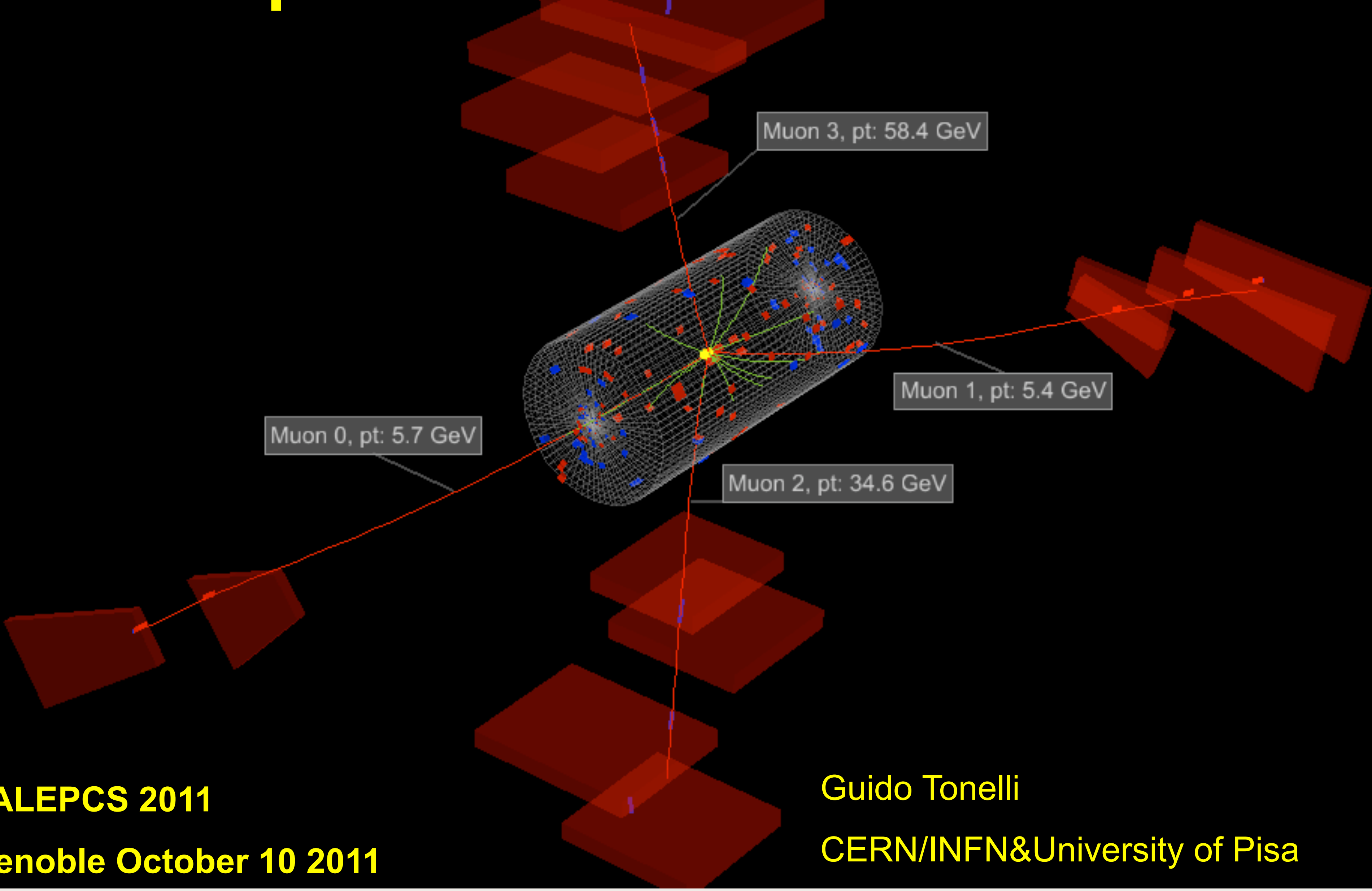
First Physics Results from LHC and expectations for the near future



ICALEPCS 2011

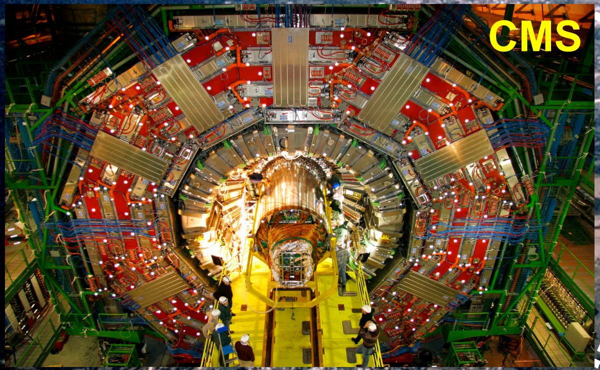
Grenoble October 10 2011

Guido Tonelli

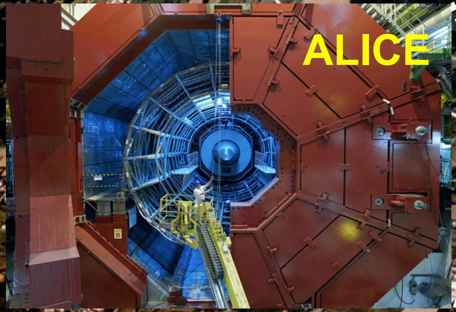
CERN/INFN&University of Pisa

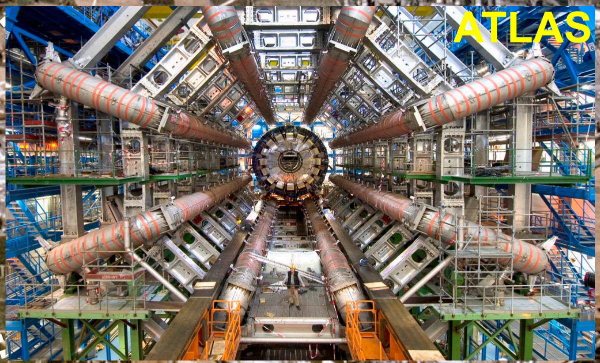
With LHC we are entering a New Era in Fundamental Science

The Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is a turning point in modern physics.

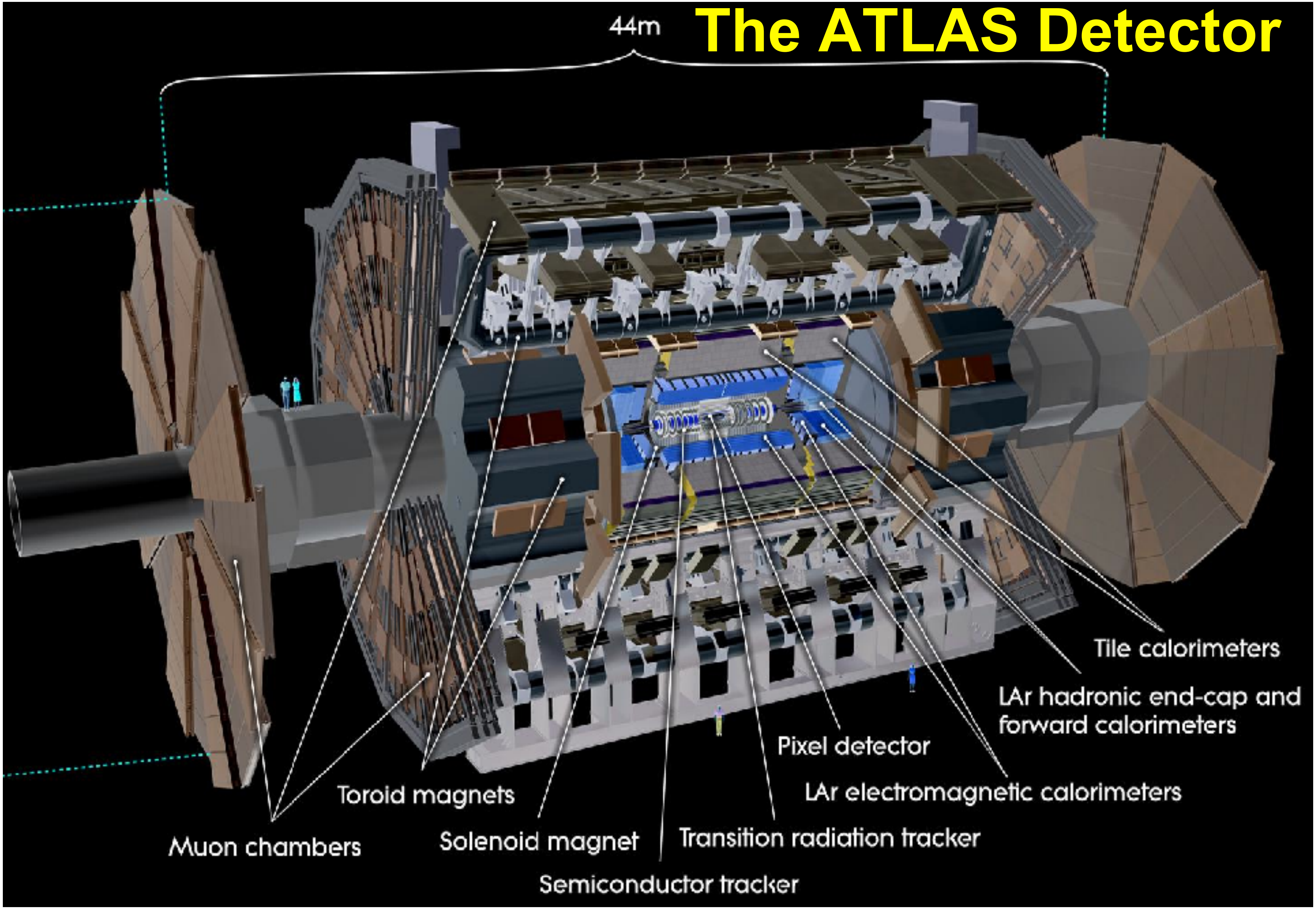


The exploration of a new energy frontier just started





The ATLAS Detector



Why everything is so complex?

•We are trying to solve some of the main puzzles of nature

• What is the origin of mass: **Higgs Scalar Field?**

• What is the dark matter that keeps together the clusters of galaxies: **Gas of Heavy Neutralinos?**

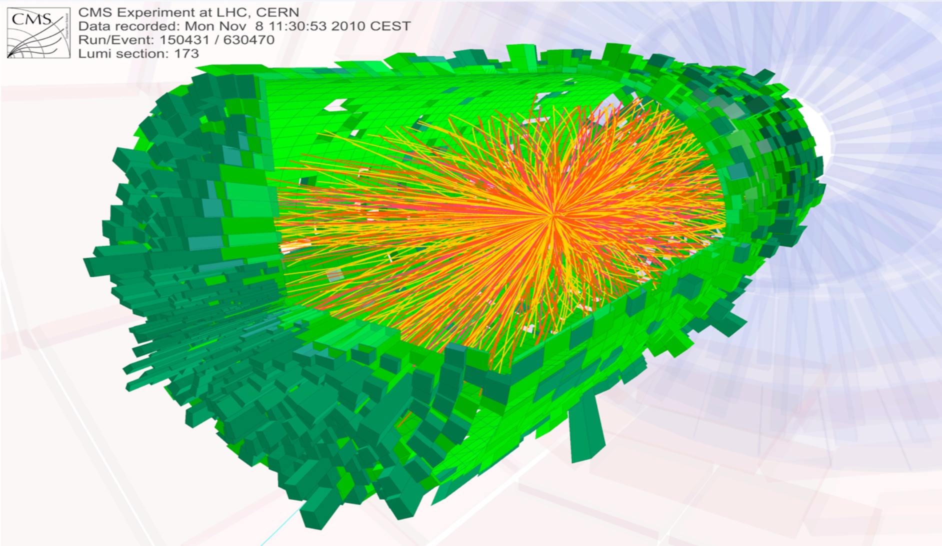
• What is the origin of the large asymmetry between matter and anti-matter in the Universe**: New Generation of Quarks? Large CP violating effects?**

• What was the state of matter in the very first instants after the Big-Bang: **Quark Gluon Plasma?**

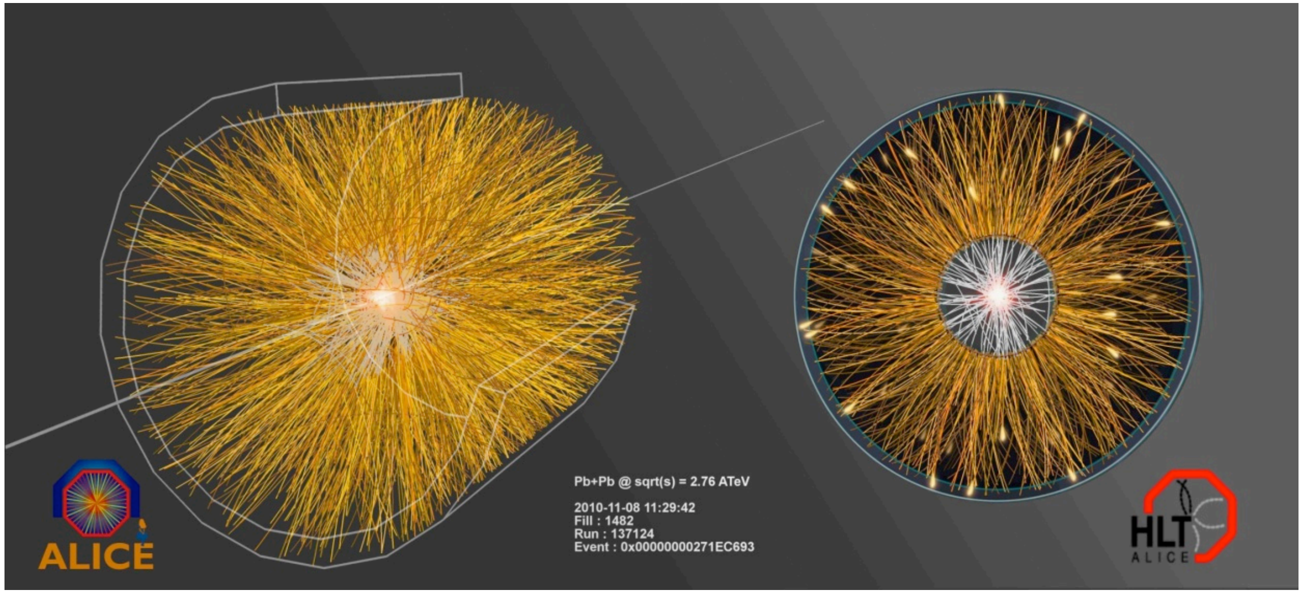
• Why gravity is so weak: **Extradimensions?**

•The answer to some of these questions is probably hidden in the so far un-explored multi-TeV region made accessible by LHC

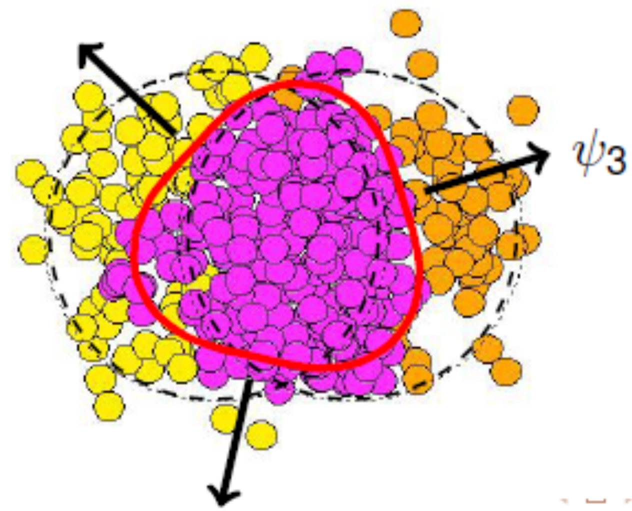
Quark- Gluon Plasma produced at LHC



- Lead Ions Collisions in LHC (November10)
- Compress a large amount of energy in a very small volume.
- Thousand of particles produced per event.



