ICHEP 2014 VALENCIA

37th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

2 - 9 - JULY - 2014 - VALENCIA

Personal Highlights of ICHEP 2014

(apologies for the many topics omitted)

Peter Watkins

Conference Hall

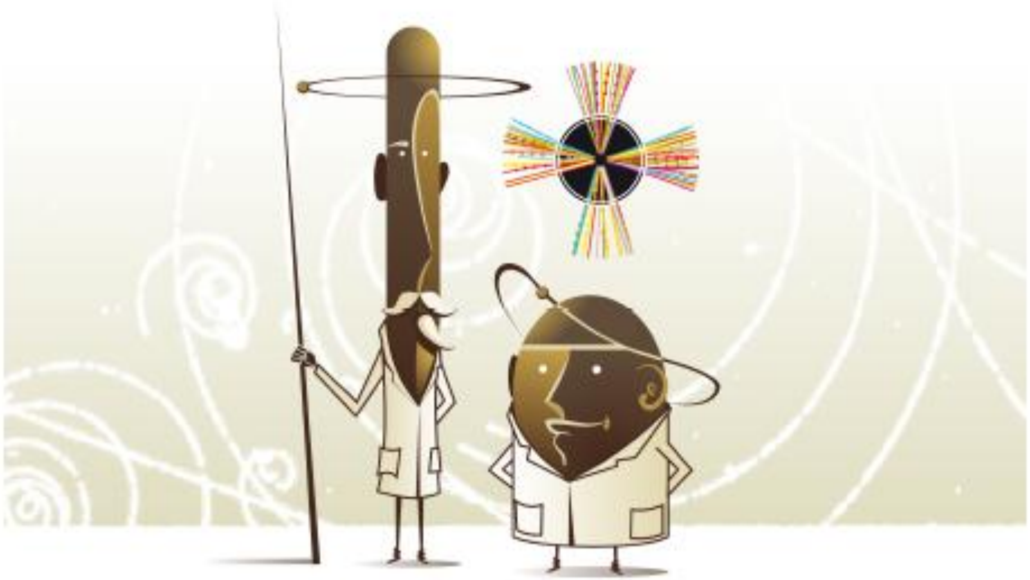
Many contributions

- 15 Parallel Sessions
- 536 Parallel Talks
- 55 Plenary Talks
- 18 Additional Talks

Theory ~ 30%

Lots of Physics

Experimental Highlights of ICHEP 2014



37th International Conference for High Energy Physics
July 2 – 9, 2014, Valencia, Spain

Young-Kee Kim
The University of Chicago

THEORY HIGHLIGHTS & OUTLOOK

A. Pich

IFIC, Univ. València - CSIC

ICHEP 2014, València, Spain, 2-9 July 2014

ICHEP 2014 VALENCIA

37th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

2-9-JULY-2014-VALENCIA

Lots of Physics!

856 Contributions: 241 posters and 624 talks (~ 30% theory)

Nicely summarized by Young-Kee Kim, Tony Pich, and
M.M. Kado, A. David, C. Grojean, F. Wuerthwein, M. Carena, R. Carlini, J. Berryhill, G. Bernardi, A. Freitas, P. Uwer, J. Albrecht, E. Browder, G. Isidori, J.P. Wessels, C. Gade, P. Nason, C. Roda, H. Peng, A.X El-Khadra, M. Lindner. M. Zito, S. Goswami, H. Araujo, J.M. Matthews, J. Berdugo, C. Stegmann, J.F. Barbon, A. Kappes, R. Mount, P.P. Allport, N.J. Walker, H.P. Beck, R. O´Brien, and E. Martinez-Gonzalez.

(Apologies for the subjects not covered!)

Teresa Rodrigo
SPC Meeting, 15-16 September 2014

This year marks several special anniversaries

On July 10th 1964, Cronin, Fitch, Christensen and Turlay submitted a paper announcing the discovery of CP violation in the weak decays of neutral kaons.

Year 2014 marks also the 50th anniversary of the Quark Model, proposed by Gell-Mann and published in January 1964.

CERN's 60th anniversary

ICHEP 2014

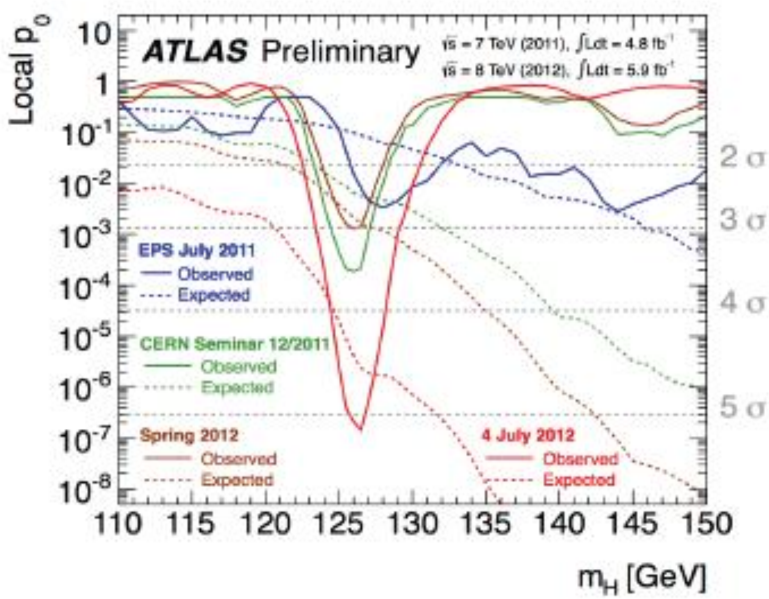
- Activities of the HEP community since ICHEP 2012
  - Producing physics results: > 500 experimental publications!!
  - Advancing future capabilities (near-term programs)
    - upgrading experiments and accelerators
    - constructing new experiments
    - developing new technologies
    - improving theoretical models and calculations
  - Developing a long-term vision
  - Involving in outreach and education

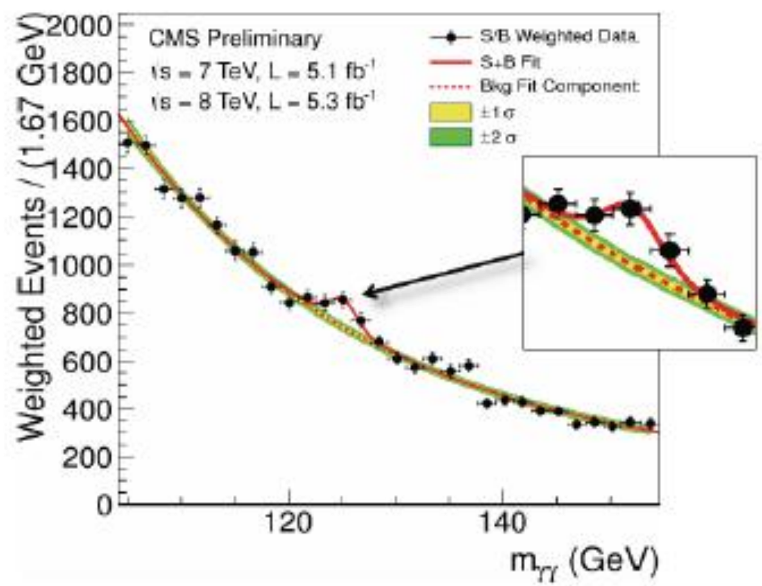
ICHEP2012
Melbourne

36th International Conference on High Energy Physics

4 – 11 July 2012
Melbourne Convention and Exhibition Centre

Discovery of a Higgs-like particle!





ICHEP2012
Melbourne

36th International Conference on High Energy Physics

4 – 11 July 2012
Melbourne Convention and Exhibition Centre

Discovery of a Higgs boson!

2013 Nobel Prize
in Physics

Francois Englert
Universite Libre de Bruxelles
Belgium

Peter Higgs
University of Edingurgh
U.K.

ICHEP2012 Melbourne

36th International Conference on High Energy Physics

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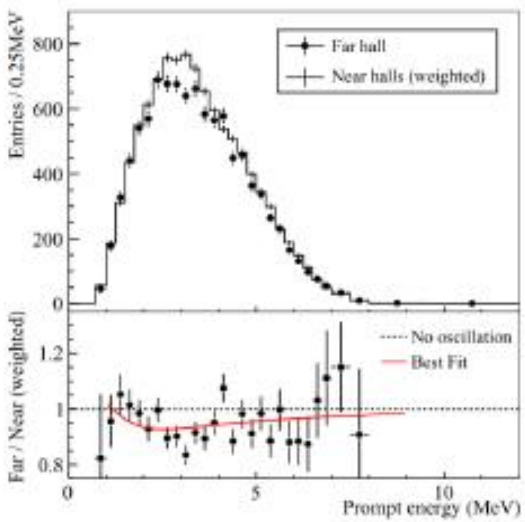
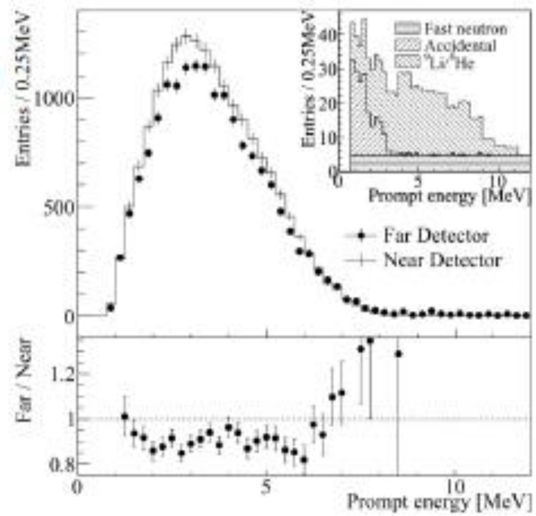
Neutrino mixing: θ_{13} ~ around 9° (large mixing angle!)

Daya Bay



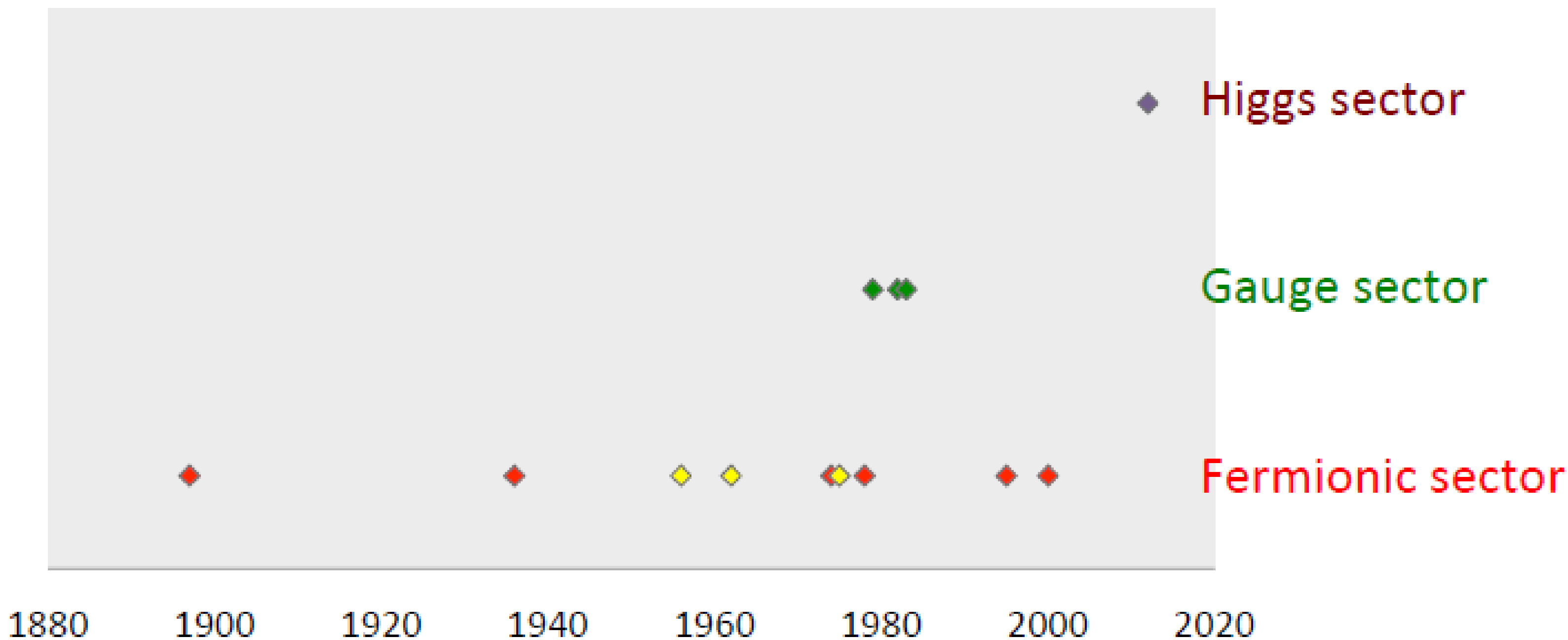
RENO



$\sin 2^2\theta_{13}$ = 0.092 ± 0.016 ± 0.005

0.113 ± 0.013 ± 0.019

Discovery of Elementary Particles



With the discovery of a Higgs boson,
the Standard Model has been completed

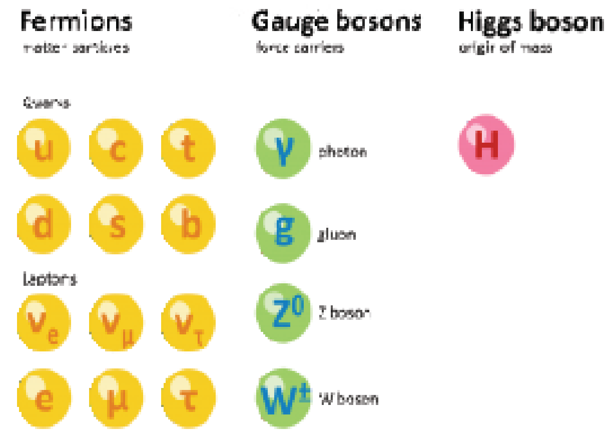
Particle Physics

Testing the Standard Model → sign of new physics

Ferminonic sector
(flavor; neutrino)

Gauge sector

EWSB / Higgs sector



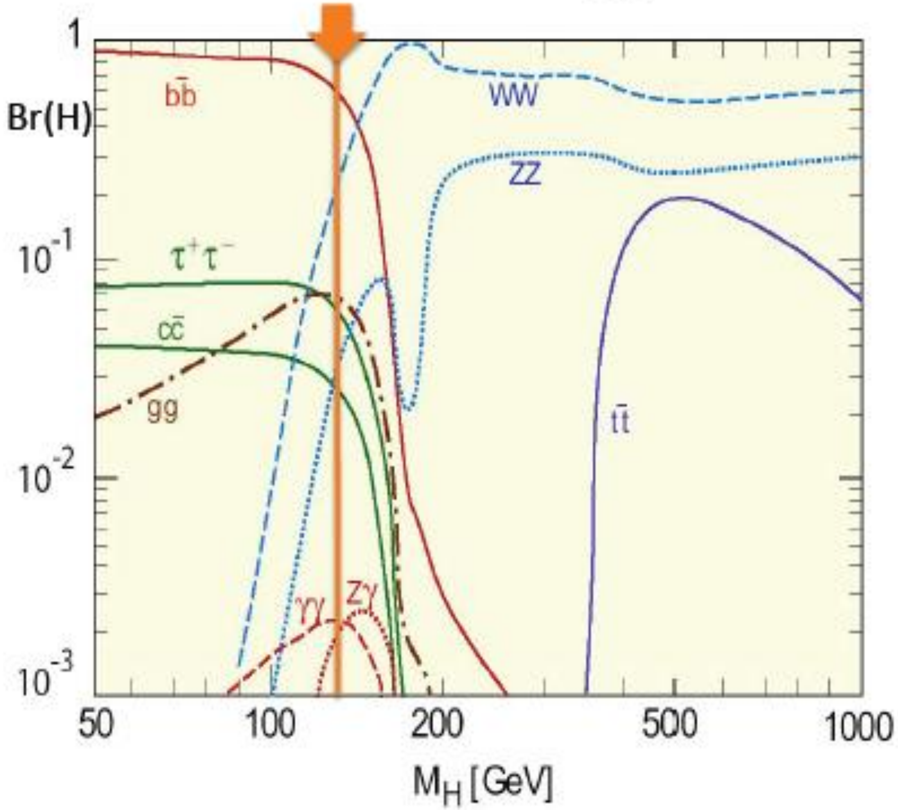
Beyond the Standard Model

Baryonic asymmetry
Dark matter
Dark energy

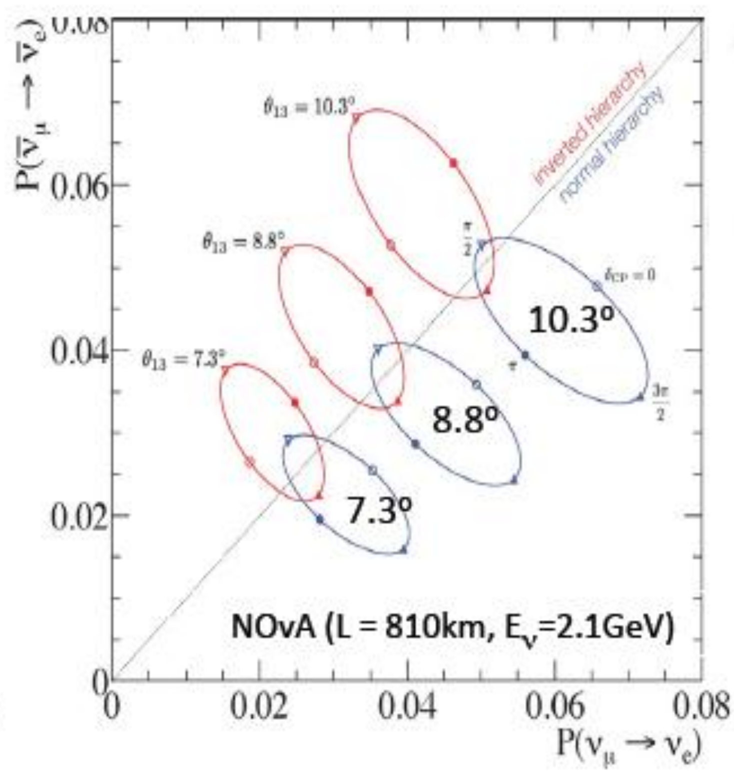
Higgs and θ_{13} help defining future directions

Nature has been kind to us

125 GeV Higgs enables to measure its interactions with many particles.



Large θ_{13} helps measurements of mass hierarchy & CP phase.



