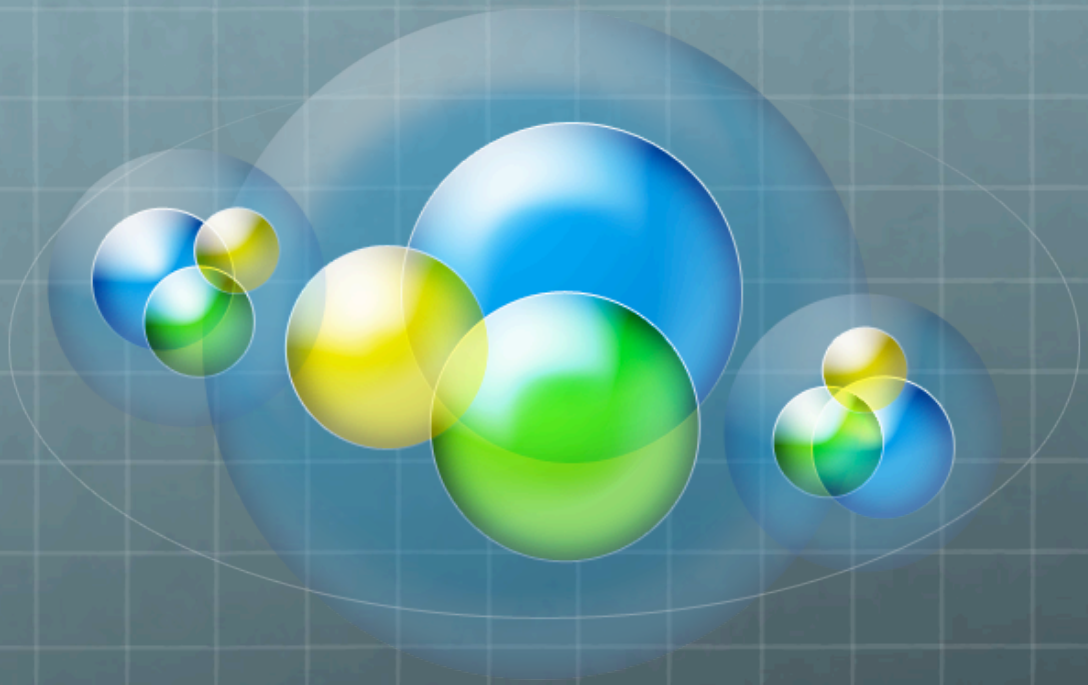

Graviton Search

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August 13, 2010

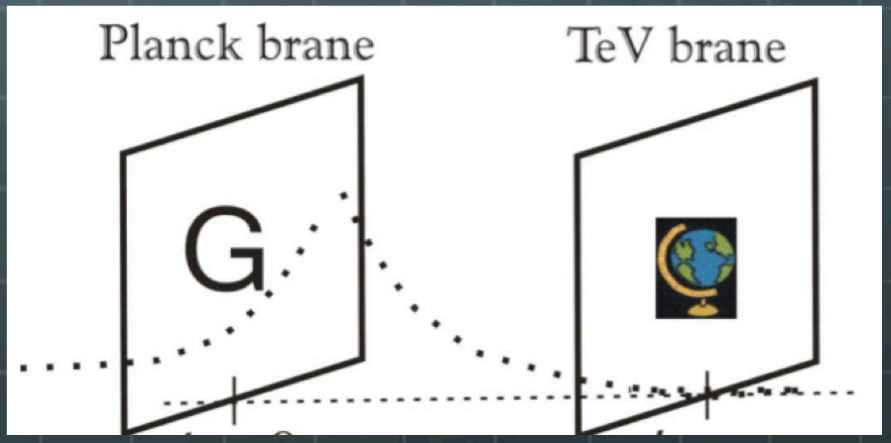
SMU Quarknet Workshop

Outline

- Extra-Dimension Theory
  - Randall-Sundrum Model
- Experiments
  - Tevatron
  - Superconducting Super Collider
  - Large Hadron Collider (LHC)
- Graviton->γγ Analysis
  - Recent Mass Limit
  - Analysis at ATLAS

