PHOTON MASTERCLASS

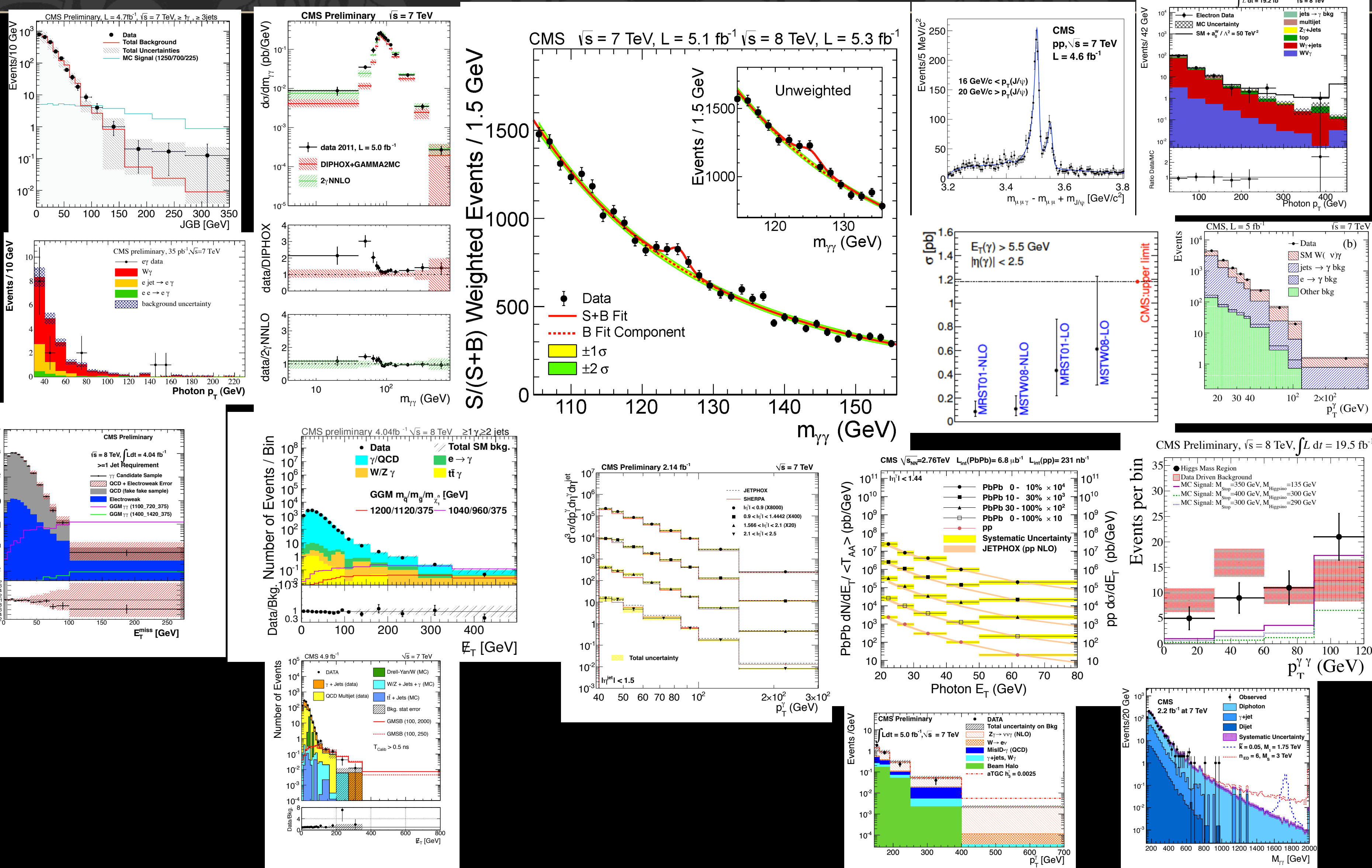
OUTLINE:

- Introduction
  - Why contemplate this at all?
- Problems
  - What complicates the matter?
- Scope
  - What will be covered in this class?

WHY CONTEMPLATE THIS AT ALL?

- What drives us to even attempt to measure/identify photons at a hadron collider?
  - I mean, isn't it only $H \rightarrow \gamma\gamma$?

