Summary Session 3
Standard Model and Beyond

- QCD and Electroweak Physics
- Higgs Physics
- SUSY
- Other BSM physics

Remarks:

- Topics with increasing level of fogginess

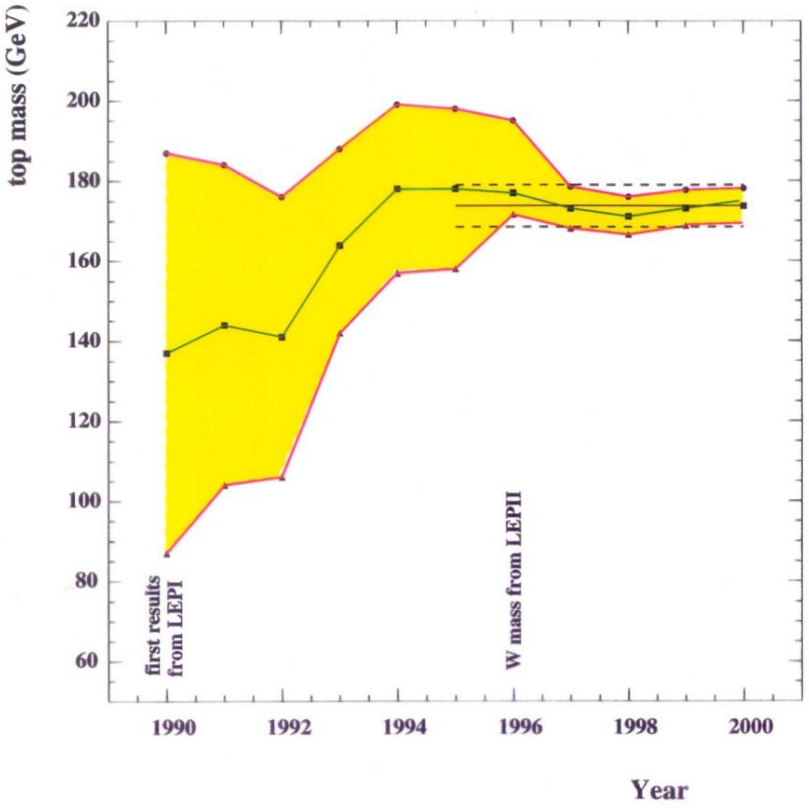
- LHC has just started

- Physics and facilities at the energy frontier

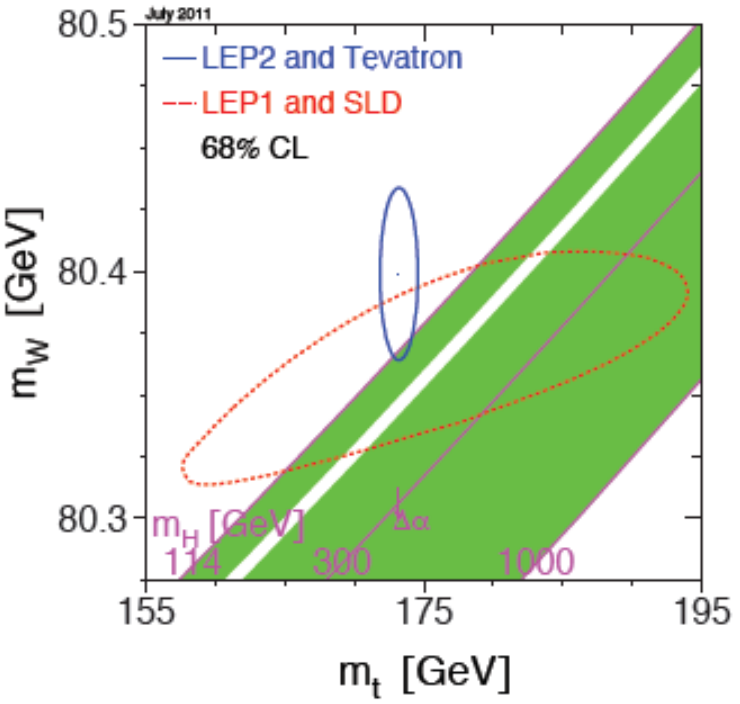
Precision Measurements (EW + QCD)