Pb-Pb@$\sqrt{s_{NN}}$=2.76TeV



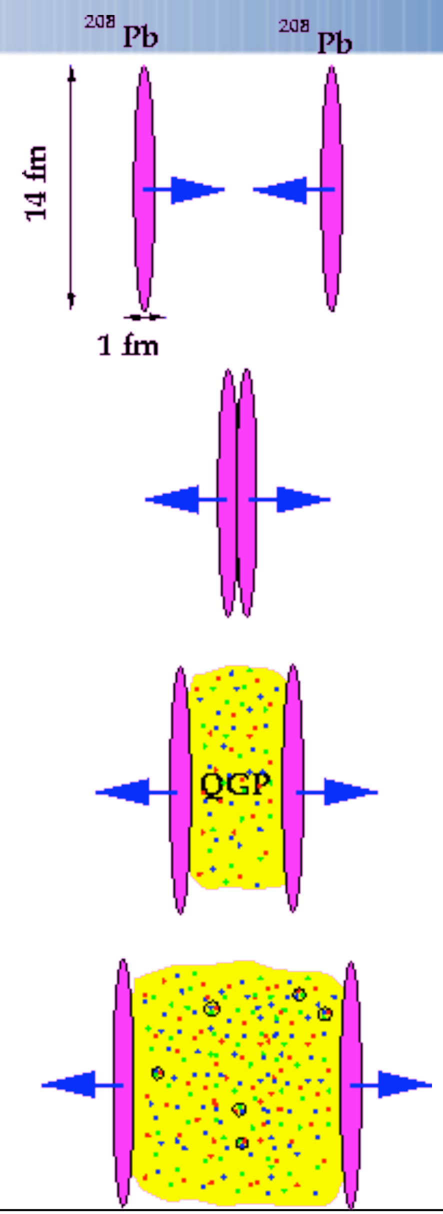
Basic Idea

- produce a "fireball" of hot matter:
- temperature O(10^{12} K)
  - ~ 10^5 x T at centre of Sun
  - ~ T of universe @ ~10μs after Big Bang

- how does matter behave under such extreme conditions?

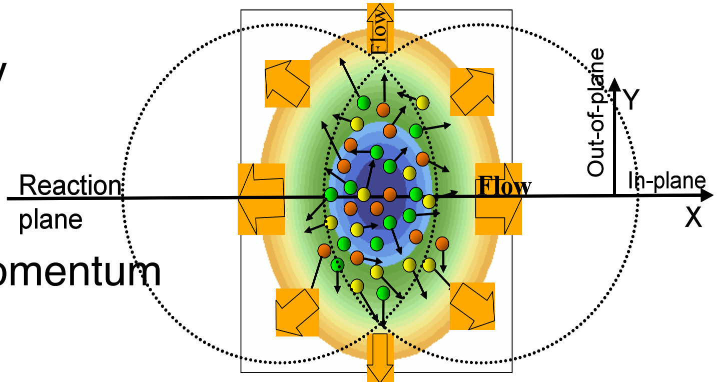
→QCD predicts state of deconfined quarks and gluons (Quark-Gluon Plasma)

→Look at the new state of matter in full detail

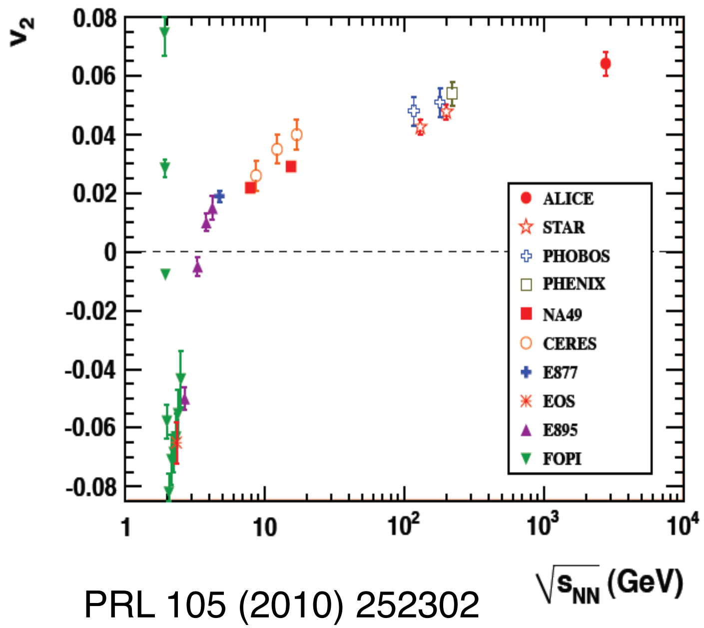


A new, fluid state of matter

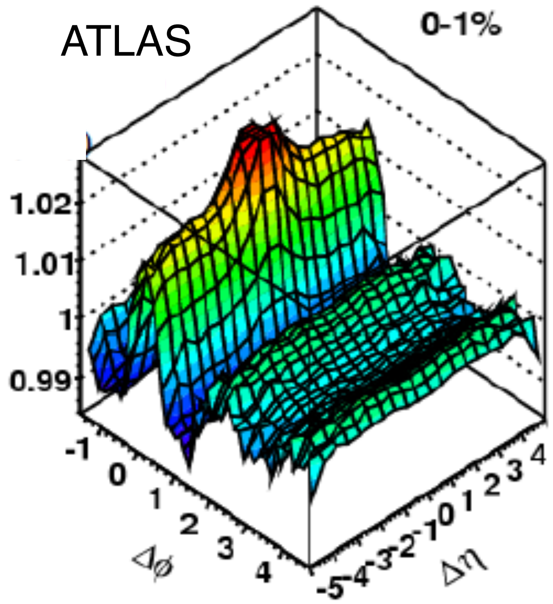
- Large mean free path
  - particles stream out isotropically, no memory of the asymmetry
  - extreme: ideal gas (infinite mean free path)
- Small mean free path
  - larger density gradient -> larger pressure gradient -> larger momentum
  - extreme: ideal liquid (zero mean free path, hydrodynamic limit

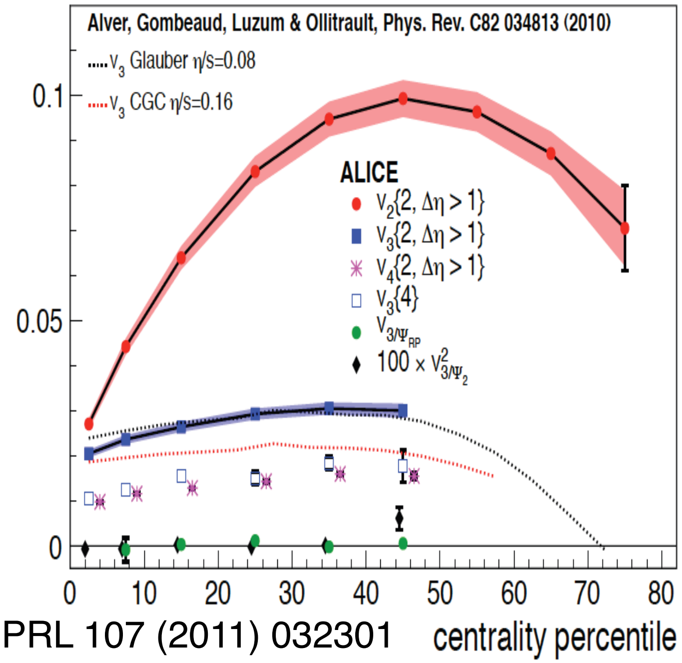


→ quantified by second coefficient (v_2) of Fourier expansion of azimuthal distribution



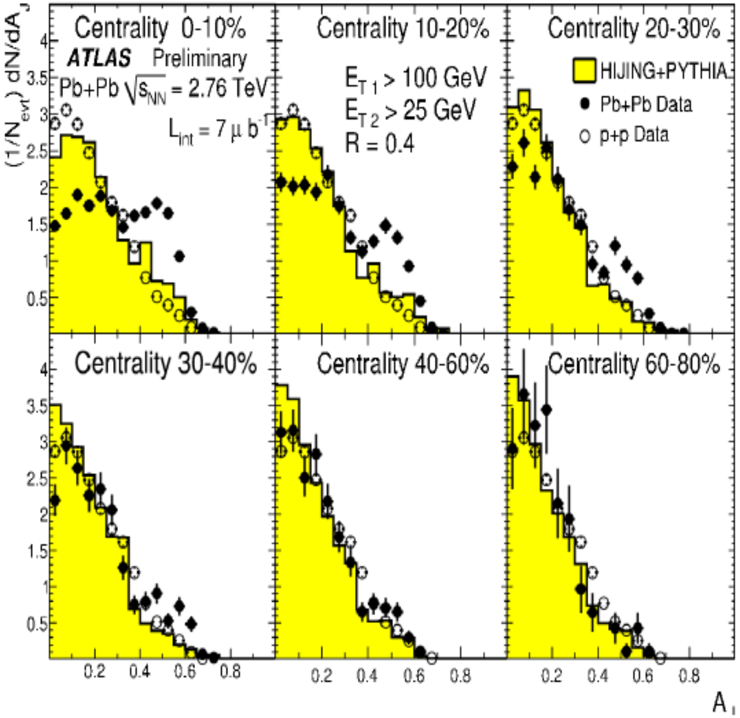
PRL 105 (2010) 252302



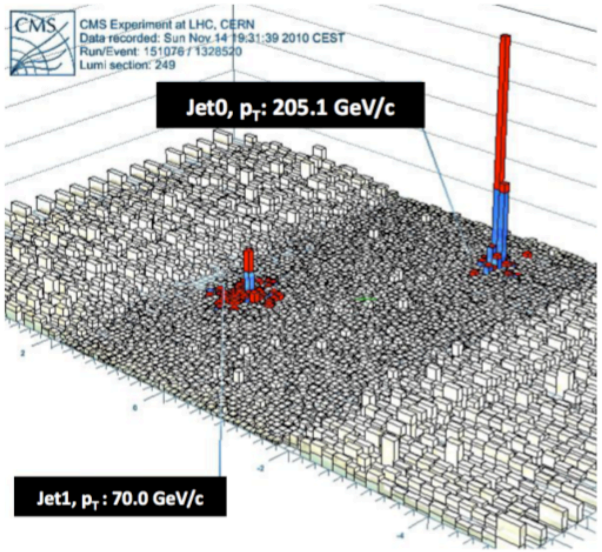


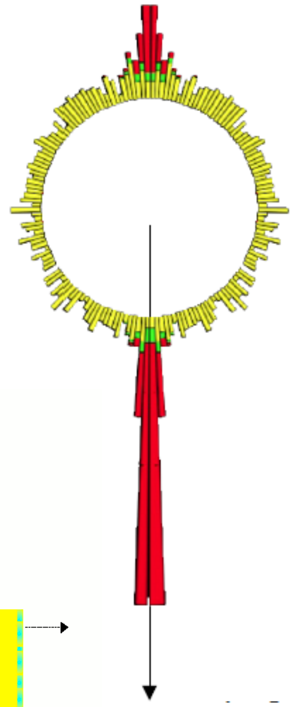
PRL 107 (2011) 032301

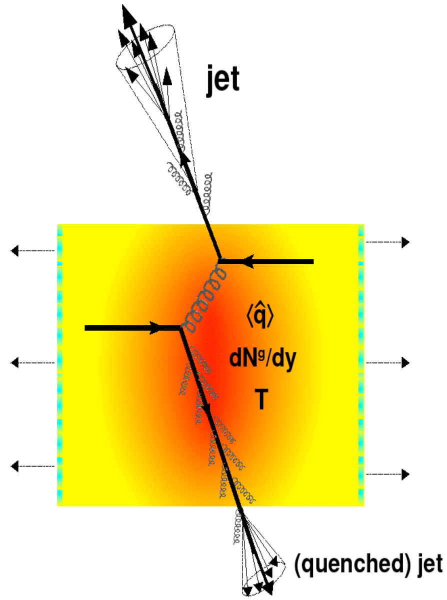
Jet-quenching



First direct evidence of strong jet quenching observed in LHC HI collisions by ATLAS and CMS.

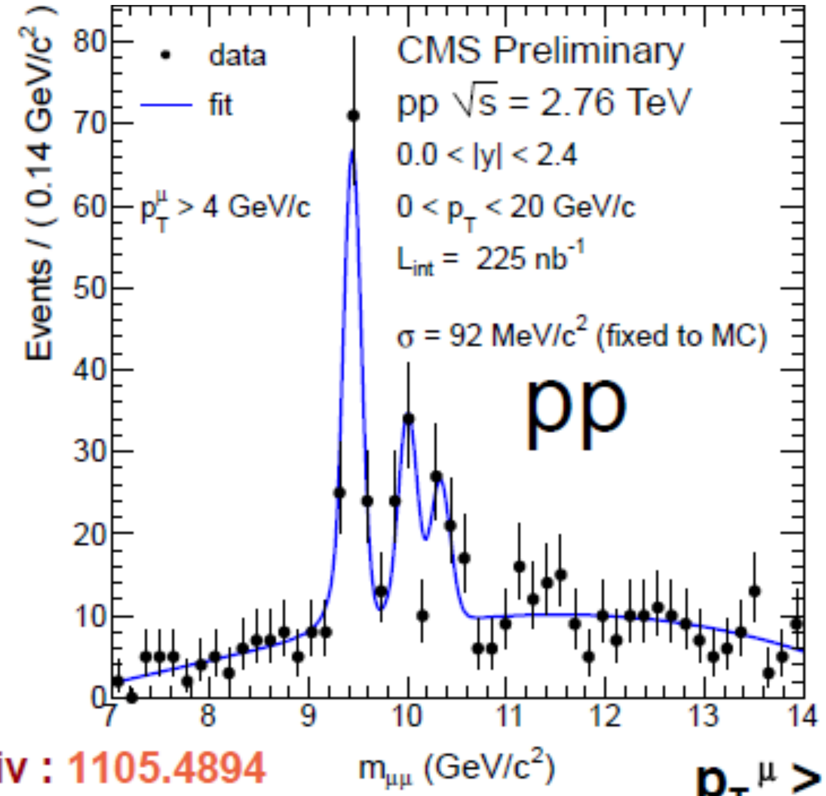


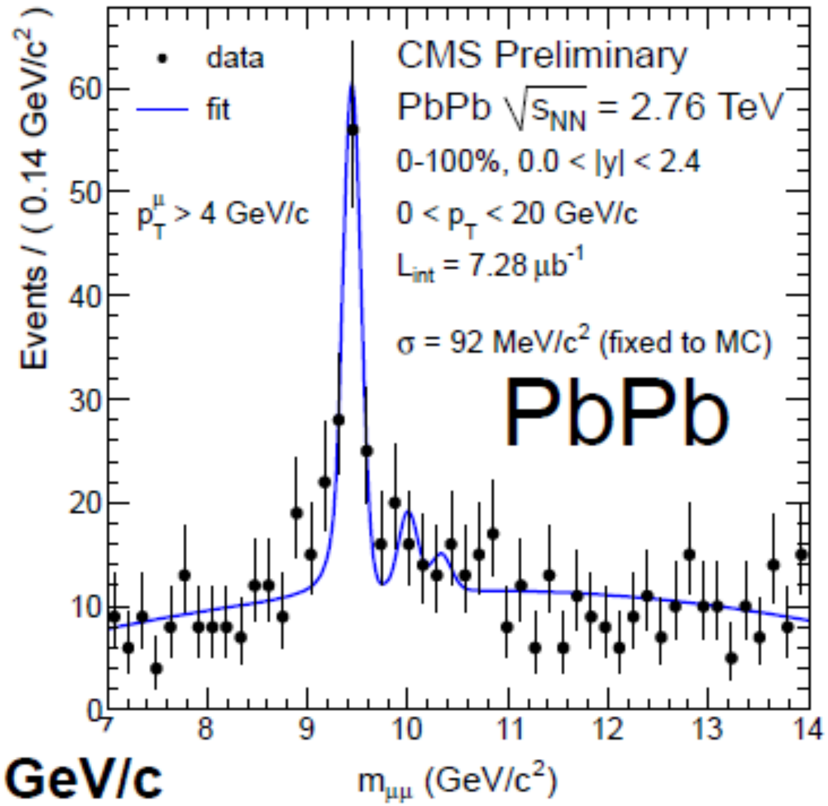




Indirect evidence of strong jet quenching measured at RHIC in single particle spectra and particle correlations.
The momentum difference in di-jet is balanced by low p_T tracks.

