

INTRODUZIONE

DIPARTIMENTO DI FISICA



SAPIENZA
UNIVERSITÀ DI ROMA

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Fisica delle Particelle Elementari, Anno Accademico 2015-2016

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ORARIO LEZIONI

- Lunedi` e Martedì`, Mercoledì` ore 14-16, Aula 2
- Alcune settimane faremo 2 lezioni
 - In totale ci saranno circa 25 lezioni
- Tutto il materiale e gli avvisi saranno disponibili sul sito web del corso

<http://www.roma1.infn.it/people/rahatlou/particelle/>

REFERENCE MATERIAL AND BOOKS

- Mostly using recent review papers and lectures at topical schools
- Some of the older topics and basics covered also in
 - Burcham & Jobes: Nuclear and Particles Physics (Prentice-Hall)

Libri consigliati

- [The Experimental Foundations of Particle Physics, 2nd Edition](#), R. N. Cahn and G. Goldhaber, Cambridge university press
- [Quantum chromodynamics](#), Dissertori, Knowles, Schmelling, Oxford university press
- [Perspectives on LHC Physics](#), G. Kane and A. Pierce, World Scientific
- [Weak scale supersymmetry](#), H. Baer and X. Tata, Cambridge university press
- [CP Violation](#), G. Branco, L.s Lavoura, and J. Silva, Oxford university press

Articoli di review

- [Precision electroweek measurements on the Z resonance](#), LEP and SLC collaborations
- [Hard Interactions of Quarks and Gluons: A Primer for LHC Physics](#), J.M. Campbell, J.W. Huston, W.J. Stirling
- [Lectures on LHC Physics](#), T. Plehn
- [Measurements of the Production, Decay and Properties of the Top Quark](#), K. Lannon, F. Margaroli, C. Neu
- [Electroweak Symmetry Breaking and Higgs Physics](#), M. Spira and P. M. Zerwas
- [The Anatomy of electro-weak symmetry breaking](#), A. Djouadi, [The Higgs boson in the Standard Model](#), [The Higgs bosons in the Minimal Supersymmetric Model](#)
- [A Supersymmetry Primer](#), S. Martin
- [General-purpose event generators for LHC physics](#), excellent and very clear review
- [Bayes and Frequentism: a Particle Physicist's perspective](#), L. Lyons

MODALITA` D'ESAME

- Non ci saranno presentazioni con le slide
- Prova orale con carta e penna
- Domande sul programma del corso
 - non sui dettagli delle misure specifiche trattate nel corso ma sullo scopo e metodo degli esperimenti e della parte teorica/fenomenologica
- Di solito cominciamo da un argomento a scelta
 - Saranno disponibili articoli di misure importanti riguardanti tutto il programma da approfondire come possibile argomento
 - ▶ Motivazione teorica e come la misura si colloca nello studio del Modello Standard o ricerca di nuova fisica
 - ▶ Scelta dei rivelatori e vantaggi e svantaggi
 - ▶ tecnica di misura
 - ▶ i fondi principali e il motivo per cui sono fondi
 - ▶ le incertezze sistematiche principali