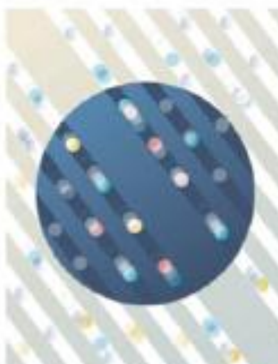
Science Drivers

U.S. Strategic Plan (Snowmass + P5, June 2014)

Five intertwined scientific Drivers were distilled from the results of a yearlong community-wide study:

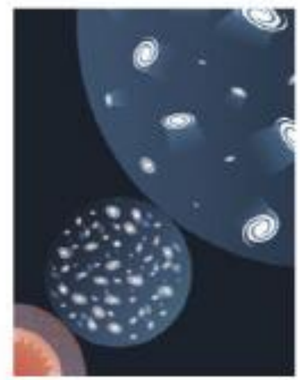
- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles

Higgs boson



Neutrino mass

Dark matter



Cosmic acceleration

Explore the unknown

Addressing the Science Drivers

- These questions are compelling, difficult, intertwined

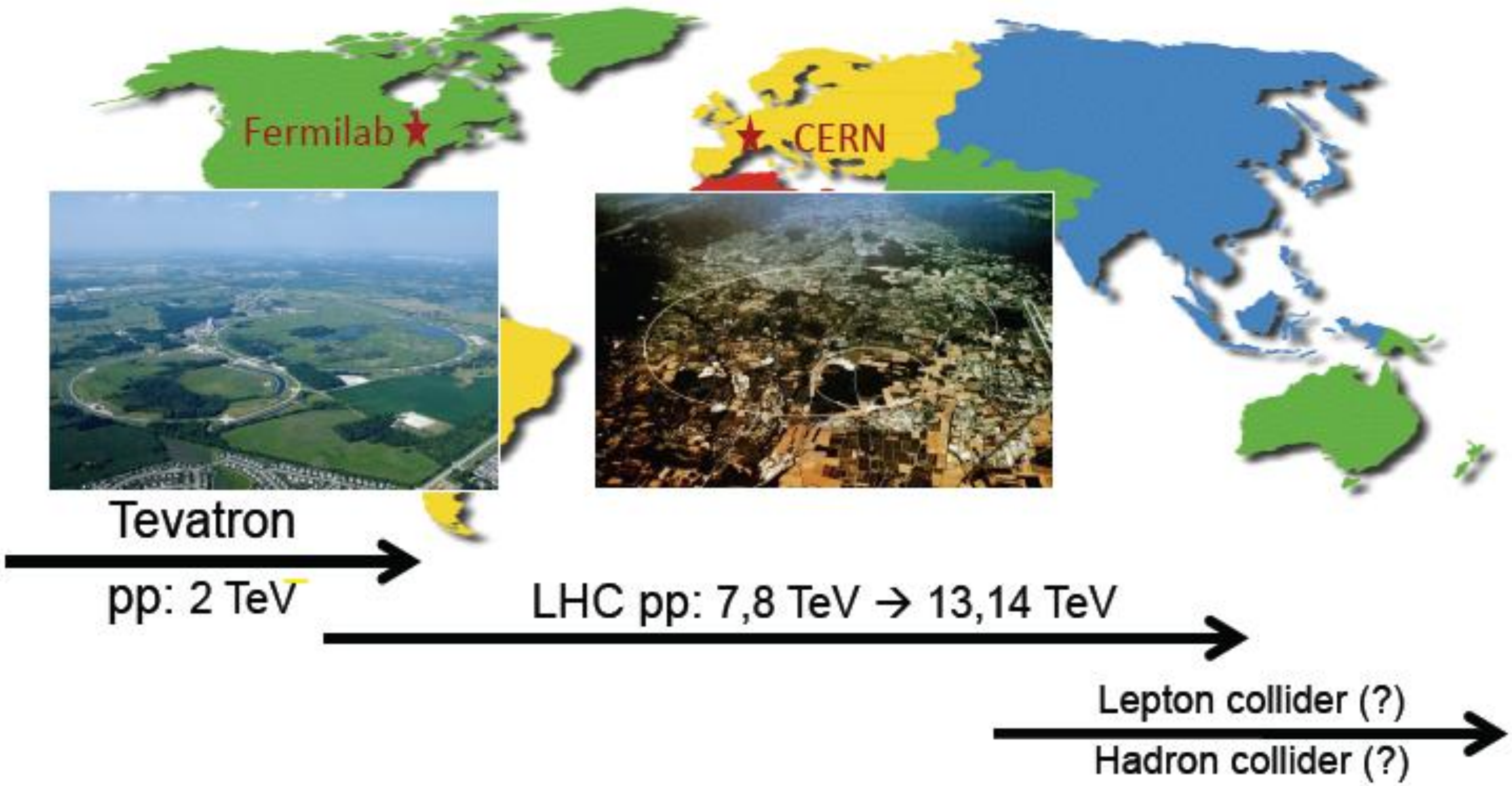
- Require multiple approaches
- Only possible thanks to advancements in accelerator detector technologies
  - high-energy colliders
  - ν experiments (solar, short/long baseline, reactors, $0\nu\beta\beta$ decays)
  - cosmic surveys (CMB, Supernovae, BAO), dark matter direct and indirect detection
  - precision measurements, rare decays and phenomena
  - dedicated searches
  - …

The open questions about the Higgs

Grojean

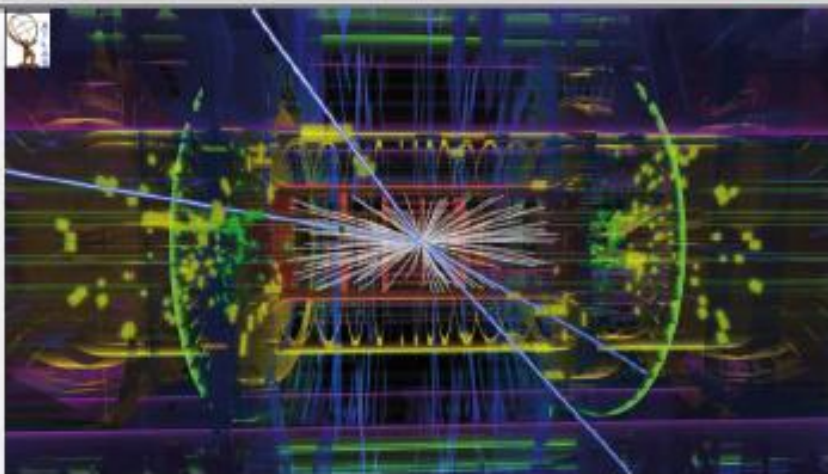
- Is it the SM Higgs?
- Is it an elementary/composite particle?
- Is it unique/solitary?
- Is it temporary?
- Is it natural?
- Is it the first supersymmetric particle ever observed?
- Is it really "responsible" for the masses of all the elementary particles?
- Is it mainly produced by top quarks or by new heavy vector-like quarks?
- Is it a portal to a hidden world?
- Is it at the origin of the matter-antimatter asymmetry?
- Has it driven the inflationary expansion of the Universe?

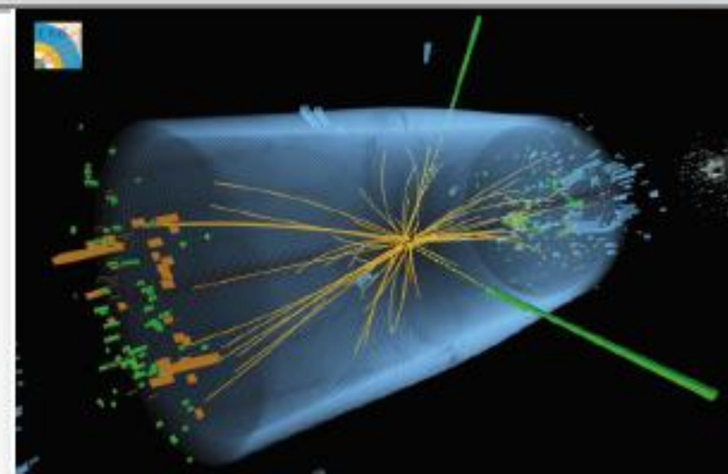
Experimental results from



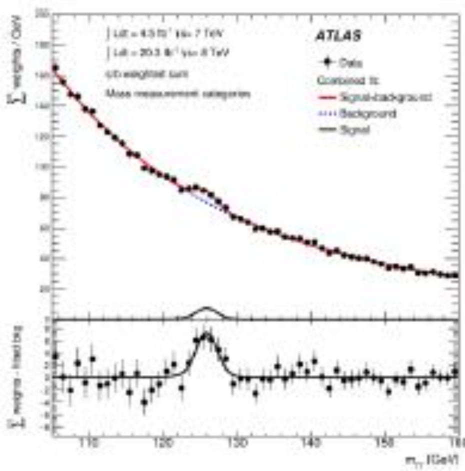
A New Higgs-like Boson

David, Kado

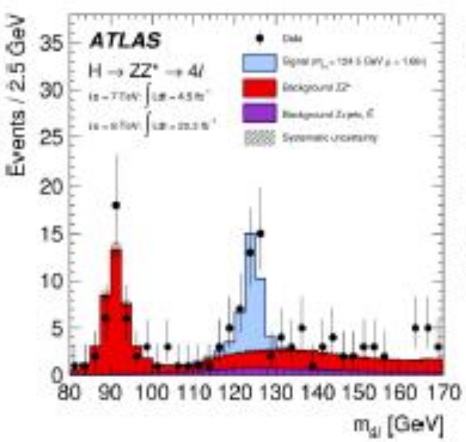




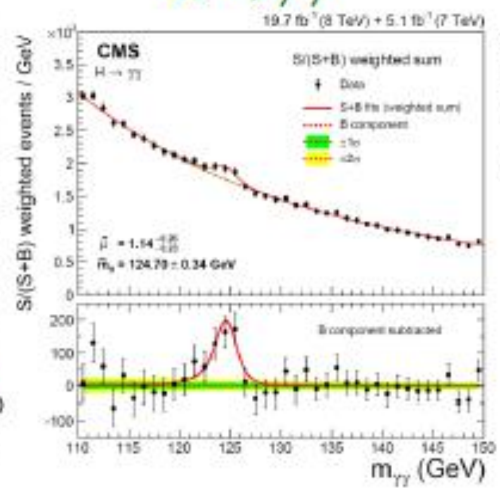
$H \to \gamma\gamma$



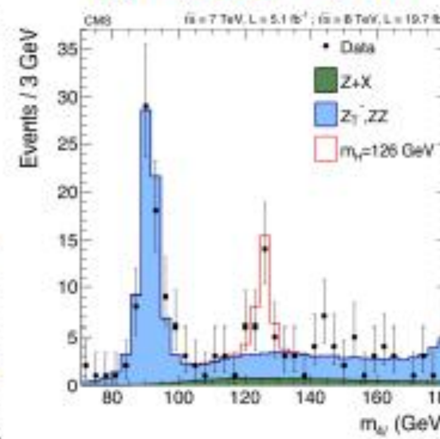
$H \to ZZ^* \to 4l$



$H \to \gamma\gamma$



$H \to ZZ^* \to 4l$

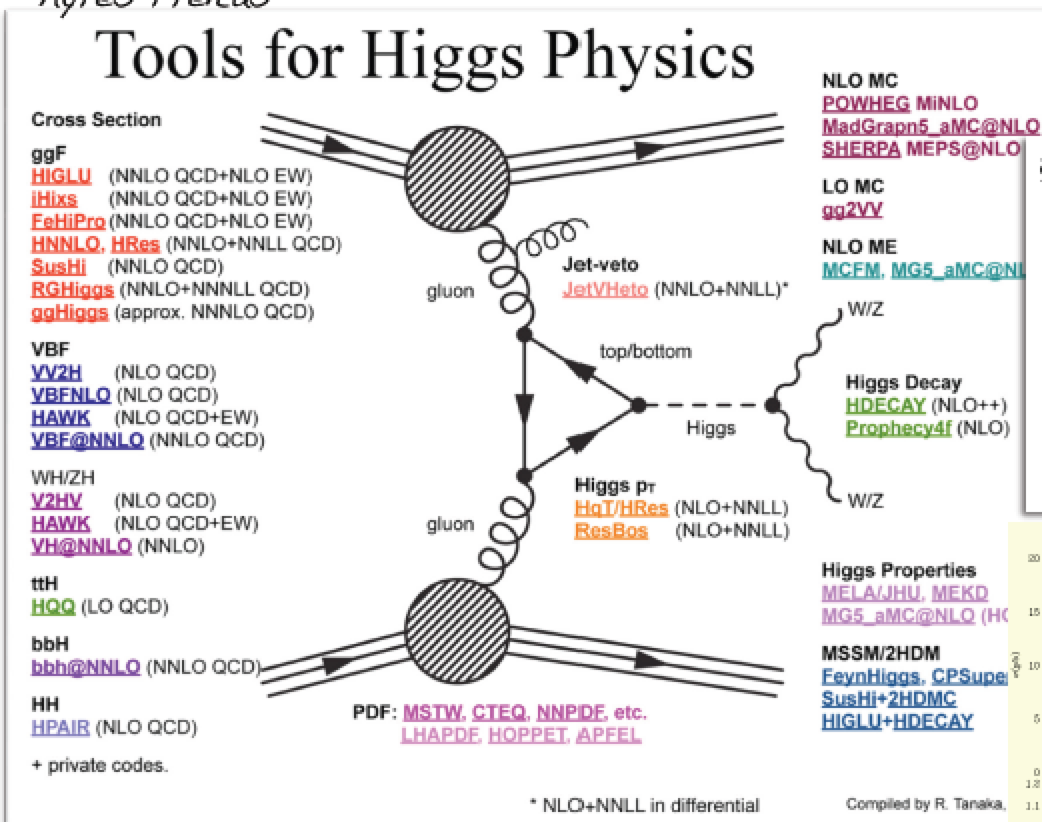


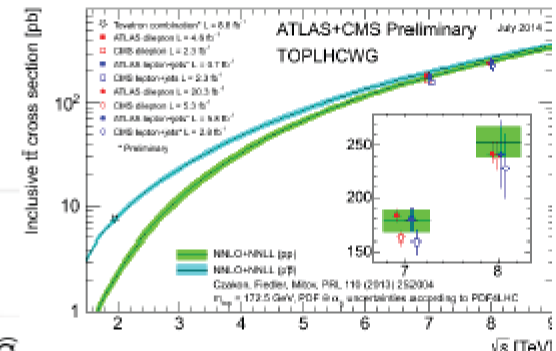
$$M_H^{ATLAS} = \left(125.36 \pm 0.37 \pm 0.18\right)\ \text{GeV} \quad , \quad M_H^{CMS} = \left(125.03\ {}^{+0.26}_{-0.27}\ {}^{+0.13}_{-0.15}\right)\ \text{GeV}$$

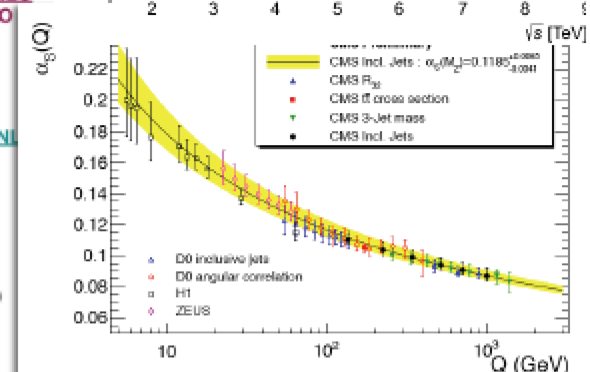
Paolo Nason
Chiara Roda
&
Jeffrey Berryhill
Roger Carlini
Ayres Freitas

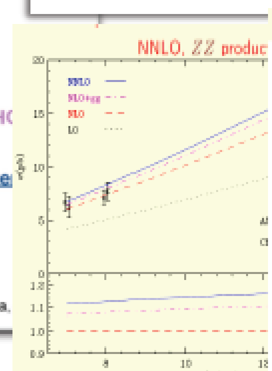
QCD & EWK Precision Tests

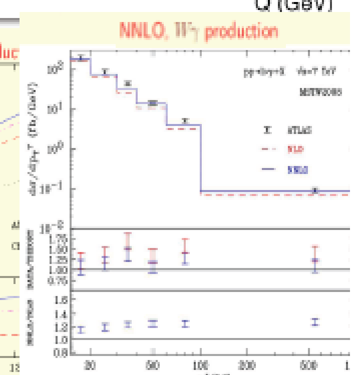
(N....LO +PS)





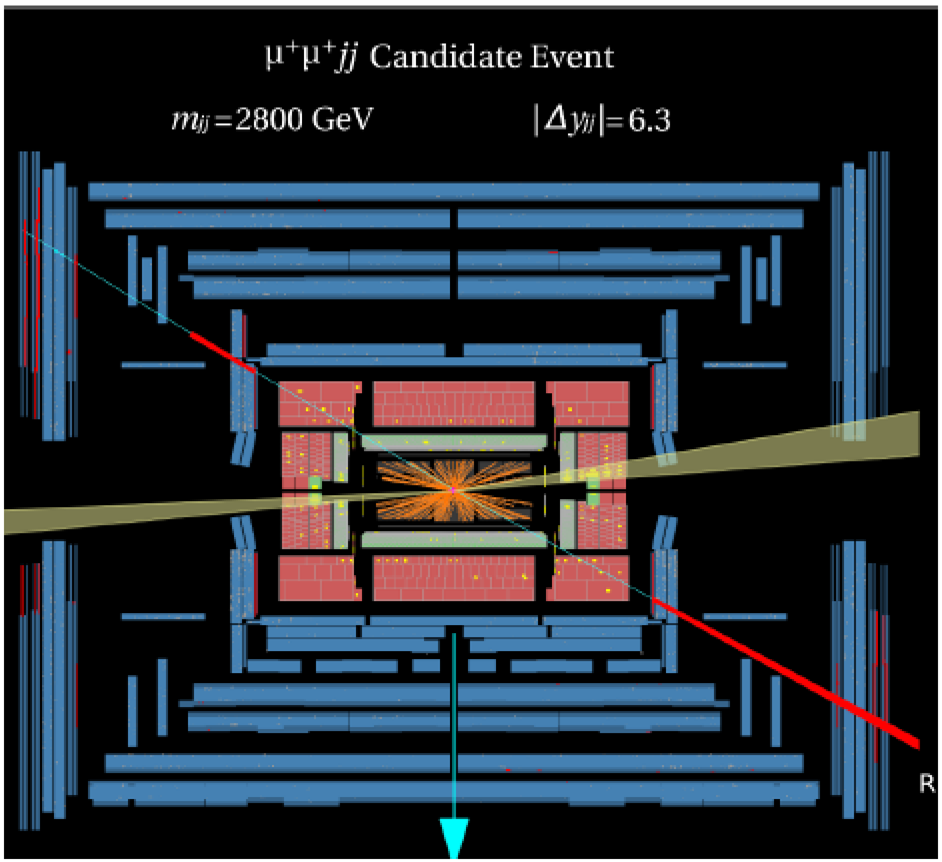


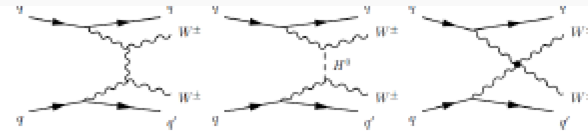


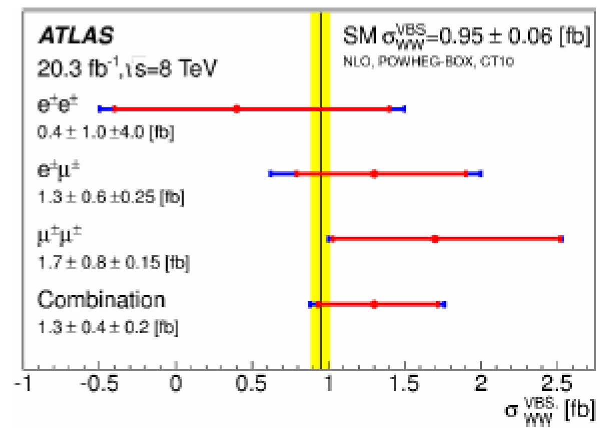


First evidence for $W^{\pm}W^{\pm}$ scattering at LHC

SM electroweak symmetry breaking with Higgs essential to preserve vector boson scattering cross section unitarity
Same-sign WW vector boson scattering production provides attractive S/B at LHC





