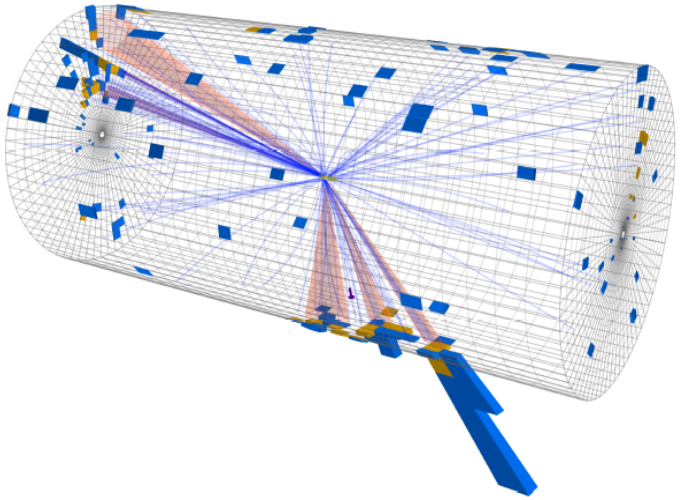
Searching for Dark Matter @ LHC
Does it matter?



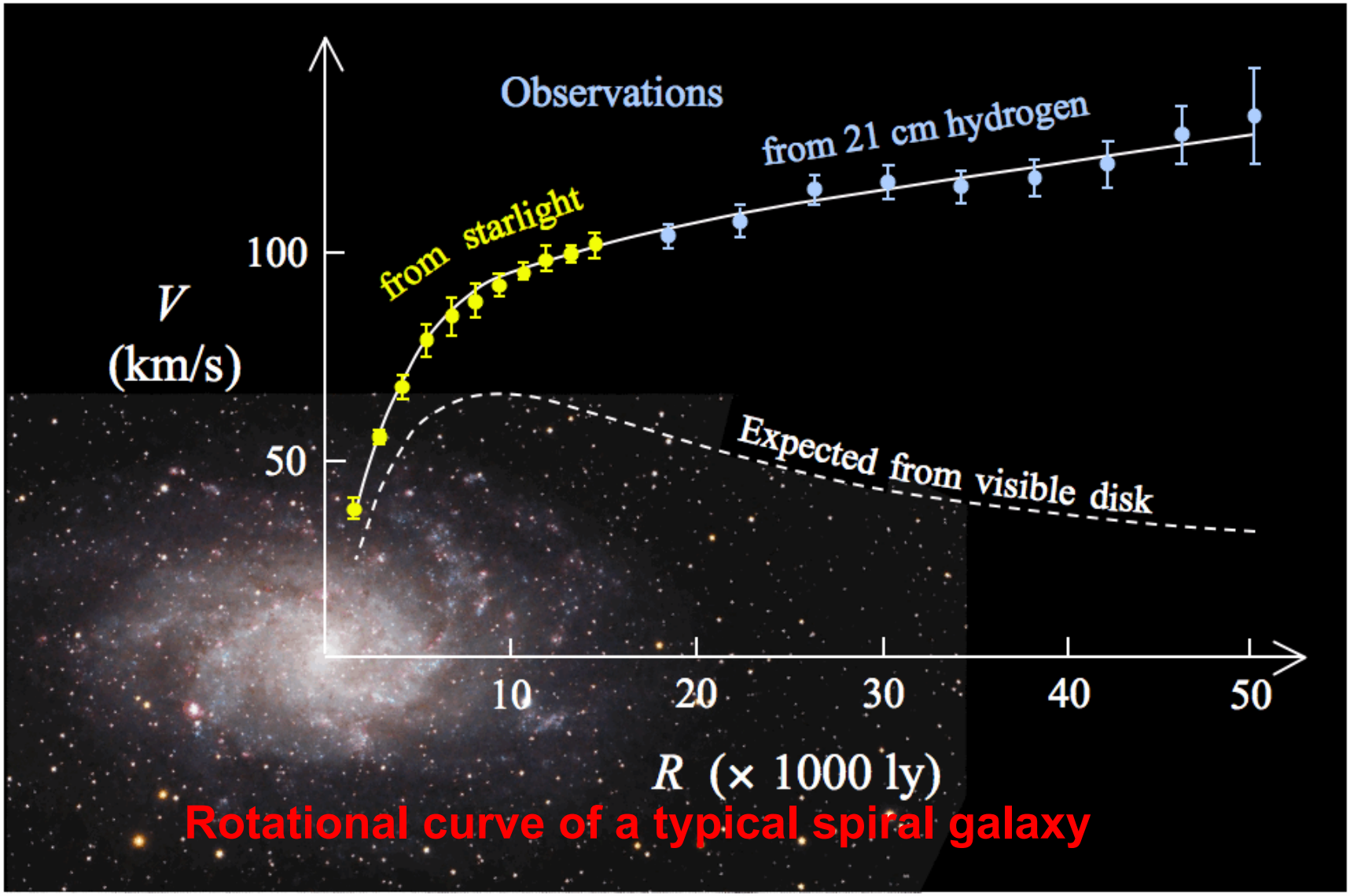
Giorgos Anagnostou,
Institute Of Nuclear & Particle Physics

Demokritos , 28 Jan 2020

Outline

- Why do we think that there is dark matter
- How to search it (indirect, direct, mainly colliders)
- How this is done @ the LHC
- A new method to search for dark matter at the LHC

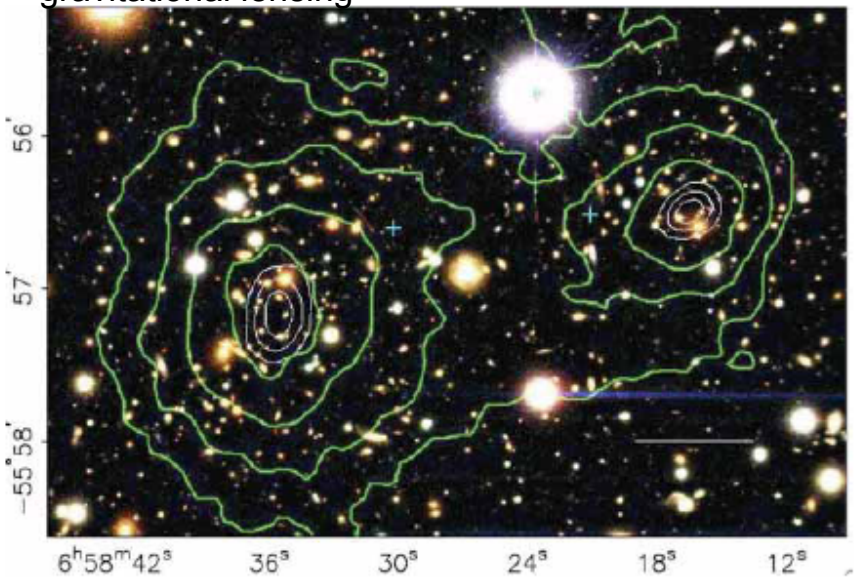
Why search in final states with missing energy @ the LHC?



