Higgs Analysis for the CMS

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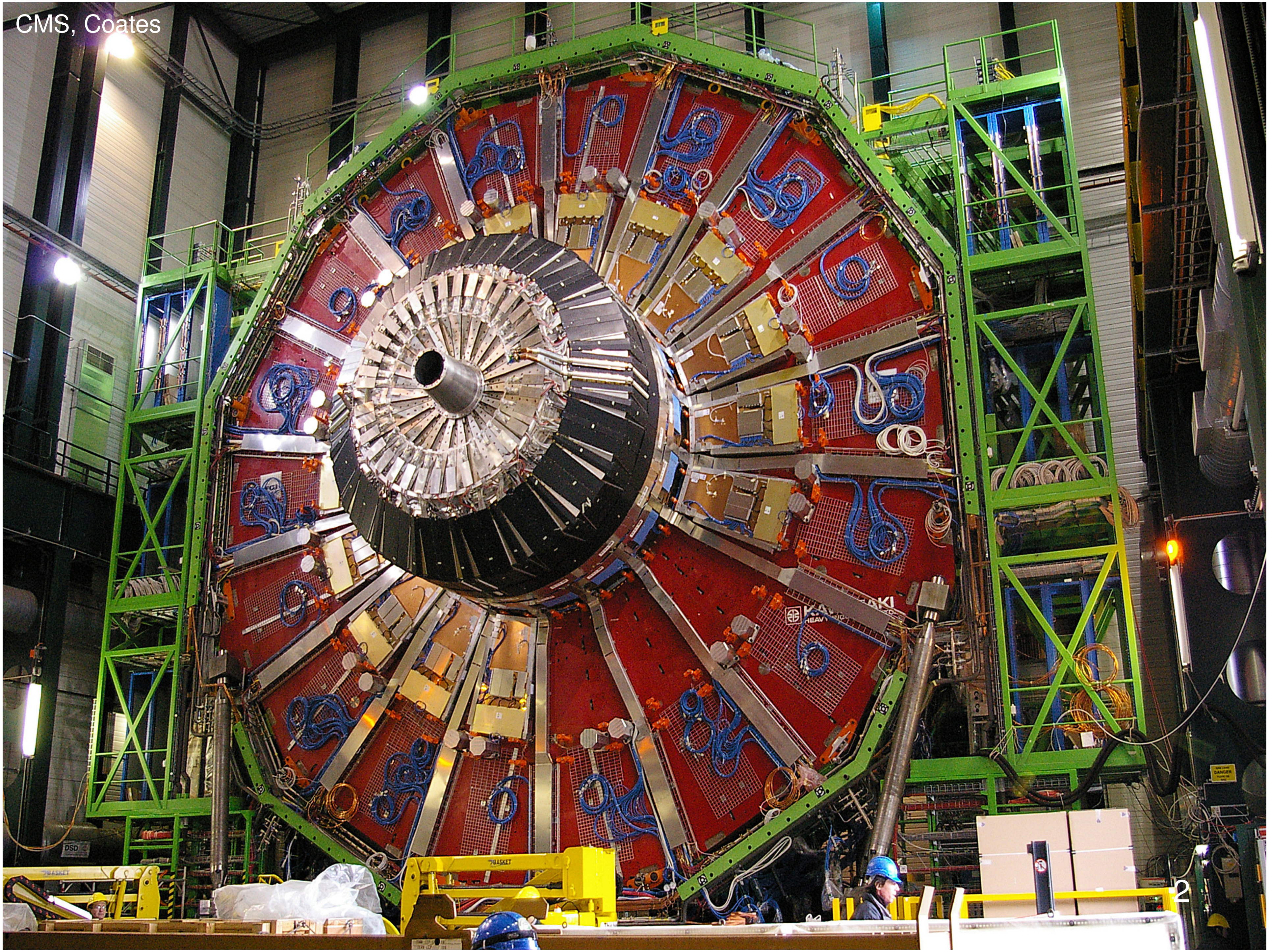
CMS, Coates

