ICHEP2012 Melbourne

36th International Conference on High Energy Physics

4 – 11 July 2012

Melbourne Convention and Exhibition Centre

-- a cherry picking summary --

INFN Frascati

Delia Hasch

ICHEP2012 Melbourne

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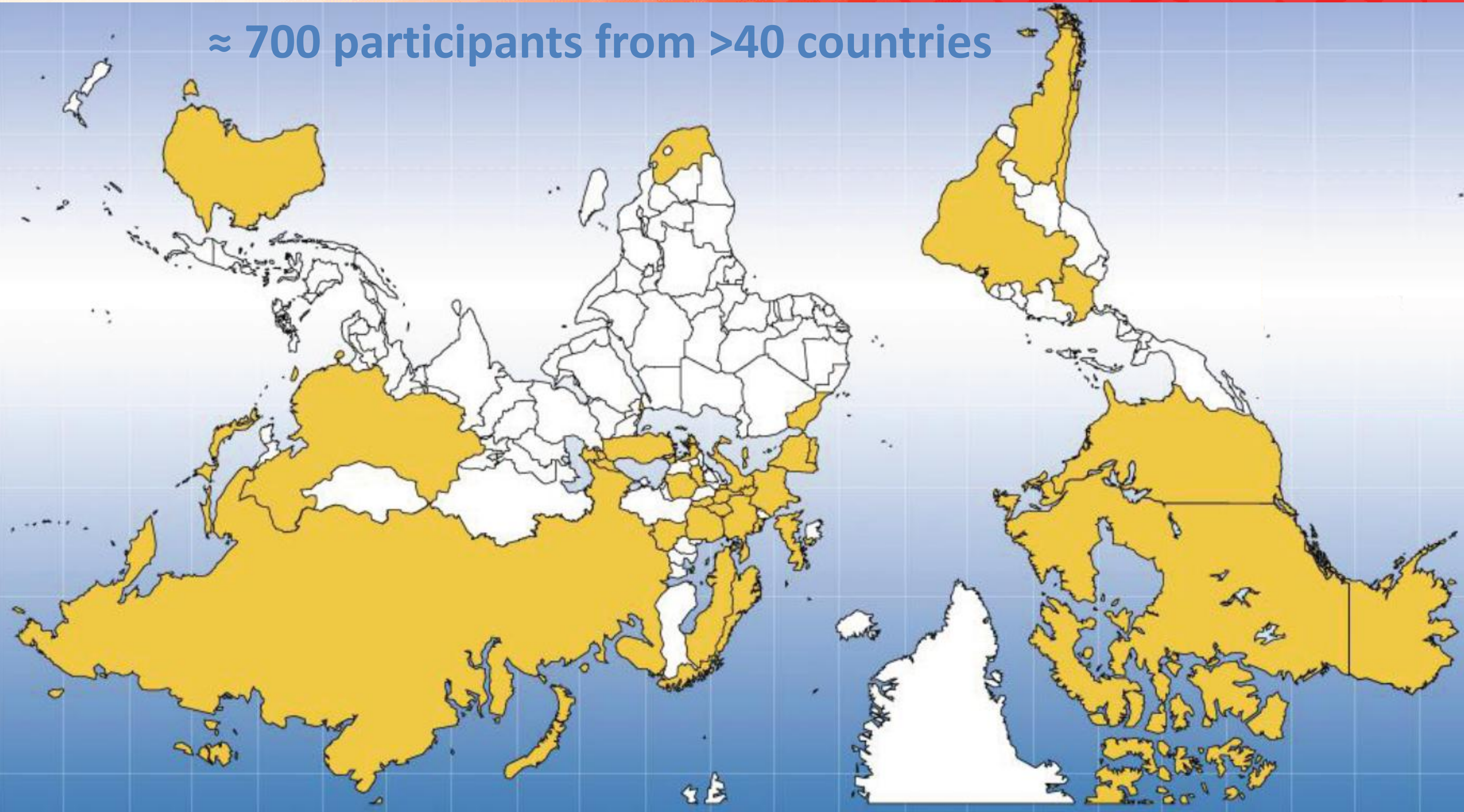
≈ 700 participants from >40 countries



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4 – 11 July 2012
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≈ 700 participants from >40 countries

- 3 days of parallel sessions: grouped in 15 topics

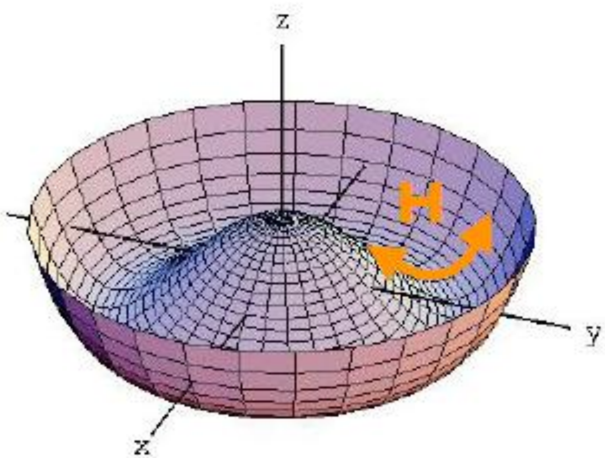
[www.ichep2012.com.au/Program]

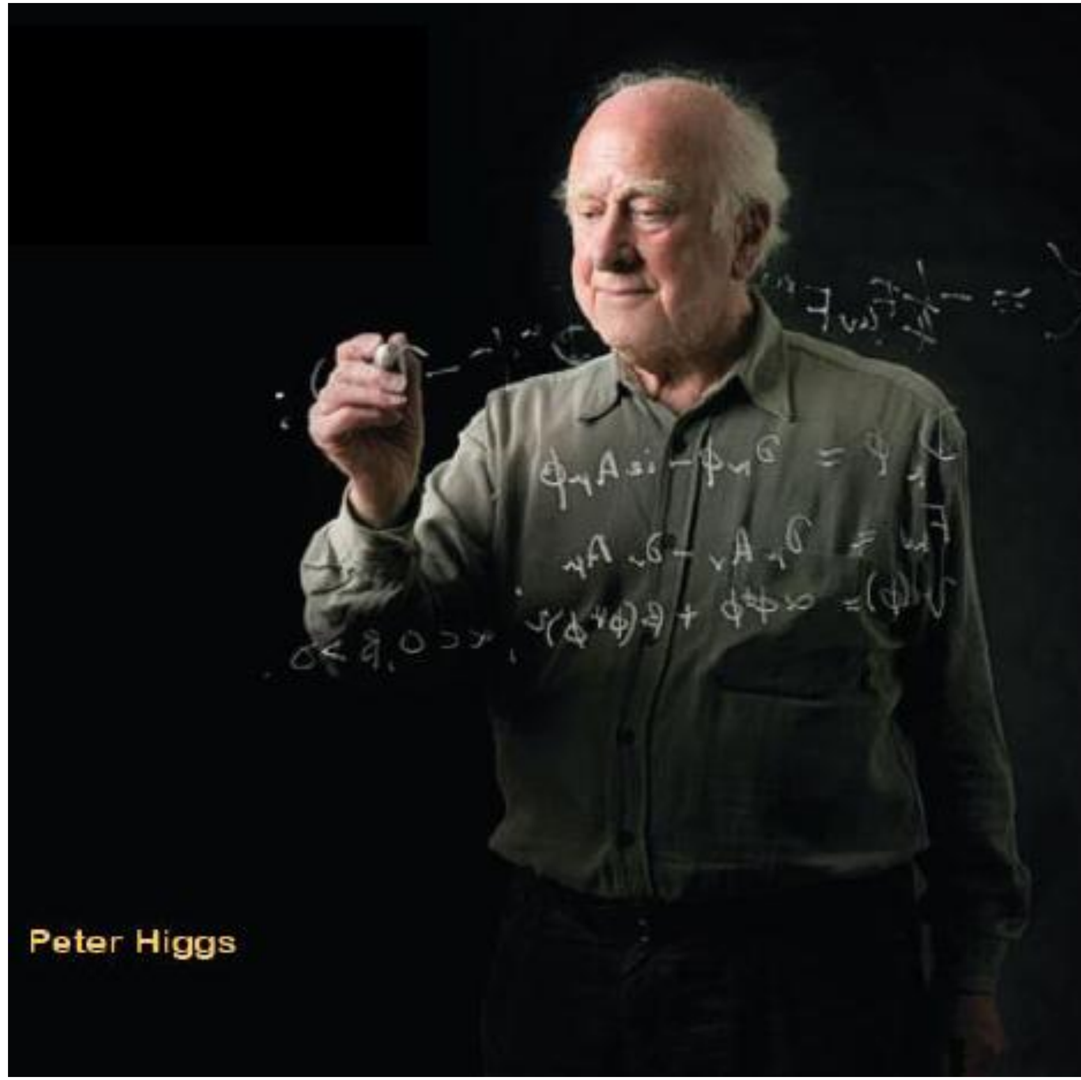
- 3 days of planary talks

Parallel session convenors

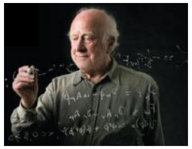
Session	Convenors
1. The Standard Model and EW Symmetry Breaking- Higgs Searches	Sara Diglio Toyoko Orimoto Albert De Roeck Marumi Kado Eric James Pietro Slavich
2. Beyond the Standard Model - SUSY	Joanne Hewitt Iacopo Vivarelli Frederic Ronga
3. BSM - non- SUSY, Exotics	Kenji Hamano Shahram Rahatlou Christophe Grojean
4. Top Quark Physics	Pamela Ferrari Roberto Chierici Stefano Frixione
5. B Physics	Jure Zupan Phillip Urquijo Timothy Gershon
6. QCD, Jets, Parton Distributions	Voica Radescu Andreas Vogt
7. CP Violation, CKM, Rare Decays, Meson Spectroscopy	Chrisoph Schwanda Valerie Gibson
8. Neutrinos	Jelena Maricic Kevin McFarland
9. Heavy Ion Collisions	Raimond Snellings Carlos Salgado
10. Lattice QCD	Ross Young Johnathon Flynn
11. Particle Astrophysics and Cosmology	Pat Scott Jodi Cooley Jason Kumar
12. Formal Theory Developments	Gary Shiu Emilian Dudas
13. Detectors and Computing for HEP	Ted Tiehui Liu Su Dong Sunanda Bannerjee Kenneth Bloom
14. Future Accelerators	Mark Boland
15. Education and Outreach	Steven Goldfarb David Barney

THE highlight





THE highlight



CERN Press Office

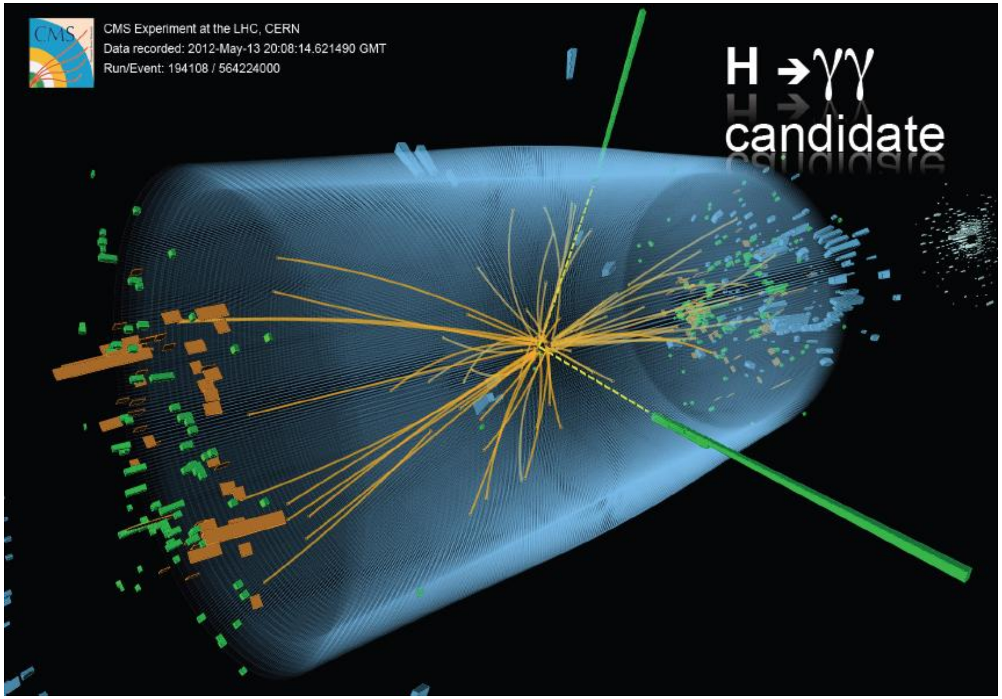
CERN experiments observe particle consistent with long-sought Higgs boson

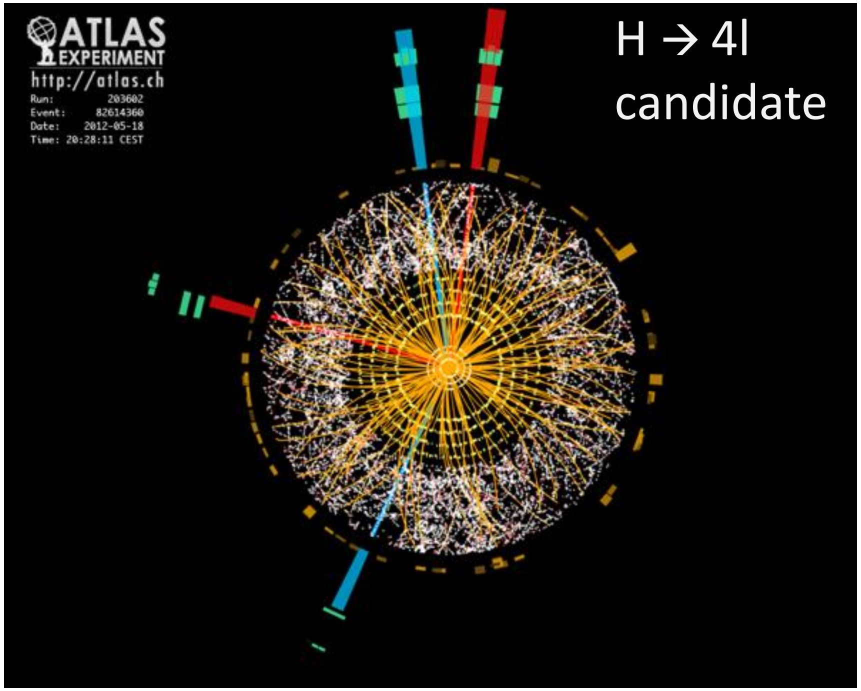
PR17.12
04.07.2012

Geneva, 4 July 2012. At a seminar held at CERN[1] today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. Both experiments observe a new particle in the mass region around 125-126 GeV.

http://www.atlas.ch/news/2012/latest-results-from-higgs-search.html

http://cms.web.cern.ch/news/observation-new-particle-mass-125-gev





ICHEP topics

HERA legacy

base line: **QCD**
→indispensable input for hadron machines (the 'discovery' machines)

lattice: information from first principles

HERA
Tevatron
Rhic
LHC
neutrinos
cosmology
high intensity exp.

ICHEP topics

base line: **QCD**
→indispensable input for hadron machines (the 'discovery' machines)

lattice: information from first principles

EW: symmetry breaking, higgs, ...

HERA
Tevatron
Rhic
LHC
neutrinos
cosmology
high intensity exp.

flavour-physics : CPV

DM&DE: (in)direct searches & cosmology

B-physics : unitarity triangle & NP

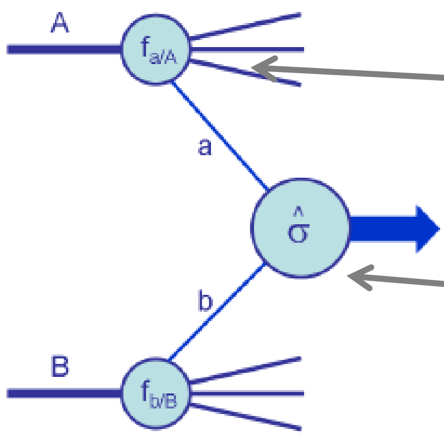
neutrino: numbers & masses

HIC : the quest for the QGP

BSM: SUSY, new physics, exotics

- *new technologies & facilities*
- *communicating science*

pQCD
-- the baseline --



determination of parton distribution fucntions

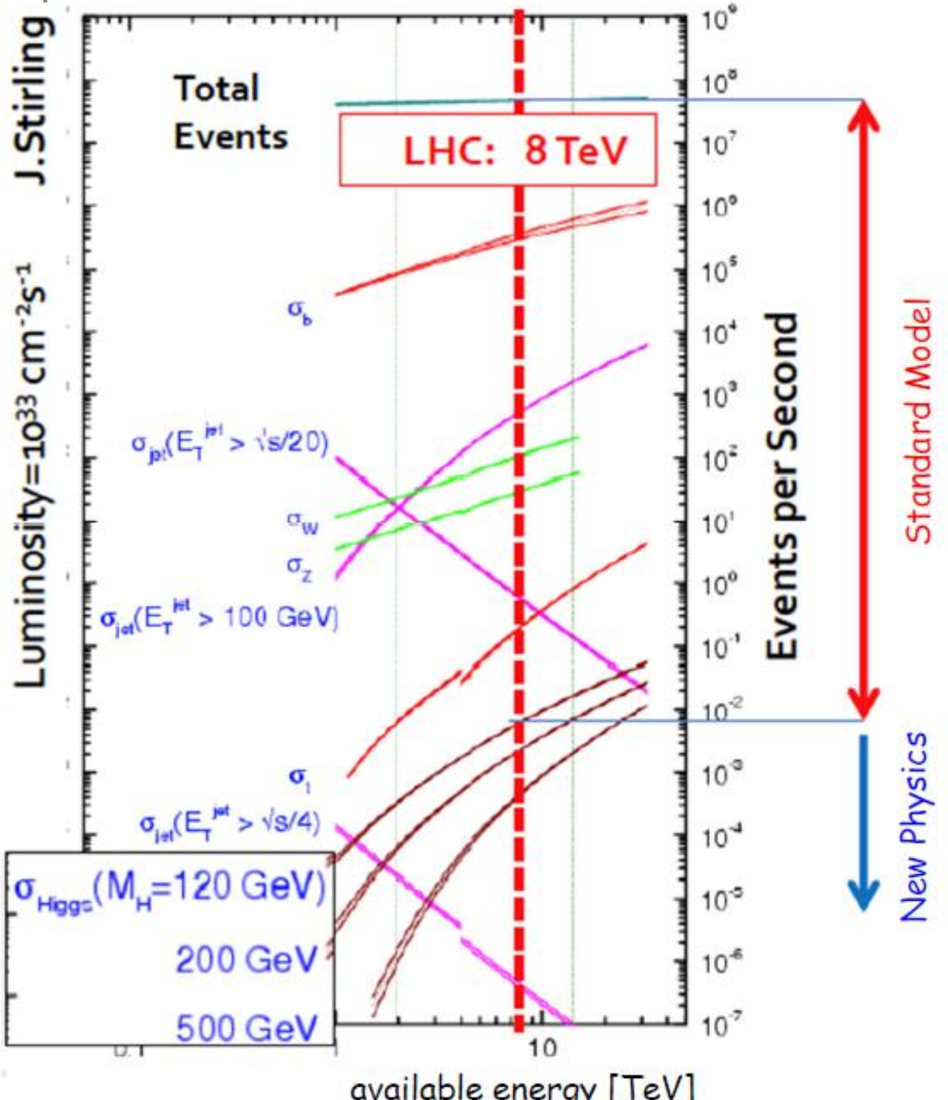
calculation of hard scattering matrix elements

expansion in strong coupling α_s

[Marco Stratmann]

