



Konrad Jende

Exploring particles at scholl with LHC data -
hands-on exercise(s)

outline

1. Search for W particles with ATLAS
2. Invariant mass searches for known and unknown particles
3. Search for the Higgs

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1. Search for W particles with ATLAS
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1. Search for W particles with ATLAS



International Particle Physics Outreach Group

INTERNATIONAL MASTERCLASSES
hands on particle physics

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International Masterclasses
12th International Masterclasses 2016

Each year about 10.000 high school students in 42 countries come to one of about 200 nearby universities or research centres for one day in order to unravel the mysteries of particle physics. Lectures from active scientists give insight in topics and methods of basic research at the fundamentals of matter and forces, enabling the students to perform measurements on real data from particle physics experiments themselves. At the end of each day, like in an international research collaboration, the participants join in a video conference for discussion and combination of their results. See [here](#) for media coverage.

International Masterclasses 2016 will take place from 11.2. - 23.3.2016..


Discover the world of Quarks and Leptons with real data

physicsmasterclasses.org

username: teacherg

password: Bohr1922


1. Search for W particles with ATLAS



[HOMEPAGE](#) [W-Path](#) [Z-Path](#)


LHC@InternationalMasterclasses

Join us on a journey to the smallest pieces of matter! Learn what is happening 100 meters below the ground at the European Organization for Nuclear Research (CERN). At the Large Hadron Collider, a circular collider with a circumference of 27 kilometres, the experiments ALICE, ATLAS, CMS, and LHCb are installed. The following short video gives an impression of the start of a fascinating journey looking for the origin of mass, Dark Matter, and new phenomena such as Supersymmetry or Extra Dimensions.




Links

Facebook-Seite



LHC Livescreen

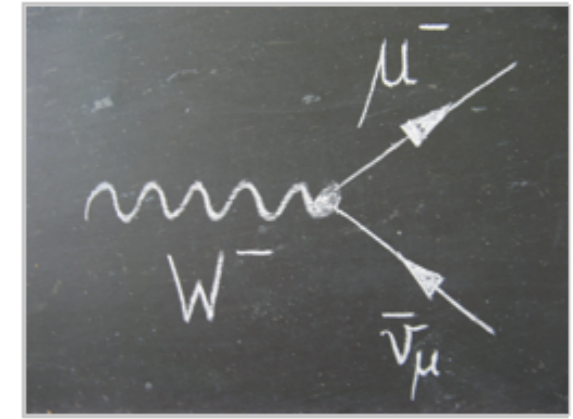
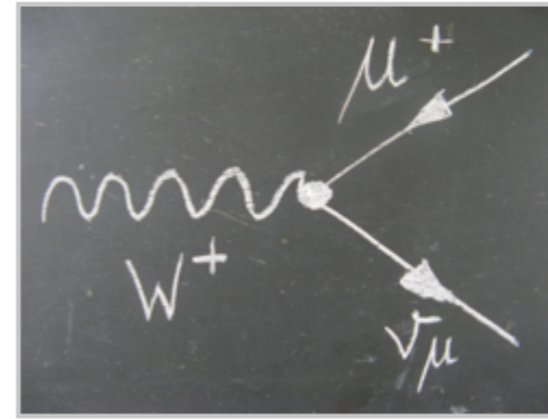
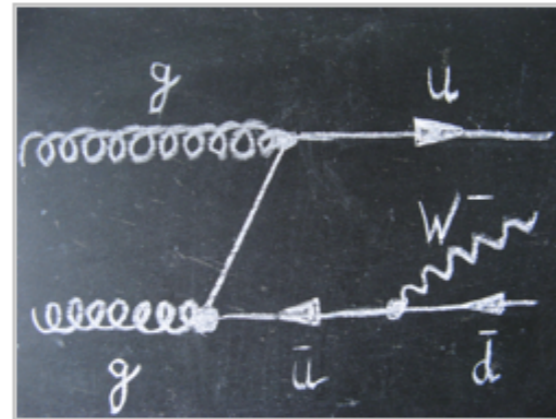
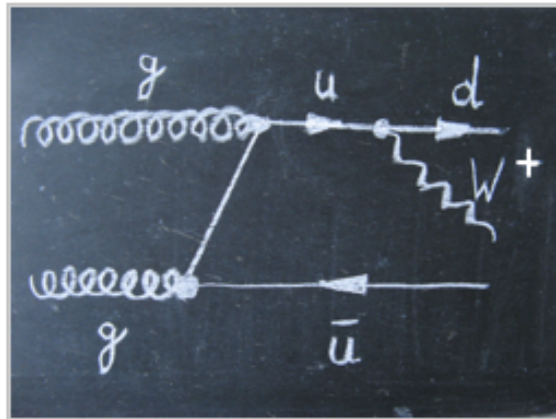
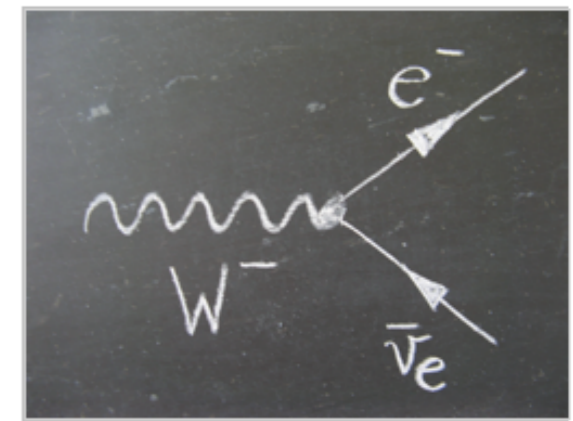
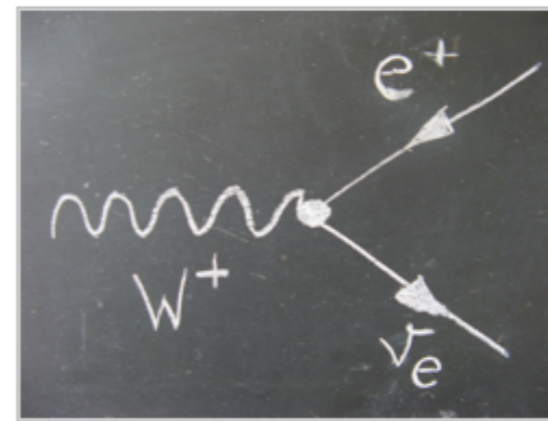
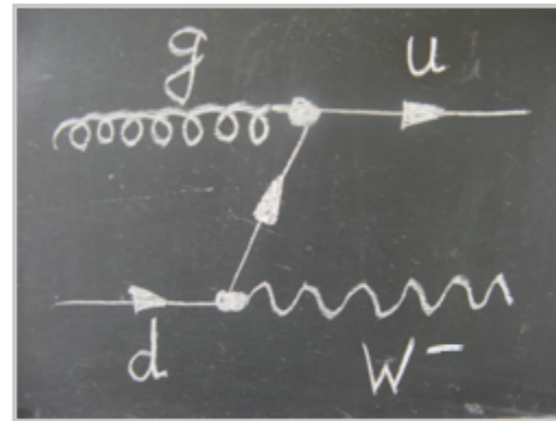
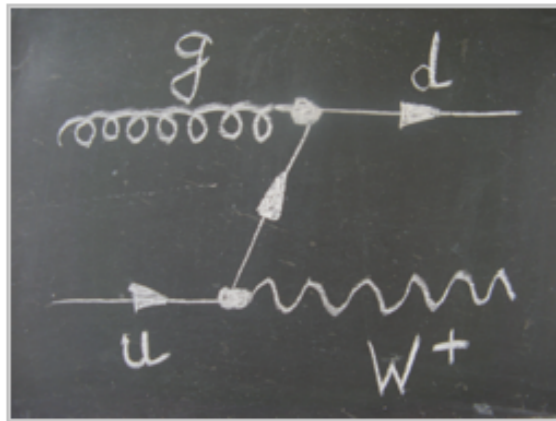


<http://atlas.physicsmasterclasses.org/en/index.htm>

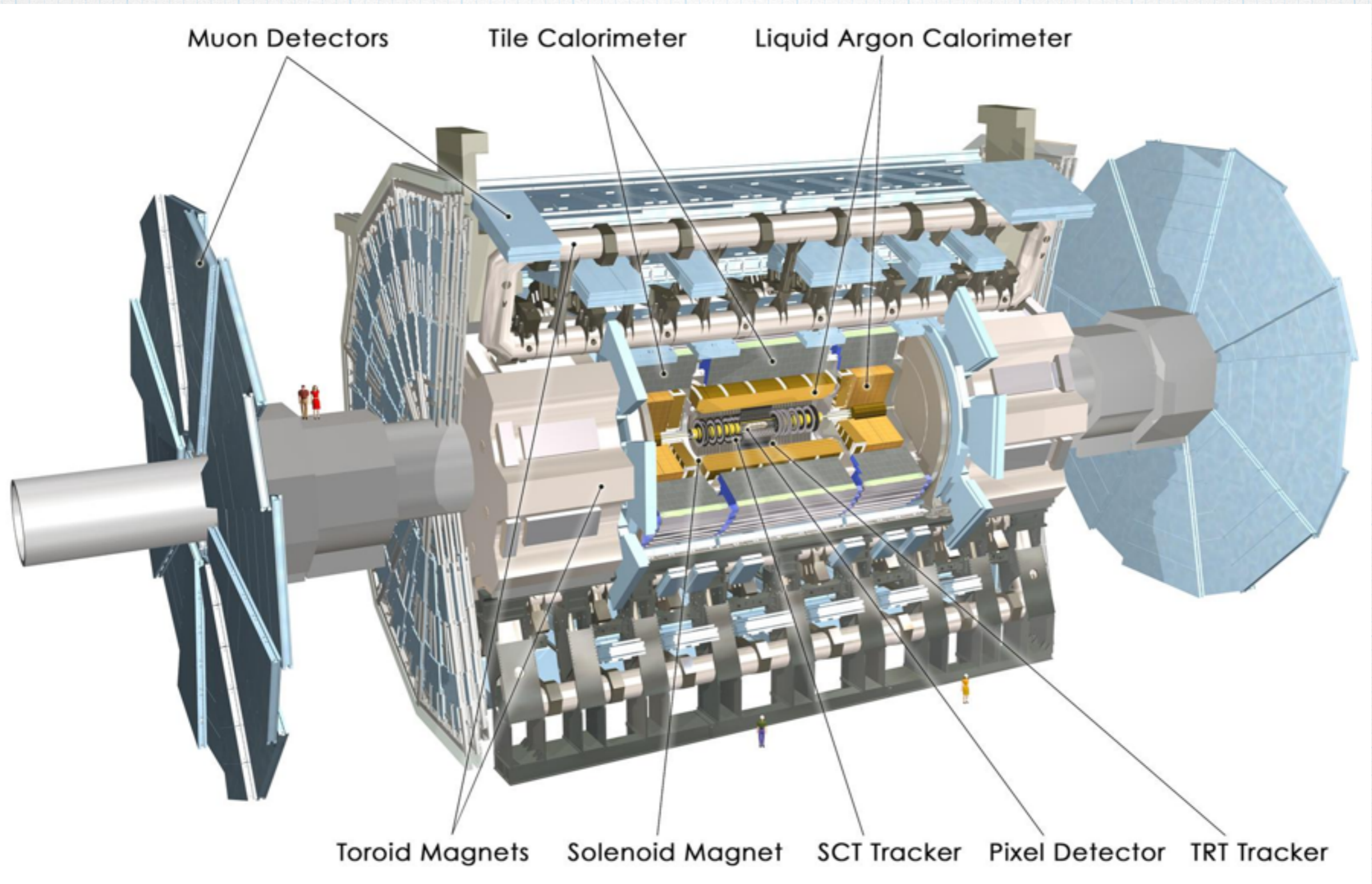
username: teacherg

password: Bohr1922

1. Search for W particles with ATLAS



1. Search for W particles with ATLAS



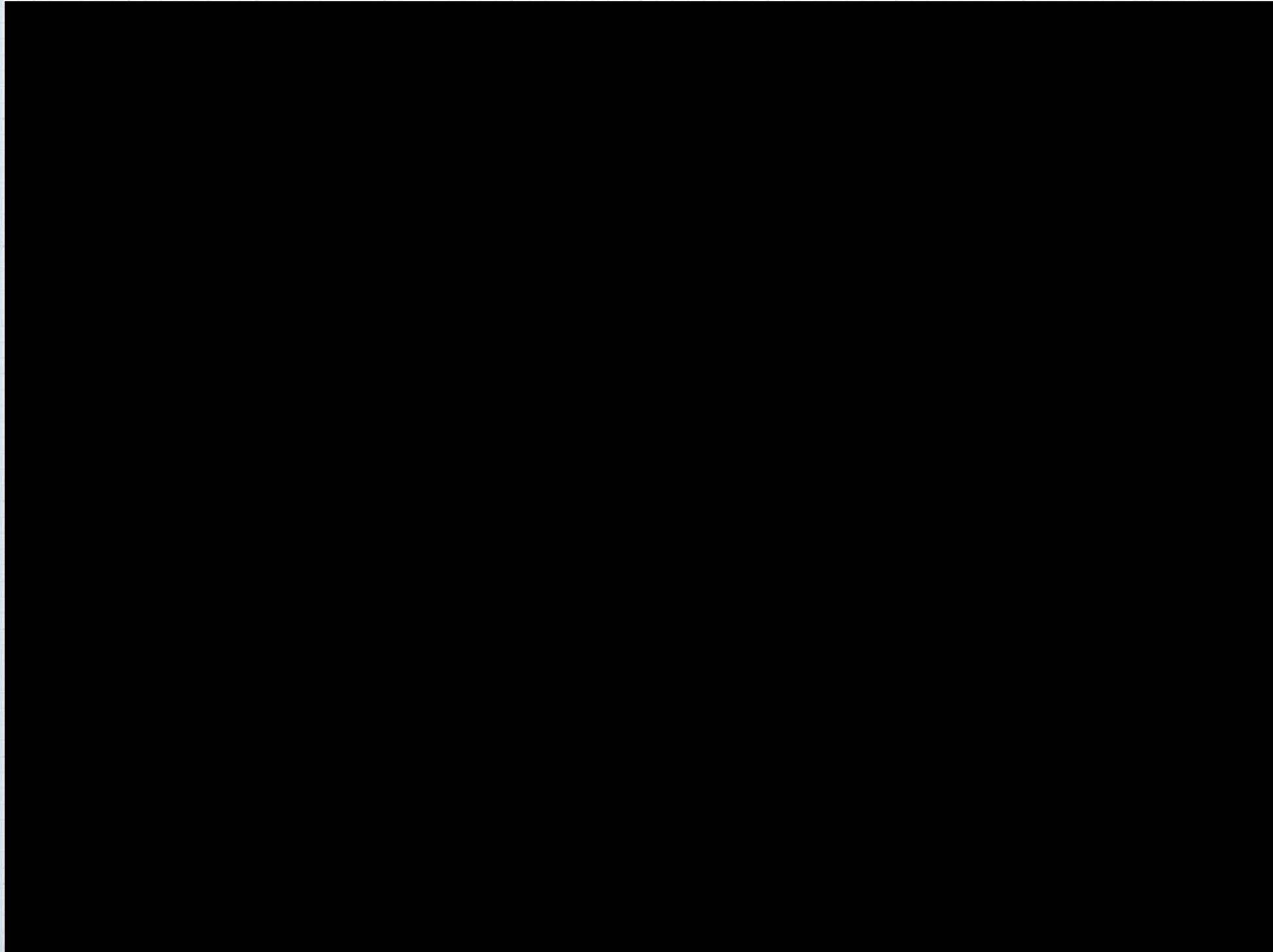
1. Search for W particles with ATLAS

1. to measure the momentum of electrically charged particles
2. to measure energy of electrically charged particles and photons
3. to measure energy of strongly charged particles
4. to measure momentum and unambiguously identify muons

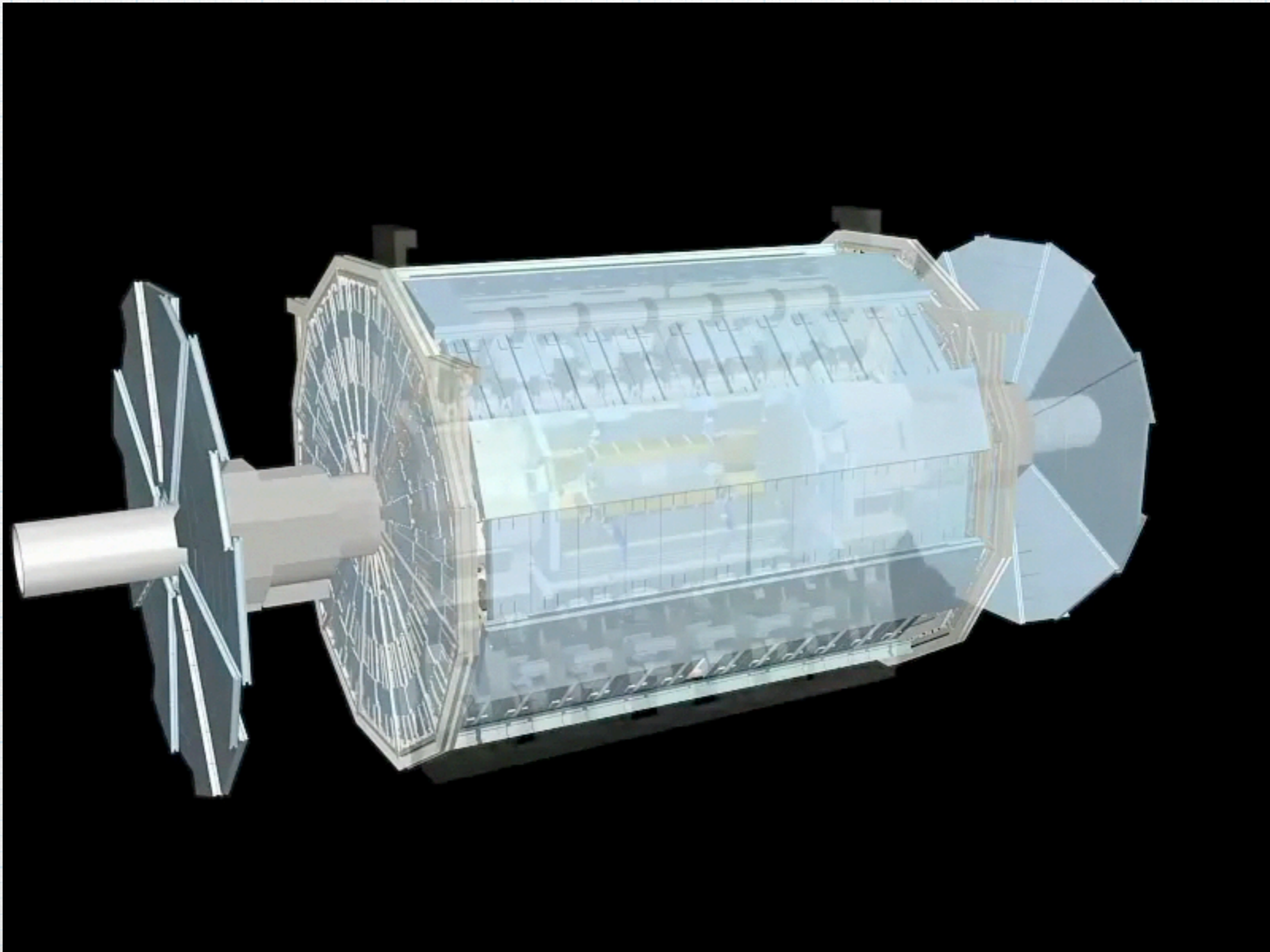
several layers of detecting material with symmetry

1. at right angles to the beam pipe (cylindric - barrel)
2. in forward/backward region (linear - endcaps)

