Preparatory studies to search for the production of new heavy particles with unusual properties in proton-proton collisions with the CMS experiment at the Large Hadron Collider LHC

Mohamed Rashad

Content

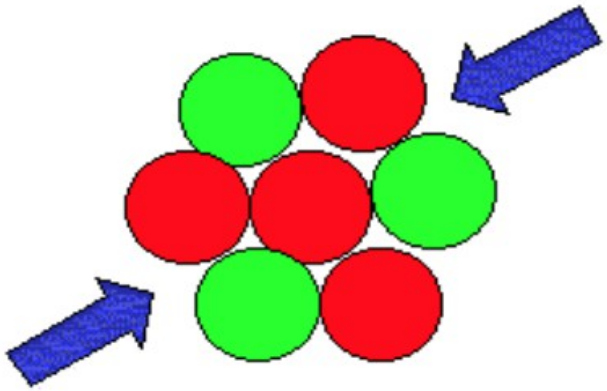
- Introduction to Standard Model
- Beyond Standard Model
- LHC: Large Hadron Collider
- Monte Carlo Signal of New Particle
- Background of New Particle
- Sensitivity to Find the New Signal

بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

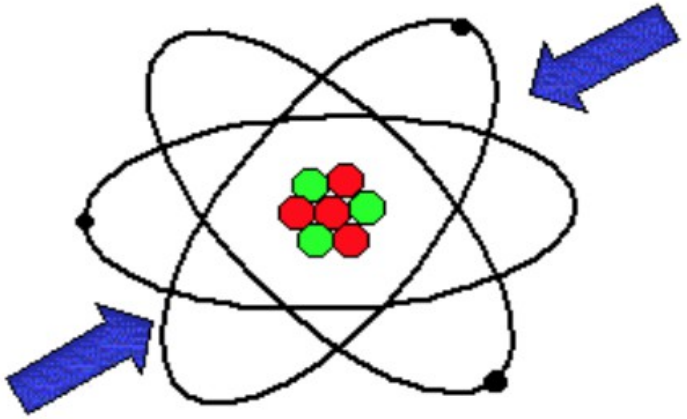
وَقُل رَّبِّ زِدْنِي عِلْمًا

صَدَق اللّٰه الْعَظِيْم

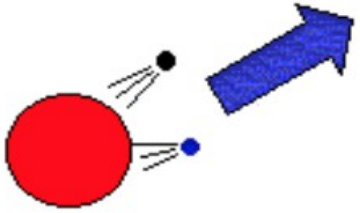
The Fundamental Forces of Nature



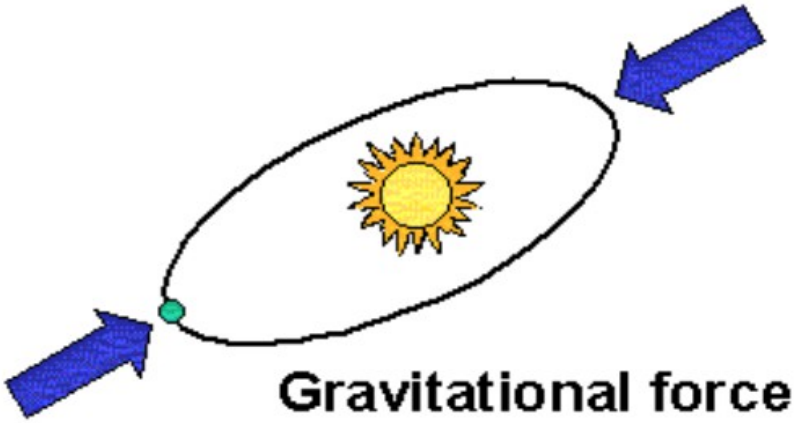
Strong force
binds the nucleus



Electromagnetic
force binds atoms



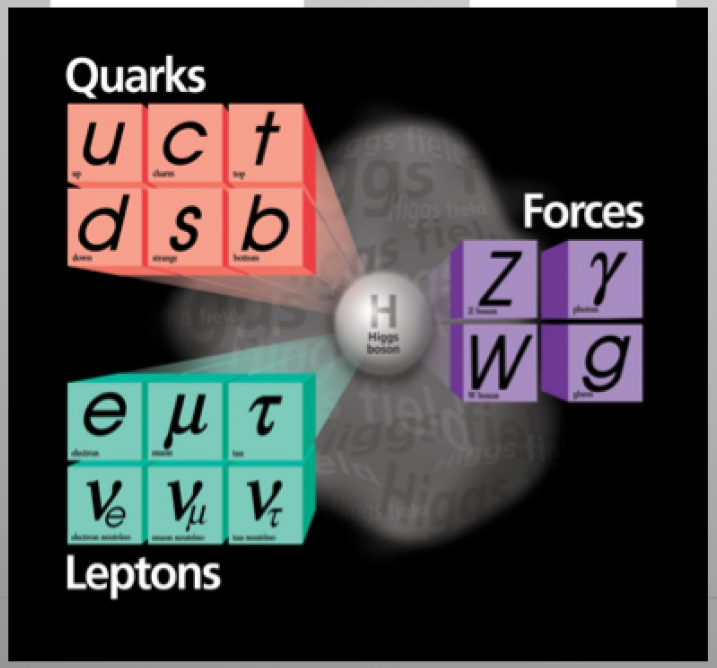
Weak force in
radioactive decay



Gravitational force
binds the solar system

The "Standard Model" of Particle Physics

Over the last 100 years: combination of
Quantum Mechanics and Special Theory of relativity
along with all new particles discovered has led to the
Standard Model of Particle Physics.
The new (final?) "Periodic Table" of fundamental elements:



The most basic mechanism of the SM, that of granting mass to particles remained a mystery for a long time
A major step forward was made in July 2012 with the discovery of what could be the long-sought Higgs boson!!

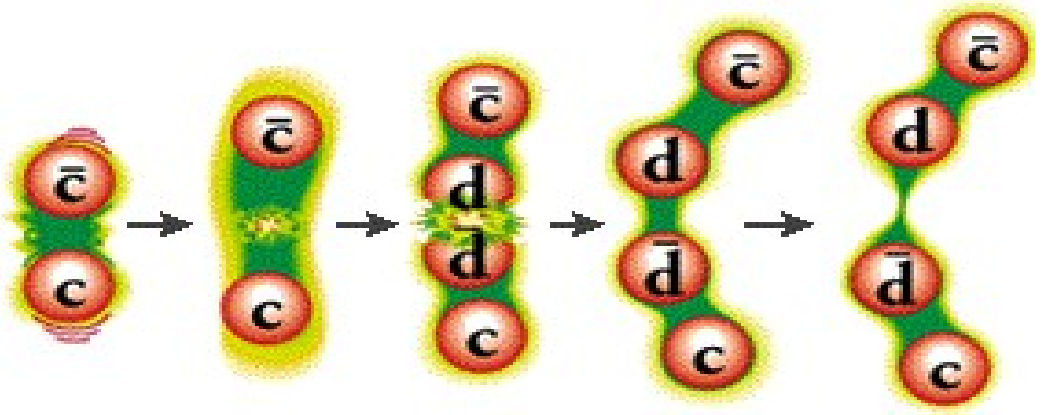
Fermions: particles with spin ½
Bosons: particles with integer spin

The Strong Force

The charge of the force is color
The force carrier is called the gluon. It is a spin-1 boson like the photon but there is an important difference: The gluon is also colored

The Fundamental Forces of Nature

Why don't we see free quarks?
Hypothesis: all particles in Nature are colorless!! (qq-bar, qqq)
When quarks separate, the force gets stronger and stronger between them (like in an elastic band)
At some point there is so much energy in that 'band' that it can break, creating new colour neutral hadrons on the way



Is that true also at the highest energies? We will check it at the LHC

Beyond Standard Model

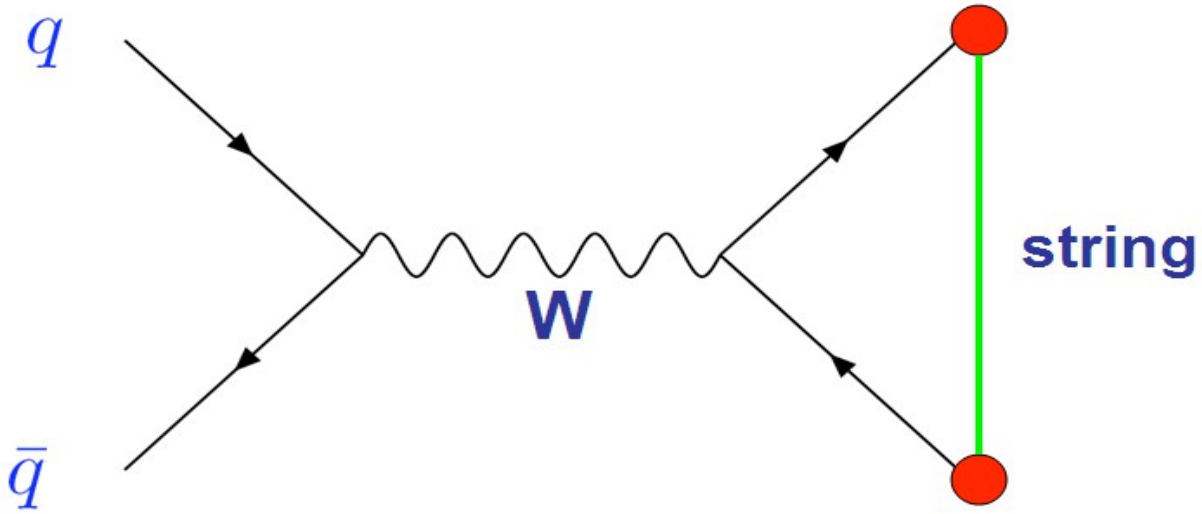
Consider the limit of QCD where all the quark masses are much larger than ΛQCD , and there are no light quarks this means that:

Gupta & Quinn

Quarks remain joined by a QCD string

The string cannot snap because there are no light quarks

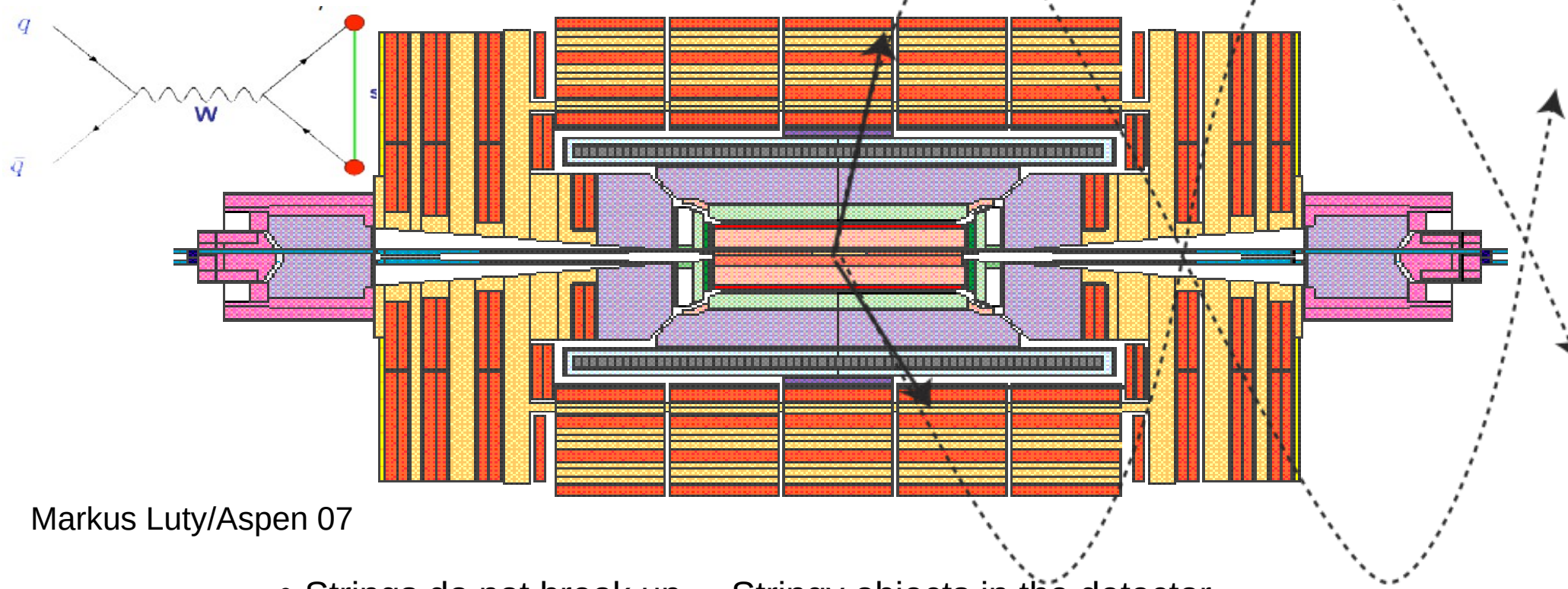
So there is not enough energy locally at any point along the string to pair-produce two heavy quarks



New Particle

Quirks are exotic vector-like fermions that transform as the fundamental (and anti-fundamental) under a hidden confining group, but also carry Standard Model charges.