Rotational curve of a typical spiral galaxy

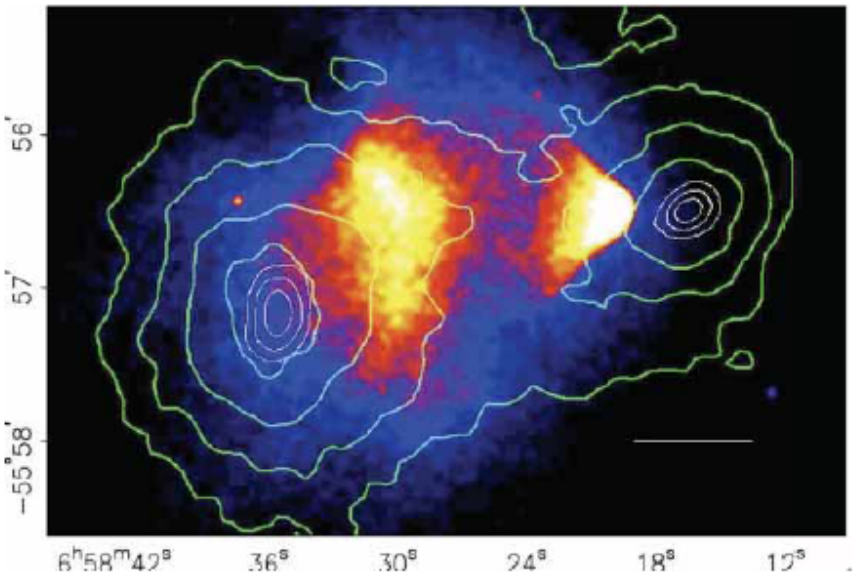
Why search in final states with 2 invisible particles @ the LHC?

Optical images from the Magellan telescope with overplotted contours of spatial distribution of mass, from gravitational lensing



Bullet cluster - Magellan

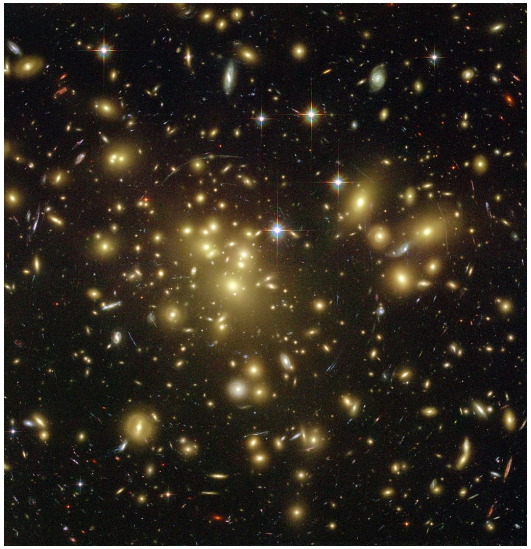
The same contours overplotted over Chandra x-ray data that traces hot plasma in a galaxy.



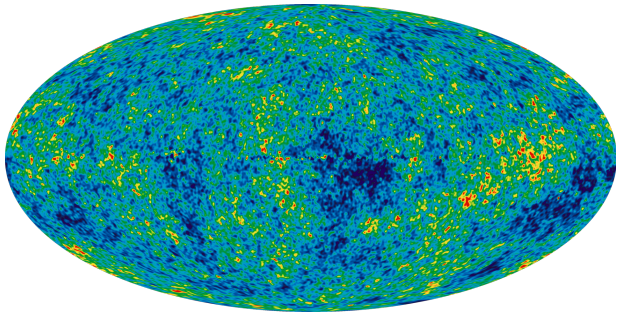
X-ray from Chandra telescope

- most of the matter resides in a location different from the plasma
- plasma underwent frictional interactions during the merger and slowed down

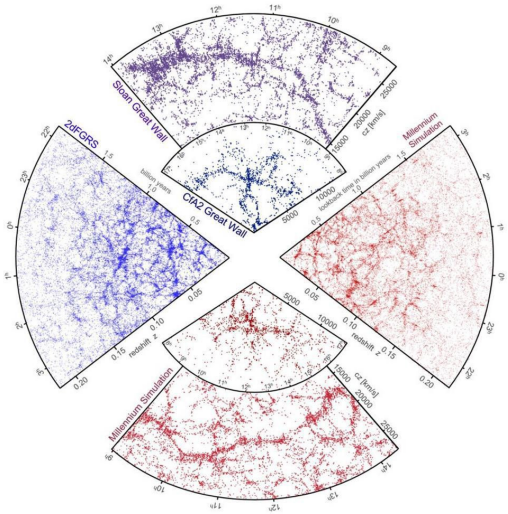
WIMP miracle



Gravitational lensing



Cosmic Microwave Background

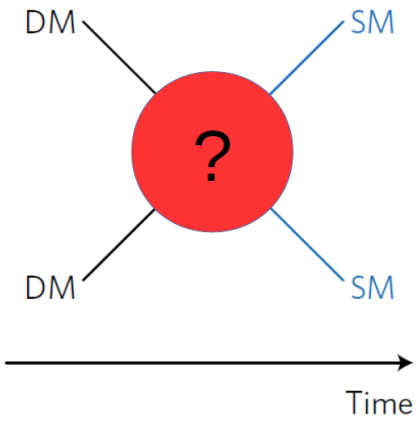


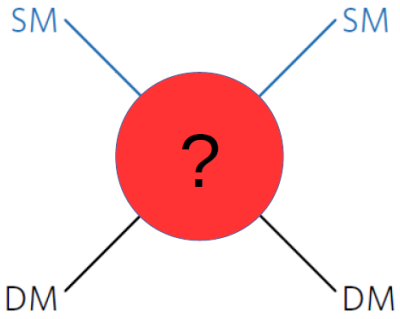
Large structure formation

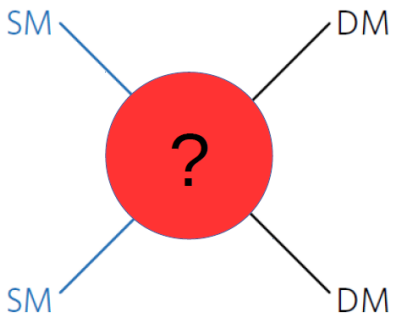
if the DM mass is around the weak scale (similar to the massive particles found in the SM) and if DM particles couple with SM particles with a strength similar to that of the SM electroweak interactions, this simple scenario approximately predicts the correct observed DM relic abundance – WIMP miracle !!

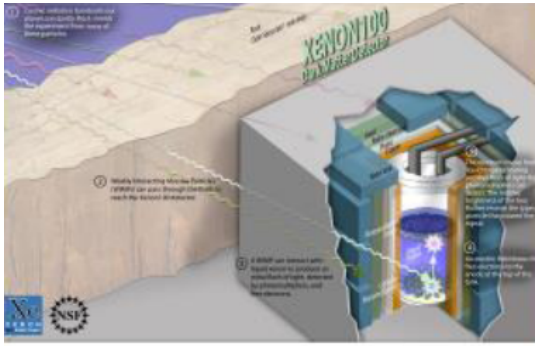
Weakly Inteacting Massive Particles @ the LHC reach !