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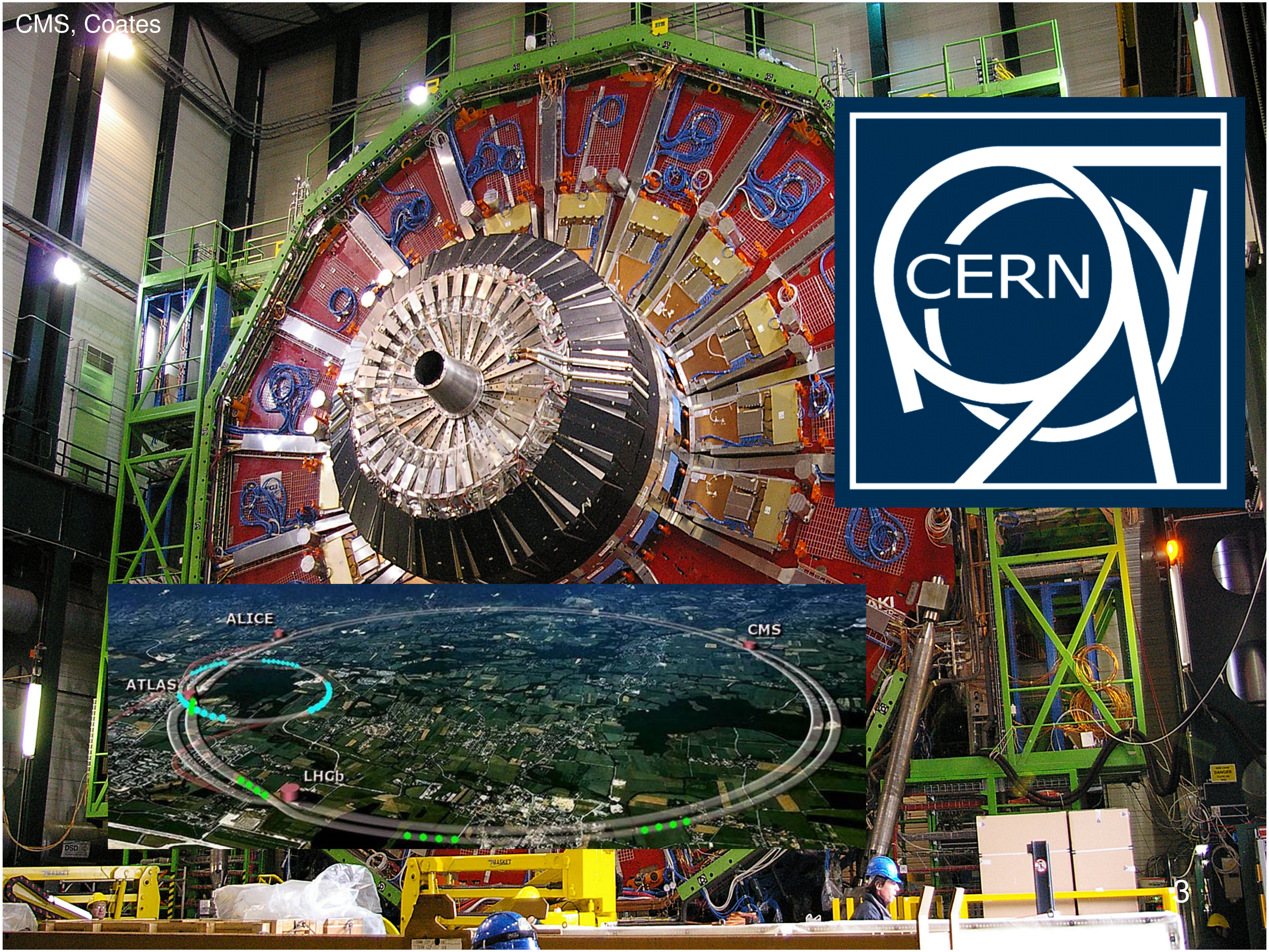