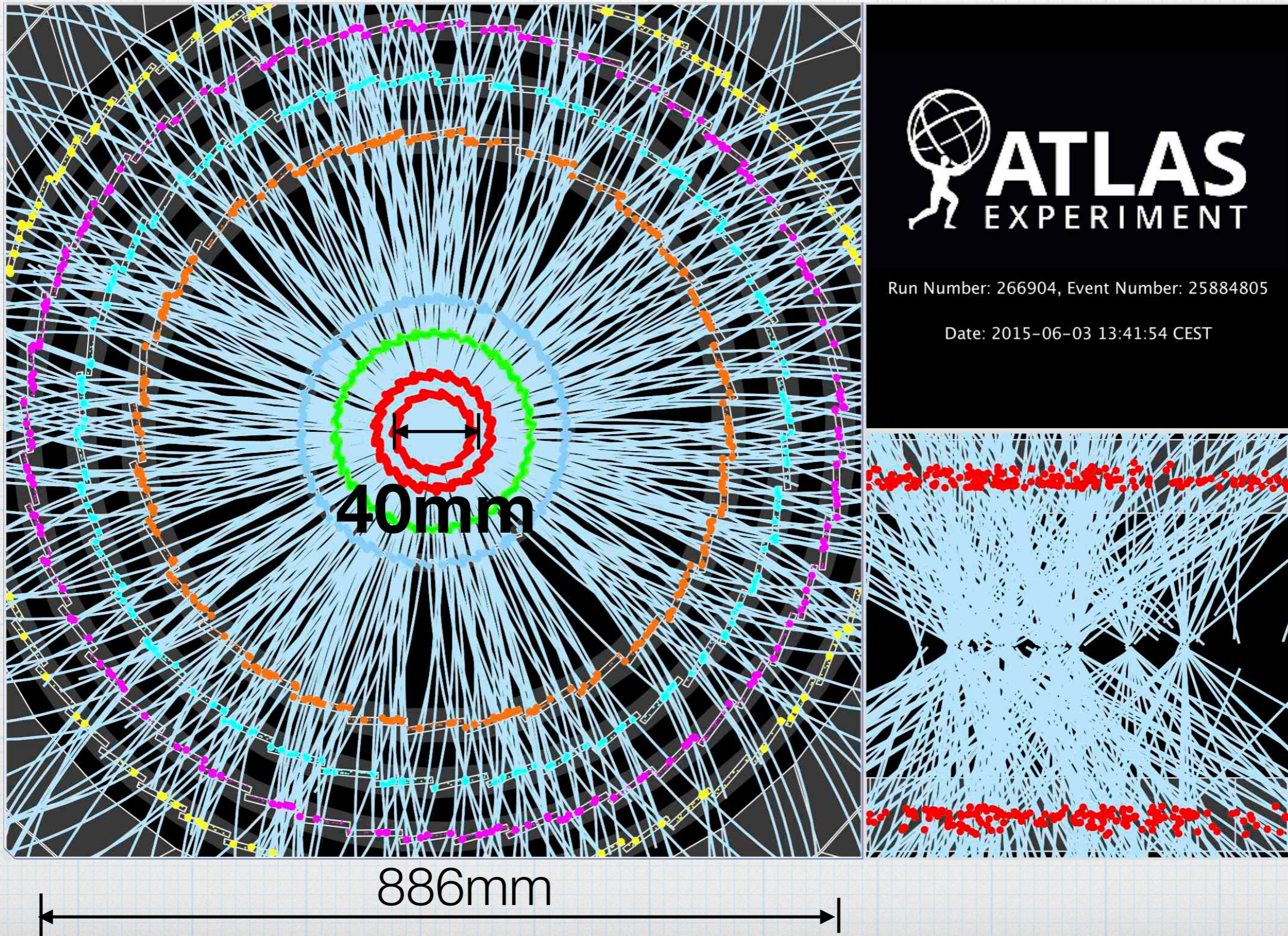
1. Search for W particles with ATLAS



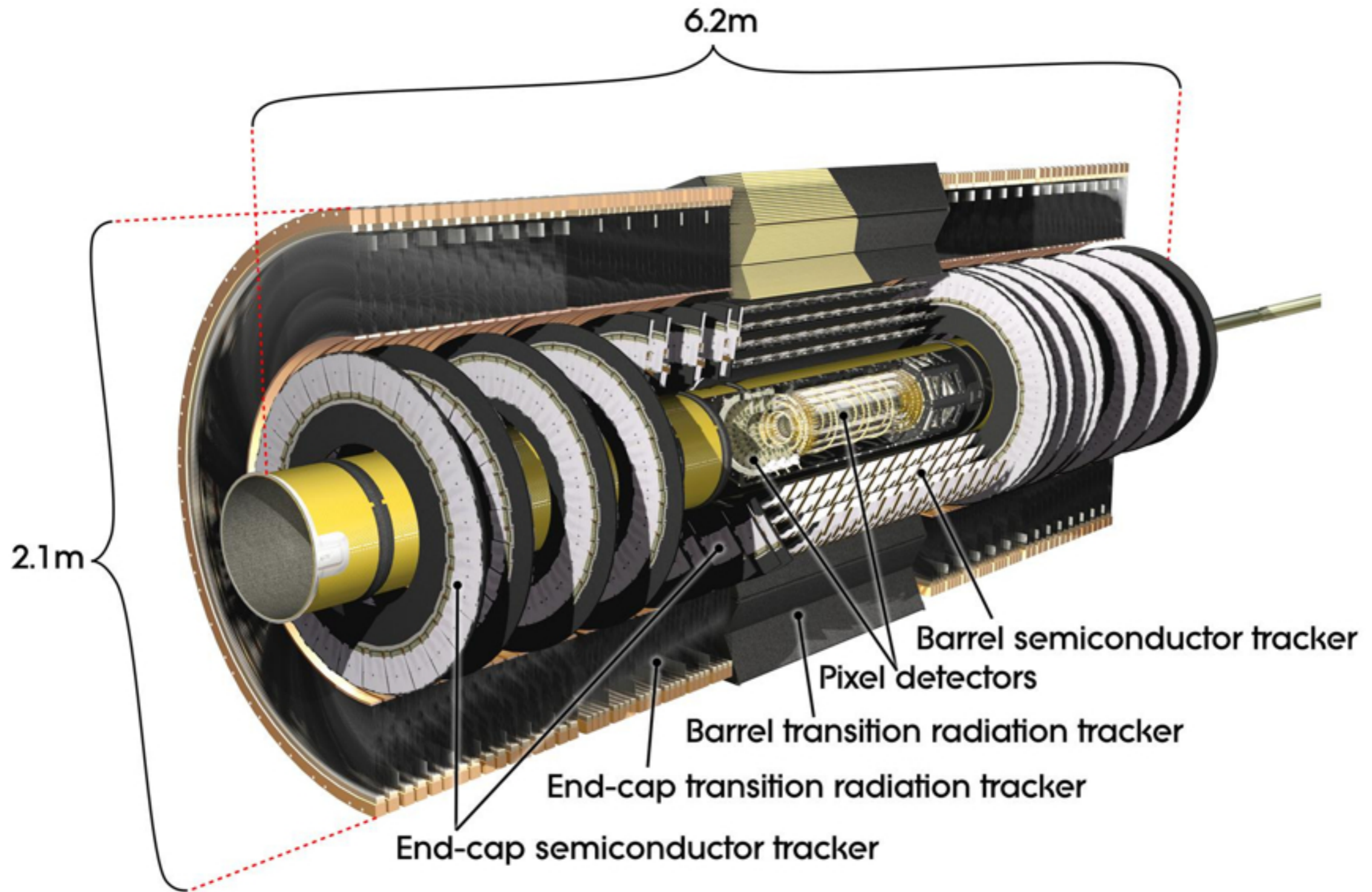
1. Search for W particles with ATLAS



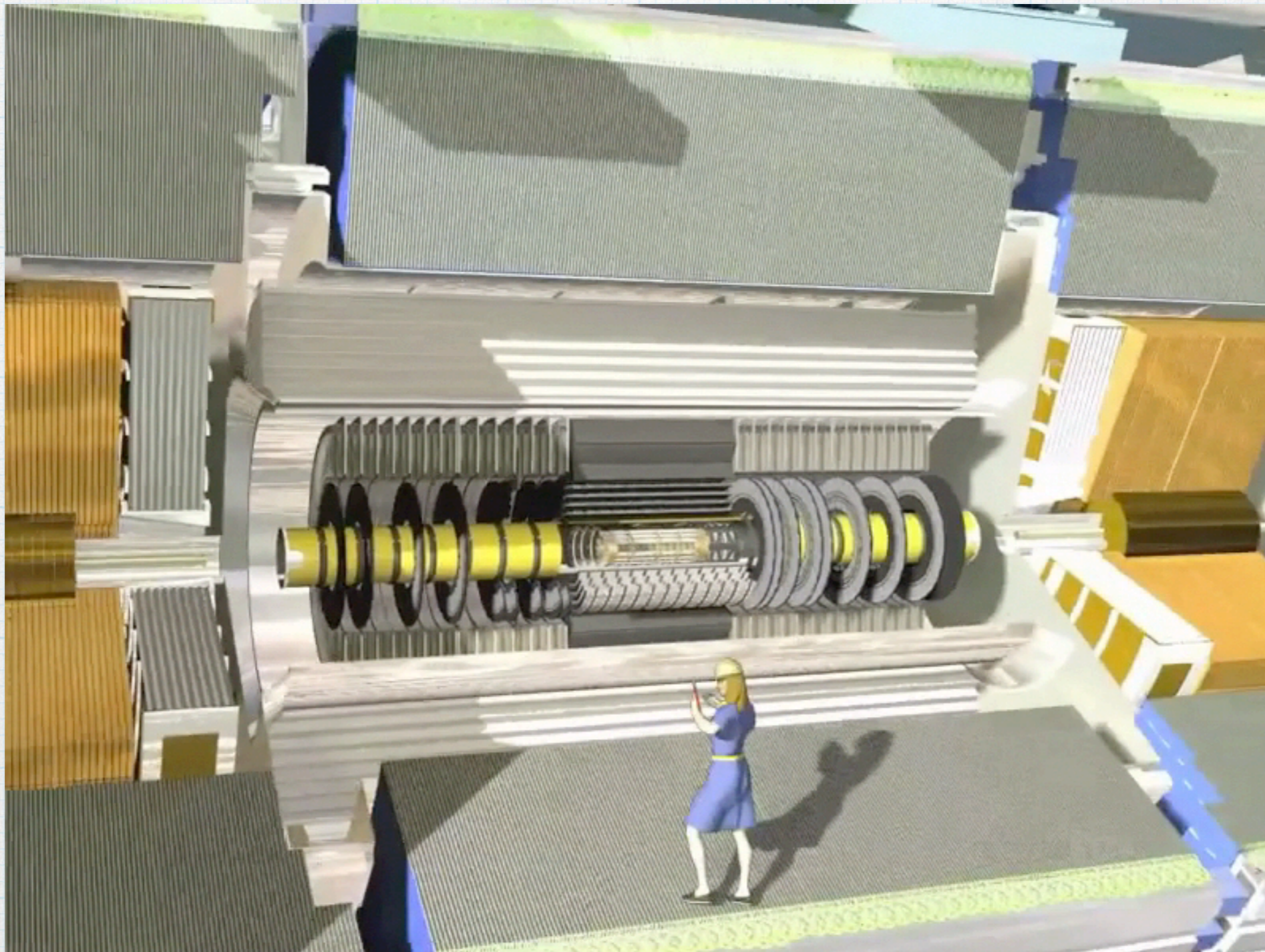
1. Search for W particles with ATLAS



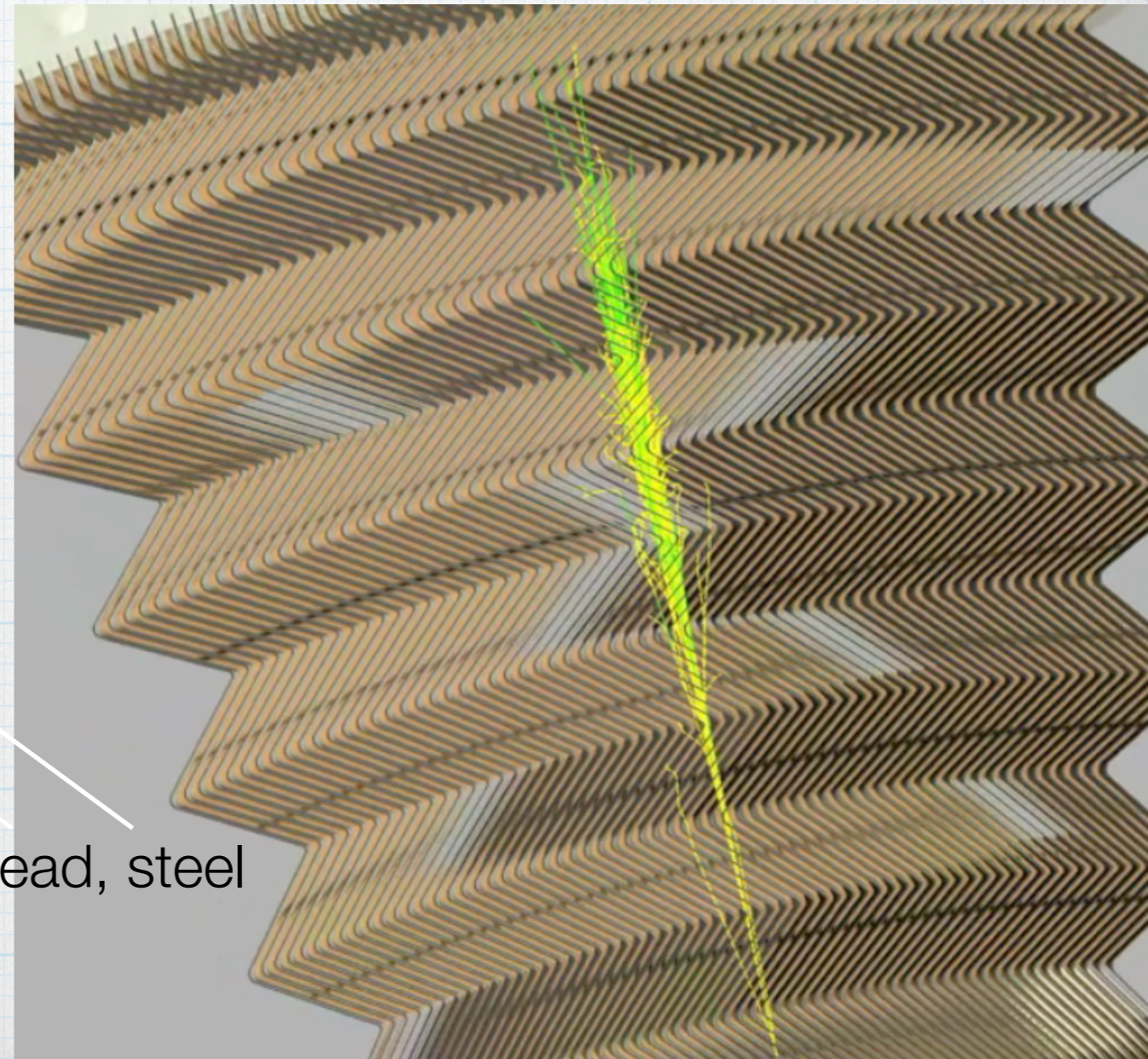
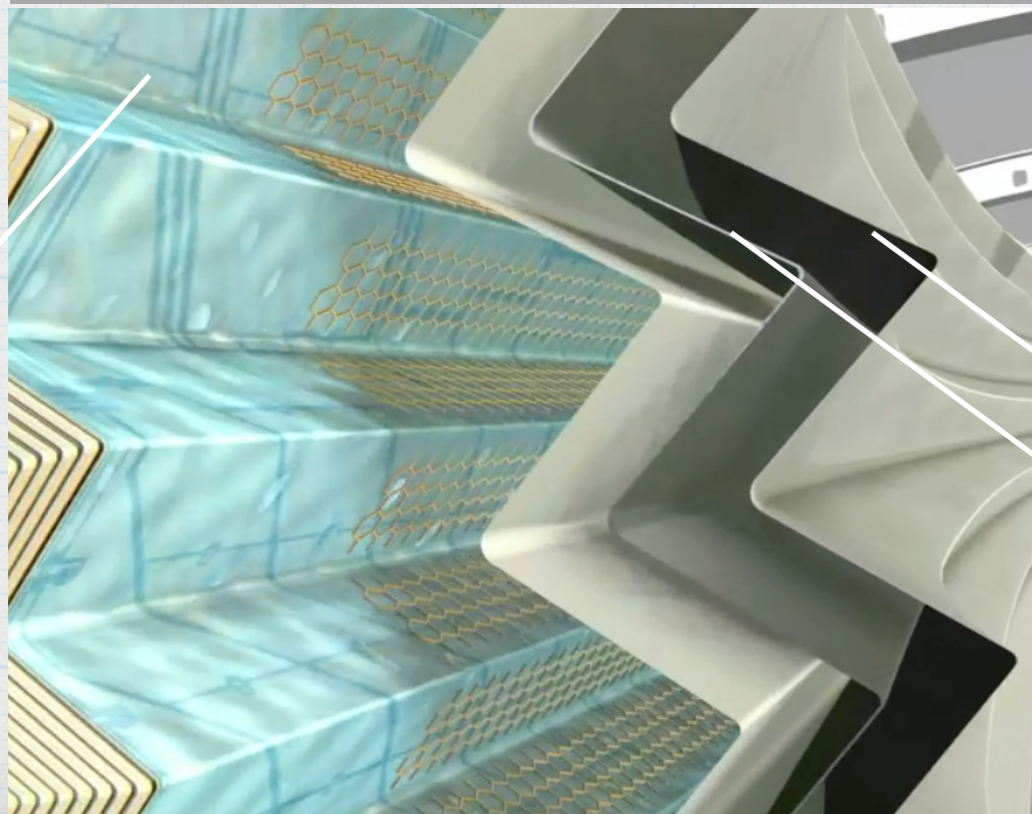
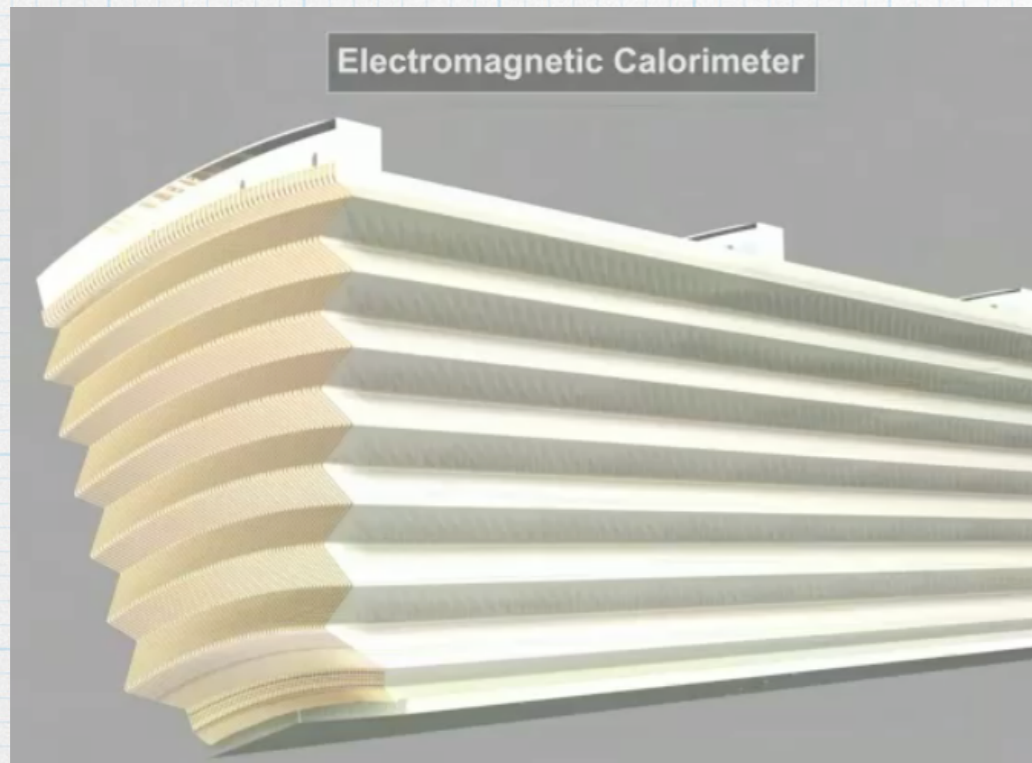
1. Search for W particles with ATLAS