- **Example indirect constraints on top and Higgs mass**

- **Top mass**



- **Higgs mass**



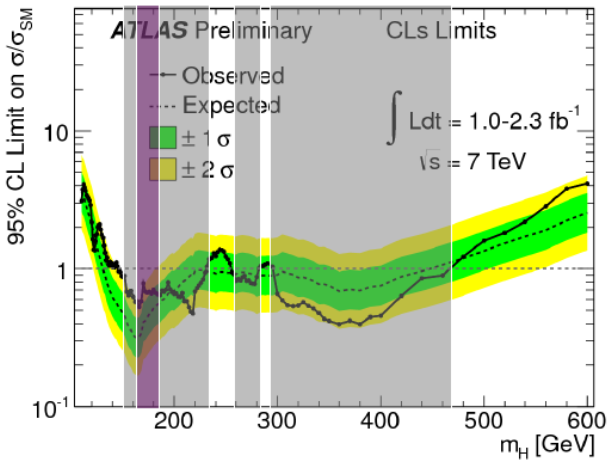
improvement mainly on m_W needed

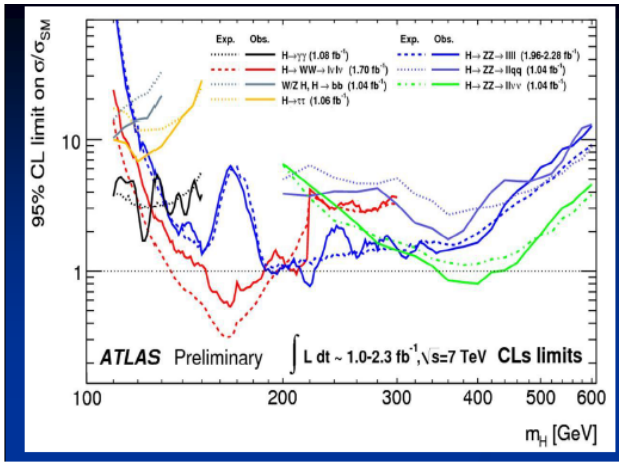
- **Precision measurements can complement but cannot replace direct studies of new physics**

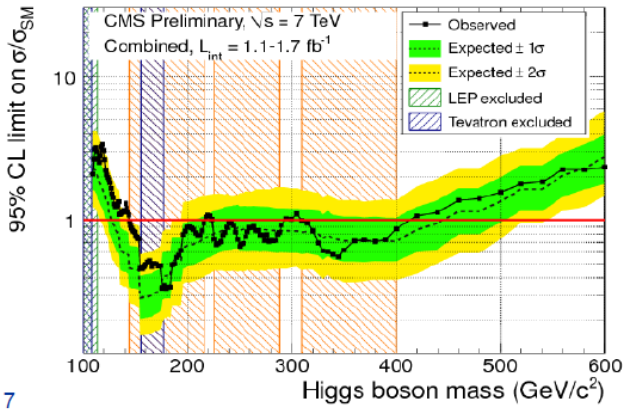
Higgs

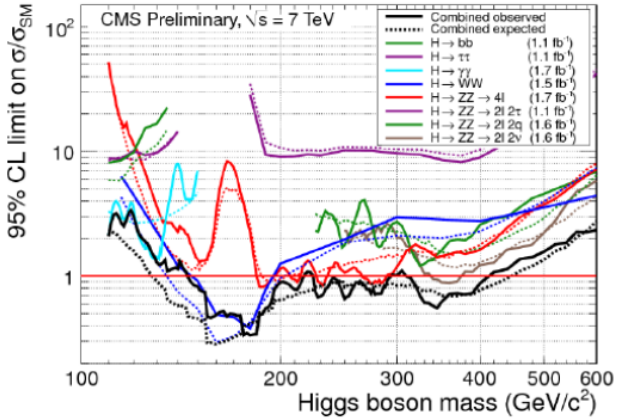
- **The Higgs is a special particle, one of a kind**
  Sachio: "worth as much as discovery of the first boson (photon) or fermion (electron)"