QCD – why do we still care (perhaps more than ever)

production rates at hadron colliders

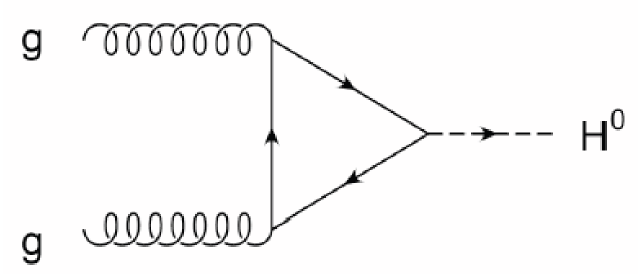


hadron colliders inevitably have to deal with QCD

discovering the Higgs or some New Physics requires a sophisticated quantitative understanding of QCD

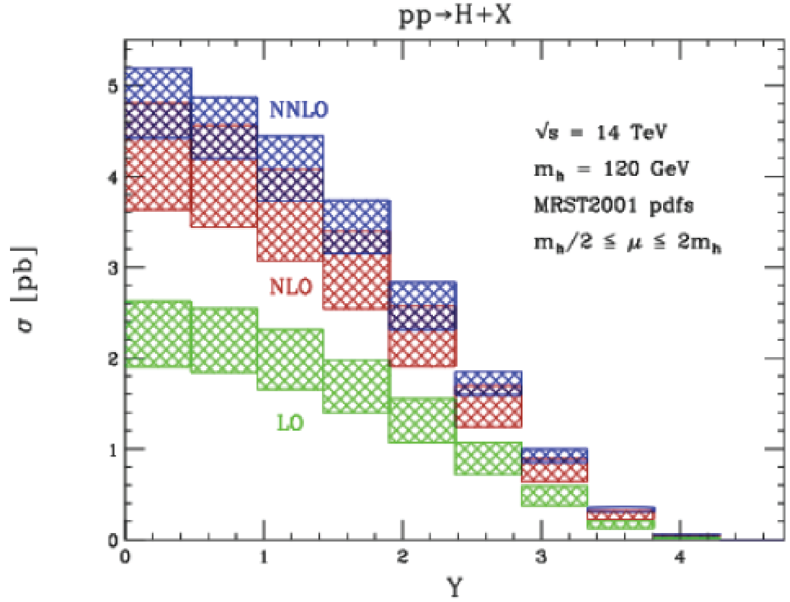
Higgs and QCD

- Despite EW role a QCD problem



Challenging perturbative expansion, NNLO required

Anastasiou, Melnikov, Petriello

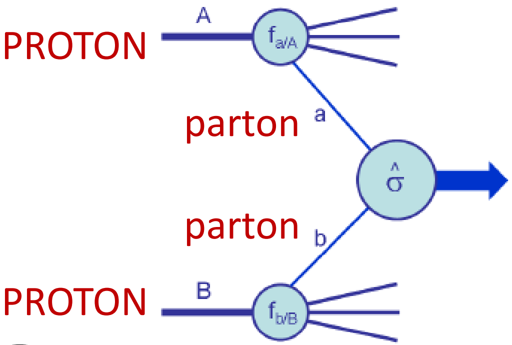


- Search strategies require good understanding of QCD issues
  - boosted jets and substructure
  - jet vetoes and resummation techniques

- Much study: "Handbook of LHC Higgs cross sections"

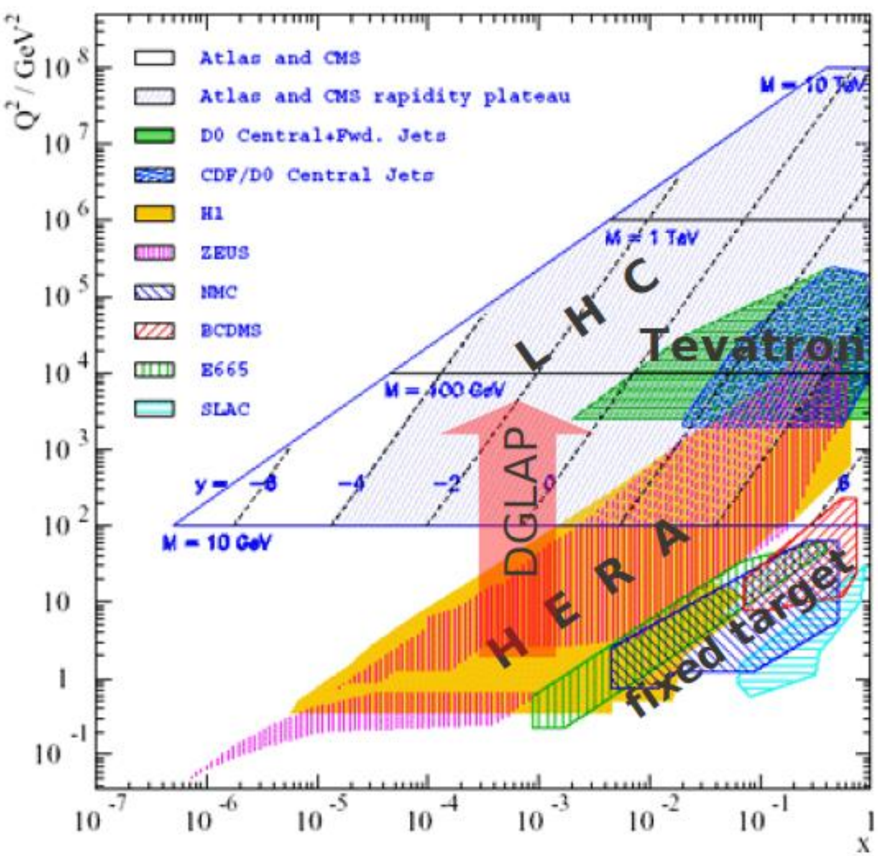
Dittmaier, Mariotti, Passarino, Tanaka

Parton distribution functions



- Parton content of the proton:
  life-blood of hadron collider physics

- Systematic exploration of proton structure at NNLO



reaching for precision

$$P^{(0)}_{ns}(x) = C_F\,(2p_{qq}(x) + 3\delta(1-x))$$
$$P^{(0)}_{ps}(x) = 0$$
$$P^{(0)}_{qg}(x) = 2n_f\,p_{qg}(x)$$
$$P^{(0)}_{gq}(x) = 2C_F\,p_{gq}(x)$$
$$P^{(0)}_{gg}(x) = C_A\Big(4p_{gg}(x) + \frac{11}{3}\delta(1-x)\Big) - \frac{2}{3}n_f\,\delta(1-x)$$

LO: 1973

$$\begin{aligned}P^{(1)+}_{ns}(x) = {}& 4C_AC_F\Big(p_{qq}(x)\Big[\frac{67}{18} - \zeta_2 + \frac{11}{6}H_0 + H_{0,0}\Big] + p_{qq}(-x)\Big[\zeta_2 + 2H_{-1,0} - H_{0,0}\Big]\\ &+\frac{14}{3}(1-x) + \delta(1-x)\Big[\frac{17}{24} + \frac{11}{3}\zeta_2 - 3\zeta_3\Big]\Big) - 4C_Fn_f\Big(p_{qq}(x)\Big[\frac{5}{9} + \frac{1}{3}H_0\Big] + \frac{2}{3}(1-x)\\ &+\delta(1-x)\Big[\frac{1}{12} + \frac{2}{3}\zeta_2\Big]\Big) + 4C_F{}^2\Big(2p_{qq}(x)\Big[H_{1,0} - \frac{3}{4}H_0 + H_2\Big] - 2p_{qq}(-x)\Big[\zeta_2 + 2H_{-1,0}\\ &-H_{0,0}\Big] - (1-x)\Big[1 - \frac{3}{2}H_0\Big] - H_0 - (1+x)H_{0,0} + \delta(1-x)\Big[\frac{3}{8} - 3\zeta_2 + 6\zeta_3\Big]\Big)\end{aligned}$$

$$\begin{aligned}P^{(1)-}_{ns}(x) = {}& P^{(1)+}_{ns}(x) + 16C_F\Big(C_F - \frac{C_A}{2}\Big)\Big(p_{qq}(-x)\Big[\zeta_2 + 2H_{-1,0} - H_{0,0}\Big] - 2(1-x)\\ &-(1+x)H_0\Big)\end{aligned}$$

$$P^{(1)}_{ps}(x) = 4C_Fn_f\Big(\frac{20}{9}\frac{1}{x} - 2 + 6x - 4H_0 + x^2\Big[\frac{8}{3}H_0 - \frac{56}{9}\Big] + (1+x)\Big[5H_0 - 2H_{0,0}\Big]\Big)$$

$$\begin{aligned}P^{(1)}_{qg}(x) = {}& 4C_An_f\Big(\frac{20}{9}\frac{1}{x} - 2 + 25x - 2p_{qg}(-x)H_{-1,0} - 2p_{qg}(x)H_{1,1} + x^2\Big[\frac{44}{3}H_0 - \frac{218}{9}\Big]\\ &+4(1-x)\Big[H_{0,0} - 2H_0 + xH_1\Big] - 4\zeta_2x - 6H_{0,0} + 9H_0\Big) + 4C_Fn_f\Big(2p_{qg}(x)\Big[H_{1,0} + H_{1,1} + H_2\\ &-\zeta_2\Big] + 4x^2\Big[H_0 + H_{0,0} + \frac{5}{2}\Big] + 2(1-x)\Big[H_0 + H_{0,0} - 2xH_1 + \frac{29}{4}\Big] - \frac{15}{2} - H_{0,0} - \frac{1}{2}H_0\Big)\end{aligned}$$

$$\begin{aligned}P^{(1)}_{gq}(x) = {}& 4C_AC_F\Big(\frac{1}{x} + 2p_{gq}(x)\Big[H_{1,0} + H_{1,1} + H_2 - \frac{11}{6}H_1\Big] - x^2\Big[\frac{8}{3}H_0 - \frac{44}{9}\Big] + 4\zeta_2 - 2\\ &-7H_0 + 2H_{0,0} - 2H_1x + (1+x)\Big[2H_{0,0} - 5H_0 + \frac{37}{9}\Big] - 2p_{gq}(-x)H_{-1,0}\Big) - 4C_Fn_f\Big(\frac{2}{3}x\\ &-p_{gq}(x)\Big[\frac{2}{3}H_1 - \frac{10}{9}\Big]\Big) + 4C_F{}^2\Big(p_{gq}(x)\Big[3H_1 - 2H_{1,1}\Big] + (1+x)\Big[H_{0,0} - \frac{7}{2} + \frac{7}{2}H_0\Big] - 3H_{0,0}\\ &+1 - \frac{3}{2}H_0 + 2H_1x\Big)\end{aligned}$$

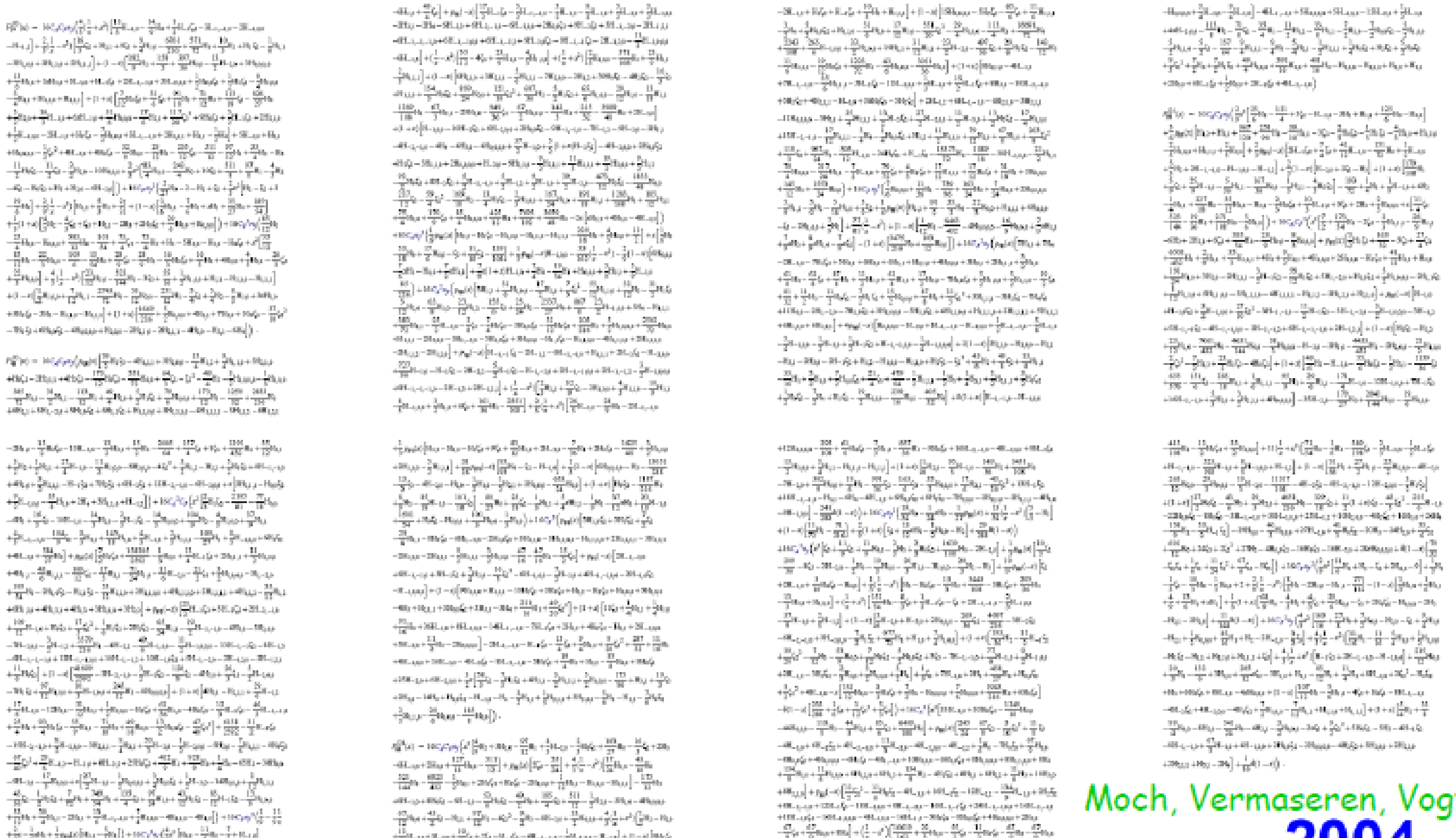
$$\begin{aligned}P^{(1)}_{gg}(x) = {}& 4C_An_f\Big(1 - x - \frac{10}{9}p_{gg}(x) - \frac{13}{9}\Big(\frac{1}{x} - x^2\Big) - \frac{2}{3}(1+x)H_0 - \frac{2}{3}\delta(1-x)\Big) + 4C_A{}^2\Big(27\\ &+(1+x)\Big[\frac{11}{3}H_0 + 8H_{0,0} - \frac{27}{2}\Big] + 2p_{gg}(-x)\Big[H_{0,0} - 2H_{-1,0} - \zeta_2\Big] - \frac{67}{9}\Big(\frac{1}{x} - x^2\Big) - 12H_0\\ &-\frac{44}{3}x^2H_0 + 2p_{gg}(x)\Big[\frac{67}{18} - \zeta_2 + H_{0,0} + 2H_{1,0} + 2H_2\Big] + \delta(1-x)\Big[\frac{8}{3} + 3\zeta_3\Big]\Big) + 4C_Fn_f\Big(2H_0\\ &+\frac{2}{3}\frac{1}{x} + \frac{10}{3}x^2 - 12 + (1+x)\Big[4 - 5H_0 - 2H_{0,0}\Big] - \frac{1}{2}\delta(1-\end{aligned}$$

Curci, Furmanski, Petronzio;
Floratos et al., ...

NLO: 1980

P_{ij} @ NNLO: a landmark calculation

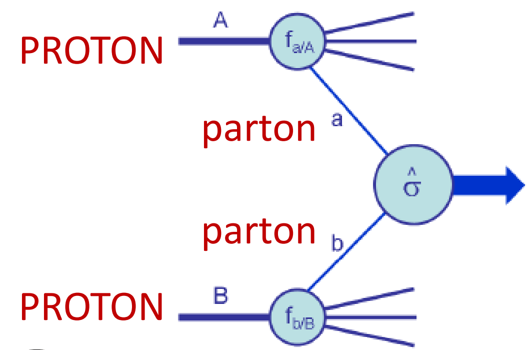
10000 diagrams, 10^5 integrals, 10 man years, and several CPU years later:



Moch, Vermaseren, Vogt
2004

NNLO the new emerging standard in QCD - essential for precision physics

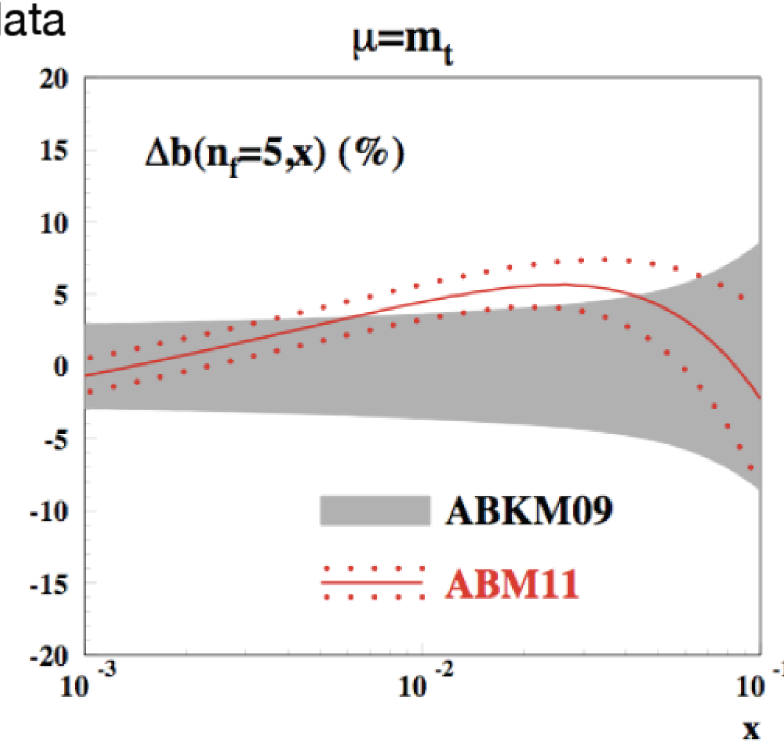
Parton distribution functions



- Parton content of the proton:
  life-blood of hadron collider physics
- Systematic exploration of proton structure at NNLO
- New this year: ABM11 Alekhin, Blumlein, Moch
  - fit to DIS and fixed-target Drell-Yan data
  - improved treatment of heavy quarks in DIS, running $\overline{\text{MS}}$ mass
    Alekhin, Moch

b-quark pdf uncertainty

- much-reduced in ABM11
- impact on many LHC cross sections, e.g. single top, charged Higgs