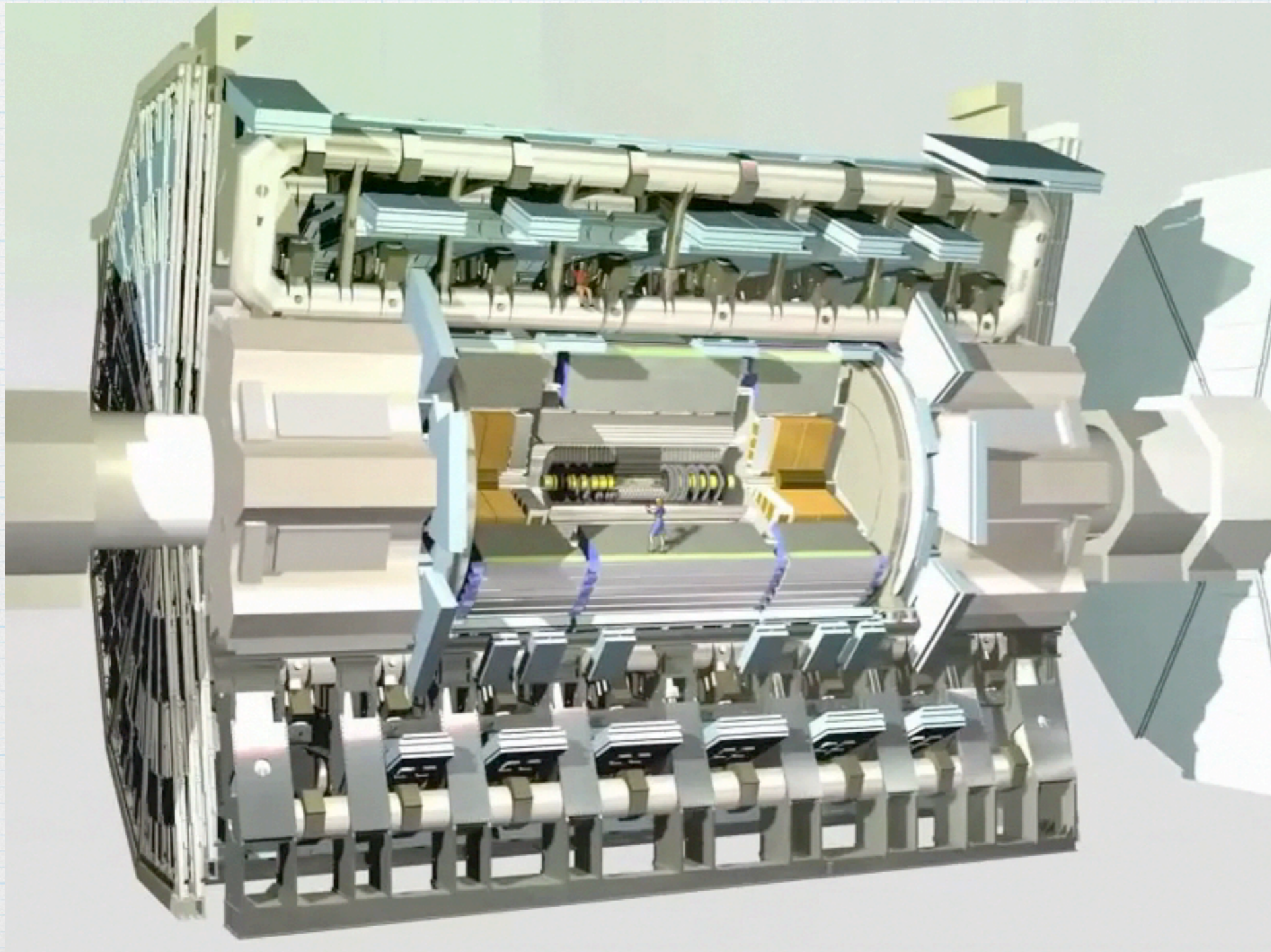
1. Search for W particles with ATLAS



1. Search for W particles with ATLAS



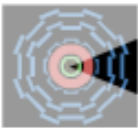
1. Search for W particles with ATLAS



6. Detektorkonzepte

ATLAS

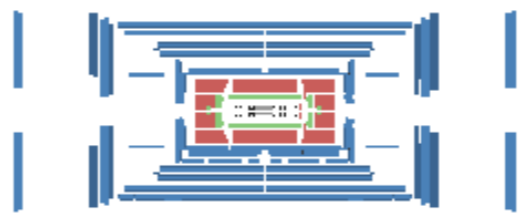
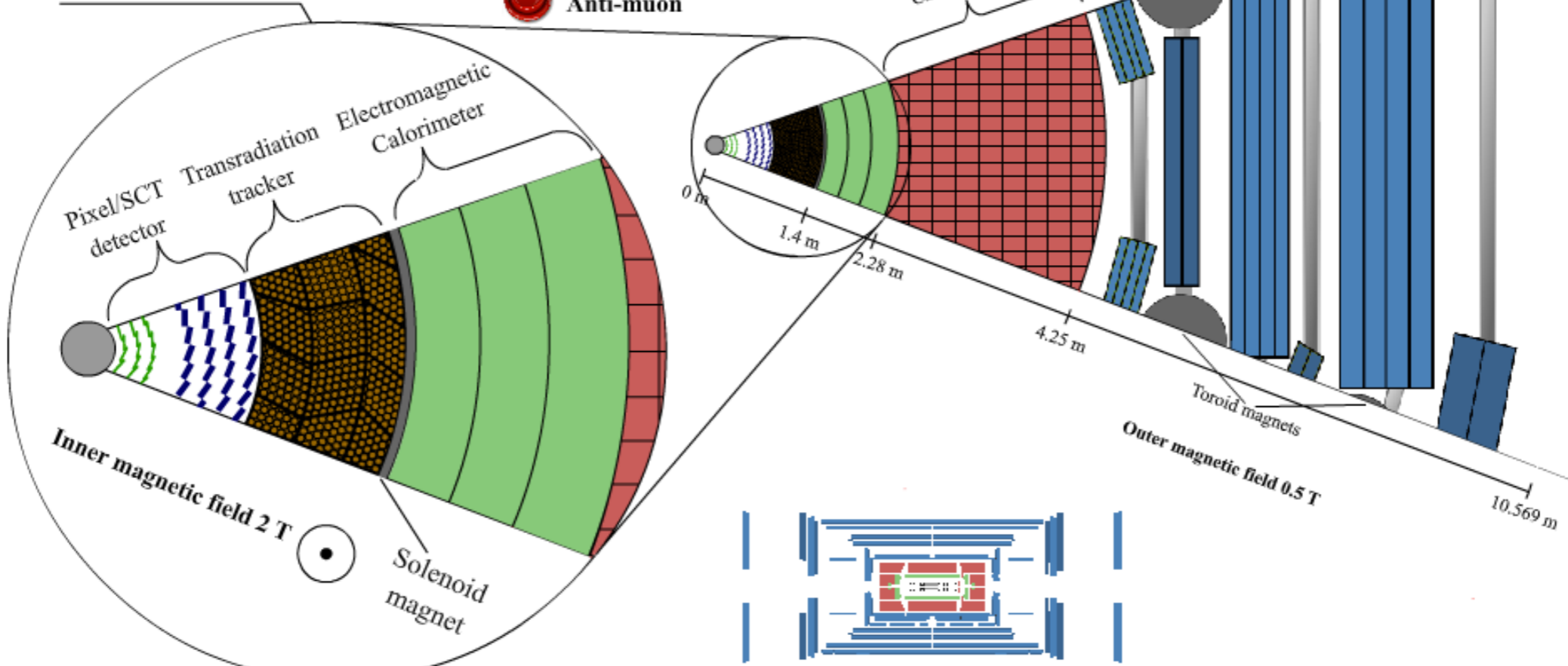
animation



display instantly

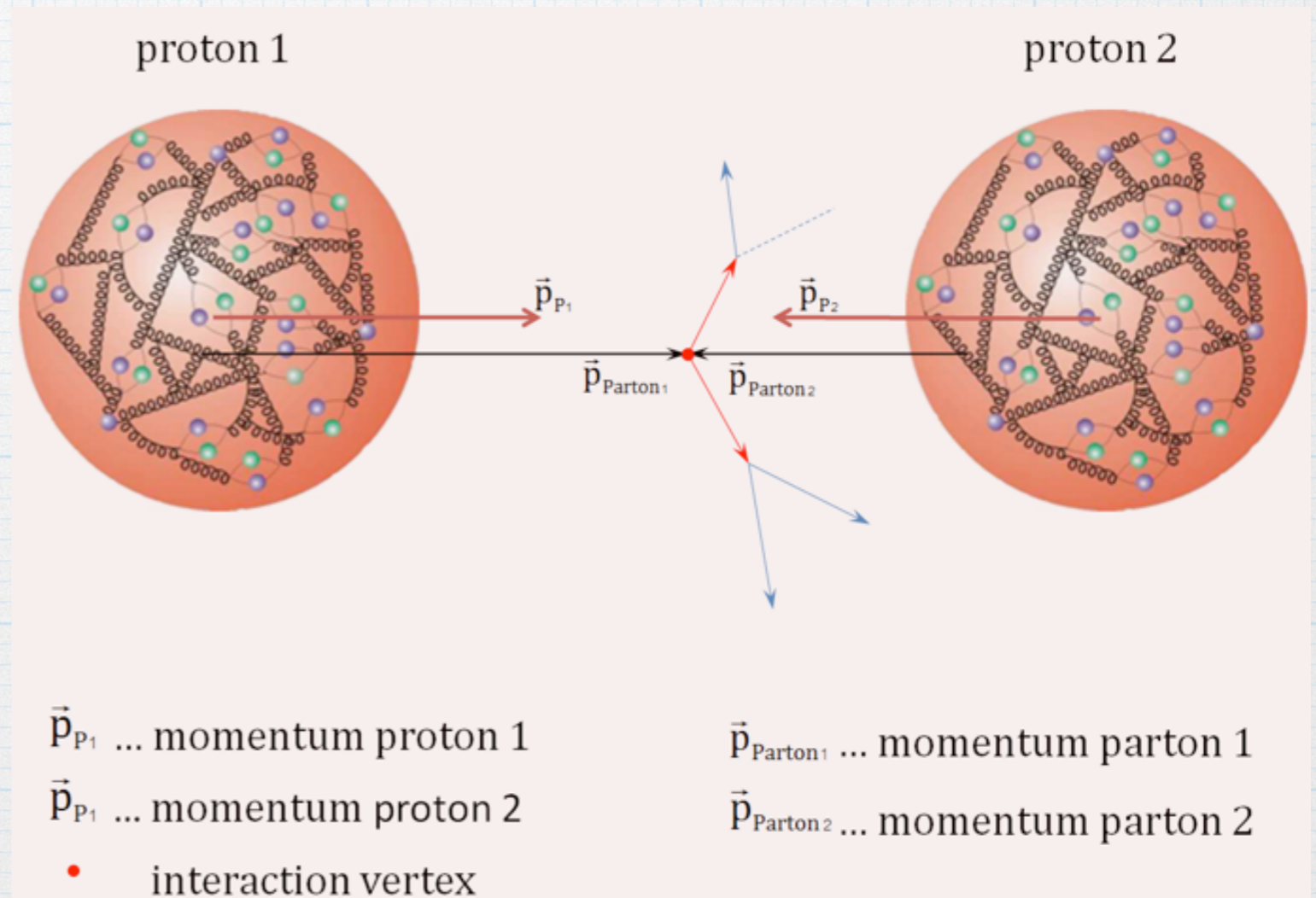
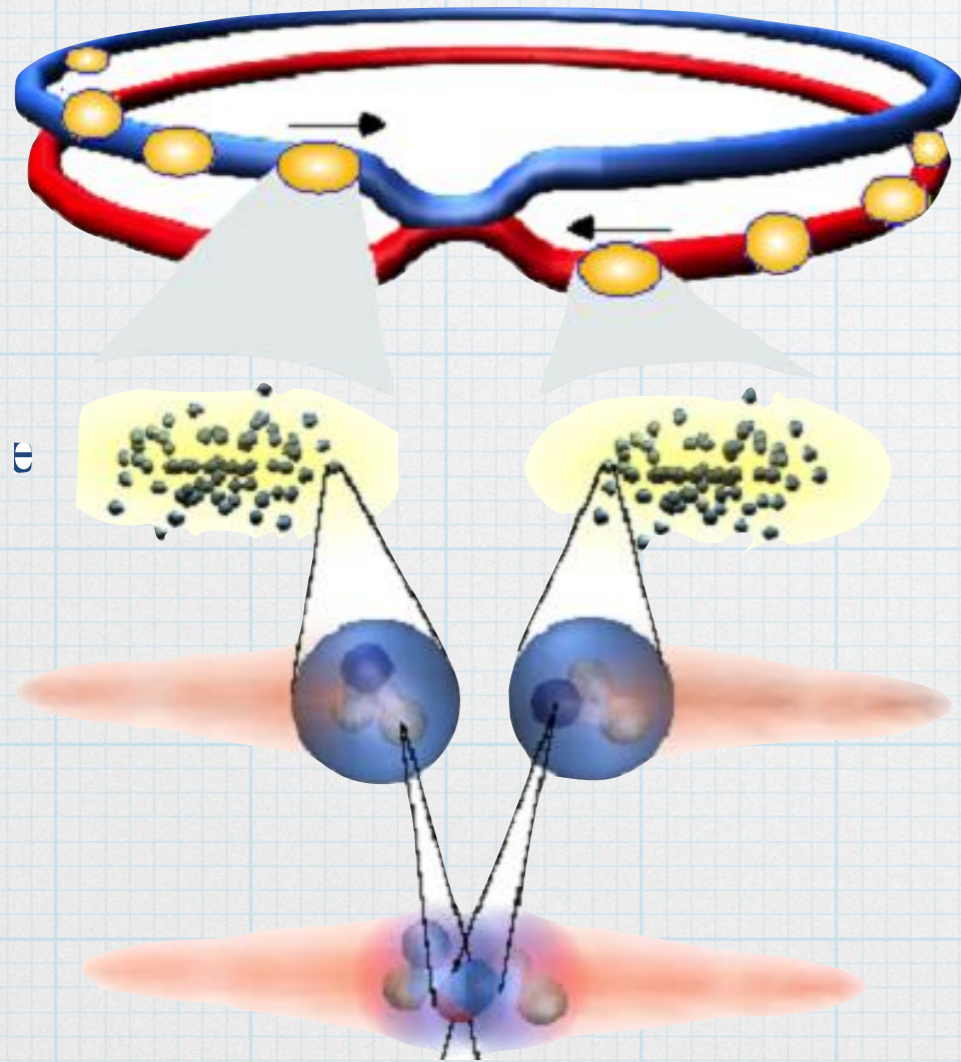
- Electron
- Proton
- Neutrino
- Photon
- Positron
- Anti-proton
- Jets
- Muon
- Neutron
- Anti-muon

Magnification 3x



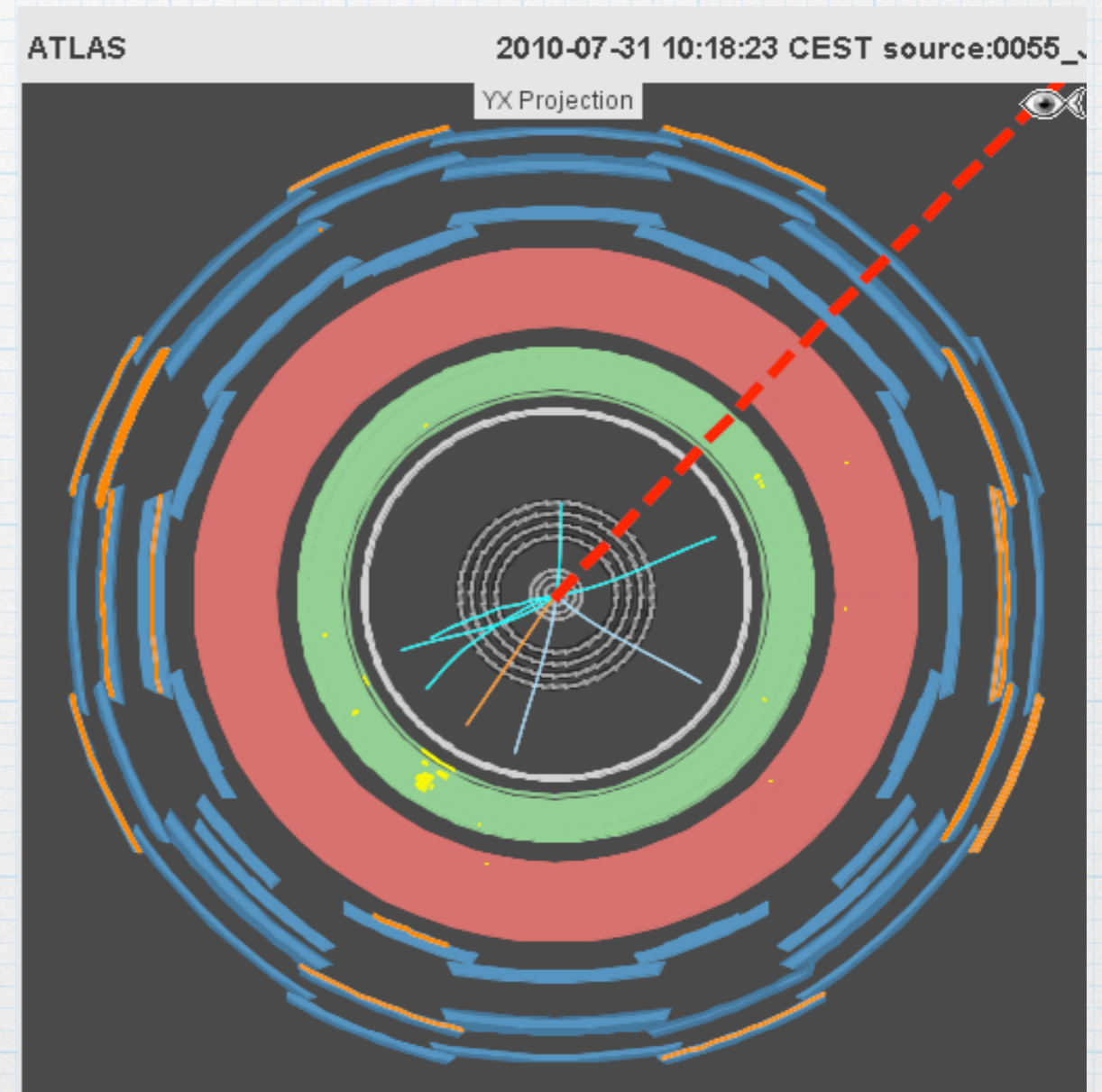
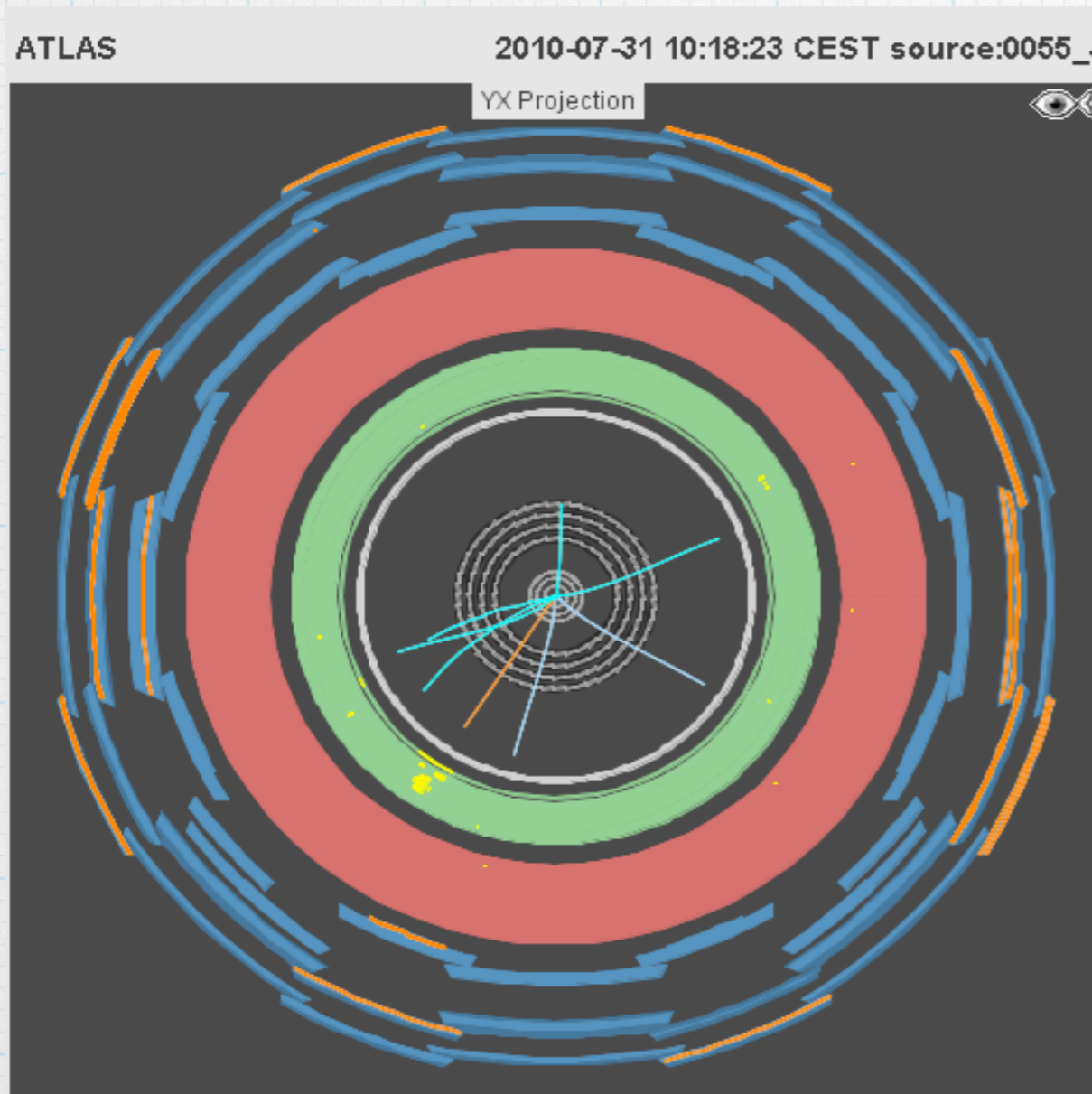
1. Search for W particles with ATLAS