- **Be prepared for a low mass Higgs:**









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Excluded either by ATLAS or CMS 145-466 GeV (except 288-296 GeV) 95%CL

Higgs

- **Finding a Higgs will be a major discovery**
- **Not finding the SM Higgs will be a revolution**

LHC experiments will answer this question soon

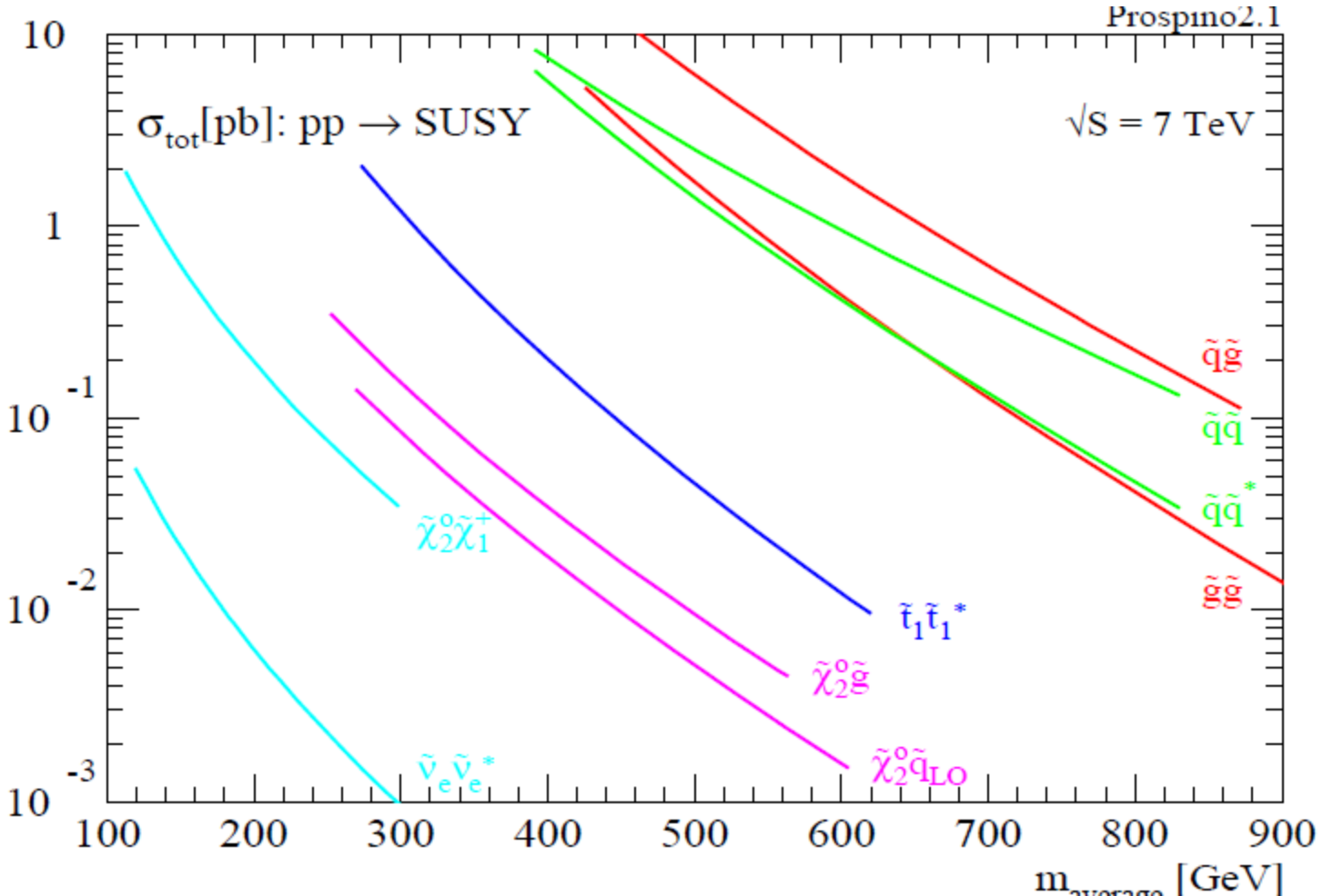
If there is a Higgs it needs to be studied as precisely as possible