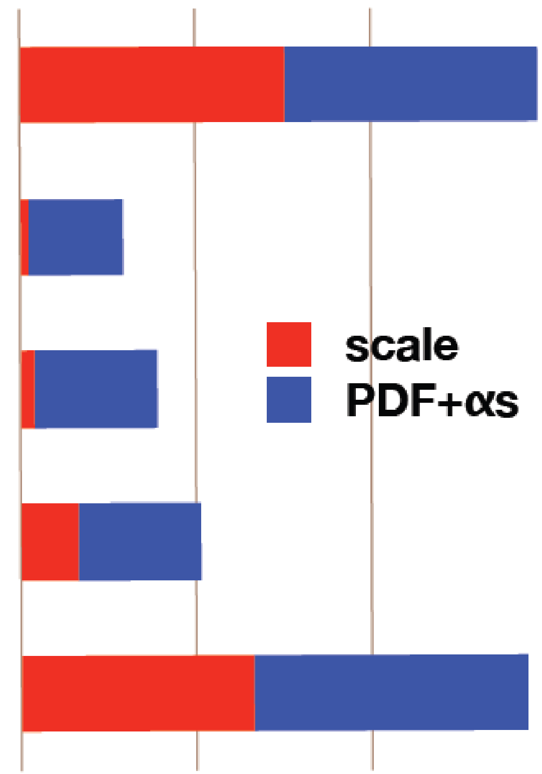
[John Campbell]

Higgs production at 125 GeV

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections

- Model testing requires assessment of theoretical uncertainties
  - uncertainties from scale variation and PDF+strong coupling

		σ (8 TeV)	uncertainty
NNLL QCD +NLO EW	gg→H	19.5 pb	14.7%
NNLO QCD +NLO EW	VBF	1.56 pb	2.9%
NNLO QCD +NLO EW	WH	0.70 pb	3.9%
NNLO QCD +NLO EW	ZH	0.39 pb	5.1%
NLO QCD	ttH	0.13 pb	14.4%

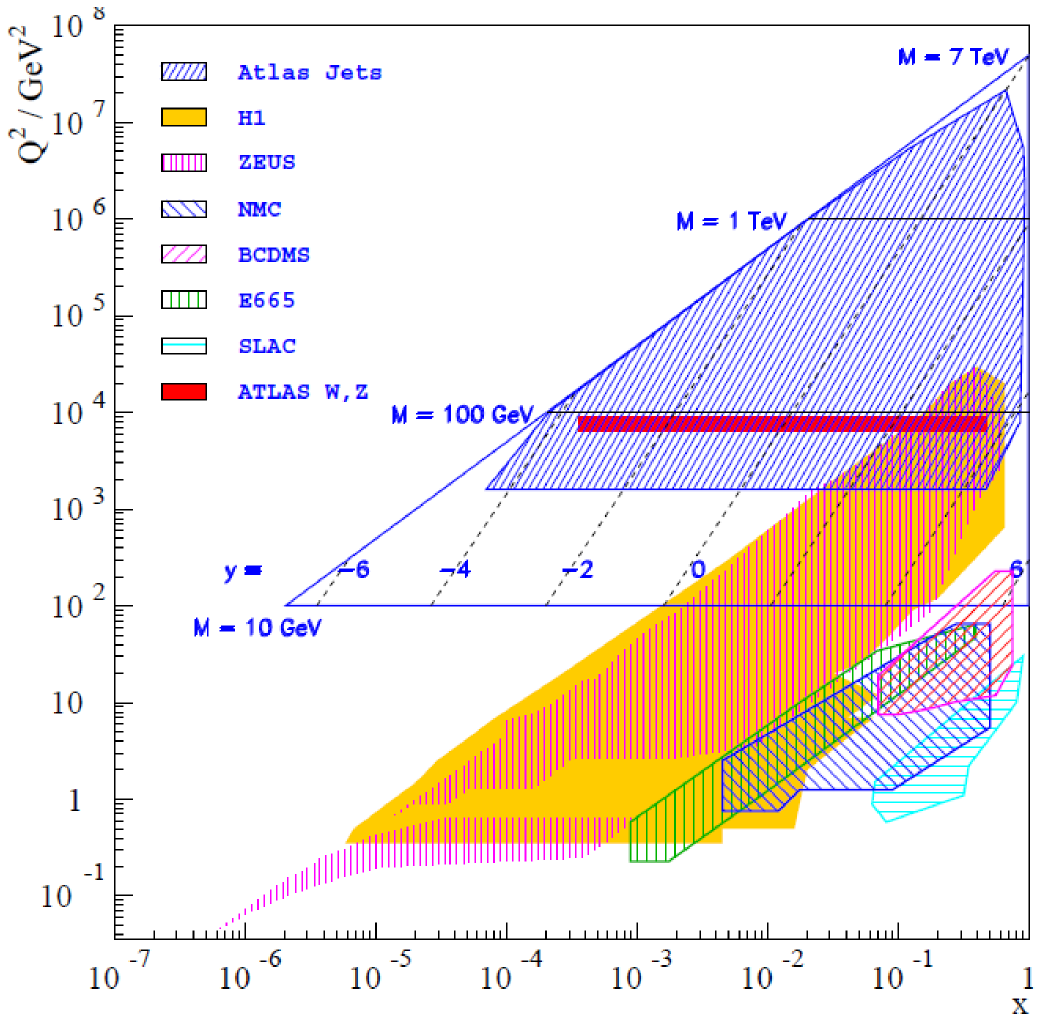


[Sasha Glazow]

cross sections @LHC

$$\sim x_1 f_1(x_1,\mu)\, x_2 f_2(x_2,\mu)\, \hat{\sigma}(x_1,x_2,\mu)$$

→ PDFs have on average > 1.3 citation per LHC paper (estimated based on study of G. Salam, La Thuile 2012)



- LHC x-range well covered by HERA data
- QCD: *evolution*
- strange distribution: constraints from neutrino data (SIDIS, LHC)
- gluon distribution: from *evolution* +
  constraints from jet prod.
  F_L from HERA

[Sasha Glazow]

PDF sets

	MSTW08	CTEQ6.6/CT10	NNPDF2.1/2.3	HERAPDF1.0/1.5	ABKM09/ABM11	GJR08/JR09
Evolution	LO	LO	LO	—	—	—
Order	NLO	NLO	NLO	NLO	NLO	NLO
	NNLO	NNLO(prel)	NNLO	NNLO	NNLO	NNLO
HF Scheme	RT-GMVF	ACOT-GMVF	FONLL-GMVF	RT-GMVF (*)	BMSN-FFNS	FFNS
α_S NLO	0.120	0.118(f)	0.1191(b)	0.1176(f)	0.118	0.1135
α_S NNLO	0.1171	0.118(f)	0.1174(b)	0.1176(f)	0.1135	0.1124
HERA DIS	not up-to-date	+	+	+/prelim.	partial	+
Fixed target DIS	+	+	+	-	+	+
DY	+	+	+	-	+	+
Tevatron W,Z	some	some	some	-	some	some
Tevatron jets	some	+	+	-	some	some
LHC	-	-	W, Z+jets (NNPDF2.3)	-	-	-

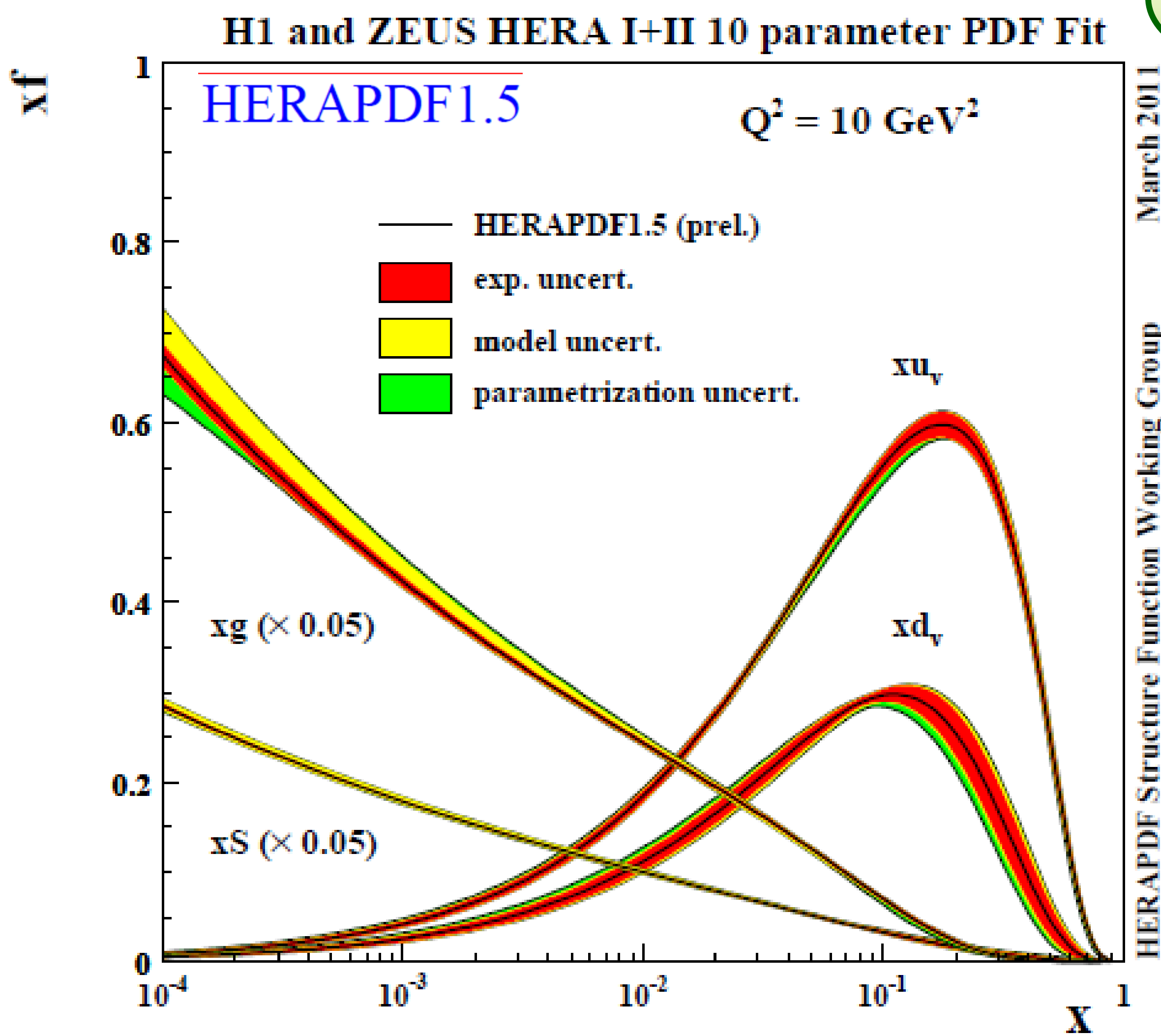
NNPDFs [Ball et.al.]

free from uncertainty due to underlaying parametrisation

PDF sets: just one example

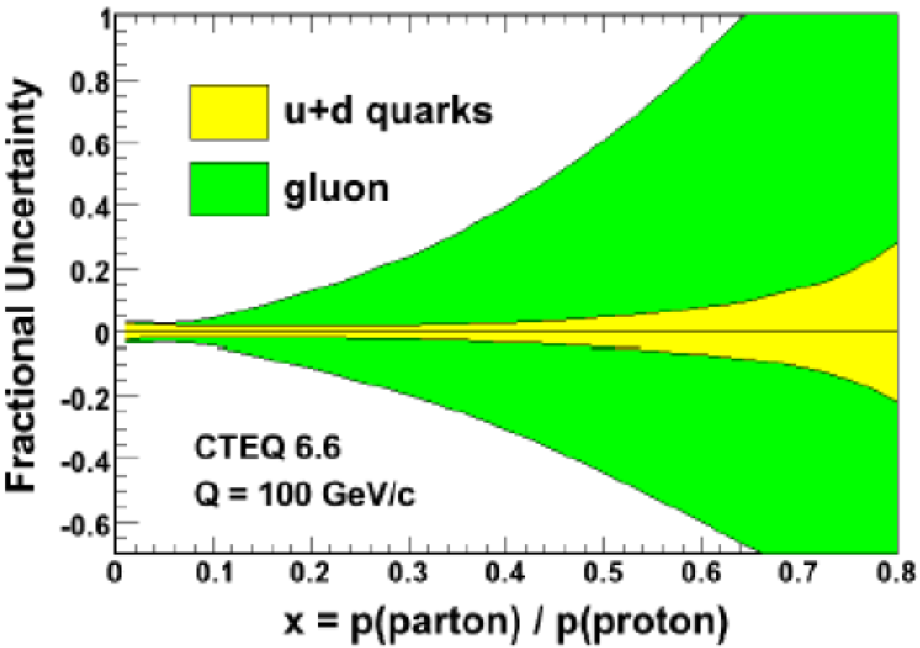
[Sasha Glazow]

HERA legacy



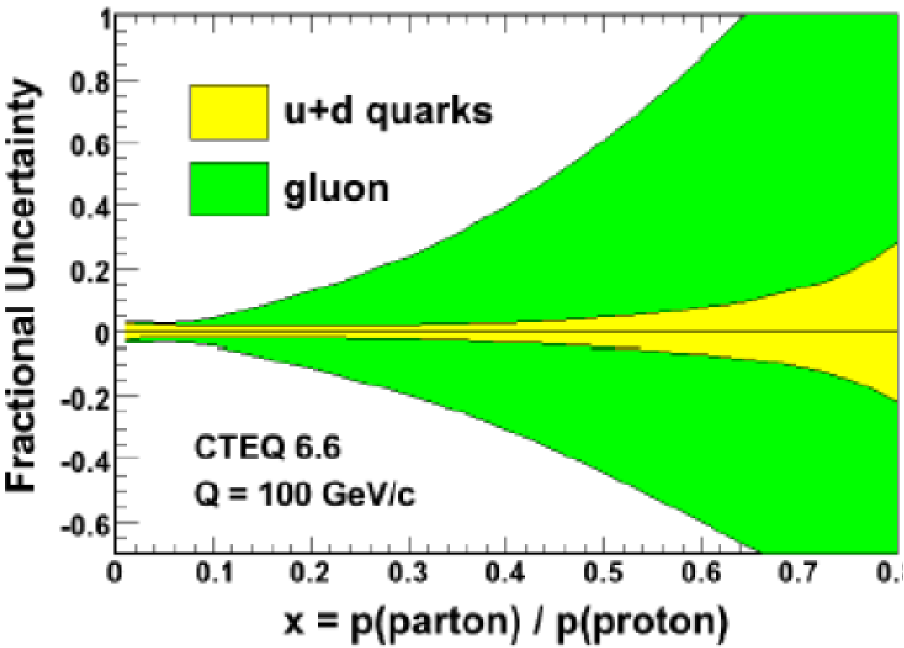
PDF sets: typical uncertainties

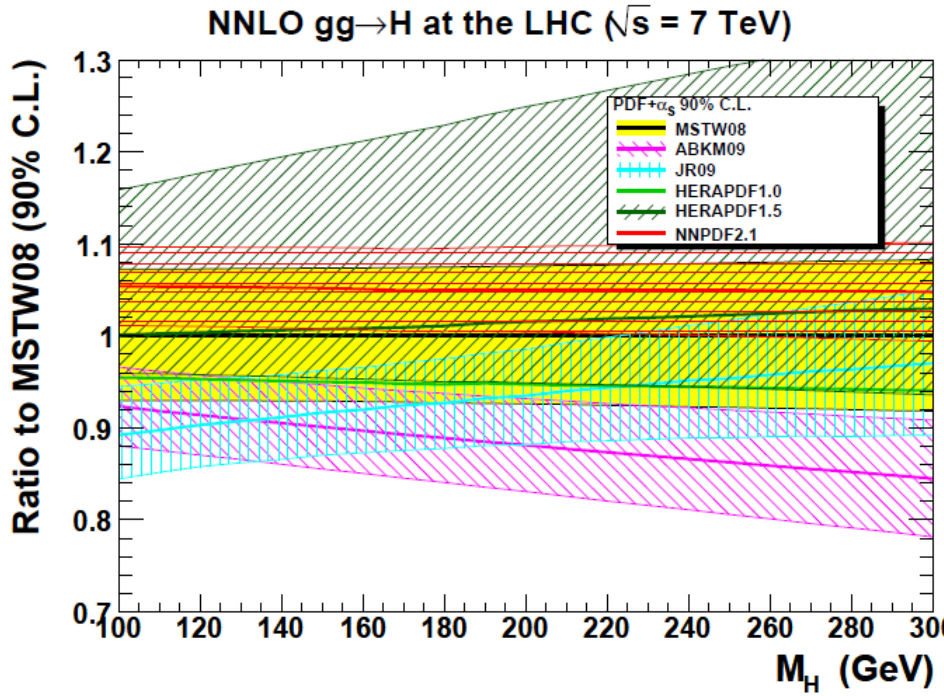
[Sasha Glazow]



[Sasha Glazow]

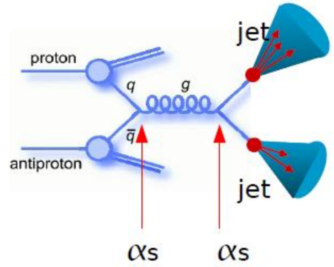
PDF sets: typical uncertainties & cross section estimates





typically 10% uncertainty due to choice of PDF set

pQCD: jets

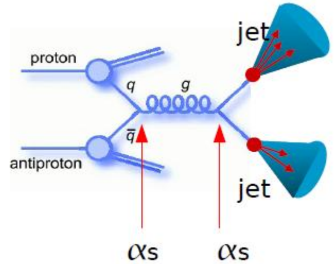


[John Campbell/Dmitry Bandurin]

- Refining "well-known" calculations, e.g. NLO QCD

HERWIG++
PYTHIA8
SHERPA

pQCD: jets



[John Campbell/Dmitry Bandurin]

✦ Refining "well-known" calculations, e.g. NLO QCD

HERWIG++
PYTHIA8
SHERPA

- Jet results: Precision measurement of fundamental observables.
  => sensitivity to PDF sets, strongest constraint on gluon PDF, extraction of α_s and test of its running up to 400 GeV, detailed studies of the effect of different jet algorithms, study of jet substructure, limits on many NP models.

- Z/W results: extensive tests of pQCD and MC models; in most cases, a triumph of NLO and ME-PS MC predictions.