JUST A FEW PHYSICS TOPICS:

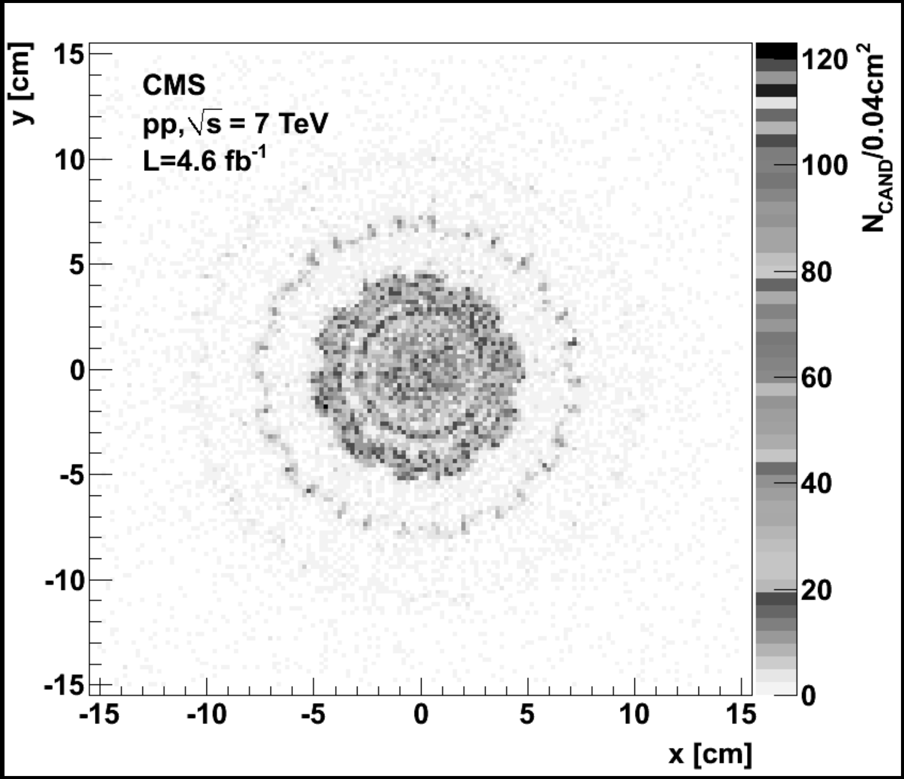


THERE'S A LOT…

- Colorless tests of QCD, both in pp and HI
- Diboson and now Triboson coupling measurements
- Higgs→γγ sure, but also H→Zγ, and Higgsino searches
- Dark matter in monophotons
- SUSY searches
- New resonances (G→γγ for instance)
- χ_c and some others
- Exclusive diphoton production
- There's a pretty long list…

ALSO:

- There are also accessory things one can learn from converted photons for instance, like material distribution and JES. We're not really going to cover that here, but it is something that we do.
- There's also a lot of the commonality between photons and electrons, so learning about one can begin to inform the other.



THE CHALLENGE

- There's a lot of nice things about photons, they form nice predictable electromagnetic showers (at least if they're not converted) that we can measure very precisely.
- Unfortunately there are two real problems with photons:
  - Photons are non-redundant: you ONLY get the measurement of energy from the ECAL, and you typically have no indication of what vertex the photon came from.
  - Jets are EVERYWHERE: any jet which fragments to a significant electromagnetic portion is going to look photon-like to some extent.
- Our photon reconstruction and Photon Identification are built to try to get the best estimate of the photon energy, and discriminate against as much of the jet background as possible.

WHAT WILL WE COVER?

- The goal of this workshop is to introduce you to how we reconstruct photons, and the choices that have been made in the algorithms.
  - I want to make these quantities real to you, relate them to what the detector actually recorded. No more simply cutting on things from your ntuple!
  - Get real hands on experience, and further think critically about the choices that have been made.
- We will mainly concentrate on the present reconstruction, that which is used in the 2012 data, but we'll look into the future at various points as well. We'll also look into what past detectors have done, and what our distinguished competition does.

THREE PARTS:

- There are three different exercises that have been prepared. Two out of the three are more fun if you have Microsoft Excel, but that's not strictly necessary.
  - We're not doing C++ coding, and we're not going to run CMSSW.
  - What we're going to do instead is look at what CMSSW is actually DOING.
- Each exercise has a lecture that corresponds with it that details what the reconstruction is doing. Then you'll take the data, and try to put it to work. What I want to do with the rest of this talk is to try to put the other steps of photon reconstruction in context.

PRESENTLY:

- We start making "Photon" objects out of "superclusters", which have had energy corrections applied to them.
  - Exercise 1 is all about how we form these clusters out of energy depositions in the ECAL.
  - The superclusters that we make "Photons" from, must be at least 10 GeV in E_T (calculated from the center of the detector).
  - That is almost ALL that is required. Thus why I put "photon" in quotation marks. Most of what lives in this collection is actually jets.
  - If you are above 100 GeV (in E_T), you enter the "photon" collection.
  - If you are below 100 GeV, you must pass a preselection cut.