- **LHC at high luminosity is inevitable**
- **LC is Higgs factory with huge potential and perspectives**
  - **Discovering a Higgs-like signal at low mass would provide a clear scientific case for a Linear Collider**
  - **and open a window of opportunity**

- **But: we have to study NOW what can be expected to be revealed at the LHC until the LC comes up**
  - **compare apples to apples to make a credible case for a LC**

Supersymmetry

- **No direct evidence yet**
- **SUSY production at the LHC:**
  - **high cross section for coloured sparticles, i.e. gluinos + squarks of first two generations**



Supersymmetry

- **Searches pointing to light Higgs are consistent with SUSY**
- **Solidified discrepancy in muon (g-2) points to light colour neutral SUSY states**
- **Dark matter**

- **Colour neutral states need more luminosity at LHC**

- **LC: very good propects for identification of underlying physics if states are within reach**

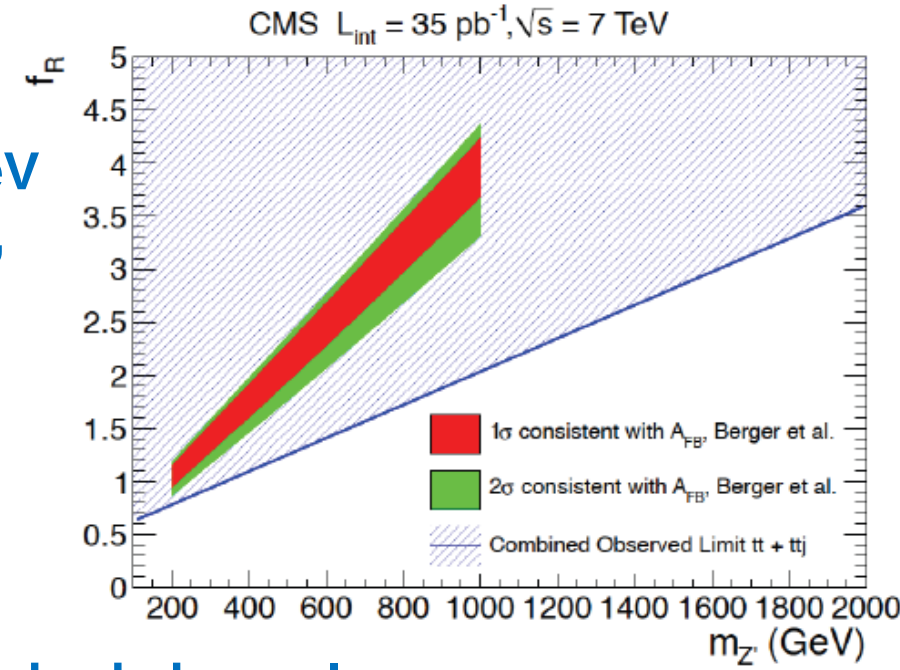
- **HE-LHC: significant increase of mass reach but needs very good justification**

Other Physics Beyond the SM

Examples

1. Search for heavy resonances

- **LHC puts significant limits 1-4 TeV**
- **Powerful in constraining models, e.g. to explain Tevatron top AFB**



- **LHC is a powerful machine entering uncharted BSM territory**

2. Deviation in Higgs sector from SM

- **Enhancement/suppresion of standard channels**
- **Higgs-Radion Mixing**
- **Higgs below 114 GeV**
- **…**

- **James: „We must prepare new colliders to answer the questions not answered or newly raised by the LHC“**

Standard Model and Beyond Facility Matrix

Facilities at the energy frontier

Time / preparation needed

Topic/ Facility	Tevatron	LHC	HL-LHC High Lumi	Linear Collider ≤ 500 GeV	LHeC	Linear Collider > 500 GeV	HE-LHC High Energy	μ-Collider
QCD/EW tests								
Higgs								
SUSY								
Other BSM								