Ypsilon (2S+3S) Suppression





arXiv : 1105.4894
accepted by PRL

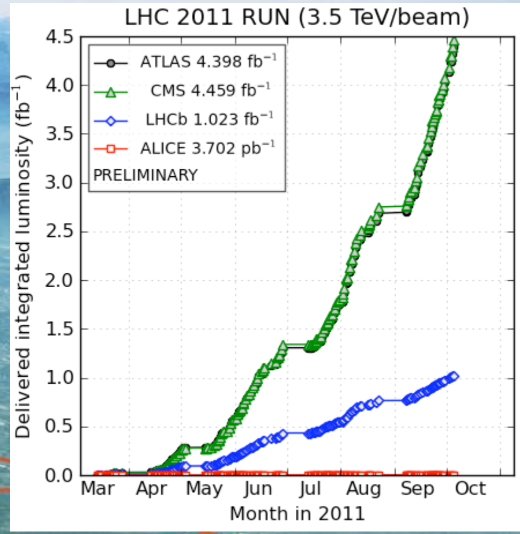
$p_T{}^{\mu}$ > 4 GeV/c

ϒ(2S+3S) production relative to ϒ(1S) in pp and PbPb

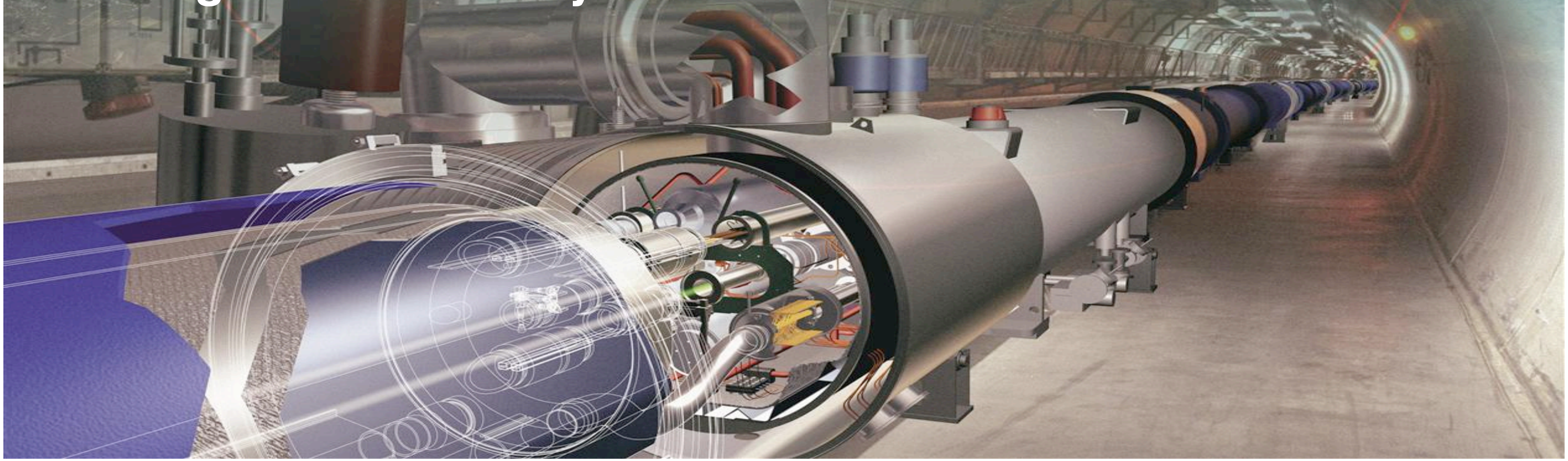
Compare pp and PbPb through a simultaneous fit

LHC operations in 2011

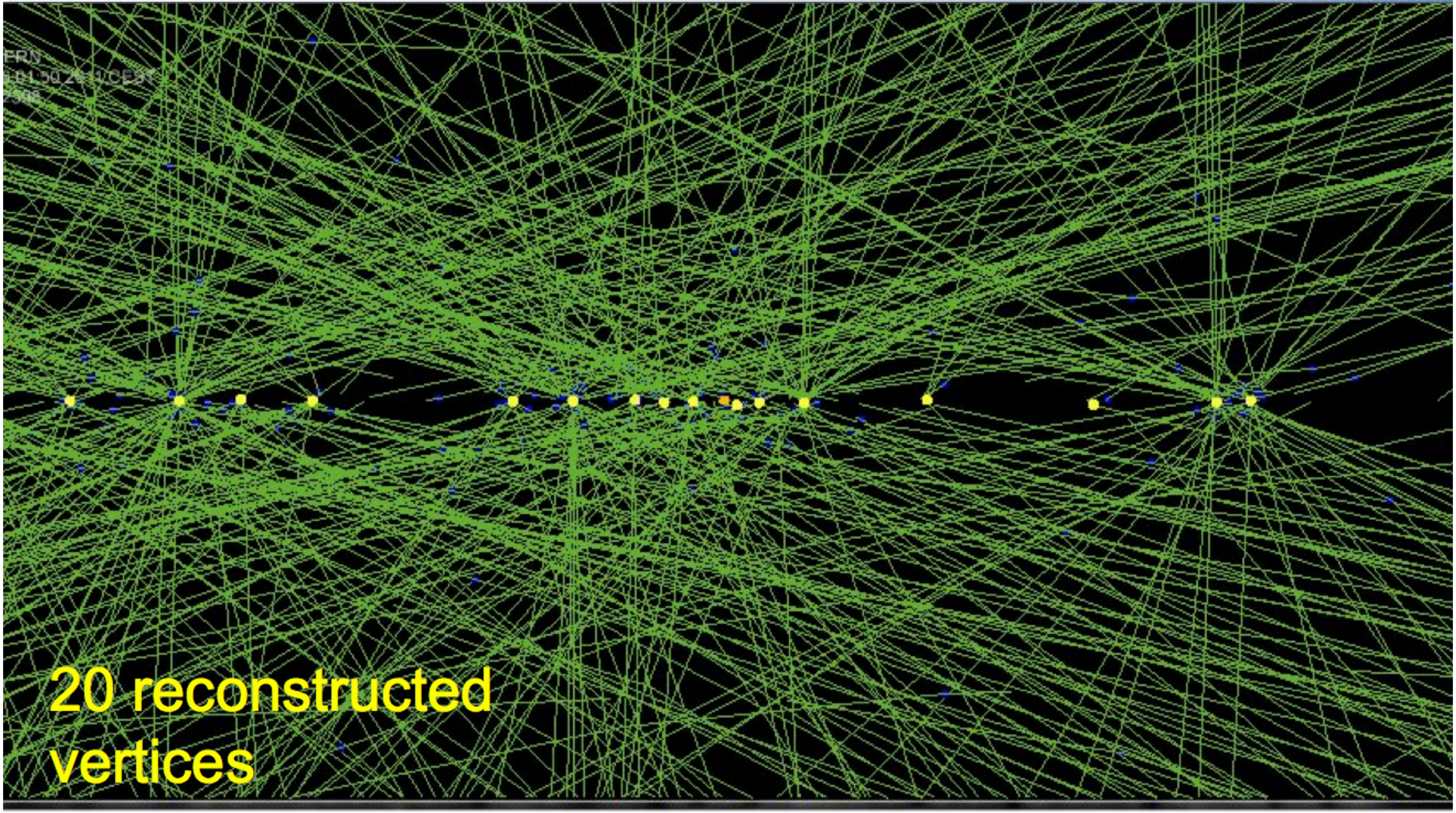
Energy per beam: 3.5 TeV
Interbunch spacing 50ns
Bunches/beam: 1380
Bunch population: 1.25×10^{11}
$\beta^* = 1$m
Max luminosity $3.3 \times 10^{33} cm^{-2}s^{-1}$



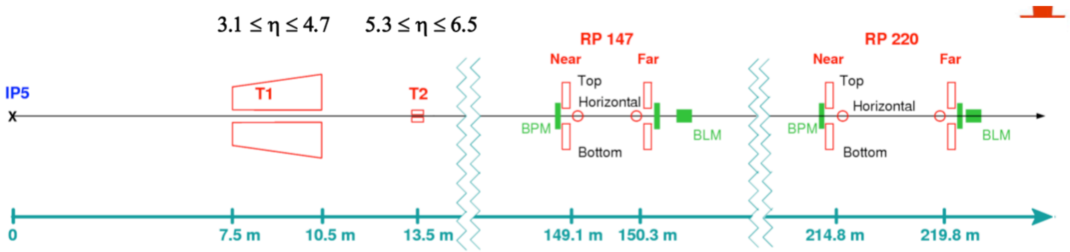
Good perspectives to achieve, by November 2011, the goal for integrated luminosity that was set for November 2012: $5fb^{-1}$

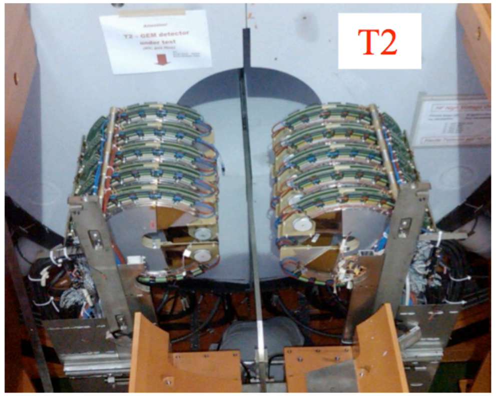


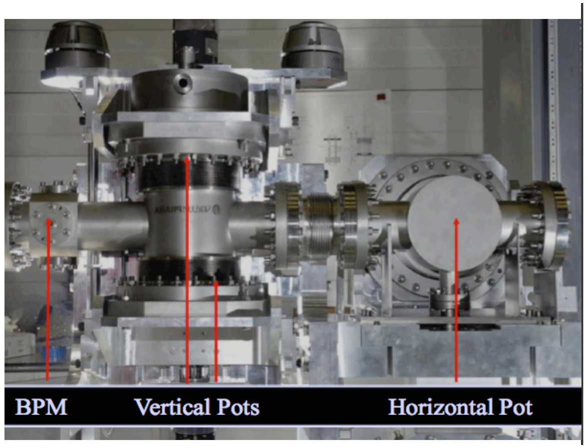
The challenge of 2011 data taking

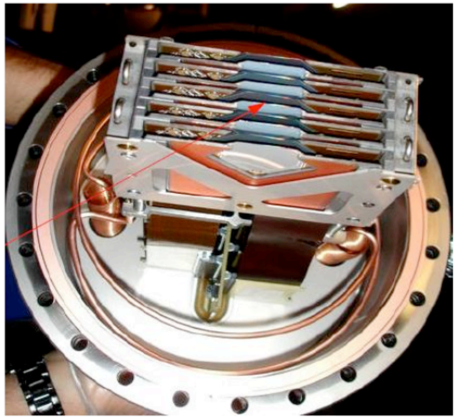


Totem $\sigma_{elastic}$ and σ_{tot}

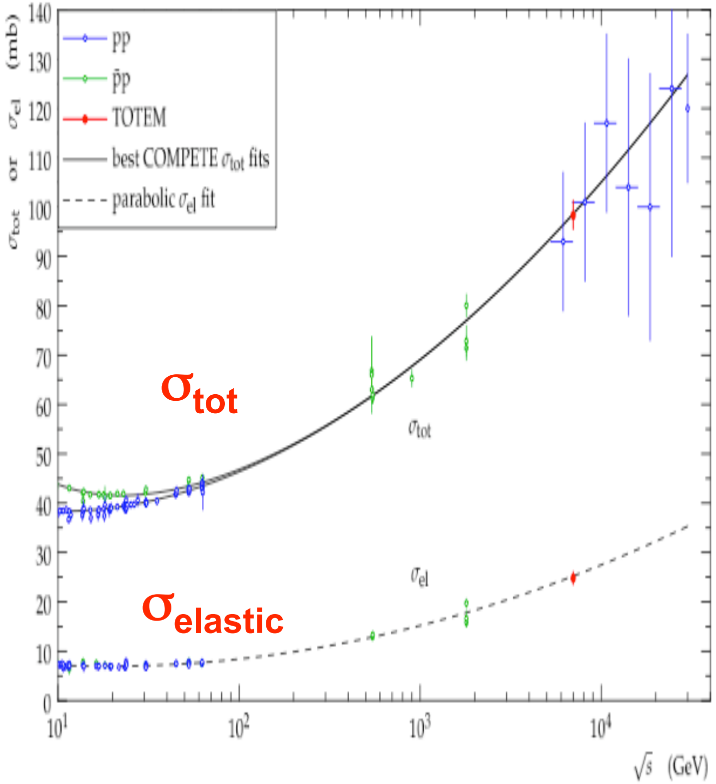






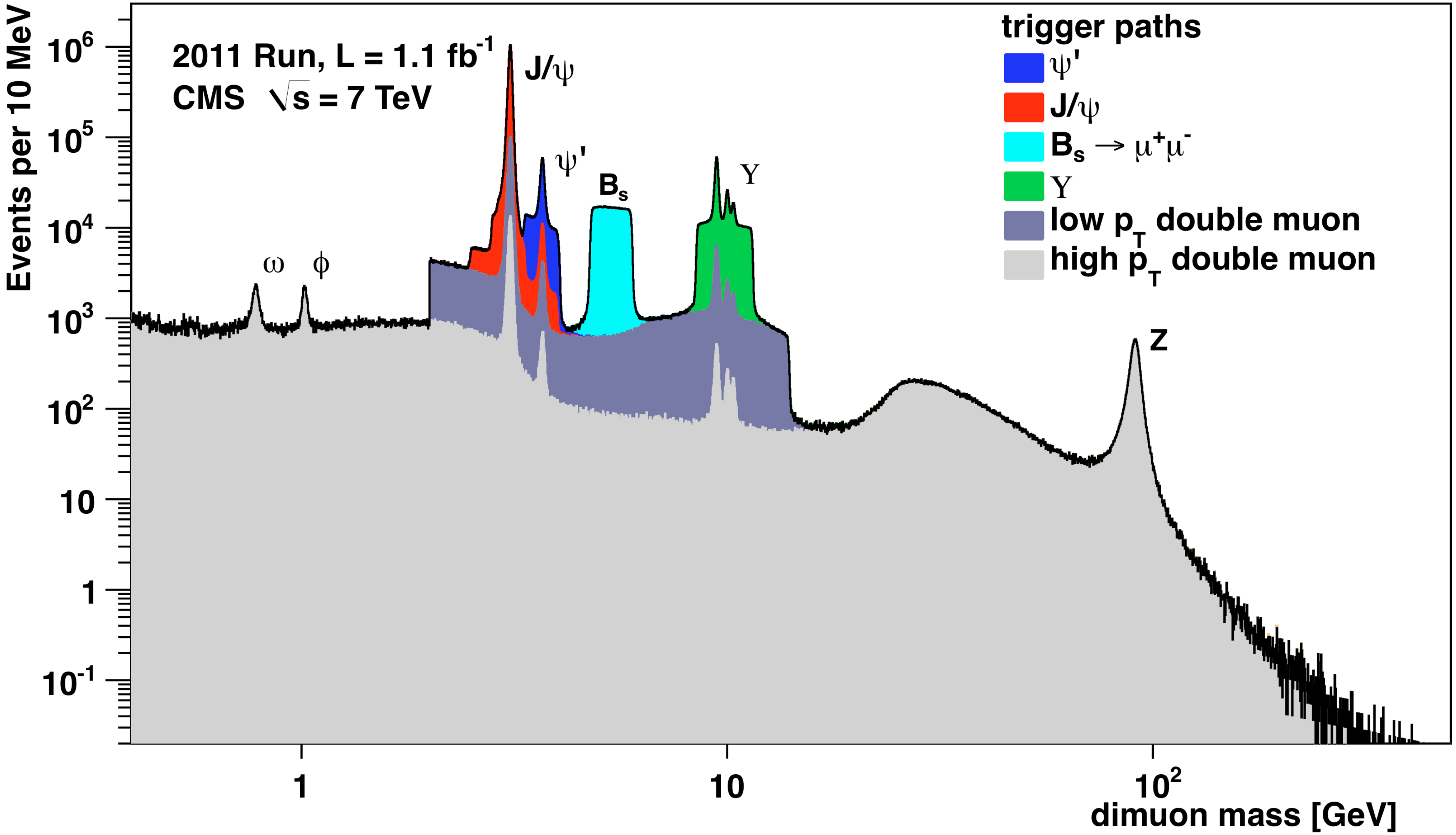


Very short run with b*=90m
Preliminary pp total and elastic cross section measured by Totem
σ_{el}=24.8 mb
σ_{tot} =98.3 ±3 mb.