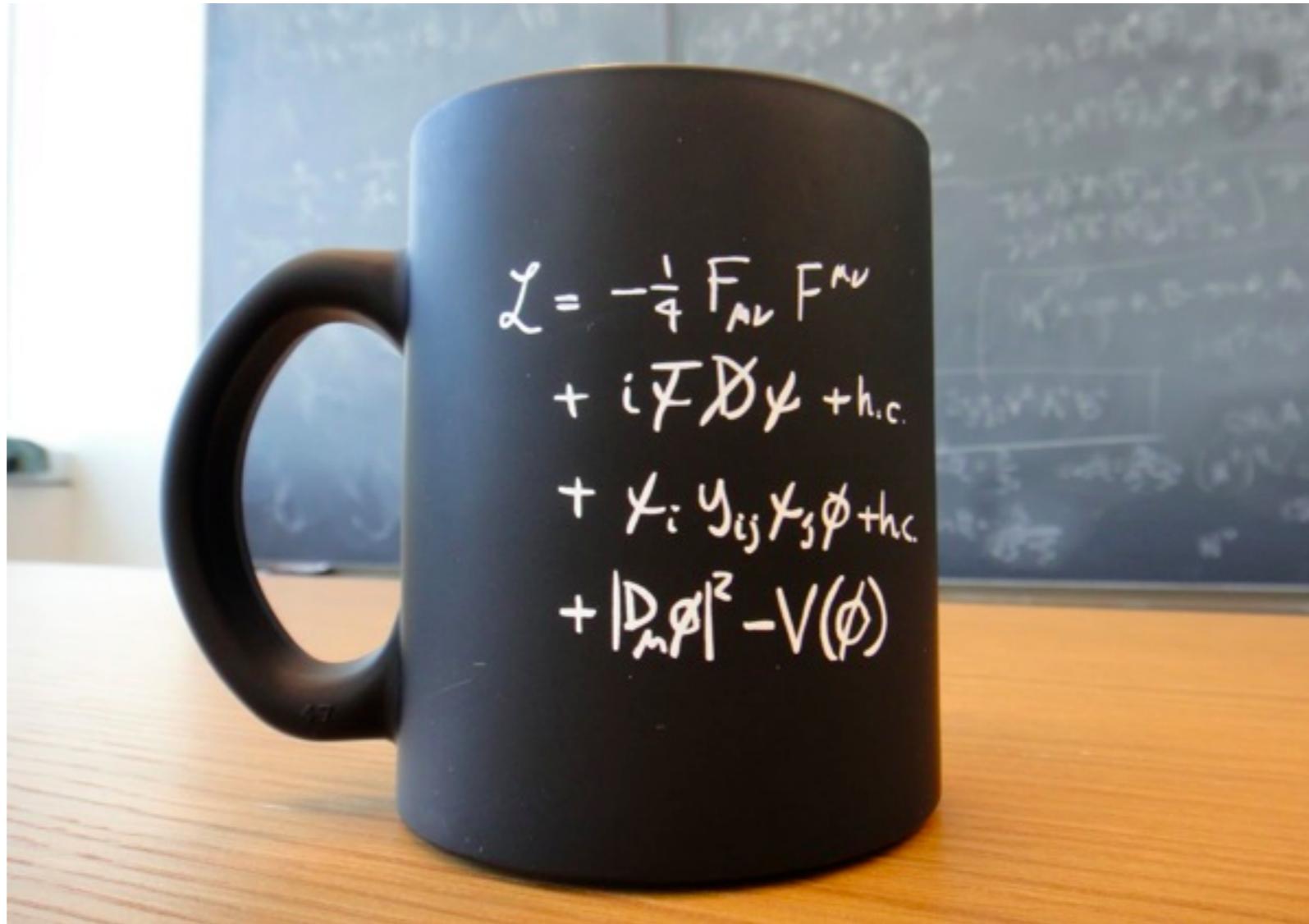
SPECIAL YEAR: A NEW DISCOVERY



FNS I & II

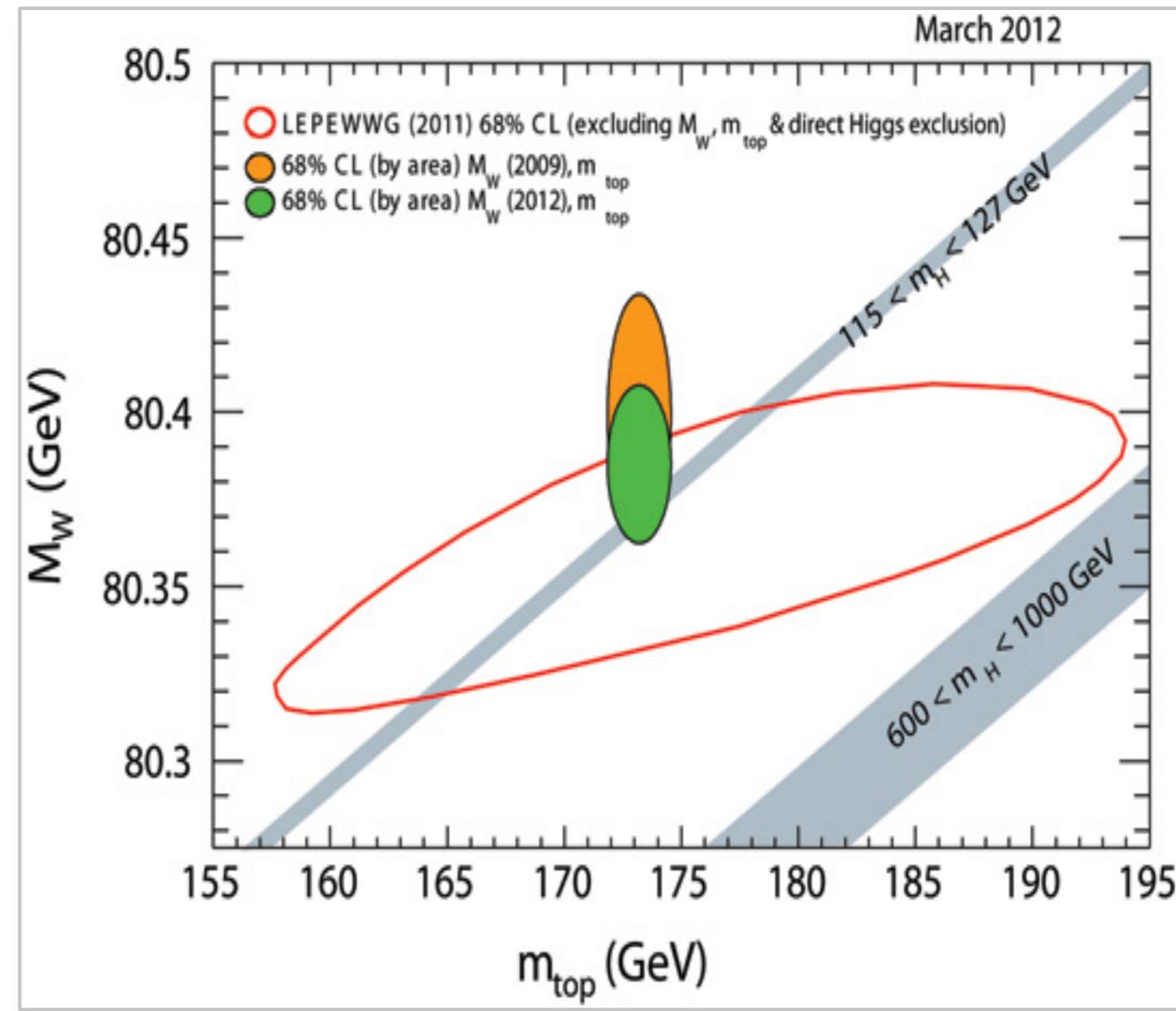
Source: *The Economist*

STANDARD MODEL



- You are familiar with Electroweak symmetry breaking mechanism from Relativistic Quantum Mechanics Course
- We will discuss the phenomenology of this lagrangian

STANDARD MODEL BEFORE JULY 2012



Will discuss
this plot in LEP