New strong interactions with small Λ & new quarks $m_Q >$ several hundred GeV

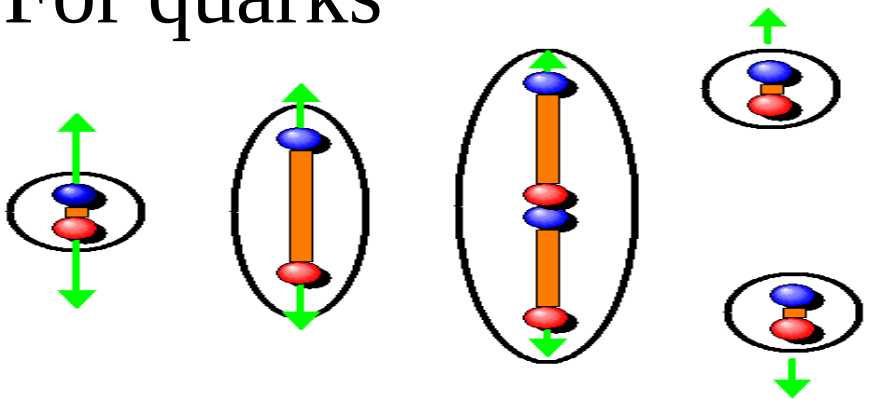


Markus Luty/Aspen 07

- Strings do not break up ⇒ Stringy objects in the detector.
- End points are massive quarks (quirks)
- The strings can oscillate ⇒ strange signature in detectors

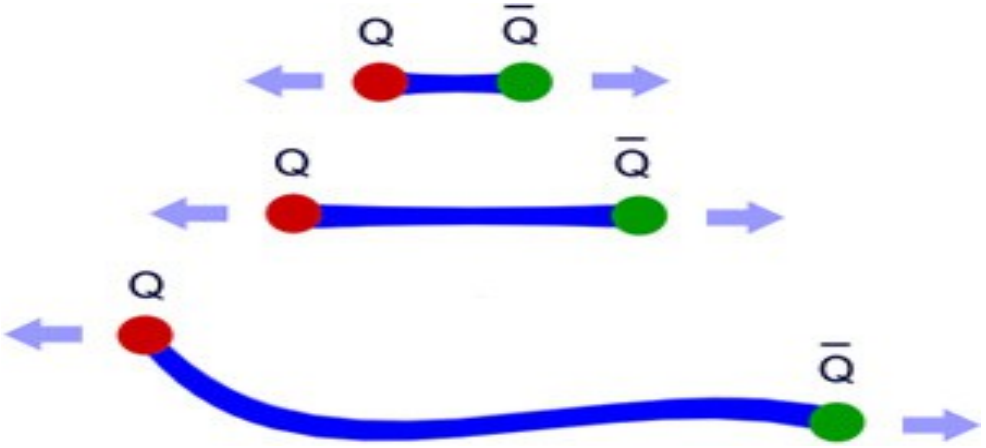
Dynamics of quirks and strings

For quarks



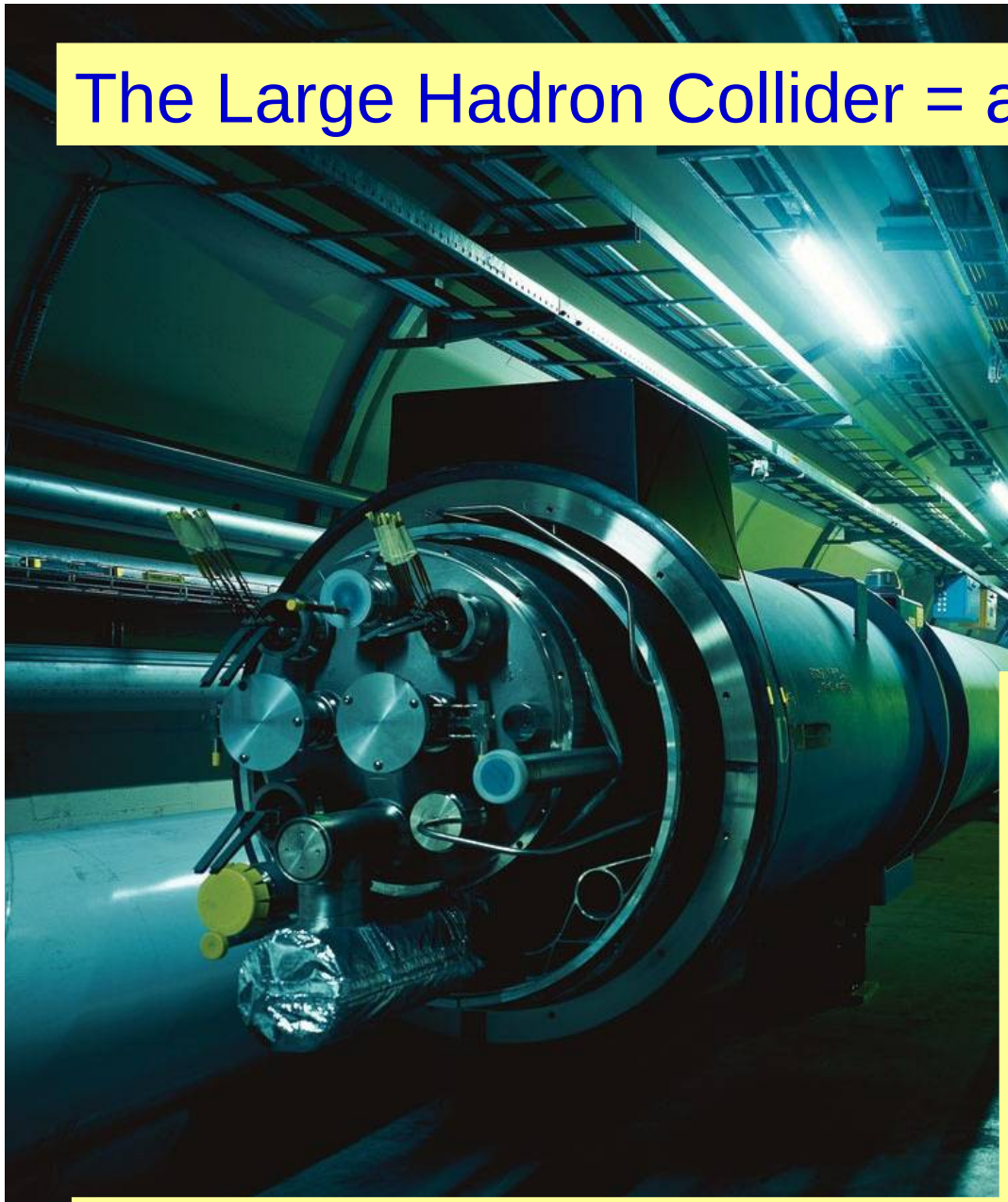
the energy in the gluon field is enough to create another quark pair bound into hadrons such as the pion and kaon

For quirks



The two quirks oscillating and remain connected by a string of hidden color

The Large Hadron Collider = a proton proton collider



7 TeV + 7 TeV
(3.5/4 TeV + 3.5/4 TeV)

1 TeV = 1 Tera electron volt
= 10^{12} electron volt

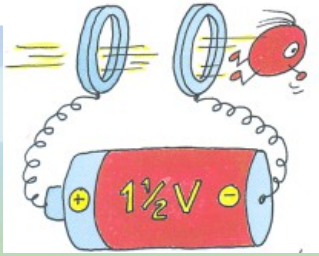
Primary physics targets

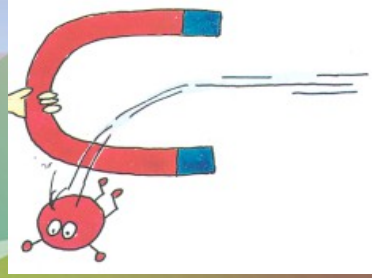
- Origin of mass
- Nature of Dark Matter
- Understanding space time
- Matter versus antimatter
- Primordial plasma
- Exotica Particles

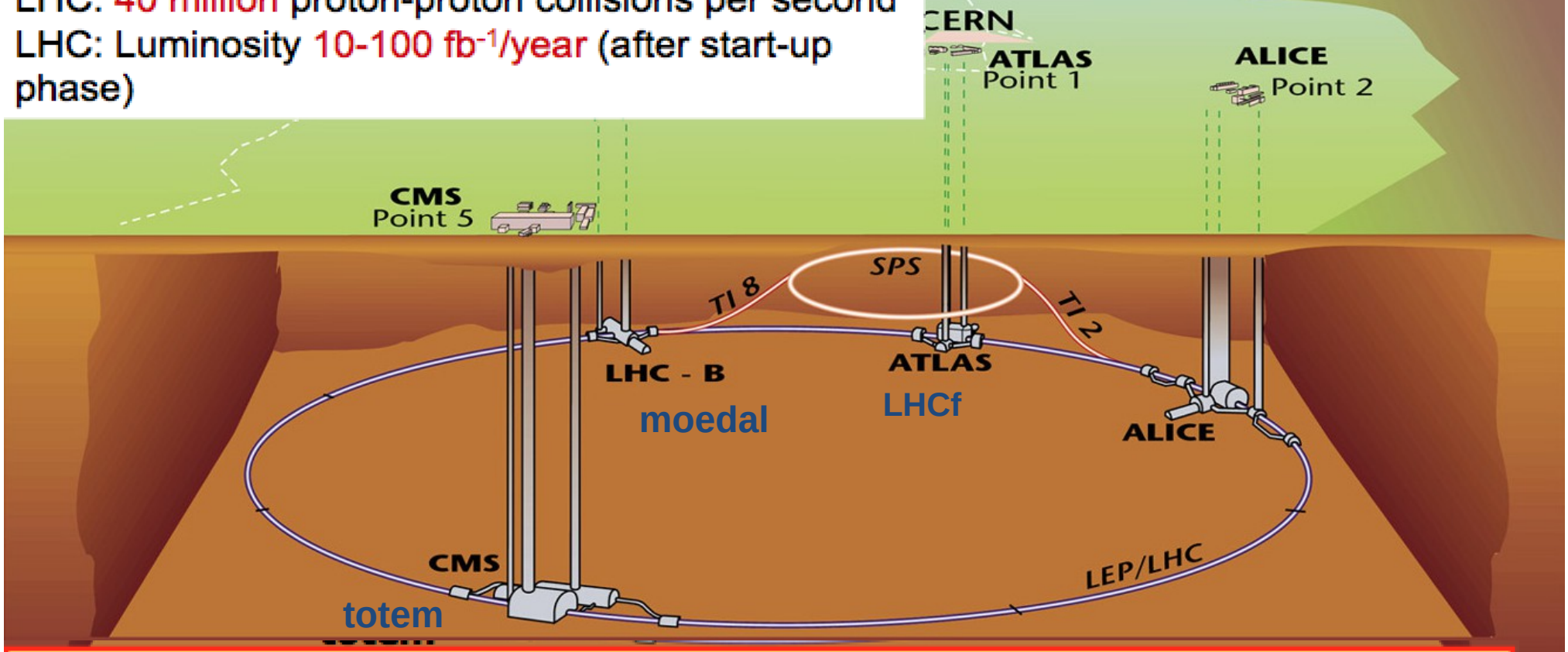
The LHC is a Discovery Machine
The LHC run at 13/14 TeV started in 2015