How to search for dark matter?







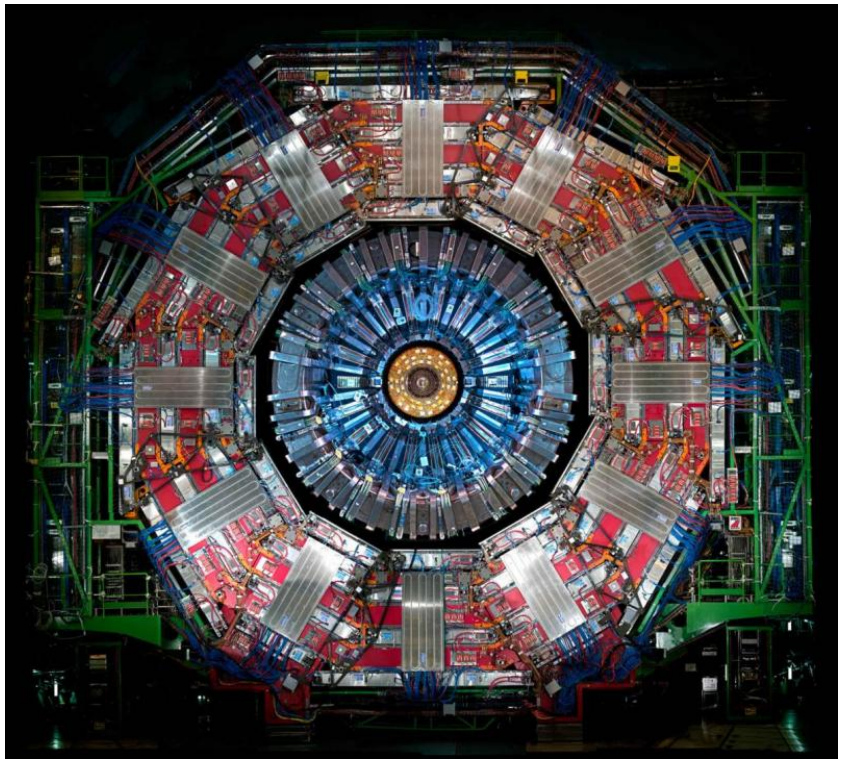


Indirect searches,
annihilation of DM into SM

Direct searches,
DM scattering from SM

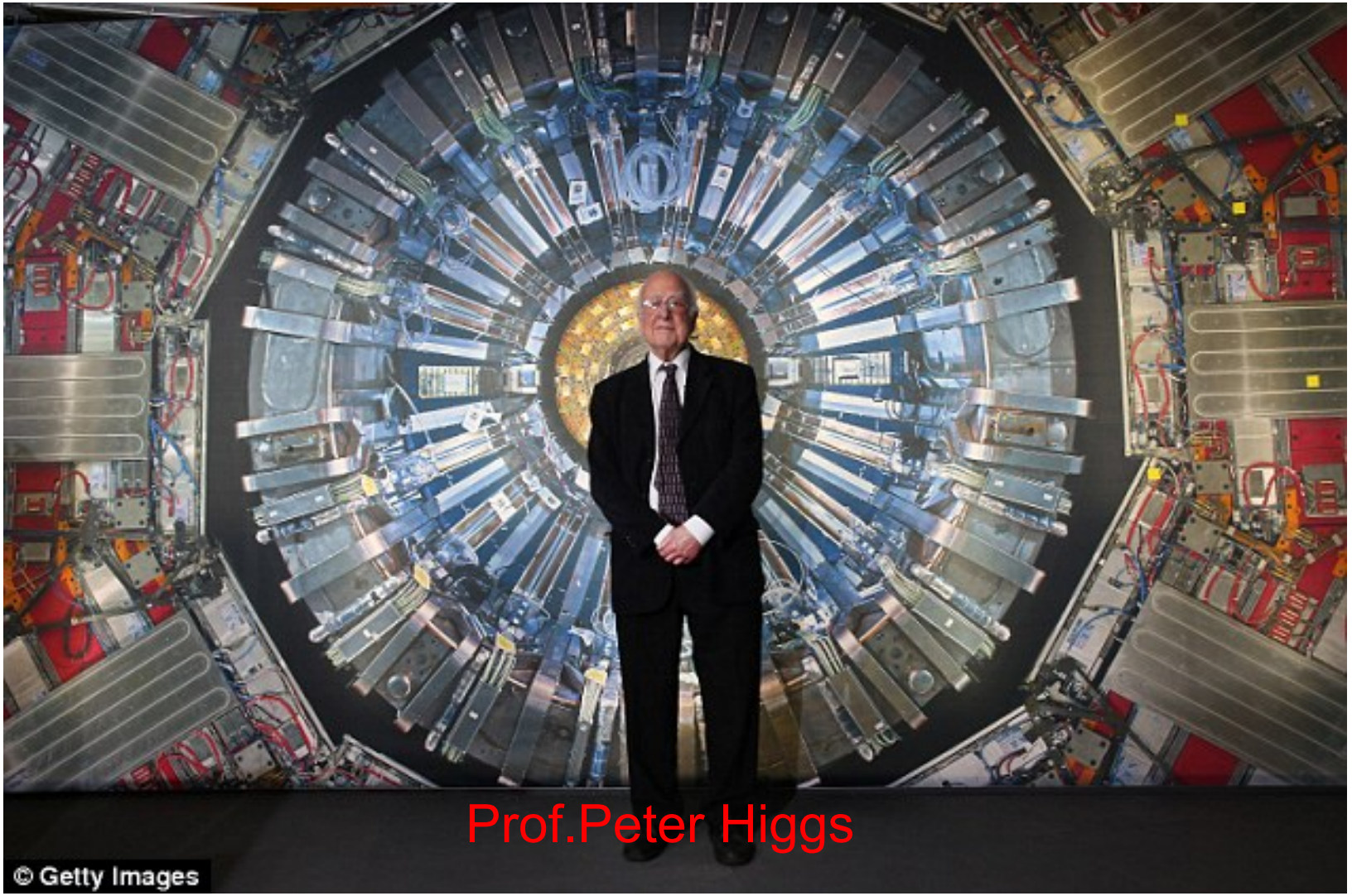
Collider searches,
SM collisions to DM

How can we search for dark matter @ the LHC?