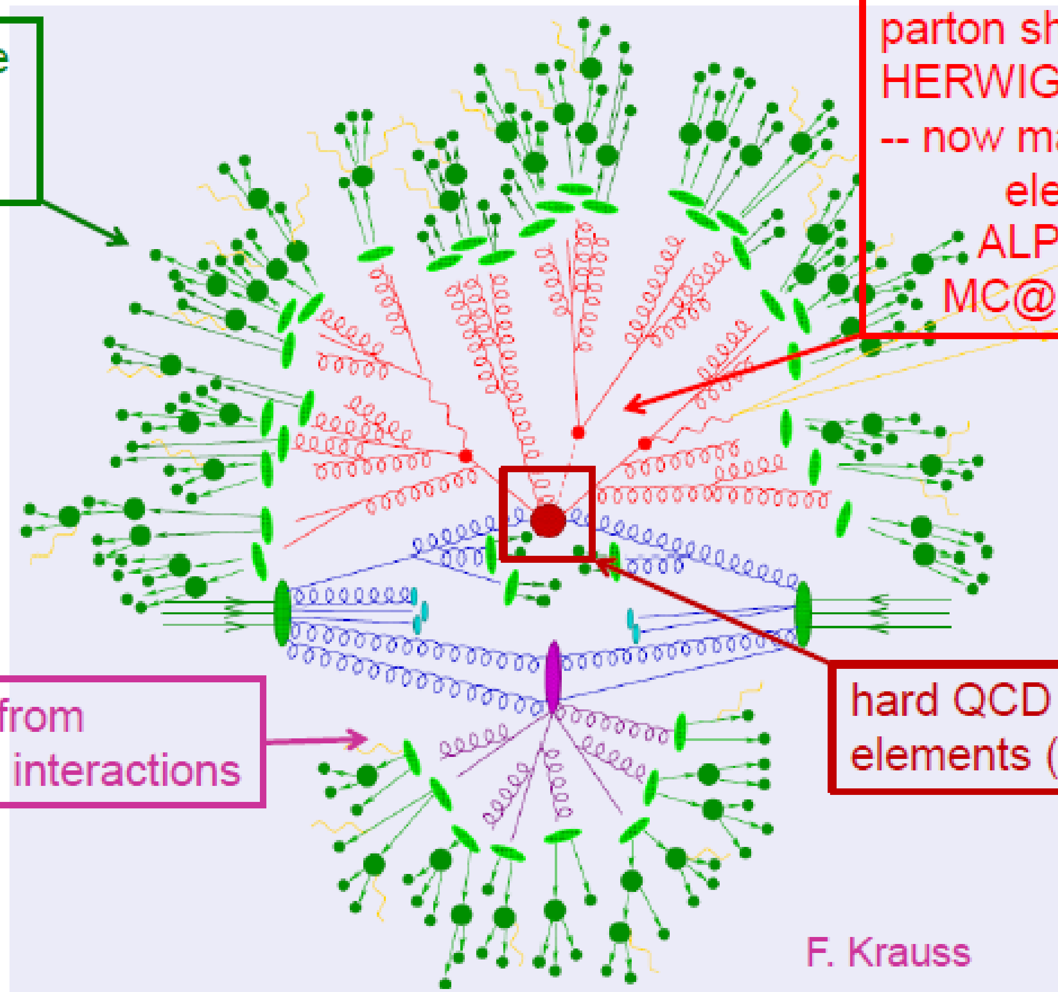
with these tools in hands…

"Typical" hadron collider event

nonperturbative string/cluster fragmentation

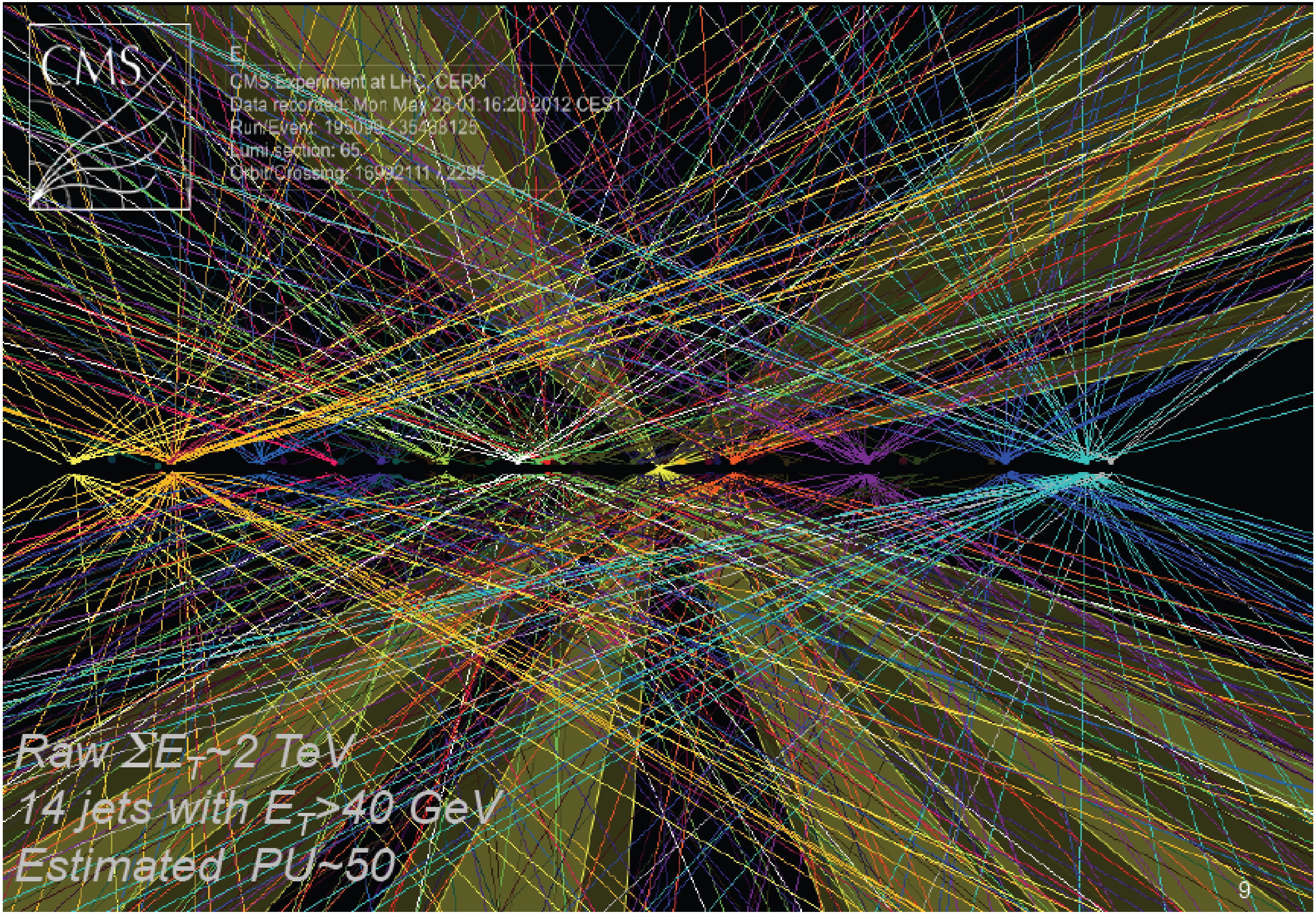
See talk by J. Campbell for review of perturbative QCD status

underlying event from secondary parton interactions



parton shower (PYTHIA, HERWIG, SHERPA)
-- now maintains matrix element accuracy: ALPGEN, SHERPA; MC@NLO, POWHEG

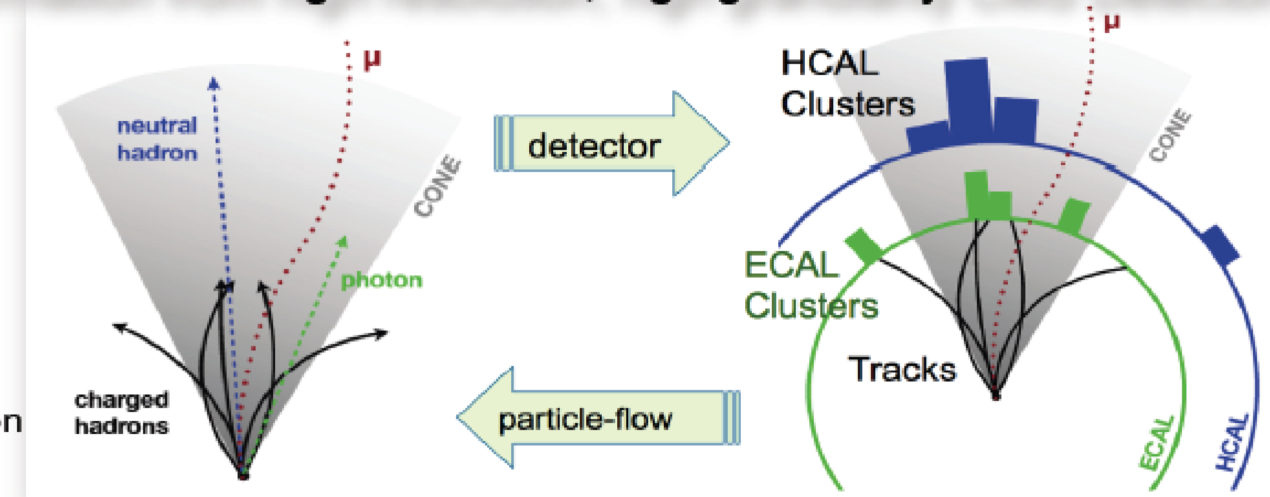
hard QCD matrix elements (THIS TALK)

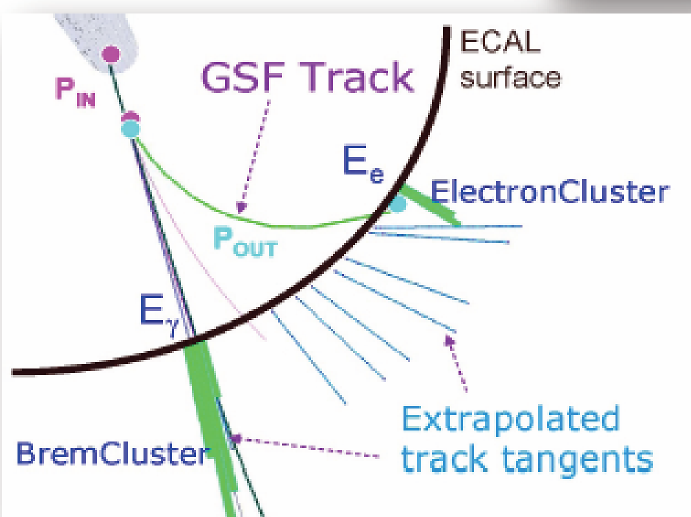

CMS
CMS Experiment at LHC, CERN
Data recorded: Mon May 28 01:16:20 2012 CEST
Lumi section: 65
Raw ΣE_T~2 TeV
14 jets with E_T>40 GeV
Estimated PU~50
9

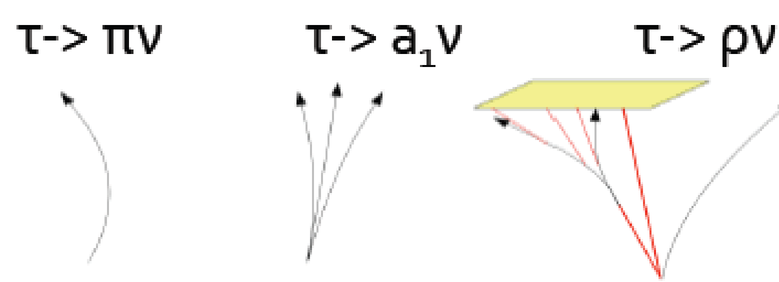
Innovation: Global Event Description

Optimal use of information from high resolution, high granularity CMS Detectors

- Lists reconstructed particles
  - e,μ,γ, charged and neutral hadrons
    - Used like "generated particles"
    - Building blocks for jets, taus , missing E_T , isolation
    - PU particle identification



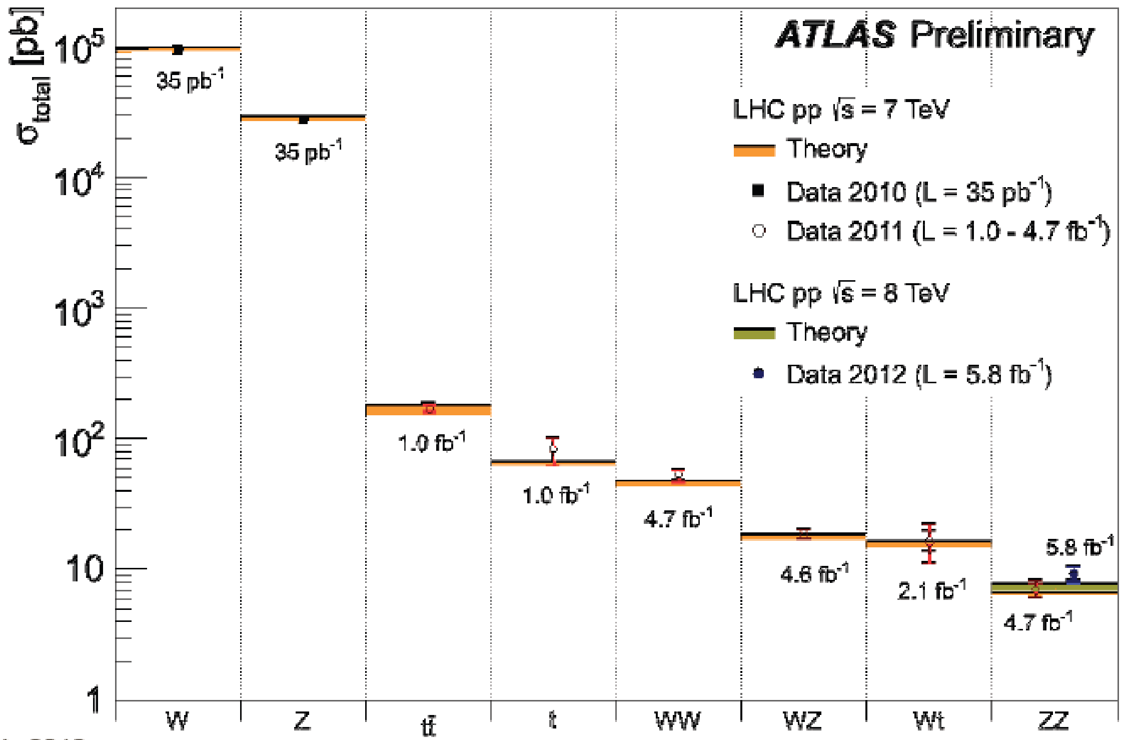




- Sophisticated algorithms
  - Examples: e/γ and hadronic τ

standard candles @LHC

- Foundations for searches - measurements of W, Z, diboson and top prod^n:



standard candles @LHC

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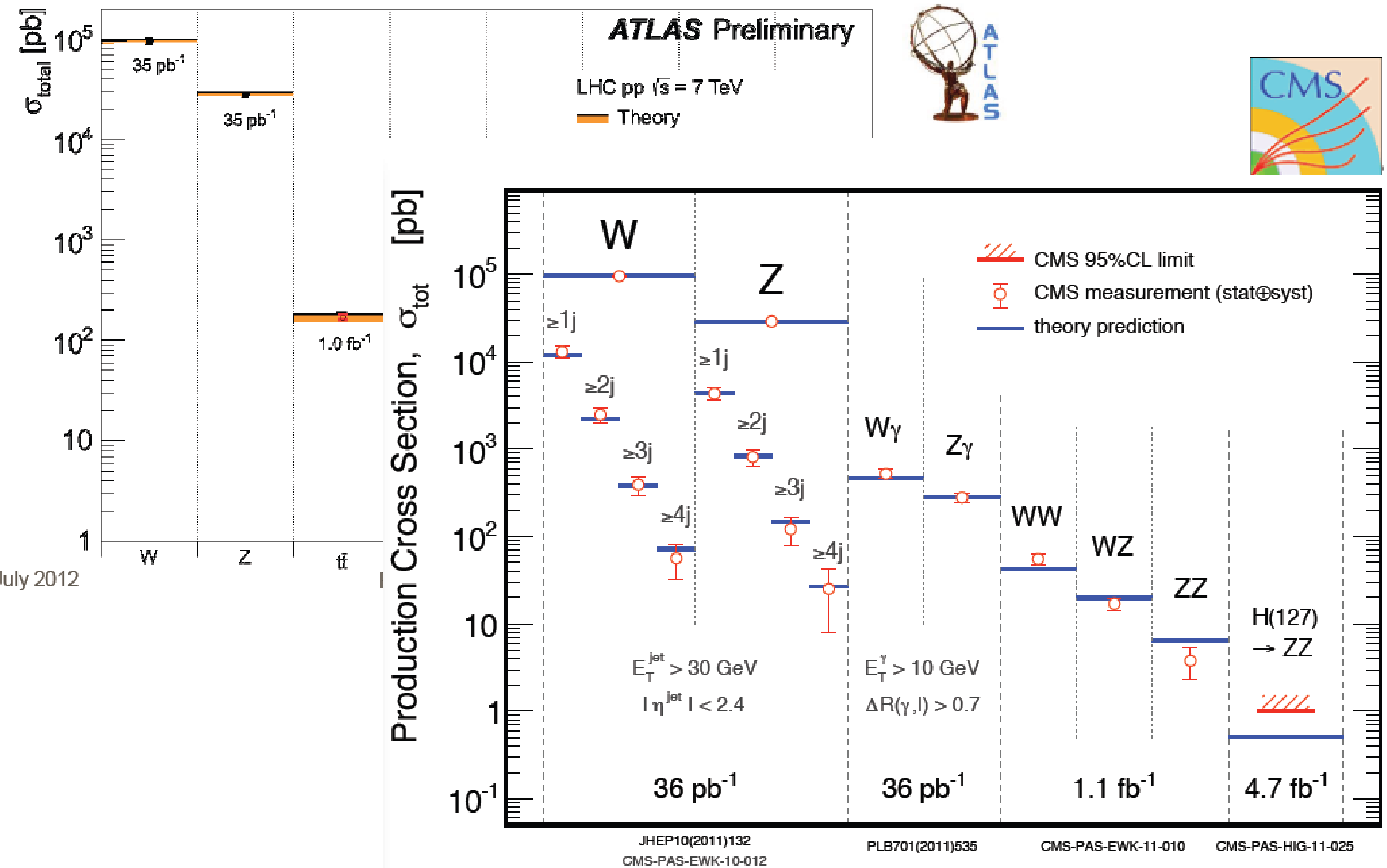