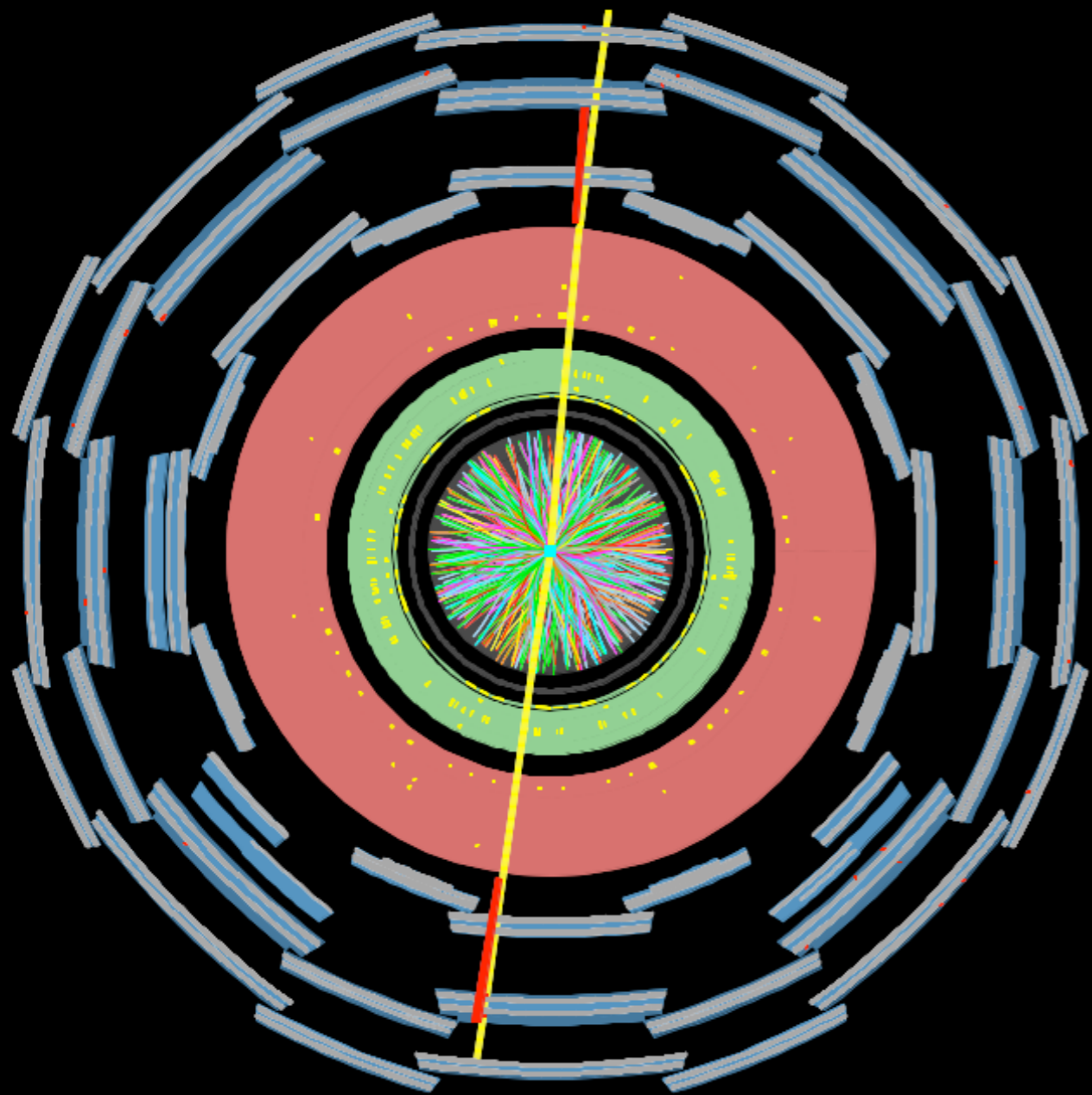
Neutrinos



1. Search for W particles with ATLAS

Neutrinos

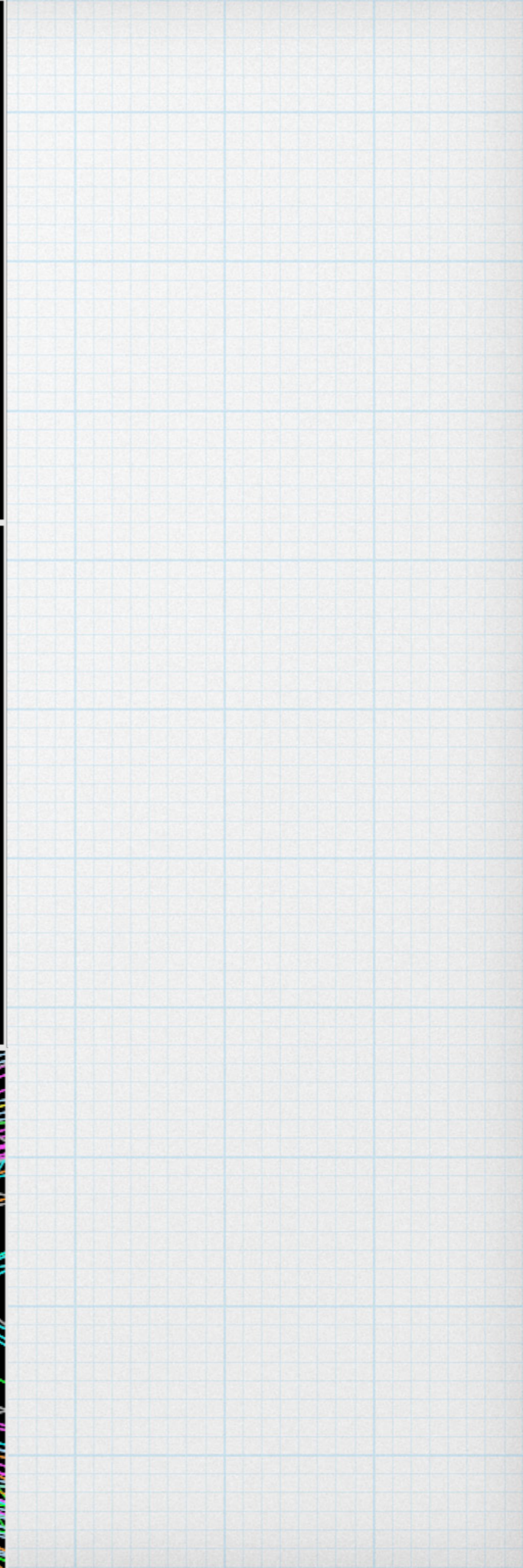
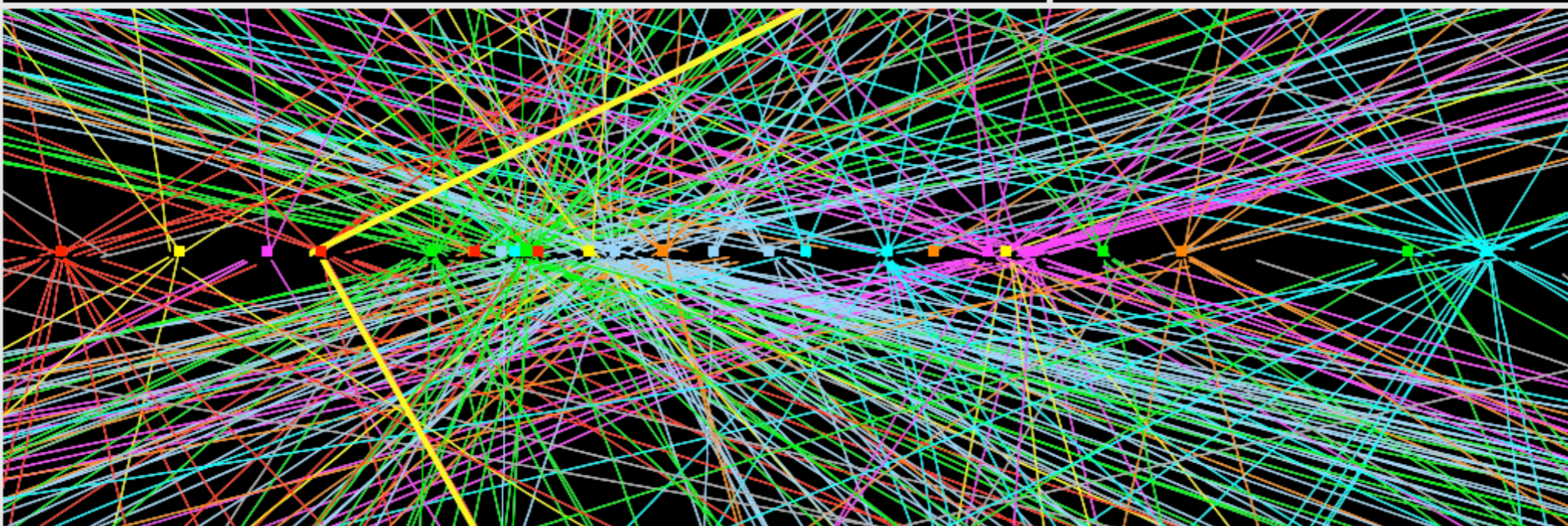
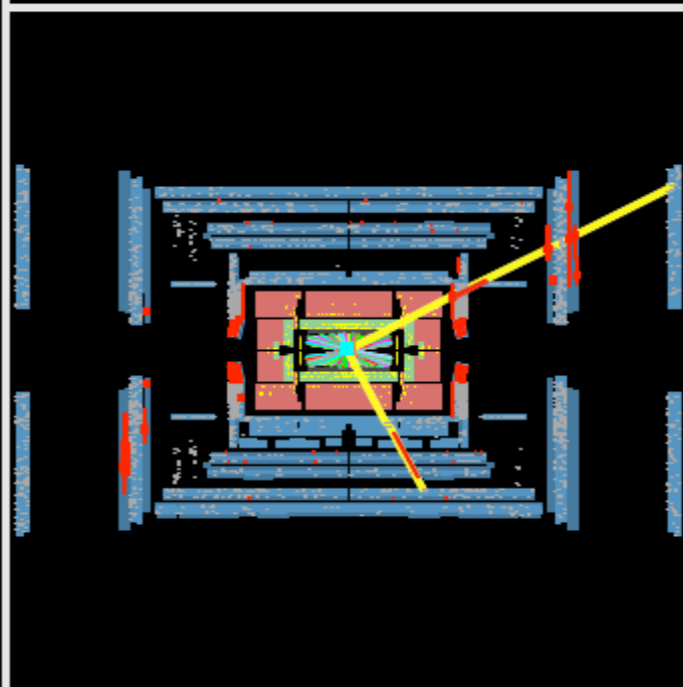




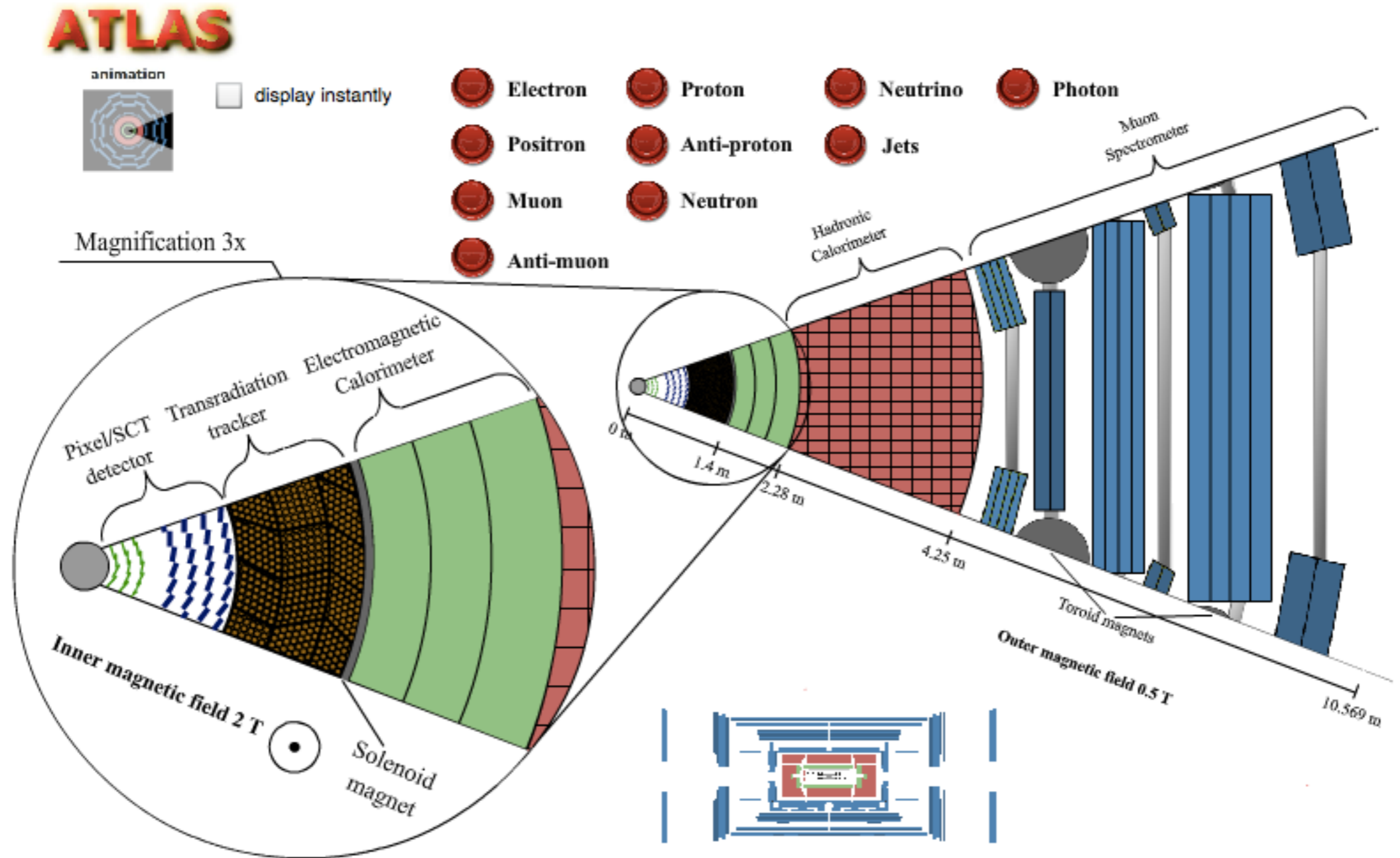
ATLAS EXPERIMENT

Run Number: 201289, Event Number: 24151616

Date: 2012-04-15 16:52:58 CEST



1. Search for W particles with ATLAS

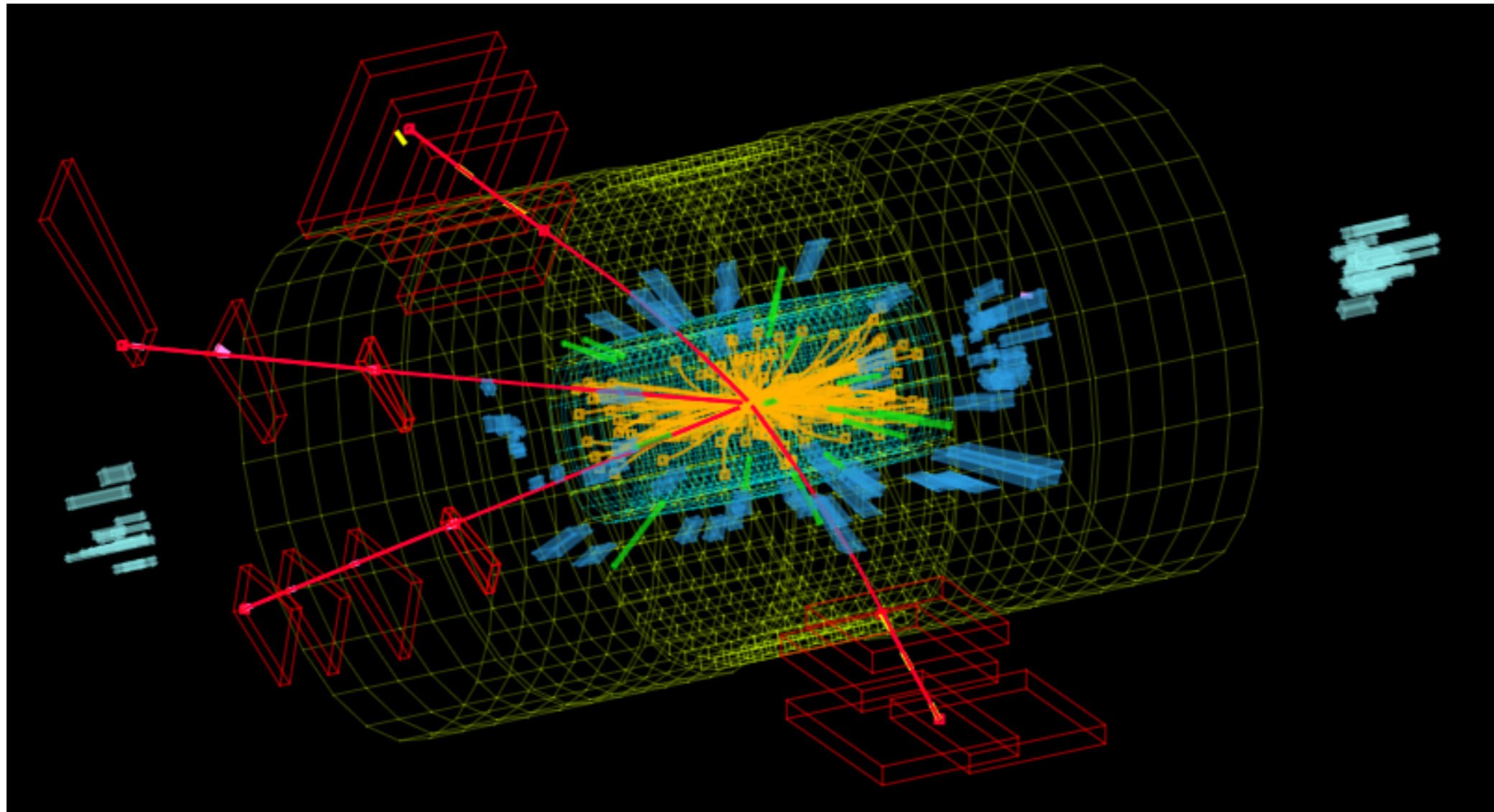


outline

1. Search for W particles with ATLAS
2. Invariant mass searches for known and unknown particles
3. Search for the Higgs

2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/education>



2. Invariant mass searches

Open Data Portal

Education

Datasets



The CMS (Compact Muon Solenoid) experiment is one of two large general-purpose detectors built on the Large Hadron Collider (LHC). Its goal is to investigate a wide range of physics such as the characteristics of the

Explore CMS >



ALICE (A Large Ion Collider Experiment) is a heavy-ion detector designed to study the physics of strongly interacting matter at extreme energy densities, where a phase of matter called quark-gluon plasma forms.