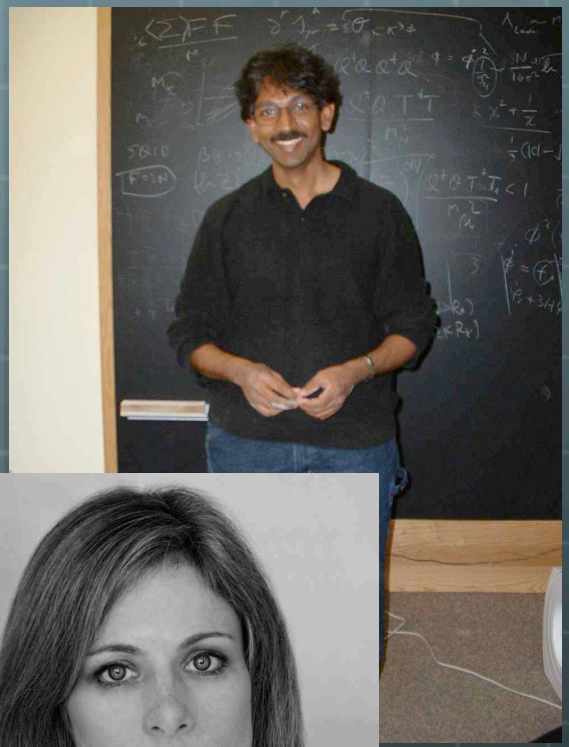
Extra-Dimension Theory

- proposes higher dimensional space in order to solve the so called *hierarchy problem*;
  - discrepancy between the Electroweak scale and Planck Scale
- Electroweak scale (TeV scale): the energy scale ~246 GeV
  - dominates the particles at low energies, standard model particles
- Planck Scale: energy scale around 10^{16} TeV.
- The gravity, one of the four forces of nature, is weak in this Electroweak scale but strong in Planck Scale

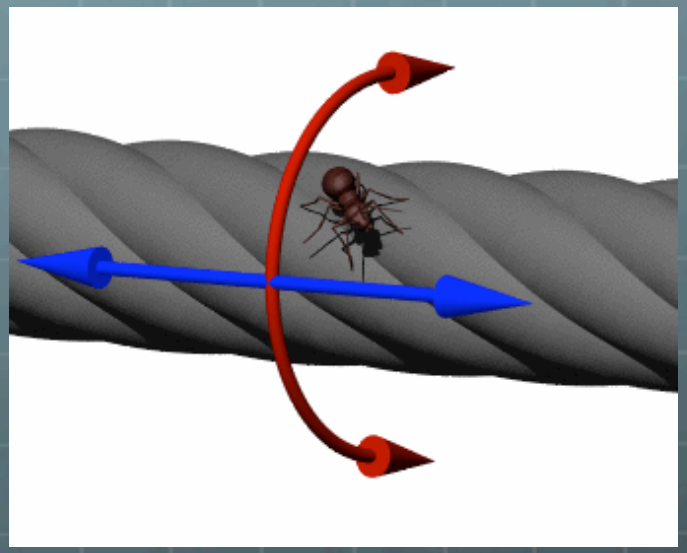


Randall-Sundrum Model

- Randall-Sundrum Model is established by Lisa Randall and Raman Sundrum in 1999.
- particles are restricted to the (3+1) dimensional brane (TeV Brane) and the graviton propagates in all the dimensions.
- *Graviton* is a hypothetical elementary particle that mediates the force of gravity



Randall-Sundrum Model (cont'd)



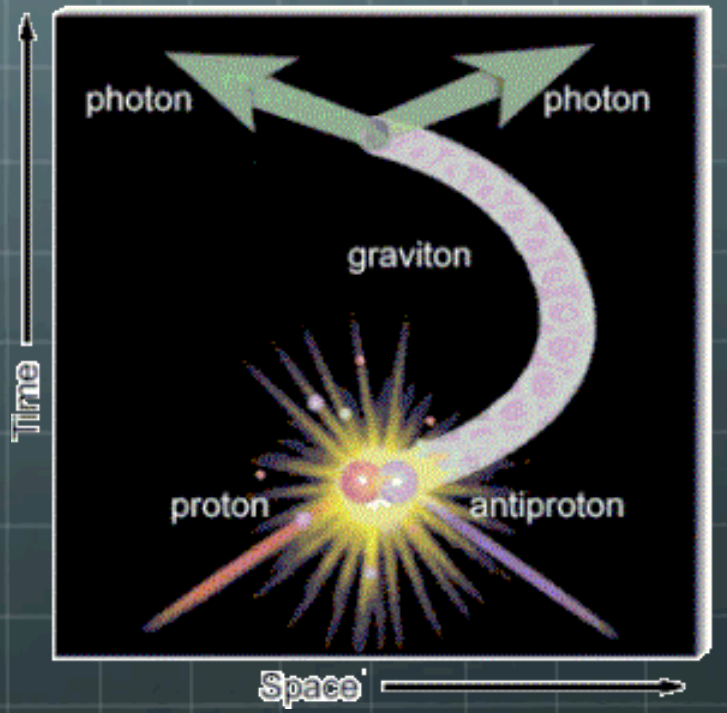
- RS Model states that
  - universe has a warped geometry
  - and the extra-dimensions which are in finite size are curled-up, or "compactified".