PRESELECTION:

- This is really pretty simple, it's a cut on the old version of H/E. Here:
  - H is the sum of Hcal towers in a cone of $\Delta R < 0.15$ about the supercluster position.
  - E is the supercluster energy.
- You are required to have this ratio be less than 0.5. This is a **really** weak preselection cut.

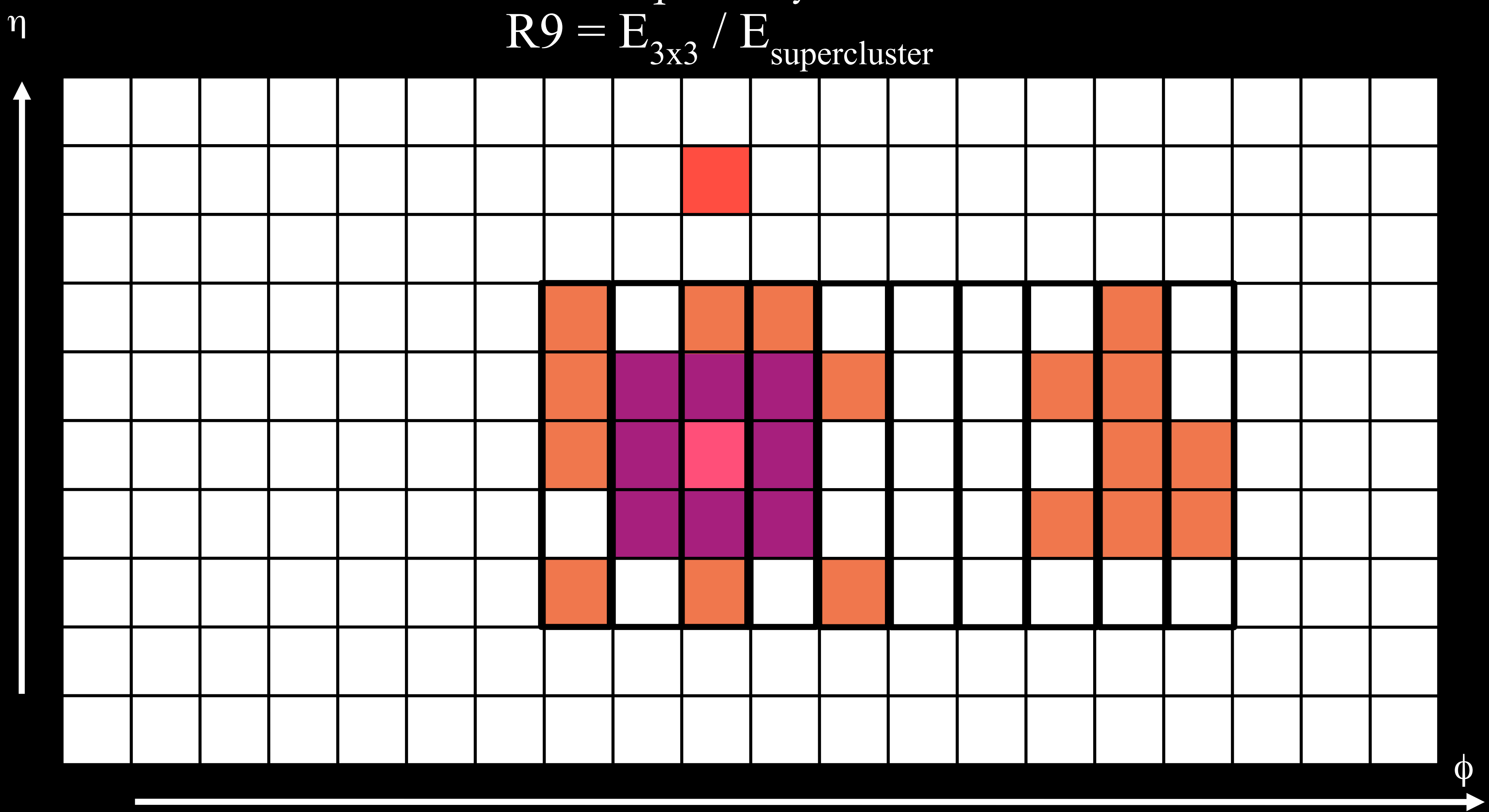
R9

- The first somewhat weird quantity we'll meet is known as R9.
  - R9 is a ratio between the energy in the 3x3 crystal array about the highest energy crystal in the cluster and the total supercluster energy.
  - This quantity is often used to classify photon candidates as being likely to be unconverted (large R9) or likely to be converted (smaller R9).
  - This quantity also controls what estimates of the photon energy and position are used.