standard candles @LHC

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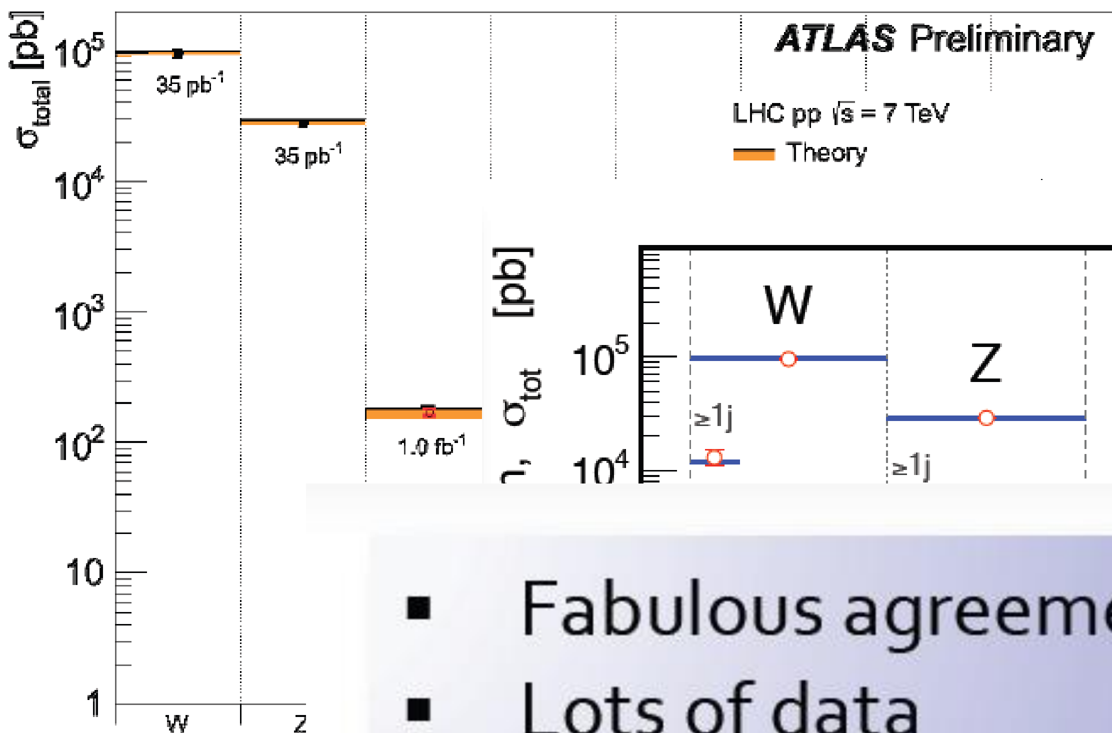
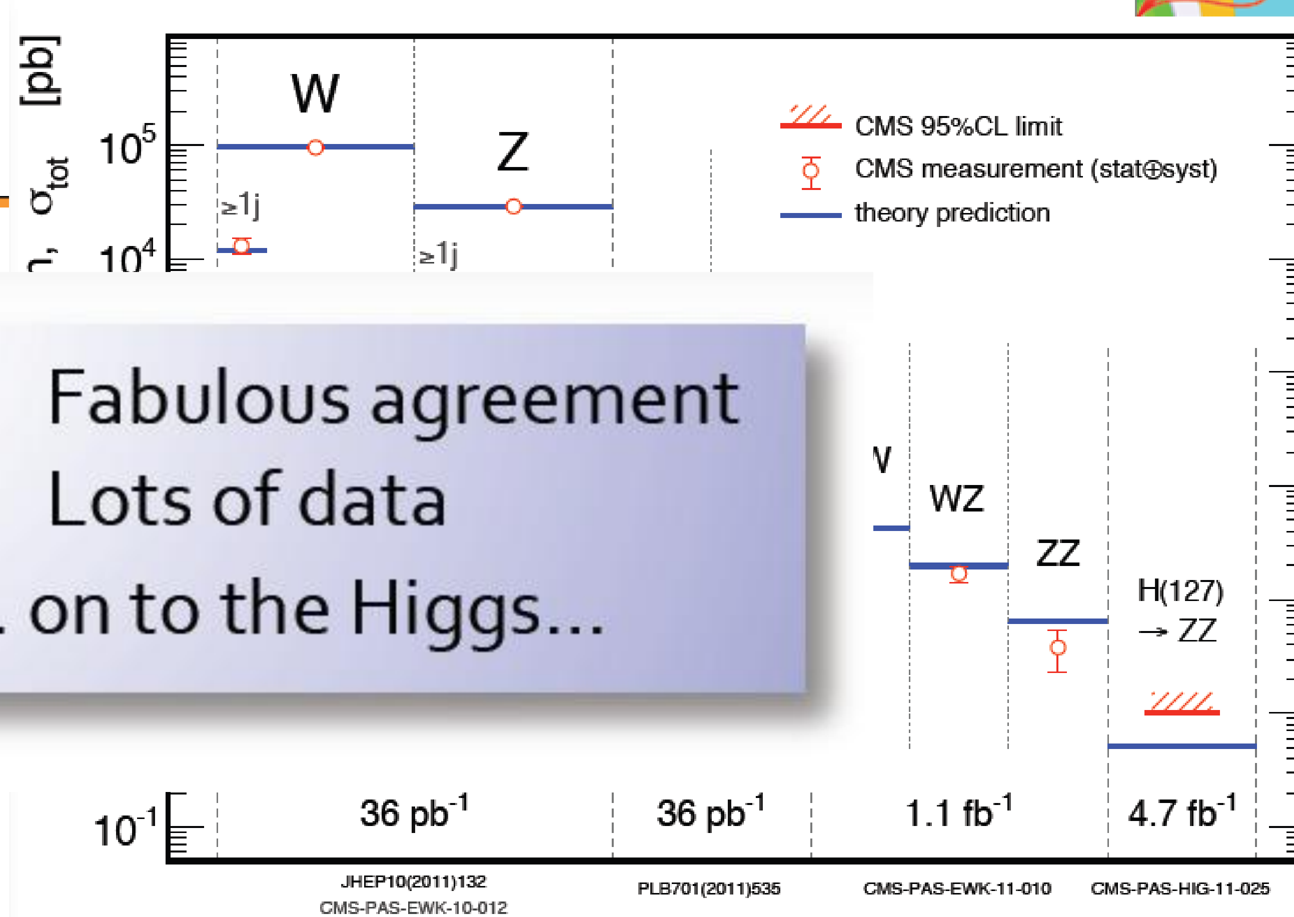




- Fabulous agreement
- Lots of data

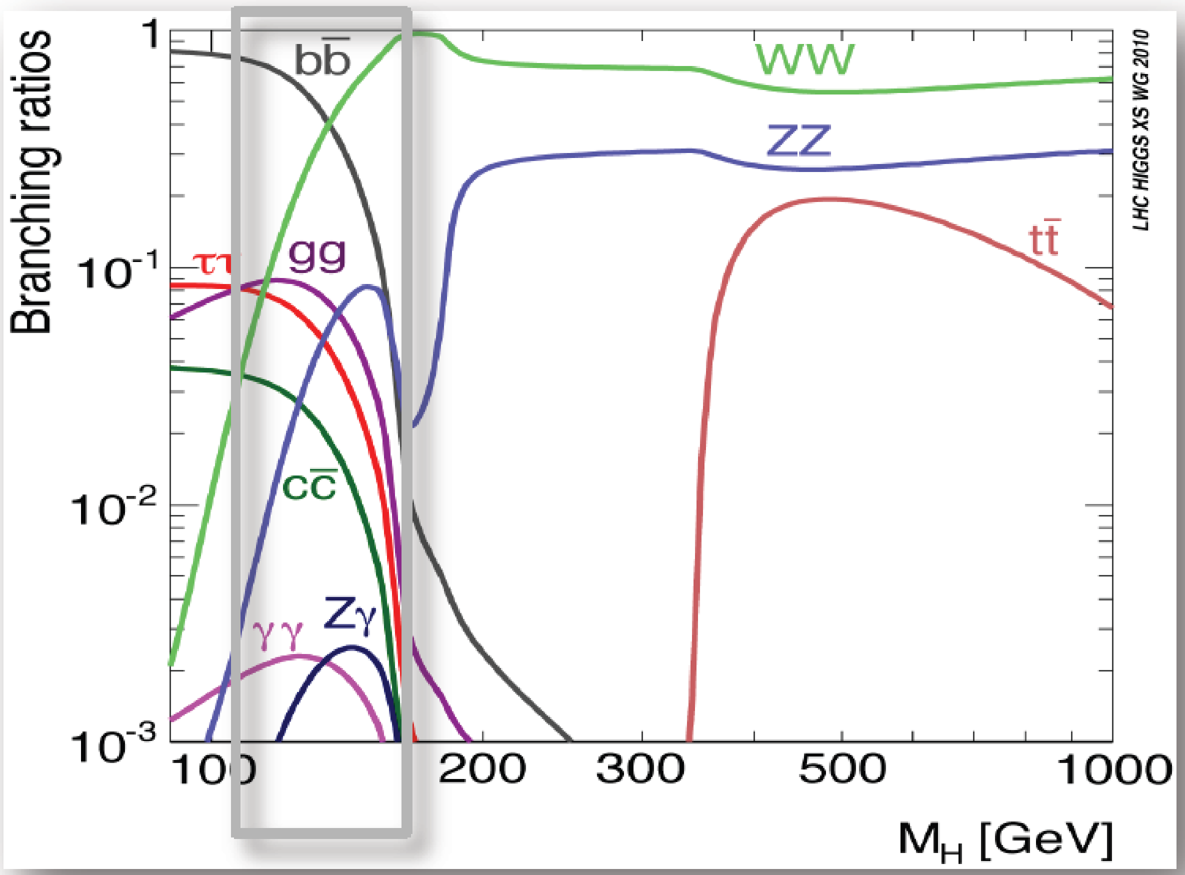
… on to the Higgs…

higgs search @LHC

➢ low mass region is left for the higgs:

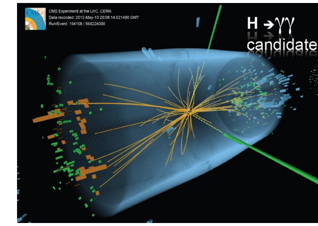
by 2011:

Decay	m_H range (GeV)
H→γγ	110-150 (*)
H→ZZ(*) →4l	110-600 (*)
H→ZZ →llqq	200-280-600
H→ZZ →llνν	200-300-600
H→WW(*)→lνlν	110-200-300-600
H→WW→lνqq	300-600
H→ττ→ll, $l\tau_h$, $\tau_h\tau_h$	110-150
VH→lνbb, llbb, ννbb	110-130



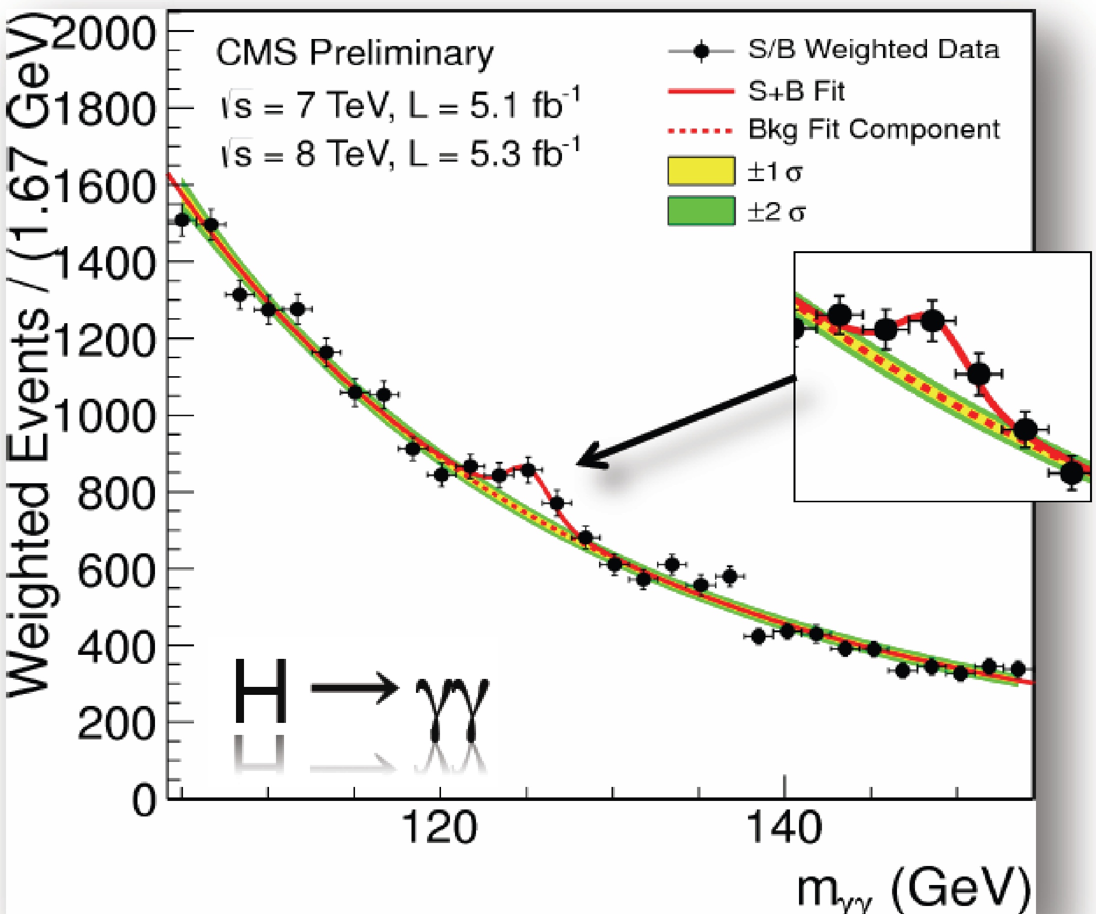
- Low mass region is very rich but also very challenging:
  main decay modes ($b\bar{b}$, ττ) are hard to identify in the huge background
- Very good mass resolution (1%): H→γγ and H→ZZ→4l

higgs search @LHC

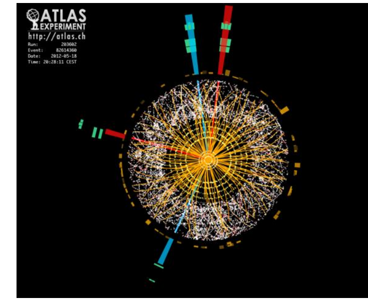


S/B Weighted Mass Distribution

- Sum of mass distributions for each event class, weighted by S/B
  - B is integral of background model over a constant signal fraction interval

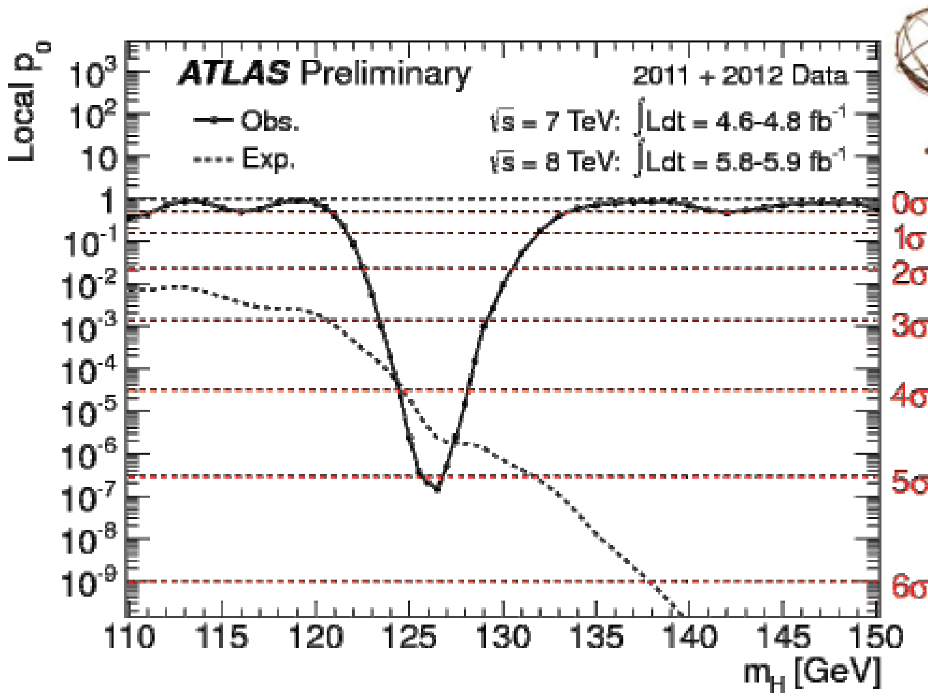


higgs search @LHC

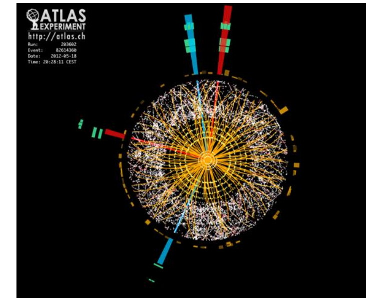


$H \rightarrow ZZ(*) \rightarrow 4l$ ($l = e,\mu$): the golden channel

- A great performing channel in the whole mass range …
  - Clean signature: narrow peak, low background
  - Background: irreducible ZZ(*); reducible Z+jets, ttbar, WZ
- But extremely demanding
  - Requires highest possible efficiencies (lepton Reco/ID/Isolation).