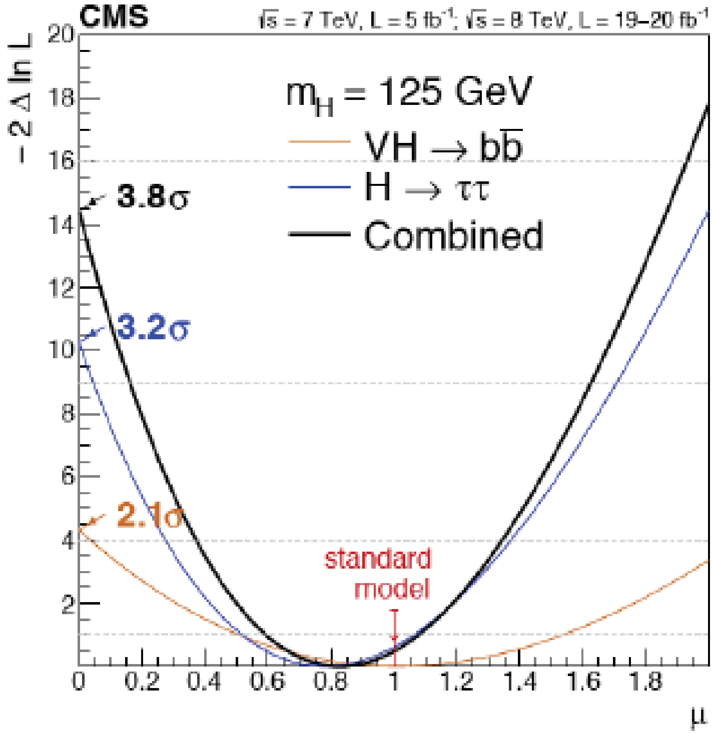


σ in VBS region is SM-like with 3.6σ significance (2.8 expected) in ATLAS [2.0σ excess (3.1 exp.) in CMS]

Several modes expected to be observed with < 300/fb

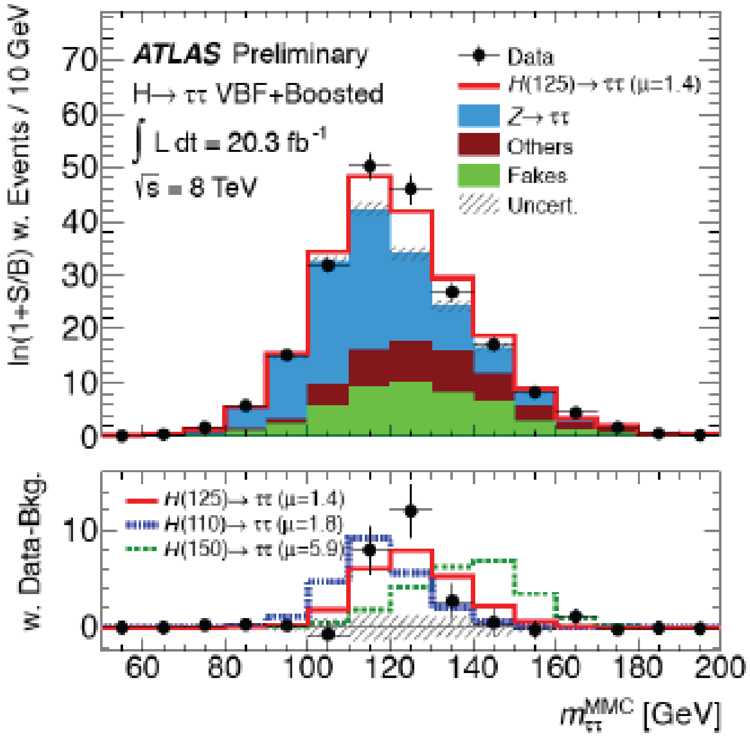
Higgs: Higgs → Fermions

CMS: H→ ττ, bb Channels



Significance	Exp	Obs
CMS (ττ)	3.4 σ	3.2 σ
CMS (bb)	2.1 σ	2.1 σ

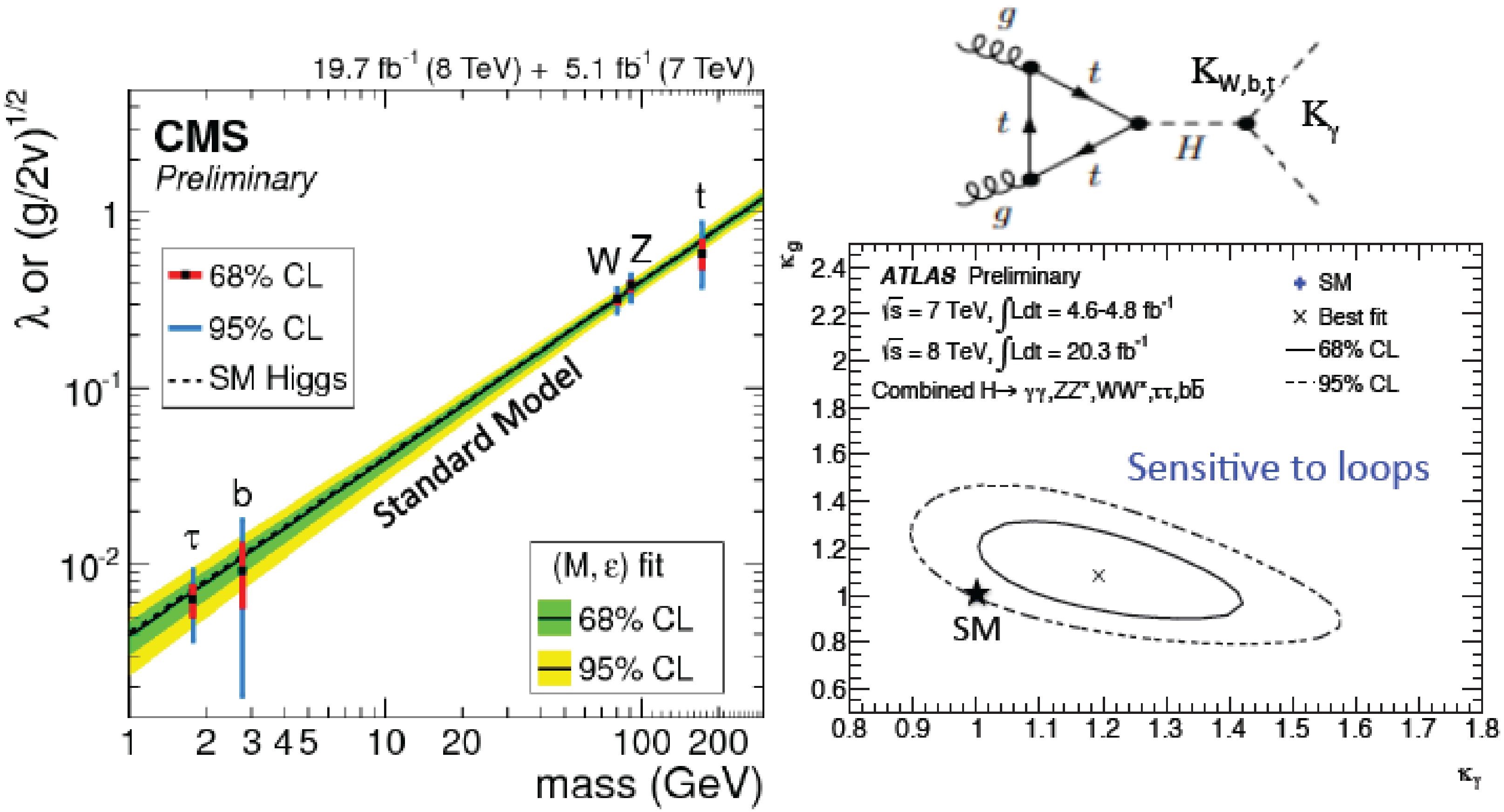
ATLAS: H→ ττ Channel



Significance	Exp	Obs
ATLAS (ττ)	3.2 σ	4.1 σ

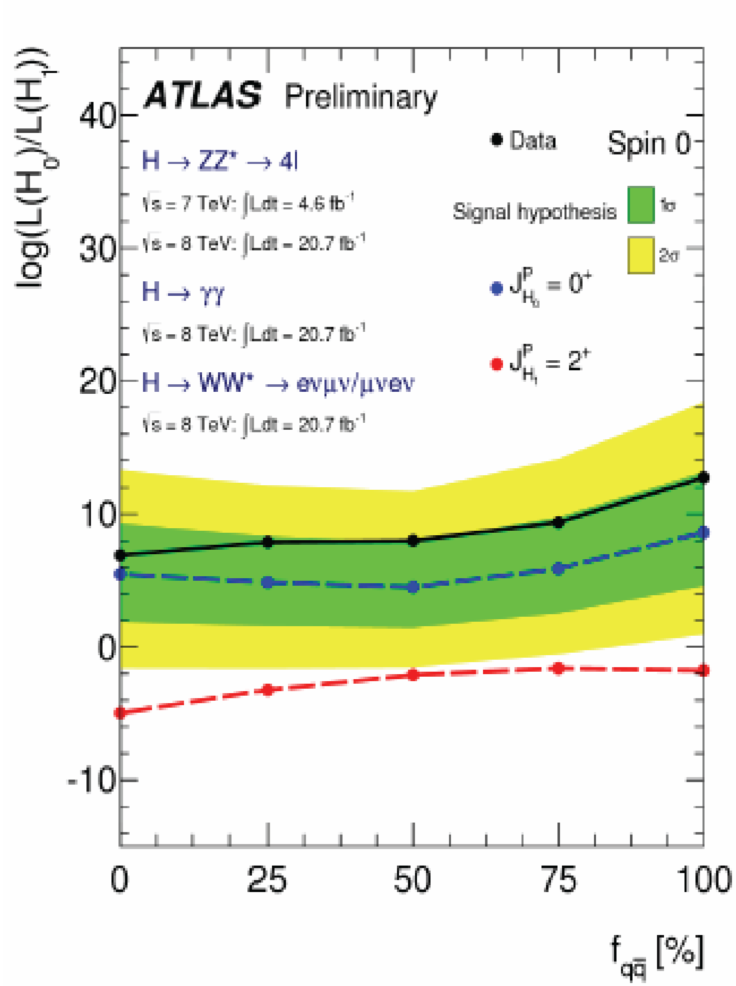
Tevatron: exp (2.1σ), obs (3.0σ)

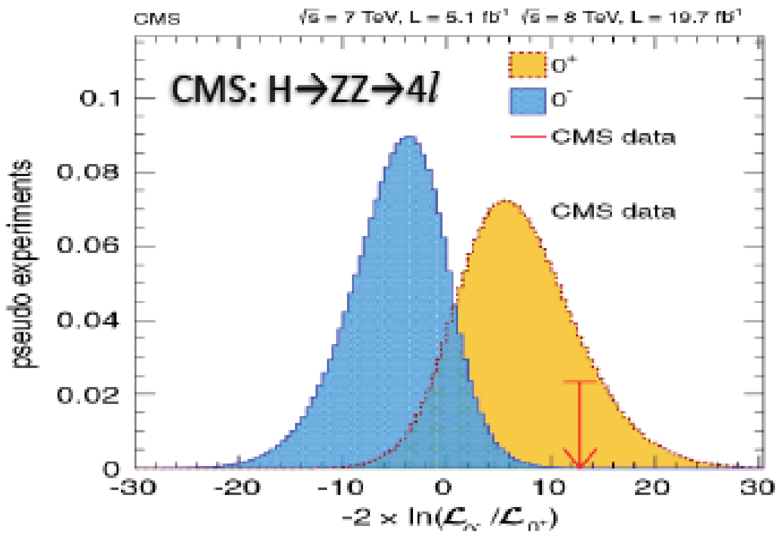
Higgs: Couplings

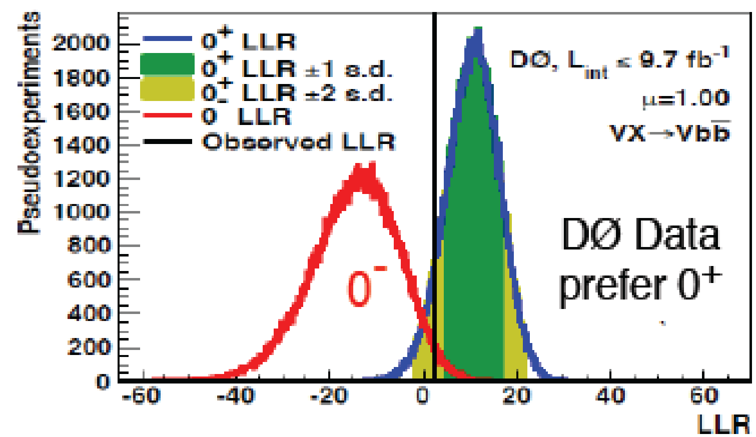


All seem to be consistent with the Standard Model expectations so far!

Higgs: Spin-Parity – 0^+ Favored







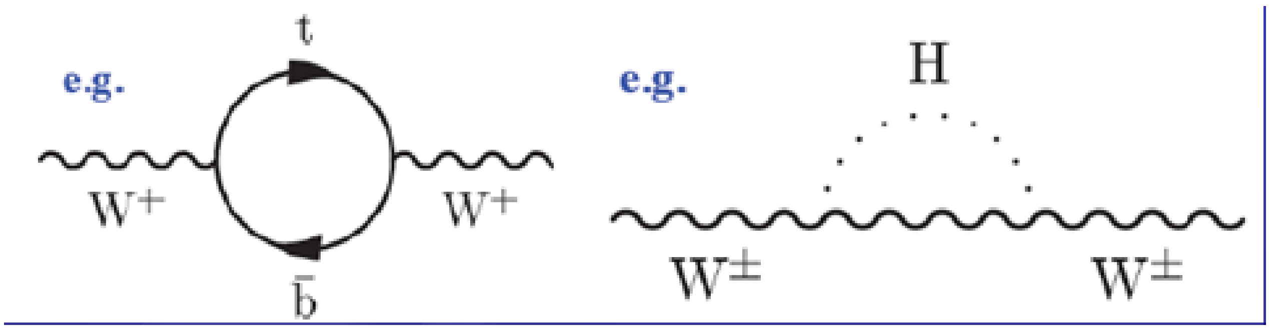
State of the Electroweak Theory: Precision Frontier

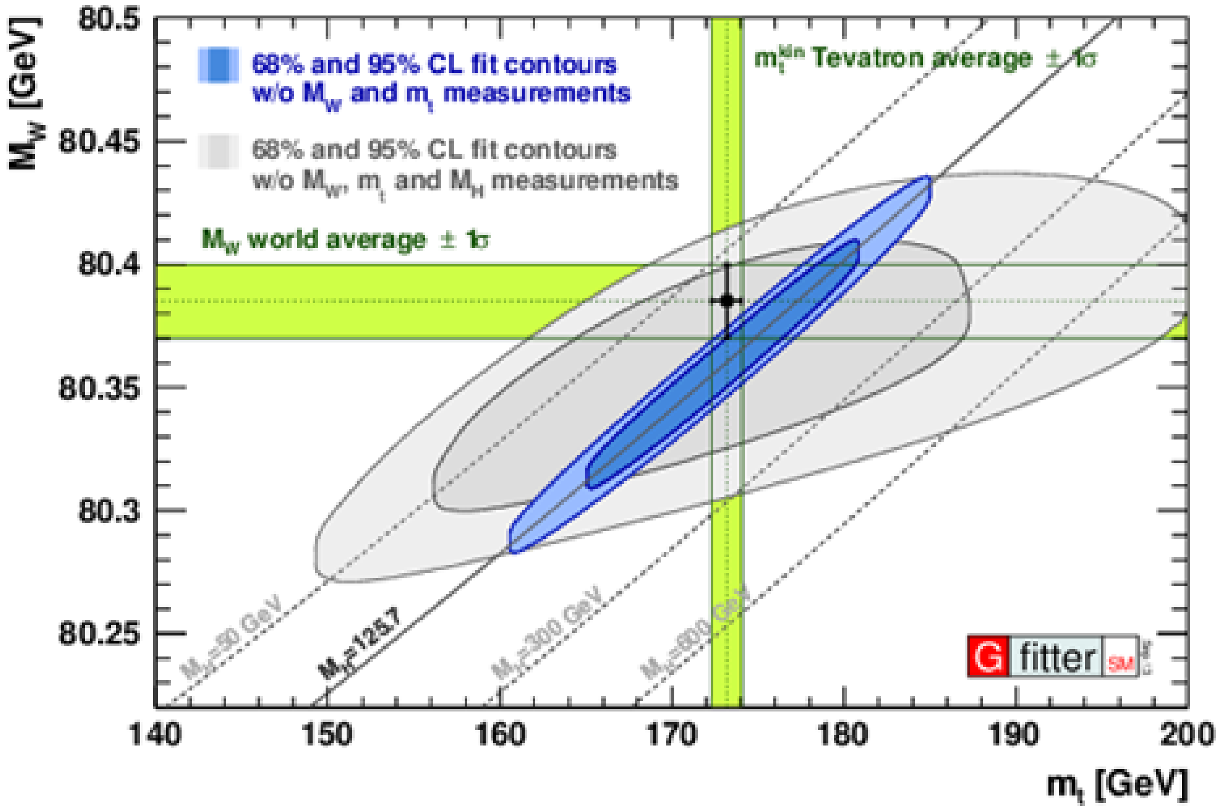
Radiative corrections to precision EWK **measurements of W, Z sensitive to Mt, MH**

SM-like Higgs discovery at ~126 GeV is compatible with global EWK data at <u>1.3 sigma (p = 0.18)</u>

Indirect constraints are now superior to precise direct W, Z measurements (MW, $\sin^2\theta_{eff}$)

Can W,Z experiment catch up?