- Precise limits on possible mass of Higgs from tests at LEP
- Stringent limits from direct searches at LHC in 2011
- On 4th July 2012 we could *finally* break badly the Standard Model

FIRST DISCOVERY IN A VERY LONG TIME



Shahram Rahatlou, Roma Sapienza & INFN



HIGGS IN THE NEWS

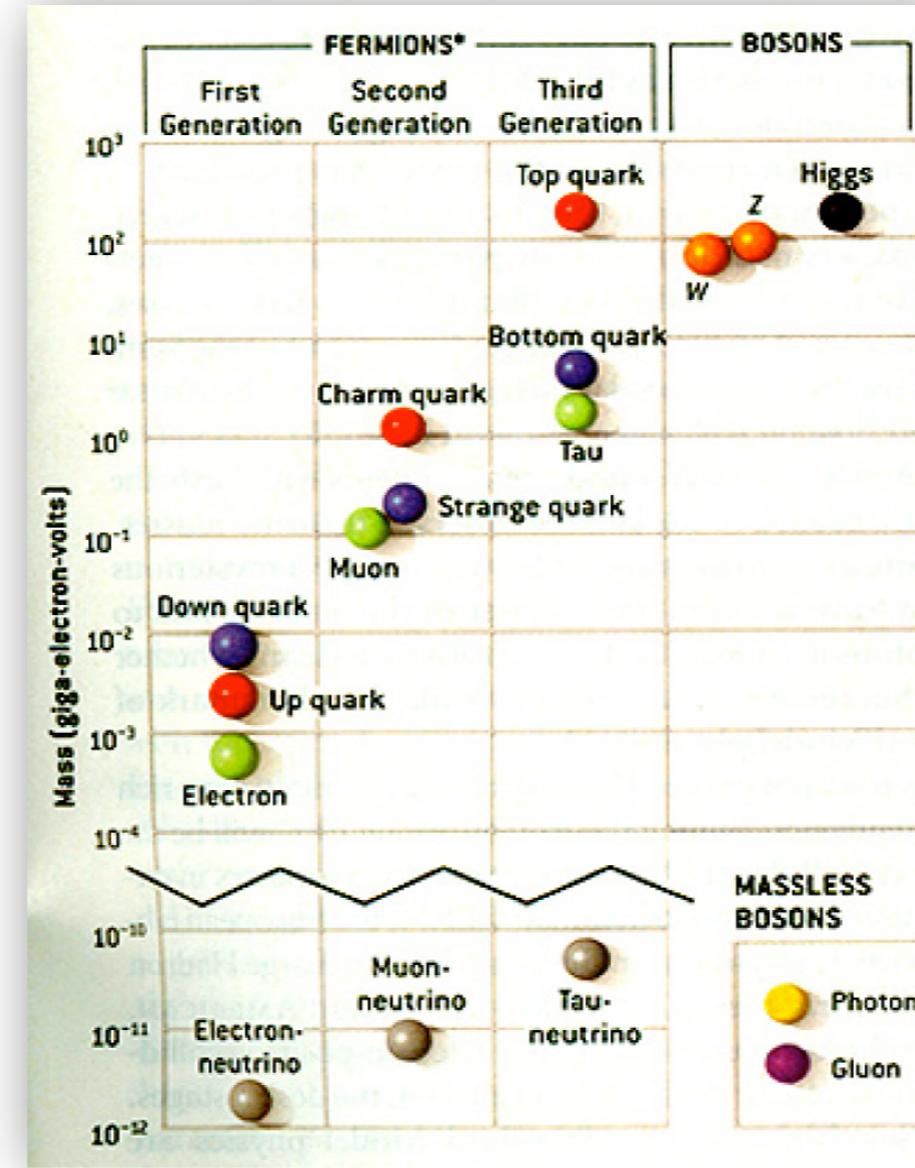
We are living a privileged moment
in the history of HEP



(picture: courtesy of A. Hoecker)