Running facilities

Proposed/planned facilities

Physics case almost assured

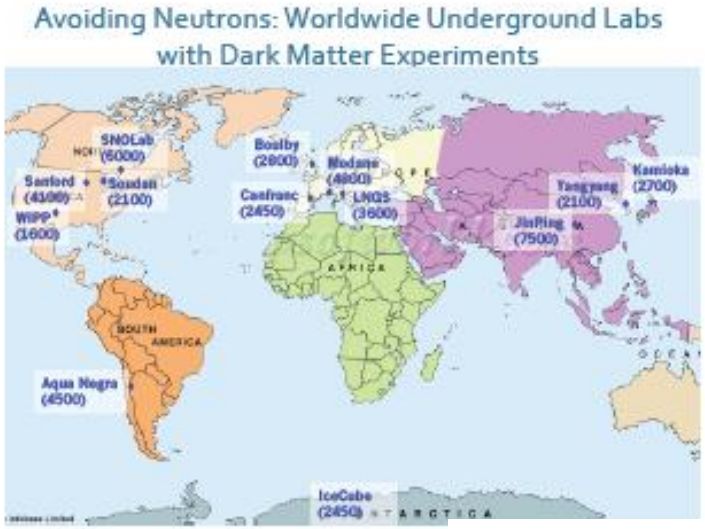
More experimental input needed

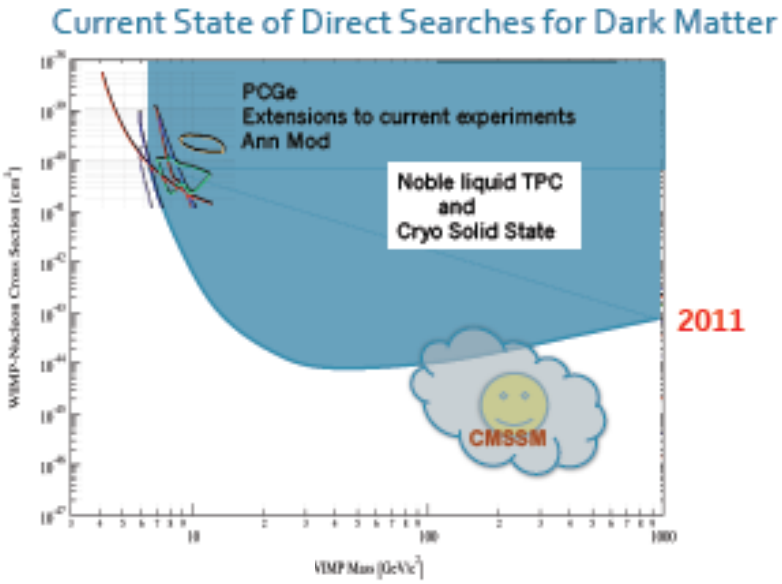
Sesion 4: Bridges of HEP with Dark Matter & Dark Energy

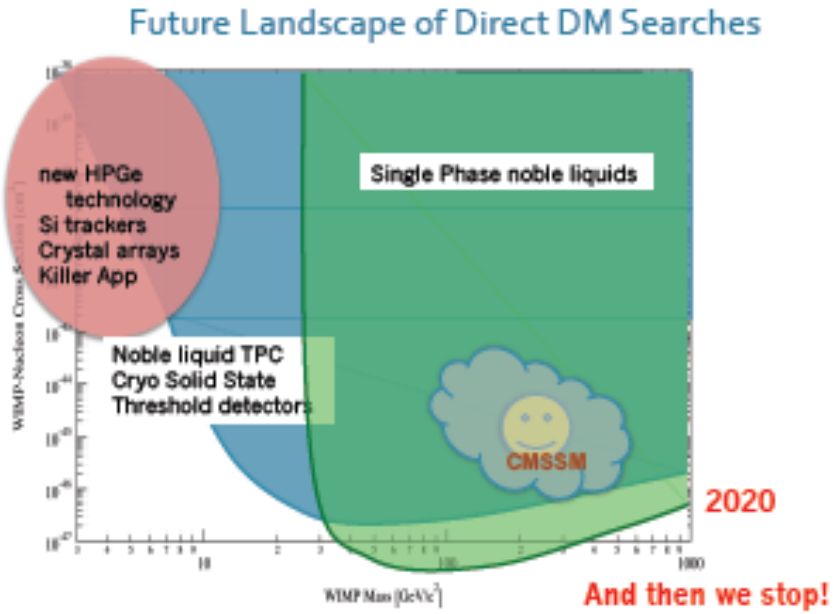
Detection of Dark Matter—The big question is 'What is it and can we detect it?'