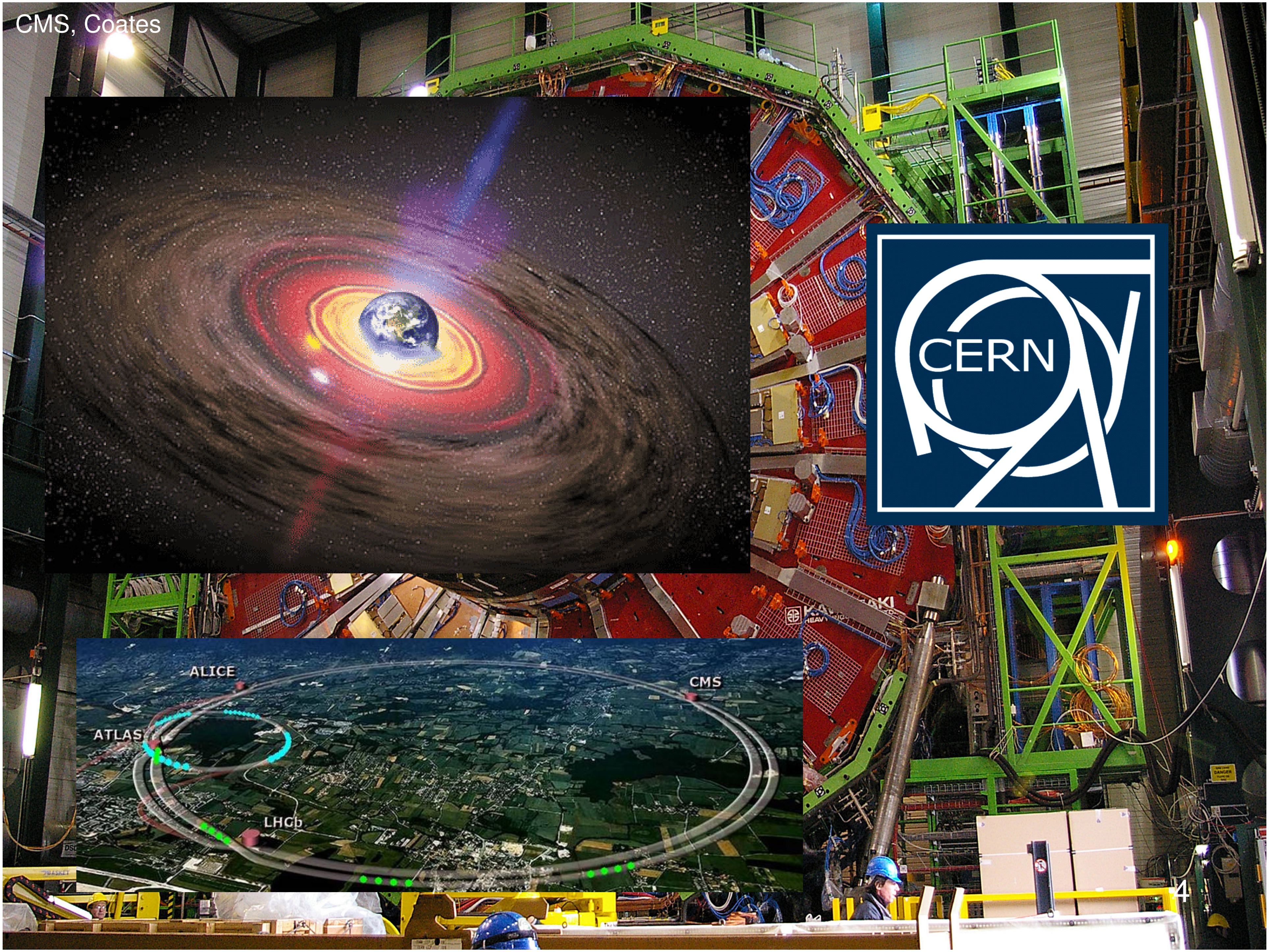
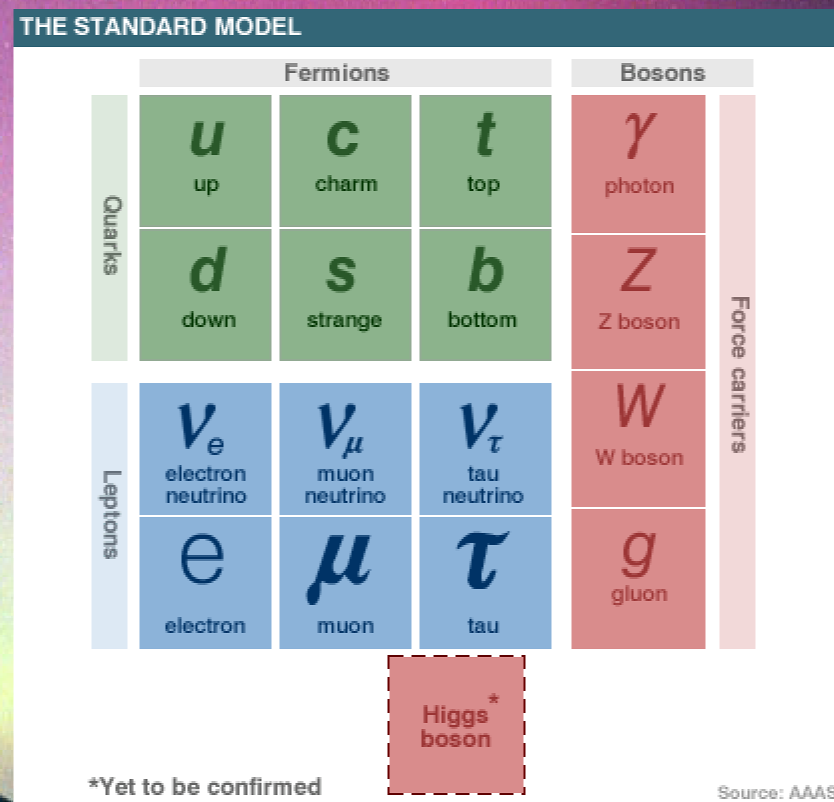