The path to discovery

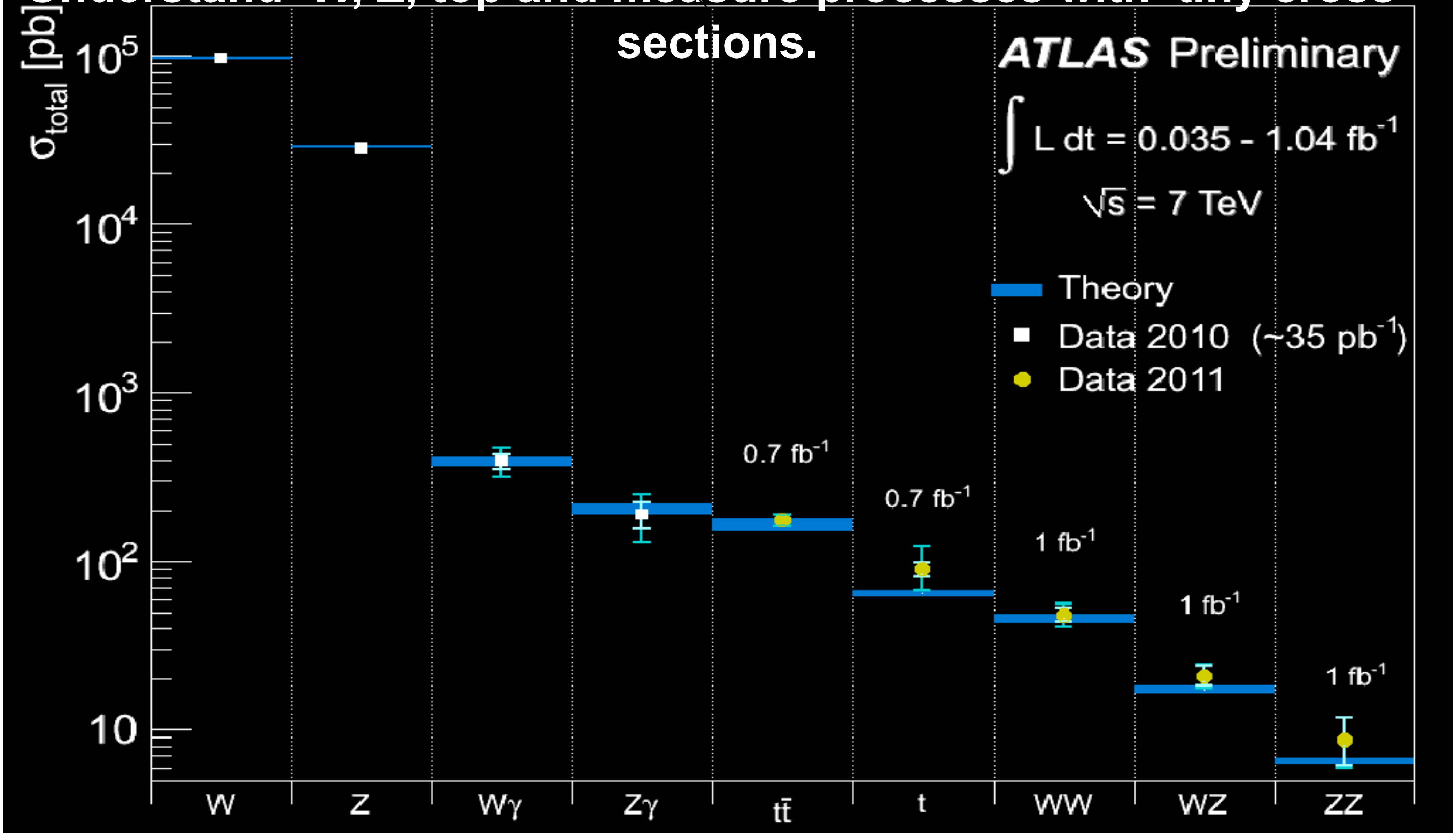
Use “standard candles” for calibration purposes.



Dimuon mass distribution obtained from overlapping several trigger paths.

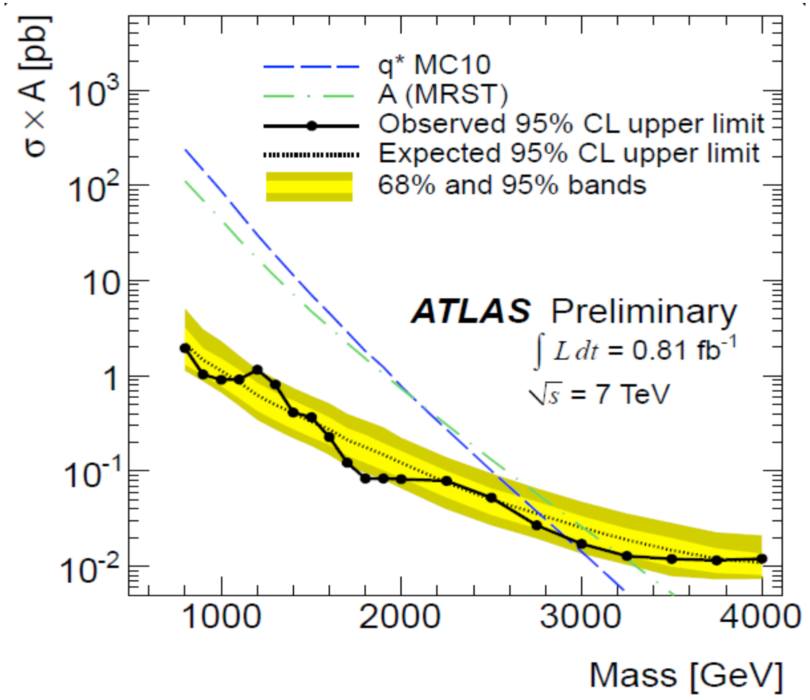
The path to discovery

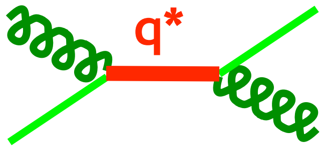
Understand W, Z, top and measure processes with tiny cross sections.

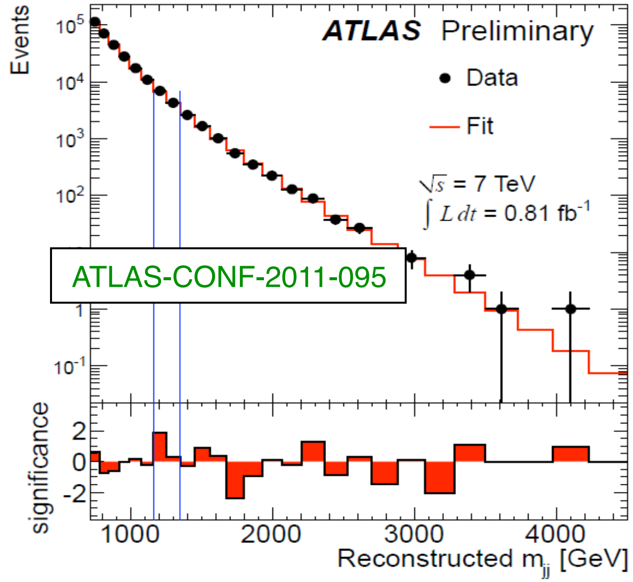


Searching for Dijet Resonances

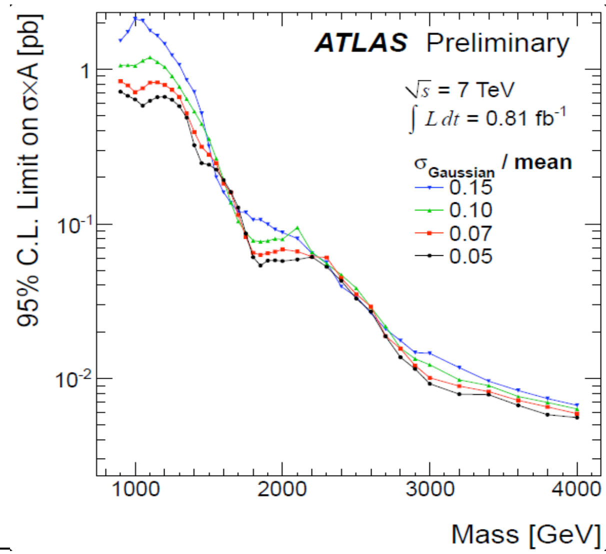
Search for bumps in the m_{jj} spectrum
Examples: q*, axigluon, colour-octet scalar models







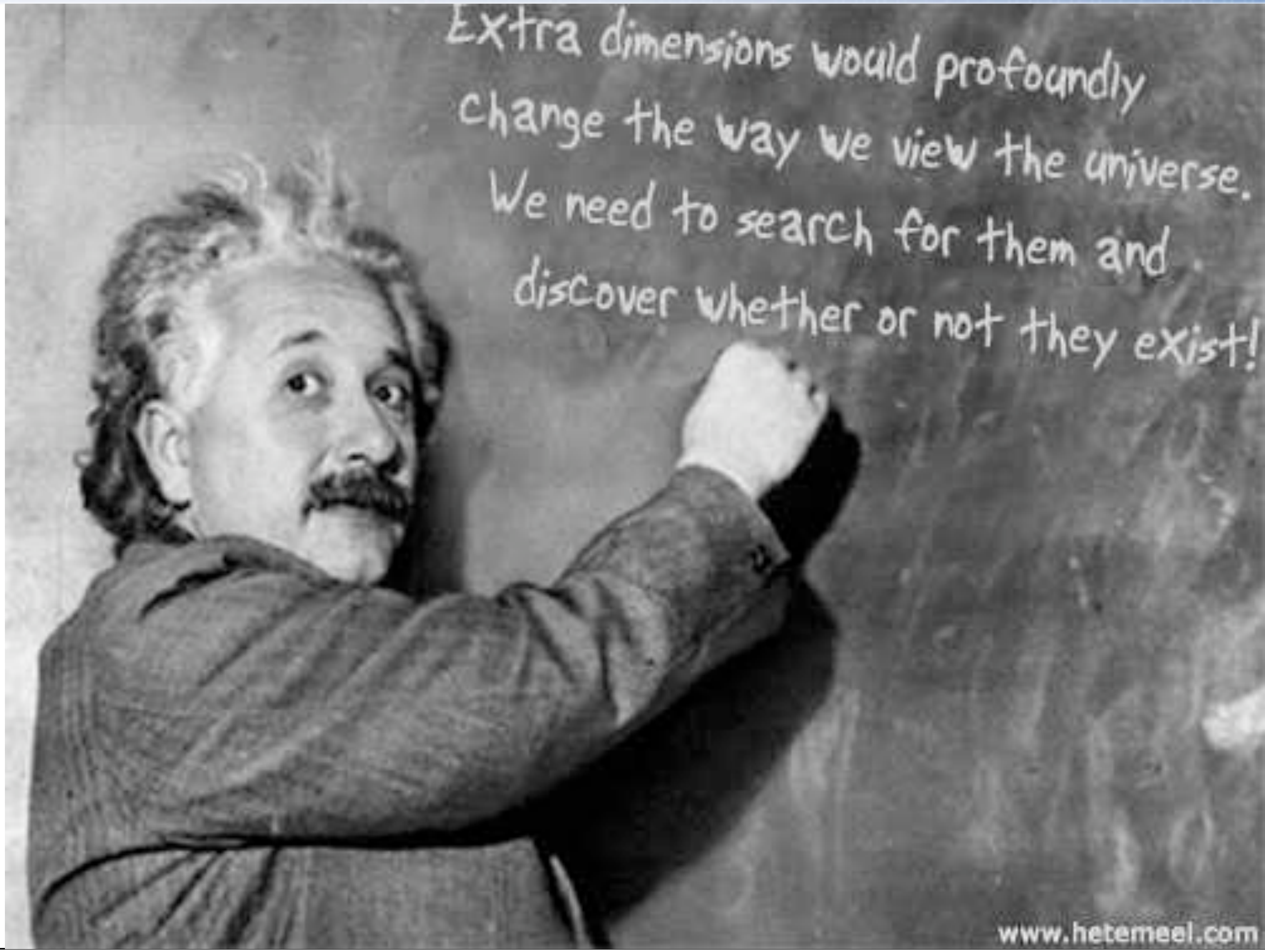
Generic limits on dijet resonances of specific widths



Model	Expected limit	Observed limit	Obs. 2010
q*	2.77	**2.91**	2.15
axigluon	3.02	**3.21**	2.10
c.o.s (s8)	1.71	**1.91**	-