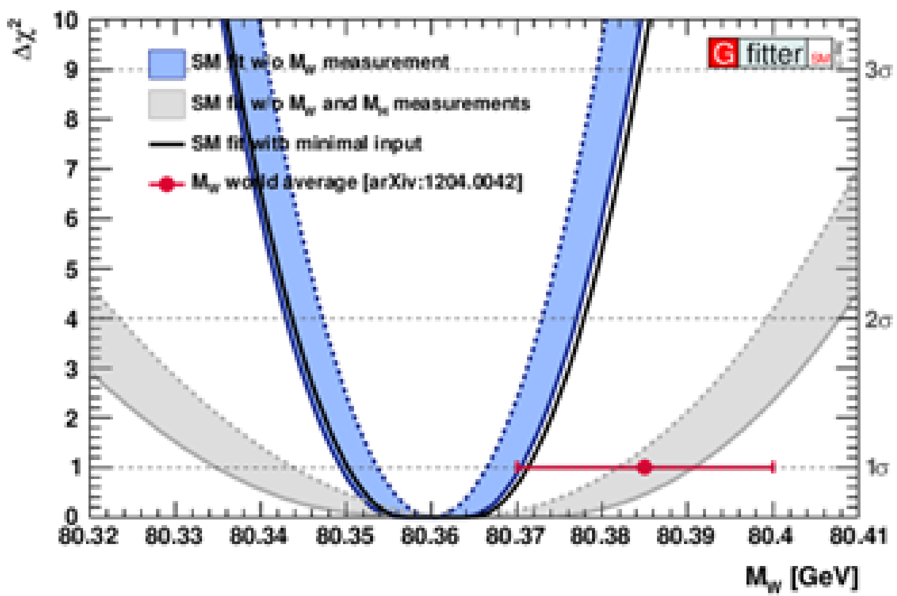
http://project-gfitter.web.cern.ch/project-gfitter/

Prospects for Tevatron W mass

- Largest single uncertainties are **stat. and PDF syst.**
- **2X PDF improvement** and incremental improvement elsewhere results in **9 MeV projected final Tevatron precision**
- <10 MeV precision is well motivated to **further confront indirect precision (11 MeV)**

arxiv:1310.6708

ΔM_W [MeV]	CDF	D0	combined	projected combined
$\mathcal{L}[\text{fb}^{-1}]$	2.2	4.3 (+1.1)	7.6	20
PDF	10	11	10	5
QED rad.	4	7	4	3
$p_T(W)$ model	5	2	2	2
other systematics	10	18	9	4
W statistics	12	13	9	5
Total	19	26 (23)	16	9



Higgs properties
(Precise measurements- SM consistency)

- Mass determination
  - 0.2% precision (stat dominated). Consistent with indirect EWK meas.
- Quantum numbers: J^P and CP
  - 0^+ is favored against spin-2 hypothesis / consistent with CP-even
- Relative Signal strengths
  - Coupling to leptons and quarks from Tevatron and LHC
- Scalar couplings
  - From κ factors (deviation away from SM) towards H-EFT
- Higgs width
  - HVV off-shell production (with strong theory assumptions)

    95%CL Limits: $\Gamma_H^{ATLAS} < 5.7 \times \Gamma_H^{SM}$ and $\Gamma_H^{CMS} < 5.4 \times \Gamma_H^{SM}$

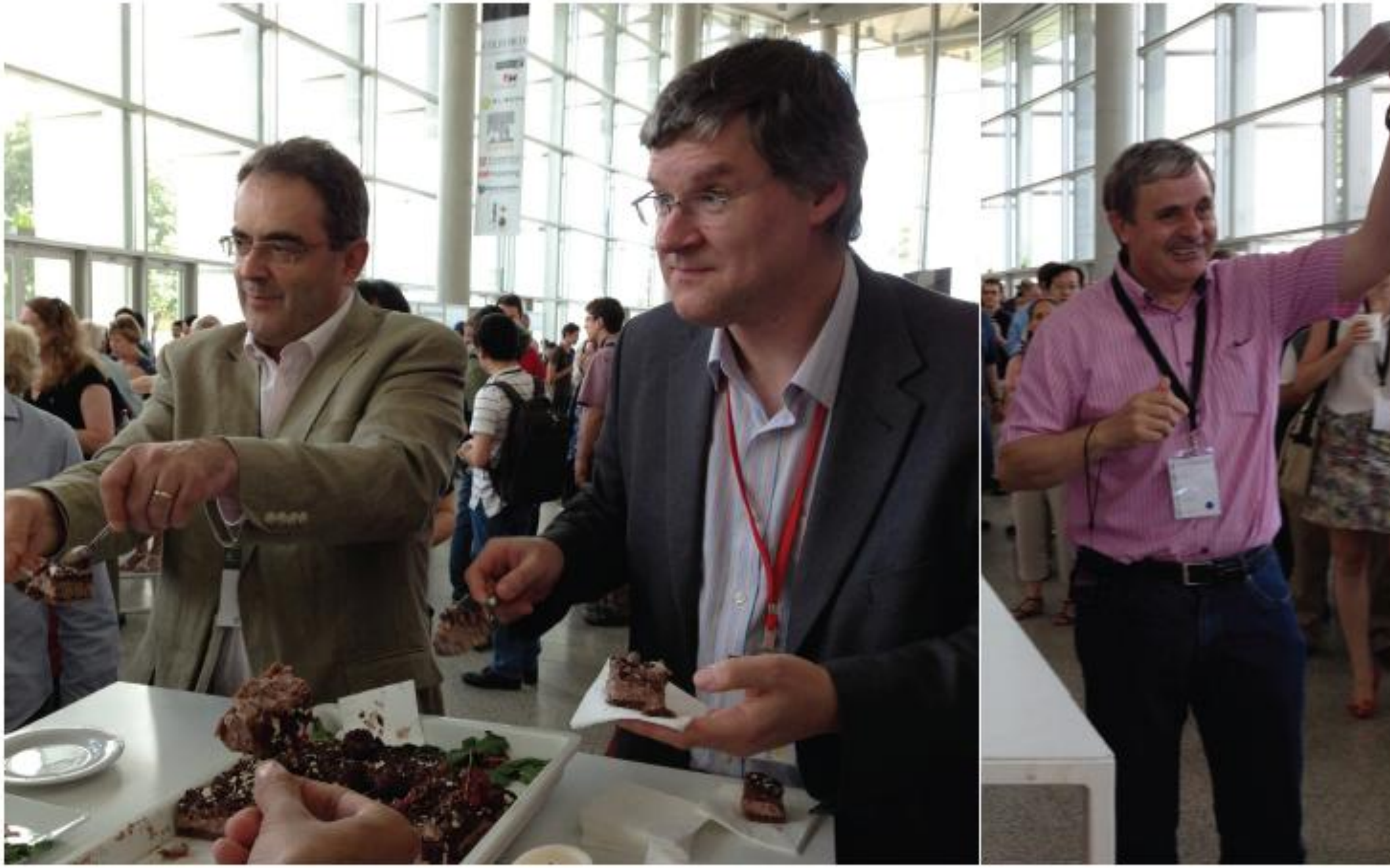
Some analyses involve the combination of results from the 5 most relevant decay channels ($\gamma\gamma$, WW, ZZ, bb, $\tau\tau$) & production mechanisms (ggH, VBF, VH, ttH)

~ 207 channels & 2.500 nuisance parameters (CMS)

~ 275 channels & 1.500 nuisance parameters (ATLAS)

This makes the LHC (ATLAS & CMS) Higgs combination far from trivial. A combined LHC Higgs mass will come soon …

Celebrating the 2nd anniversary of the Higgs discovery



Beautiful Discovery

Boson (J = 0)

Fermions = Matter ; Bosons = Forces

- Fundamental Boson: New interaction which is not gauge
- Composite Boson: New underlying dynamics

If New Physics exists at Λ_{NP}

$$\delta M_H^2 \sim \frac{g^2}{(4\pi)^2} \Lambda_{NP}^2 \log\left(\frac{\Lambda_{NP}^2}{M_H^2}\right)$$

Which symmetry keeps M_H away from Λ_{NP} ?

- Fermions: Chiral Symmetry
- Gauge Bosons: Gauge Symmetry
- Scalar Bosons: Supersymmetry, Scale/Conformal Symmetry ... ?

Two possible Solutions:

Supersymmetry: a fermion-boson symmetry

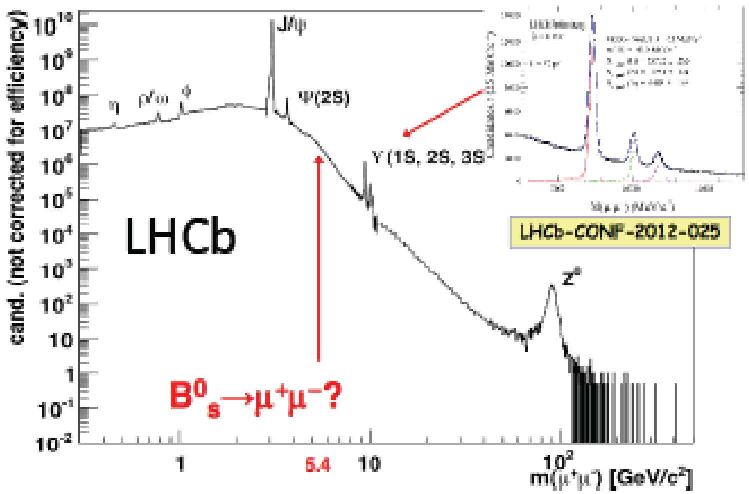
The Higgs remains elementary but its mass is protected by the new fermion-boson symmetry

Composite Higgs Models:

The Higgs does not exist above a certain scale, at which the new strong dynamics takes place

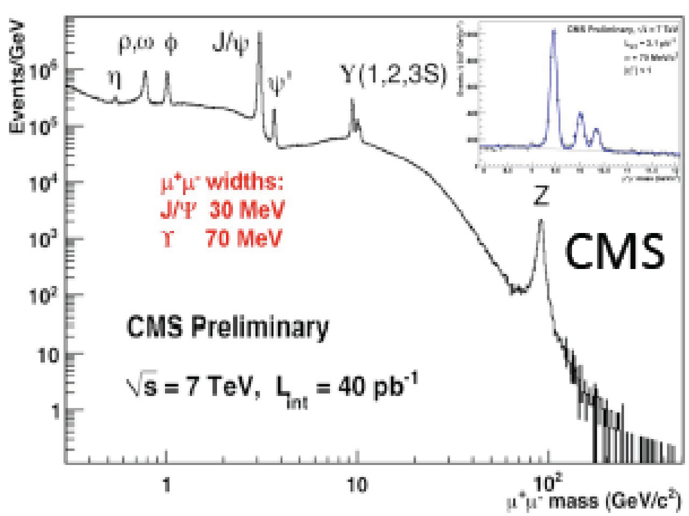
Both options imply changes in the Higgs phenomenology and New particles that *may* be seen at the LHC or indirectly in rare decay processes

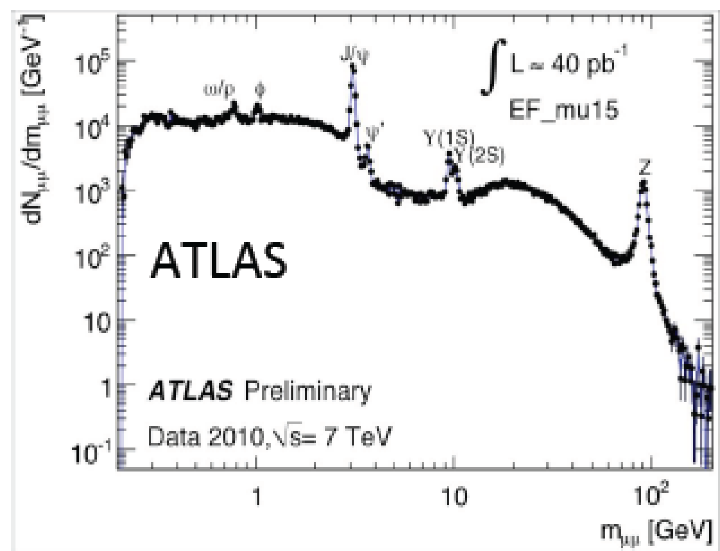
Di-muons



- Play critical roles in detector calibration

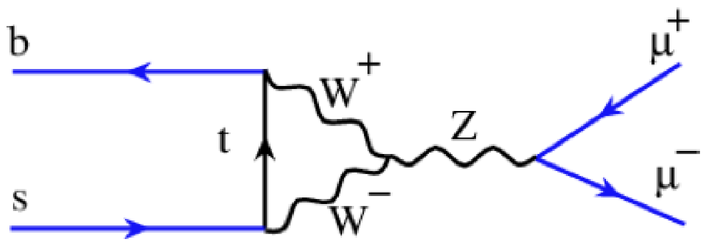
- Physics measurements (e.g. rare processes)



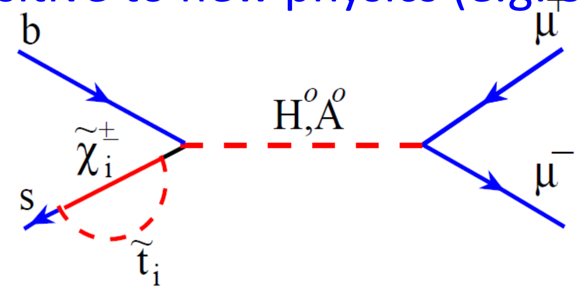


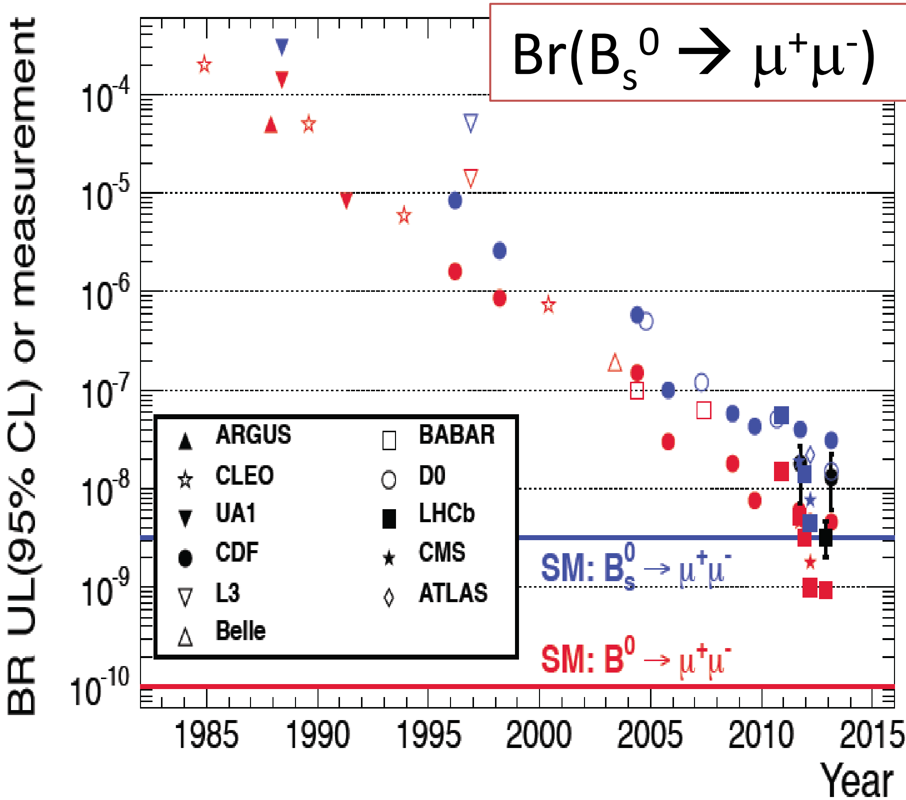
Rare decays: $B_s^0 \rightarrow \mu^+\mu^-$

Standard Model

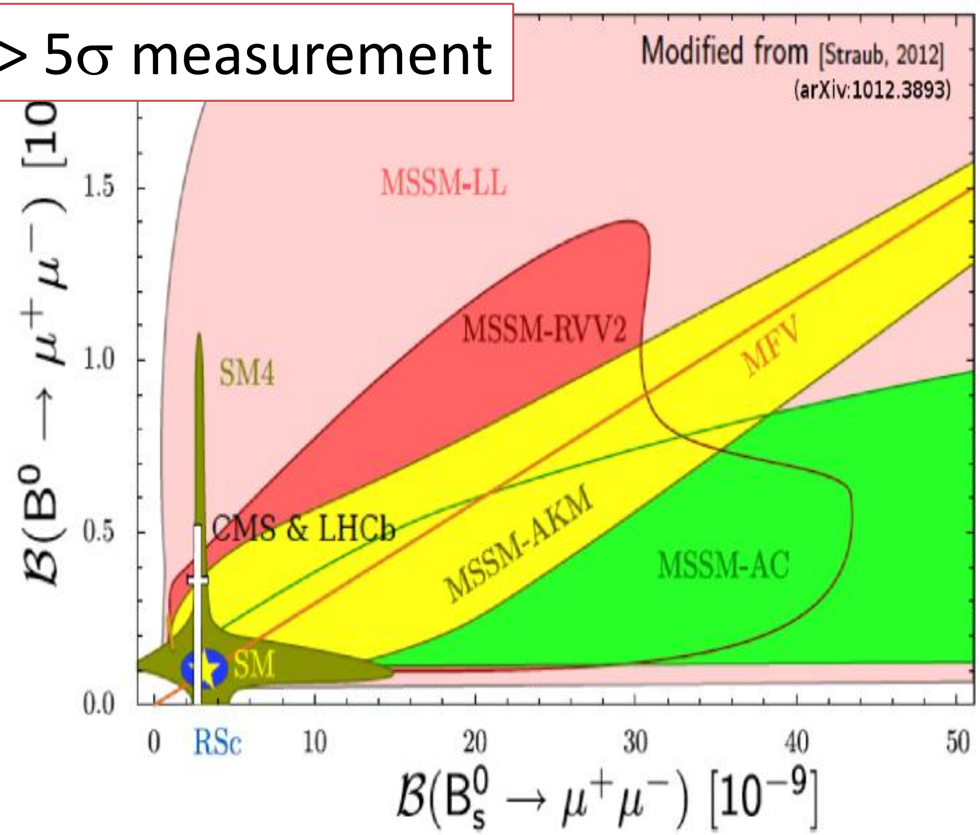


sensitive to new physics (e.g. SUSY)

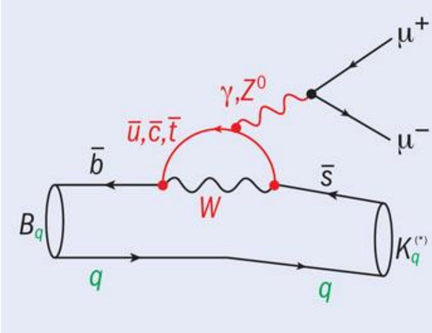




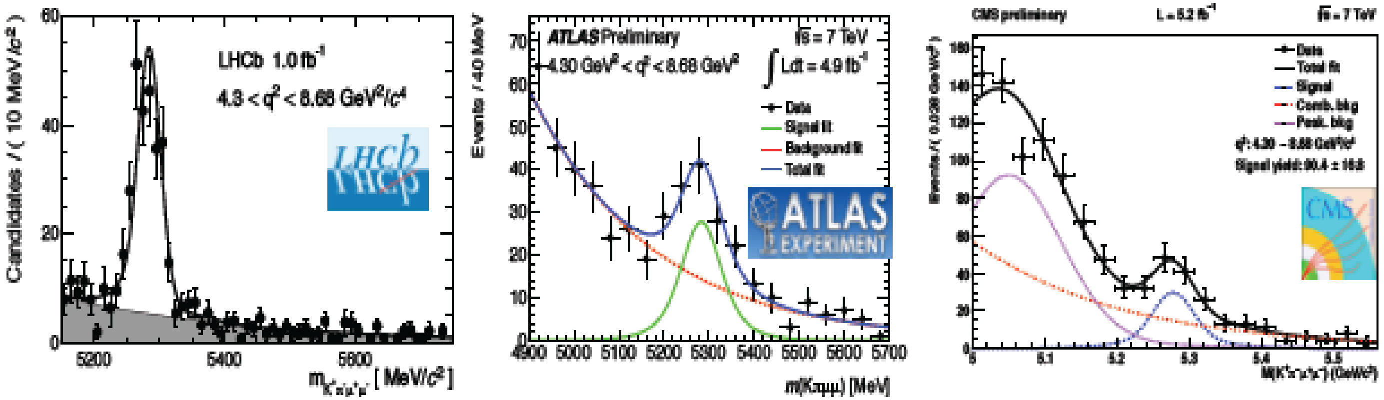
$Br(B_s^0 \rightarrow \mu^+\mu^-)$ > 5σ measurement



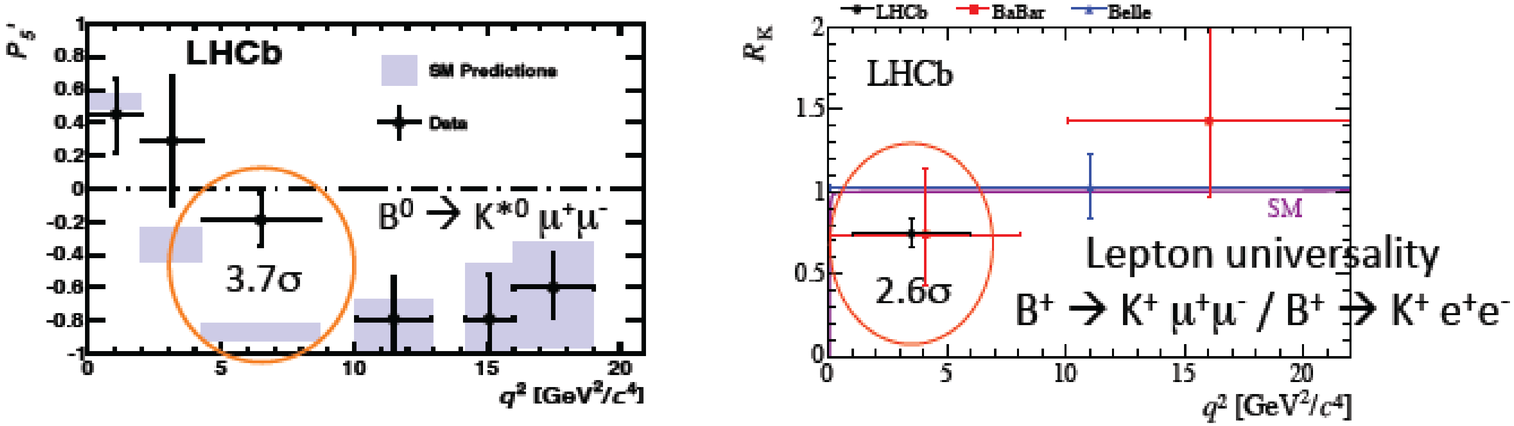
Electroweak penguins: $b \rightarrow s\mu^+\mu^-$