CMS, Coates



Extend the Standard Model

- The Standard Model of Particle Physics does not account for masses.
- The theorized Higgs Boson, however, if added to the Standard Model, would allow particles to have mass.



The Higgs Mechanism

- There are no mass terms in Lagrangians
  - Simply adding the mass terms would violate gauge invariance
- Higgs Field
  - A spin-zero field that carries a non-zero hypercharge extends through all of space
  - breaks gauge invariance, but in a subtle, helpful way
    - Lagrangian is invariant, but the vacuum is not.

Spontaneous Symmetry Breaking

- Give Lagrangian Weak Isospin—left and right-handed chiralities have different charges, i.e. left-handed particles are doublets, right-handed particles are singlets
- Vacuum
  - Because the quantum numbers of the vacuum are non-zero, the symmetries are effectively broken

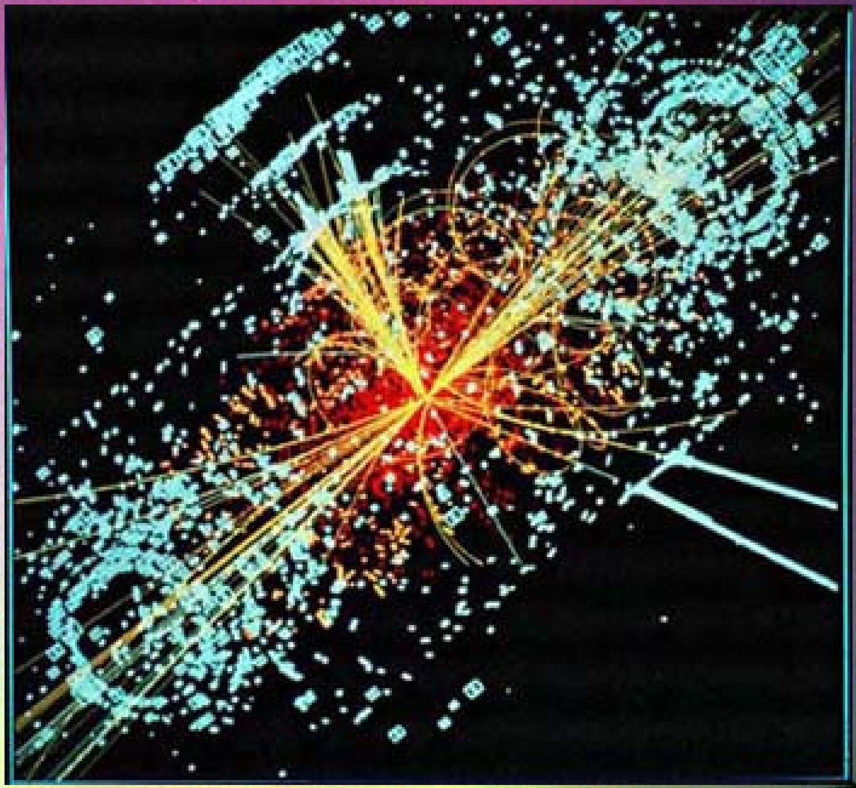
Spontaneous Symmetry Breaking

- Higgs Field takes on the value of the vacuum expectation, v
  - $v = \pm\sqrt{(-\mu^2 / \lambda)}$
  - The field stays symmetric when you take +v, but when you take –v, the vacuum does not have the symmetry of the original Lagrangian
- Consequentially, the Higgs-Goldstone Boson is emitted when SSB occurs

NOTE: μ and λ are potential energy parameters

Evidence of the Higgs Mechanism

- At the CMS, we will look for the product of SSB—the Higgs-Goldstone Boson
- Massive Higgs decays before it reaches our detectors
  - Decays into two weak force bosons, which then decay into leptons and neutrinos



Evidence of the Higgs Mechanism

- By reconstructing the decay products, we can see if the Higgs Boson really exists
- Problem: hadron colliders produce messy collisions
  - Background elimination
  - Isolated signal will appear as some new physics that we haven't seen yet
    - Mass peak, MET, etc.—no one knows yet