The LHC Machine and Experiments

LHC is 100m underground
LHC is 27 km long
Magnet Temperature is 1.9 Kelvin = -271 Celsius
LHC has ~ 9000 magnets
LHC: 40 million proton-proton collisions per second
LHC: Luminosity 10-100 fb^{-1}/year (after start-up phase)

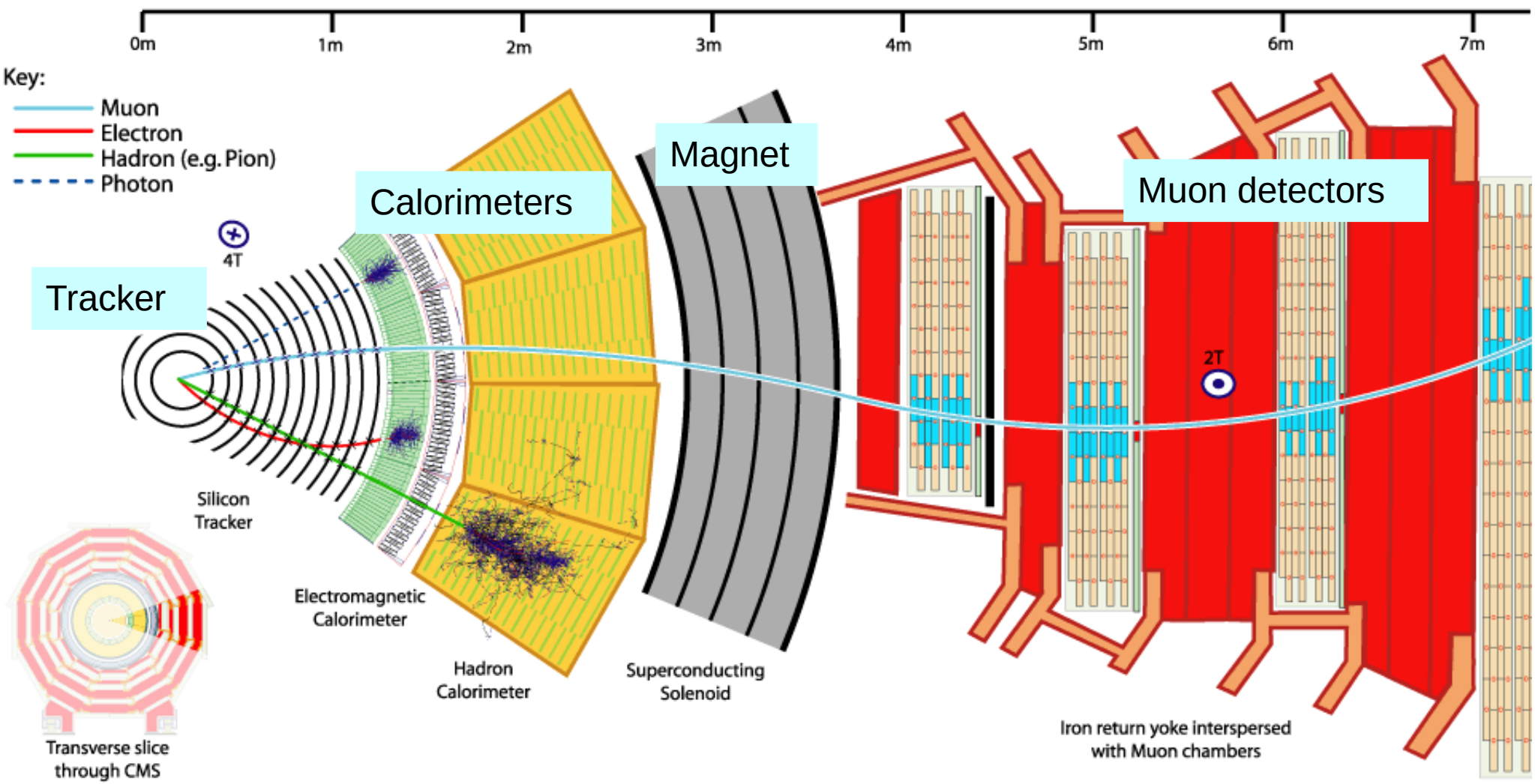






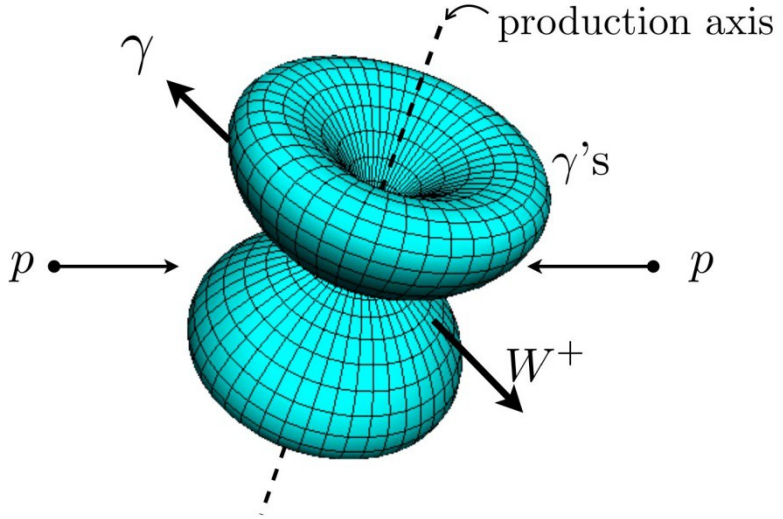
- High Energy ⇒ factor 7 increase w.r.t. present accelerators
- High Luminosity (# events/cross section/time) ⇒ factor 100 increase

CMS Detector



Della Negra, Michel; Petrilli, Achille; Herve, Alain; Foa, Lorenzo;Cern

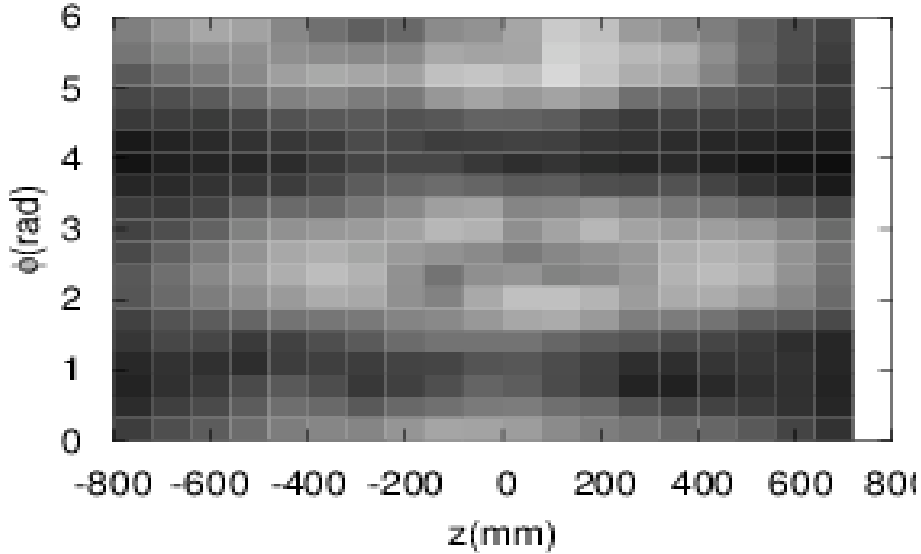
Generation of the Signal



One possibility of a fast charged oscillator

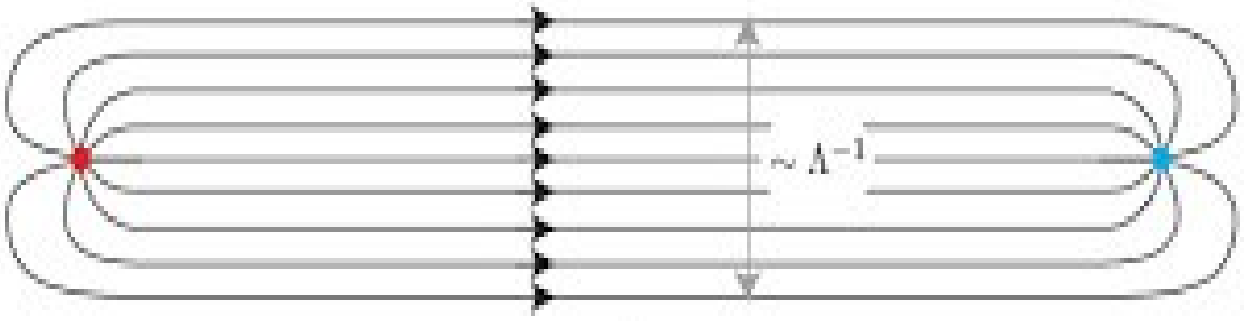
Lots of QED radiation
Lots of soft photons
…A photon cloud

Harnik & Wizansky arXiv:0810.3948



Distribution of photons in toy detector simulation where an antenna pattern of soft photons is appeared