- Direct Detection
  - Good mass measurement
    - Low background requires underground labs
- Indirect Detection
  - Map dark matter in the cosmos
    - Gammas-Cherenkov (ground based)
    - Gammas-Calorimeter & Magnetic spectrometers (space based)
    - Neutrinos
- Production
  - Greatest insight into fundamental physics
    - Direct production at LHC

Direct Detection







In-direct Detection

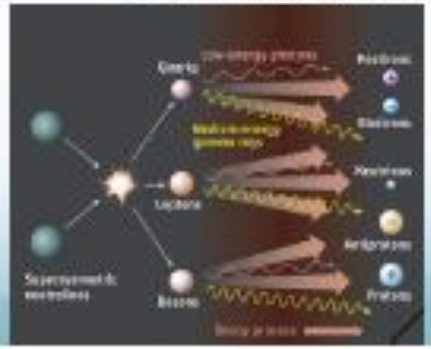
What is "Indirect" Detection ?

We already have plenty of indirect evidence of Dark Matter
Why do we need more?

Because there is no astrophysical evidence of WIMPs!

What do we look for?

WIMP pair annihilation: the same σ_A used to determine relic density also fixes astrophysical annihilation rate

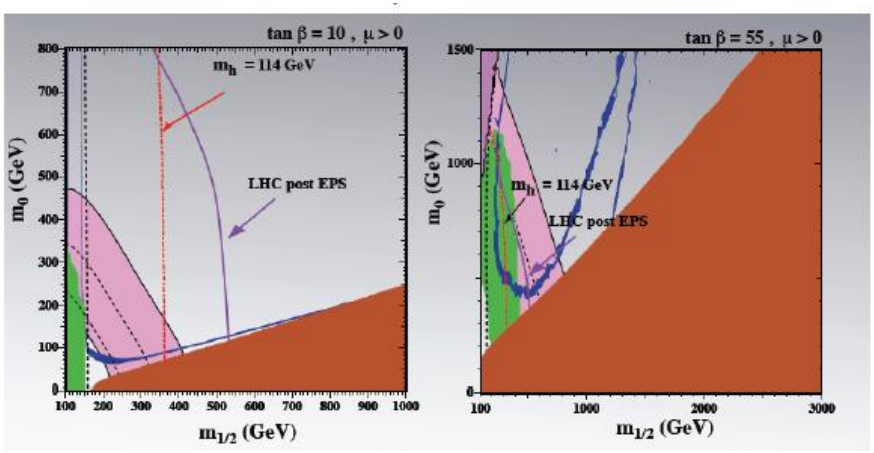


Indirect Detection of WIMPs: *Detectors*

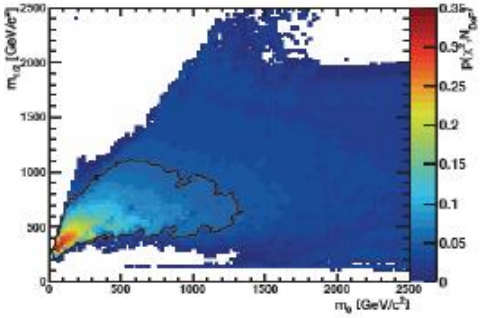
Enormous FUTURE Cerenkov Detectors		EM Calorimeters
γ (look up)	ν (look down)	
→ CTA (proposed)	SuperK → HyperK	**Balloon** ATIC, CAPRICE, HEAT, BESS
	Baikal → GVD (Gigaton)	
	NESTOR (Greece) + NEMO (Italy) → KM3NET	**Space** PAMELA, AMS EGRET, FERMI LAT
	ICECUBE → ??	
→ HAWC (Mexico)		