PRESS
COVERAGE
after July 4th seminars at CERN

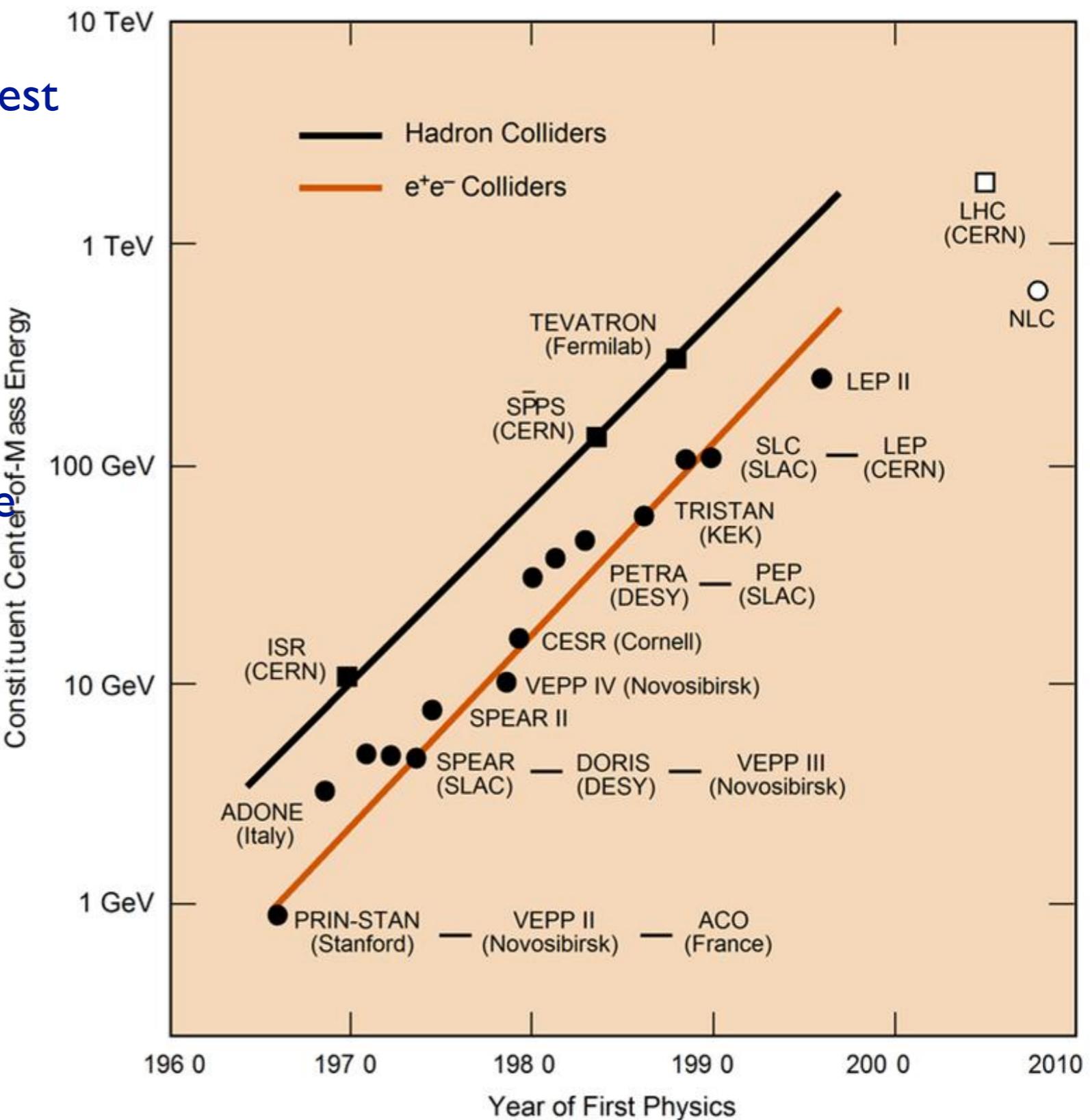
FIRST EVER SCALAR IN NATURE



- Heaviest boson so far in Nature!
- First scalar particle ever discovered
- Now testing whether the Higgs boson predicted in Standard Model
 - so far no surprises

ROAD TO DISCOVERY

- Start with LEP
 - crucial role with precision test of Standard Model
- Re-discovery of Standard Model with LHC
 - new proton-proton machine
- Discovery of a new boson
- What else we expect to see at a hadron collider?



NEW BOSON AND OUR UNIVERSE

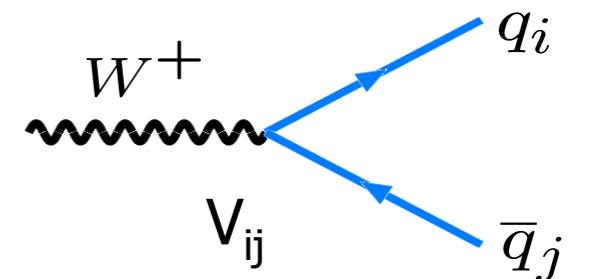
- Important implications of Higgs-like discovery
- Will discuss in this course what it means to be in a meta-stable universe
- Main question remains: have we discovered the SM Higgs or something else?