Classification Of the Signal

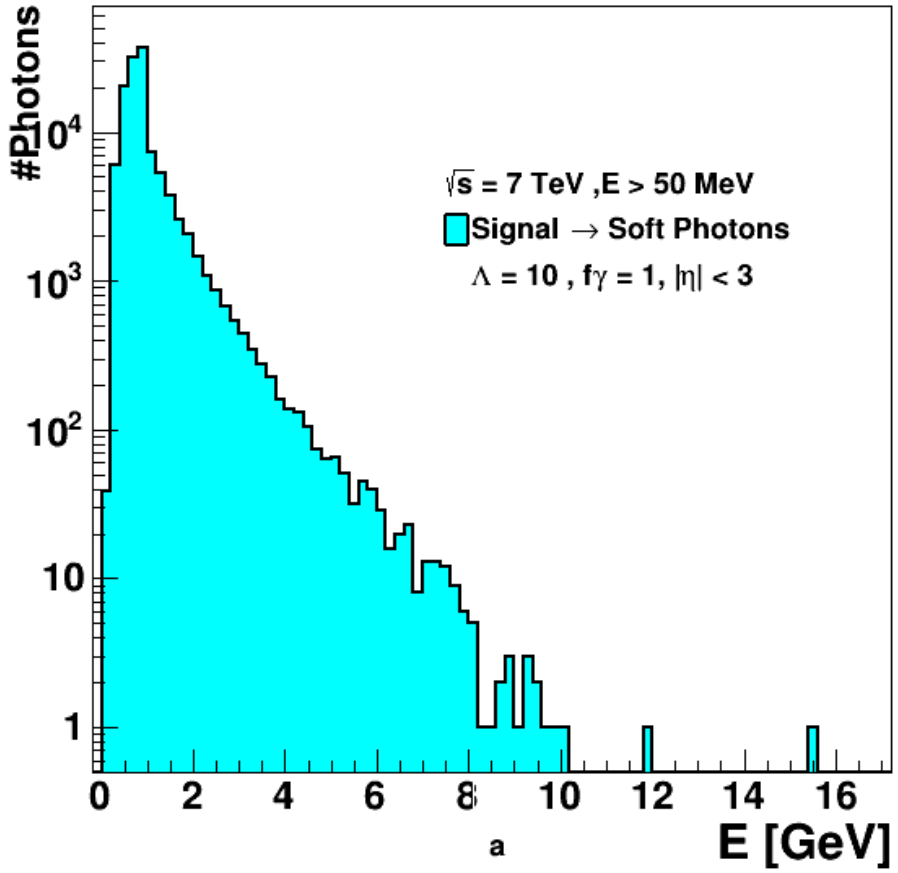


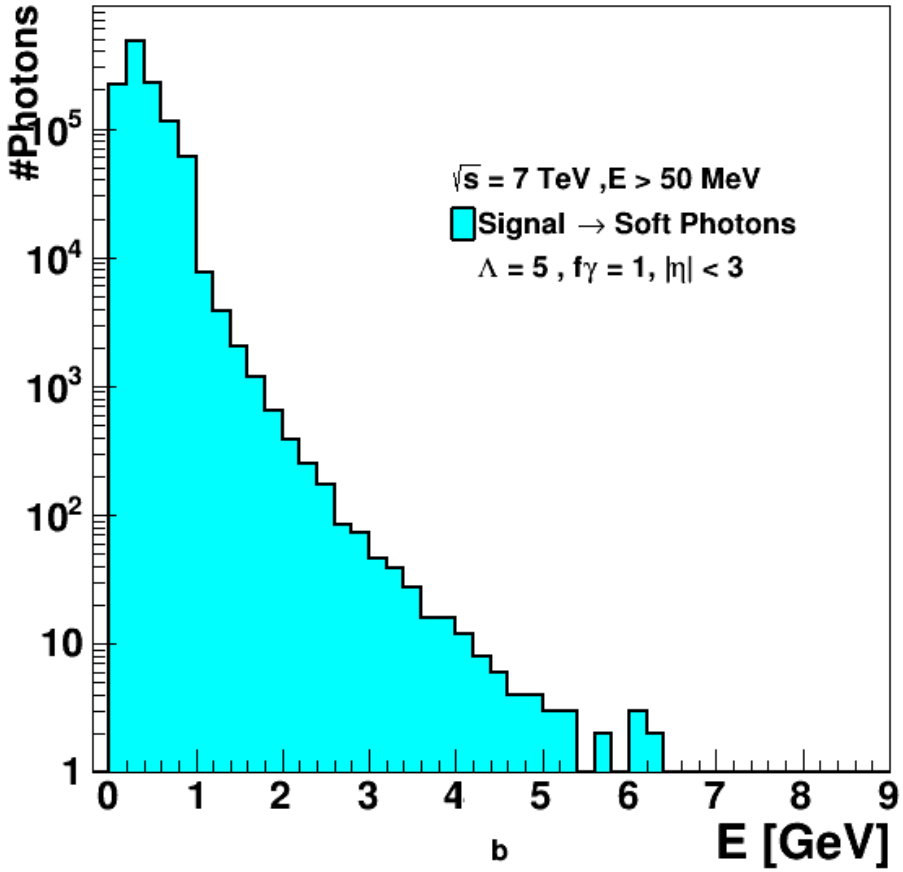
Case (1): glueball emission is suppressed and all of the energy is emitted in photons

Case (2): 50% of the signal will be soft photons and the rest will be glueballs,

For each case we have two kind of string force Λ = 5 GeV and Λ = 10 GeV .

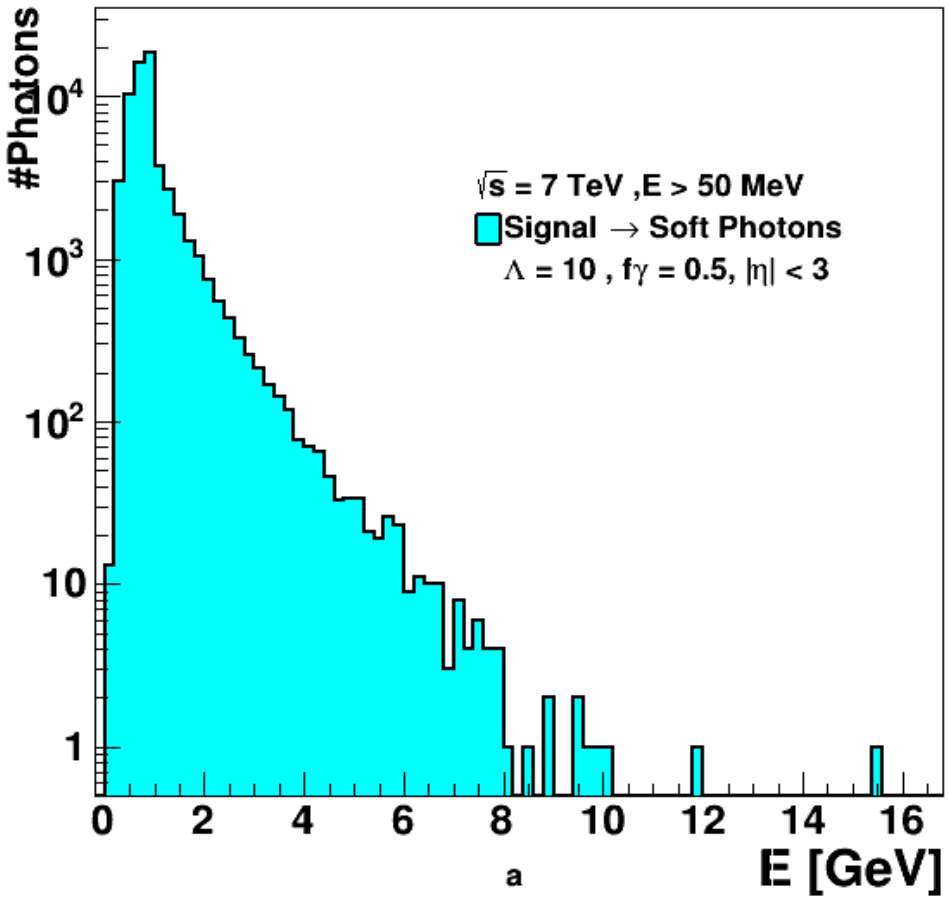
Signal of New Particle

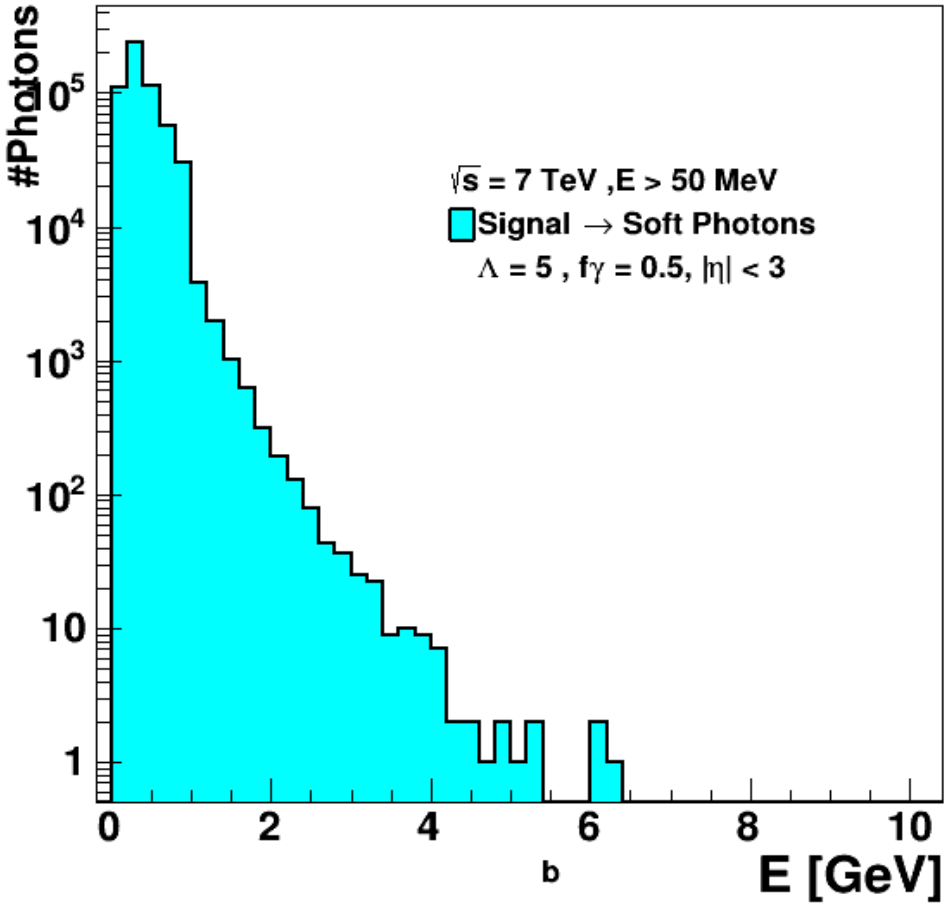




(a) Distribution Energy of Signal with 100% of energy released in photons at Λ =10 GeV.
(b)Distribution Energy of Signal with 100% of energy released in photons at Λ =5 GeV.