Higgs Analysis

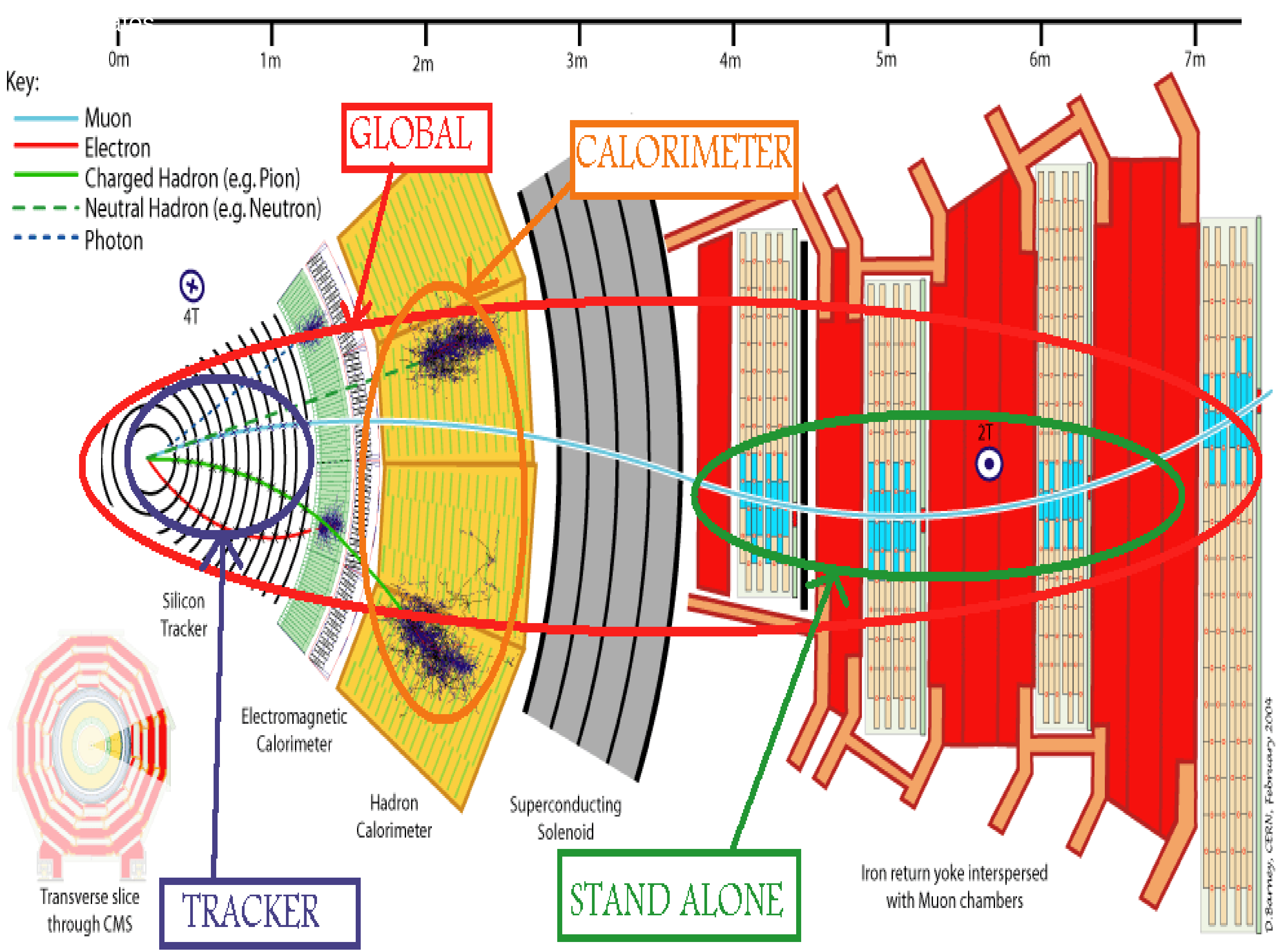
- $H \rightarrow ZZ^{(*)} \rightarrow 4l$ channel
  - 4 muons
  - 2 electrons, 2 muons
  - Others exist (4 electrons, taus)
- Three other physics processes will also occur during the collision that could be misinterpreted as a Higgs decay
- Our goal is to remove these processes so that we can find the Higgs signal amongst this background

Search for the Higgs Boson

- The Background
  - ttbar
  - Zbbbar
  - ZZ
- ttbar→Wb (W→lv)
- qqbar/gg→Zbbbar (Z→2l)
- qqbar→ZZ→4l
- Obviously, the muons need to be discriminated from each other

Search for the Higgs Boson

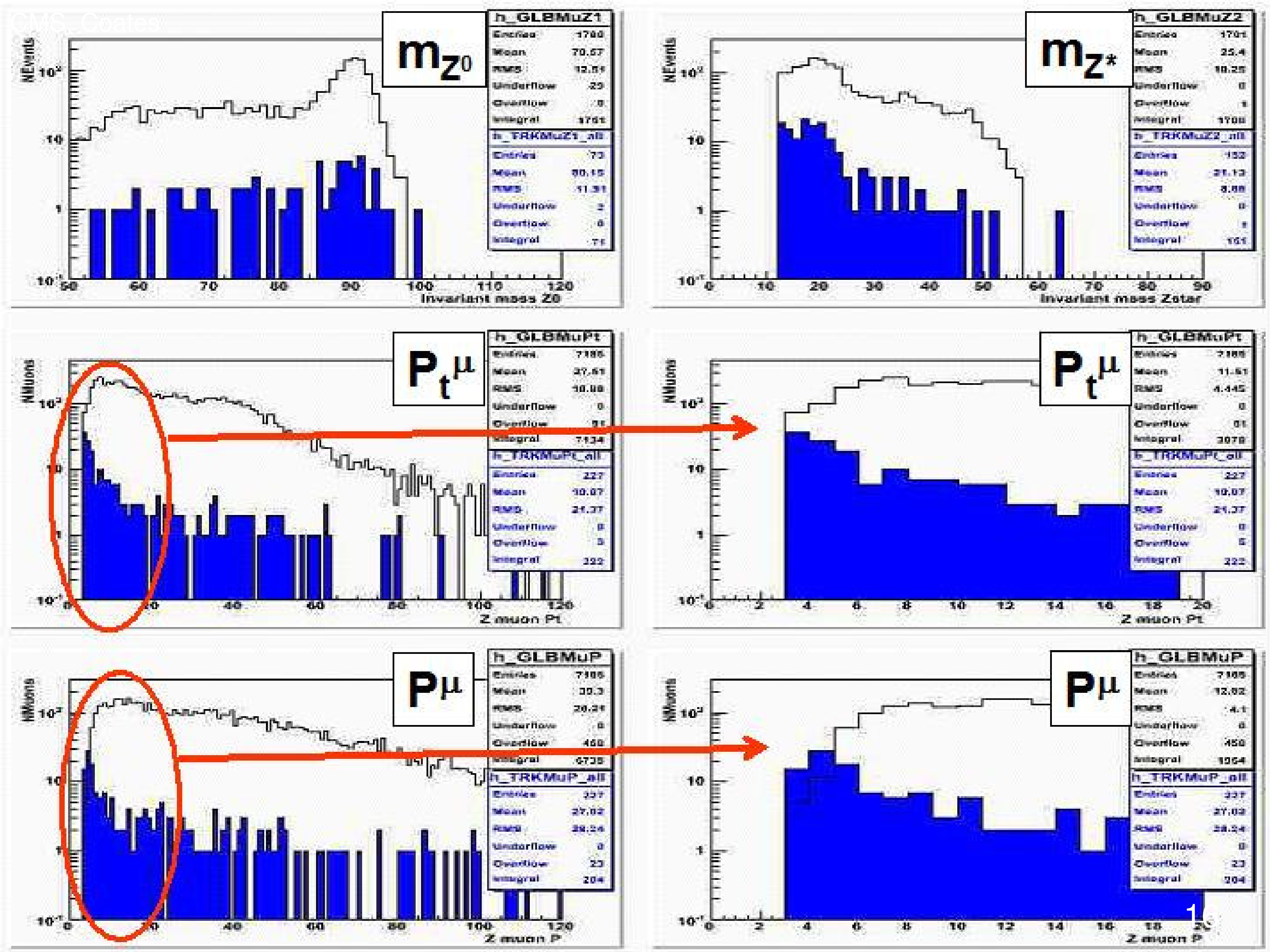
- In order to discriminate amongst the muons, we classify the muons into different types
  - Global, Tracker, Calorimeter, Stand Alone
  - Each muon is spatially different from the others
  - By segmenting the muon paths, we can analyze the stages much easier