Explore ALICE >



The ATLAS (A Toroidal LHC ApparatuS) experiment is a general purpose detector exploring topics like the properties of the Higgs-like particle, extra dimensions of space, unification of fundamental forces, and

Explore ATLAS >

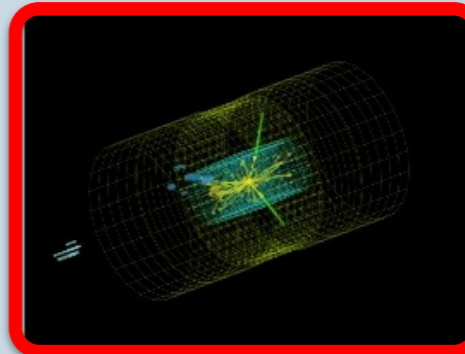


The LHCb (Large Hadron Collider beauty) experiment aims to record the decay of particles containing b and anti-b quarks, known as B mesons. The detector is designed to gather information about the identity,

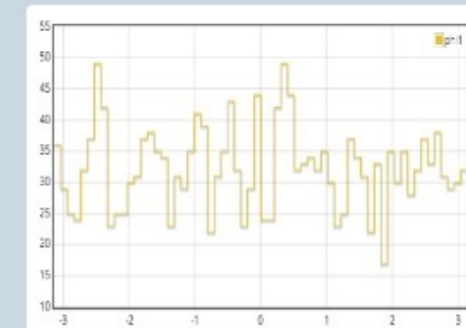
Explore LHCb >

For education purposes, the complex primary data need to be processed into a format (examples below) that is good for simple applications. Get in touch if you wish to build your own applications similar to those shown here

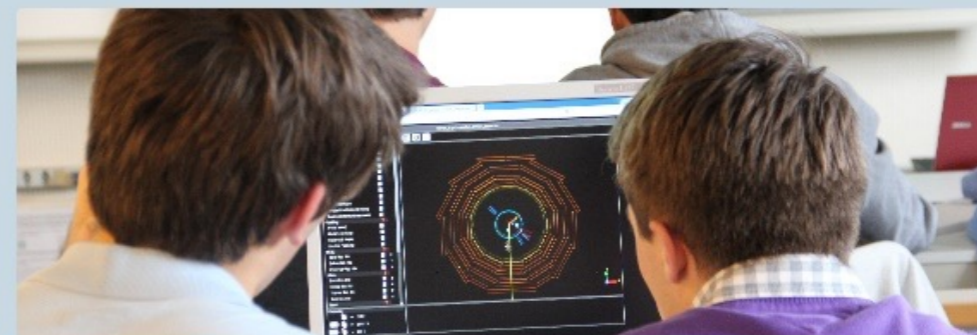
Event display



Visualise events >



Visualise histograms >



Learning Resources >

2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/collection/CMS-Derived-Datasets>

Home > CMS > CMS Derived Datasets

CMS Derived Datasets

This collection includes data that have been derived from the CMS primary datasets. The data may be reduced in the sense that (a) only part of the information is kept or (b) only part of the events are selected. Datasets include those which may be accessed using the VM image of the CMS environment or those which are adapted for other tools and applications. The tools and instructions to access and use these data are linked to each record.

Dimuon event information derived from the Run2010B public Mu dataset

This document contains 100k dimuon events selected from the Mu dataset from Run2010B. Each line corresponds to an event. The main file contains all 100k events

Collection CMS-Derived-Datasets Author McCauley, Thomas

DOI 10.7483/OPENDATA.CMS.CB8H.MFFA Parent Dataset AOD/Mu/Run-2010B-Apr21ReReco-v1/

2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/collection/CMS-Derived-Datasets>

The image shows an Excel spreadsheet with data for two particles. The columns are labeled as follows:

- Column D: Energy (particle1)
- Column E: Momentum (particle1) - px1
- Column F: Momentum (particle1) - py1
- Column G: Momentum (particle1) - pz1
- Column M: Energy (particle2)
- Column N: Momentum (particle2) - px2
- Column O: Momentum (particle2) - py2
- Column P: Momentum (particle2) - pz2
- Column Q: Mass (crossed out)

The data rows are:

	D	E	F	G	M	N	O	P	Q
1	E1	px1	py1	pz1	E2	px2	py2	pz2	M
2	19.1712	3.81713	9.04323	-16.4673	5.43984	-0.362592	2.62699	-4.74849	2.72205
3	12.9435	5.12579	-3.98369	-11.1973	11.8636	4.78984	-6.26222	-8.86434	2.10256
4	12.3999	-0.849742	9.4011	8.04015	8.55532	-4.85155	6.97696	-0.983229	9.41149

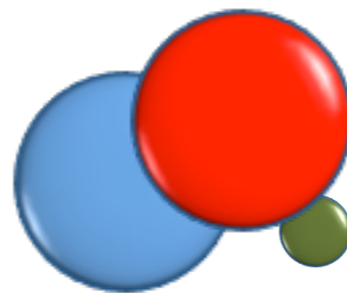
Annotations:

- Light blue arrows point from the labels "Energy (particle1)" and "Momentum (particle1)" to the corresponding columns in the spreadsheet.
- Green arrows point from the labels "Energy (particle2)" and "Momentum (particle2)" to the corresponding columns in the spreadsheet.
- A purple arrow points from the label "Mass" to the "M" column, which is crossed out with a large purple 'X'.

2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/collection/CMS-Derived-Datasets>

$E_0, m_0, p_{0,x}, p_{0,y}, p_{0,z}$



$$E_0^2 = m_0^2 c^4 + \mathbf{p}_0^2 c^2$$

$$m_0 = (E_0^2/c^4 - \mathbf{p}_0^2/c^2)^{1/2}$$

$E_1, m_1, p_{1,x}, p_{1,y}, p_{1,z}$
 $E_1^2 = m_1^2 c^4 + \mathbf{p}_1^2 c^2$

$E_2, m_2, p_{2,x}, p_{2,y}, p_{2,z}$
 $E_2^2 = m_2^2 c^4 + \mathbf{p}_2^2 c^2$

$$m_0 = ((E_1 + E_2)^2/c^4 - (\mathbf{p}_1 + \mathbf{p}_2)^2/c^2)^{1/2}$$

to measure energy and momentum

$$m_0 = (((m_1^2 c^4 + \mathbf{p}_1^2 c^2)^{1/2} + E_2)^2/c^4 - (\mathbf{p}_1 + \mathbf{p}_2)^2/c^2)^{1/2}$$

to measure momentum and identify the particle unambiguously

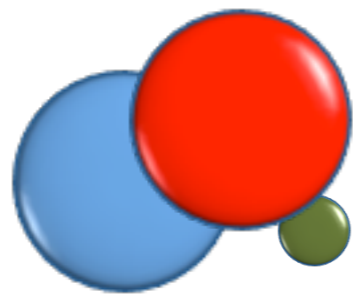
2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/collection/CMS-Derived-Datasets>

Energy (particle1) Momentum (particle1) Mass

	E1	px1	py1	pz1	E2	px2	py2	pz2	M
1	19.1712	3.81713	9.04323	-16.4673	5.43984	-0.362592	2.62699	-4.74849	2.72205
2	12.9435	5.12579	-3.98369	-11.1973	11.8636	4.78984	-6.26222	-8.86434	2.16256
3	12.3999	-0.849742	9.4011	8.04015	8.55532	-4.85155	6.97696	-0.983229	9.41149

Energy (particle2) Momentum (particle2)



$E_0, m_0, p_{0,x}, p_{0,y}, p_{0,z}$

$E_1, m_1, p_{1,x}, p_{1,y}, p_{1,z}$

$E_2, m_2, p_{2,x}, p_{2,y}, p_{2,z}$

$$m_0 = ((E_1 + E_2)^2 / c^4 - (\mathbf{p}_1 + \mathbf{p}_2)^2 / c^2)^{1/2}$$

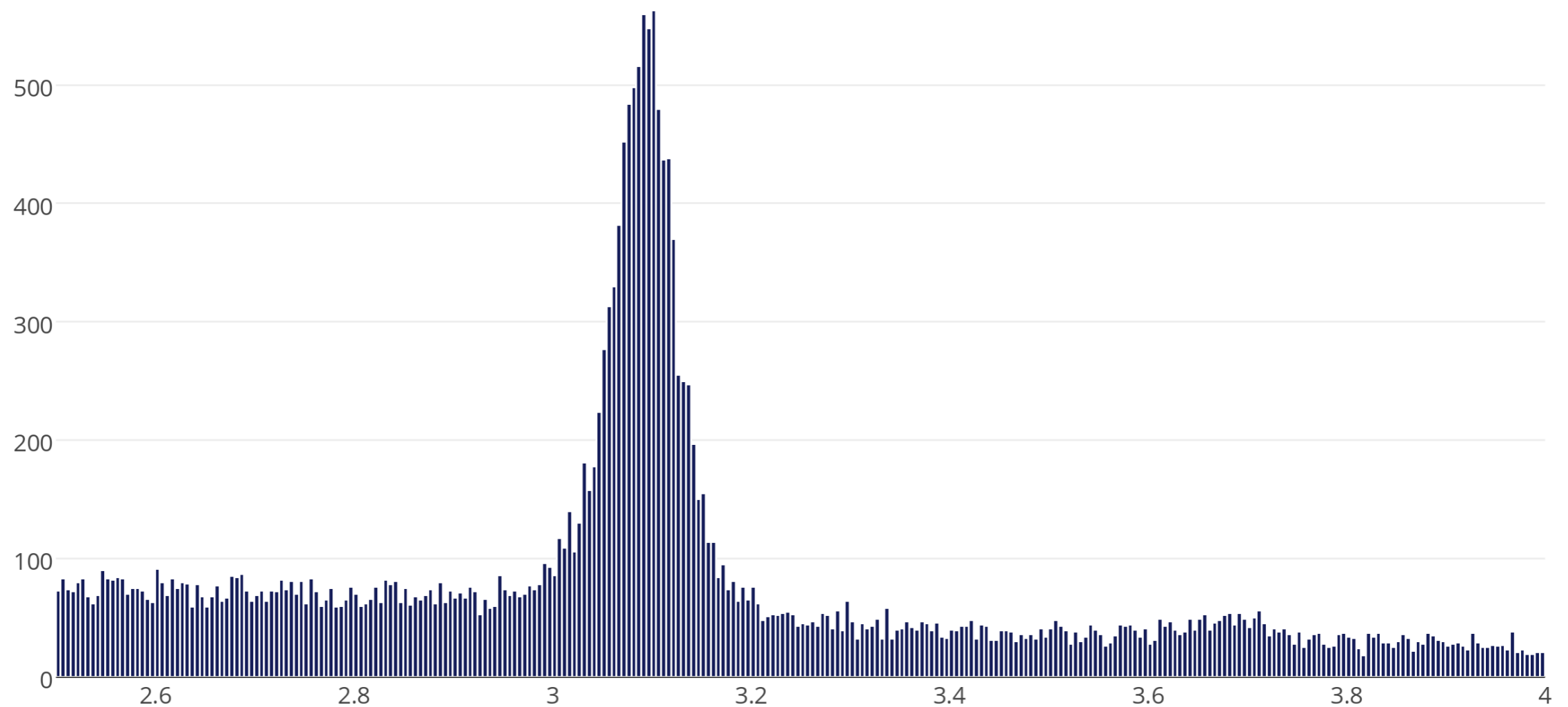
$$m_0 = (((m_1^2 c^4 + \mathbf{p}_1^2 c^2)^{1/2} + E_2)^2 / c^4 - (\mathbf{p}_1 + \mathbf{p}_2)^2 / c^2)^{1/2}$$