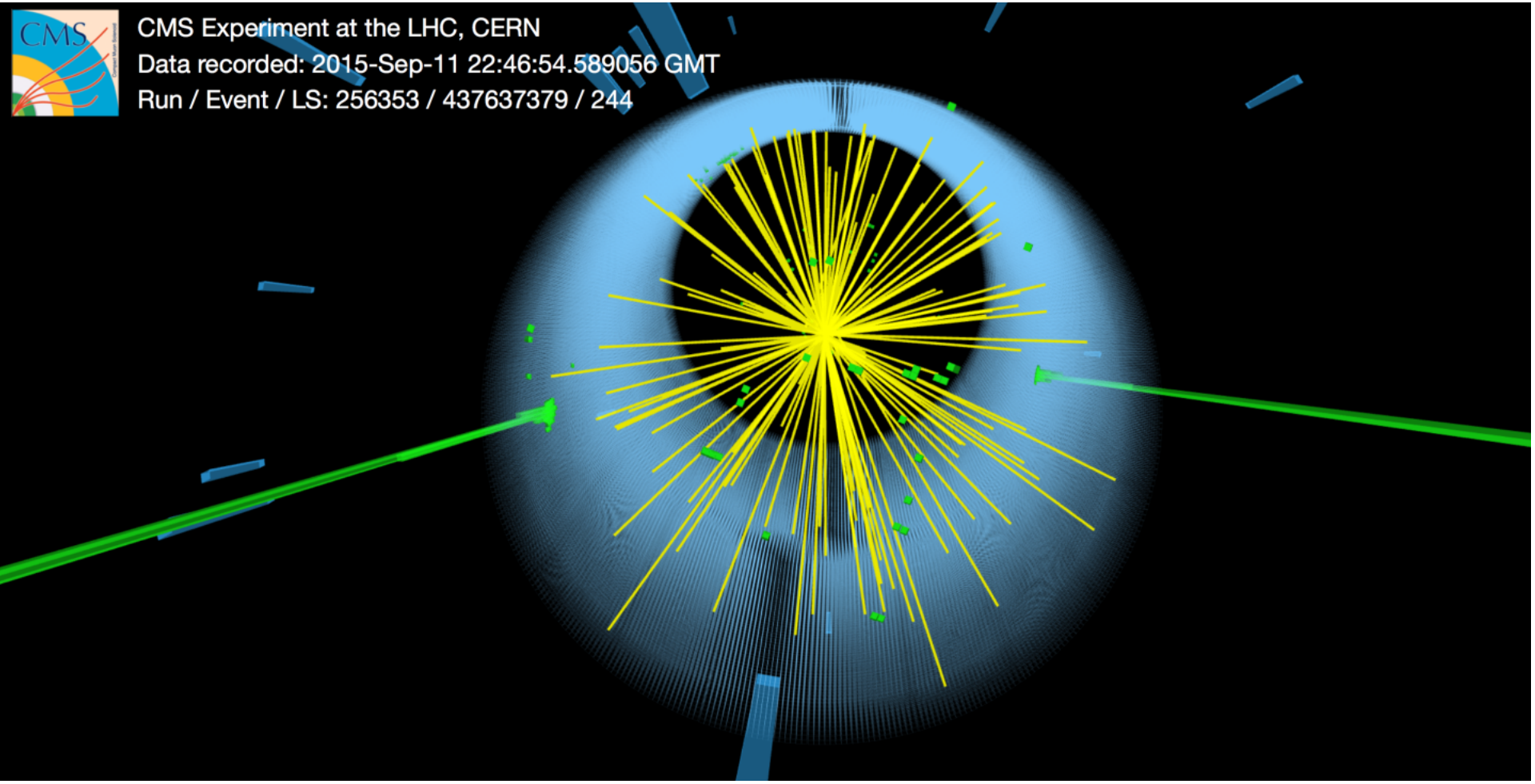
What is the signature of possible DM particles @ LHC?

Higgs found in CMS detector



Higgs found in ATLAS detector

Higgs discovery



Higgs discovery

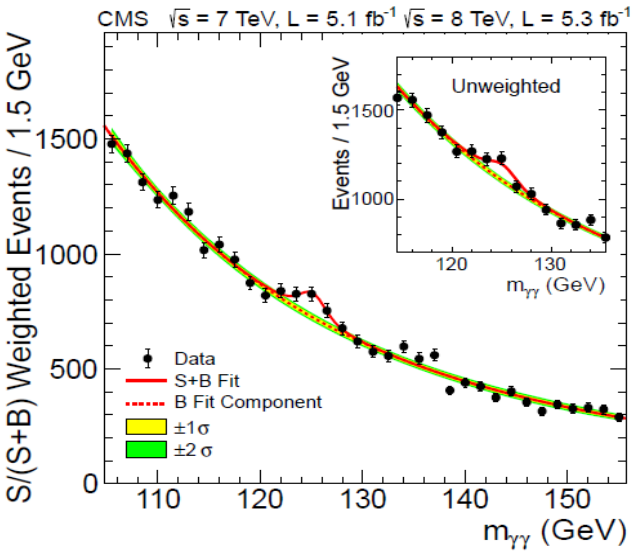
- Find invariant mass of events with 2 photons
- Put it in a histogram
- Wait until you see a peak

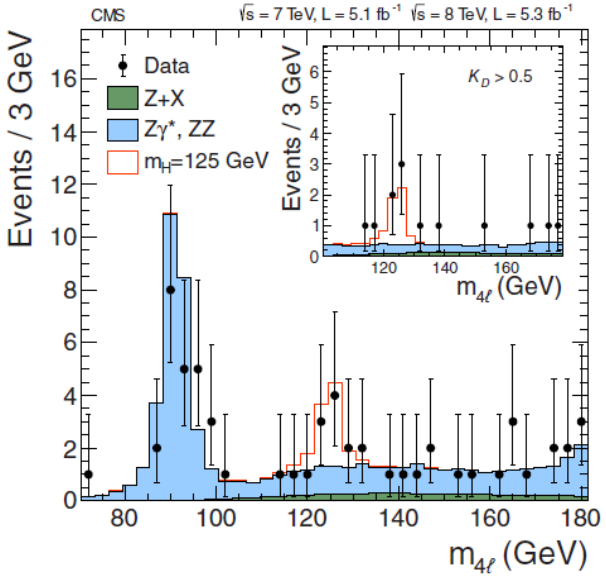
Number of Events

Mass (GeV)

How to search for dark matter @ the LHC?

Higgs discovery “easy”: mass peaks at predicted region:

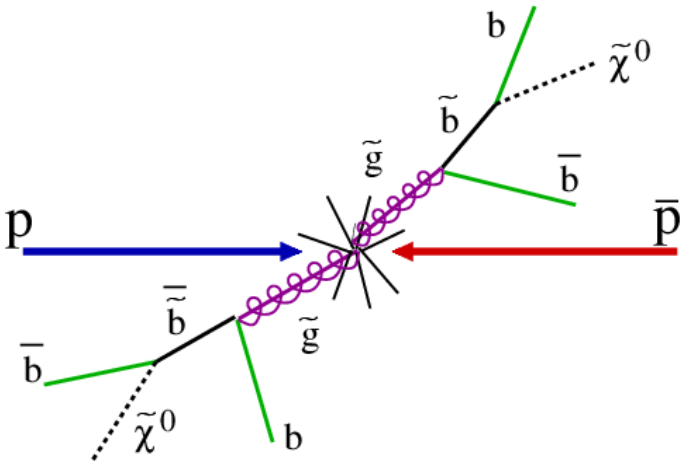


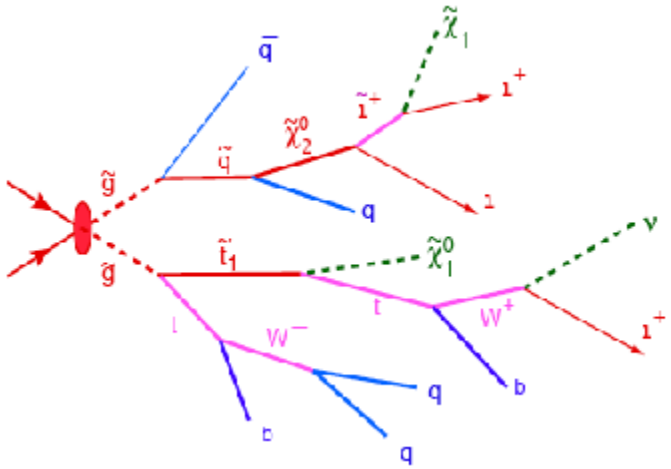


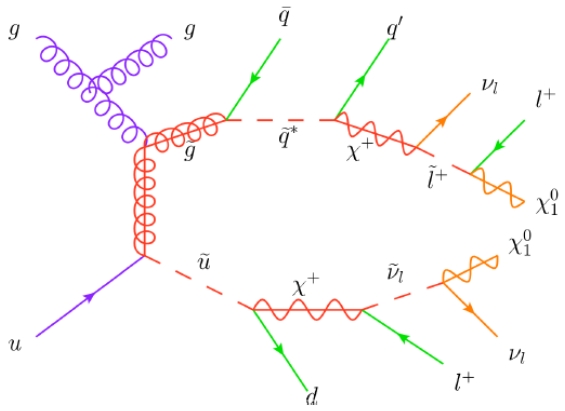
Many models with dark matter particles (e.g susy) have at least 2 invisible (undetectable) particles

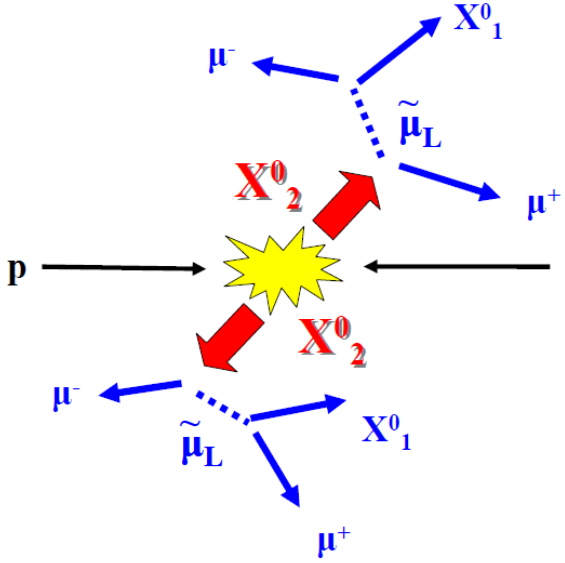
use missing energy – like observables.