- $B^0 \rightarrow K^{*0} \mu^+\mu^-$ seen by LHC experiments



- Several tensions emerge (LHCb)



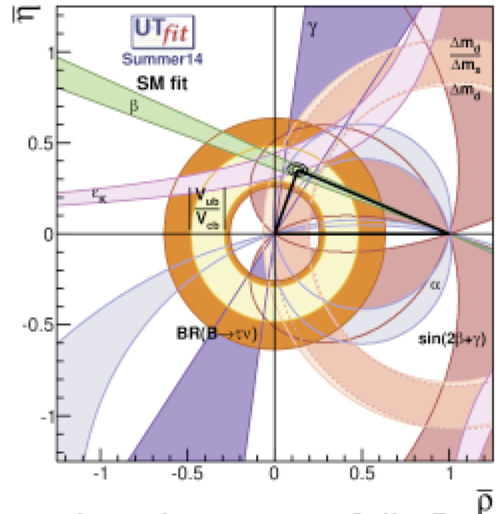
The Flavor window

Some highlighted/new results at ICHEP2014:

(BaBar, Belle, Tevatron, and LHC)

Rare decays, CKM and CP observables

- $B_{s,d} \rightarrow \mu^+\mu^-$ (LHCb and CMS)
- $b \rightarrow s\,(d)\,\ell^+\ell^-$ (LHCb)
- $B^+ \rightarrow K^+\pi^+\pi^-\gamma$ (LHCb)
- β: $B^0 \rightarrow \pi^- \pi^+$ (Belle)
- γ: $B_s \rightarrow D_s^- K^+$ (LHCb)
- Phase of B_s –antiB_s (CMS)
- Multibody semi-leptonic b-> c decays (BaBar)
- new Flavor Physics with Higgs (LFV: H-> $\tau\mu$)



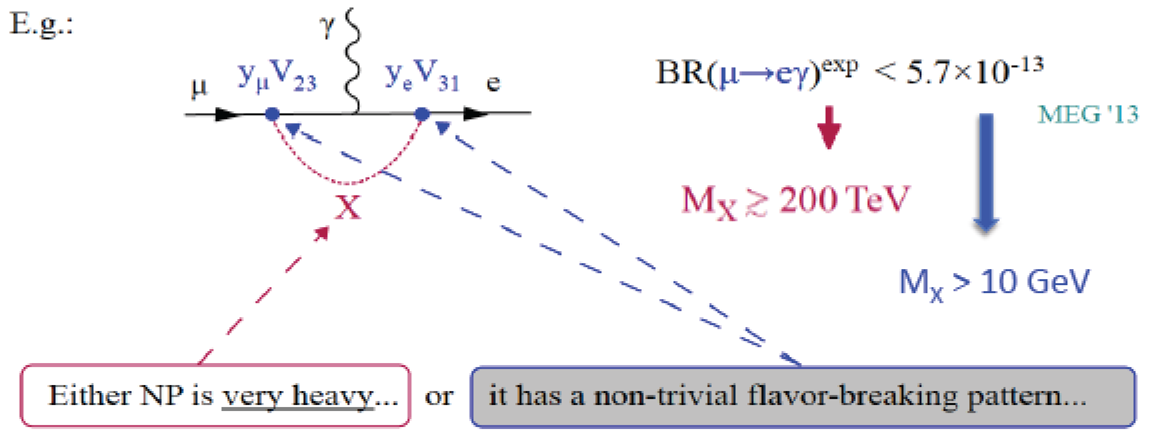
CKM describes successfully flavor mixing in the quark sector

Great progress on γ (or φ_3) first from B factories and now in the last two years from LHC (LHCb)

Twofold role of Flavor Physics

- Identify symmetries and symmetry-breaking patterns beyond those present in the SM
- Probe physics at energy scales not directly accessible at accelerators

Precision measurements of flavor changing processes of quarks and charged leptons & searches fit well with the SM, so far, implying strong limits on NP



Minimal Flavour Violation: **The up and down Yukawa matrices are the only source of quark-flavour symmetry breaking** D'Ambrosio et al, Buras et al

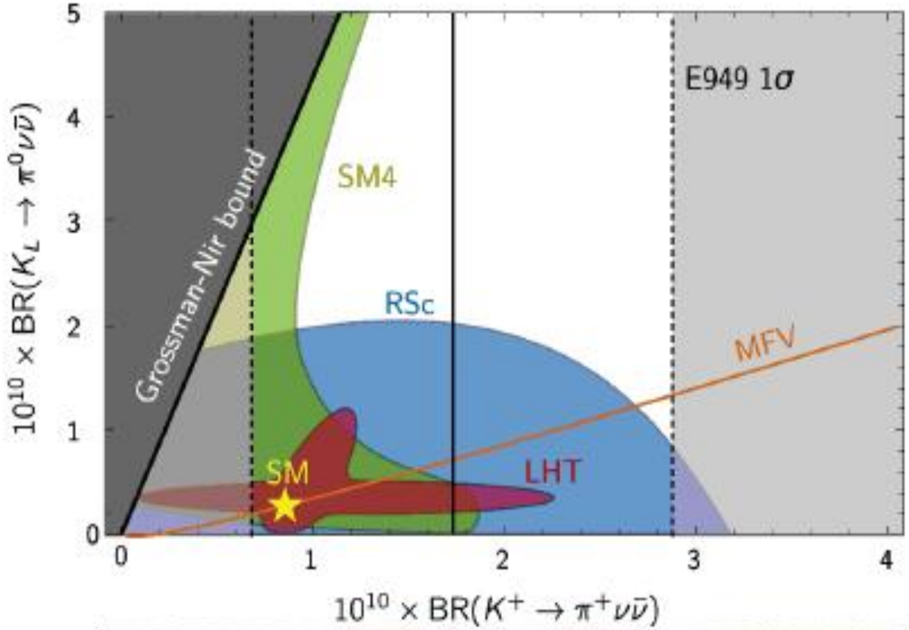
Nevertheless the current exp & theo precision still allows the presence of NP signals (from well-motivated models e.g. "split-SUSY") @ 10% level. There is still a wide region of NP parameter space to be explored in particular in FCNC processes and $\Delta F=2$ observables.

$\Delta m_{B_{s,d}}$ $|V_{ub}|$ & CKMfits $B_{s,d} \to \mu\mu$

$\varepsilon_K, \phi_{s,d}$ $B \to X_s\gamma$

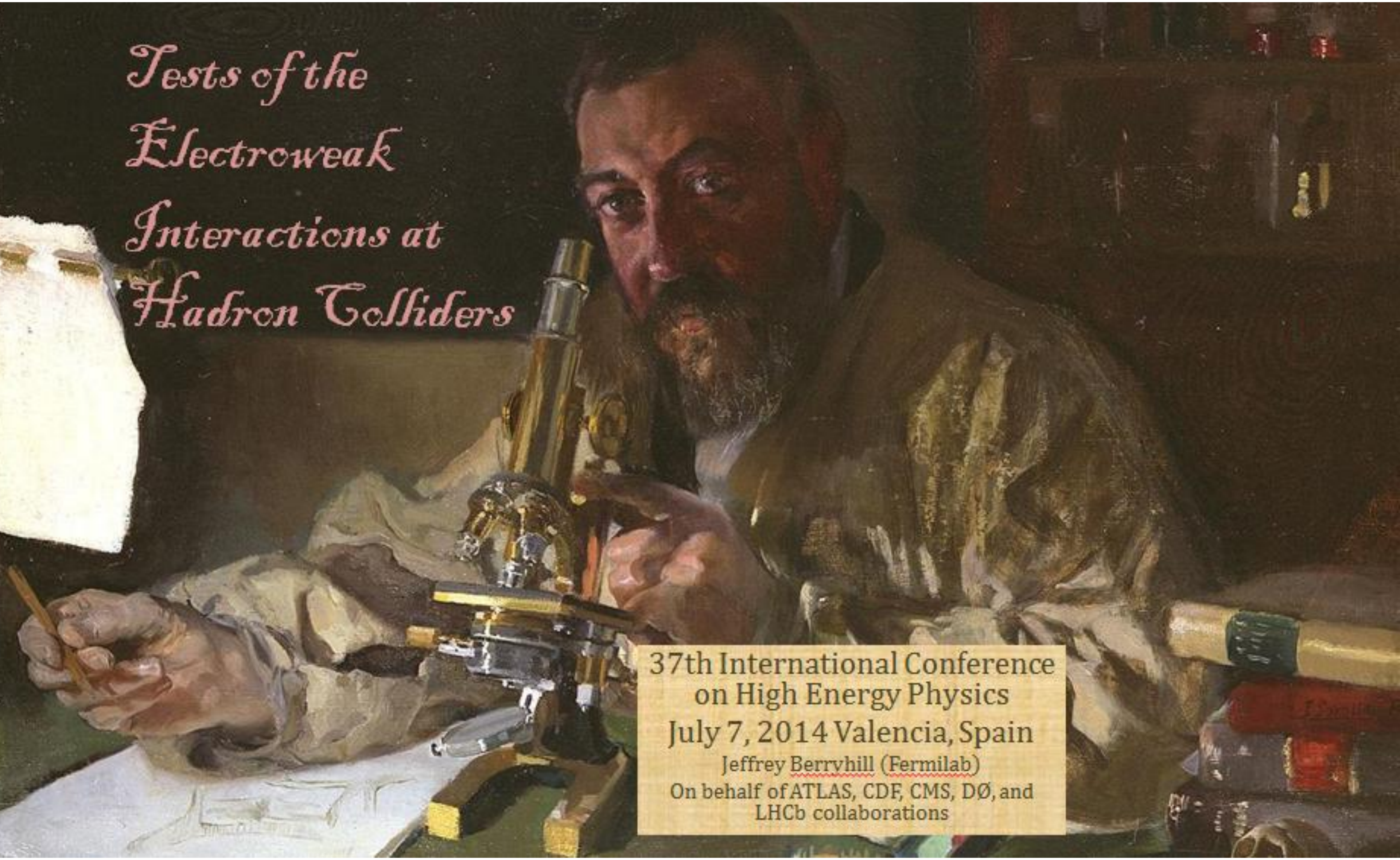
New generation of Kaon experiments!!

O(1) SM $K_L \rightarrow \pi^0\nu\nu$ events
in the next couple of years



O(100) SM $K^+ \rightarrow \pi^+\nu\nu$ events
in the next couple of years

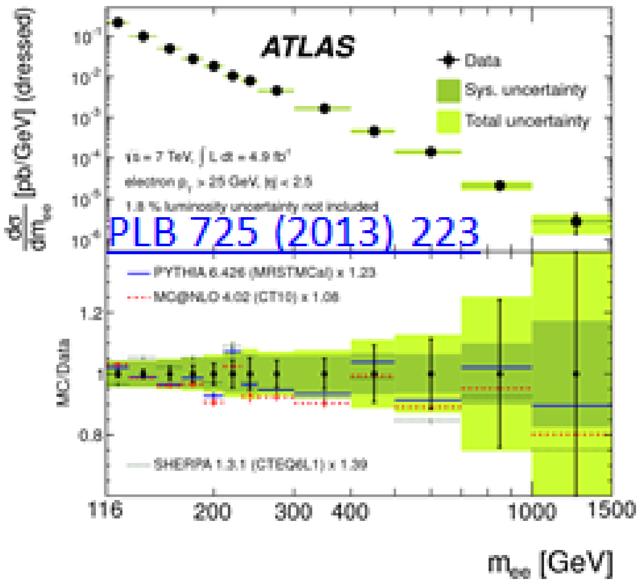
- OKA at U-70 Protvino,Russia: Ke3 (analysis) → Kμ3, Ke3γ, Kμ3γ, Kμ2γ, …
- KLOE-2 at DAΦNE: commissioning



Joaquin Sorolla - Valencia

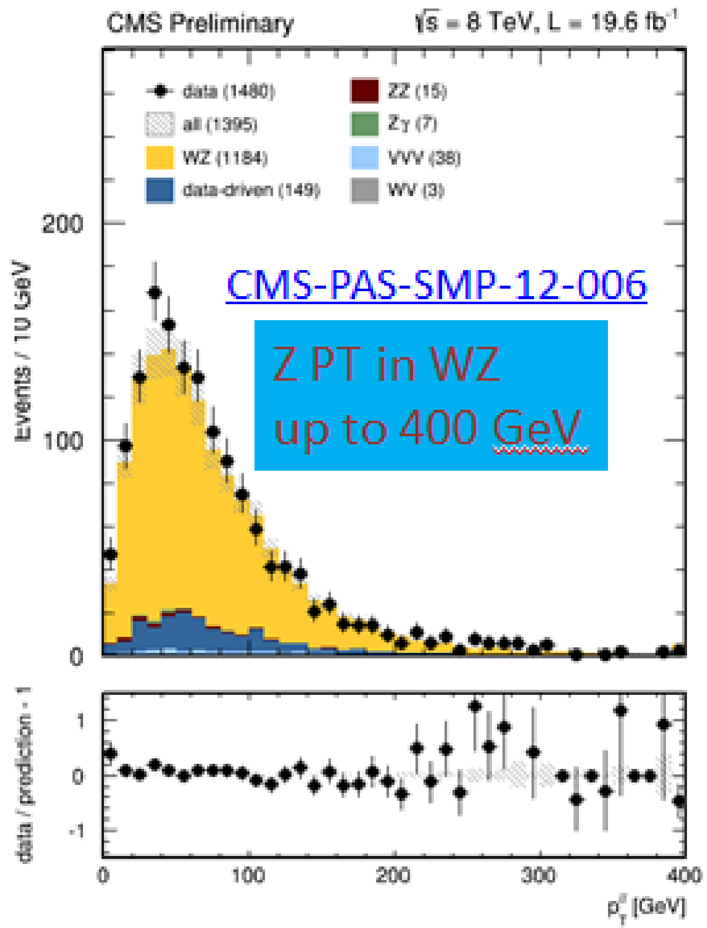
State of the Electroweak Theory: Energy Frontier

Mass of DY pairs up to 1500 GeV



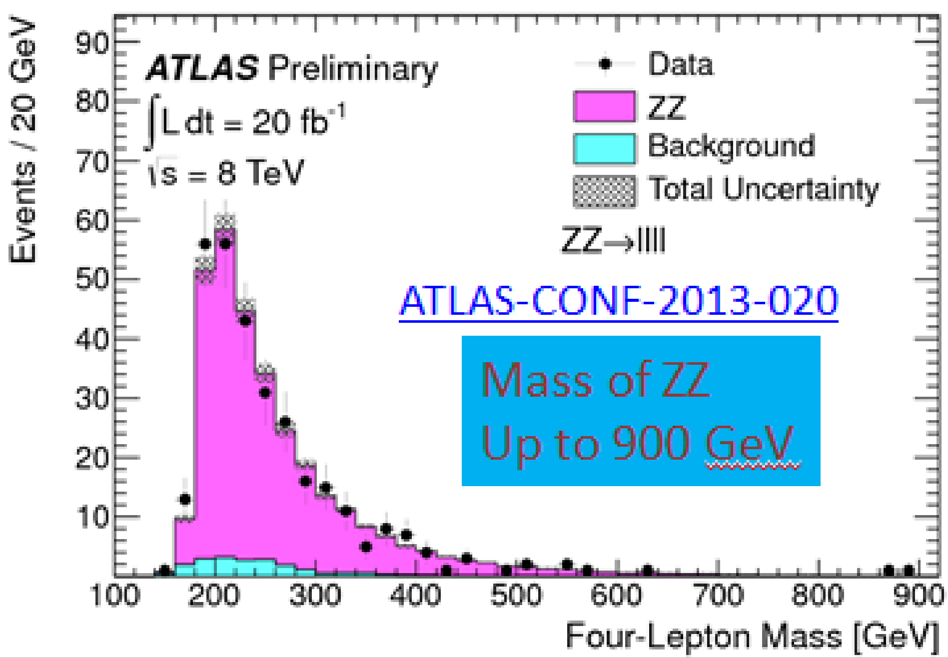
PLB 725 (2013) 223

The **successful LHC Run 1 is now providing TeV-scale tests** of single and multiple electroweak boson production