95% CL limits in TeV

Search for extra-dimensions

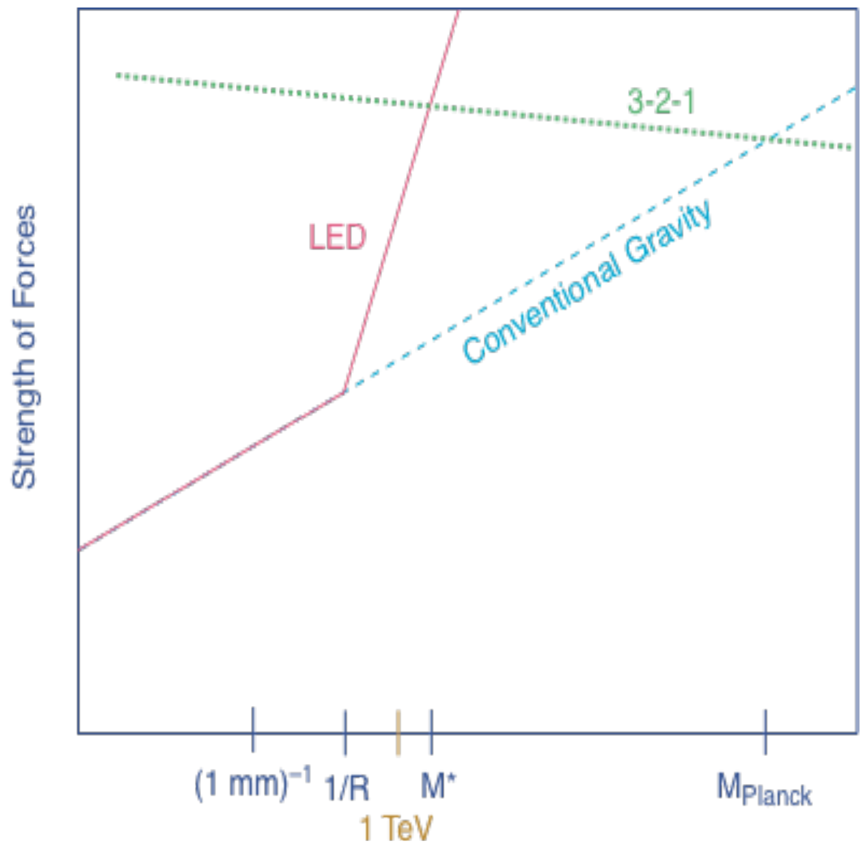


Why Extradimensions are attractive

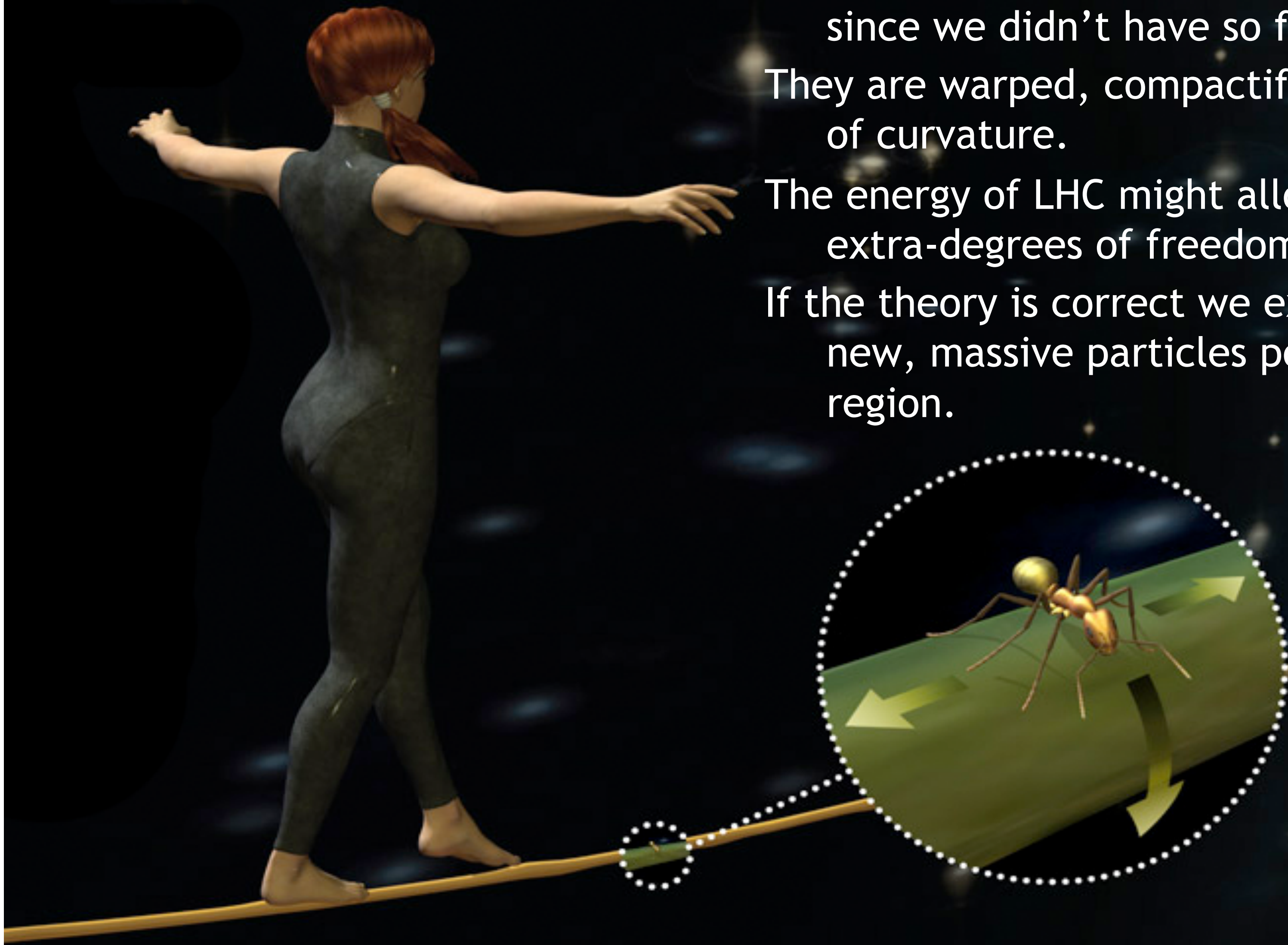
There are strong indications that the strenght of major interactions run with the available energy… but gravity is not yet in the picture. It is by far too weak.

Great idea some years ago.
Gravity is NOT weak, it appears weak to us because we observe it in a 4-dimensional world. **If we assume that our universe can really evolve in 5-10 dimensions**, immediately gravity becomes much stronger than the simple 4-dimensional projection that we are used to deal with.

The Great Unification of Forces can be proven at lower energies.



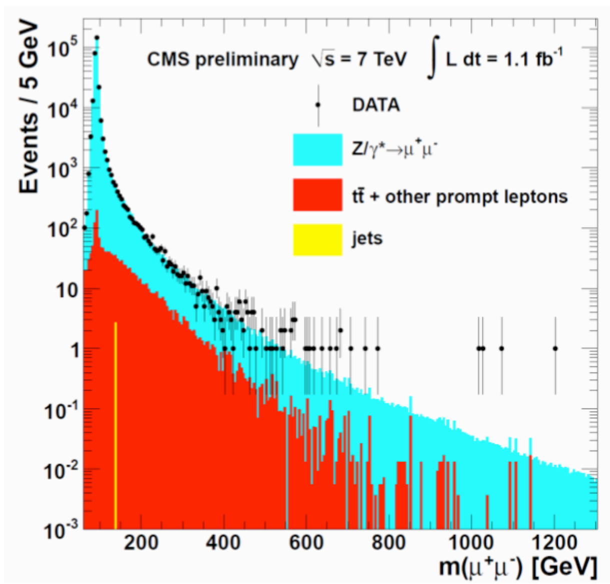
Extradimensions

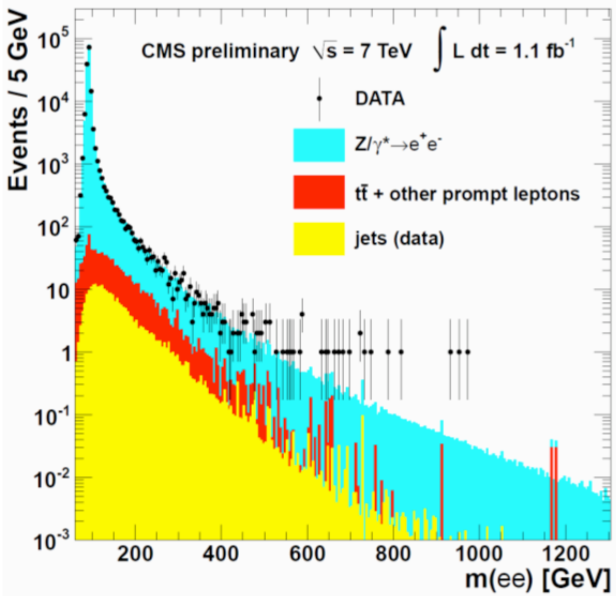


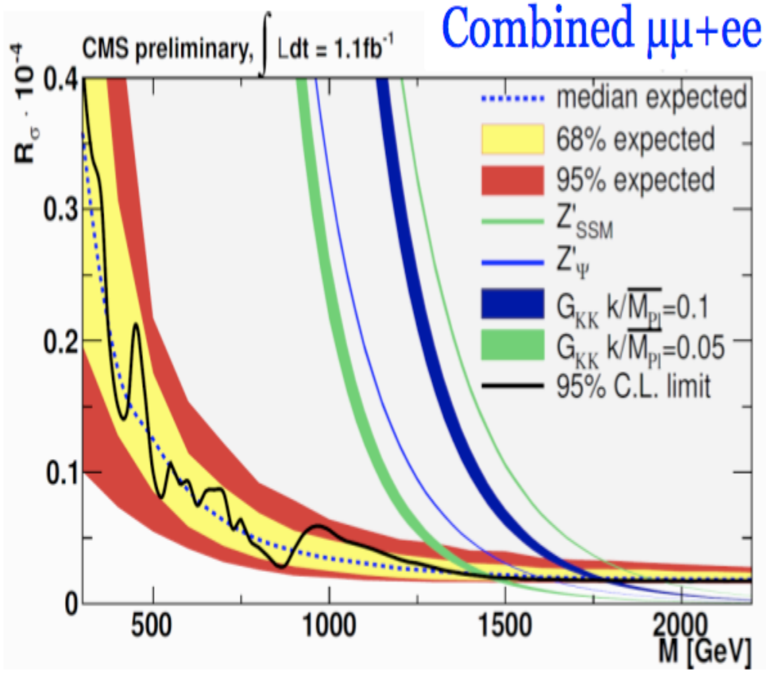
- The additional dimensions were not accessible to us since we didn't have so far enough energy.
- They are warped, compactified with very small radii of curvature.
- The energy of LHC might allow us to access these extra-degrees of freedom.
- If the theory is correct we expect a full spectrum of new, massive particles populating the TeV region.

Looking for massive extra-bosons

The high mass tail of the Z is studied in great detail. Spectra are consistent with known SM processes and 95% CL limits are extracted







CMS-PAS-EXO-11-019.

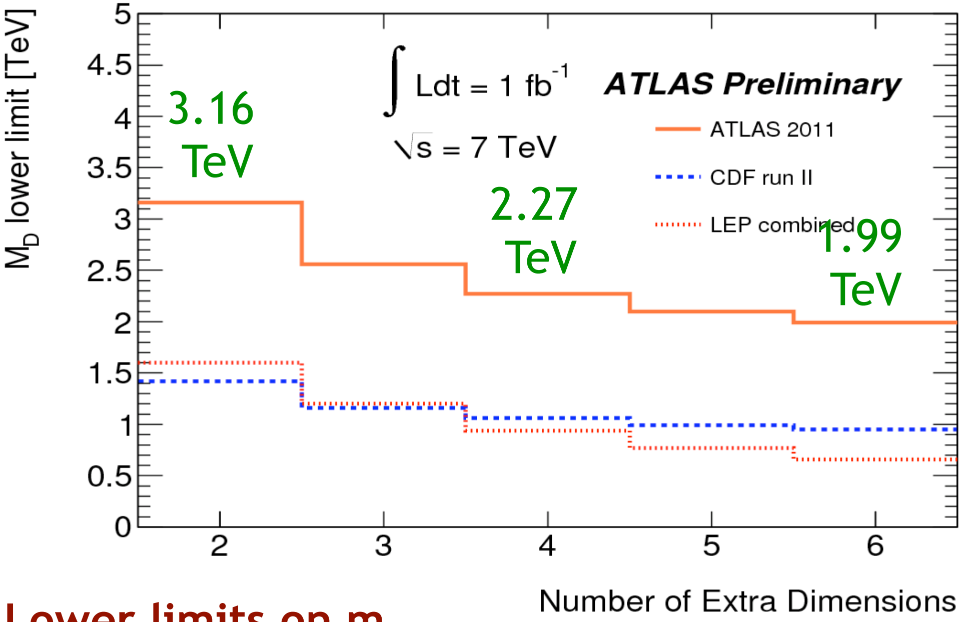
1940 GeV for the Sequential Standard Model Z'_{SSM},
1620 GeV for Super-String inspired models, Z'_{ψ}.
1450-1780 GeV for RS Kaluza-Klein Gravitons for (k/M_{Pl}) 0.05-0.1.