- We don't feel the extra dimension because the displacement in our brane is "0" when we move in curled extra-dimension.

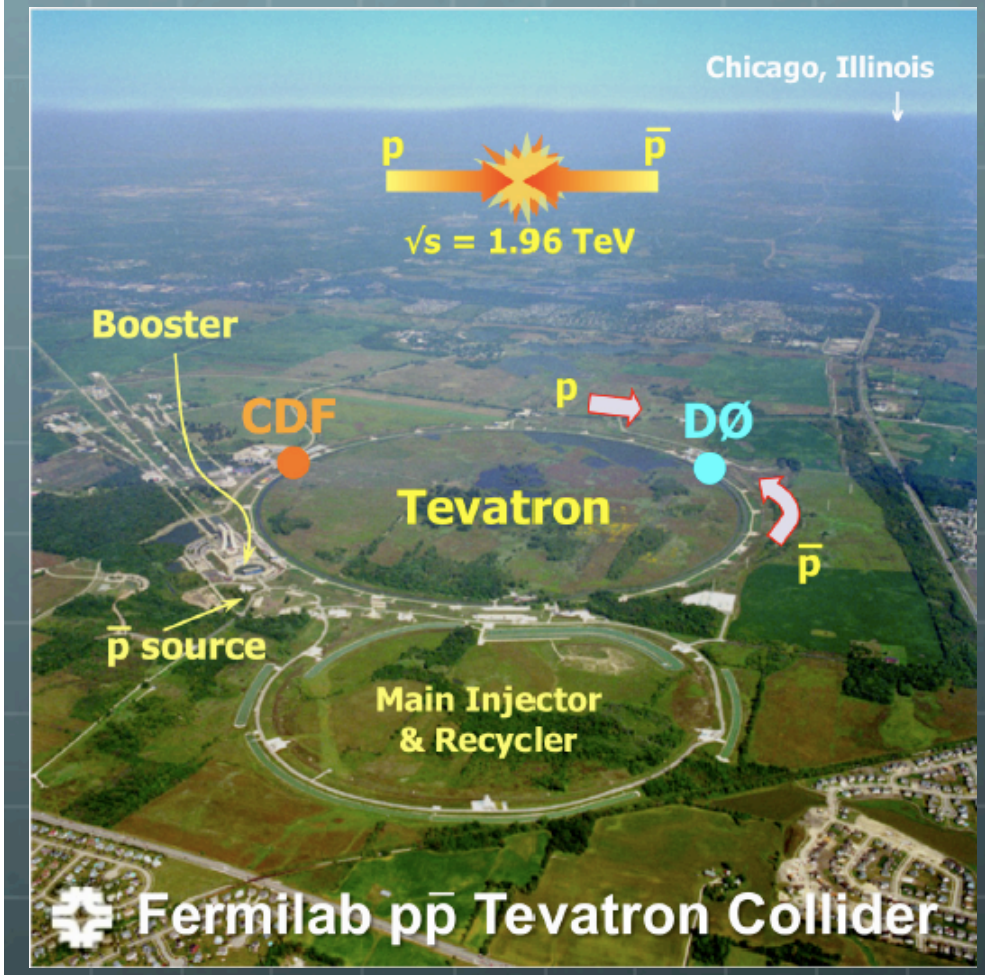
Randall-Sundrum Model (cont'd)

- According to Randall-Sundrum Model, Graviton decays to
  - Dilepton (G*-> e+e-, G*->μ+μ-, G*->τ+τ-)
  - Diphoton (G*->γγ)

- And Proton collisions in high energies produce graviton
- Tevatron and LHC are the highest energy experiments of the world