CMS-PAS-SMP-12-006

Z PT in WZ up to 400 GeV



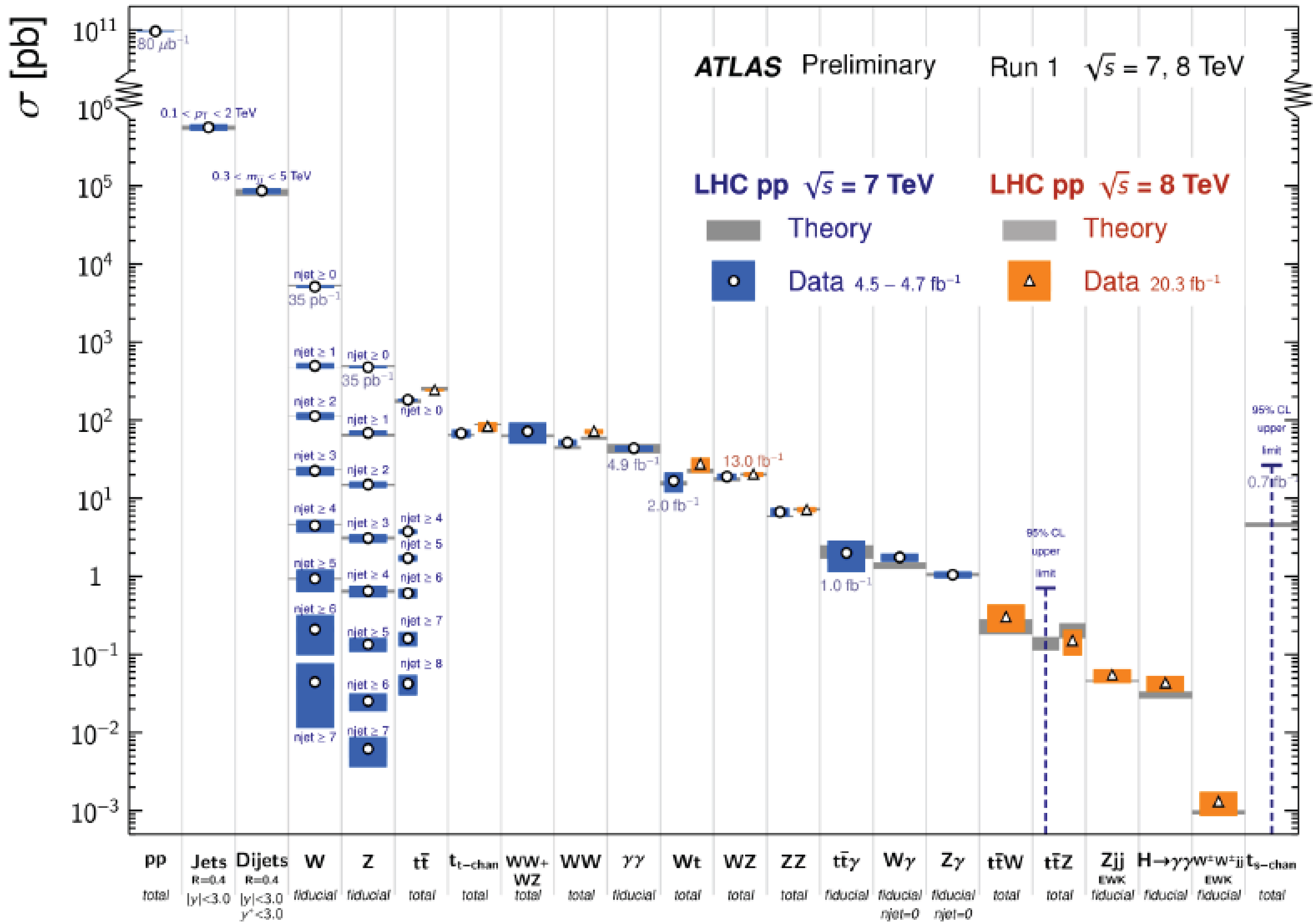
ATLAS-CONF-2013-020

Mass of ZZ Up to 900 GeV


Zand
Drell-Yan

Standard Model Production Cross Section Measurements

Status: July 2014



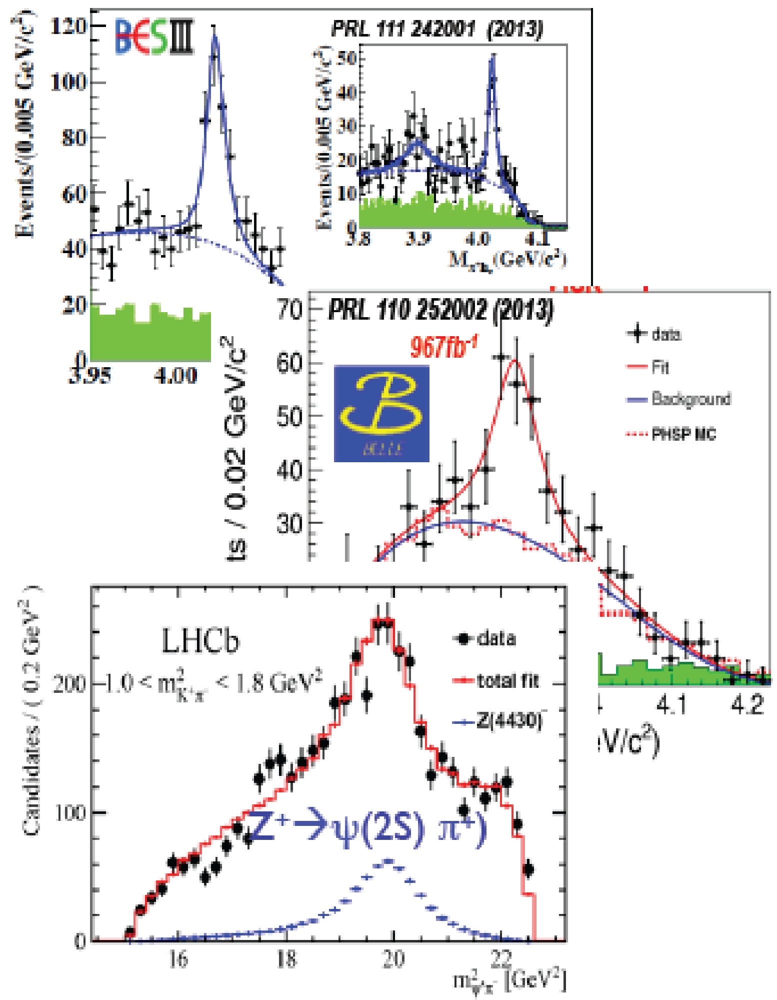
The Quark Hypothesis

A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations $(q\,q\,q)$, $(q\,q\,q\,q\,\bar{q})$, etc., while mesons are made out of $(q\,\bar{q})$, $(q\,q\,\bar{q}\,\bar{q})$, etc. It is assuming that the lowest



Long history of searching for exotic hadrons. No conclusive results

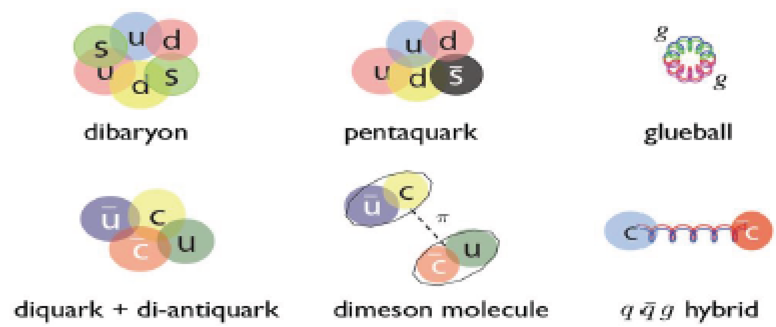
$Z_c(3900)$, $Z_c(4020)$, $Z_c(4430)$ established recently

Not conventional charmonium

Exotic Spectroscopy

QCD allows hadrons with $N_{quarks} \neq 2, 3$

Long history of searching for exotic hadrons. A lot of puzzles and controversies remain to be solved. No conclusive results



$Z_c(3900)$, $Z_c(4020)$, $Z_c(4430)$ established recently

Nature is still unclear (but not conventional charmonium)

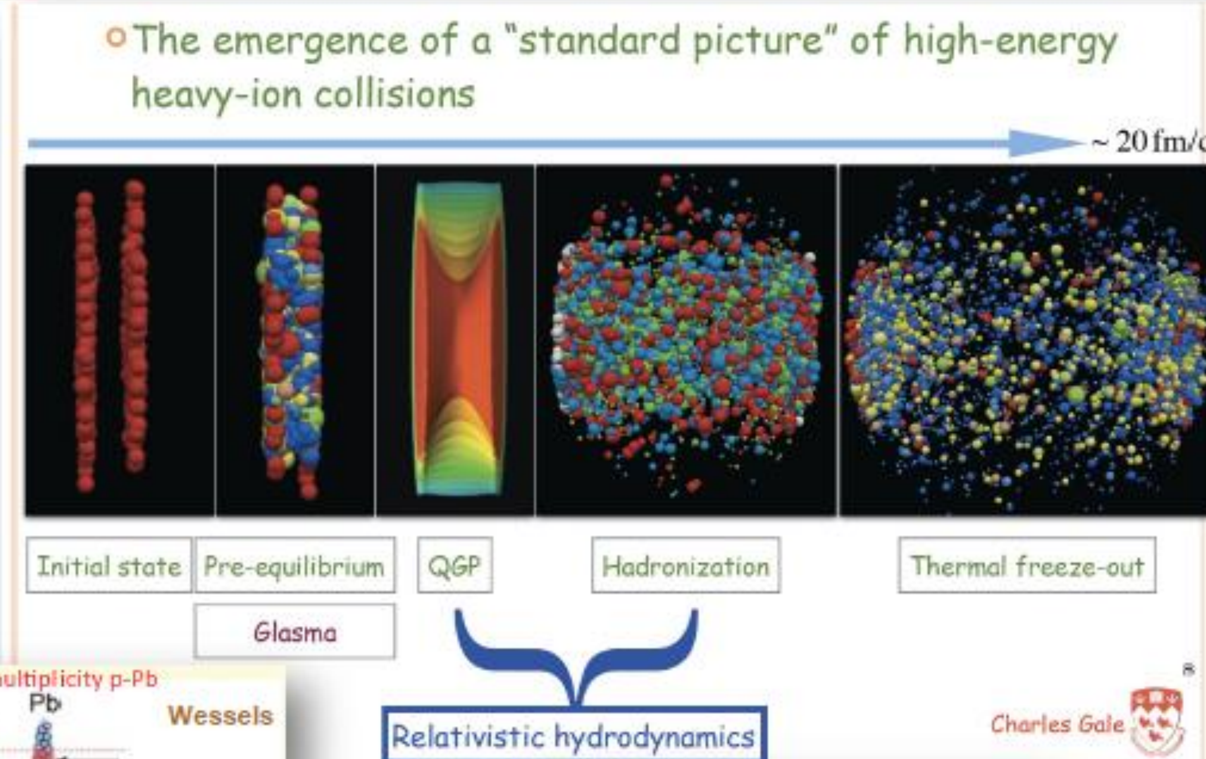
Three established charged charmonium-like structure $Z_c^{\pm}$

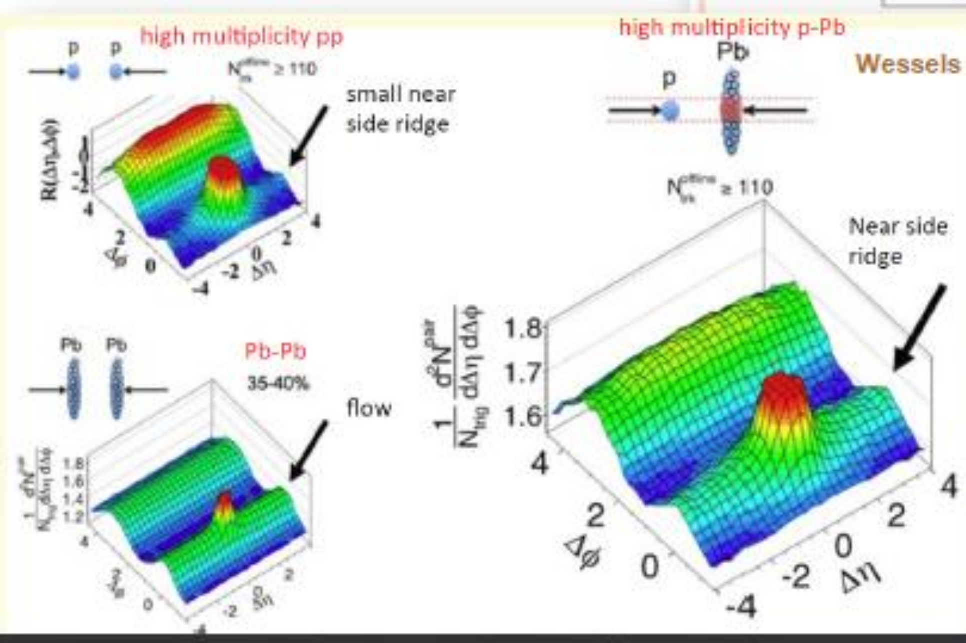
$Z_c(3900)^{\pm}$	$Z_c(4020)^{\pm}$	$Z_c(4430)^{\pm}$/ $Z_c(4480)^{\pm}$
Narrow charged structure above $(DD^*)^{\pm}$ mass threshold	Narrow charged structure above $(D^*D^*)^{\pm}$ mass threshold	Charged structure above $(D_1D^*)^{\pm}$ mass threshold
Observed in $\pi^{\pm}J/\psi$ final state	Observed in $\pi^{\pm}h_c$ final state	Observed in $\pi^{\pm}\psi(2S)$, evidence decay to $\pi^{\pm}J/\psi$
Decay to $(D\bar{D}^*)^{\pm}$ and $\pi^{\pm}J/\psi$ in ratio of 6±3:1	Decay to $(D^*\bar{D}^*)^{\pm}$ and $\pi^{\pm}h_c$ in ratio of 12±5 : 1	Unknown
Neutral isospin partner $Z_c(3900)^0$	Neutral isospin partner $Z_c(4020)^0$	Unknown
$J^P=1^+$	unknown	$J^P=1^+$
Production seems correlated with Y(4260) decay	Production correlated with Y(4260) or Y(4360) is unclear	Production in B decay

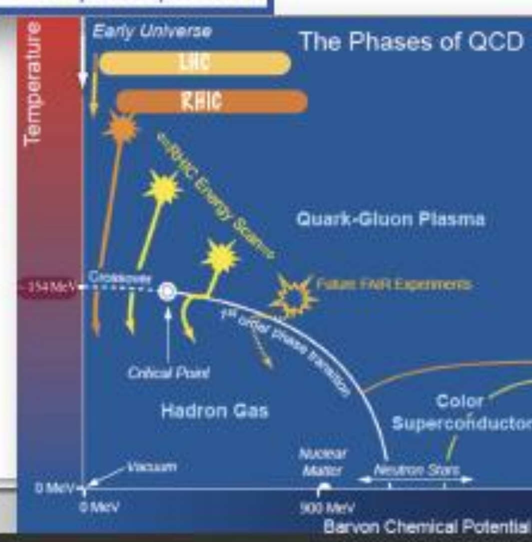
Heavy-Ion Collisions

Gale, Wessels

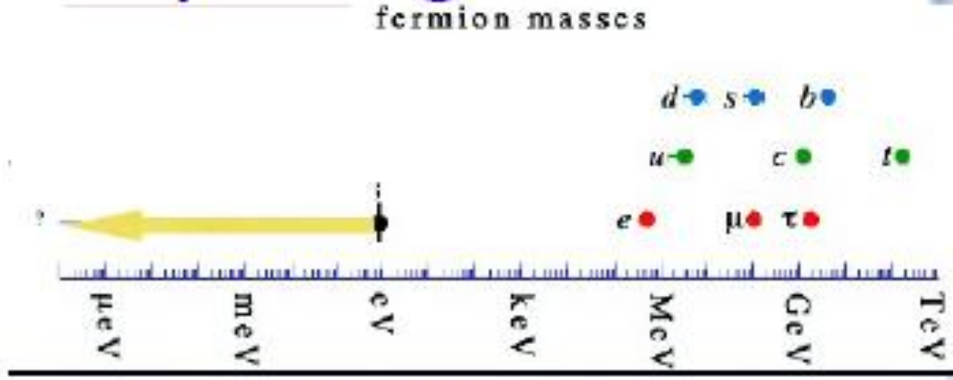
- Near-perfect relativistic fluid
- Jet quenching
- Screening (J/ψ, Υ)
- Regeneration (J/ψ)
- Evidence for collective phenomena in p-Pb







Neutrino physics: surprising results

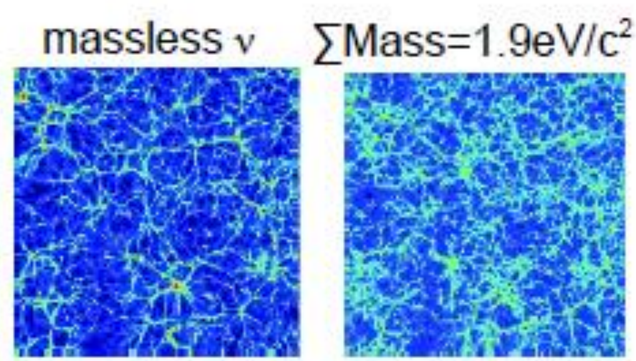


- The unbearable lightness of neutrino masses begs a compelling explanation

- The neutrino mixing angles are large, at variance with the quark mixing angles: large CP violation effects are allowed

$$V_{PMNS} = \begin{pmatrix} 0.8 & 0.5 & 0.2 \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix} \quad V_{CKM} = \begin{pmatrix} 1 & 0.2 & 0.001 \\ 0.2 & 1 & 0.01 \\ 0.001 & 0.01 & 1 \end{pmatrix}$$

- Neutrinos play a fundamental role in the evolution of the Universe. Can they explain matter-antimatter asymmetry ?



Baryon density

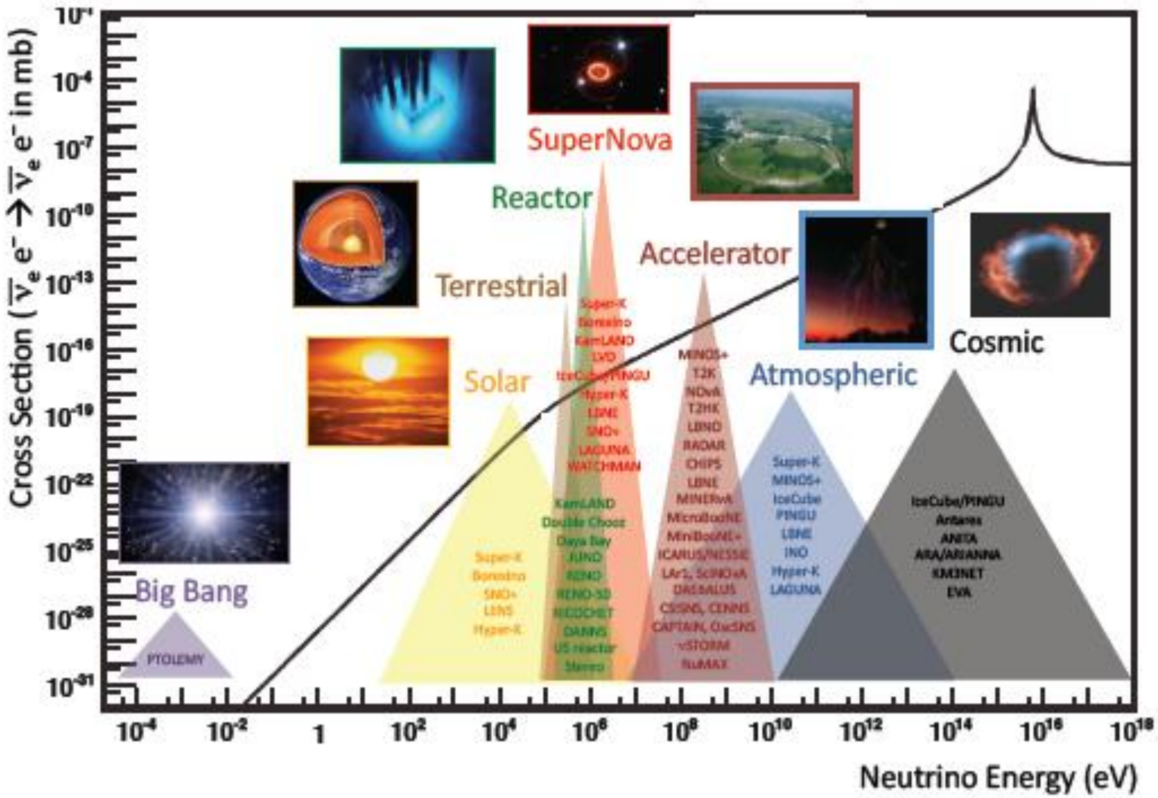
Agarwal, Feldman 2010

Neutrinos

- Propelled by surprising discoveries from a series of pioneering experiments, neutrino physics has progressed dramatically over the past two decades.

- Many aspects of neutrino physics are puzzling:
  - What are the origin of neutrino mass?
  - What are the masses?
  - How are the masses ordered (mass hierarchy)?
  - Do neutrinos and antineutrinos oscillate differently? ($\not{CP}$)
  - Are there additional neutrino types or interactions?
  - Are neutrinos their own antiparticles?

Neutrinos are everywhere!

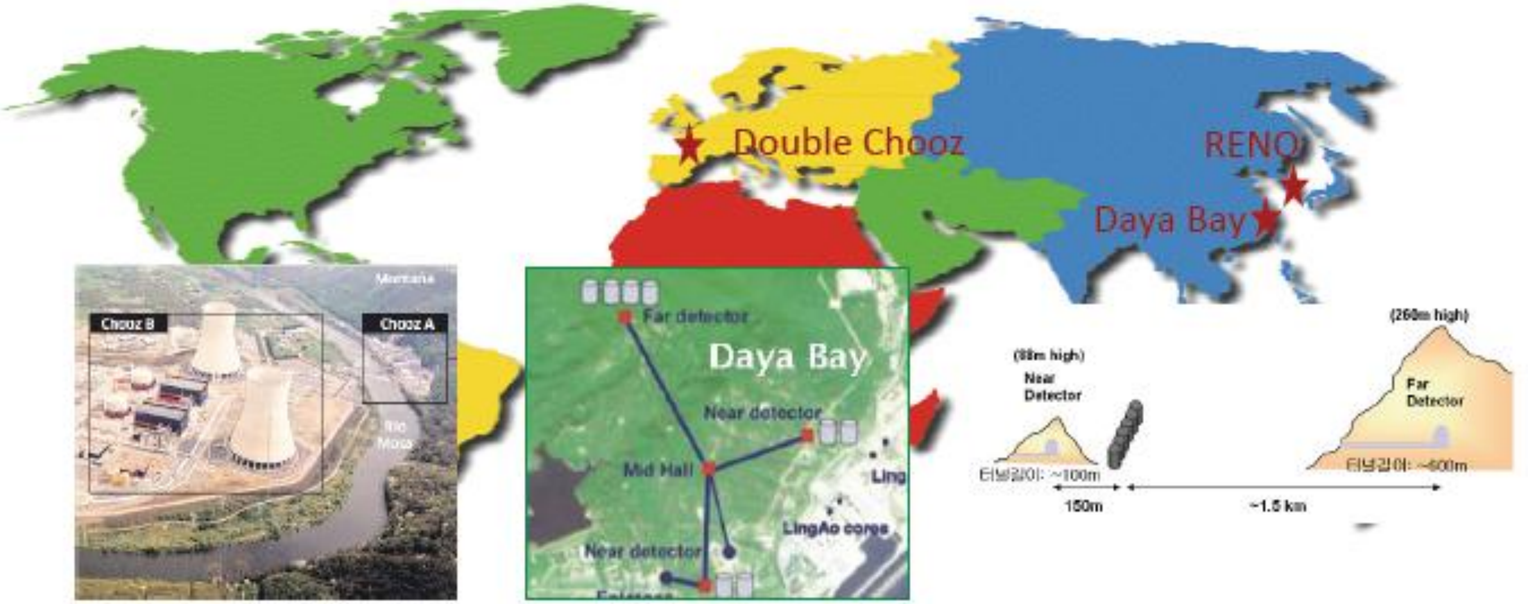


Many neutrinos over many different energies!