HIGGS AND CKM

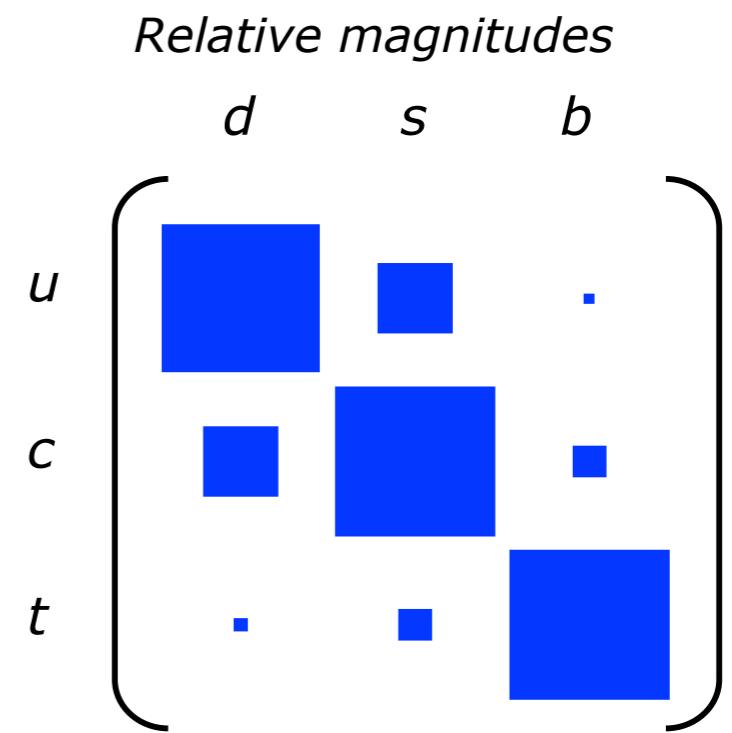
$$\mathcal{L}_Y = -\mathbf{G}_{ij} \overline{Q_{Li}^I} \phi d_{Rj}^I - \mathbf{F}_{ij} \overline{Q_{Li}^I} \tilde{\phi} u_{Rj}^I + \text{H.c.}$$

No more universal coupling constant!

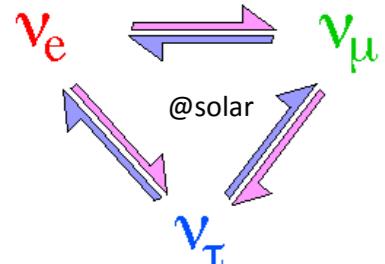
$$\mathcal{L}_W = -\sqrt{\frac{1}{2}} g \overline{u_{Li}} \gamma^\mu \overline{\mathbf{V}_{ij}} d_{Lj} W_\mu^+ + \text{h.c.} \quad \overline{\mathbf{V}} = \mathbf{V}_{uL} \mathbf{V}_{dL}^\dagger$$



$$\mathbf{V}_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



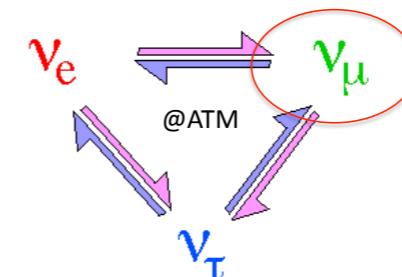
NEUTRINOS HAVE MASS!



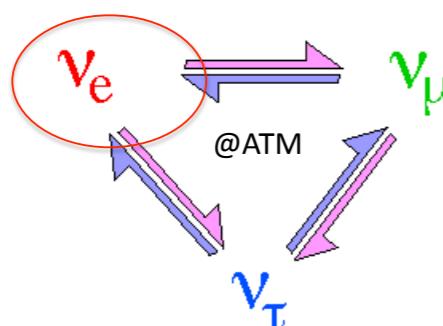
$$P_{\alpha\beta}(L) = \sin^2 2\theta \sin^2 \left(1.27 \frac{\Delta m^2 (eV^2) L(km)}{E(GeV)} \right)$$

Pontecorvo

$$|\Delta m_{12}^2| \sim \frac{O(\text{MeV})}{O(100\text{km})}$$



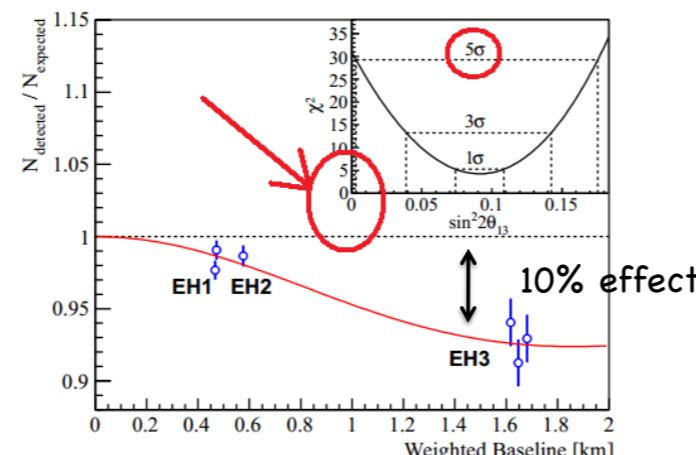
$$|\Delta m_{13}^2| \sim \frac{O(\text{GeV})}{O(1000\text{km})} \sim \frac{O(\text{MeV})}{O(1\text{km})}$$



$$|\Delta m_{13}^2| \sim \frac{O(\text{GeV})}{O(1000\text{km})} \sim \frac{O(\text{MeV})}{O(1\text{km})}$$