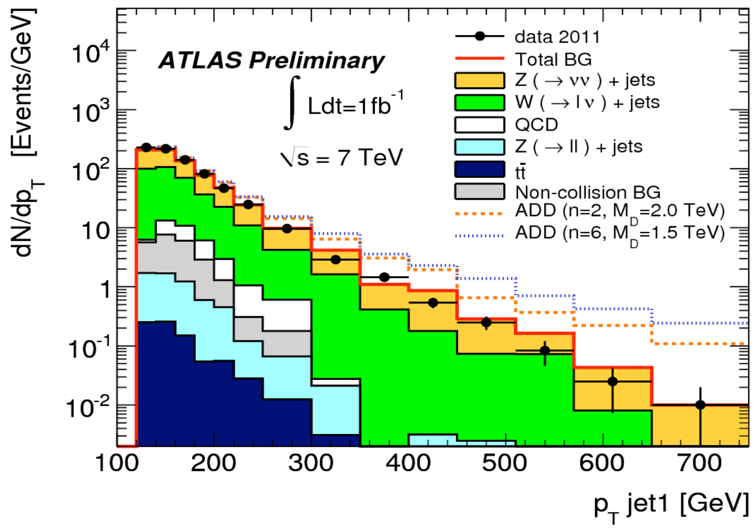
Monojet: Jet + E_T^{miss}

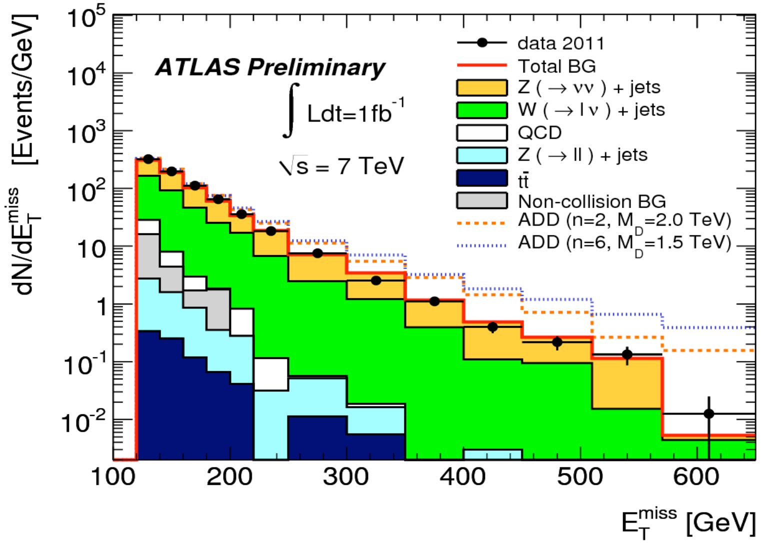
High-p_T jet opposite ~no activity

- Standard Model: Z→νν
- Large-extra dimensions with unobserved graviton

4+n dimensions, 4+n-dimensional Planck scale M_D

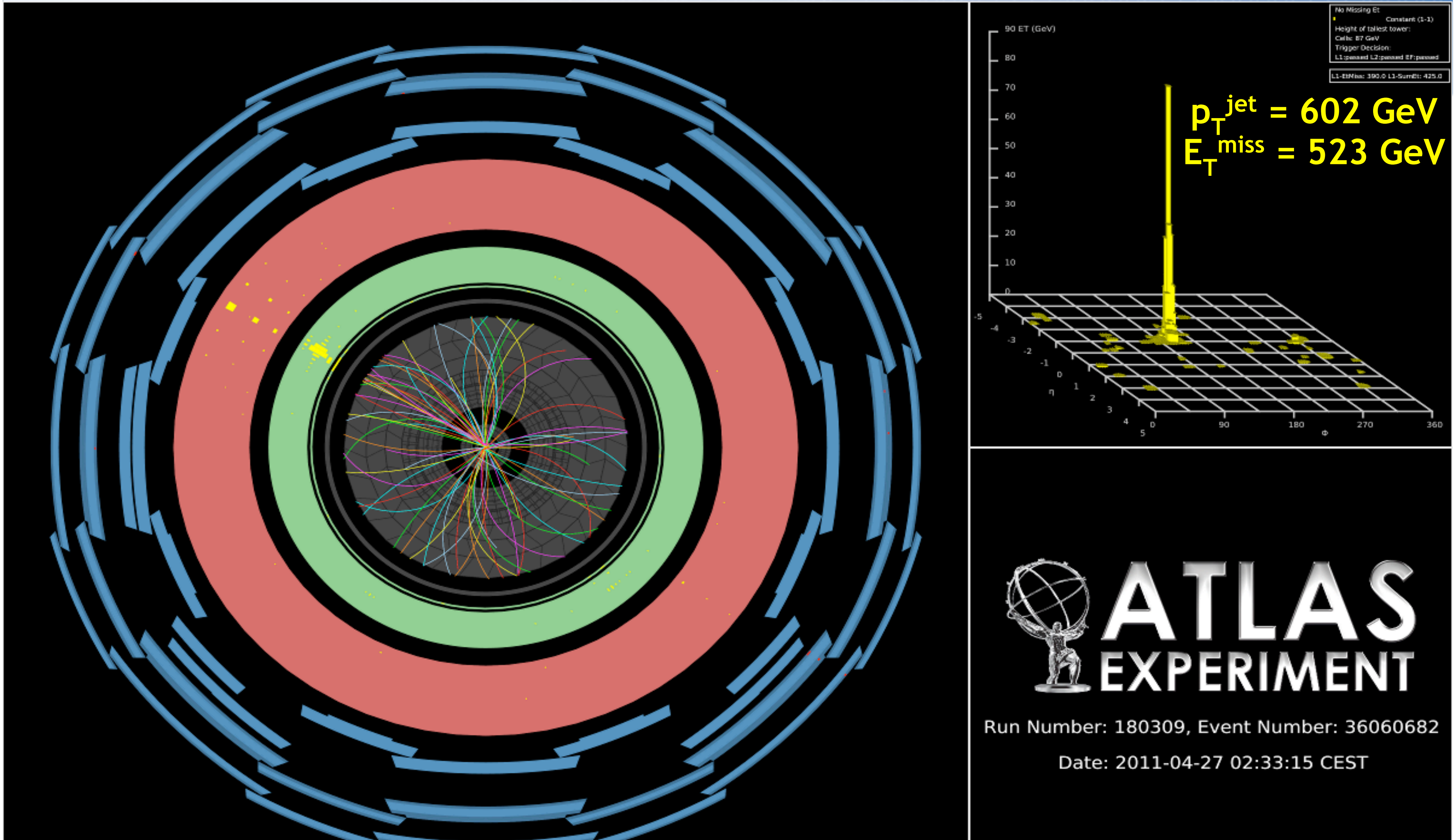






Lower limits on m_D

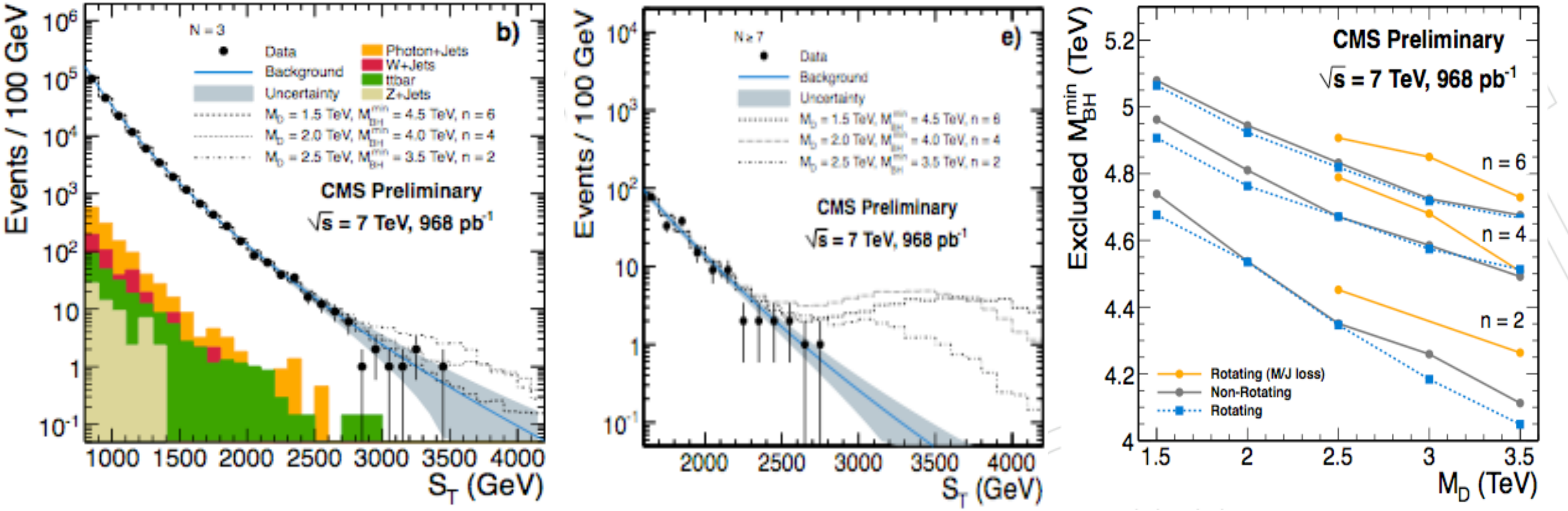
If we only consider $\hat{s} < m_D^2$, $m_D > 1.68$ TeV for n=6



A high-p_T monojet event - SM interpretation Z → νν + jet

Search of microscopic black holes signatures.

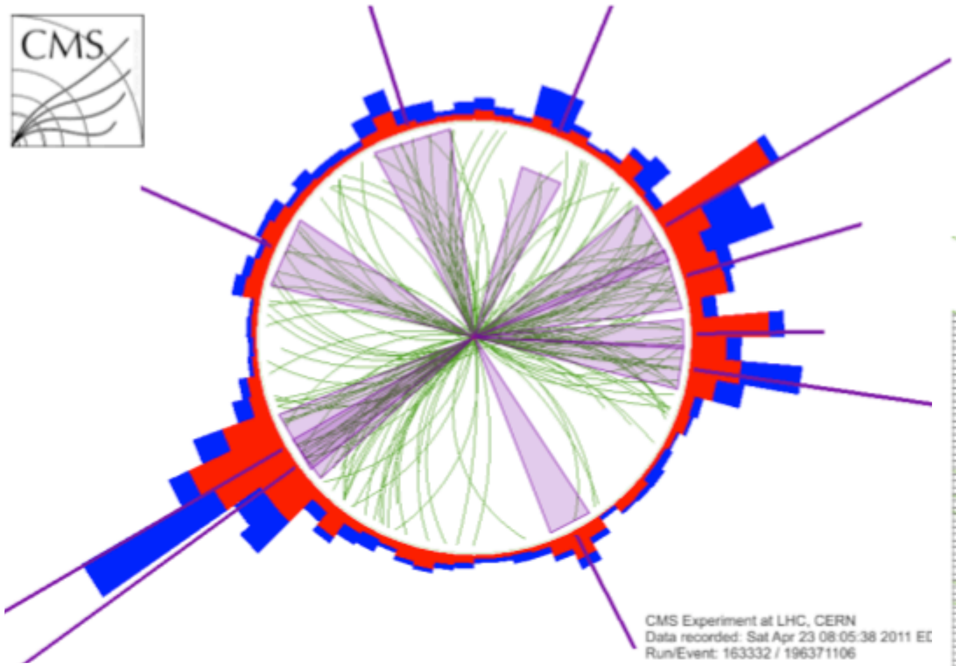
Events with large total transverse energy are analyzed for the presence of multiple high-energy jets, leptons, and photons, typical signal expected from a microscopic BH.



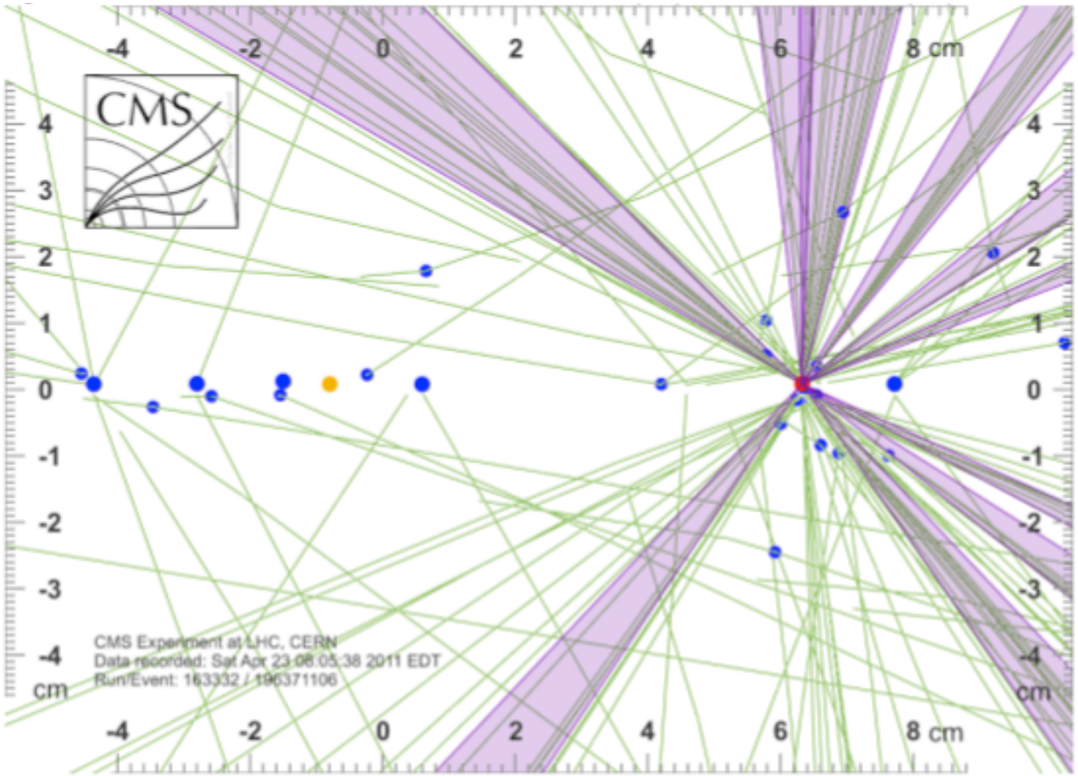
Good agreement with the expected standard model backgrounds, dominated by QCD multijet production, is observed for various final-state multiplicities. Limits on the minimum black hole mass are set, in the range **4-5 TeV**, for a variety of parameters in models with large extra dimensions.

arXiv:1012.3375; CMS-PAS-EXO-11-071;

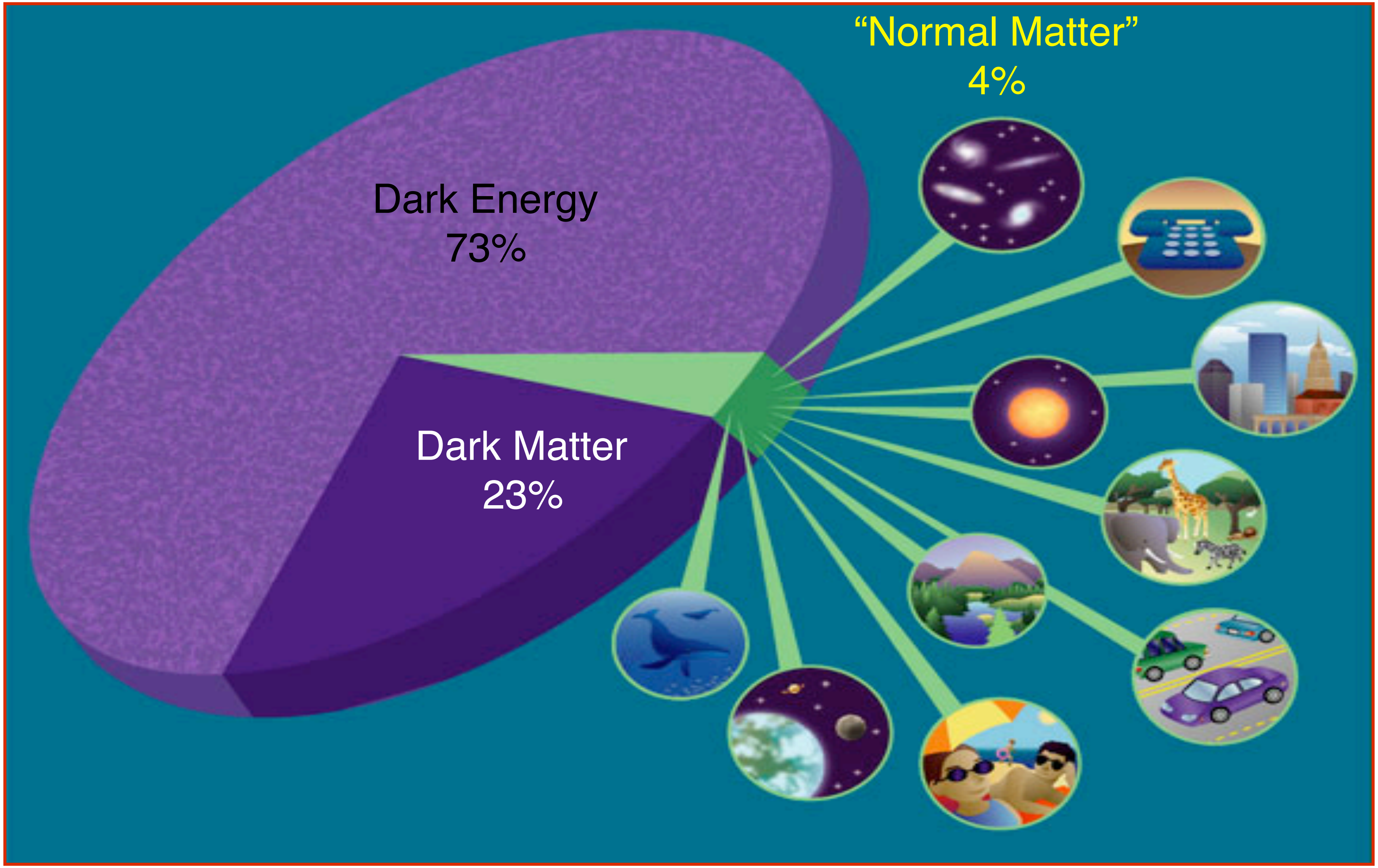
Spectacular events



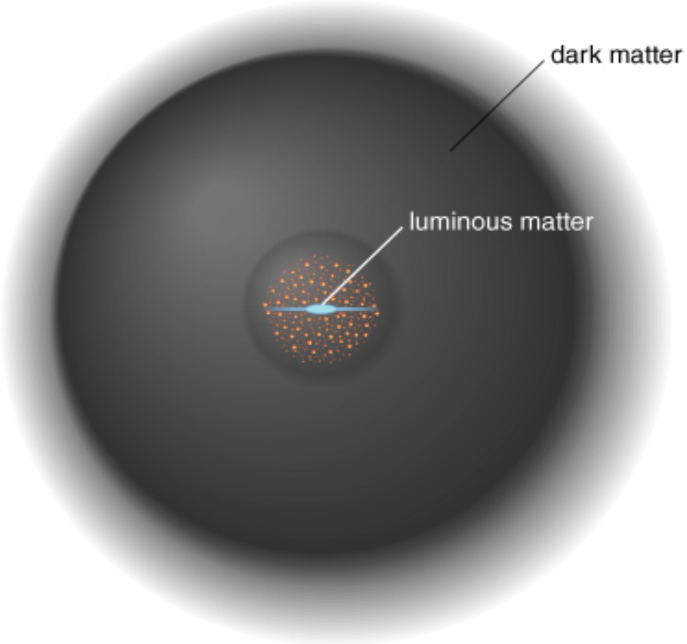
N=10
S_T=1.1 TeV



What is dark matter?



SUSY could provide good DM candidates

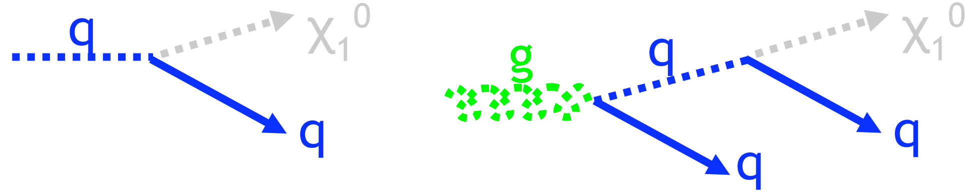


Each SM particle could have a super-symmetric (SUSY) partner with spin 1/2 difference. In super-matter the carriers of the interactions are fermions and the particles are bosons. Elegant and nice symmetry of nature (similar to matter-antimatter where the spin plays the role of the charge).