Oscillations over broad range of distances and energies..

Tell us about neutrinos and about the universe…

Reactor-based neutrinos



Double Chooz in France

Daya Bay in China

RENO in South Korea

Next generation experiments: JUNO

RENO50

Accelerator-based neutrinos

Long baseline

Fermilab → NOvA (810km)
MINOS (735km)

CERN → OPERA (732km)

J-PARC → T2K (295km)

$\nu_\mu \rightarrow \nu_\tau$ appearance
4^{th} event, 4.2σ

First θ_{13} measurement from accelerators: T2K (2013)

Short baseline

MicroBooNE

Open questions for Oscillation experiments

The neutrino mass hierarchy

The octant of the 2-3 mixing angle

CP violation in the lepton sector

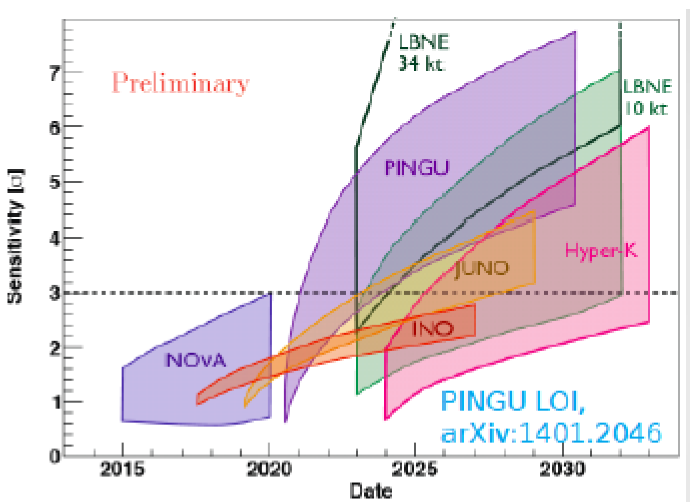
Are there sterile neutrinos

Major efforts towards answering the remaining questions and to increase precision

Some of the emerging pillars of the neutrino program:

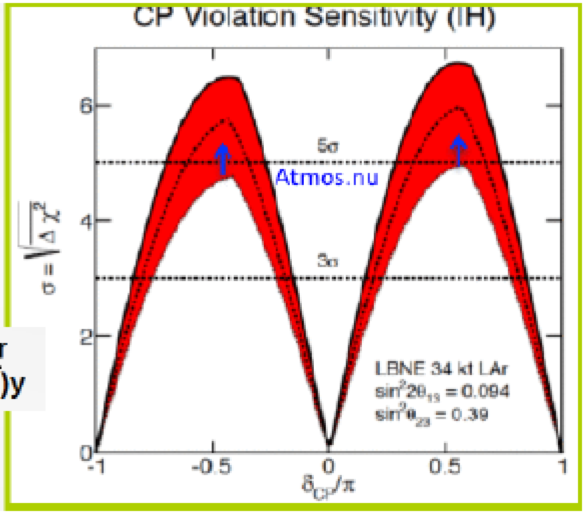
- ✓ A platform at CERN for detector R&D
- ✓ The proposed upgrade of the J-PARC beam and the proposal to construct Hyper-Kamiokande
- ✓ The P5 recommendations to host an international facility for short and long-baseline neutrino oscillations at FNAL

Sensitivity to mass hierarchy



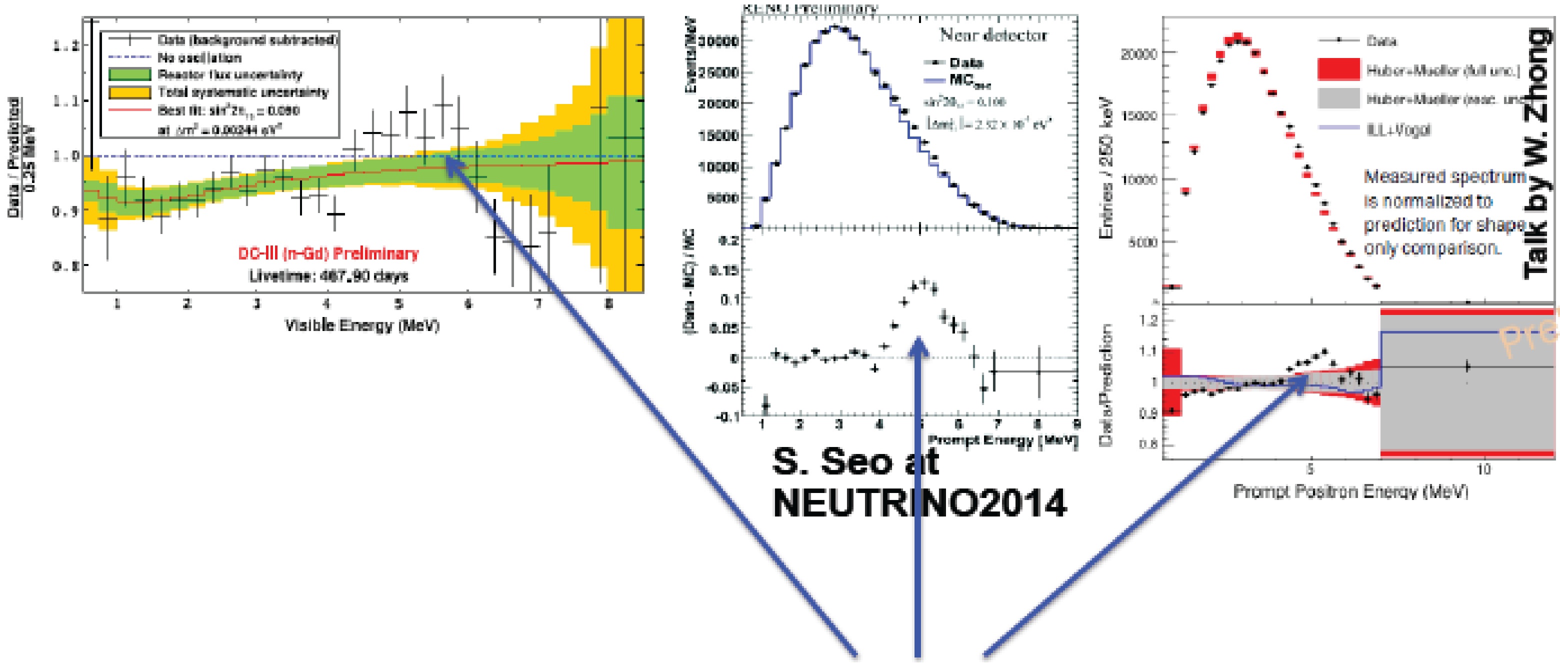
LBNE

Exposure 245 kt.MW.yr
34kt × 1.2MW × (3ν+3$\bar{\nu}$)y



Something peculiar…

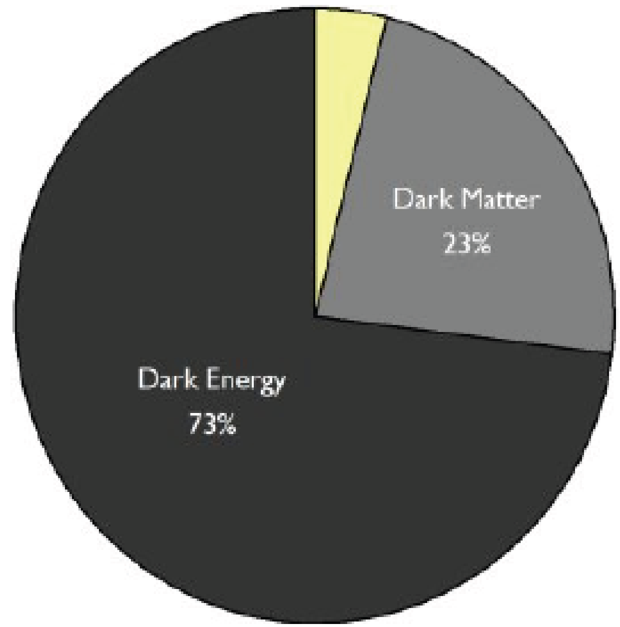
Reactor neutrino flux



Distortion in the spectrum observed by Double Chooz, RENO, Daya Bay

Dark Matter

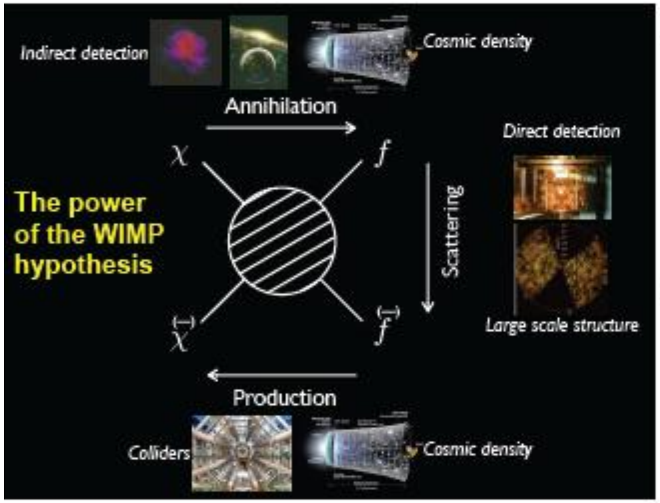
- Its mere existence implies
  - our inventory of the basic building blocks of nature is incomplete
  - we don't fully understand how the universe evolved to its present state and how it will evolve in the future.



- A grand challenge for fundamental physics and astronomy
- An extraordinary diversity of approaches united by the common goal of discovering the identity of dark matter.

HOW TO CATCH A WIMP

1. Direct detection (scattering XS)
   - **Nuclear (atomic) recoils from elastic scattering**
   - A/J-dependence, annual modulation, directionality
   - Galactic DM at the Sun's position – our DM!
   - Mass measurement (if not too heavy)



2. Indirect detection (decay, annihilation XS)
   - High-energy cosmic-rays, γ-rays, neutrinos, etc.
   - Over-dense regions, annihilation signal $\propto n^2$
   - Very challenging backgrounds

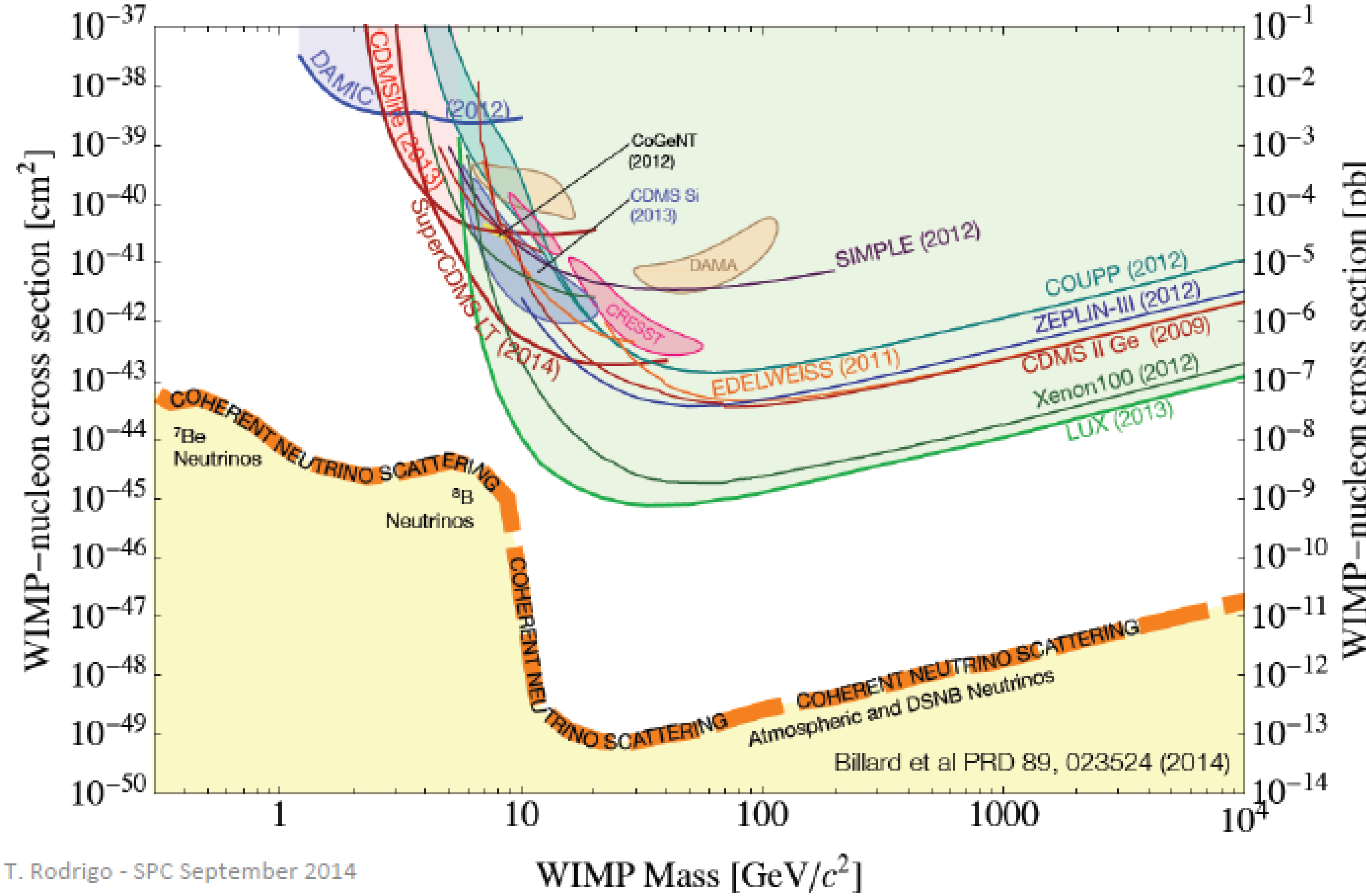
3. Accelerator searches (production XS)
   - MET, mono-X, dark photons, etc.
   - Mass measurement may be poor at least initially
   - Can it establish that new particle is the DM?

Direct dark matter (WIMP) searches

(underground facilities are also for neutrinos, proton decays)

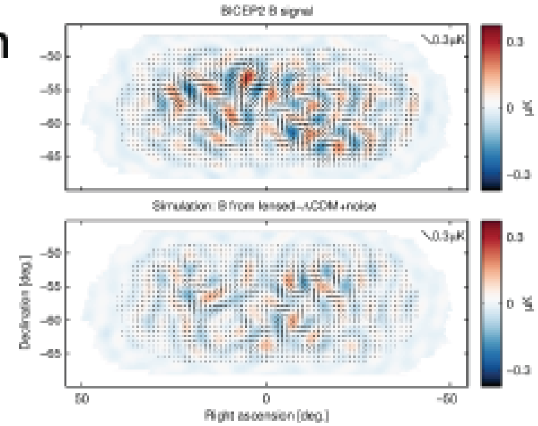
DM Direct detection searches - Present status

(Spin independent cross section)

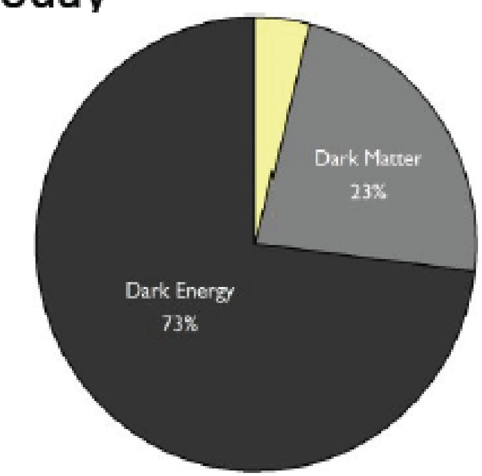


Dark Energy

- Two periods during which the expansion Universe accelerated

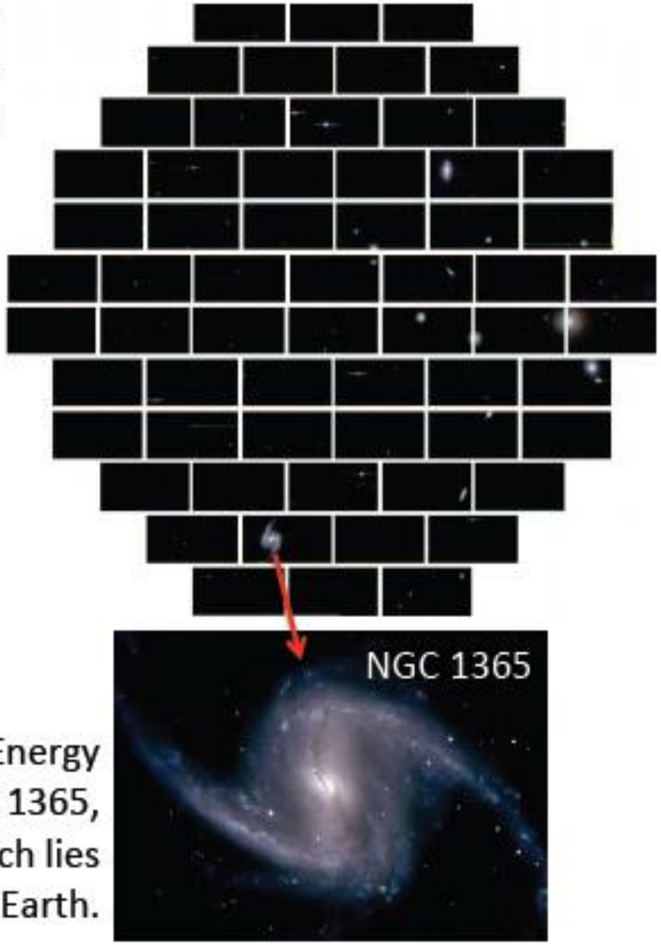


  - 1st epoch: Inflation, a primordial epoch of acceleration
  - 2nd epoch: began recently, continues today
    - Driven by dark energy?
    - How does it evolve with time?
    - Related to Einstein's cosmological constant?
    - Requires gravity modification?



DES (Dark Energy Survey)

- DES, world's most powerful digital camera (570 megapixel), began its 5-year mission on Aug. 31, 2013
- First season data being processed
- First dark energy results from 2 first seasons of data. Stay tuned!!



Zoomed-in image from the Dark Energy Camera of the barred spiral galaxy NGC 1365, in the Fornax cluster of galaxies, which lies about 60 million light years from Earth.