higgs search @LHC



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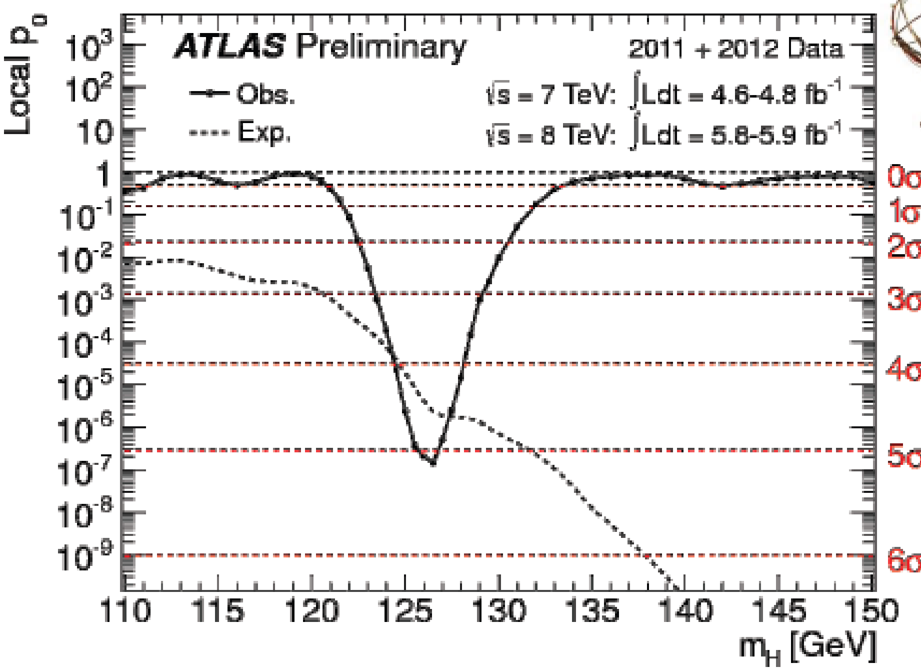
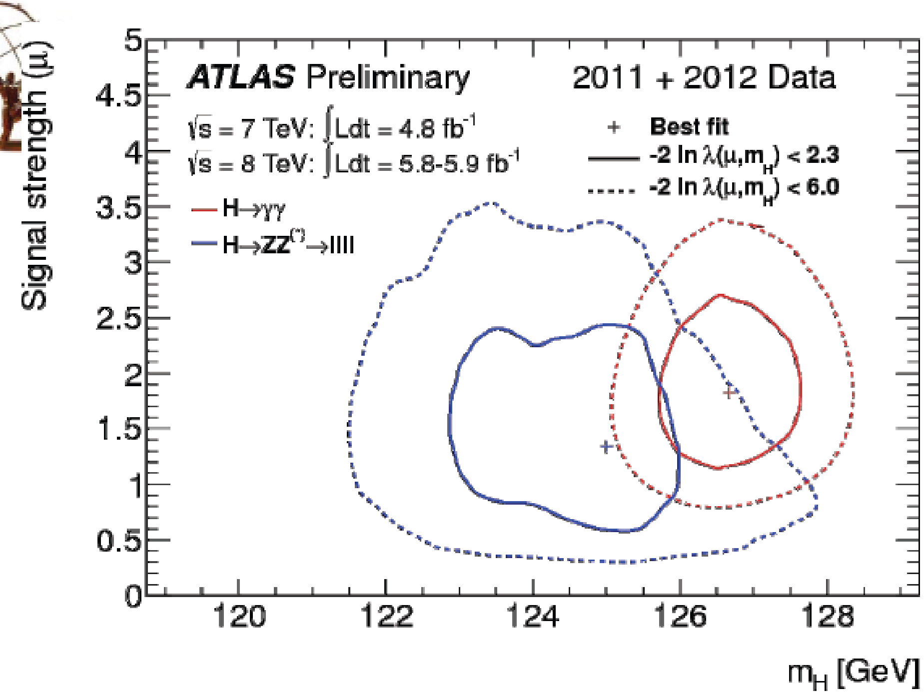
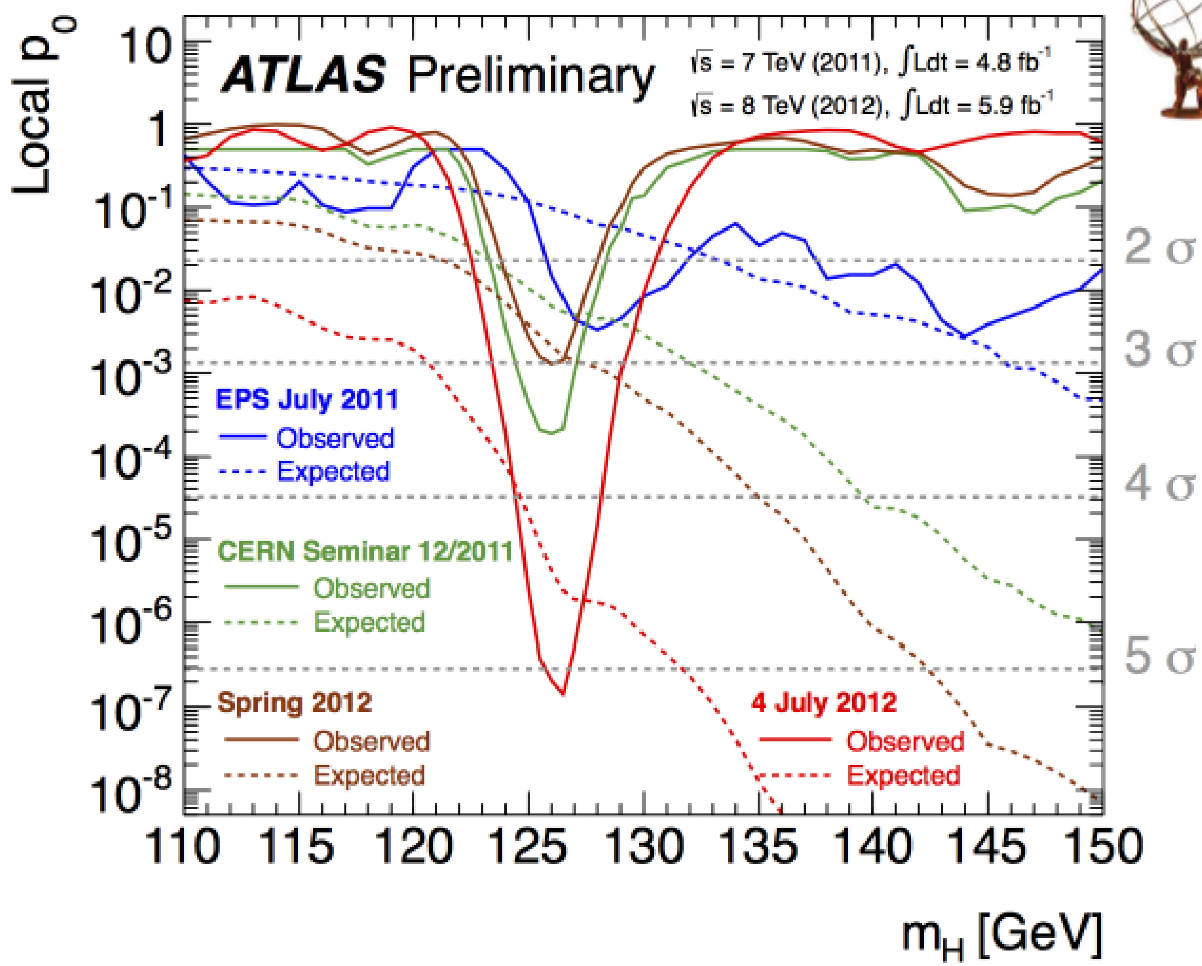




higgs search @LHC

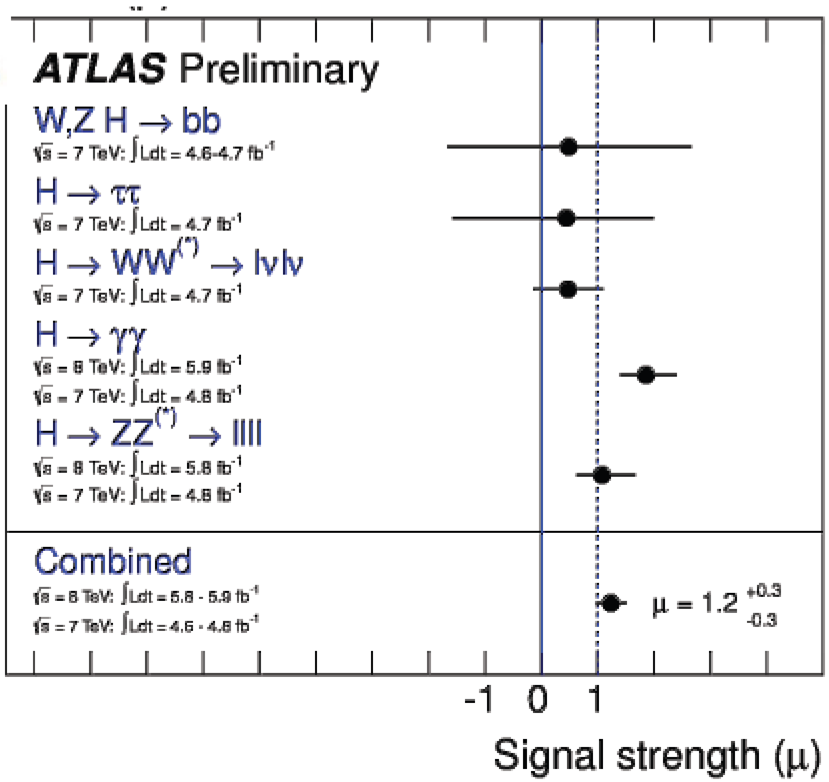
Evolution of the excess with time

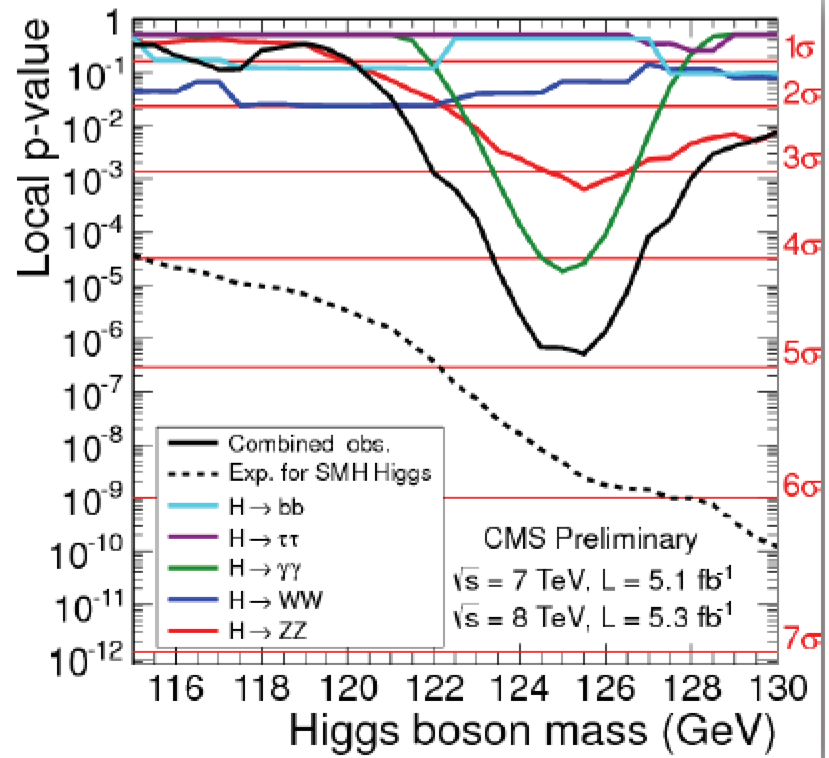


all channels

higgs search @LHC

All together





Combined search sees excess with local significance of **5.0σ** at m_H=126.5 GeV

Combination	Expected (σ)	Observed (σ)
γγ + ZZ→4l	4.7	5.0
γγ + ZZ→4l + WW	5.2	5.1
All	5.9	4.9

higgs search @LHC

[Joe Incandela for CMS]

Conclusion

We have observed a new boson
with a mass of
125.3 ± 0.4 (stat) ± 0.5 (syst)
at significance level of 5 σ

higgs search @LHC

[Joe Incandela for CMS]

Conclusion

We have observed a new boson
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125.3 ± 0.4 (stat) ± 0.5 (syst)
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3. As next step, need to know:

[Ricardo Barbieri]

$\Rightarrow$ Its quantum numbers: $J^{PC} = 0^{++}$, gauge q.n.s

$\Rightarrow$ The strength of its interactions
with all other particles and with itself

$\Rightarrow$ Is it alone or accompanied?

$\Rightarrow$ Is it "elementary" or "composite"?

$\Rightarrow$ Is it "natural"?

is it a higgs ?

[Alex Pomarol]

Disclaimer: We have gotten more data on EWSB in one single day than in more than 40 years

➥ Not enough time to digest it!

[Alex Pomarol]

What makes the Higgs special?

<u>Not just about</u> finding the the condensate responsible for giving masses

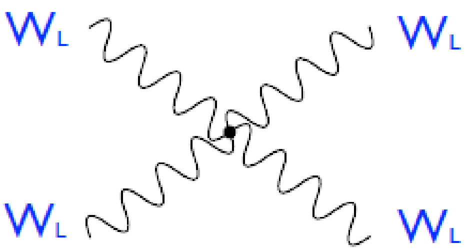
What makes the Higgs special?

[Alex Pomarol]

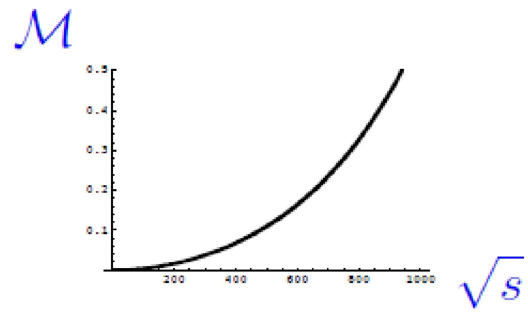
<u>Not just about</u> finding the the condensate responsible for giving masses

Without a Higgs, the states W_L, Z_L **spoil** the nice calculability power of gauge theories

a)

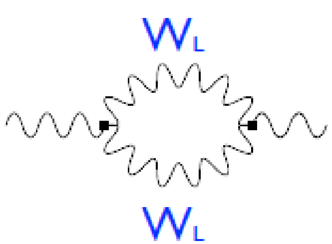


$$\propto \frac{s}{v^2}$$



Unitarity is lost at high-energies

b)

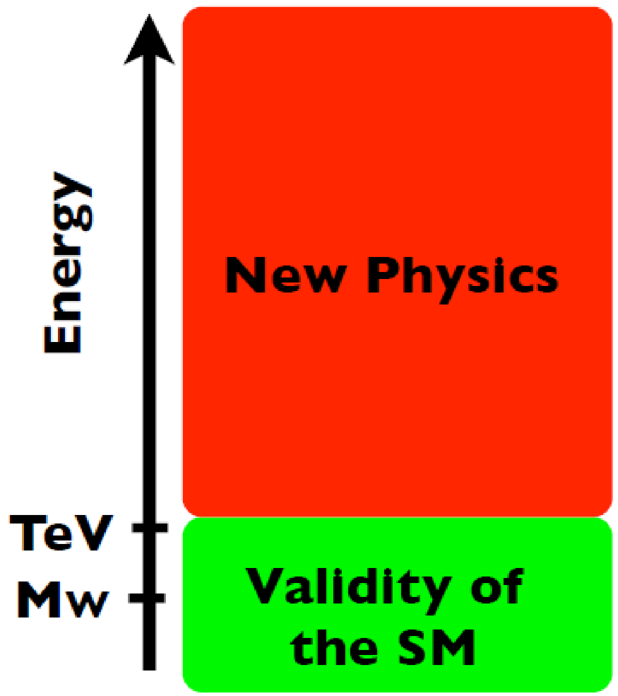


Loops are not finite!

Do not allow for precision calculations

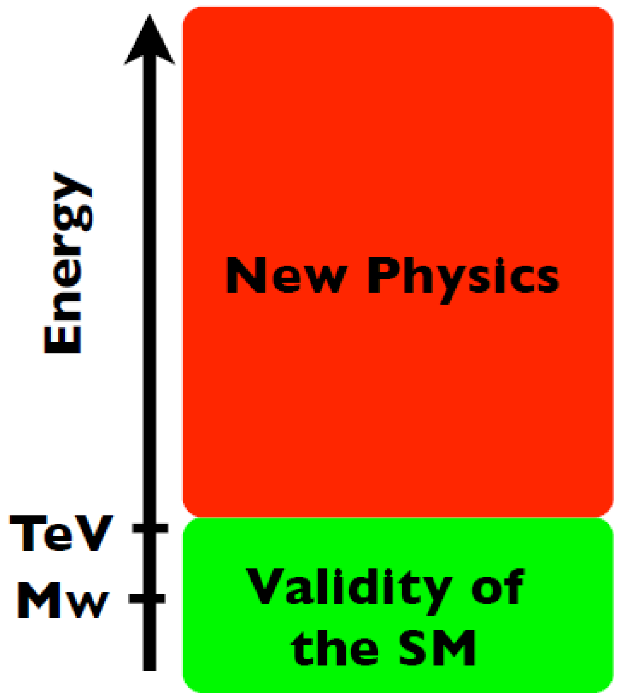
[Alex Pomarol]

Without a Higgs...

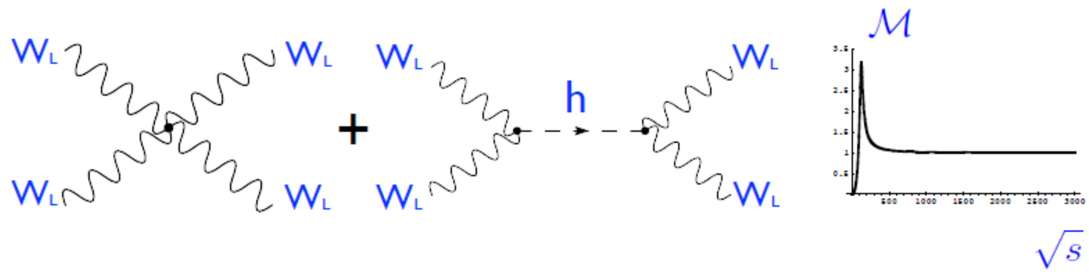


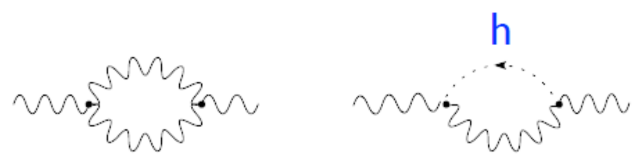
[Alex Pomarol]

Without a Higgs...



With the Higgs **calculability** is recovered:



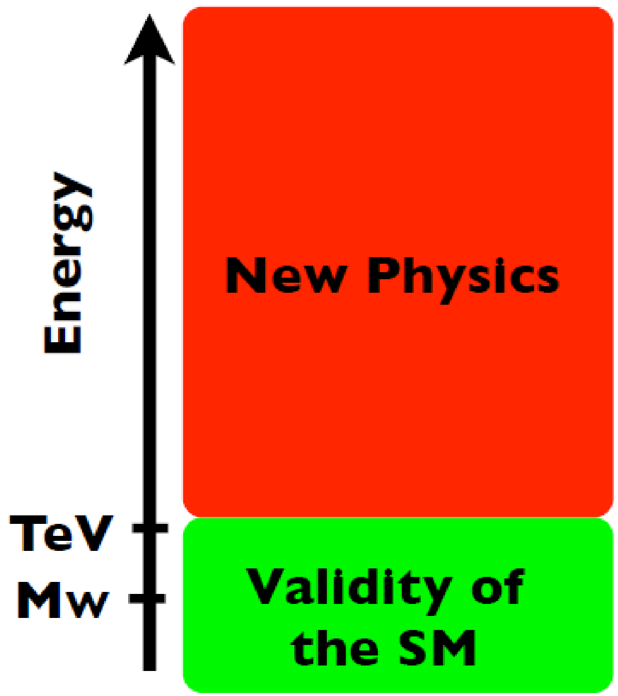


Finite results!

Back to the prediction era!

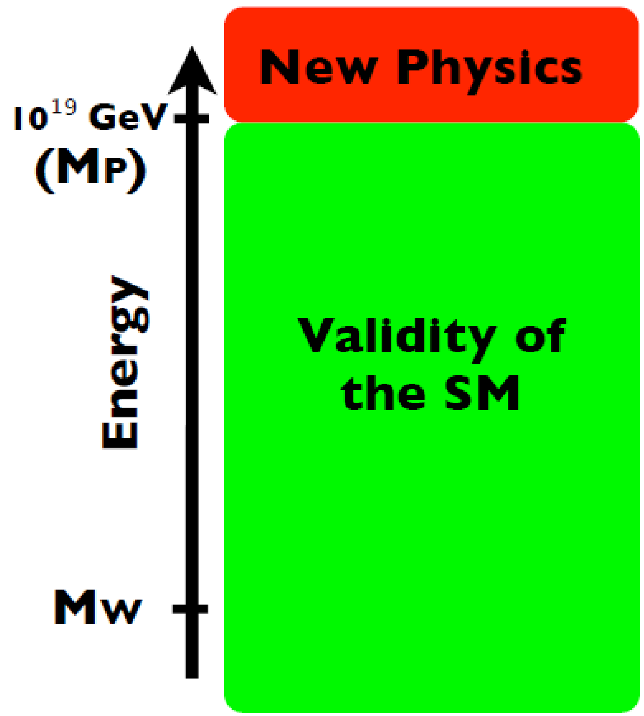
[Alex Pomarol]

Without a Higgs...