Typical missing energy signatures @ the LHC

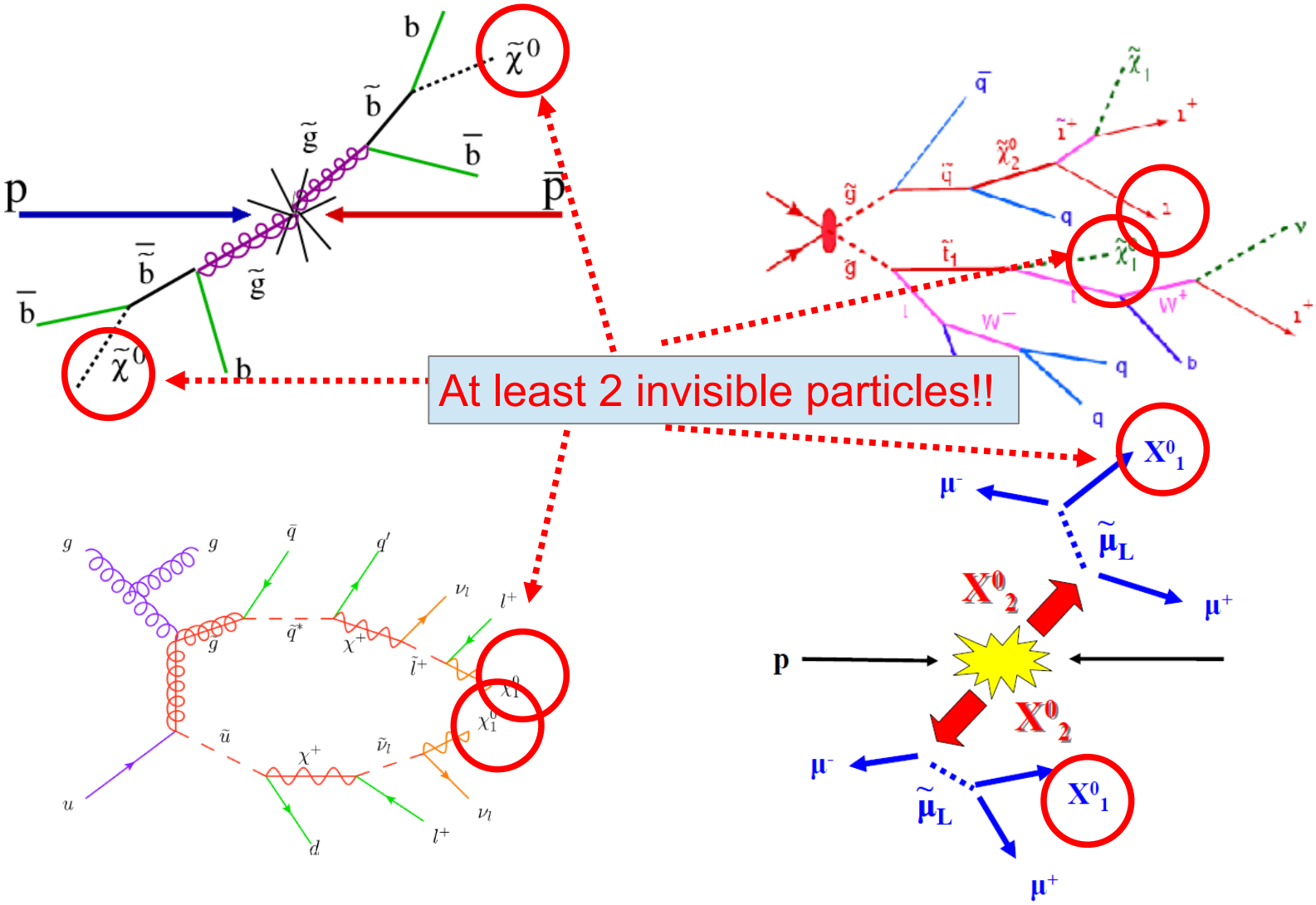




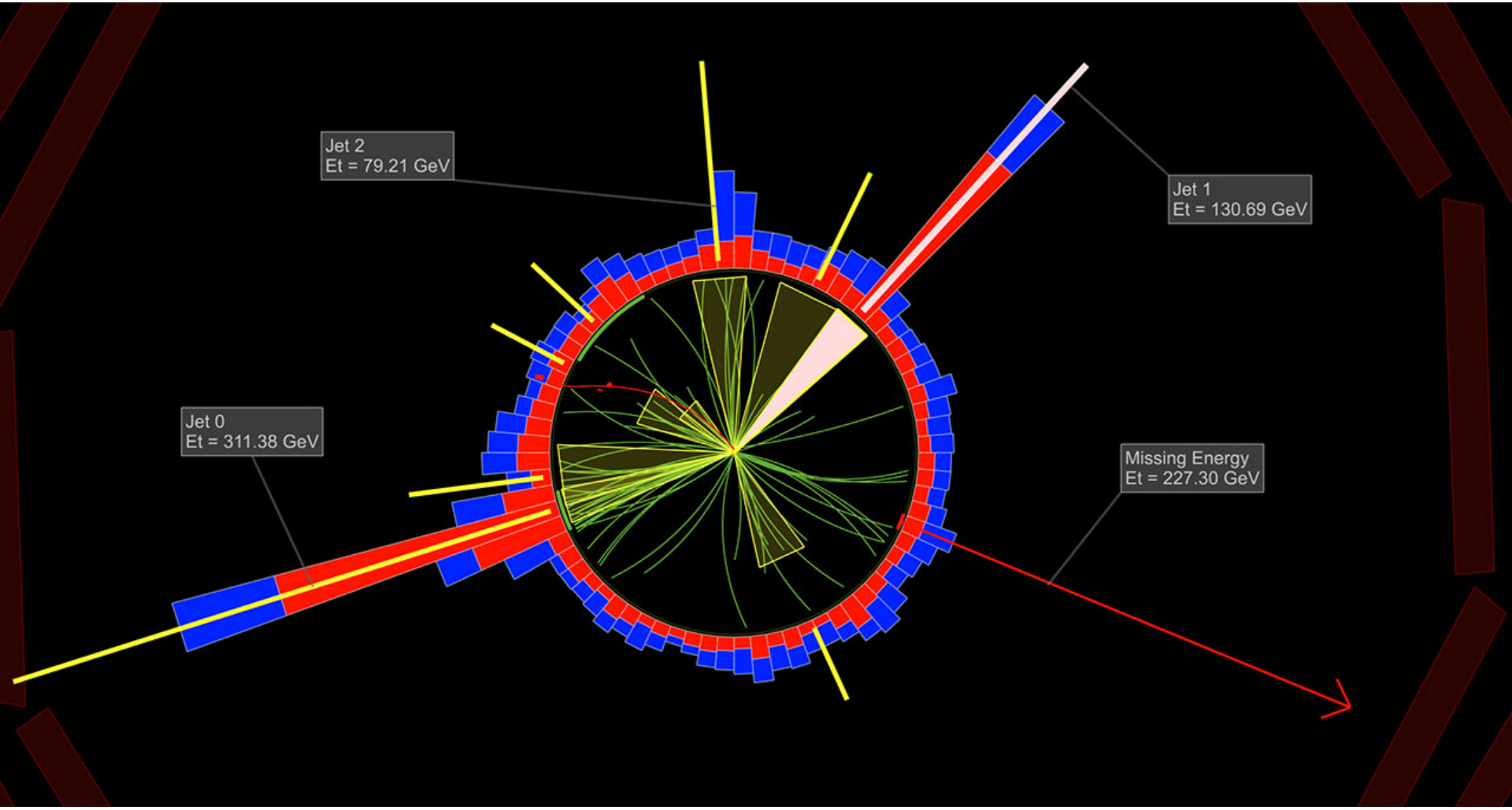




Typical missing energy signatures @ the LHC



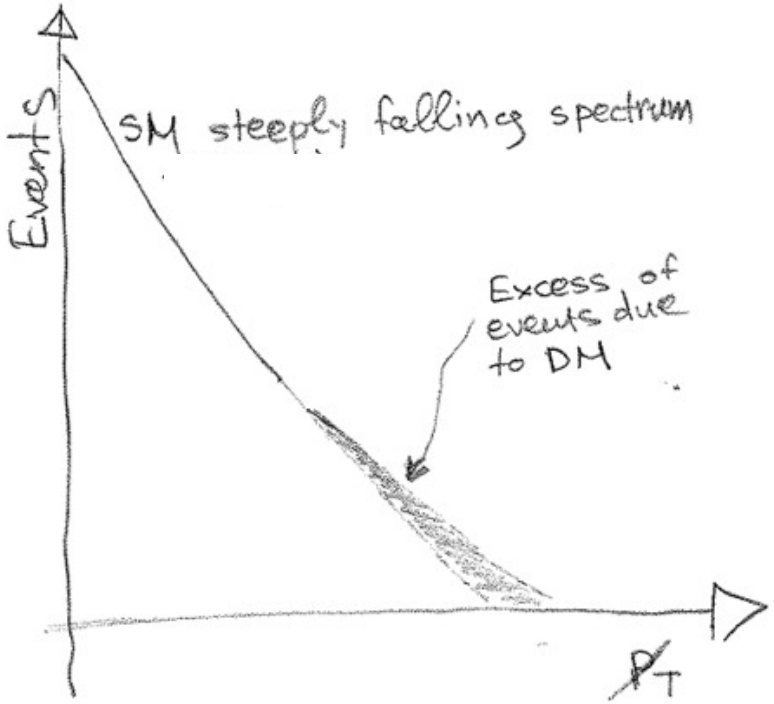
Typical missing energy signatures @ the LHC



transverse momentum imbalance escaping the detector

How to search for dark matter @ the LHC?

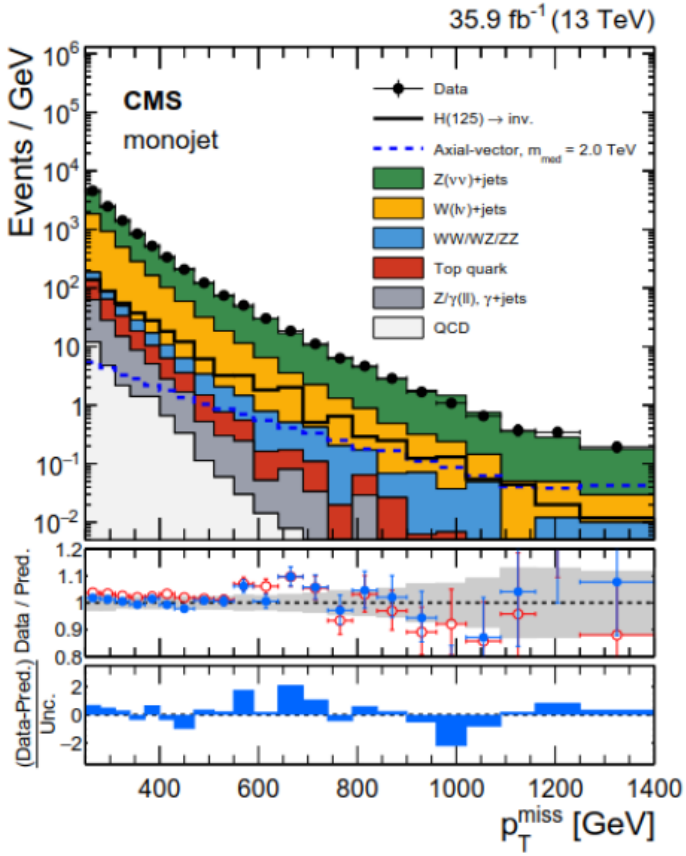
Discovery with missing energy difficult to be established (tail of a rapidly falling distribution).