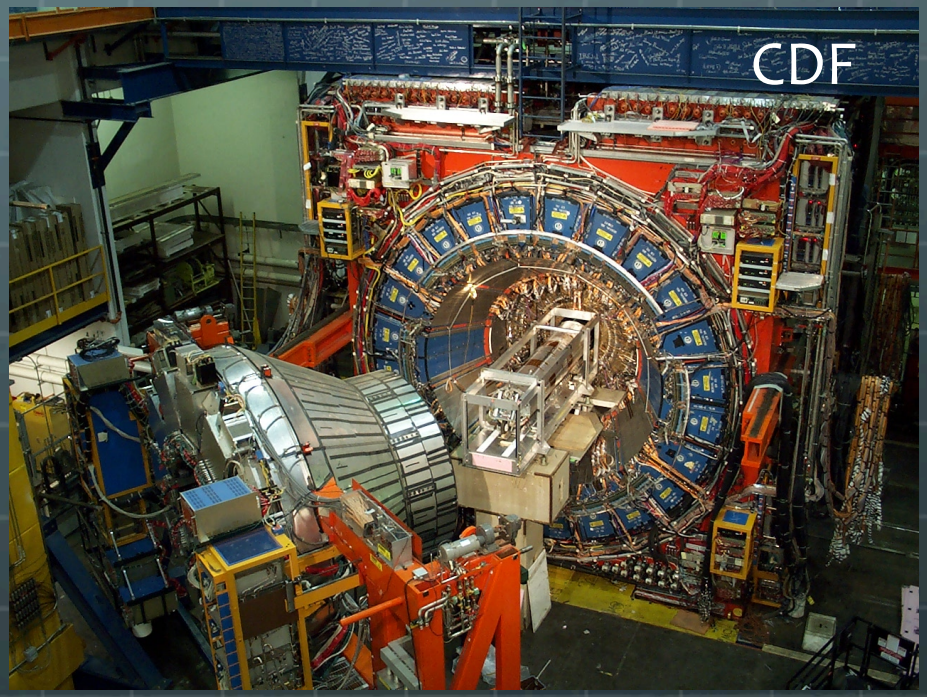
Tevatron



- Located in Brookhaven National Laboratory (BNL), Chicago, Illinois
- World's 2nd highest energy particle collider
- Costs over $400 million
- Running since 1983
- Planned to keep running till 2011 (2012)
- Center of mass energy= 1.96 TeV

Tevatron (cont'd)

- Two experiment in the ring of Tevatron accelerator: DØ and CDF
- In 1995, the CDF and DØ collaborations announced the discovery of the top quark

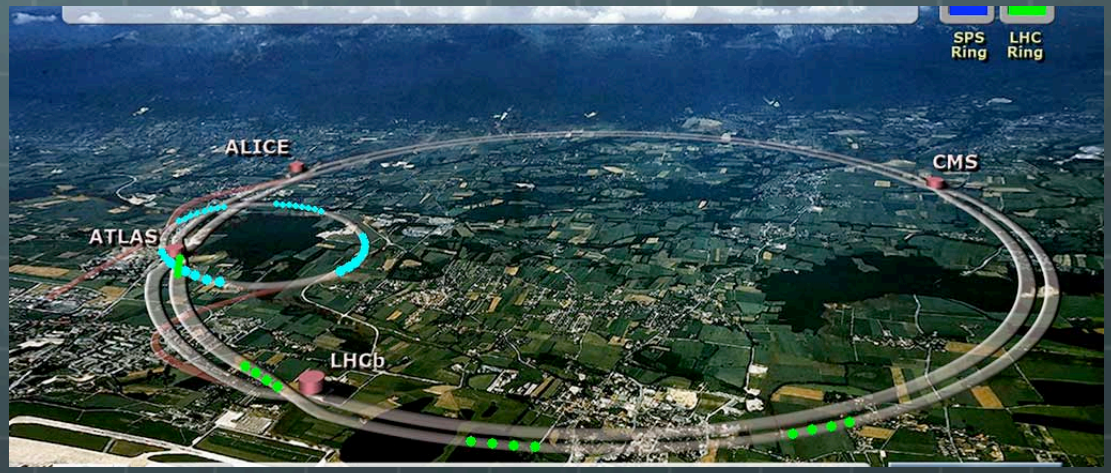


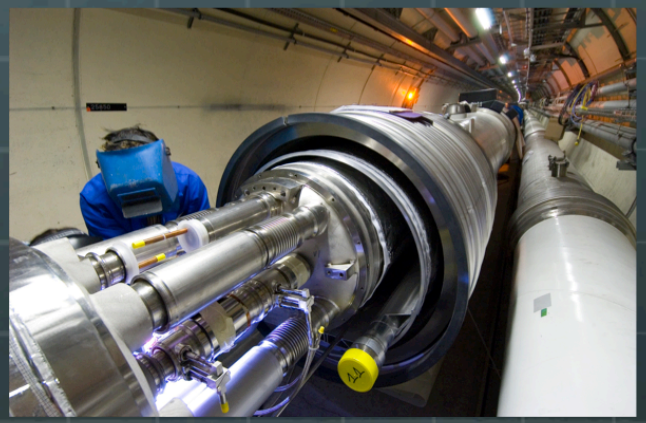
Superconducting Super Collider

- started to be constructed in Waxahachie, TX in 1991
- Canceled in 1993 due to budget issues
  - Available funds are used for LHC
- Center of mass energy=40 TeV
  - 20 times larger than Tevatron
  - 3 times larger than LHC

Large Hadron Collider (LHC)

- World's largest proton-proton collider
- located near Geneva, where it spans the border between Switzerland and France
- Accelerator ring circumference: 27 km, and 100m underground
- Center of mass energy = 14 TeV (each beam has 7 TeV)
  - Now running with 7 TeV center of mass energy
- Experiments: ATLAS, CMS, ALICE, LHCb, TOTEM, LHCf.