$$E_0^2 = m_0^2 c^4 + \mathbf{p}_0^2 c^2$$

$$m_0 = (E_0^2 / c^4 - \mathbf{p}_0^2 / c^2)^{1/2}$$

2. Invariant mass searches

Open Data Portal: <http://opendata.cern.ch/collection/CMS-Derived-Datasets>



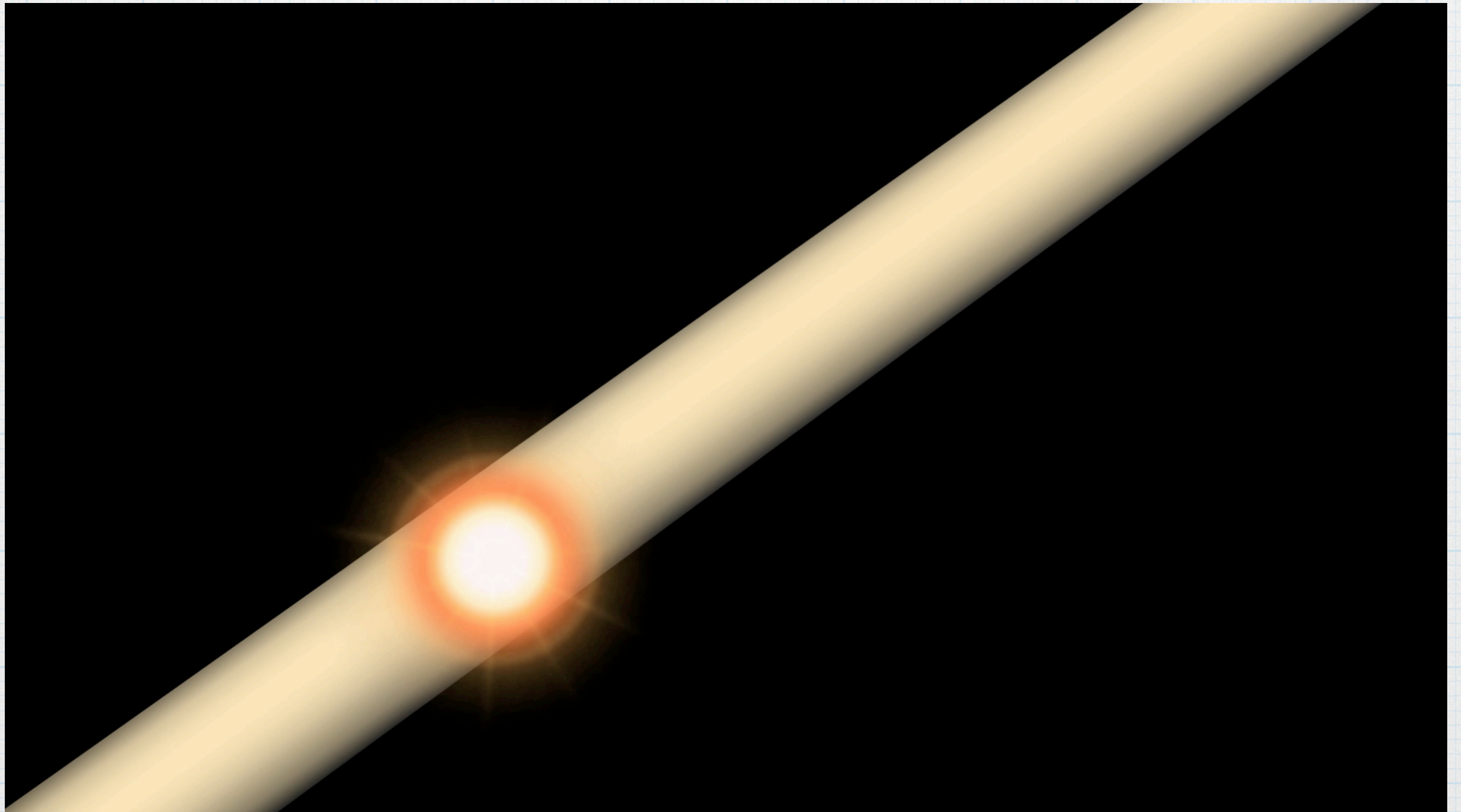
outline

1. Search for W particles with ATLAS
2. Invariant mass searches for known and unknown particles
3. Search for the Higgs

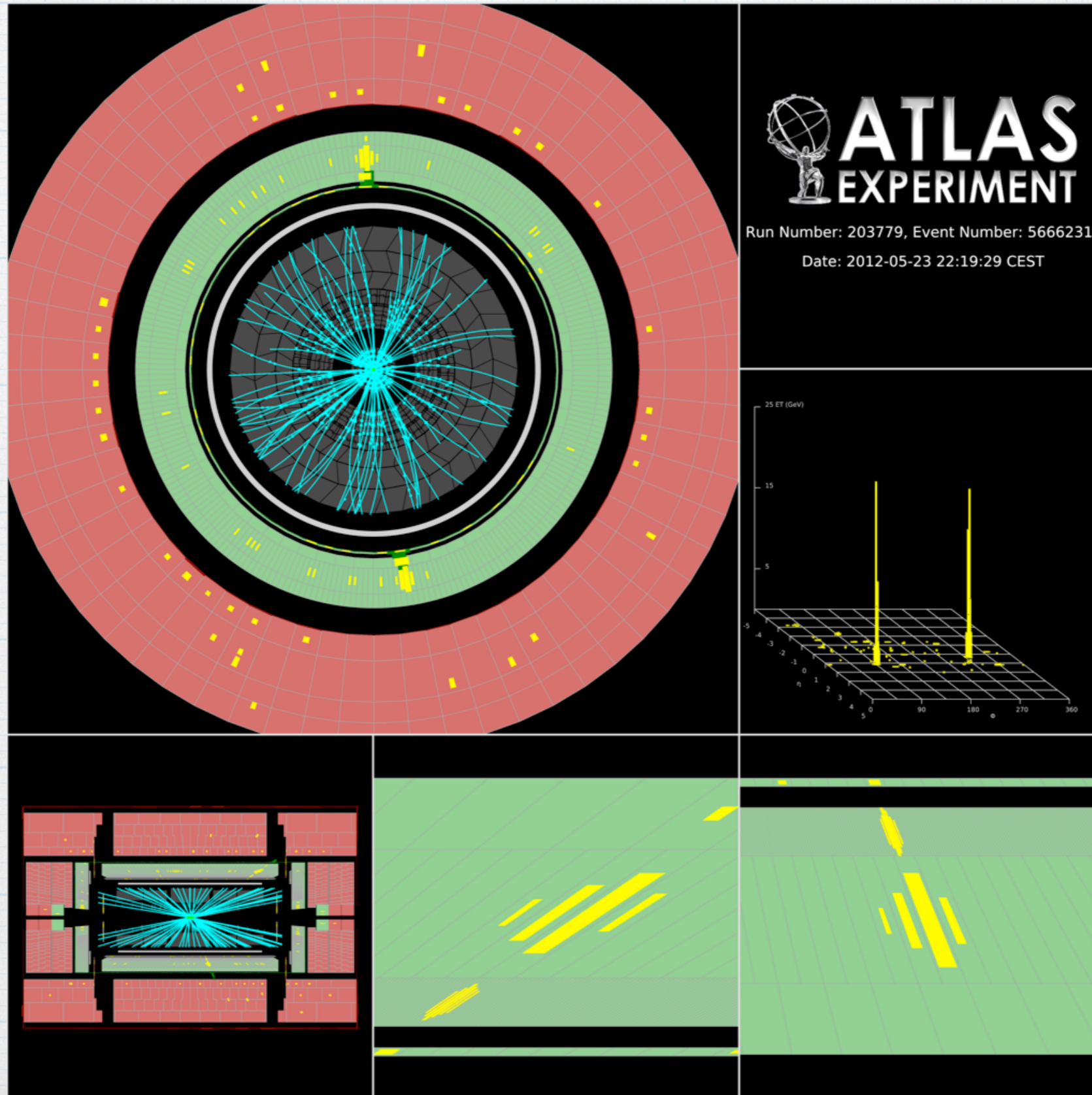
3. Search for the Higgs



3. Search for the Higgs

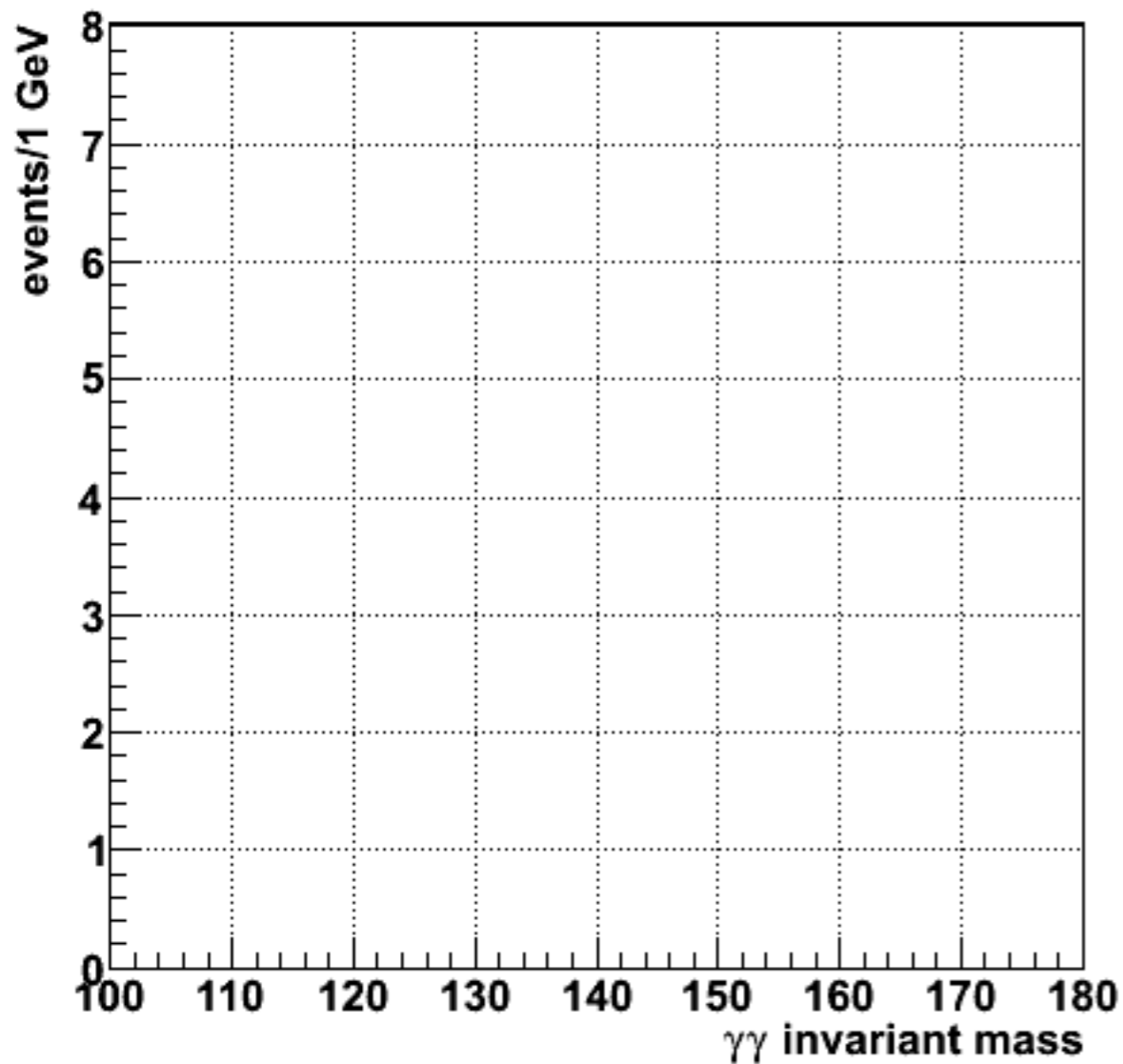


3. Search for the Higgs

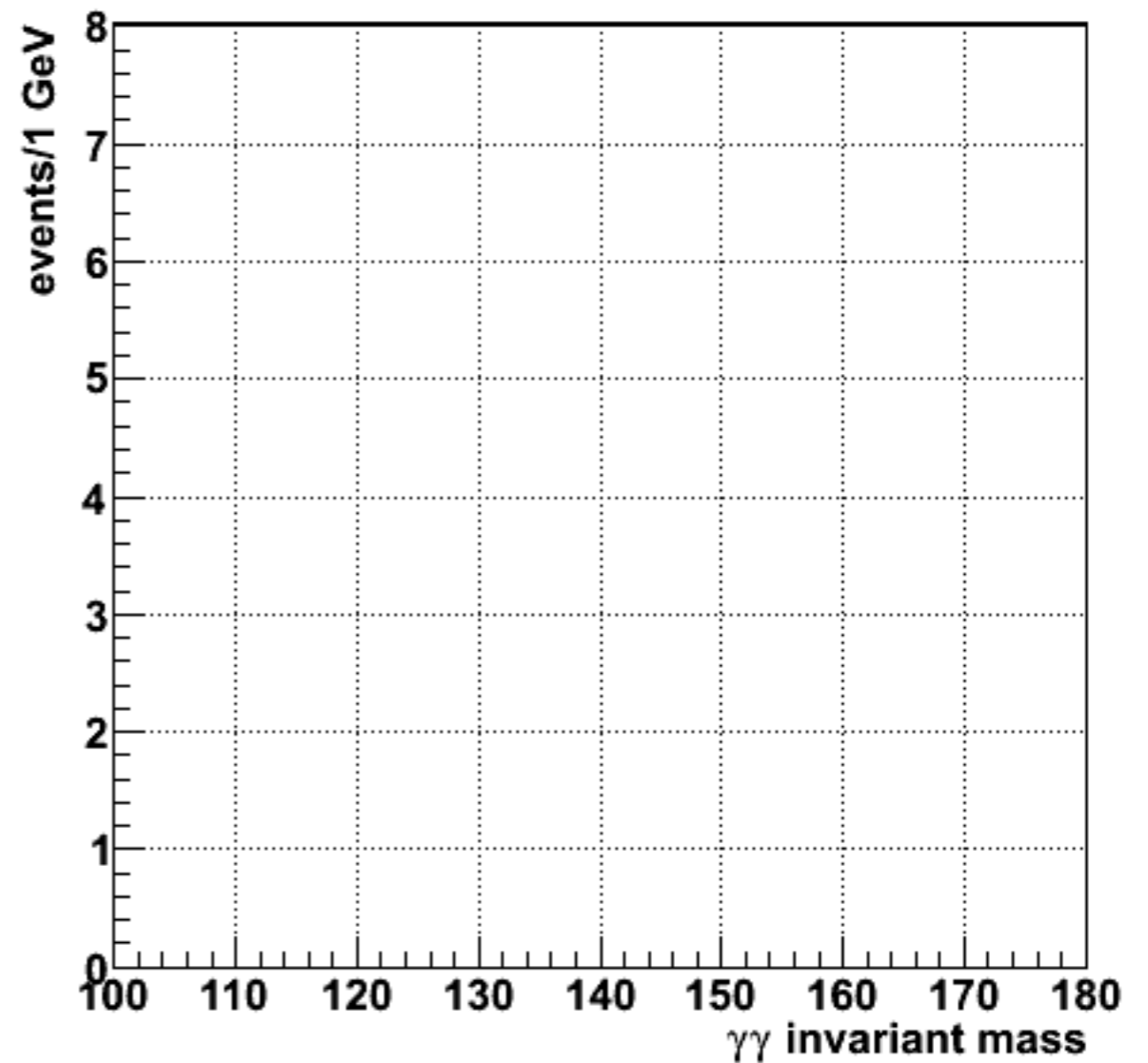


3. Search for the Higgs

$L=0.00 \text{ fb}^{-1}$



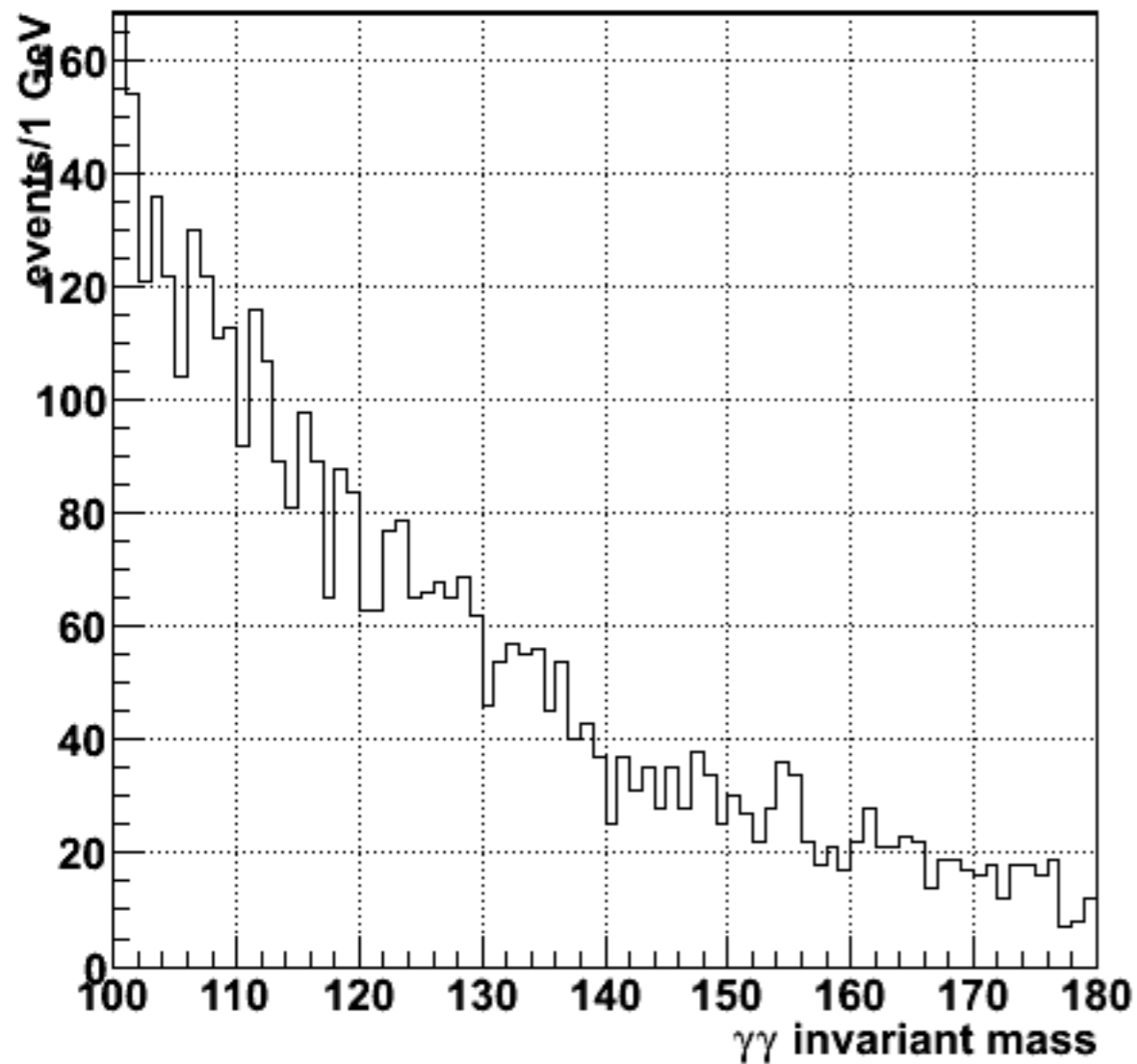
$L=0.00 \text{ fb}^{-1}$



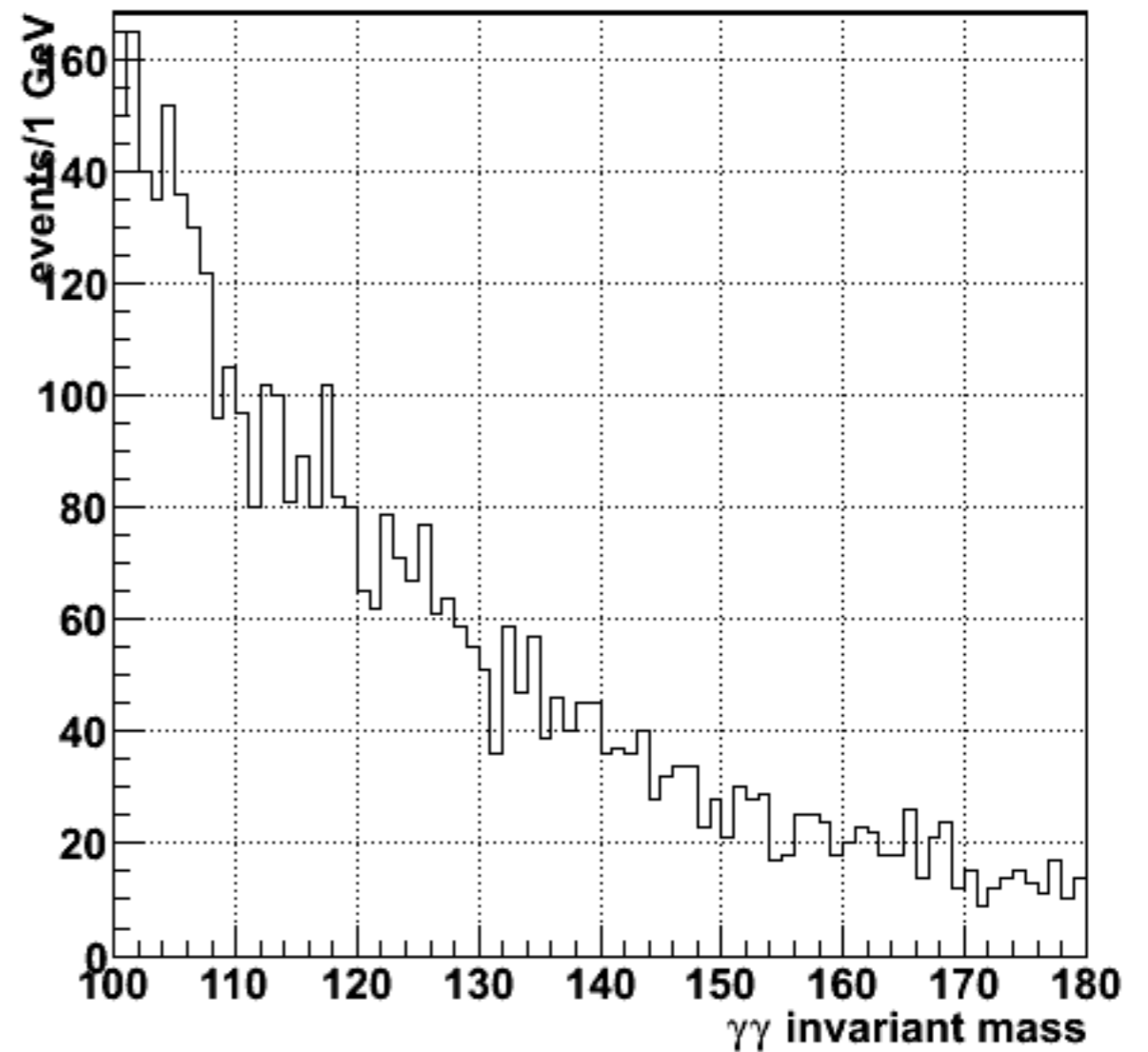
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs