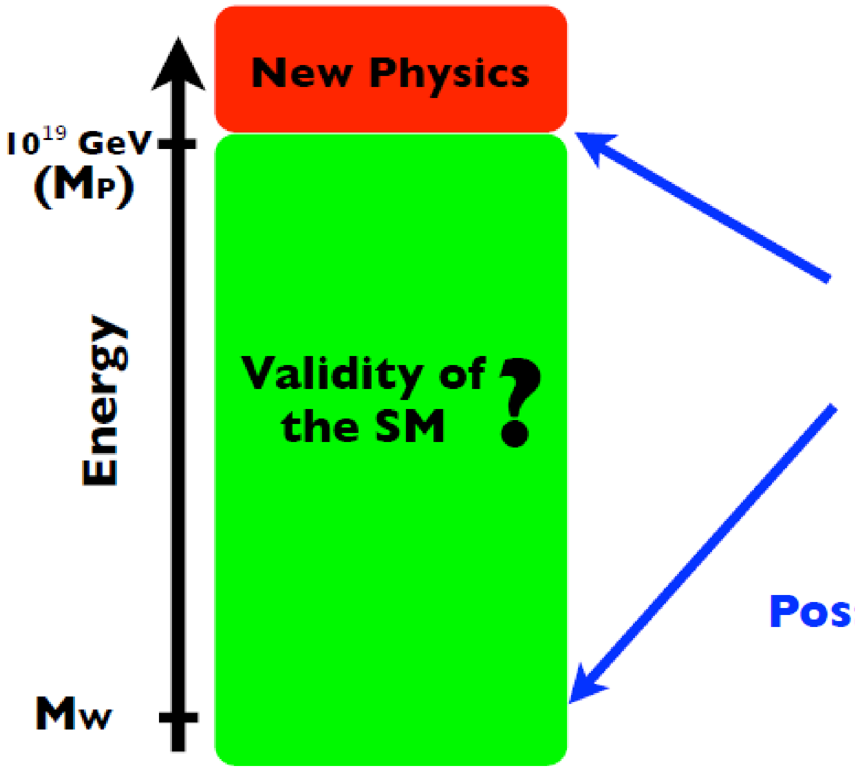
With a Higgs

(100 GeV <mh<170 GeV)



[Alex Pomarol]

Although consistent, we think (and hope) the SM is not the full story



Not understandable the origin of such a small EW scale as compared to the Planck scale

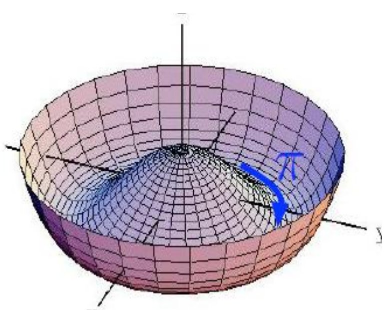
Possibilities that theorists envisage to tackle this problem:

1) Keep the Higgs elementary, but protect it by symmetries: **Supersymmetry**

2) The Higgs is not elementary: **Composite Higgs**

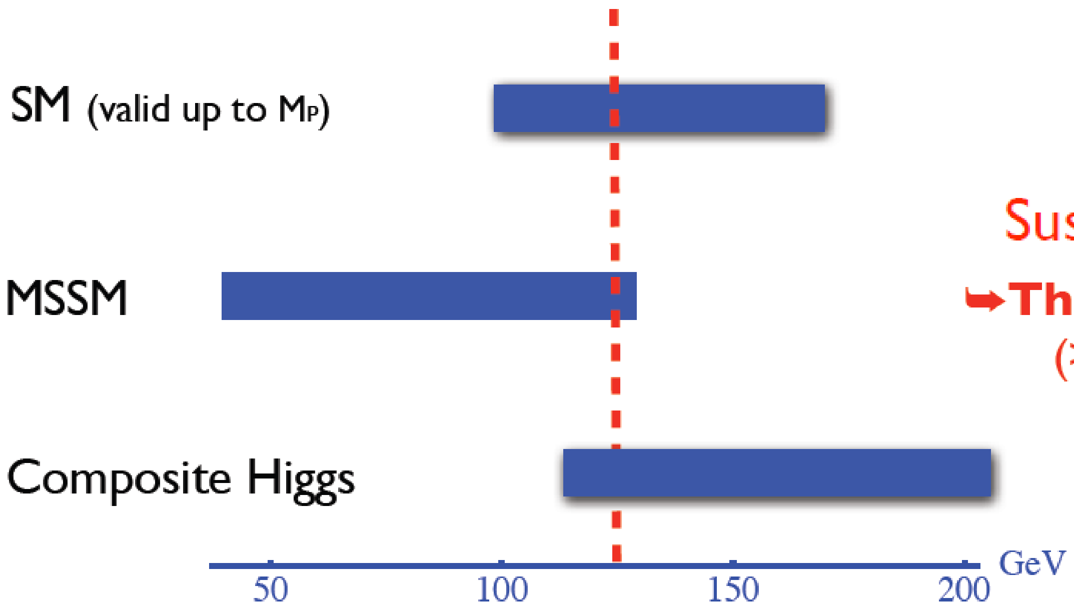
➥ Both imply **changes** in the Higgs sector

Pseudo-Goldstone bosons (PGB)



[Alex Pomarol]

Higgs mass range

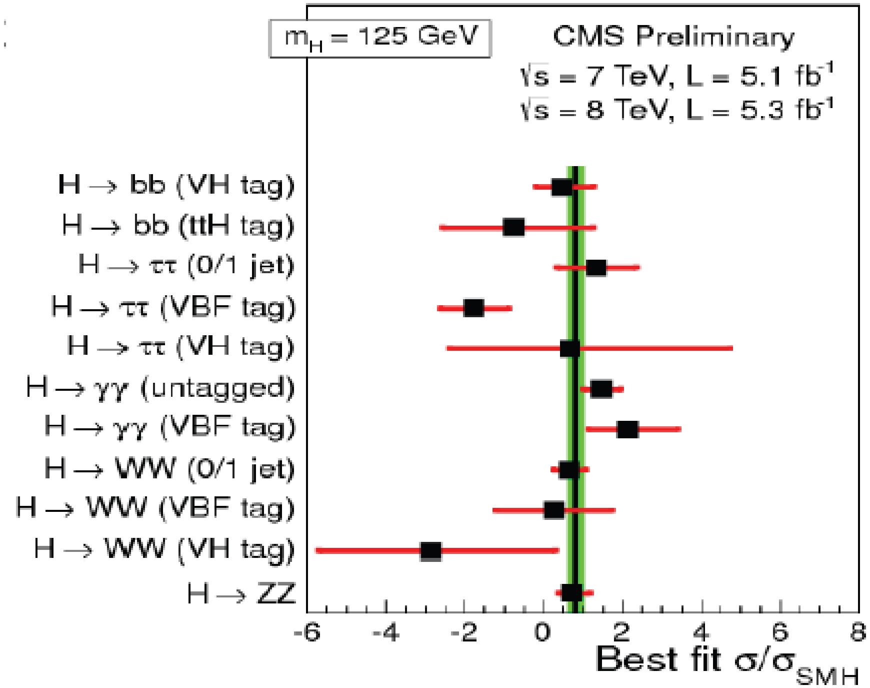


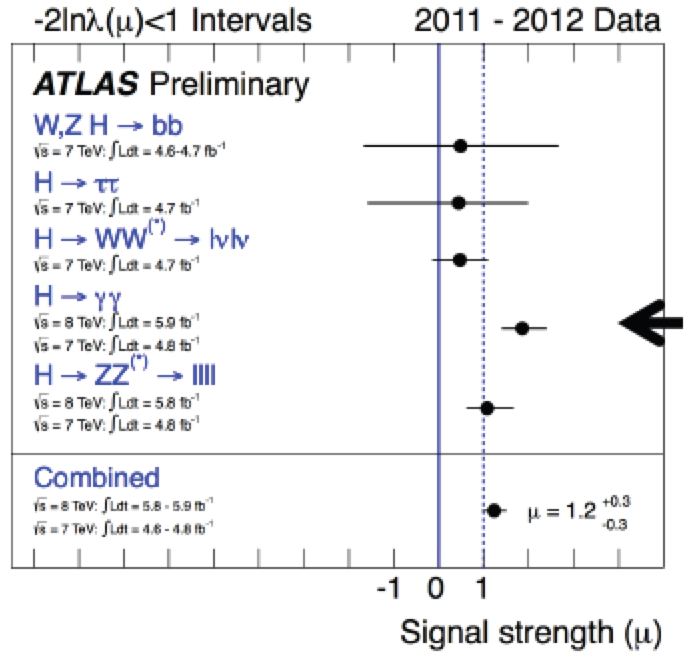
Susy must be "badly" broken!

➥**The MSSM is becoming unnatural**

(>99% parameter space excluded)

What the Higgs couplings tells us?





Not significant deviations from a SM Higgs

(The **more** natural the Higgs sector is,
the **more** we expect
deviations from the SM Higgs couplings)

EWSB:

[Alex Pomarol]

A new era has begun ...

"Sit down before fact as a little child,
be prepared to give up every preconceived notion,
follow humbly wherever and to whatever abysses nature leads,
or you shall learn nothing"

Thomas Henry Huxley

ν highlight

Reactor $\overline{\nu_e}$ (D-Chooz, **Daya-Bay, Reno**)

- At the intensity frontier:

Large mixing angle

θ_{13} around 9 °

neutrinos are massive

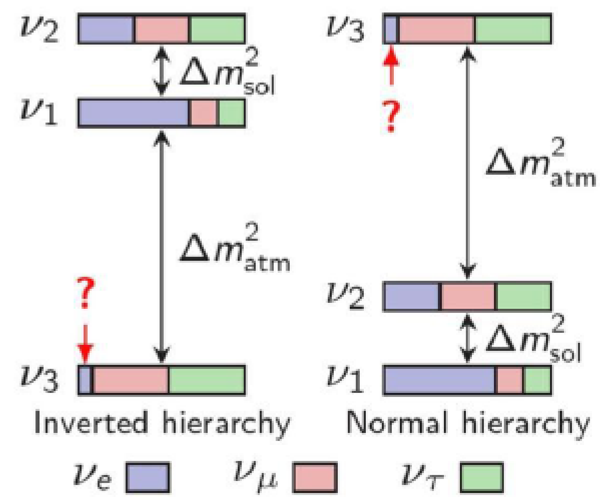
and There is Physics Beyond SM

The New Minimal Standard Model

Neutrino Mixing

In a 3-ν framework

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$



$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13} \\ 0 & e^{-i\delta} & 0 \\ -s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e^{i\rho} & 0 & 0 \\ 0 & e^{i\sigma} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$\theta_{23} \sim 45°$ Atmospheric Accelerator	$\theta_{13} = ?$ Reactor Accelerator	$\theta_{12} \sim 34°$ Solar Reactor	0νββ

The New Minimal Standard Model

Neutrino Mixing

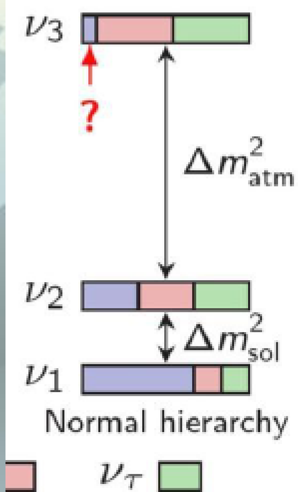
- Sensitive to
  - CPV $\propto \sin\delta \cdot s_{12} \cdot s_{23} \cdot s_{13}$
  - sign of Δm_{13} (Mass hierarchy) thru Matter effect

Existence of ν_e appearance

➔ Non-zero (reasonable size) θ_{13}

➔ CPV term can exist

Chance to detect CPV in the future!



$U = \ldots \begin{pmatrix} e^{i\rho} & 0 & 0 \\ 0 & e^{i\sigma} & 0 \\ 0 & 0 & 1 \end{pmatrix}$

$\theta_{23} \sim 45°$	$\theta_{13} = ?$	$\theta_{12} \sim 34°$	
Atmospheric	Reactor	Solar	$0\nu\beta\beta$
Accelerator	Accelerator	Reactor	

[Takashi Kobayashi]

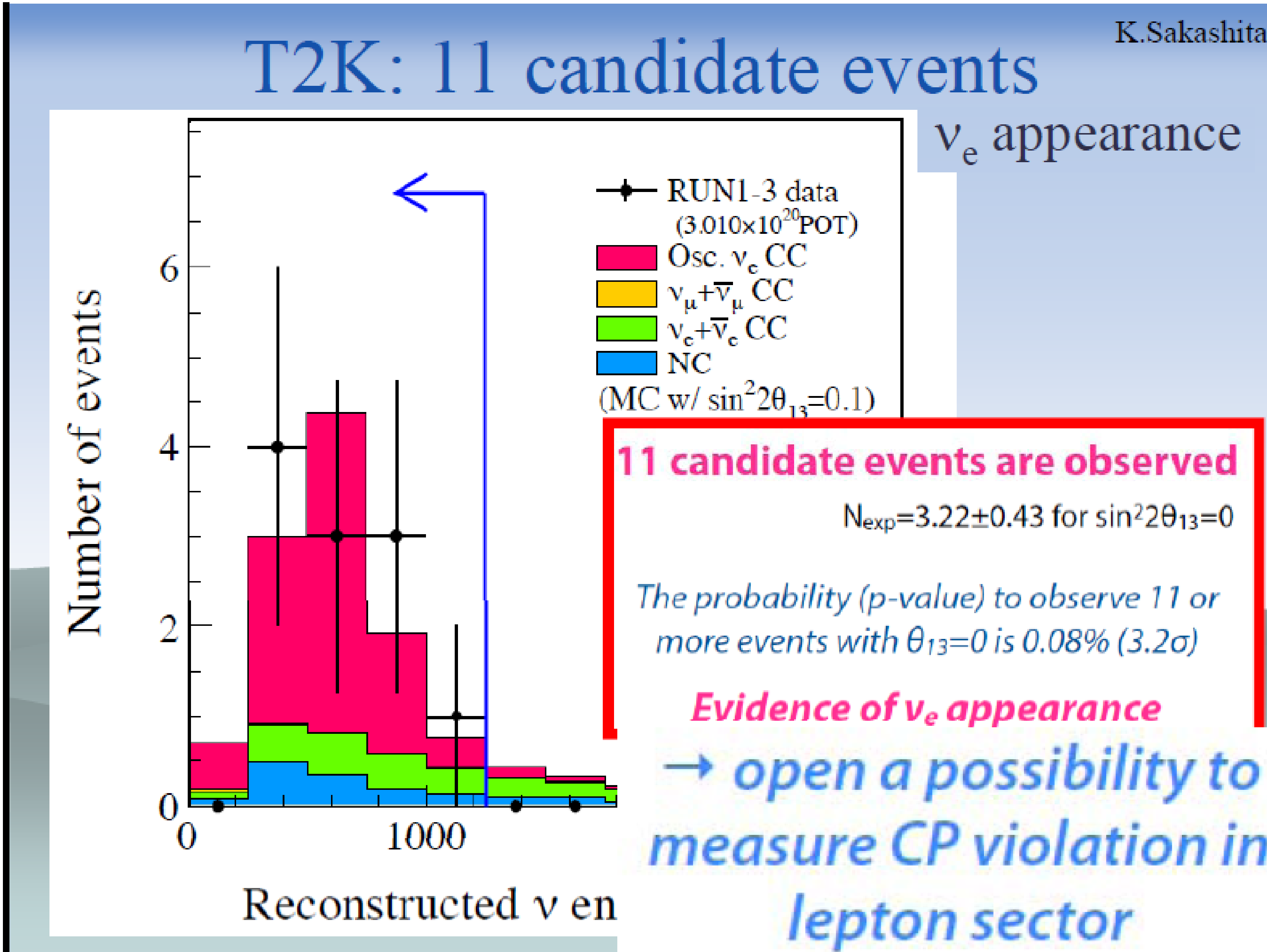
- ν_e appearance
- ν_μ disappearance
- ν_τ appearance
- Speed of neutrino

(Accelerator-based) Long baseline neutrino experiments

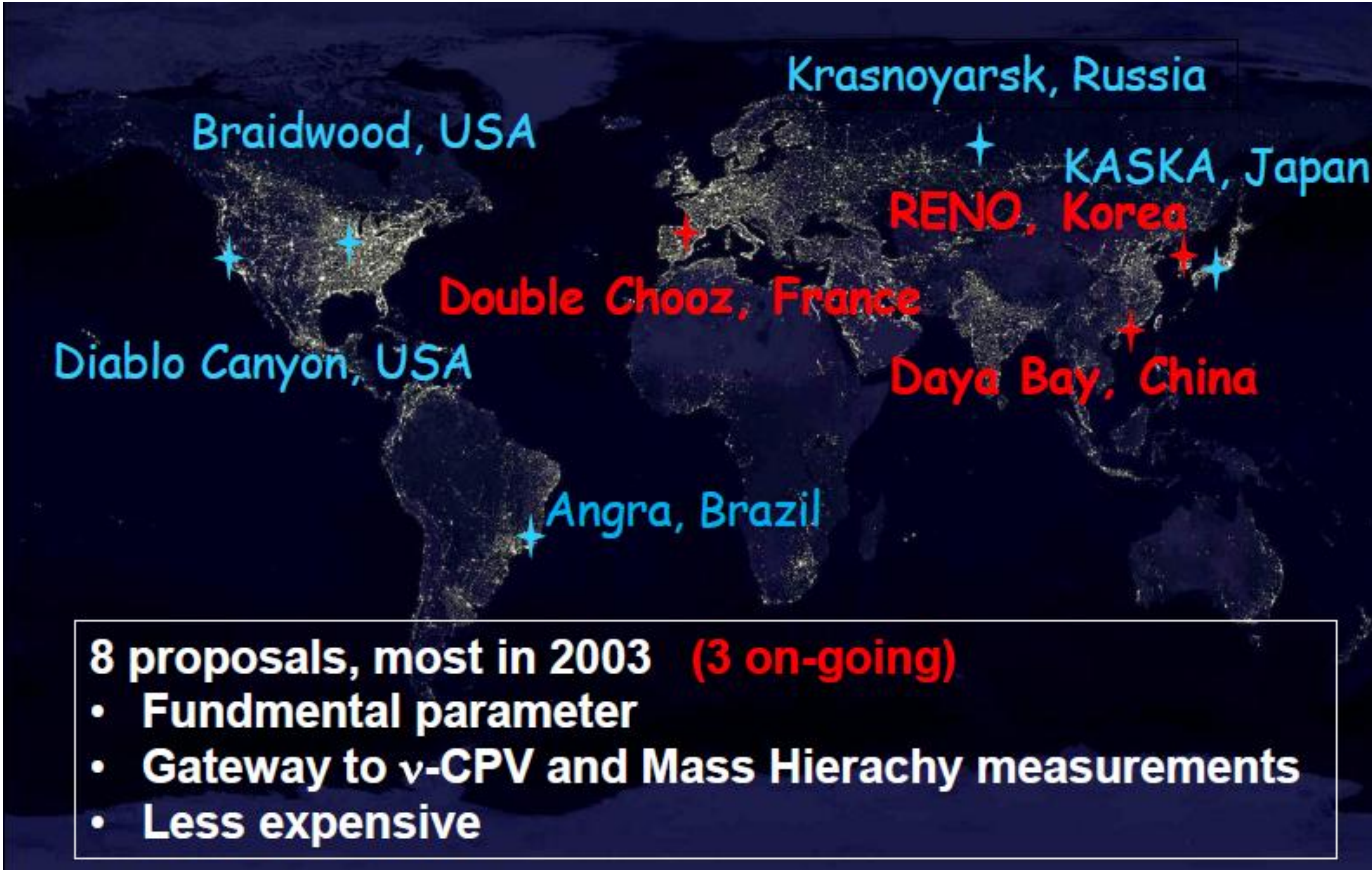
- Exhibit first violation of standard "SM": Non-zero mass
- Surprisingly large mixing unlike quarks

- Yet unknowns & puzzles (>40yrs behind quark)
  - Flavor mixing
    - Standard 3 x 3 PMNS mixing picture is correct?
    - All three flavors participate mixing? (θ_{13}?)
    - Why so different from quark mixing?
    - CP is violated?
  - Mass
    - Absolute mass
    - "Unexplained lightness of the existence"
    - Mass ordering (hierarchy)
  - Any additional neutrino??

more results from MINOS (ν−μ disappearance) & OPERA (ν−τ appearance)