2012

T2K, Double Chooz
Daya Bay, RENO



Beautiful measurement
in 2012

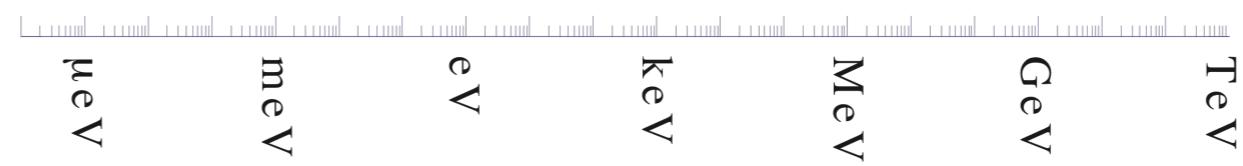
$d \bullet$ $s \bullet$ $b \bullet$

$u \bullet$ $c \bullet$ $t \bullet$

$e \bullet$ $\mu \bullet$ $\tau \bullet$

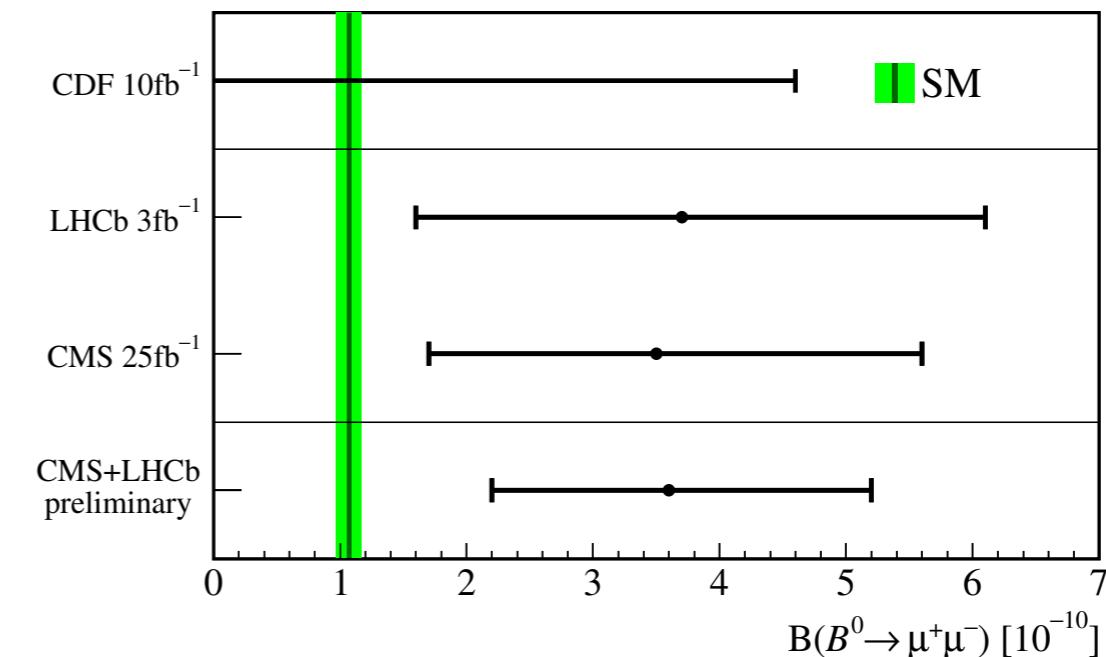
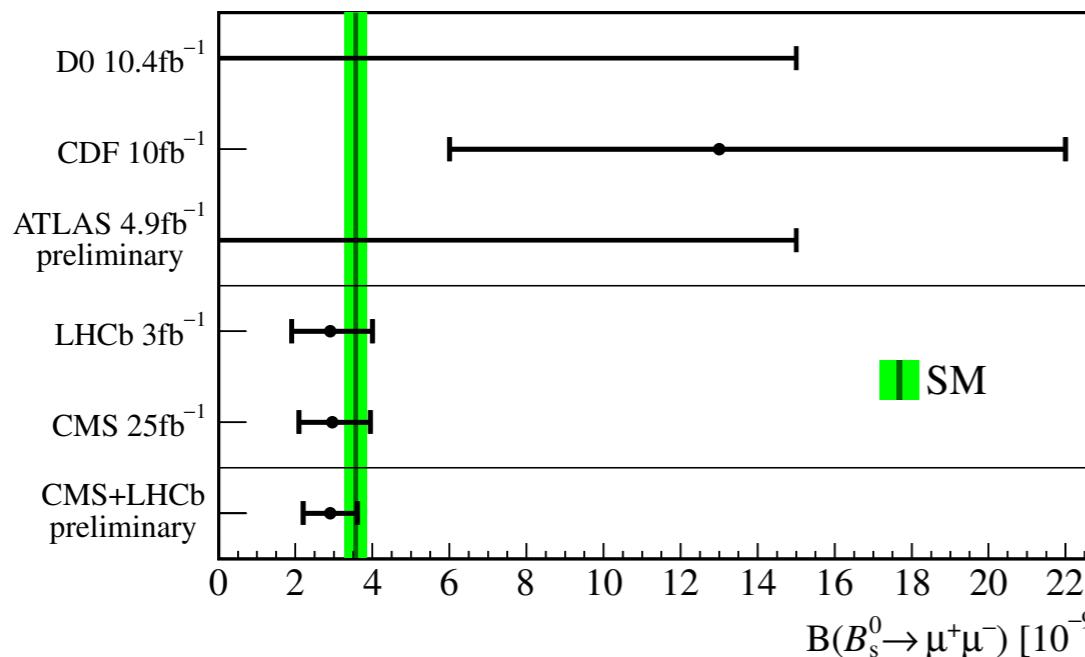
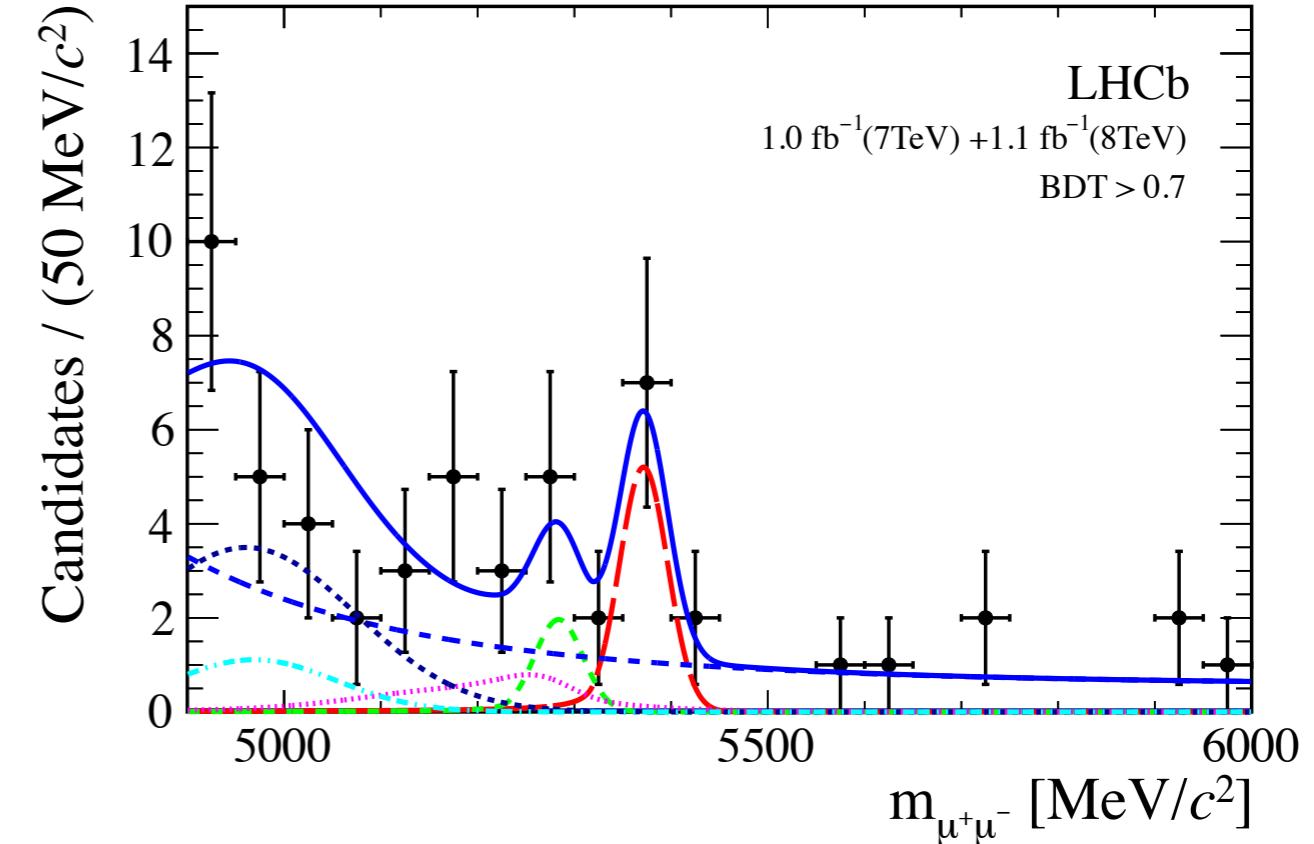
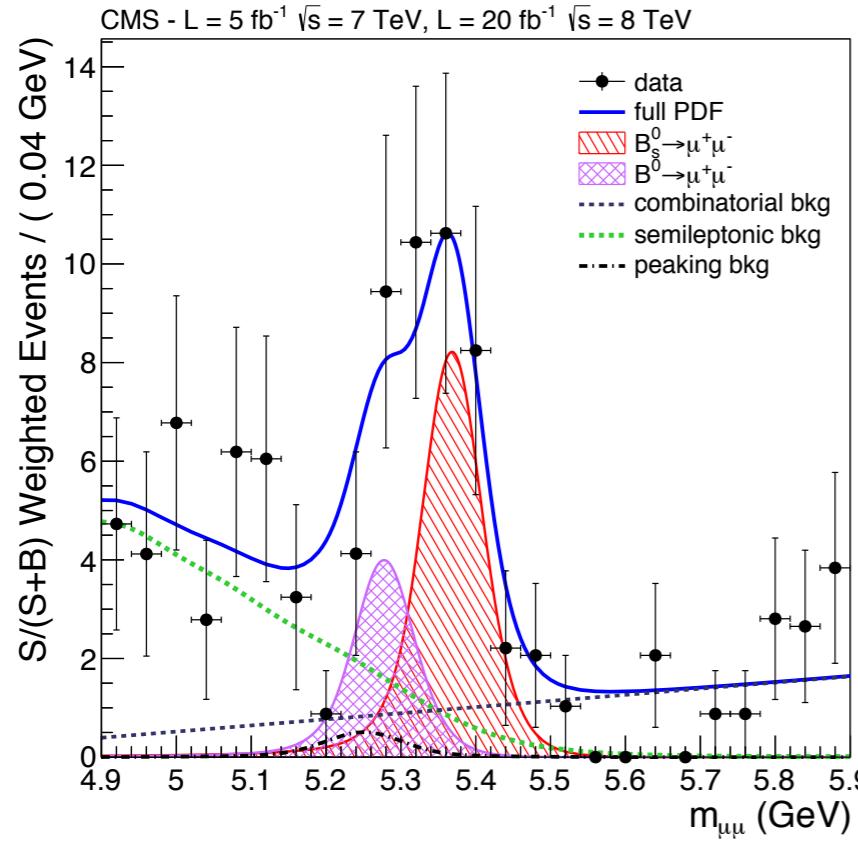
(large angle MSW)