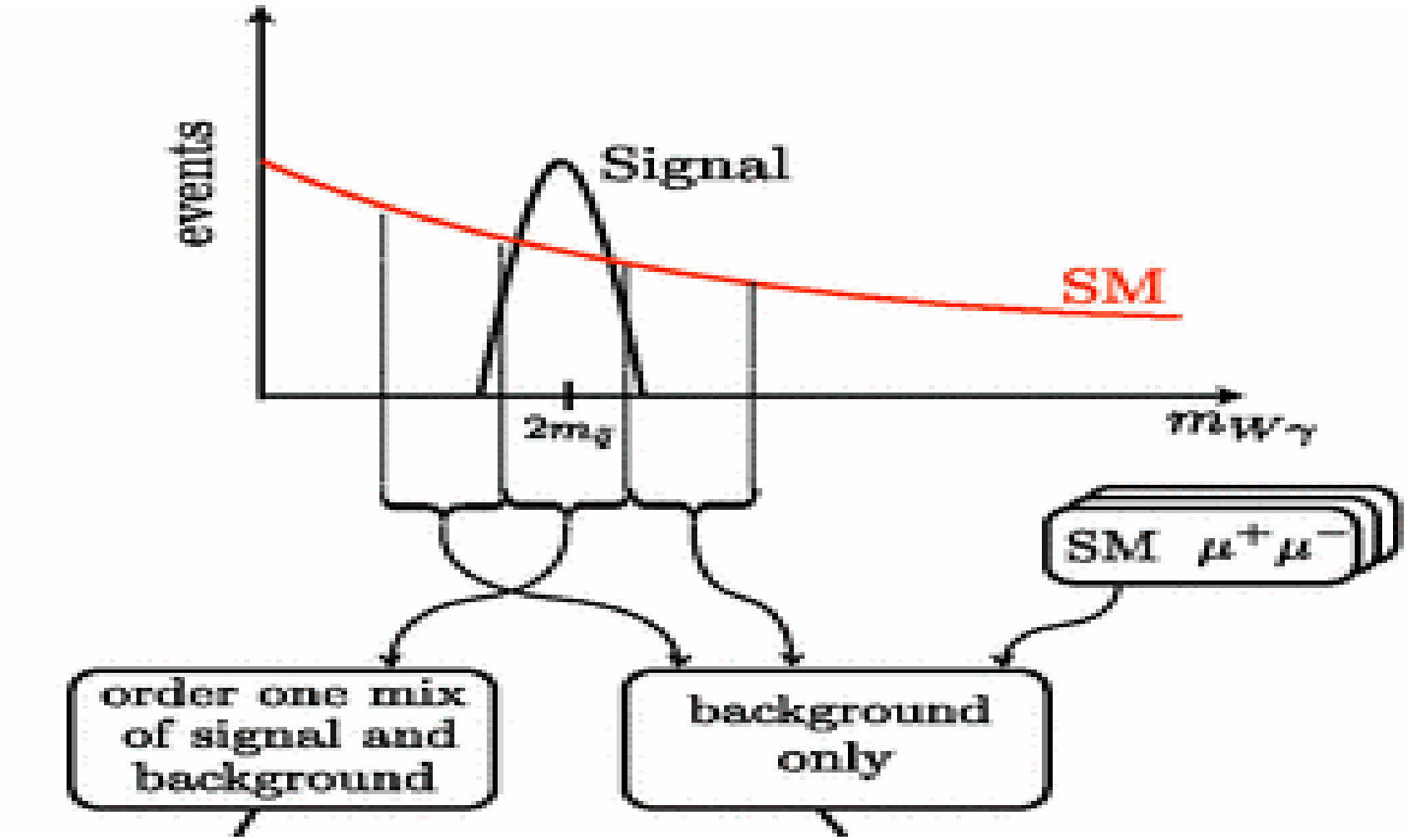
Signal of New Particle





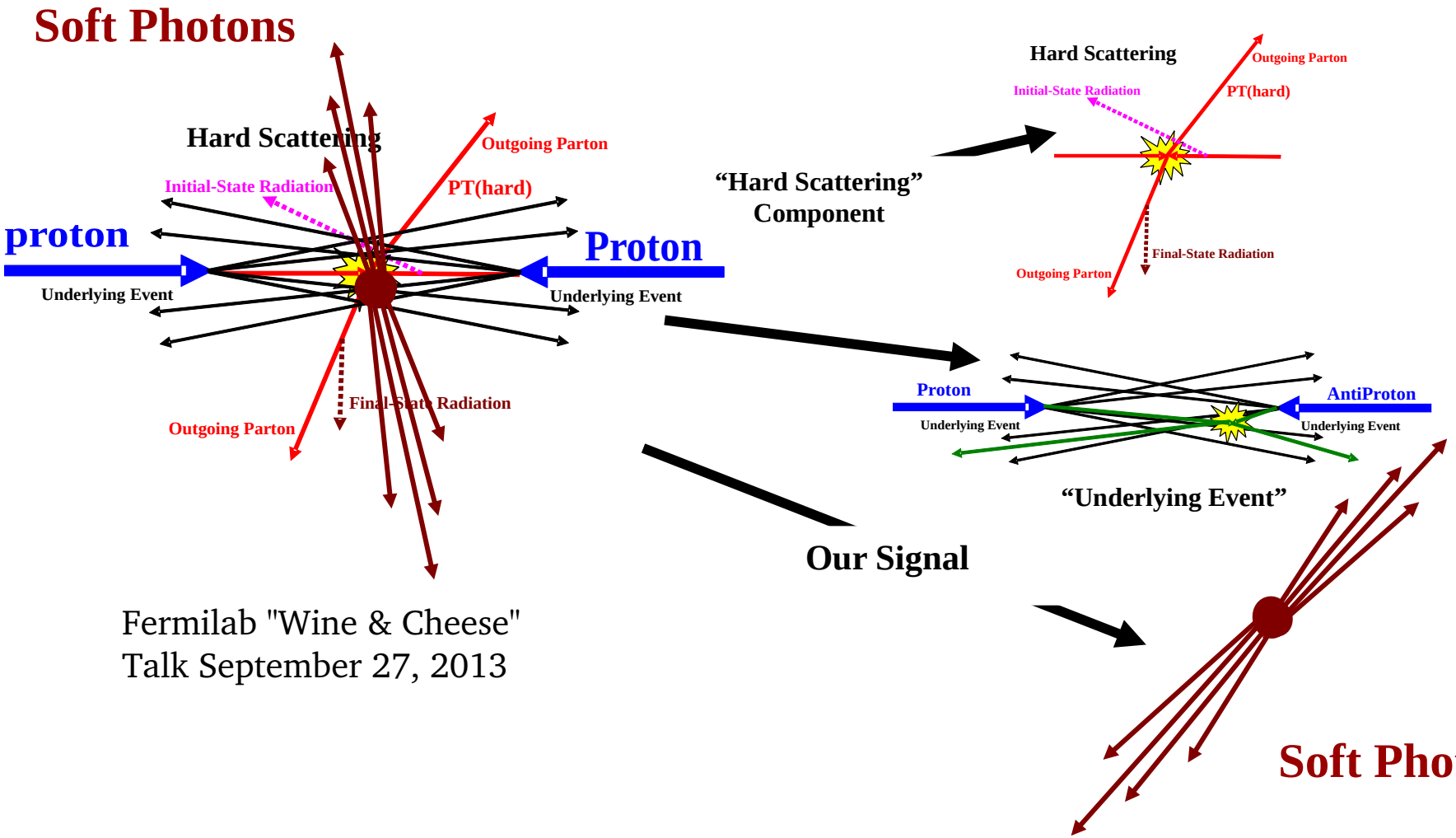
(a) Distribution Energy of Signal with 50% of energy released in photons at Λ = 10 GeV.
(b)Distribution Energy of Signal with 50% of energy released in photons at Λ = 5 GeV.

Possible strategy to making these discoveries



Harnik & Wizansky arXiv:0810.3948

Study the Background at LHC



Fermilab "Wine & Cheese"
Talk September 27, 2013

➔**The "underlying event" consists of the "beam-beam remnants" and defined as "every thing in the event not associated with hard jets or leptons".**

➔**We are looking for Anomalous Tracks which consist of an excess of photons emitted from charged quirks**

Background to the Signal

➔**New Particle Signal: large number of soft photons are emitted.**

➔**Background sample : should consist of the underlying part of soft photon events.**

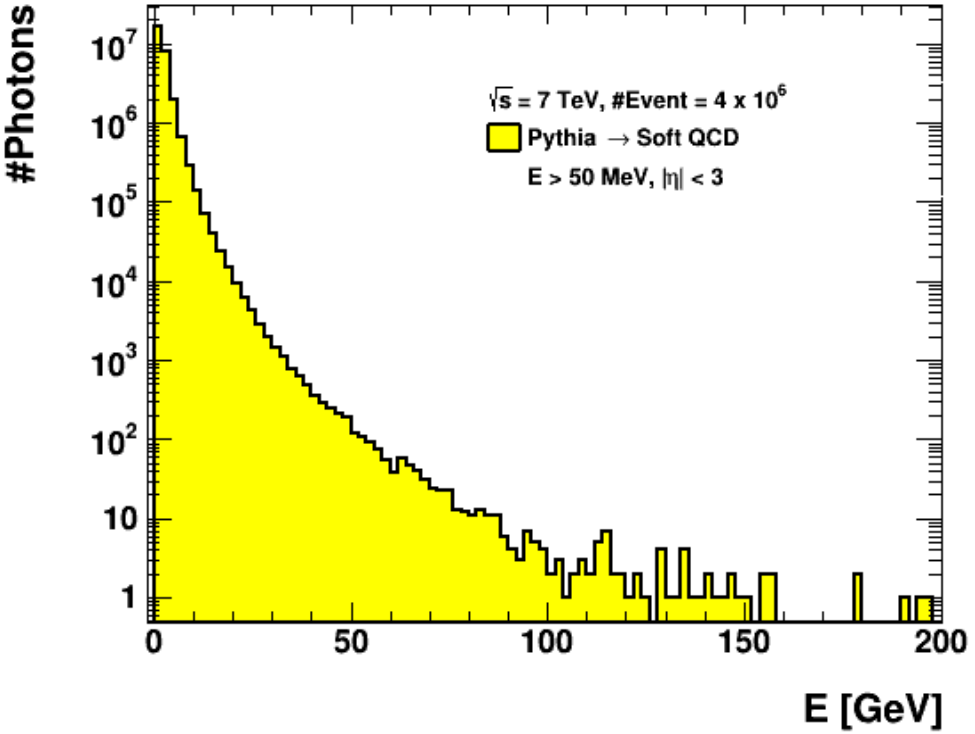
➔**A significant portion of this background is expected to come from pileup of minimum bias which are typical soft QCD events**

➔**Then we used PYTHIA 8 (Tune 4C) program to generate our background as follows:**

1- Minbias events generated through soft QCD channel

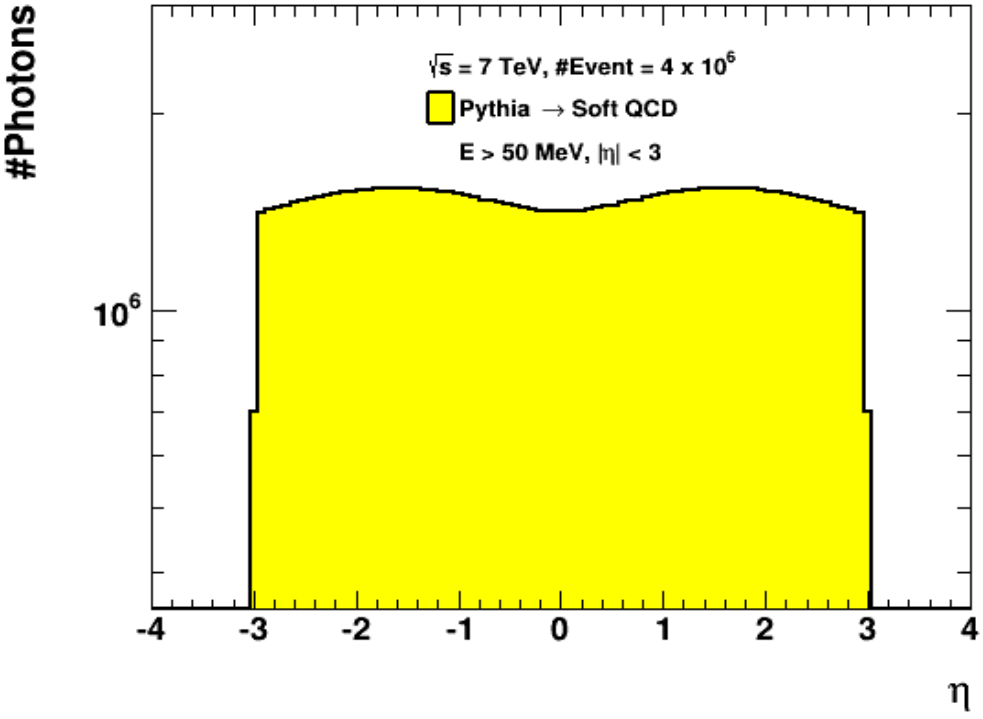
2- Defining all outgoing particles to be photons

Background to the Signal



The Energy distribution of photons producing by Simulated 40 million pp events With Pythia8 (tune4C), through soft QCD channel.

The Pseudorapidity of photons which producing by Simulated 40 million pp events with Pythia8 (tune4C), through soft QCD channel.