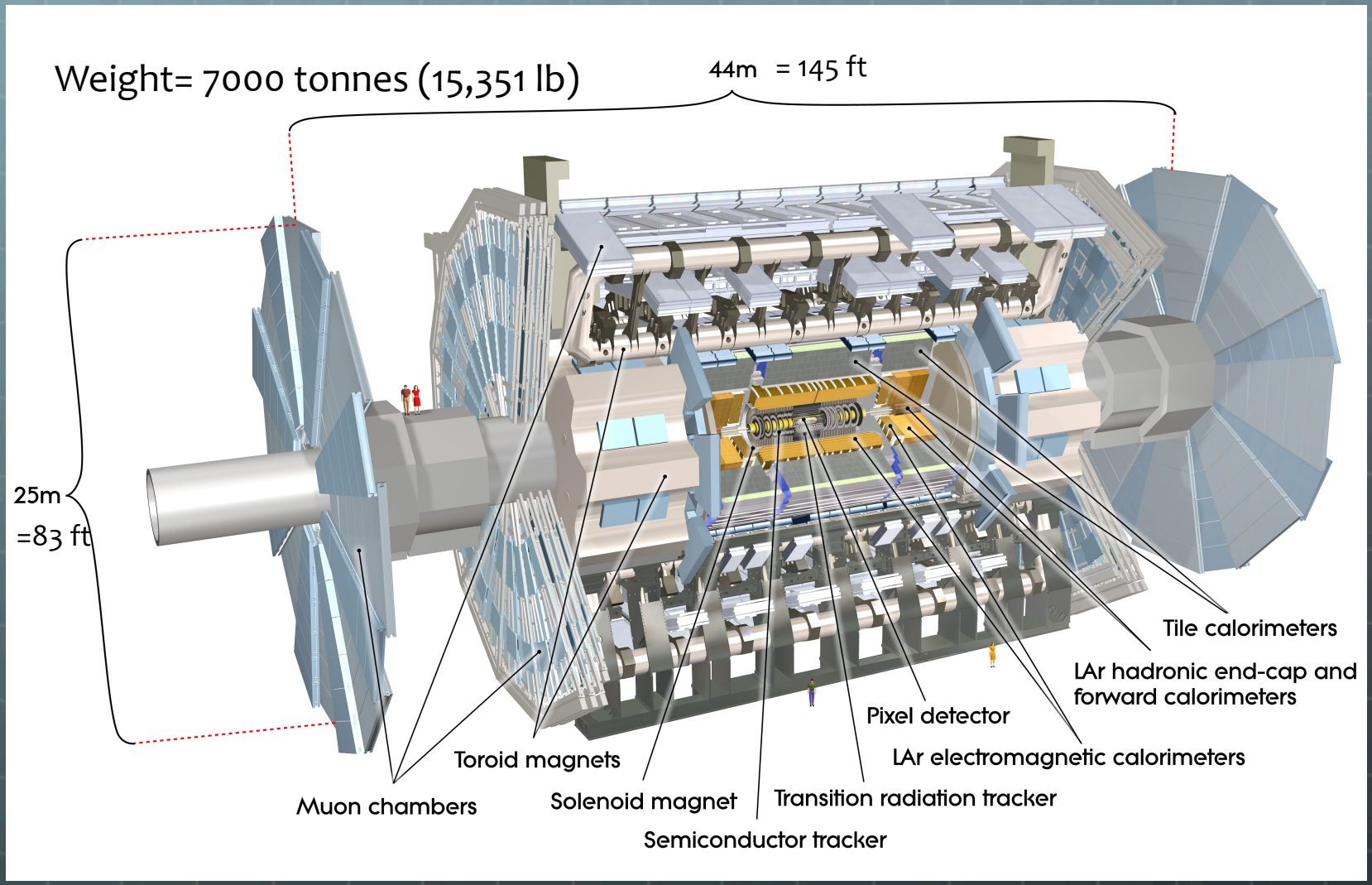




ATLAS EXPERIMENT

- ATLAS is one of two general-purpose detectors at the LHC
- It will investigate a wide range of physics:
  - Higgs boson,
  - extra dimensions,
  - particles that could make up dark matter
- will record sets of measurements on the : their paths, energies, and their identities.
- More than 2900 scientists from 172 institutes in 37 countries