R9

- The first somewhat weird quantity we'll meet is known as R9.

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



BASED ON R9

- We assign the position of our photon to either:
  - The position of the seed basic cluster within the supercluster, if R9>0.94(0.95) in the barrel (endcap).
  - The position of the supercluster if not.
- We then take the first vertex in the offlinePrimaryVertex collection and calculate our physics rapidity.
- The ENERGY of the photon is presently set to either:
  - The energy of the 5x5 array of crystals corrected for containment if R9 > 0.94 (0.95) in the barrel (endcap)
  - The corrected supercluster energy if not.
  - Either way there is an additional correction for cracks.

SO:

- What the superclustering does is actually pretty darn relevant. Ultimately that's what will determine your value for R9:
  - and R9 will determine what you do for your position calculation
  - and R9 will determine what you do for your energy estimate.
- Exercise 1 is all about the clustering.

HERE'S THE REST:

The cone size for all isolation sums is 0.3

BARREL	Loose (90%)	Medium (80%)	Tight (70%)
Conversion safe electron veto	Yes	Yes	Yes
Single tower H/E	0.05	0.05	0.05
$\sigma_{i\eta i\eta}$	0.012	0.011	0.011
Rho corrected PF charged hadron isolation	2.6	1.5	0.7
Rho corrected PF neutral hadron isolation	3.5 + 0.04*pho_Pt	1.0 + 0.04*pho_Pt	0.4 + 0.04*pho_Pt
Rho corrected PF photon isolation	1.3 + 0.005*pho_Pt	0.7 + 0.005*pho_Pt	0.5 + 0.005*pho_Pt

ENDCAPS	Loose (85%)	Medium (75%)	Tight (65%)
Conversion safe electron veto	Yes	Yes	Yes
Single tower H/E	0.05	0.05	0.05
$\sigma_{i\eta i\eta}$	0.034	0.033	0.031
Rho corrected PF charged hadron isolation	2.3	1.2	0.5
Rho corrected PF neutral hadron isolation	2.9 + 0.04*pho_Pt	1.5 + 0.04*pho_Pt	1.5 + 0.04*pho_Pt
Rho corrected PF photon isolation	-	1.0 + 0.005*pho_Pt	1.0 + 0.005*pho_Pt

Ex.2

Ex.3

- These are the cut based photon identification requirements. These take you, ostensibly, from the very low purity set of "photons" to something more pure.

H/E NEW:

- Single tower H/E is supposed to be a more pileup safe version of the previous H/E.
  - Recall, the previous version, and the version still used in the preselection uses a cone of $\Delta R < 0.15$ to pick the Hcal towers in proximity to the supercluster.
  - This time the DetId of the highest energy crystal (or the seed crystal) is used to look up the tower that this channel belongs to. Then only the corresponding Hcal energy is used. So in principle, you could have a large spread (as you'll see) across the Ecal, but only that one tower will be considered for H/E.

CONVERSION SAFE VETO:

- This is an outgrowth of the older "pixel seed veto" that used to stand in for electron rejection.
  - The "pixel seed" in question was a combination of hits in the pixel detector found based on the E_T, η, ϕ of the electron candidate, which originated from the same superclusters that seed photons.
  - Which is *still* used as an option for analyses that suffer from substantial electron backgrounds.
- The conversion safe veto is in some sense a looser variant of this, see next slide.

CONVERSION SAFE VETO (2)

- Take your photon. Find it's supercluster.
  - Check to see if this supercluster is shared by an electron candidate.
    - If it does, check if there are missing inner hits. If there are missing hits, you're still okay.
    - Otherwise, check if this electron matches a conversion. If it does, and this is a bona fide conversion (good vertex, distance from beamspot, and missing inner hits), you're still okay.
    - If you HAVE a matched conversion that isn't bona fide then you're an electron. (meaning you match an electron, which even if it is found as a conversion doesn't qualify as a displaced conversion).

SO THAT'S WHERE WE ARE:

- We'll now backtrack and look at the clustering, and then the shower shape from the identification requirements.
- After we get through that, we'll look at photon ID at different detectors. Tomorrow we'll study isolation, and look to the future.
- Let's get ready!