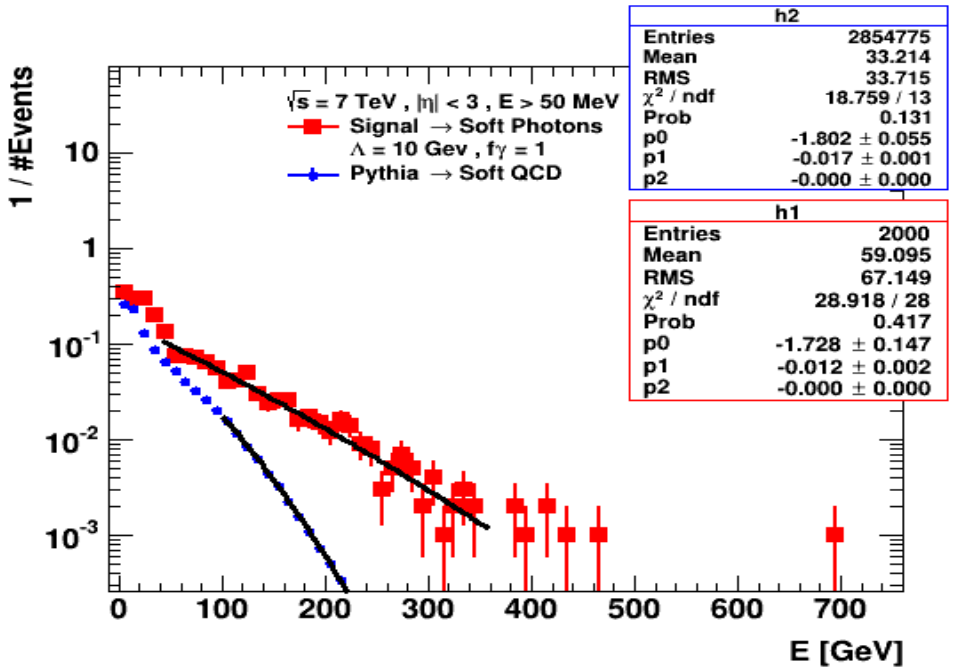


Background and Signal

➔Search for features of signal different from background

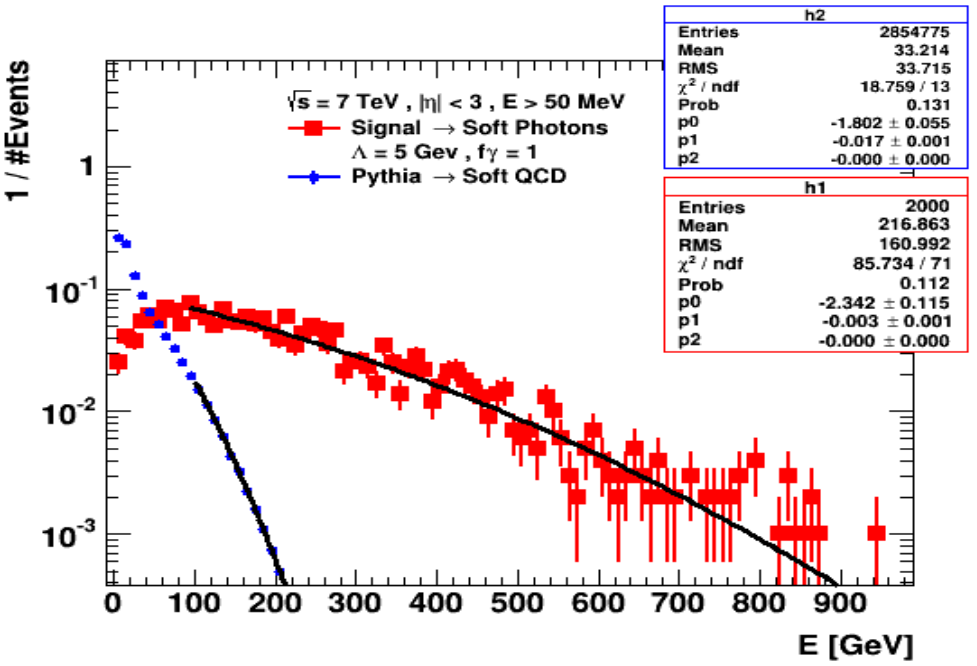
1-study the signal and background in case photons are unclustered.

2-study the signal and background after applying clustering algorithm on the photons



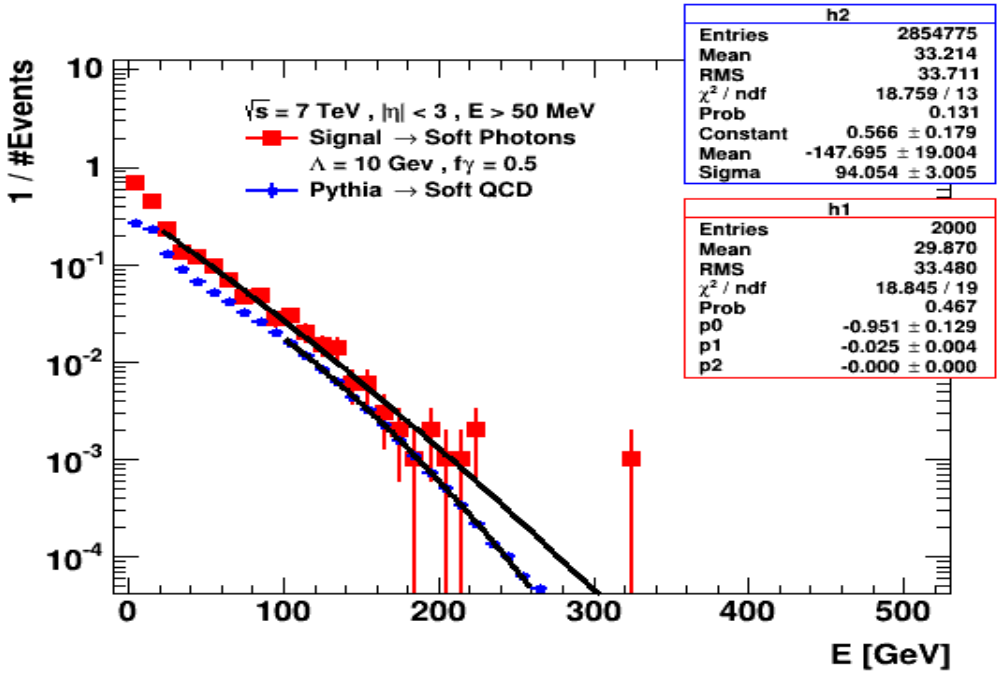
The total energy per event of both signal and background after exponential fitting where String force Λ = 10 GeV and with 100% of the energy released in photons.

The total energy per event of both signal and background after exponential fitting where String force Λ = 5 GeV and with 100% of the energy released in photons.

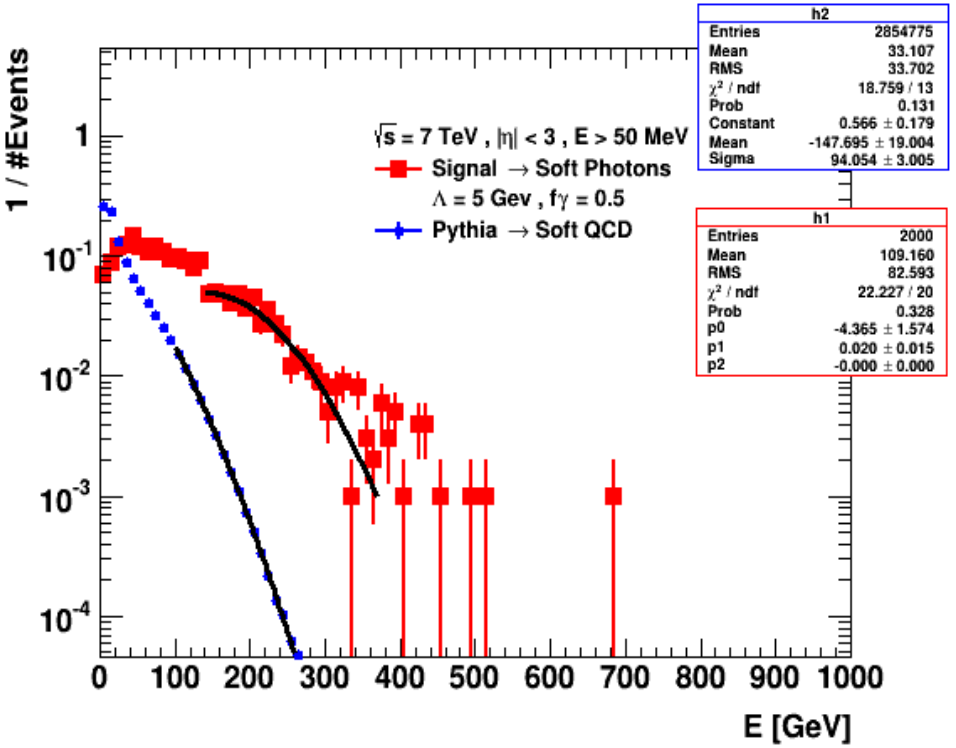


Background and Signal

Unclustered Case



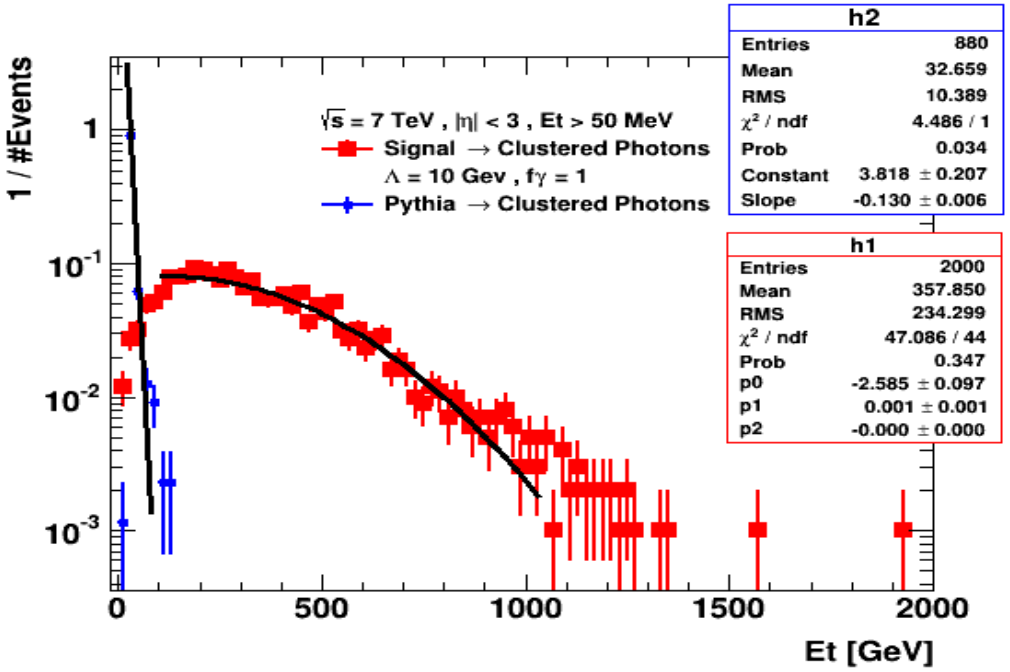
The total energy per event of both signal and background after exponential fitting where String force Λ = 10 GeV and with 50% of the energy released in photons.



The total energy per event of both signal and background after exponential fitting where String force Λ = 5 GeV and with 50% of the energy released in photons.