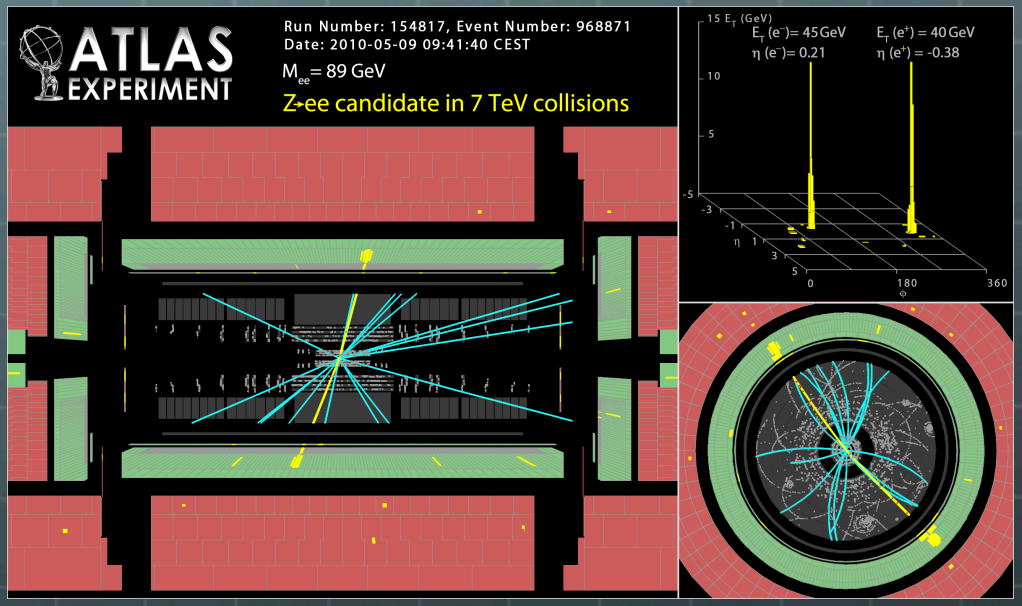
ATLAS (cont'd)

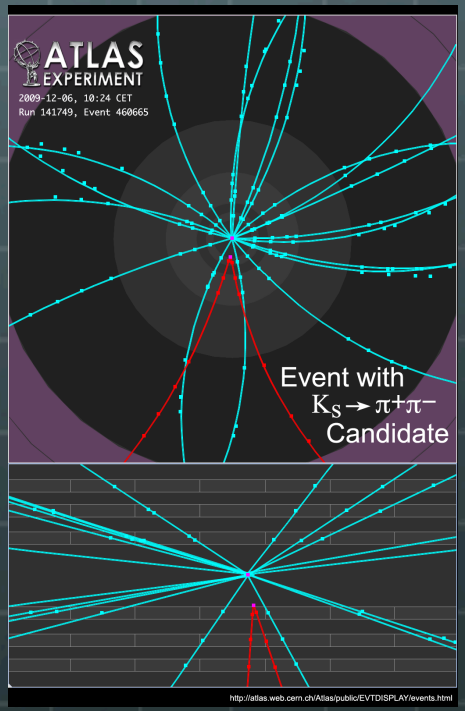


http://www.atlas.ch/detector-overview/detects-particles.html

ATLAS (cont'd)

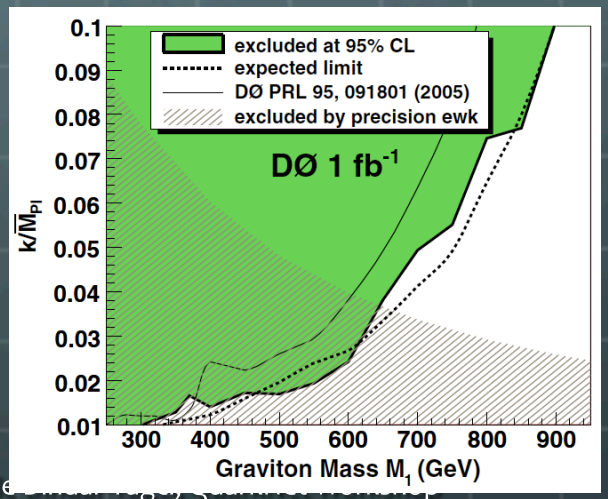
- On November 23, 2009 ATLAS collaboration saw the first collisions at 900 GeV .
  - The world record of 2.36 GeV on November 30, 2009
- And on March 30, 2010 saw the first collision at 7 TeV
  - http://www.atlas.ch/multimedia/html-nc/animation-7TeV-event.html