Even if established what can we say about the model?

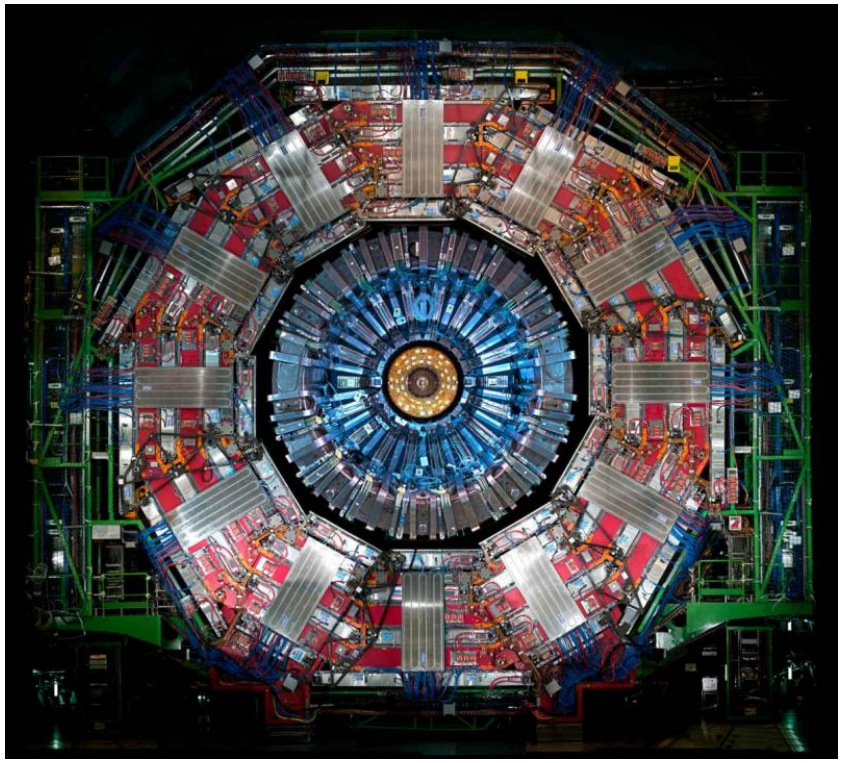
How to search for dark matter @ the LHC?

Discovery with missing energy difficult to be established (tail of a rapidly falling distribution).

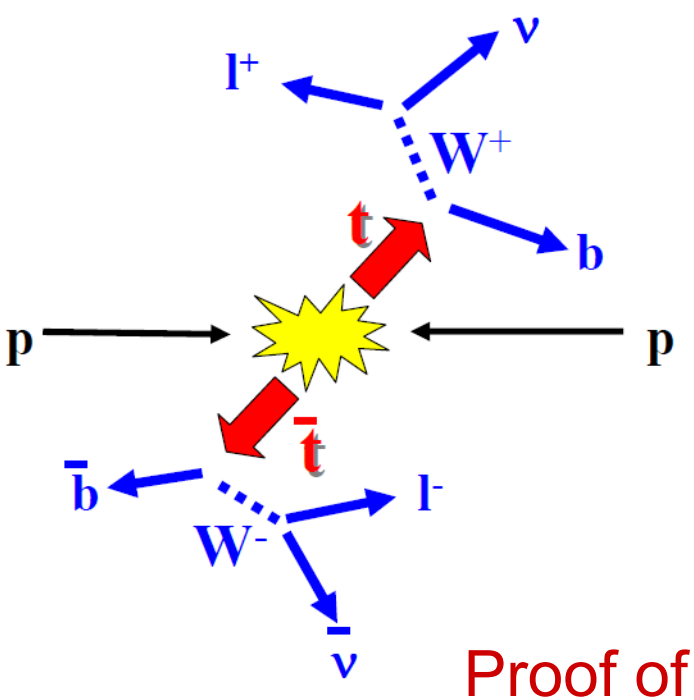


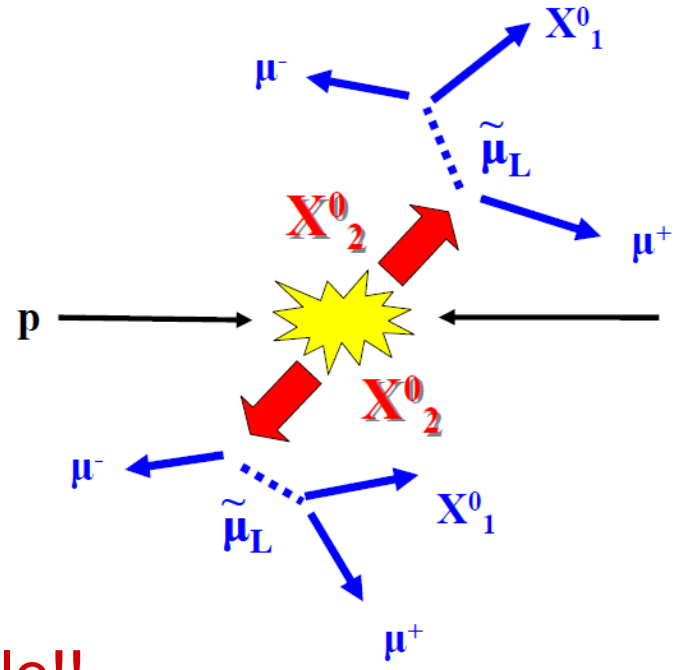
Even if established what can we say about the model?

A new method: 2-Dimensional mass reconstruction in final states with 2 invisible particles



Searching for susy similar to searching for top pairs



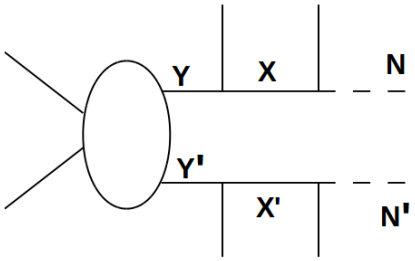


Proof of principle!!

- Topology of dilepton top pairs is similar with susy cascades
  2-dimensional mass reconstruction can be performed in this topology.
  More unknown masses (3) compared to top pairs.

- Searching for peaks in 2-dimensional mass plane instead of the tail of a distribution. Better final state in terms of mass detector resolution than top pairs (4 leptons).