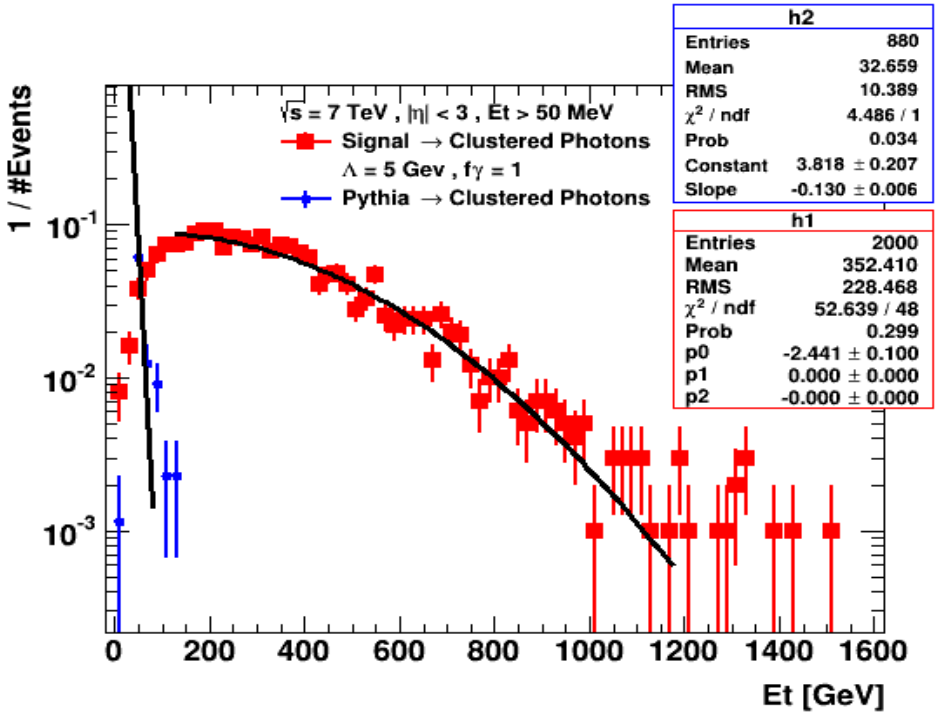
Background and Signal

clustered Case



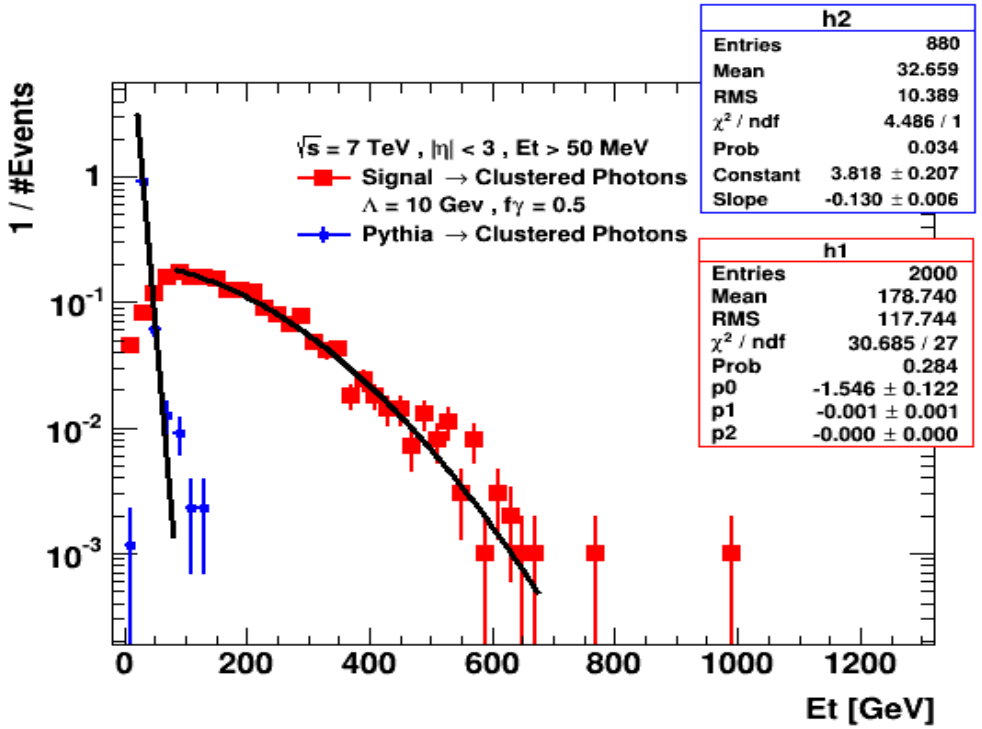
The total transverse energy per event of both signal and background after exponential fitting where String force Λ = 10 GeV and with 100% of the energy released in photons.

The total transverse energy per event of both signal and background after exponential fitting where String force Λ = 5 GeV and with 100% of the energy released in photons.



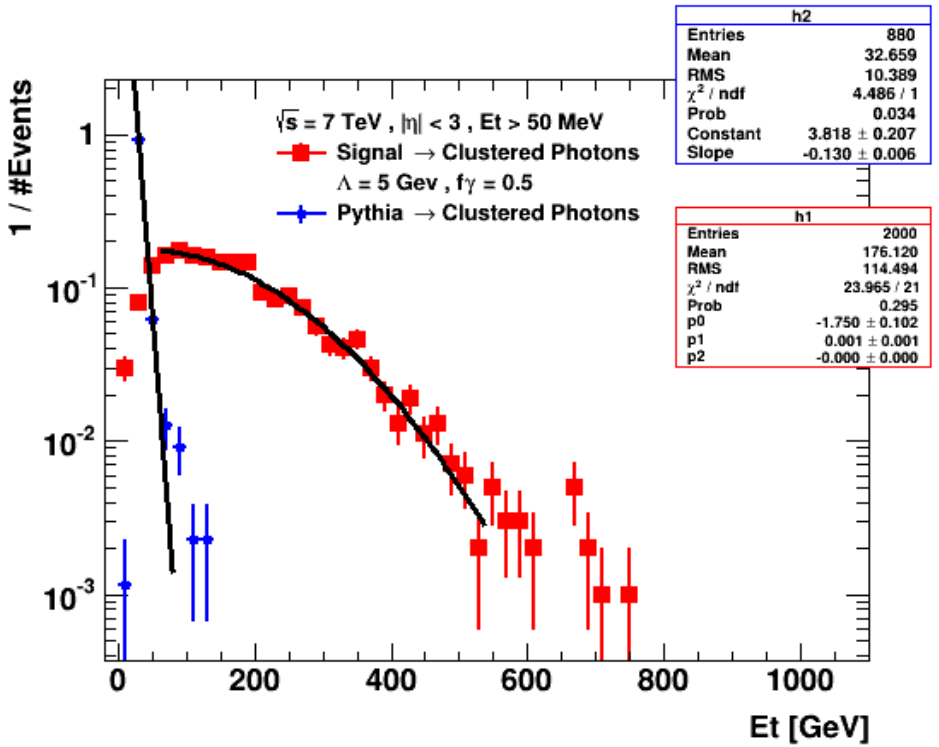
Background and Signal

clustered Case



The total transverse energy per event of both signal and background after exponential fitting where String force Λ = 10 GeV and with 50% of the energy released in photons.

The total transverse energy per event of both signal and background after exponential fitting where String force Λ = 5 GeV and with 50% of the energy released in photons.



Reduction of Background

Enhance the sensitivity to New Physics signals in study of the transverse energy per events containing clustered photons

Photons Selection ⟶ PYTHIA8

1- Select channel → Soft QCD

2- Define all the out coming particles to be photons.

3- Transverse energy Et > 50 MeV → remove background noise in ECAL

4- Pseudorapidity range $|\eta| < 3$ → to cover wide range in the detector.

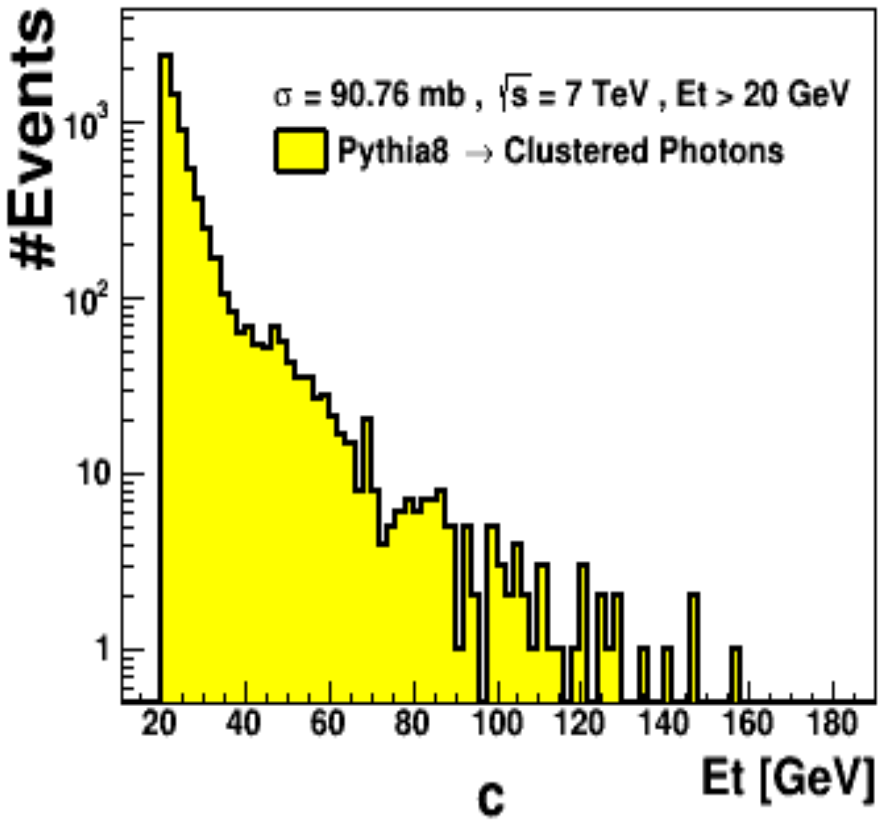
5- Transverse energy inside the of clustered cone Et > 4 GeV.

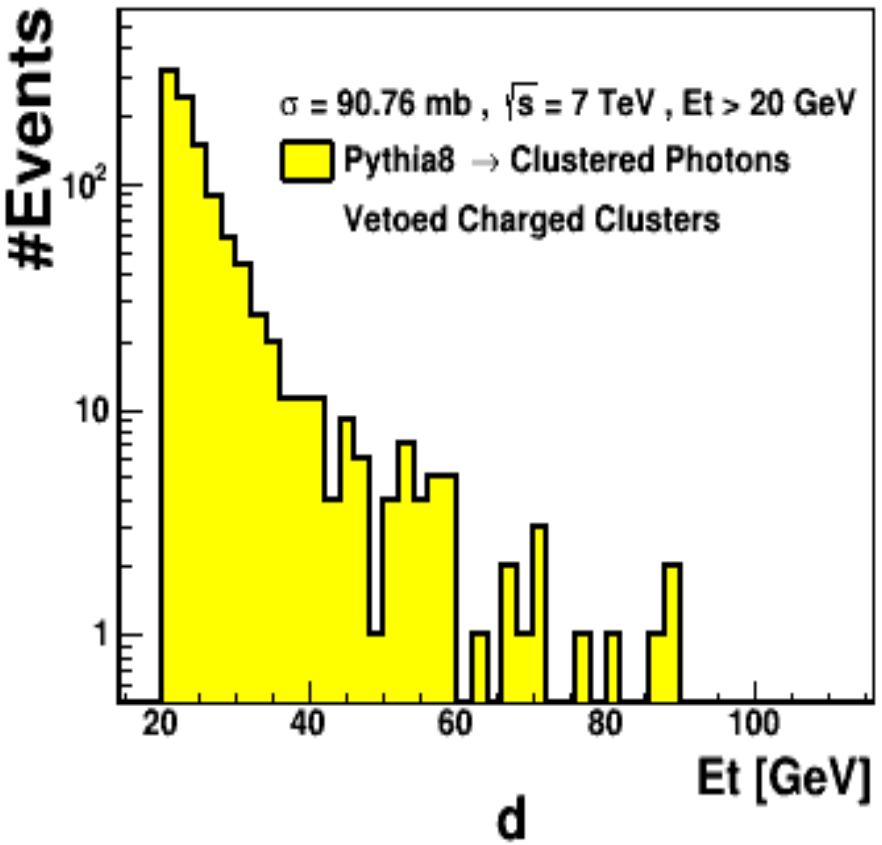
6- The cone radius R < 0.7 cm.