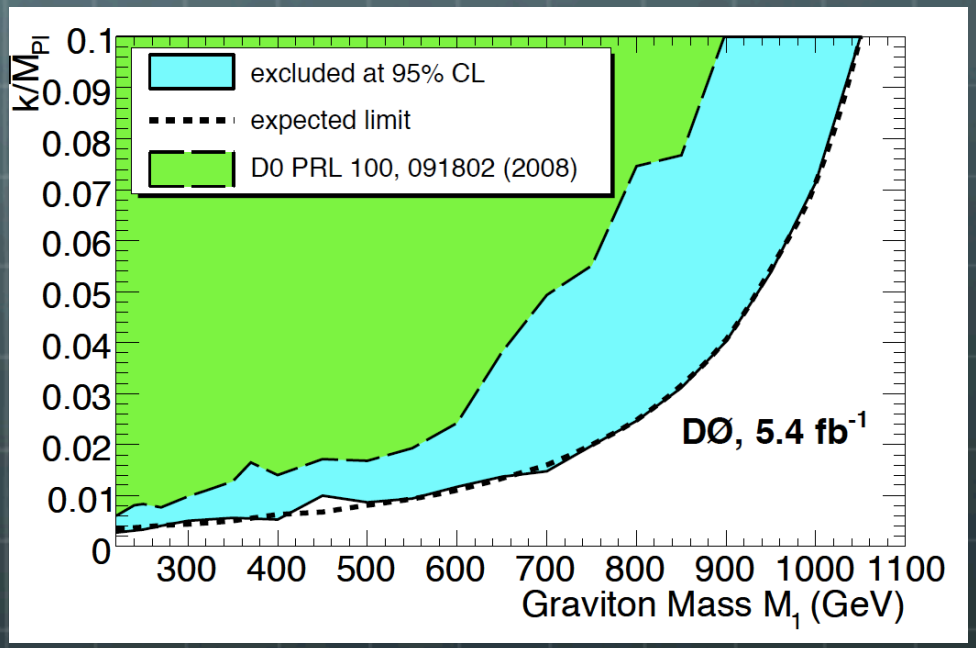




Recent Limit on Graviton Mass

- analyses on the Tevatron data put limits on the graviton mass
- 1 fb^{-1} DØ (2008) data excluded Graviton $M_G < 300\ GeV/c^2$
- 5.4 fb^{-1} DØ data (2010) excluded Graviton $M_G < 560\ GeV/c^2$
  - with coupling $k/M_{Pl}=0.01$
  - M_{Pl} : effective Planck scale
  - k: curvature of extra dimension





Graviton->γγ Analysis at ATLAS

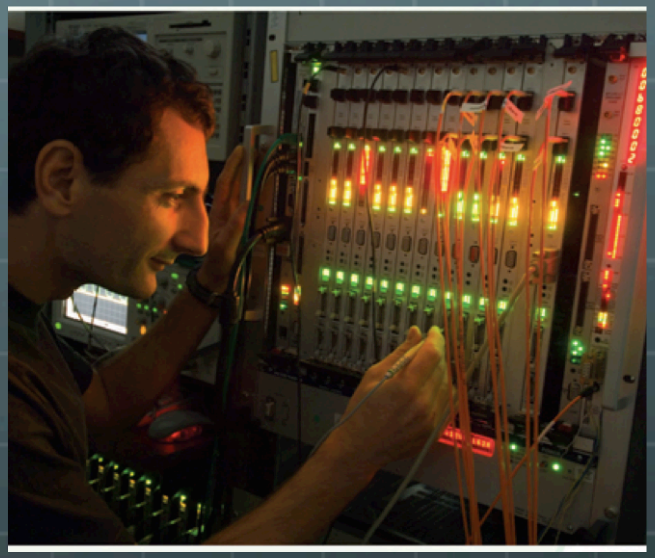
- Current ATLAS luminosity is ~1 pb^{-1}
  - not enough to detect or exclude Graviton mass
  - How much luminosity we need to beat DØ limit (560 GeV)?
- simulation datasets are used to estimate the limits
- These datasets are generated by PYTHIA
- PYTHIA is the event generator system that reflects the theoretical calculations

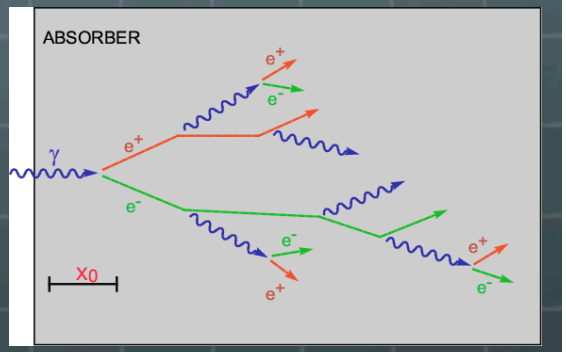
G*->γγ Analysis at ATLAS (cont'd)

- Till mid 2009, I studied the Graviton at 14 TeV energy
  - Since this was the planned center of mass energy
- Simulation Datasets
  - Signal: M_G=500 GeV/c² and M_G=1 TeV/c² (k/M_{Pl}=0.01)
  - Background: Diphoton, γ + Jets, Dijets
    - Probable pairs those looks like Graviton signal