0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
GLOBAL
CALORIMETER
TRACKER
STAND ALONE
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

Search for the Higgs Boson

- At the CMS, the 4l strategy currently uses only global muons to uncover signal
- We proposed to use tracker muons along with global muons to increase significance
- Create custom-made ROOT files on the CMSSW to retrieve Tracker Muons
  - Calorimeter Muons
  - Missing Transverse Energy

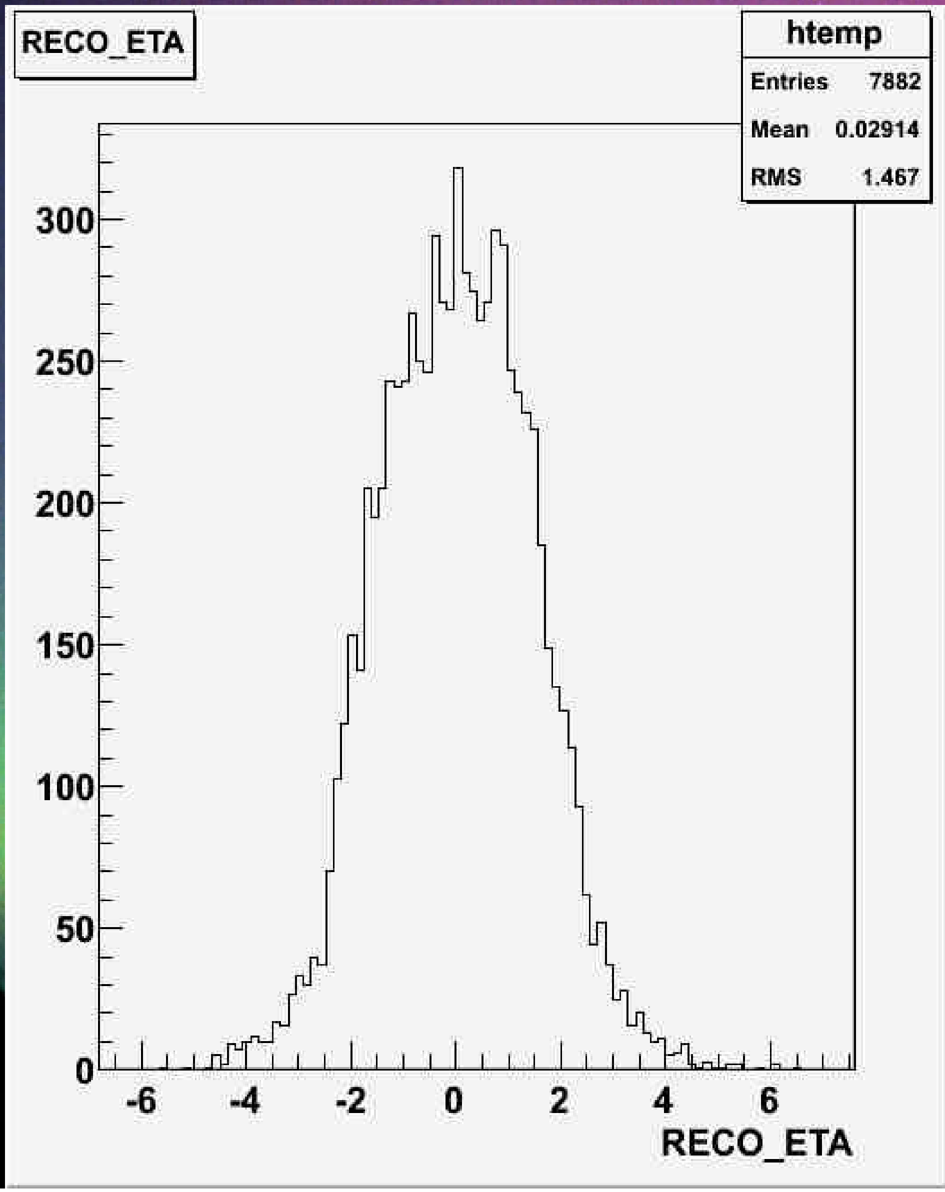


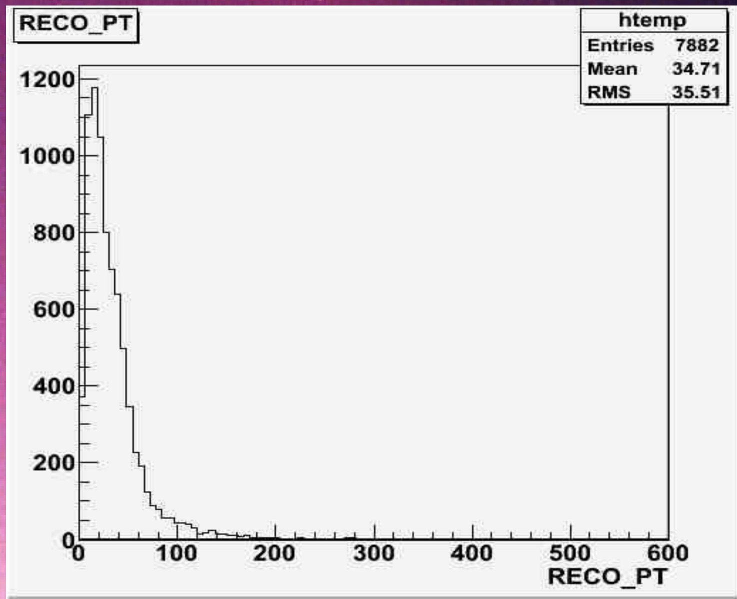
m_{Z^0}
h_GLBMuZ1
h_TRKMuZ1_all
NEvents
Invariant mass Z0
m_{Z^*}
h_GLBMuZ2
h_TRKMuZ2_all
NEvents
Invariant mass Zstar
P_t^{μ}
h_GLBMuPt
h_TRKMuPt_all
NMuons
Z muon Pt
P_t^{μ}
h_GLBMuPt
h_TRKMuPt_all
NMuons
Z muon Pt
P^{μ}
h_GLBMuP
h_TRKMuP_all
NMuons
Z muon P
P^{μ}
h_GLBMuP
h_TRKMuP_all
NMuons
Z muon P

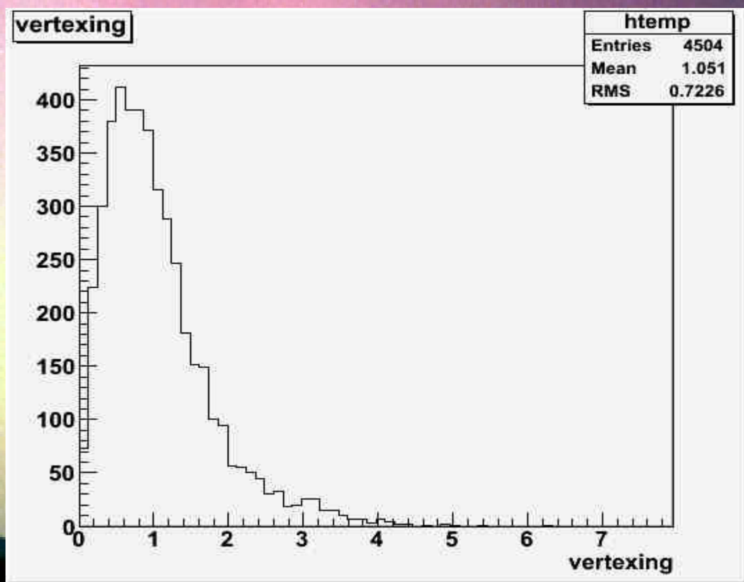
Tracker Analysis

- With the addition of the tracker muons, a lot of background is accepted
- Use the ROOT files for physics analysis
  - Reveal decay angles, momentum, energy, MET
  - Signal Discrimination
- We analyzed the physical processes to discriminate between signal and background
  - Decay angles, momentum, missing energy, what the detectors accept