7- Transverse energy correction is applied by remove all cells below 20 GeV.

8- Remove the clusters which have in the same theta phi region of charged clusters

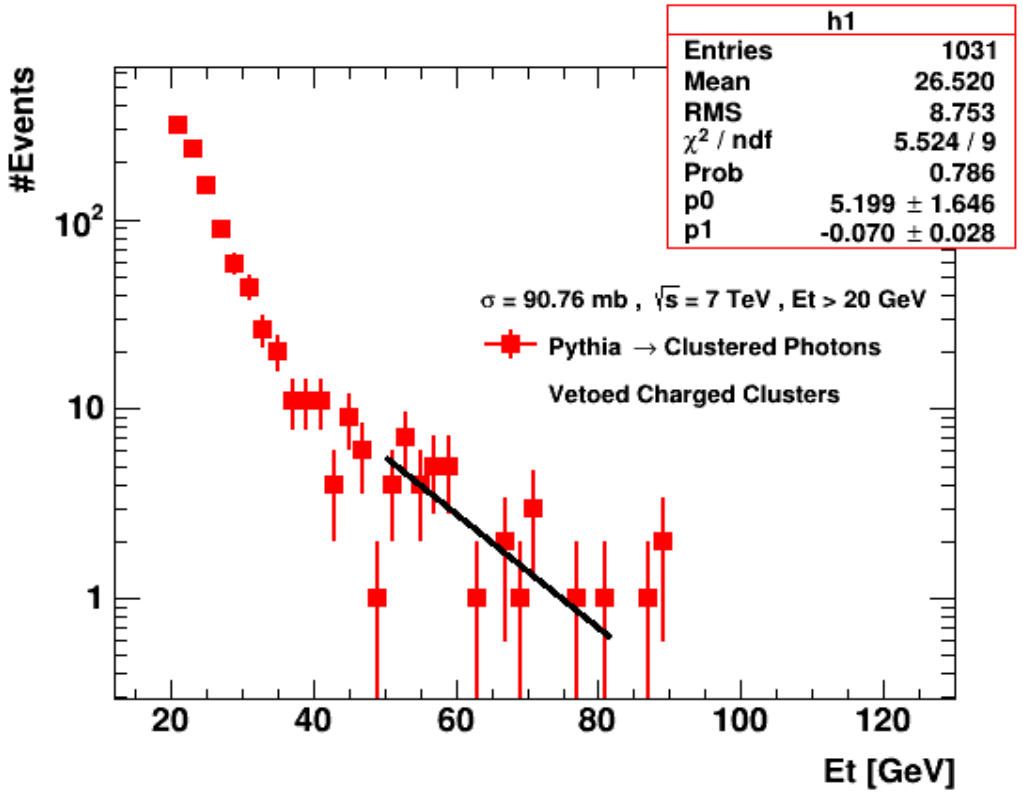
Reduction of Background





(c) transverse energy of clustered photons through soft QCD channel PYTHIA 8,
(d) transverse energy of clustered photons through soft QCD channel PYTHIA 8 after vetoed charged clusters.

Sensitivity to Signal

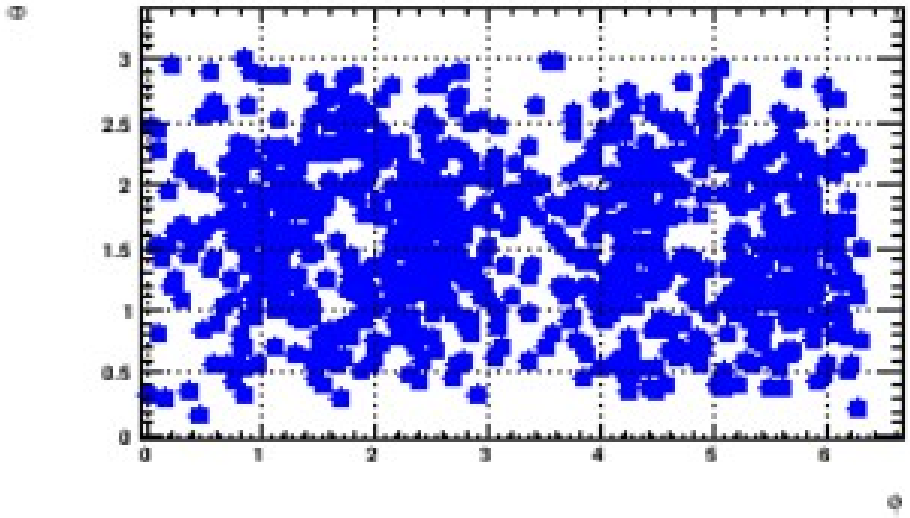


Transverse energy of clustered photons through soft QCD channel PYTHIA 8 after vetoed charged clusters with fitting.

Estimation the cross section for the background at different energies, estimation of the percentage of the "signal" at each energy.

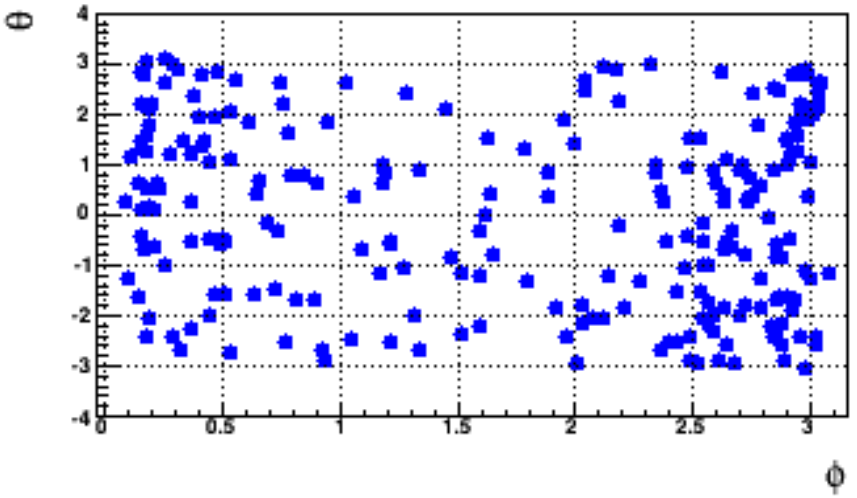
Et [GeV]	Cross Section σ Background	Efficiency of the signal	
		Λ=5 GeV, fγ =100%	Λ=10GeV, fγ =100%
100 GeV	14.98 mb	90%	90.45%
200 GeV	13.66 μb	71.15%	69.6%
300 GeV	12.46 nb	52.7%	49.5%
400 GeV	11.36 fb	33.2%	34.5%

Distribution of Photons



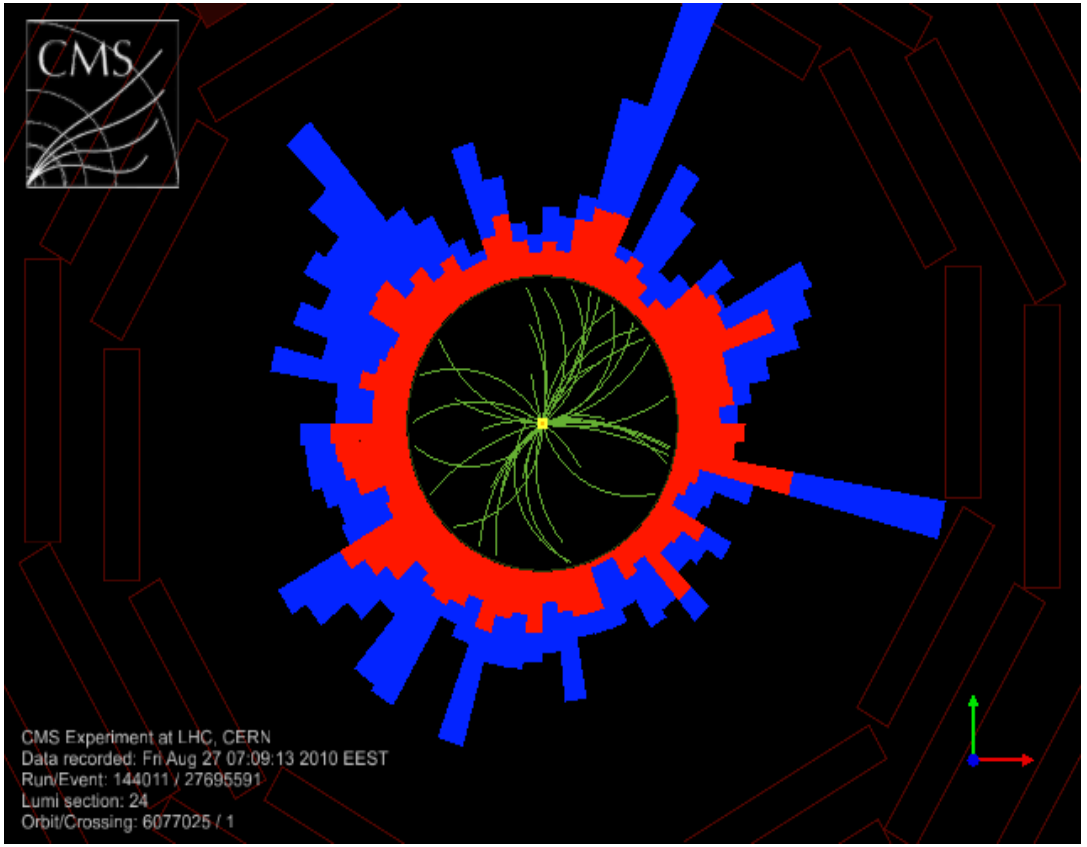
The distribution of photons in (θ , Φ) coordinates , an antenna pattern of soft photons (two cone like shapes aligned with the Quirk production axis)

The distribution of photons in (θ ,Φ) coordinates through soft QCD channel from PYTHIA8



Real Data 2010

CMS had a trigger in 2010 to Look for 160 GeV (HLT) in ECAL, summing energies in towers larger than 200 MeV. About 25 pb-1 of data on tape



A skim of the actual event displayed by CMS Fireworks in (θ, Φ) coordinates

Outlook & Conclusion

1- We have focused on a particular example of new physics.

2-production of new particles which are charged under a new strong force.

3-These particles will shower and hadronize according to the strong dynamics of the new sector.

4-The strong conformal dynamics will load to a fast oscillation (yoyo effect) of two electromagnetically charged particles in the tracker of the experiment, which form a dipole and emit a lot of soft photons.

5-the analysis shows that there is an interesting potential to detect these signatures in the experiment.

6-We are looking to prepare the trigger for the High Energy LHC run 2017, based on the new triggers

Thanks