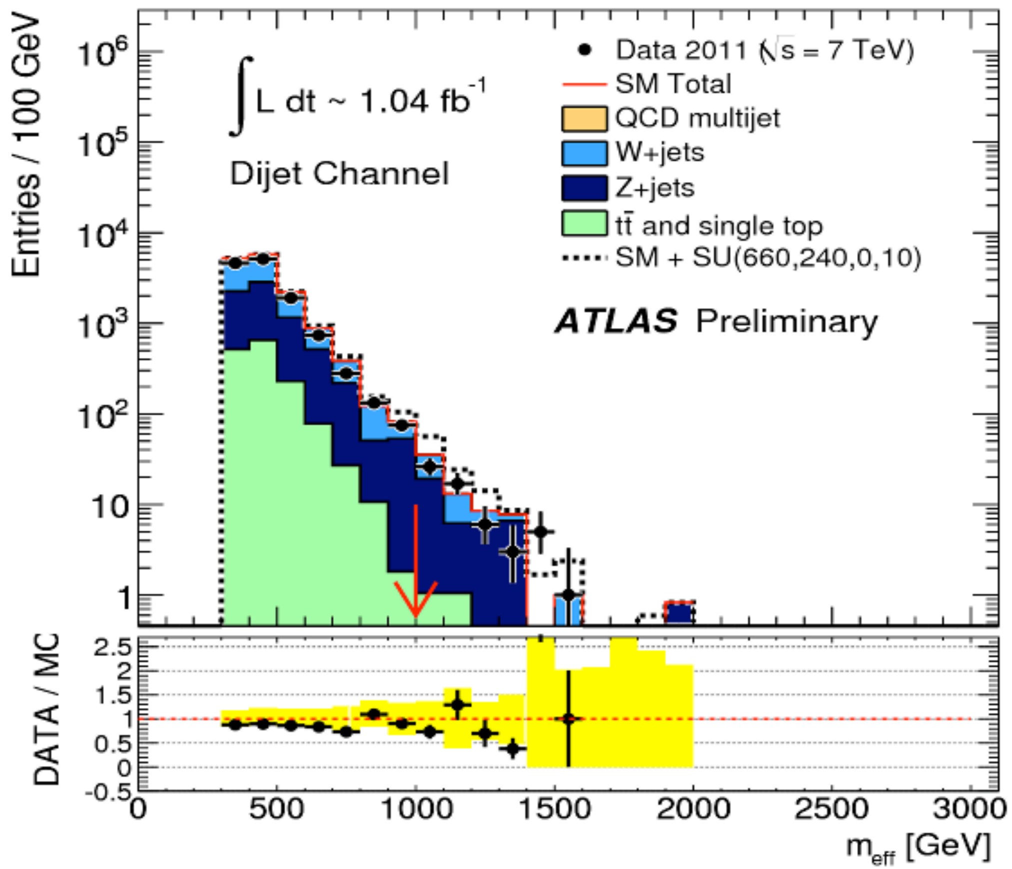
The Lightest SUSY particle, the neutralino, could be stable and a gas of heavy neutralinos could be responsible of the dark matter that keeps together the clusters of galaxies

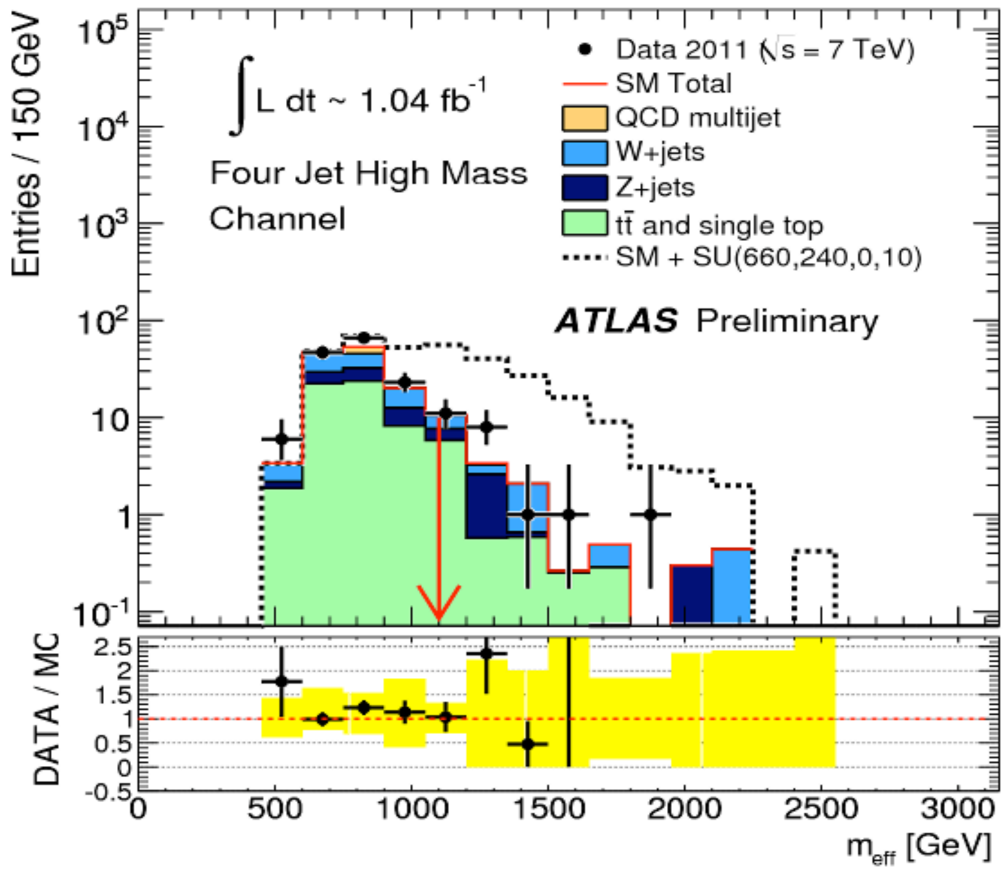
SUSY in 0-lepton channel

Strong production: gg, gq, qq

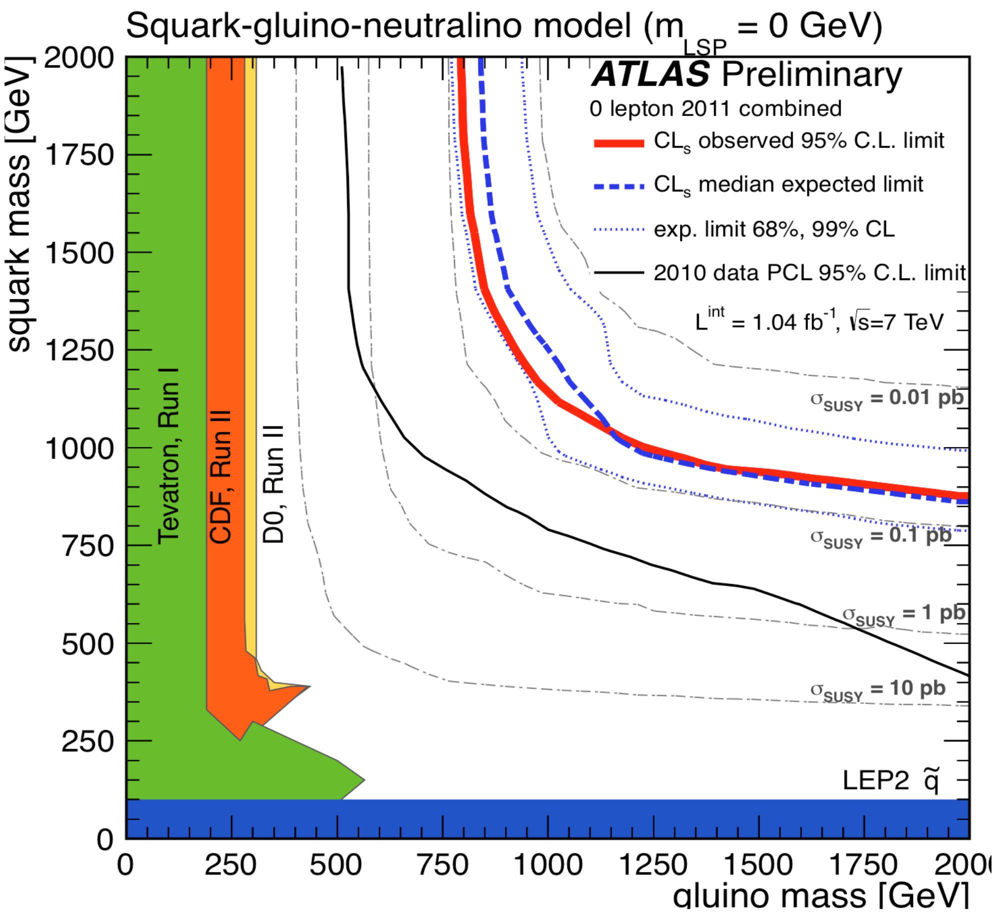


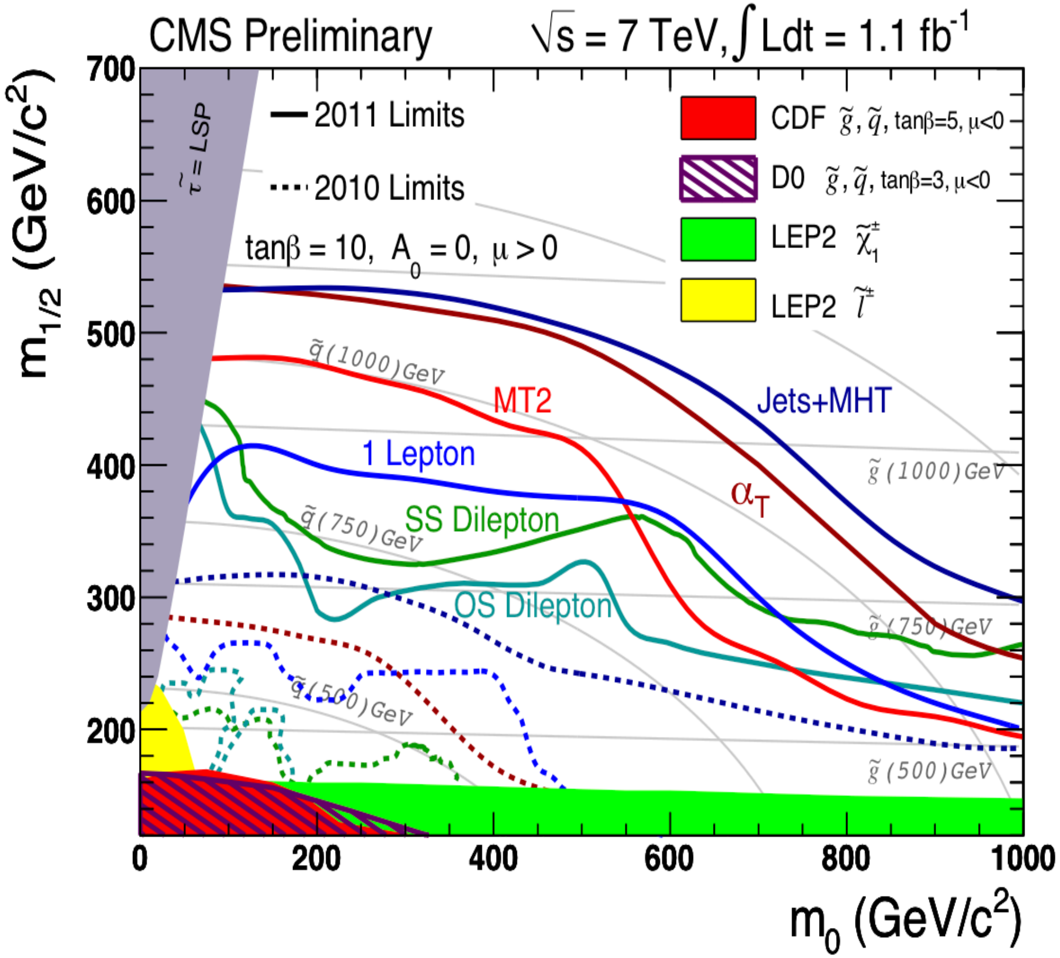
Multi-jet plus E_T^{miss}, e/μ veto
Analysis includes ≥4 jet event category





SUSY: new limits on CMSSM

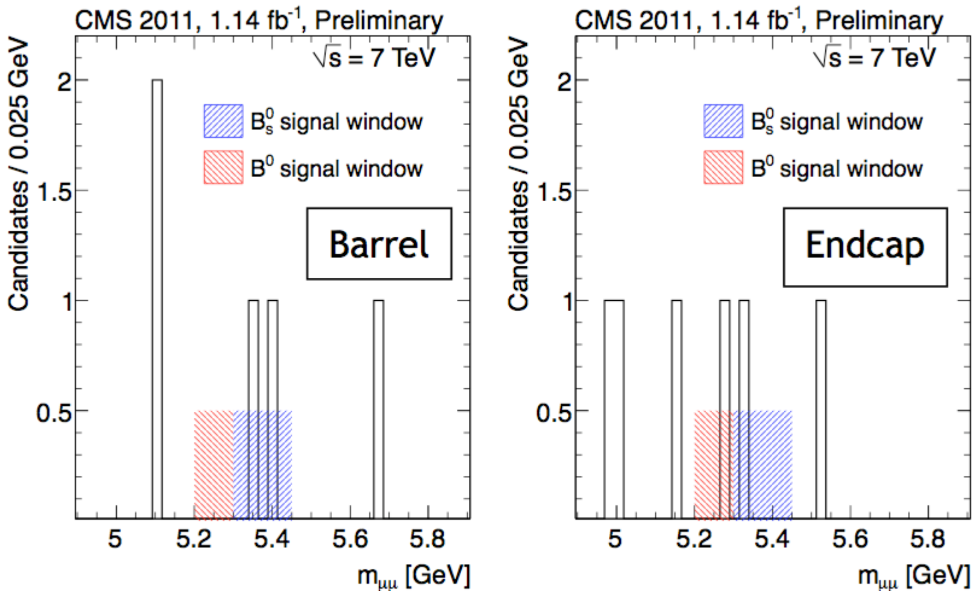




Within the constrained SSM models we have crossed the border of excluding gluinos and squarks up to 1TeV and beyond. More conclusive results for the winter conferences.

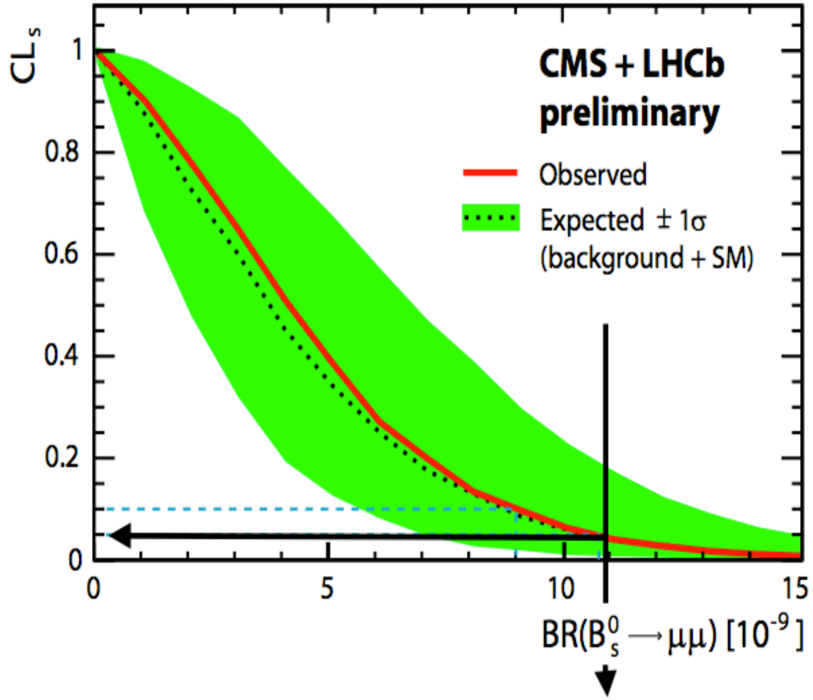
$B_s \rightarrow \mu^+\mu^-$

Indirect sensitivity to new physics. Very rare process in Standard Model $B_s \rightarrow \mu^+\mu^- = (3.2 \pm 0.2) \times 10^{-9}$ **Any excess would indicate new physics.**



Events observed in the unblinded windows consistent with background plus SM expectations.

Combination of LHCb+CMS:
$B_s \rightarrow \mu^+\mu^- < 1.08 \times 10^{-8}$



CMS limit: $B_s \rightarrow \mu^+\mu^- < 1.9 \times 10^{-8}$ **(95% CL)**
LHCb limit: $B_s \rightarrow \mu^+\mu^- < 1.5 \times 10^{-8}$

CMS PAS-BPH-11-002 11x10^{-9} @ 95% CL

Search for the Higgs boson

The bare SM could be consistent with massless particles **but** matter particles range from almost 0 to about 170GeV while force particles range from 0 to about 90GeV.

