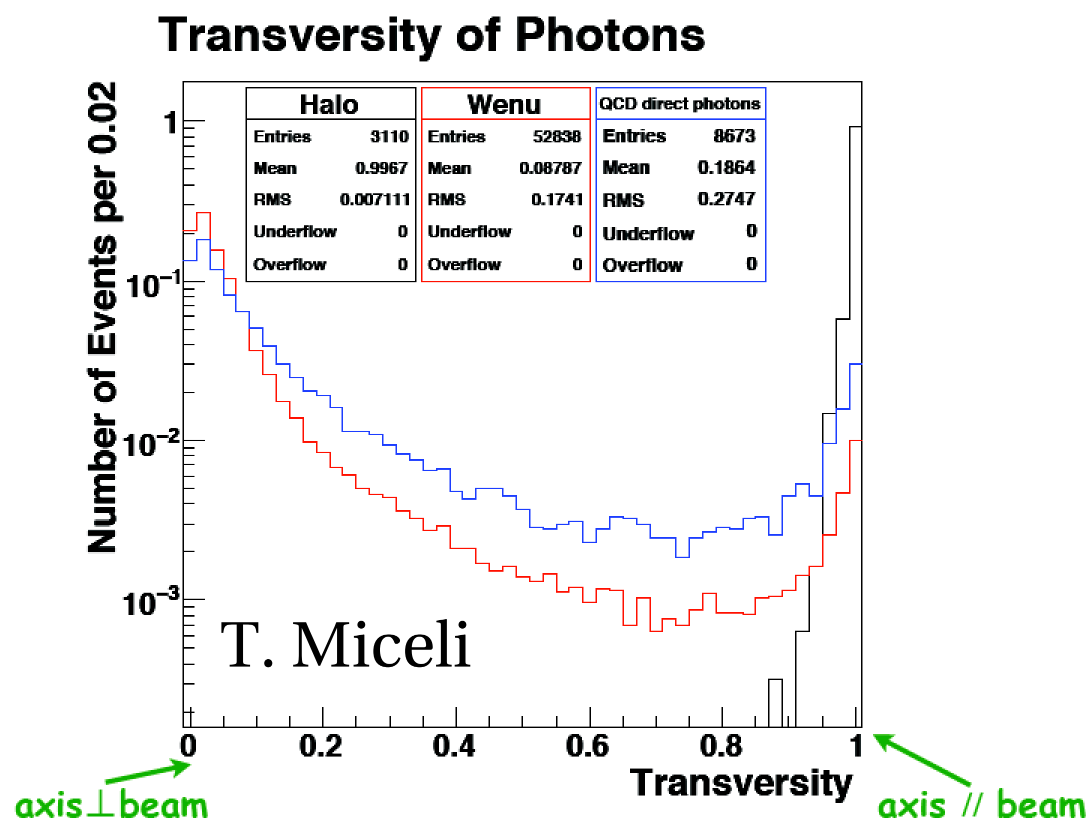




T. Miceli

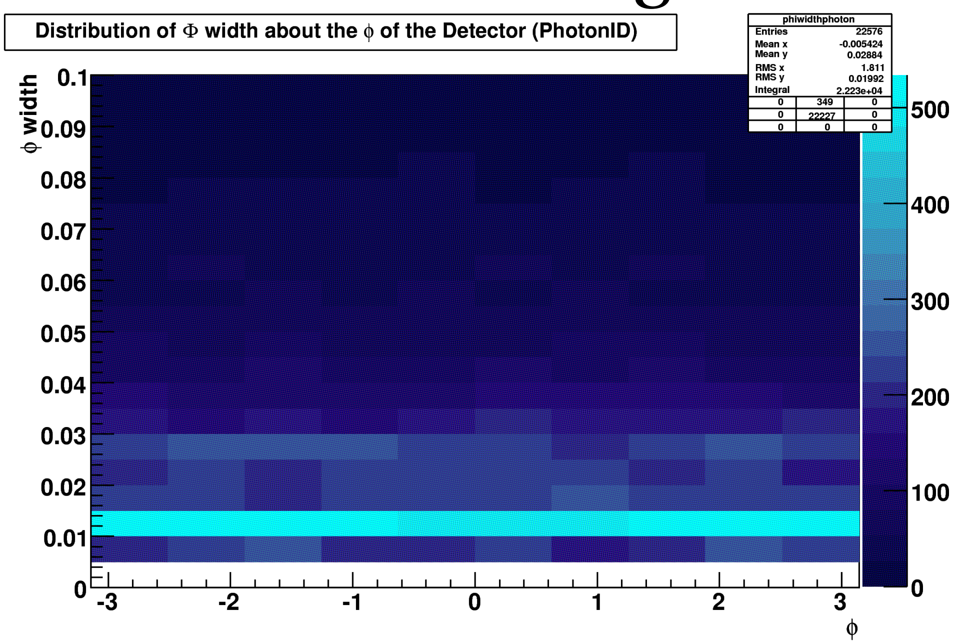
One candidate for BH discr.