Physics Analysis

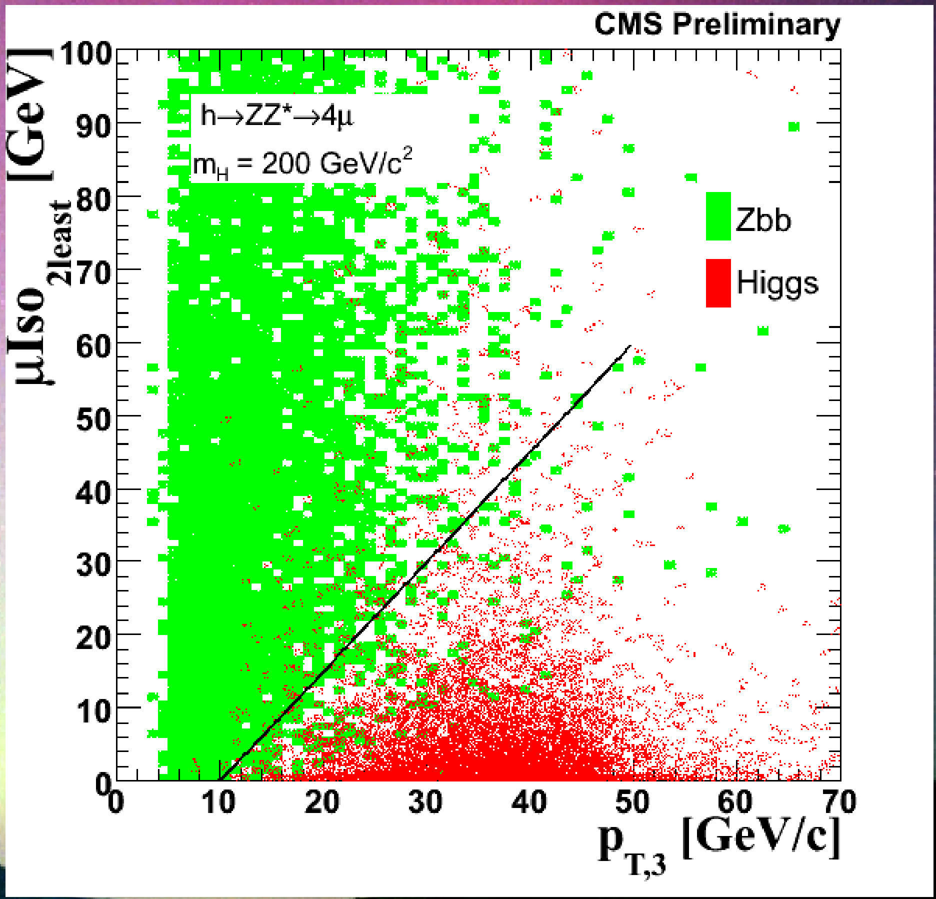




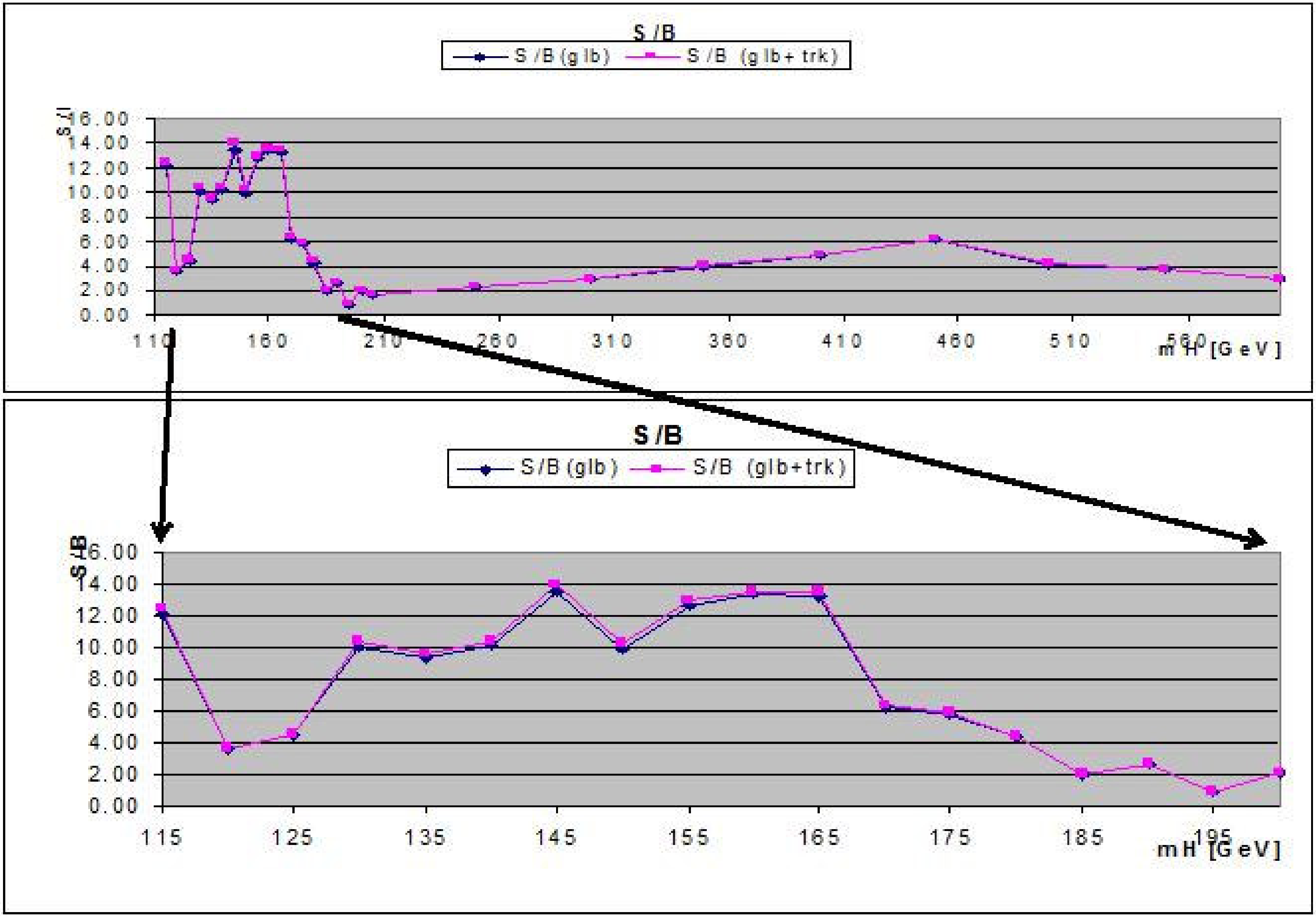


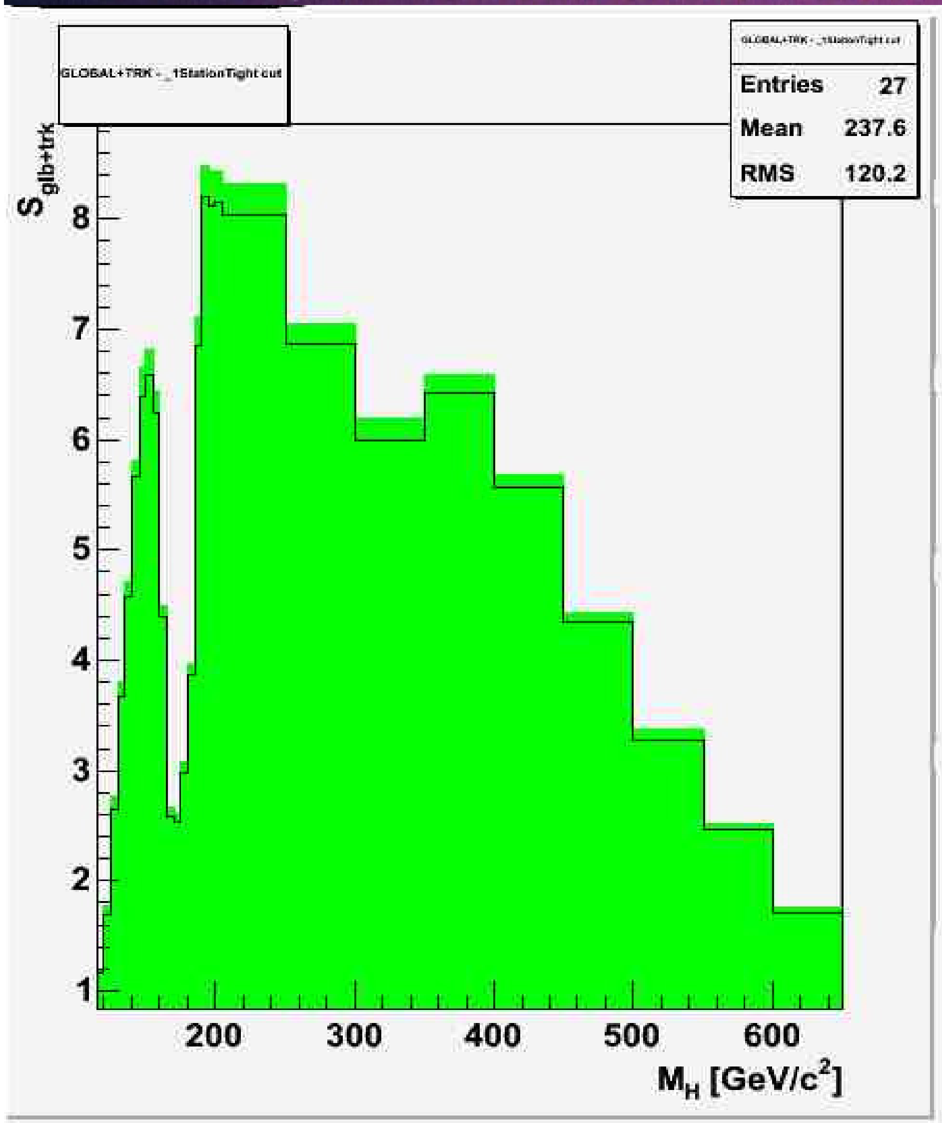
Results

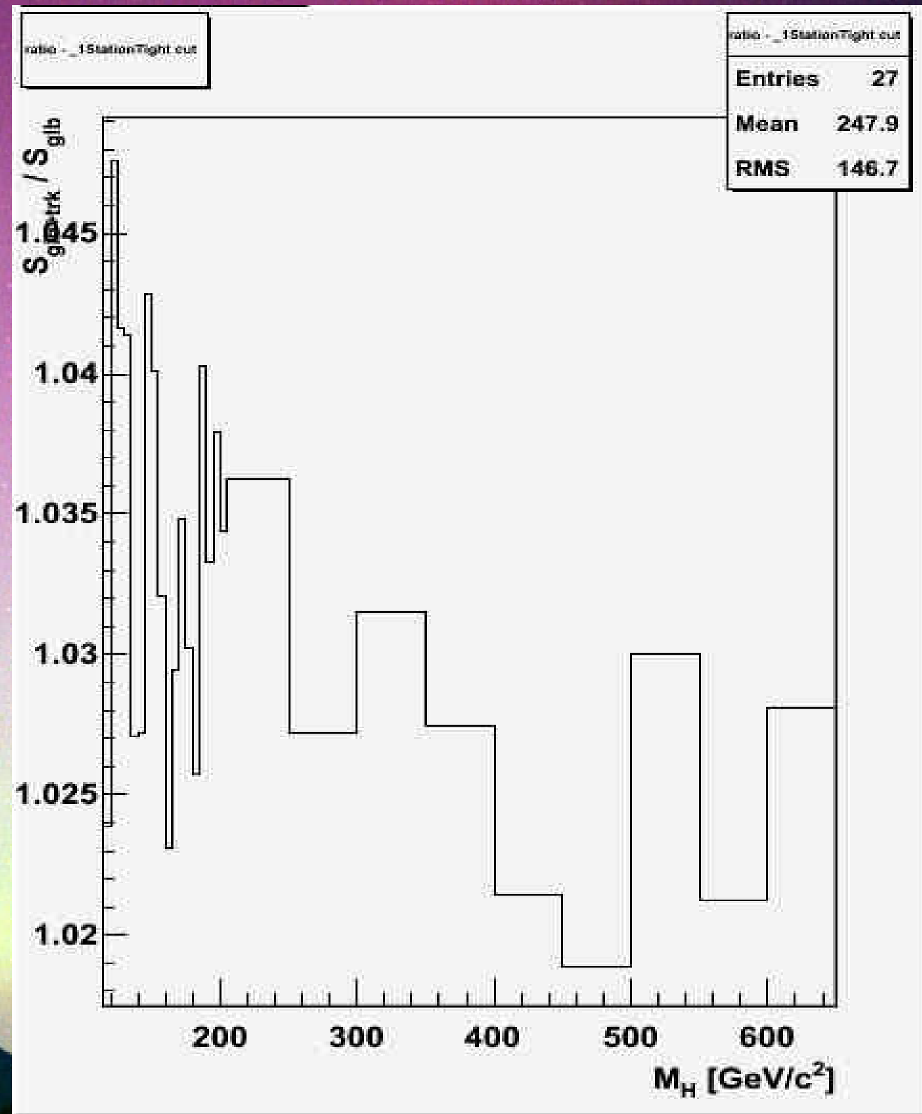
- Chi Squared— 4
- Isolation of the Z* muons depends on their Transverse Momentum
  - Isolation = 1.5 * $P_{T,3}$ – 15
- ZZ background is currently overwhelming at 1 fb^{-1}
- Significance increase of about 11% when tracker muons are added
  - Significant?



S/B comparison

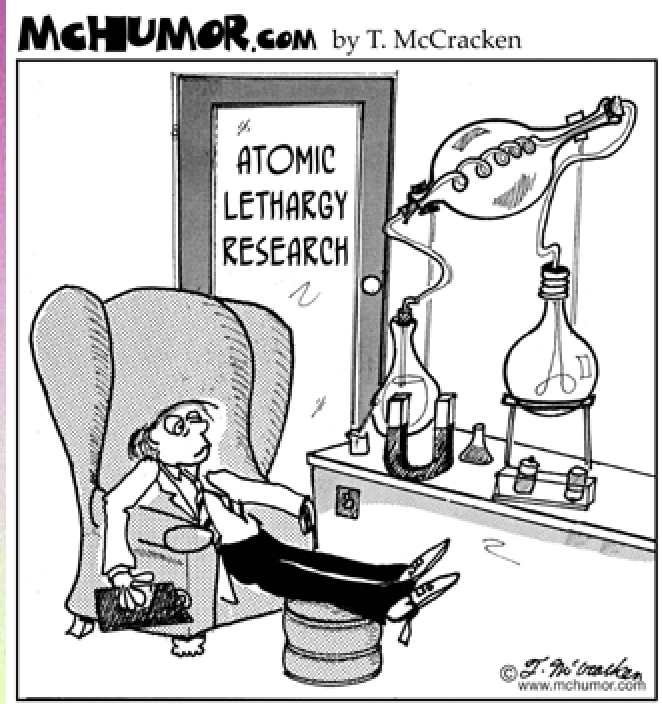



GLOBAL+TRK - _1StationTight cut
Entries 27
Mean 237.6
RMS 120.2
$S_{glb+trk}$
M_H [GeV/c^2]


ratio - _1StationTight cut
Entries 27
Mean 247.9
RMS 146.7
$S_{glb+trk} / S_{glb}$
M_H [GeV/c^2]

The Future

- Other possibilities
  - MET
    - Great discrimination for ttbar—possibly ZZ if we stick to H → ZZ → 2l2v
  - Calorimeter Muons
    - Hits in the calorimeter towers (will ZZ have them)
  - Relaxation?



Probably not…

Acknowledgements

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