$v_1 - v_2 - v_3$



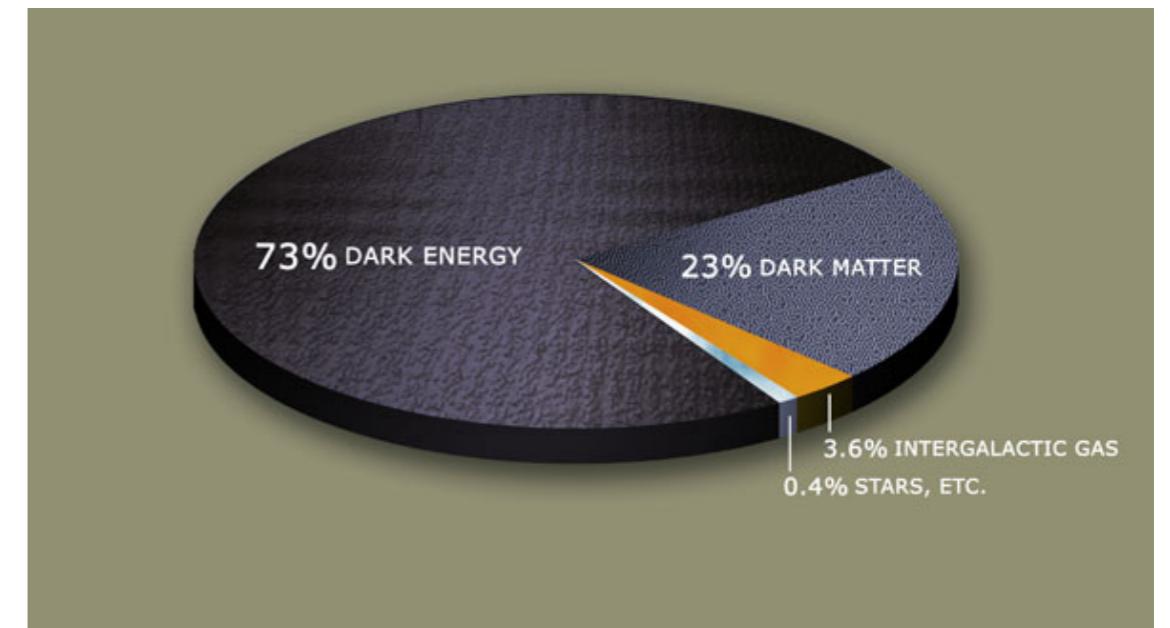
OBSERVATION OF RARE SM EVENTS

Summer 2013



SOME QUESTIONS COVERED IN THIS COURSE

- Why is Higgs so light? (Hierarchy problem and fine tuning)
- Is there really supersymmetry in Nature and if so where are the new particles?
- Are there new forces and particles?
- What about extra spatial dimensions and black holes?
- Where does the neutrino mass come from?
- What is the origin of matter—anti-matter asymmetry in universe?
- What is Dark Matter and how to search for it?



TENTATIVE COURSE PLAN

- Brief review of deep inelastic scattering (2h)
- LEP precision measurements (4h): **Not anymore!**
- LHC vs LEP: challenges of pp collisions (2h)
- Standard Model at LHC: W, Z, top (6h)
- Higgs searches: LHC (8h)
- Supersymmetry: introduction. Search strategy (4h)
- Exotics physics: new forces, extra dimensions, 4th generation, black holes and more (4h)
- CP Violation and B physics (6h)
- Neutrinos: oscillations and search for double beta decay (6h)
- Lepton Flavor Violation (4h)
- Dark matter and LHC (2h)