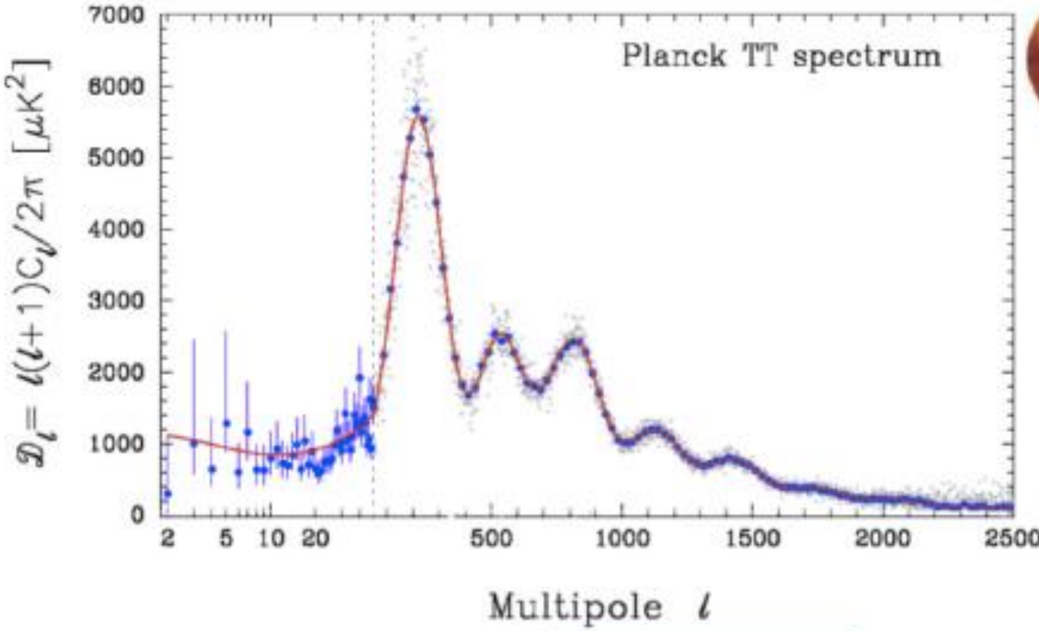
37th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
ICHEP 2014 VALENCIA
2-9 - JULY - 2014 - VALENCIA

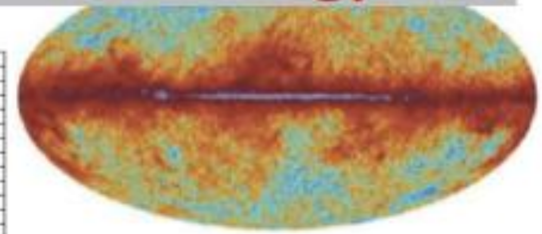
Inflationary Cosmology and Particle Physics

— Alan Guth —
MIT
Massachusetts Institute of Technology

37th International Conference on High Energy Physics
Palacio de Congresos
Valencia, Spain
Auditorium 1
July 7, 2014

Neutrino Properties from Cosmology



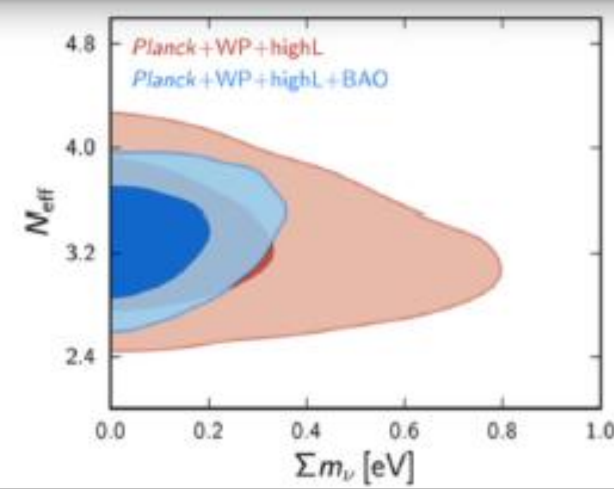


$$\text{maps} \Rightarrow \mathcal{C}_\ell(\vec{\Omega}) \Rightarrow \mathcal{L}_{Planck}(\mathcal{C}_\ell, \psi)$$

success of ΛCDM
+ 3 active neutrinos
+ $\Sigma m_\nu \geq 0.06$ eV
(from oscillations)

➔ limits on Σm_ν and N_{eff}

$$N_{\text{eff}} = 3.32 \pm 0.27 \ (68\% CL)$$
$$\sum m_\nu < 0.28 \text{ eV} \ (95\% CL)$$

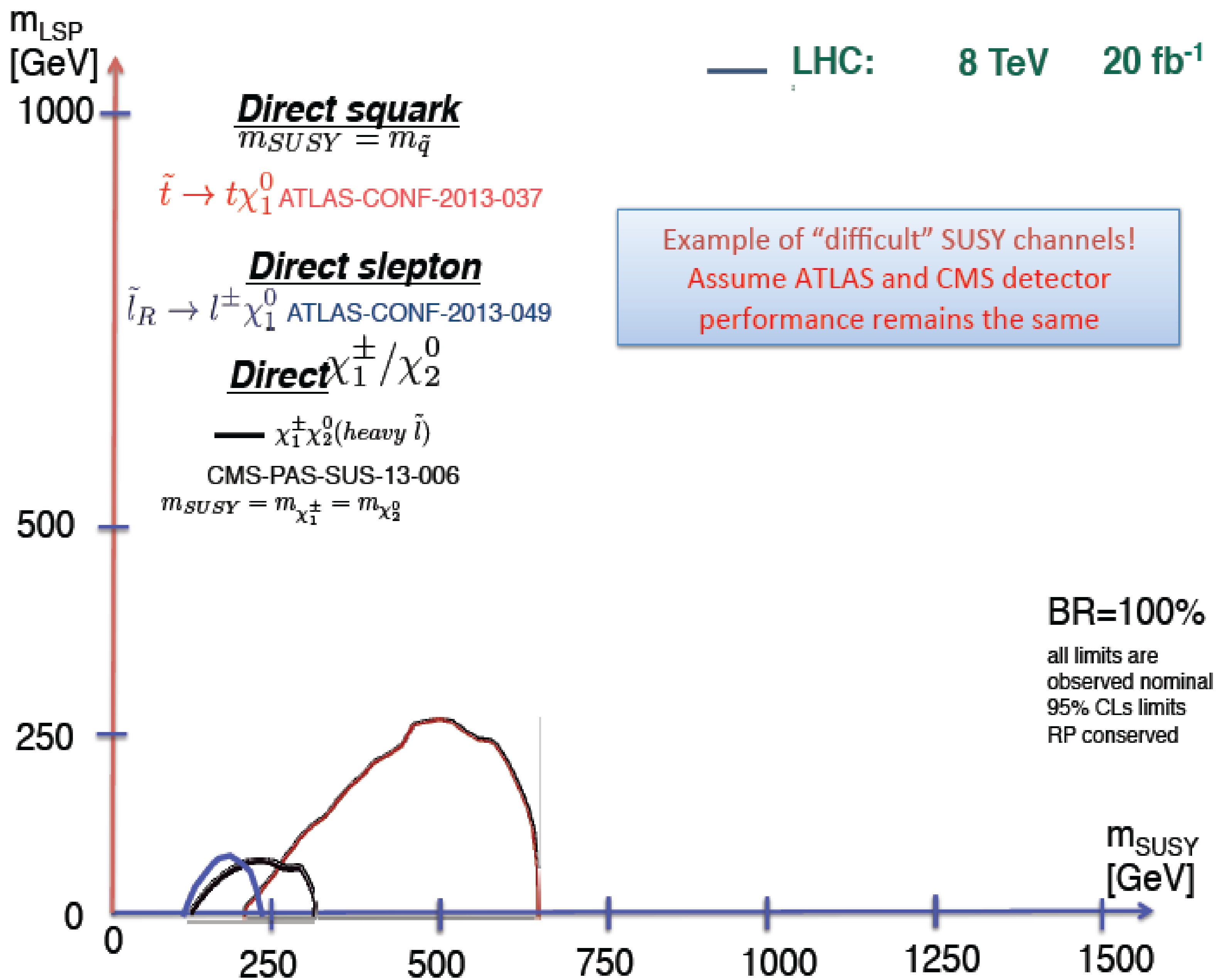


Producing new particles

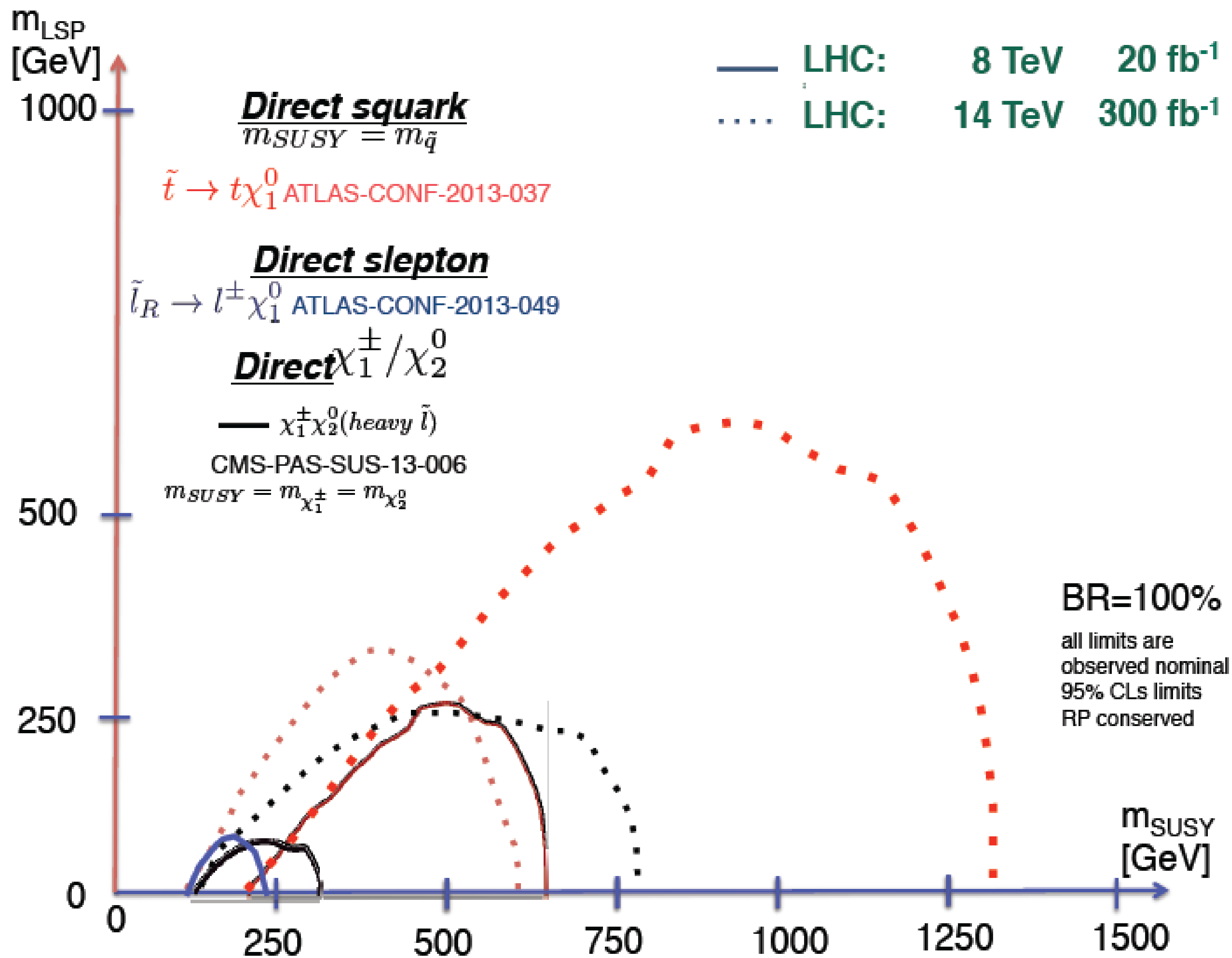
Summary from Frank Wuerthwein

- ATLAS and CMS looked all over the place
  - Vast diversity of signatures
  - Singly produced resonances up to ~5TeV
  - Pair produced new particles up to ~1.5 TeV

- No new physics found anywhere they looked
  - Devil's in the details → many places left to hide
  - Will do it all over again next few years at higher energy and larger luminosity!!



m_{LSP} [GeV]
LHC: 8 TeV 20 fb^{-1}
Direct squark
$m_{SUSY} = m_{\tilde{q}}$
$\tilde{t} \rightarrow t\chi_1^0$ ATLAS-CONF-2013-037
Example of “difficult” SUSY channels!
Assume ATLAS and CMS detector performance remains the same
Direct slepton
$\tilde{l}_R \rightarrow l^{\pm}\chi_1^0$ ATLAS-CONF-2013-049
Direct $\chi_1^{\pm}/\chi_2^0$
$\chi_1^{\pm}\chi_2^0(heavy\ \tilde{l})$
CMS-PAS-SUS-13-006
$m_{SUSY} = m_{\chi_1^{\pm}} = m_{\chi_2^0}$
BR=100%
all limits are observed nominal 95% CLs limits RP conserved
1000
500
250
0
0
250
500
750
1000
1250
1500
m_{SUSY} [GeV]

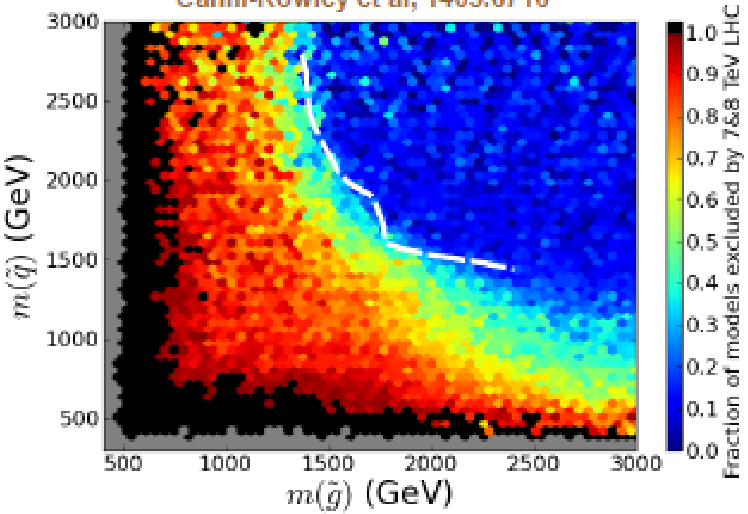


m_{LSP} [GeV]
1000
500
250
0
Direct squark
$m_{SUSY} = m_{\tilde{q}}$
$\tilde{t} \to t\chi_1^0$ ATLAS-CONF-2013-037
Direct slepton
$\tilde{l}_R \to l^{\pm}\chi_1^0$ ATLAS-CONF-2013-049
Direct $\chi_1^{\pm}/\chi_2^0$
$\chi_1^{\pm}\chi_2^0(heavy\ \tilde{l})$
CMS-PAS-SUS-13-006
$m_{SUSY} = m_{\chi_1^{\pm}} = m_{\chi_2^0}$
LHC: 8 TeV 20 fb-1
LHC: 14 TeV 300 fb-1
BR=100%
all limits are observed nominal 95% CLs limits RP conserved
m_{SUSY} [GeV]
0
250
500
750
1000
1250
1500

Which SUSY?

- **Looks bad in CMSSM** (120 MSSM parameters reduced to 4 + 1 sign)
- **More freedom in the Phenomenological MSSM**

Cahill-Rowley et al, 1405.6716



120 MSSM parameters reduced to 19-20

Many "models" consistent with data

Data-driven search

- **Many SUSY variants:** NMSSM, Split, High-Scale, Stealth, 5D ...

Naturalness?

$$\Delta M_h^2 \propto M_{\rm SUSY}^2$$

Bharucha, Bosch, De Vries, Di Chiara, López, Rolbiecki, Sarrazin

The HEP landscape after LHC_{8TeV}

Nicely summarized by M. Mangano @Aspen'14:

My key message

- The days of "guaranteed" discoveries or of no-lose theorems in particle physics are over, at least for the time being ....
- .... but the big questions of our field remain wild open (hierarchy problem, flavour, neutrinos, DM, BAU, ...)
- This simply implies that, more than for the past 30 years, future HEP's progress is to be driven by experimental exploration, possibly renouncing/reviewing deeply rooted theoretical bias

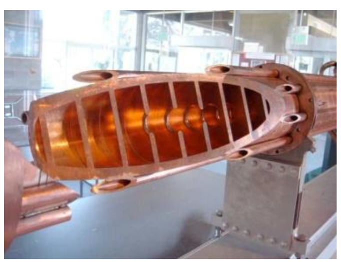
The Higgs discovery sets a large part of the agenda for the theoretical and experimental HEP programs over the next couple of decades.

Unless a new major discovery soon (supersymmetry, DM...)!

(R)Evolutionary Advancement

Accelerator on a Chip

Traditional Manufacturing



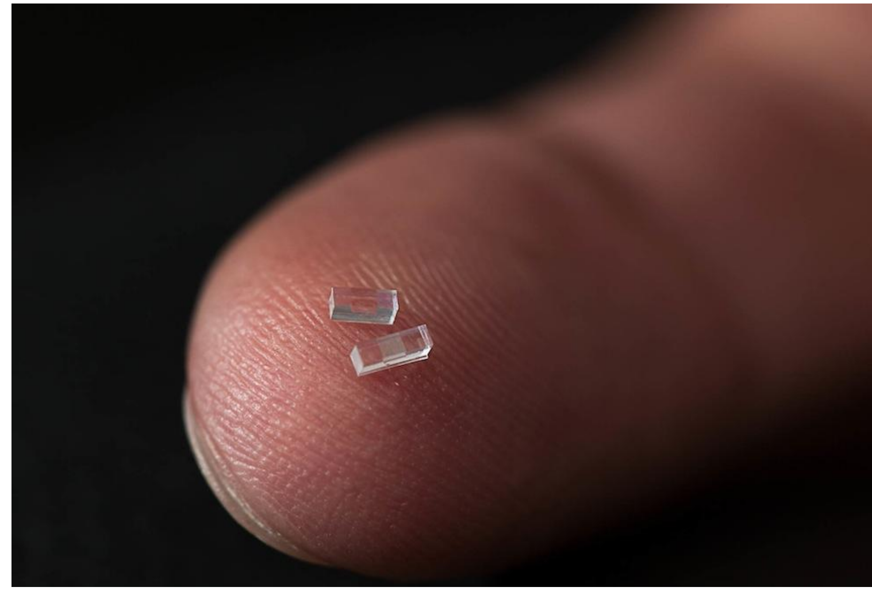
Room temp.

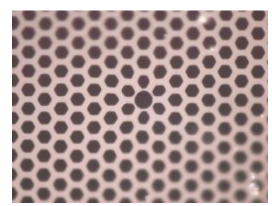
Super conducting

E_{acc} = 30 MV/m
λ = 10 cm

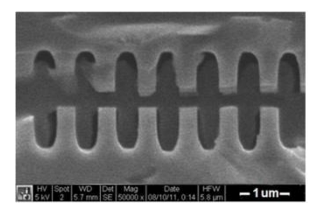
10E-4

Semiconductor Manufacturing

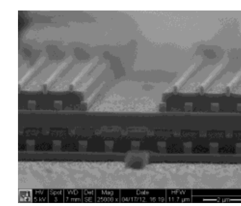




Fibers



Gratings



Crystals

Robert L. Byer
rlbyer@stanford.edu

E_{acc} = 2 GV/m *
λ = 1 - 2 μm

* in theory

300 MV/m demonstrated

Concert


Universitat de València

Status & Outlook

- The SM appears to be the right theory at the EW scale
- The H(125) behaves as the SM scalar boson
- The CKM mechanism works very well
- Neutrinos do have (tiny) masses. Lepton flavour is violated
- Different flavour structure for quarks & leptons
- **New physics needed** to explain many pending questions:
  Flavour, CP, baryogenesis, dark matter, cosmology...

- **How far is the Scale of New-Physics Λ_{NP} ?**
- **Which symmetry keeps M_H away from Λ_{NP} ?**
  Supersymmetry, scale/conformal symmetry...
- **Which kind of New Physics?**