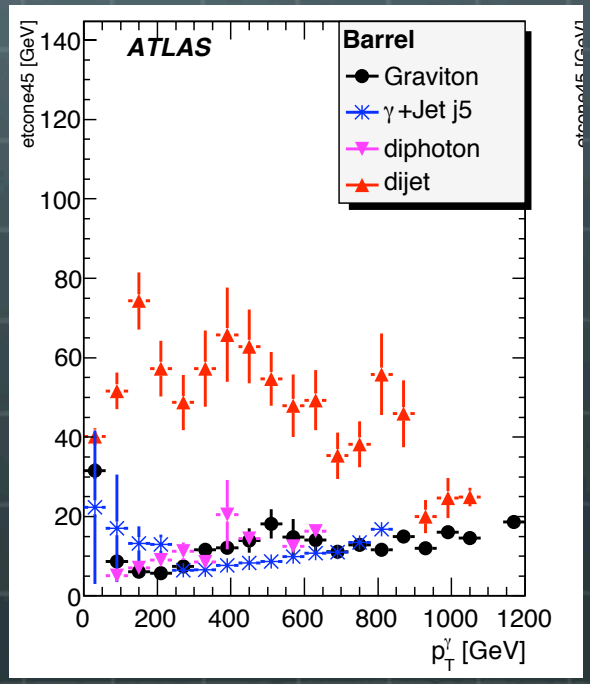
G*->γγ Analysis at ATLAS (cont'd)

- We selected the diphoton events from data based on
  - interesting collisions (by electronic system: trigger)
  - The shower shapes in the Electromagnetic calorimeter
    - Photons produce shower in EM calorimeter as deposits energy
  - P_T (transverse energy)





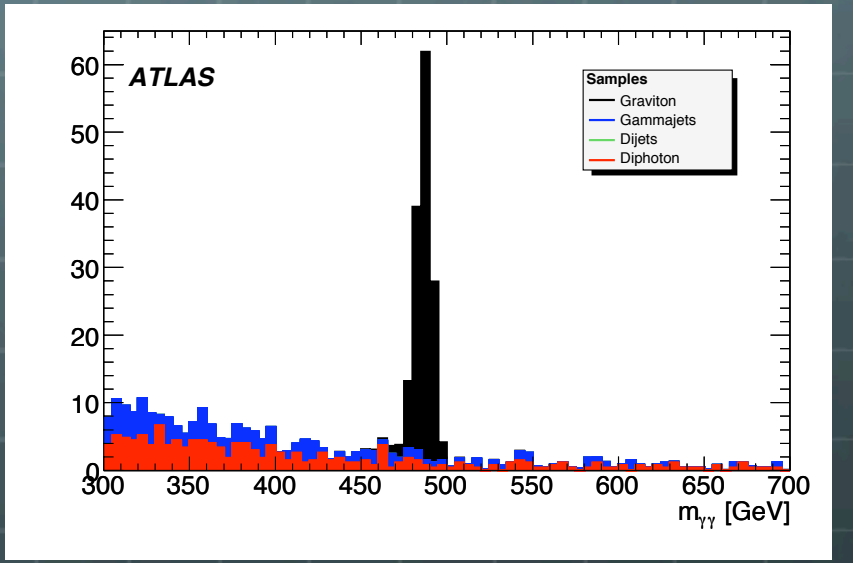
Etcone45: energy deposited in cone of 0.45 rad



G*->γγ Analysis at ATLAS (cont'd)

- Event yields for G->γγ 500 GeV/c^2 signal normalized to 1fb^{-1} luminosity are listed in table:

Sample	σ × BR (pb)	Yield 470 < $m_{\gamma\gamma}$< 500 1fb^{-1}
Graviton M_G = 500 GeV/c^2	0.38	137.7±2.3
Diphoton	0.66	6.3±1.5
γ+Jets	211.66	5.7±1.9
DiJets	329860	0.028±0.003



- we estimated that 13 pb^{-1} integrated luminosity is needed to exclude *Graviton M_G = 500 GeV/c^2* (k/M_{Pl}=0.01)
  - at 14 TeV with 95% C.L.

G*->γγ Analysis at 7 TeV

- According to our latest analysis in 7 TeV Data simulation data shows that
  - 78 pb^{-1} integrated luminosity is needed to exclude 500 GeV Graviton mass with $k/M_{Pl}=0.01$
  - However 10 pb^{-1} will be enough to put a limit above 600 GeV, if the G->γγ coupling is greater than 0.03.
- LHC is going to reach the 10 pb^{-1} luminosity this winter
  - So will have enough data to go further than Tevatron limits