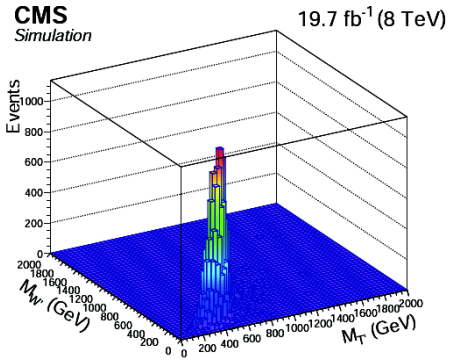
2-D mass reconstruction - What is it?



Topology

MET+
Visible particles momenta

2 unknown masses
M_X & M_Y per event

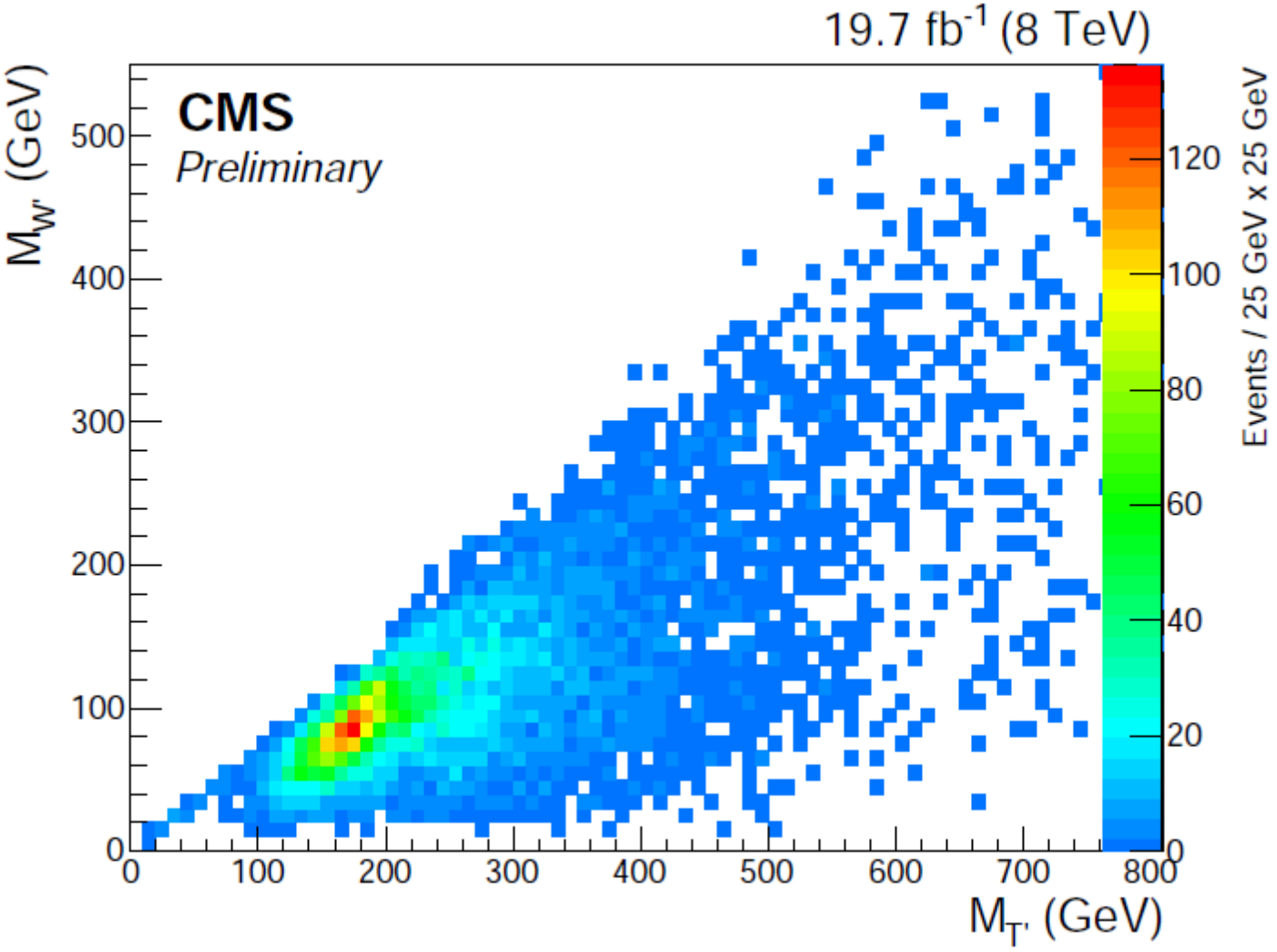


- Needs the topology

- 2 invisible particles

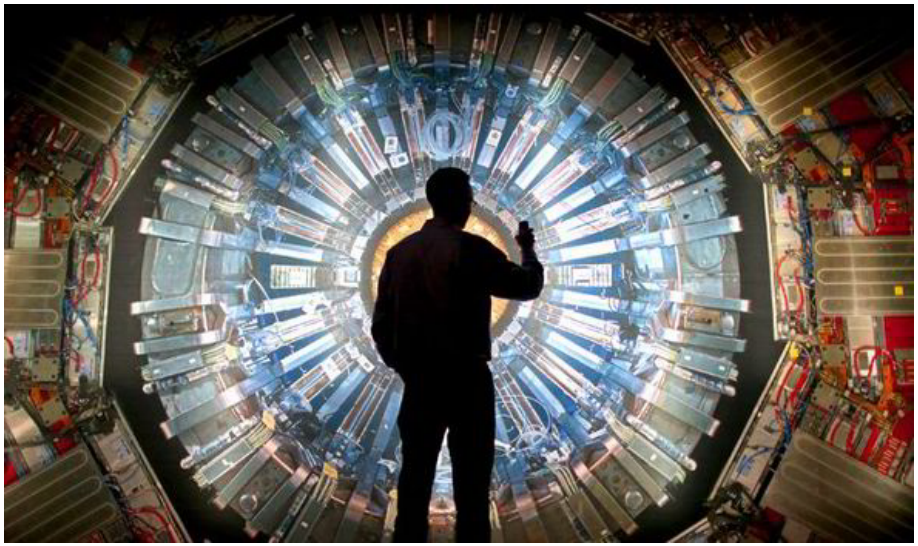
G.Anagnostou,Model Independent Search in 2-Dimensional Mass Space, EPJ Web of Conferences, Vol 71, 2014.

2-Dimensional mass space – A search method for final states with missing energy



What else can we find?

Higgs



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Conclusions

Dark matter searches well motivated from both astrophysics and particle physics

LHC is the right place to search (we think). Main signature is missing energy.

Missing energy is currently used by many searches in both CMS & ATLAS.

The shape of MET distribution similar for signal and background processes

It is feasible to reconstruct particle masses in topologies with two invisible particles.

Method can help to understand the BSM physics (masses, parameters)

Vera Rubin

Vera Cooper Rubin at the Lowell Observatory. a Rubin as an undergraduate at Vassar, 1940s

Vera Cooper Rubin at the Lowell Observatory.

“We have peered into a new world and have seen that it is more mysterious and more complex than we had imagined. Still more mysteries of the universe remain hidden. Their discovery awaits the adventurous scientists of the future. I like it this way.”