Production

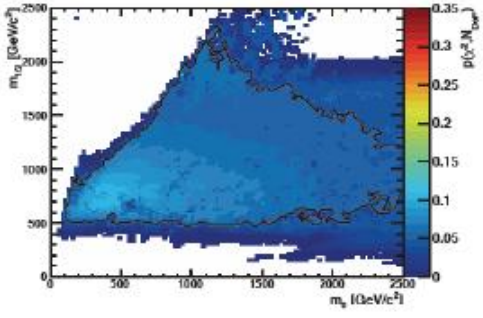
- LHC results so far have seriously diminished available CMSSM space for WIMPs



Probabilty maps for the CMSSM (preliminary)



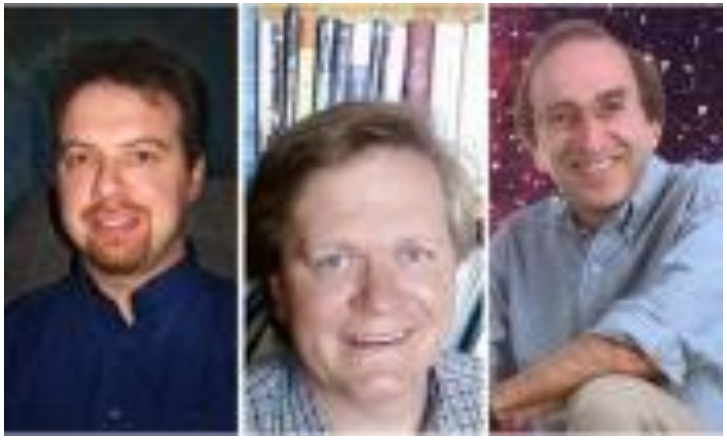
Before new LHC data



After new LHC data

Study of Dark Energy: The big question: What is it?

- Dark Energy has won its first Nobel Prize!



- Now the hard work begins

- Cosmological parameters to sub-%
- Can we deduce the nature of DM?
- Can we detect neutrino mass?
- Can we rule out w=–1?
- Can we distinguish

  Dark Energy from Modified Gravity?

  A new paradigm shift?

What is Dark Energy?

- Vacuum energy (cosmological constant)?
- Dynamical scalar field?
  - $w=p/\rho$
  - for cosmological constant: $w = -1$
- Manifestation of modified gravity?
- Inhomogeneous Universe?

- What if cosmological constant after all?
- Multiverse - Landscape?
- The Anthropic Principle?

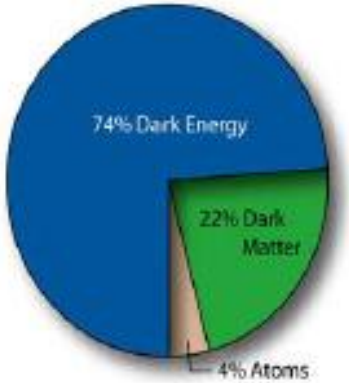
Darkness Visible

Observational data:

- Gravitational Lensing
- Peculiar Velocities
- Galaxy Clusters
- Cosmic Microwave Background
- Large Scale Structure
- Type Ia Supernovae
- Integrated Sachs-Wolfe

Physical effects:

- Geometry
- Growth of Structure



The Landscape of Large Surveys 2011-2020

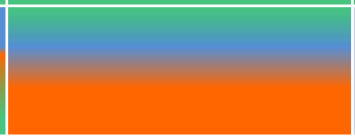
(some under construction, some proposed)

Photometric surveys: DES, VISTA, Pan-STARRS, HSC, Skymapper, PAU, LSST, ...

Spetroscopic surveys: WiggleZ, BOSS, e-BOSS, BigBOSS, DESpec, HETDEX, Subaru/Sumire , VISTA/spec, SKA, ...

Space Missions: Euclid, WFIRST

Matrix of Experiments

	Underground laboratories	Ground based observatories	Space based observatories	Accelerators
What is dark matter?				
What is dark energy?				

Messages for the Future

- A coherent strategy will be needed to answer these exciting and fundamental questions in DM and DE
  - ‘Marriages’ will be necessary
    - Best marriages are love marriages rather than shot gun marriages
  - Imagination will be needed to resolve technological, national, political issues
- The evolution from small technology R&D to full scale project needs resources and structure
  - Competition and collaboration need to be wisely balanced