- This is effectively the moment of inertia along the η direction.
- Shows good separation, needs further refinement.
- Plan to acquire templates from data to do statistical separation.

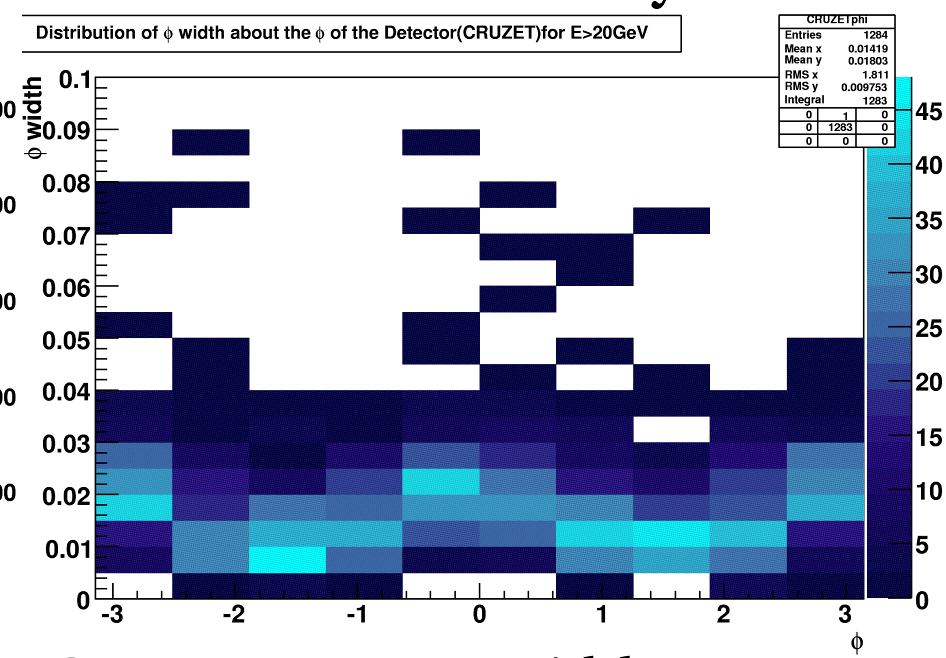


Cosmic shapes:

- 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

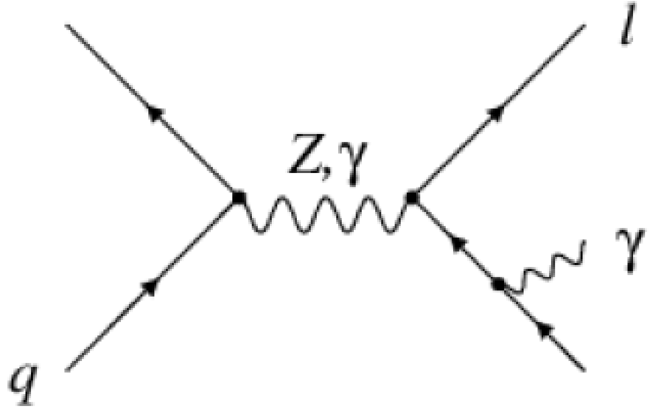


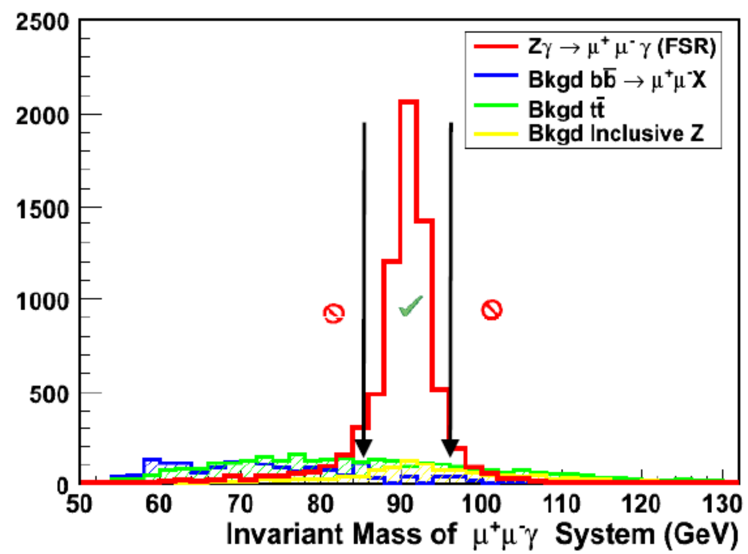
CRUZET Data, ϕ-width

S. Shrestha

Longer Term:In Situ measurement?

- We can go a long way using Z->ee events, but real photon events in data are best.
- One can use Zγ->llγ events in data to test efficiency in-situ, once sufficient luminosity is available:





J. Veverka

Summary:

- The infrastructure specifically for photons is now available, both in reco::Photon and pat::Photon (for 3_0).
- We've set forth our initial methods for:
  - Verifying performance in the data.
  - Reduce/determine out of time backgrounds.
- Refining these ideas, and assembling new ones is a big job! Help is welcomed! Much of this work was done right here, at the LPC Photon+X group.