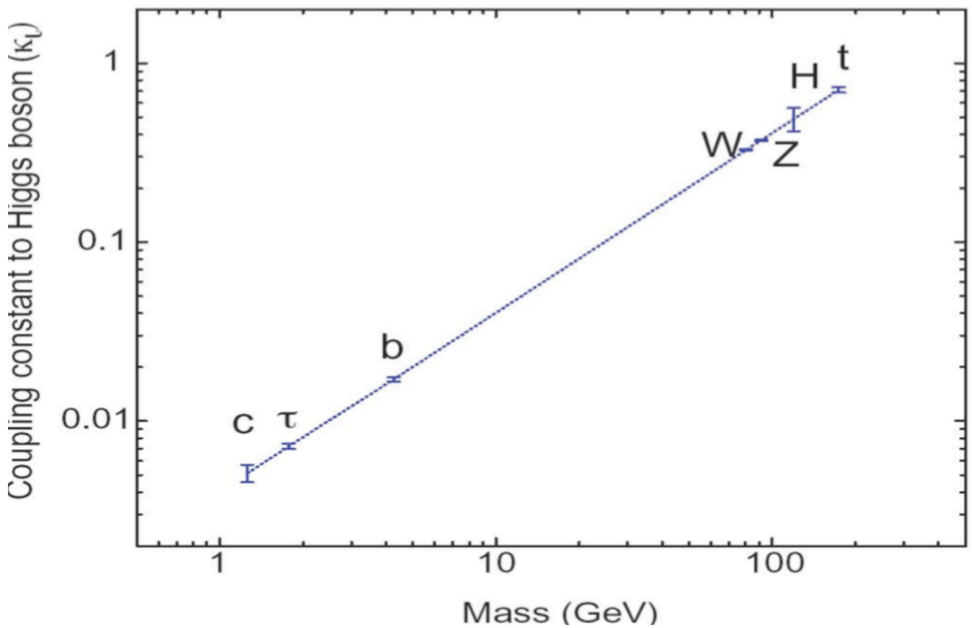
How can it be that a massless photon can carry the same electroweak interaction of a 80-90 GeV W or Z?

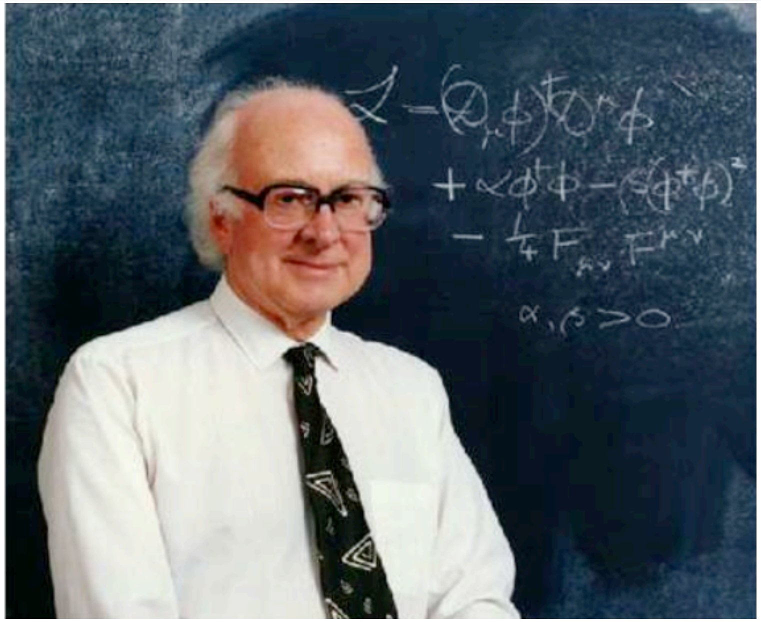
The simplest solution (Higgs, Kibble, Brout, Englert 1960's)

All particles are massless !!
A new scalar field pervades the universe.

Particles interacting with this field acquire mass: the stronger the interaction the larger the mass.

The Higgs mechanism





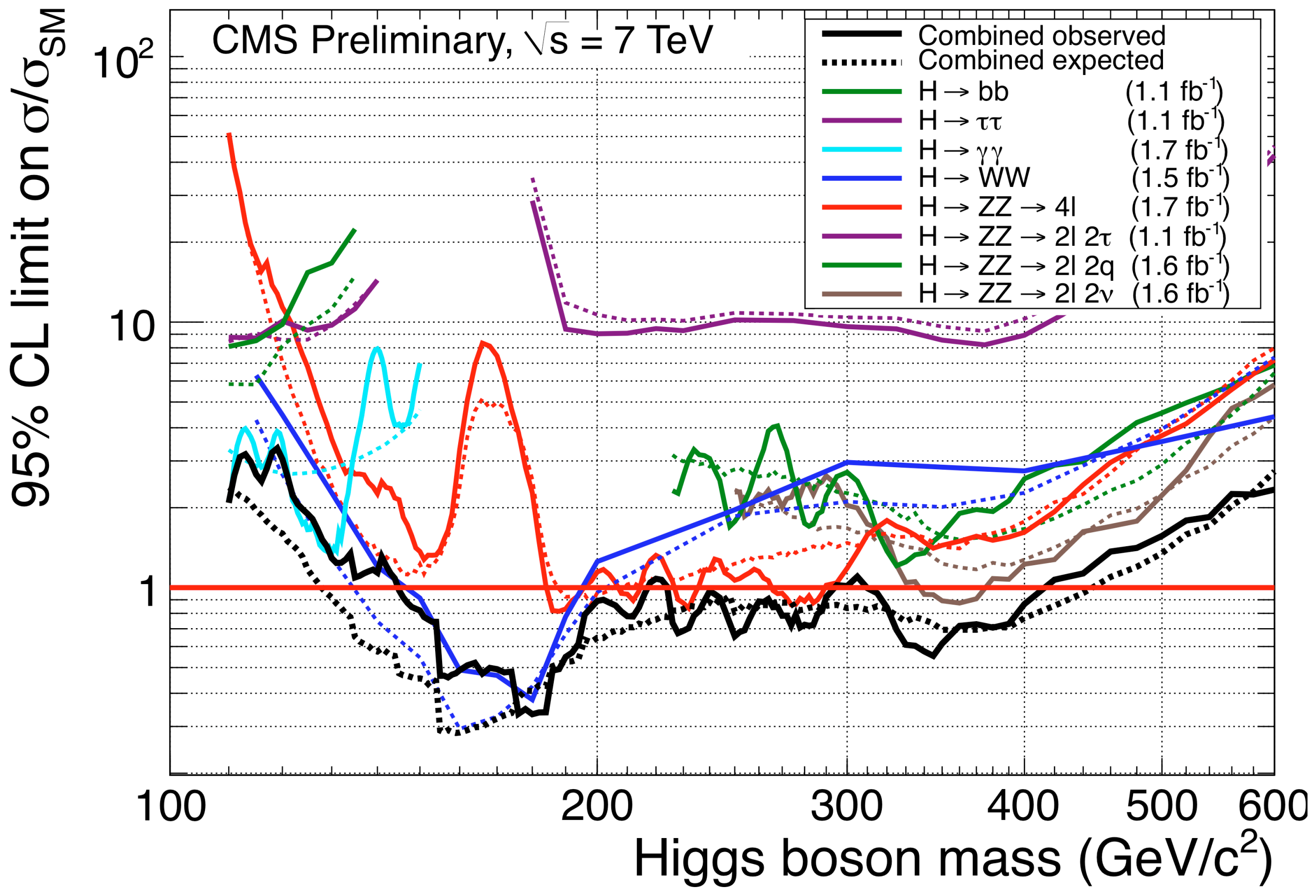
The theory is elegant, coherent, and consistent with all observations….. but nobody has been able so far to identify this new particle.

Unfortunately the theory does not constrain significantly the mass of the boson. M_H can be considered as a free parameter. The SM Higgs boson can live anywhere between ~100GeV and ~1000GeV.

A definitive answer can come only from careful experiments.

Search for the SM Higgs Boson

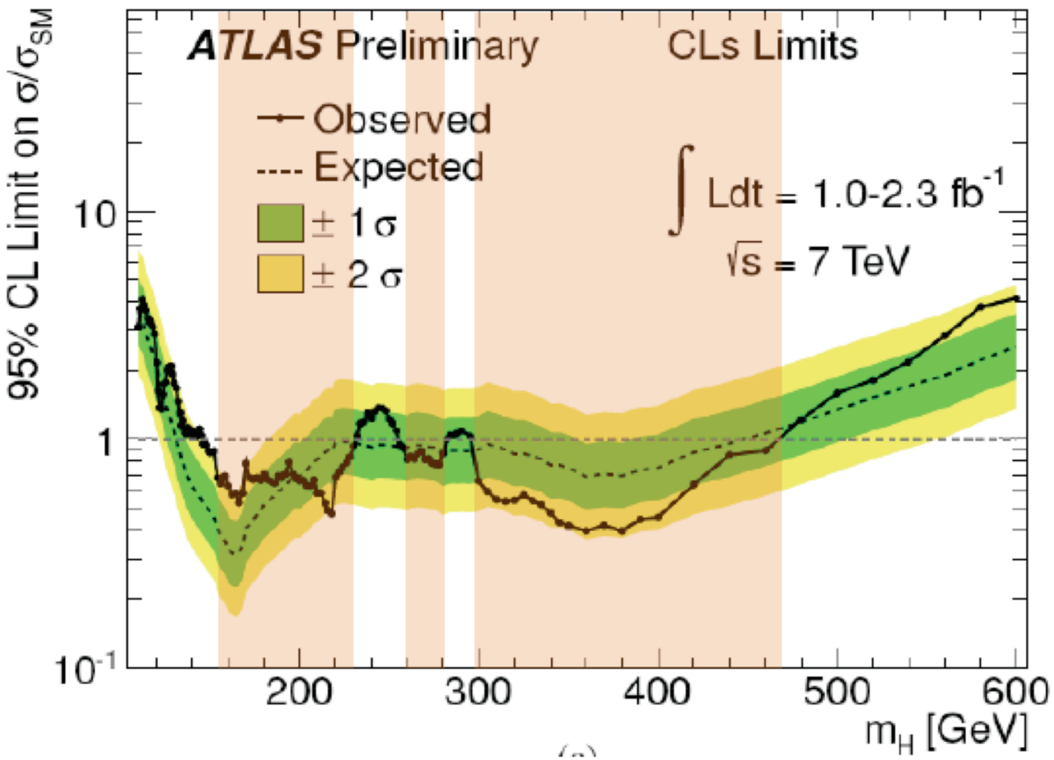
"Bringing together many droplets of water to make an ocean"

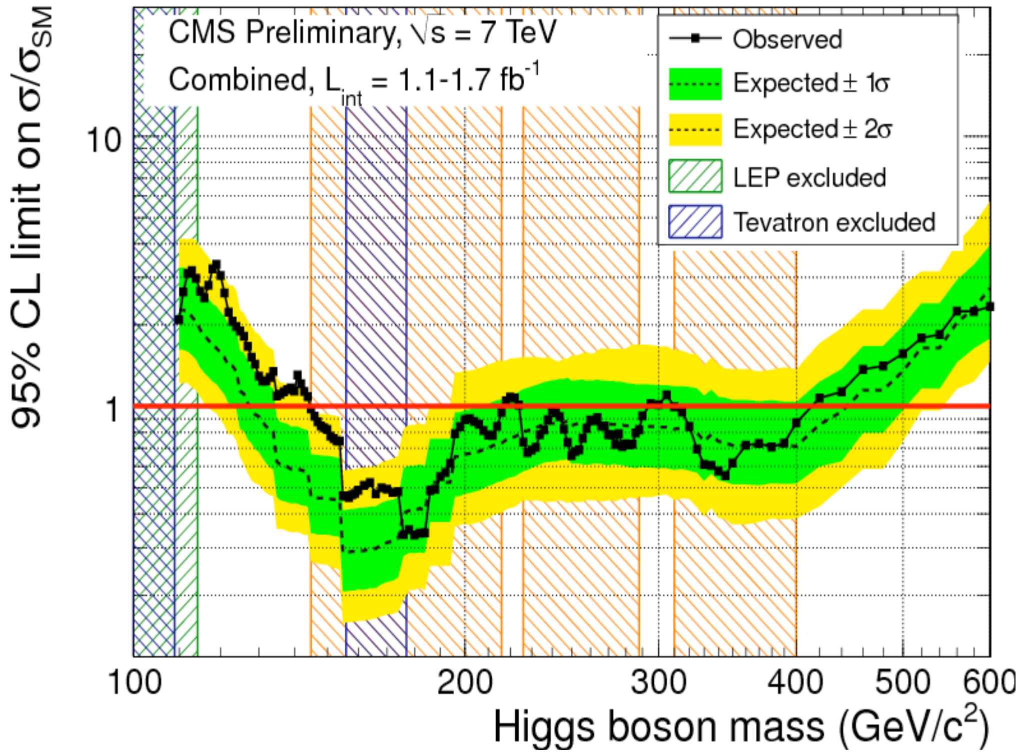


CMS PAS-HIG-11-011

ATLAS and CMS are looking for the Higgs boson in a very wide mass range combining together many different decay channels.

SM Higgs 95% CL exclusion limits





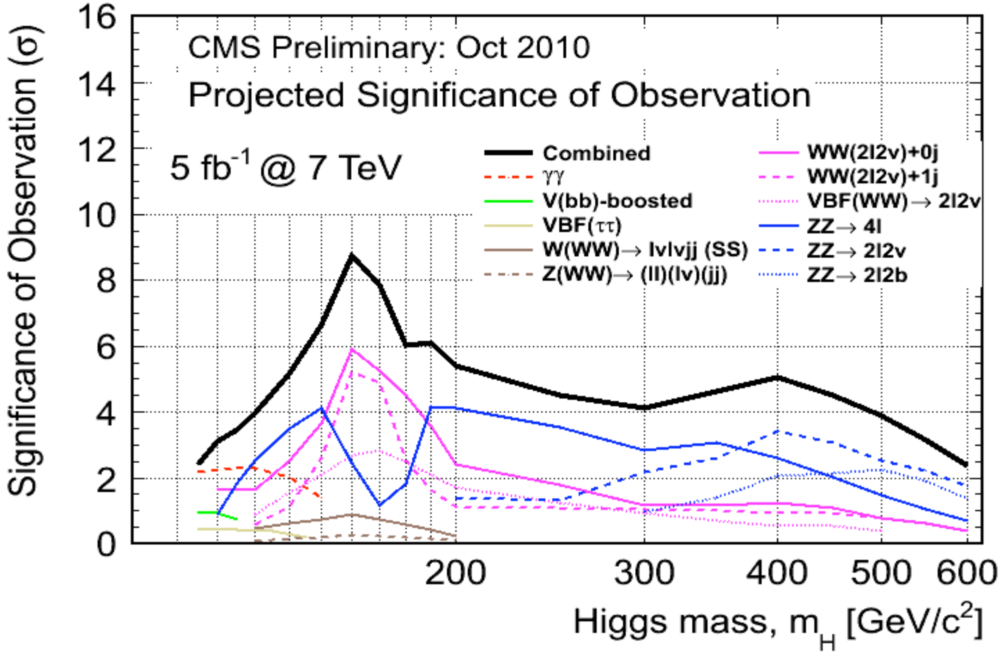
In the low mass part (114-145 GeV) we see a couple of interesting regions showing some excess. Further study with the new data we are collecting will hopefully tell us if we are seing a background fluctuation or the first hints of the presence of a Higgs boson.

Prospects for the SM Higgs Observation

With $5 fb^{-1}$ and the combination of the two major LHC experiments the discovery reach is almost everywhere in the range from 114 to 600GeV.

Alternatively, we could start ruling out the SM Higgs.

Before the end of 2012 we'll know the answer.



SM Higgs Search Prospects (Mass in GeV)			
ATLAS + CMS	95% CL exclusion	3 σ sensitivity	5 σ sensitivity
$1 fb^{-1}$	120 - 530	135 - 475	152 - 175
$2 fb^{-1}$	114 - 585	120 - 545	140 - 200
$5 fb^{-1}$	114 - 600	114 - 600	128 - 482
$10 fb^{-1}$	114 - 600	114 - 600	117 - 535

Conclusion

- LHC operations are proceeding very well. Plenty of new physics results are being published by all LHC experiments.

- Unfortunately no evidence for physics beyond the Standard Model so far.

- Good expectations to be able to discover the SM Higgs boson or to exclude it fully by the end of 2012.

- Surprises and signals of new physics might appear any moment in LHC data.

- **Many thanks to:**

  - the LHC team for the outstanding performance of the machine.
  - the Conference Organizers for their kind invitation.
  - you for your attention.