$L=1.00 \text{ fb}^{-1}$



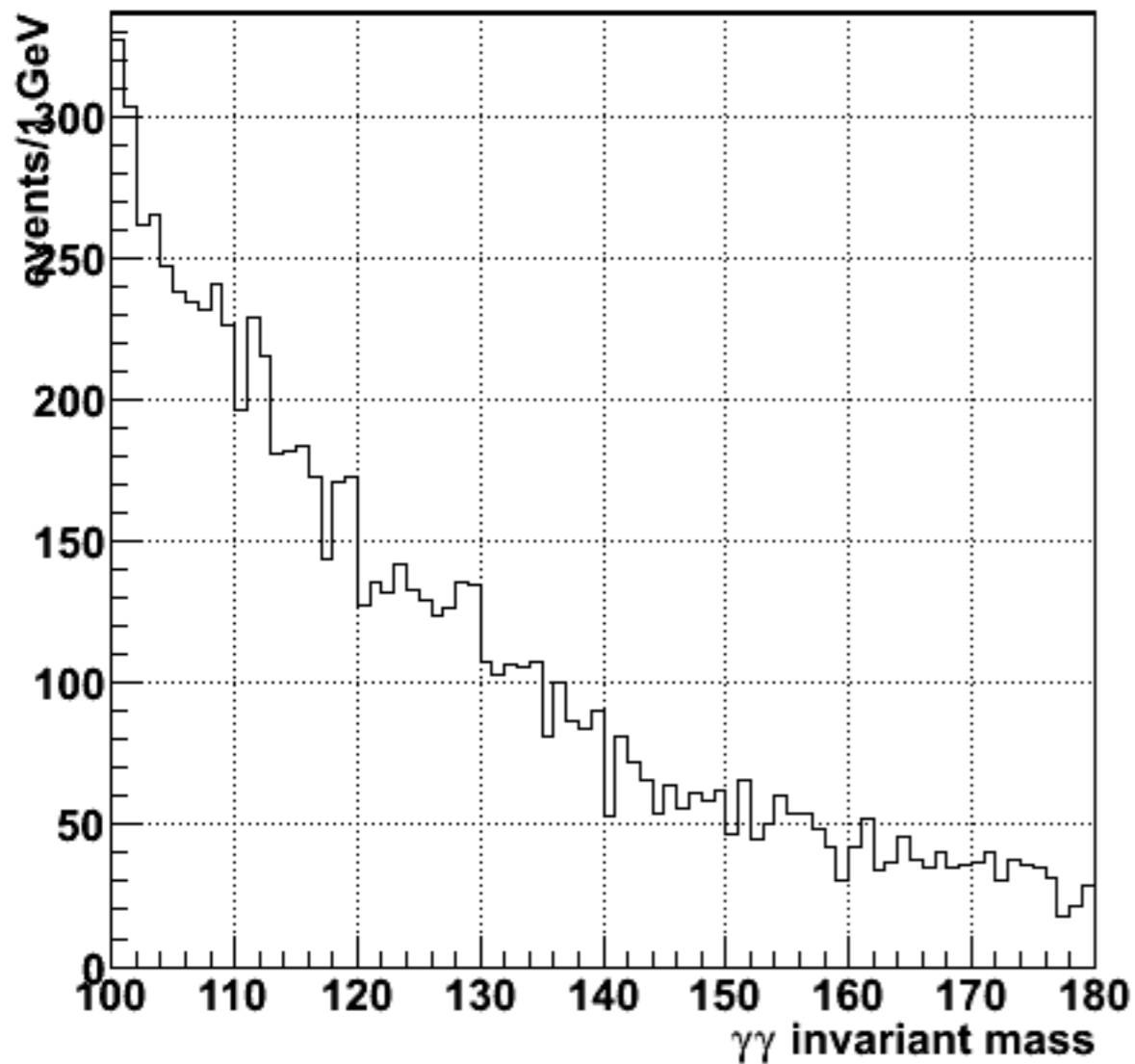
$L=1.00 \text{ fb}^{-1}$



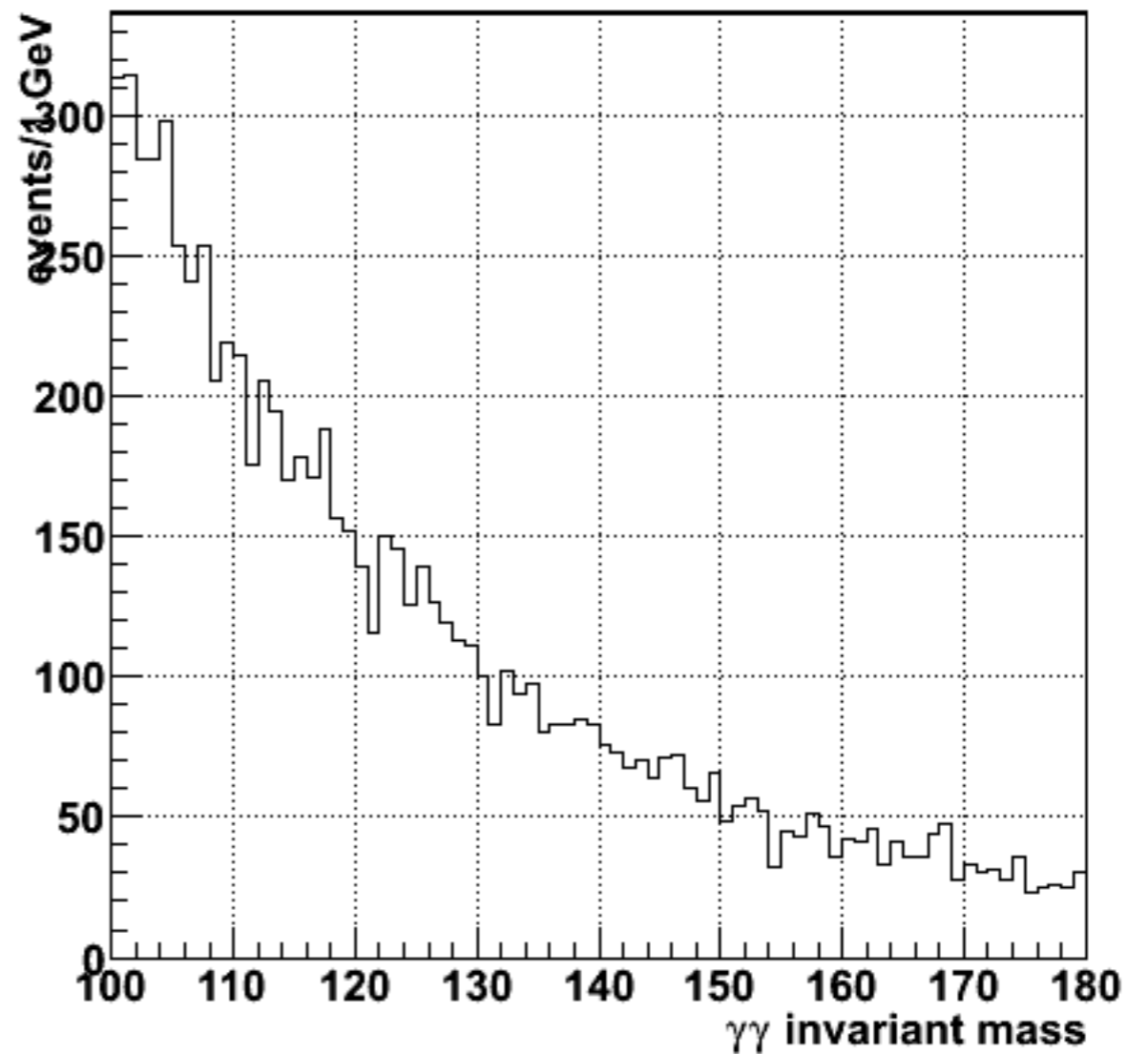
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs

$L=2.00 \text{ fb}^{-1}$



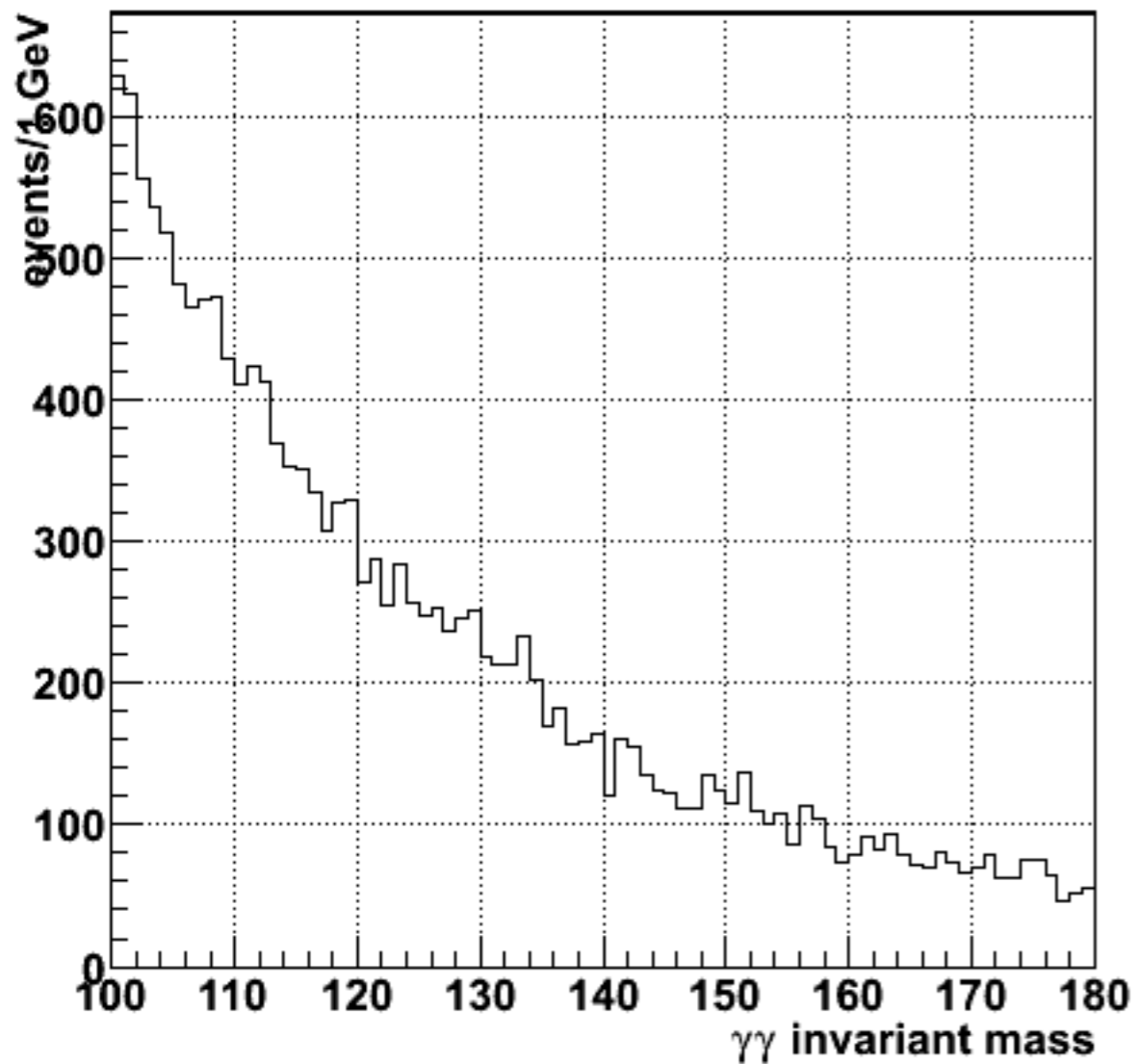
$L=2.00 \text{ fb}^{-1}$



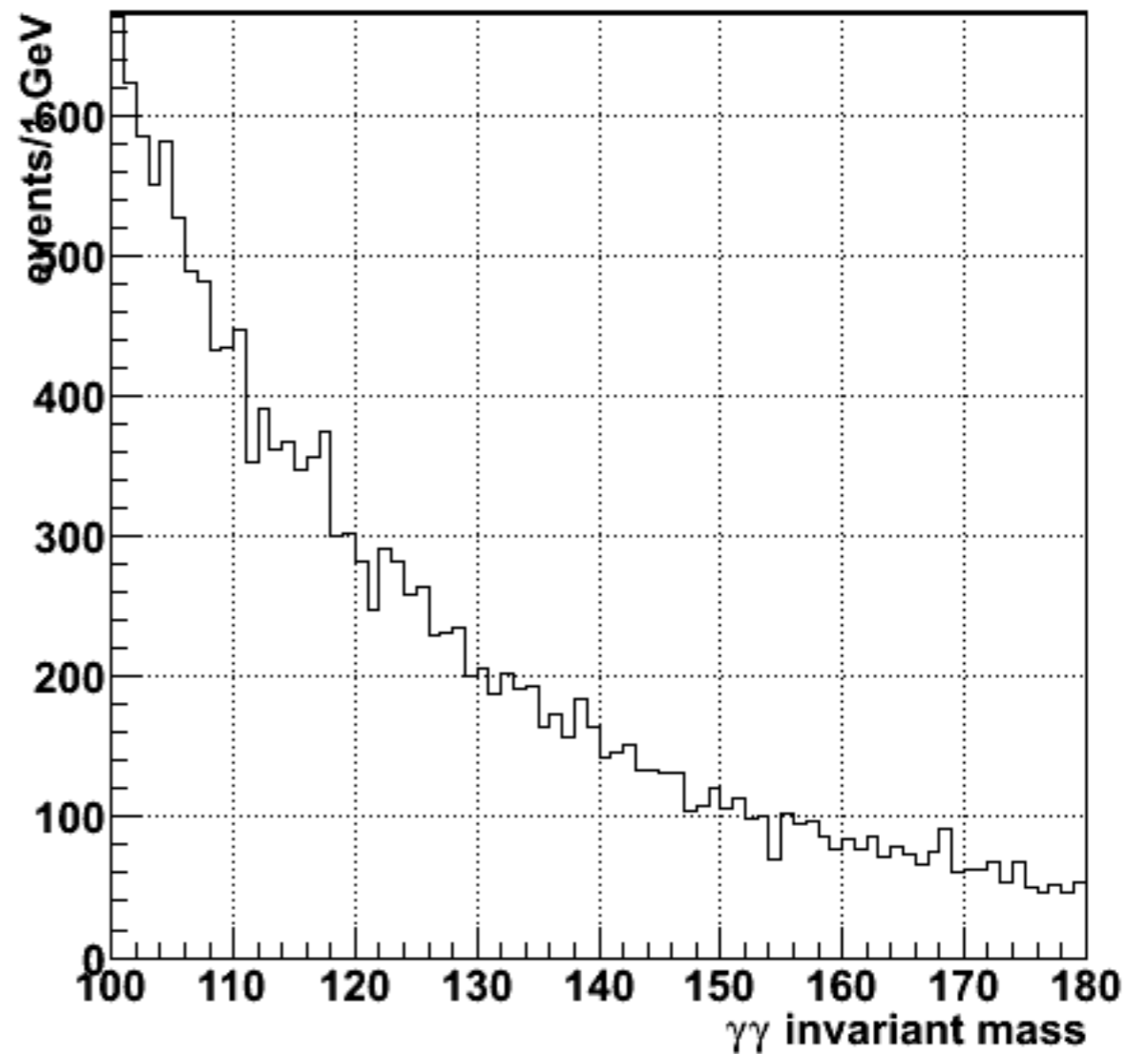
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs

$L=4.00 \text{ fb}^{-1}$



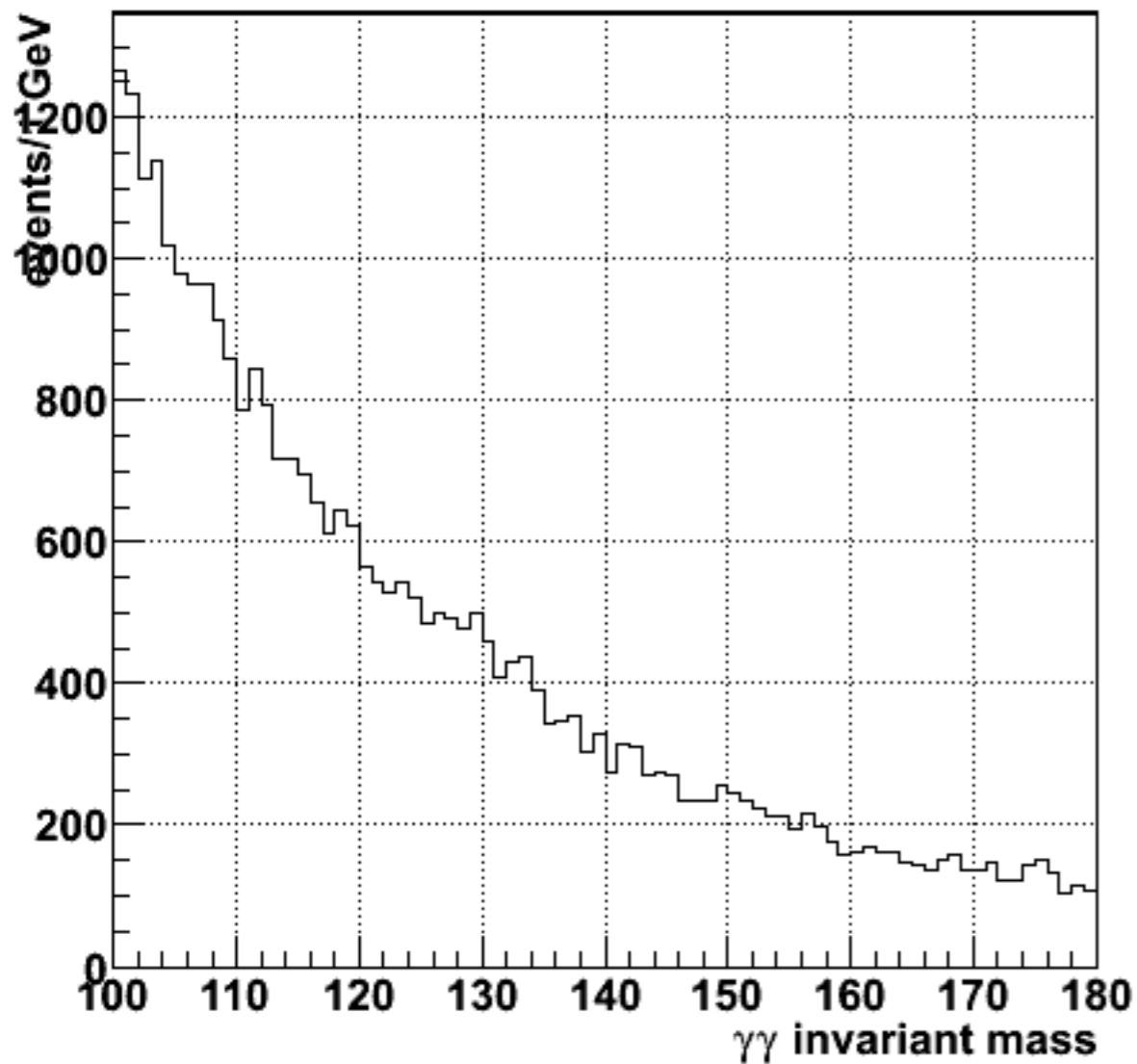
$L=4.00 \text{ fb}^{-1}$



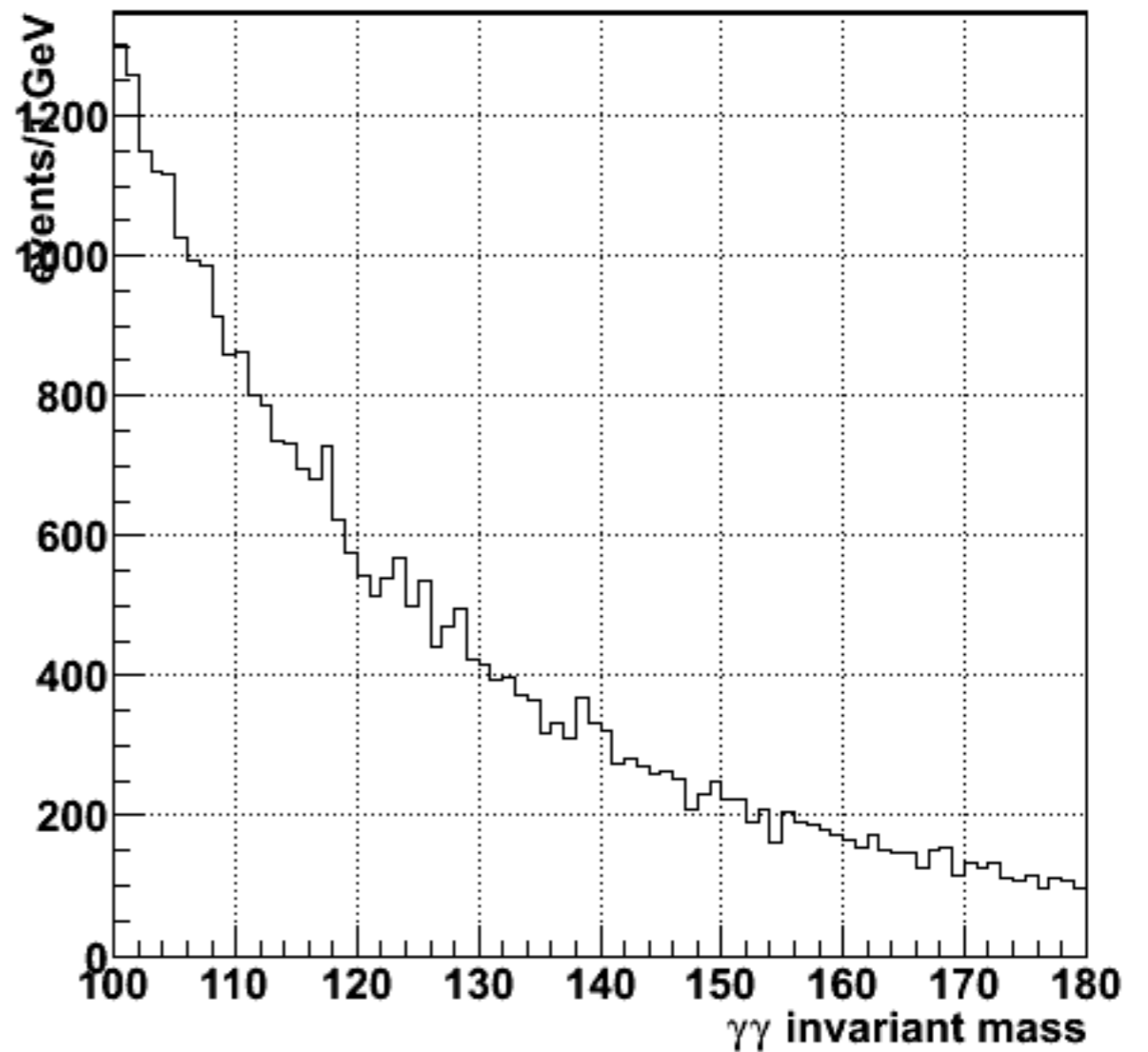
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs

$L=8.00 \text{ fb}^{-1}$



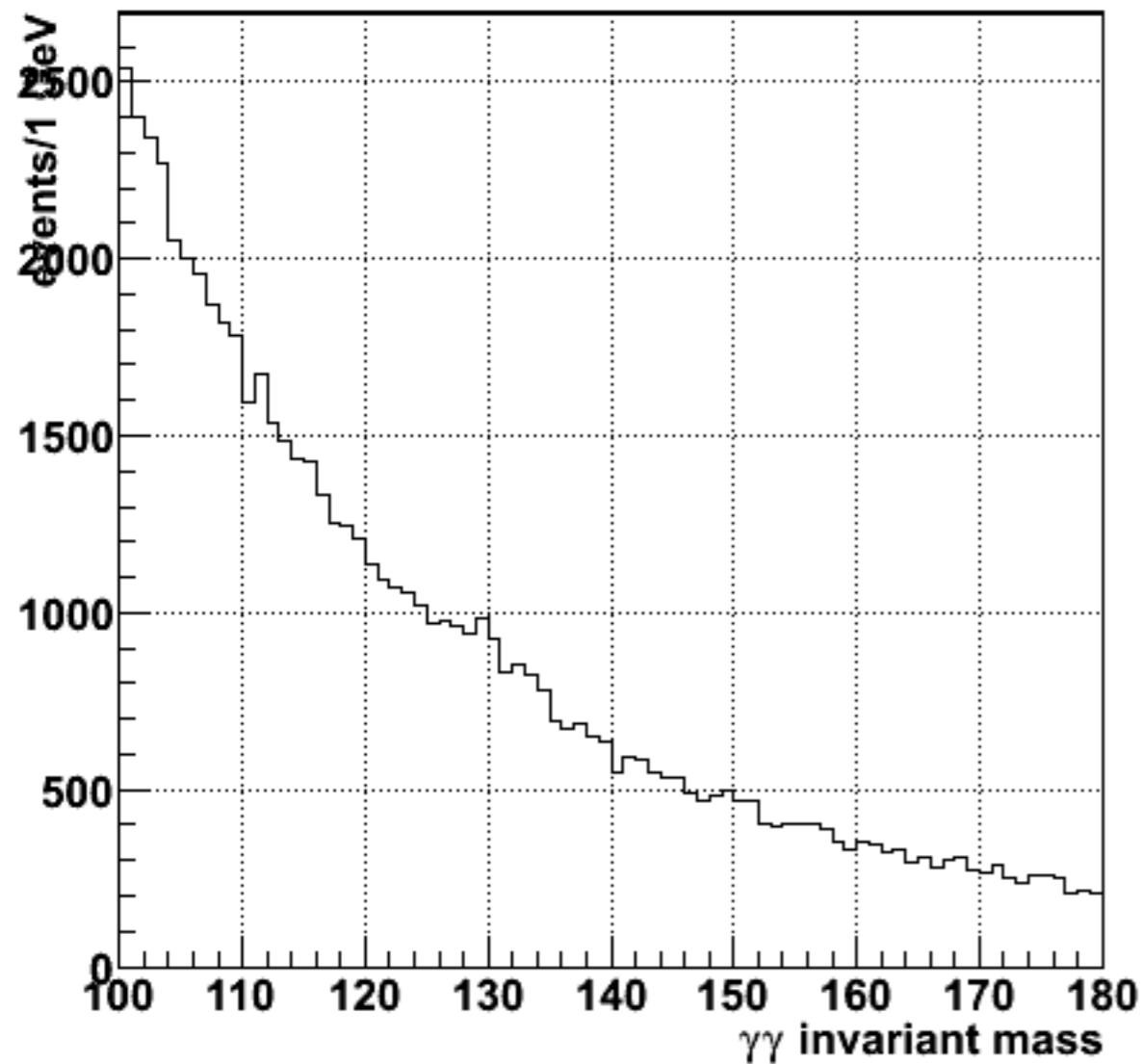
$L=8.00 \text{ fb}^{-1}$



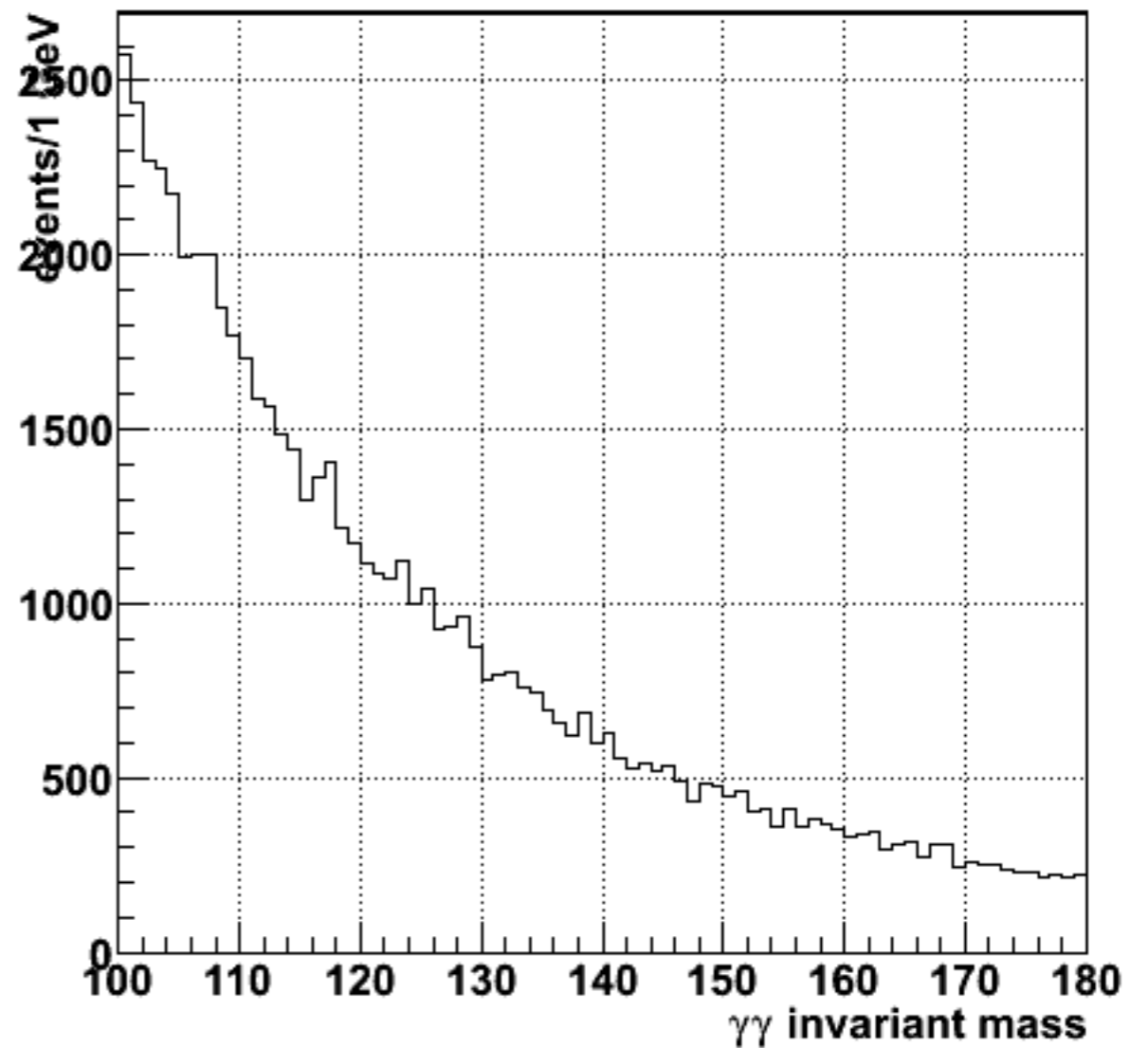
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs

$L=16.00 \text{ fb}^{-1}$

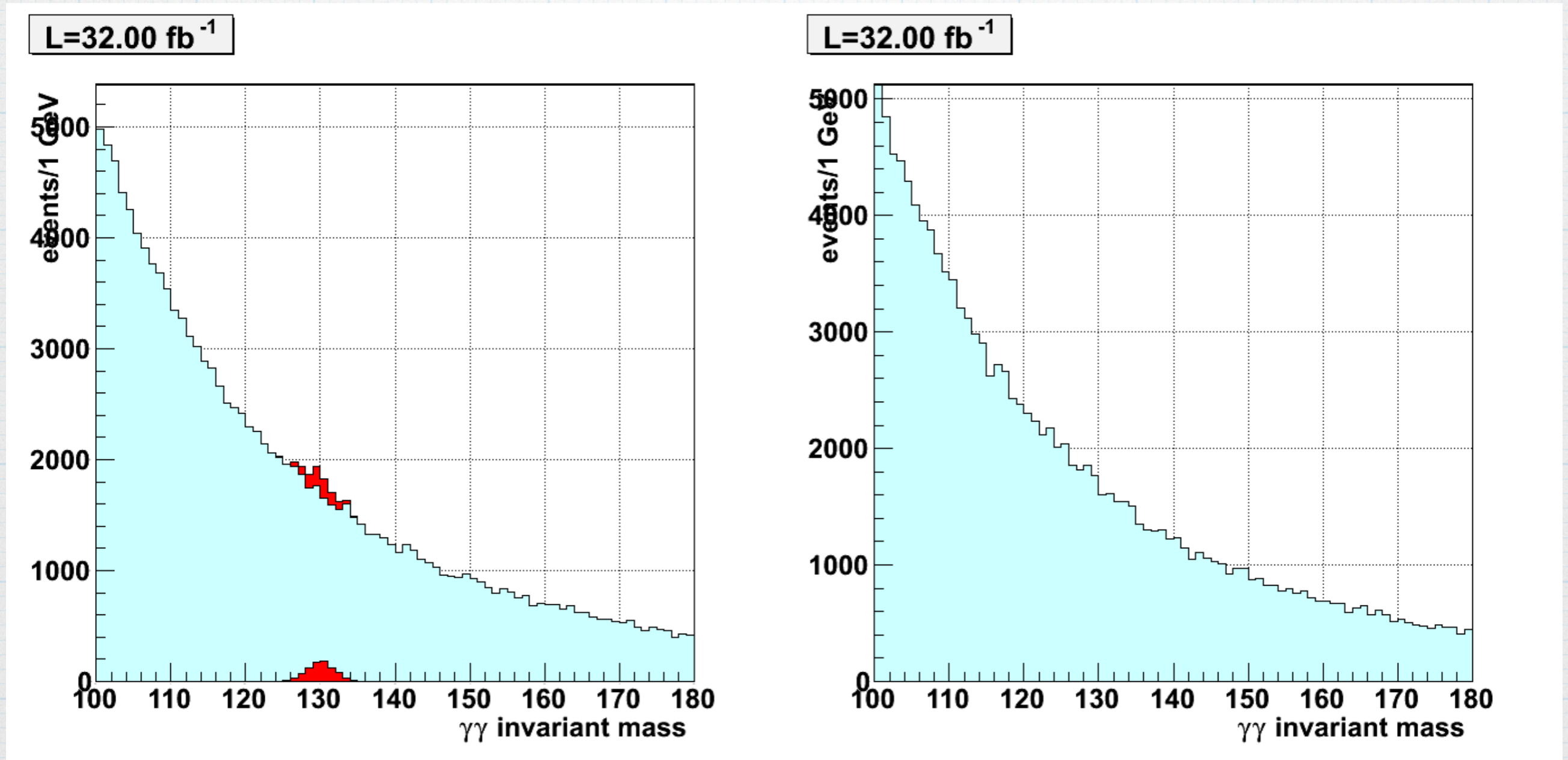


$L=16.00 \text{ fb}^{-1}$



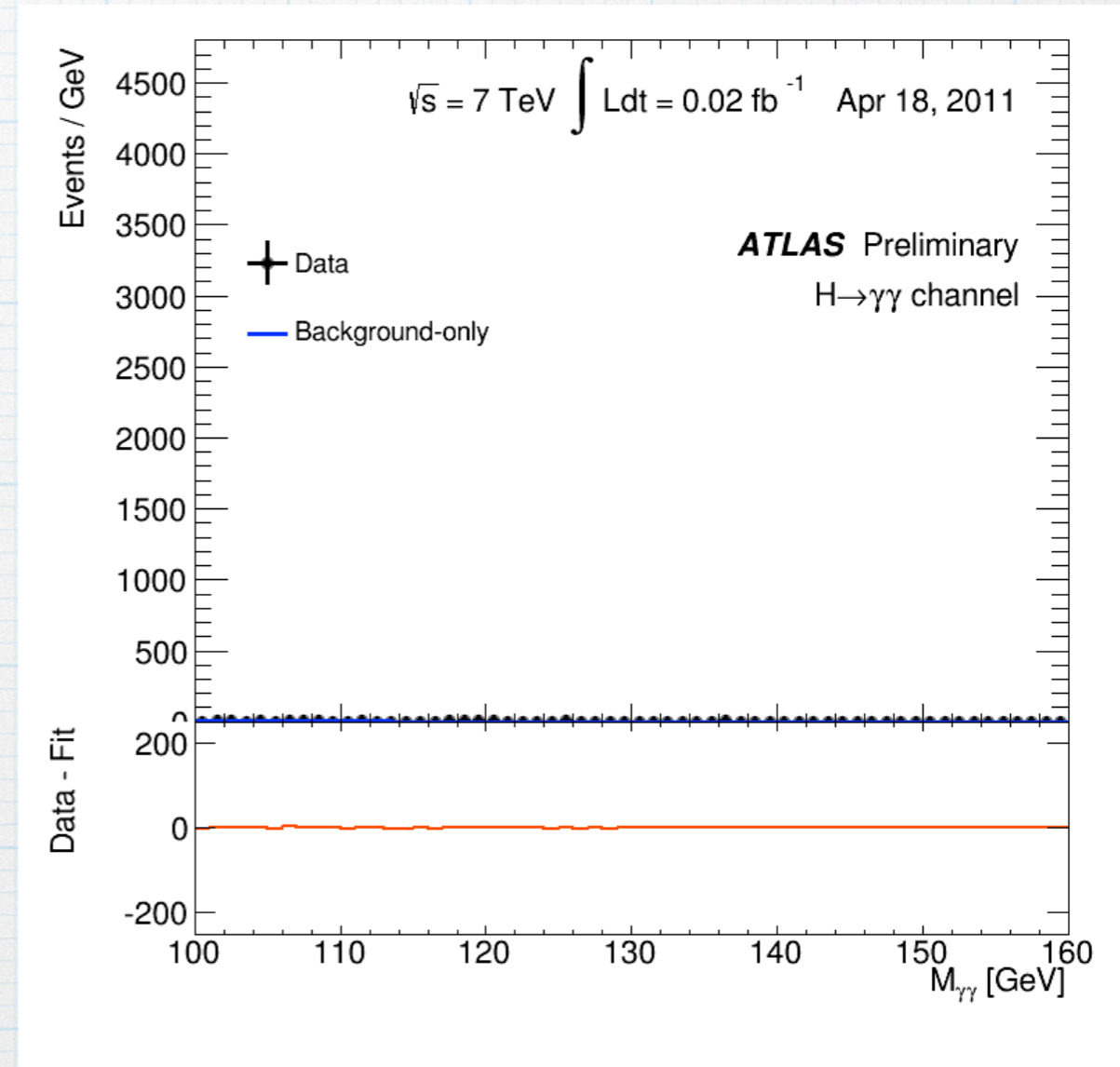
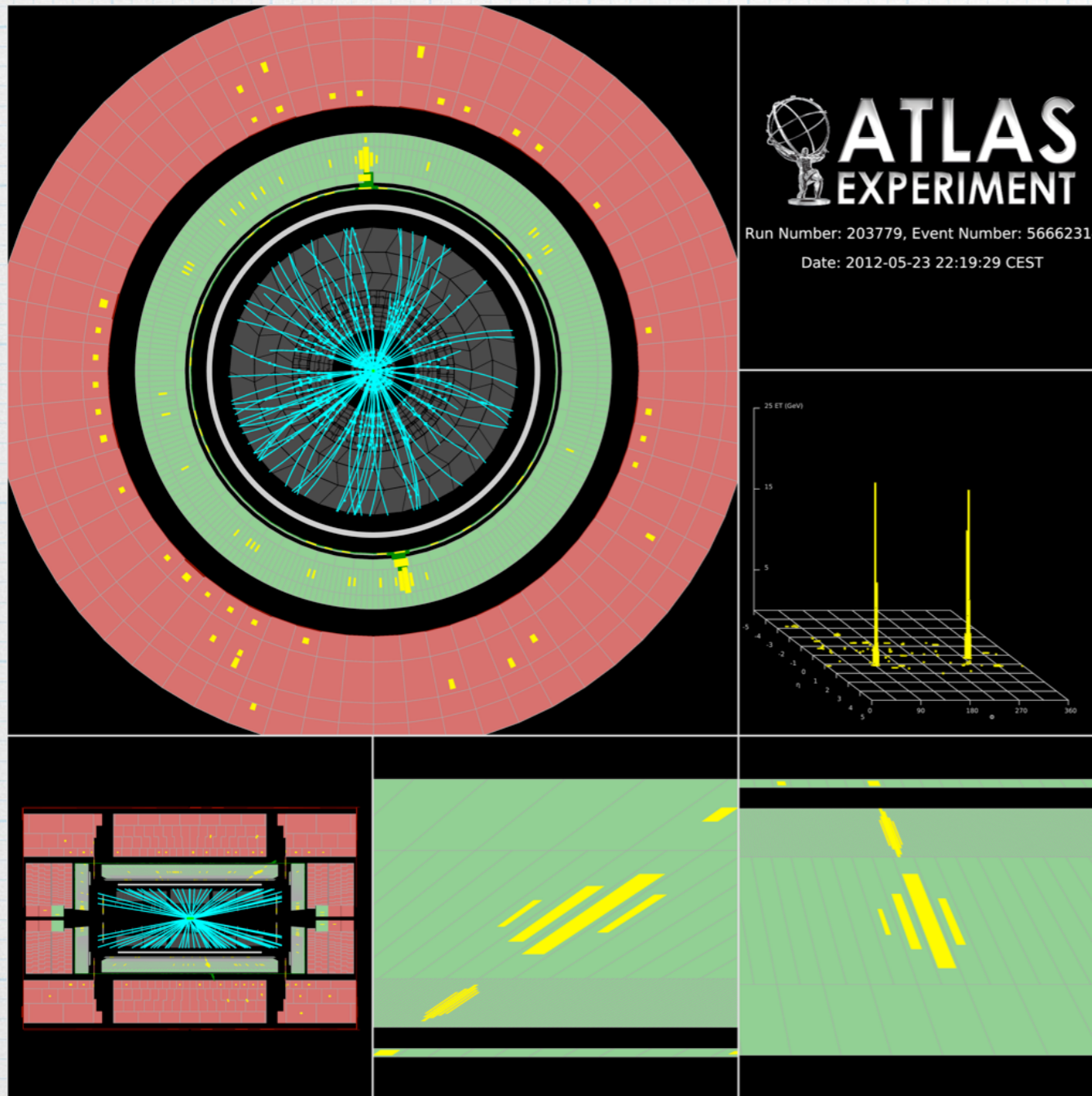
1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs



1 fb^{-1} (inverse femtobarn) corresponds to about 100 trillion (100 times 10^{12}) proton-proton collisions

3. Search for the Higgs





Thanks very much!