Precision Measurement at Reactors



8 proposals, most in 2003 (3 on-going)

- Fundmental parameter
- Gateway to ν-CPV and Mass Hierachy measurements
- Less expensive

Precision Measurement at Reactors

[JunCao]

April 8, 2012:

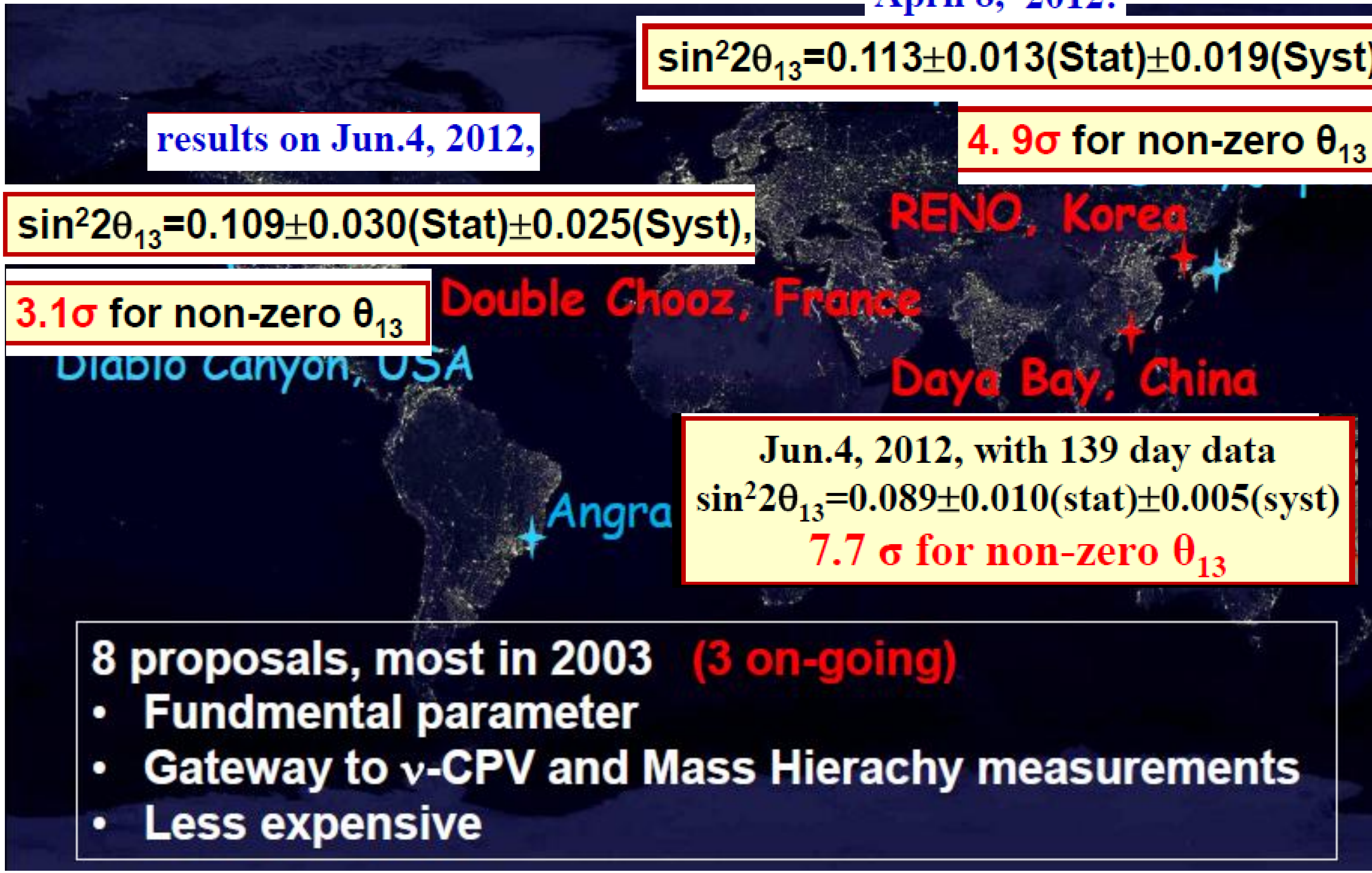
$\sin^2 2\theta_{13} = 0.113 \pm 0.013(\text{Stat}) \pm 0.019(\text{Syst})$,

4. 9σ for non-zero θ_{13}

results on Jun.4, 2012,

$\sin^2 2\theta_{13} = 0.109 \pm 0.030(\text{Stat}) \pm 0.025(\text{Syst})$,

3.1σ for non-zero θ_{13}



Jun.4, 2012, with 139 day data

$\sin^2 2\theta_{13} = 0.089 \pm 0.010(\text{stat}) \pm 0.005(\text{syst})$

7.7 σ for non-zero θ_{13}

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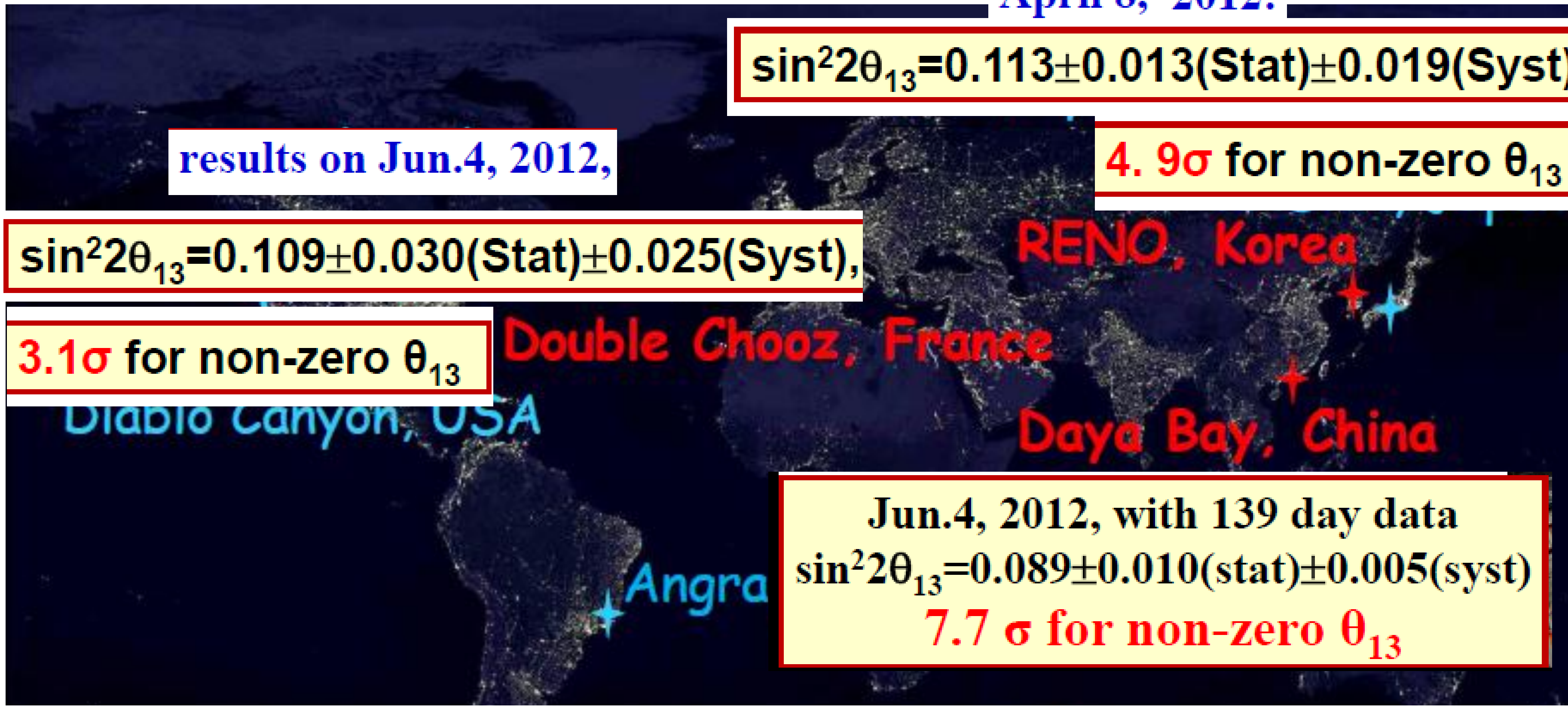

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Jun.4, 2012, with 139 day data

$\sin^2 2\theta_{13}=0.089\pm0.010(\text{stat})\pm0.005(\text{syst})$

7.7 σ for non-zero θ_{13}

- **Daya Bay experiment discovered the new oscillation and proved θ_{13} is quite large.**
  - ⇨ **We can measure the MH and CPV in our lifetime!**

- Why are neutrinos so light?

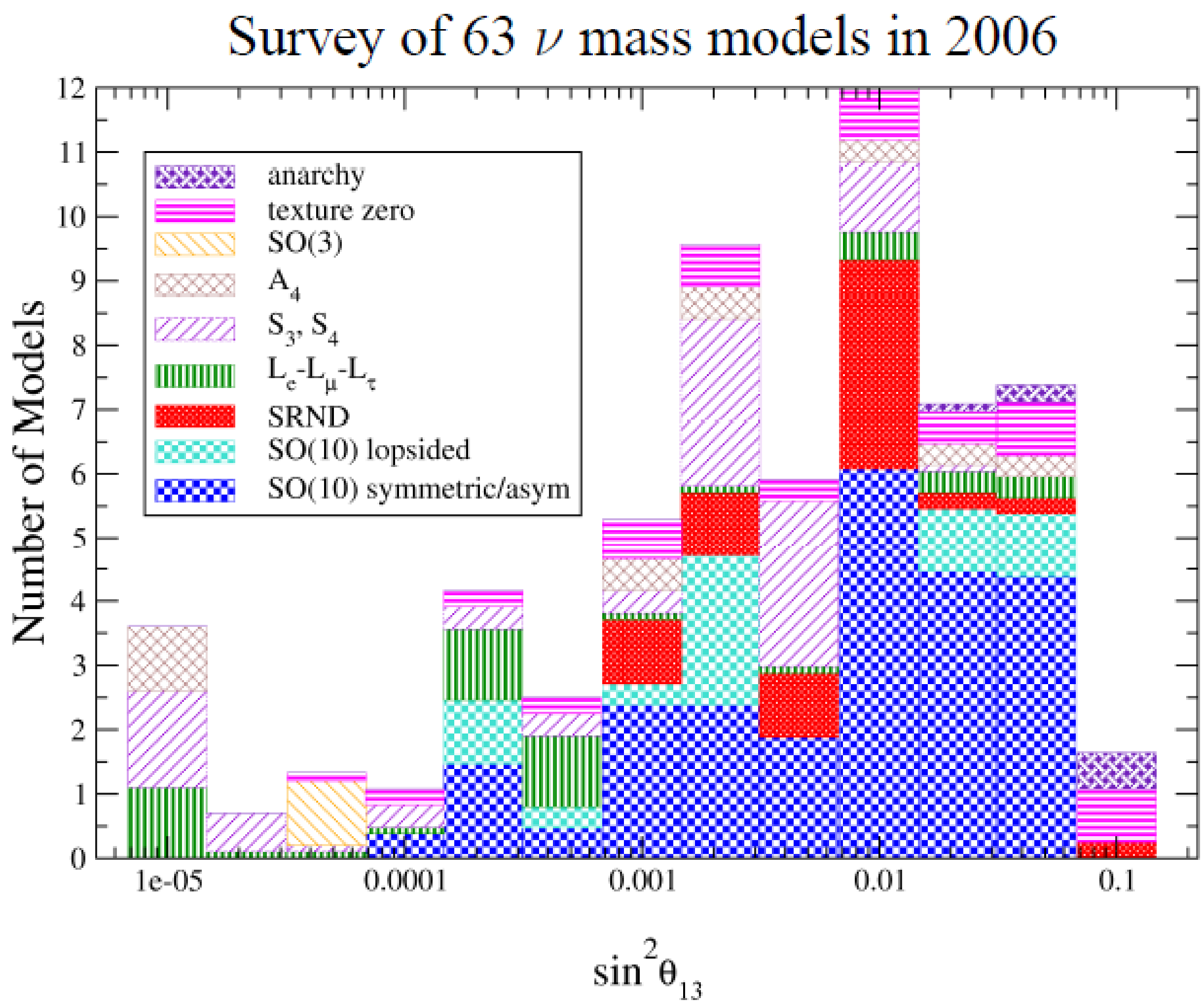
  The Origin of Neutrino Mass

- Why are lepton mixing so different from quark's?

  The Flavour Puzzle

- Why are neutrinos so light?

The Origin of Neutrino Mass



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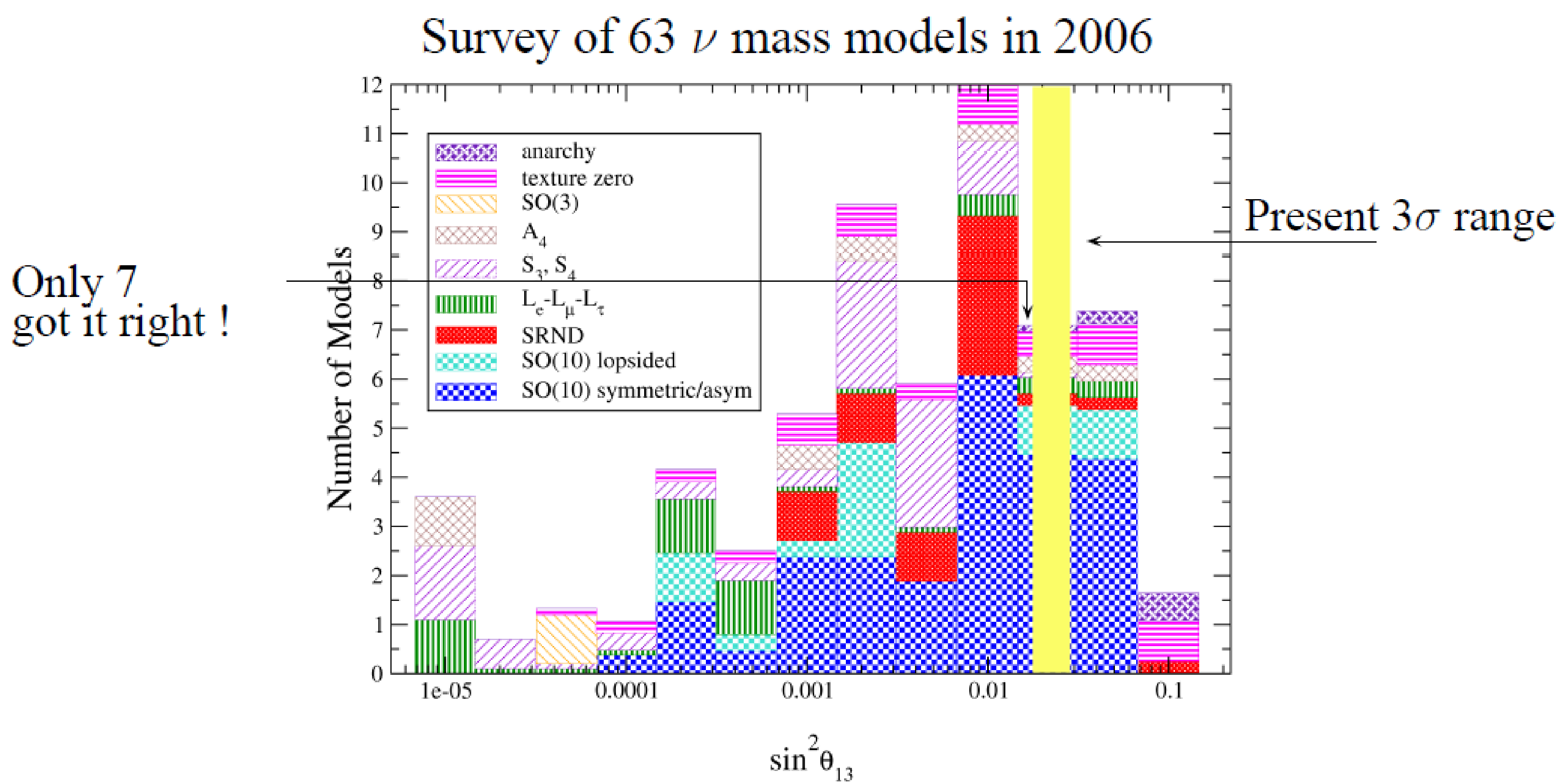
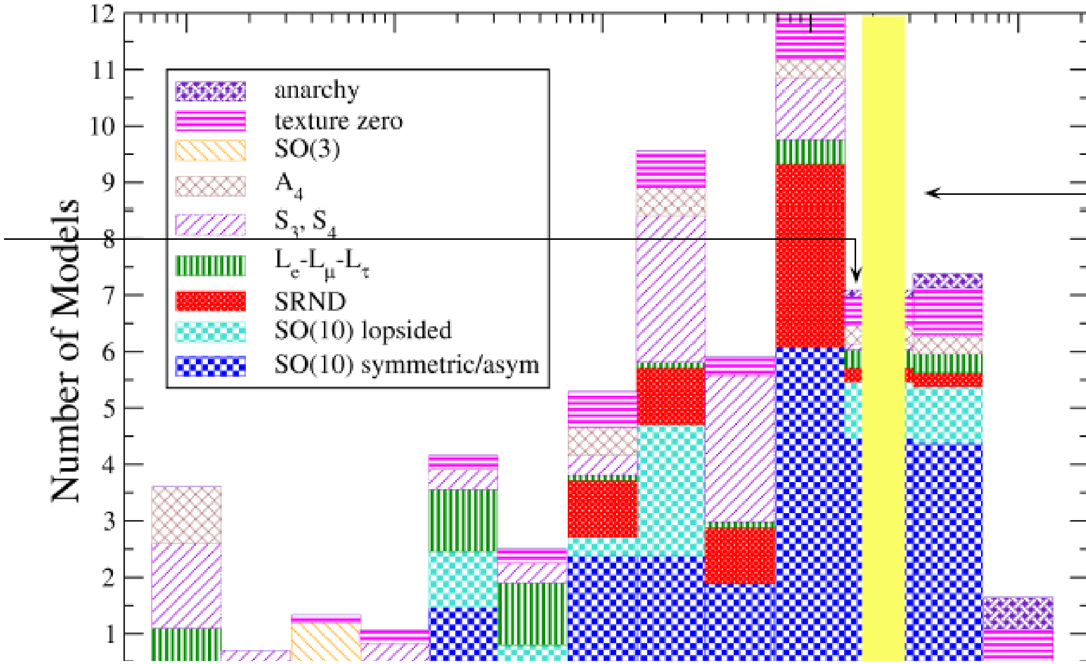


- Why are neutrinos so light?

The Origin of Neutrino Mass

Survey of 63 ν mass models in 2006

Only 7 got it right !



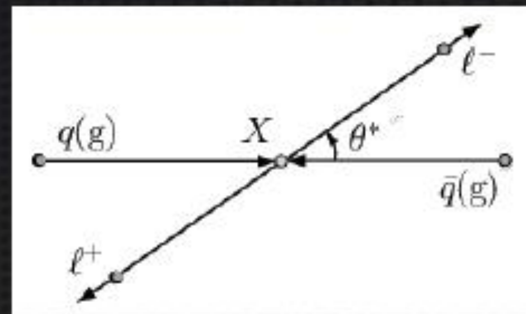
Present 3σ range

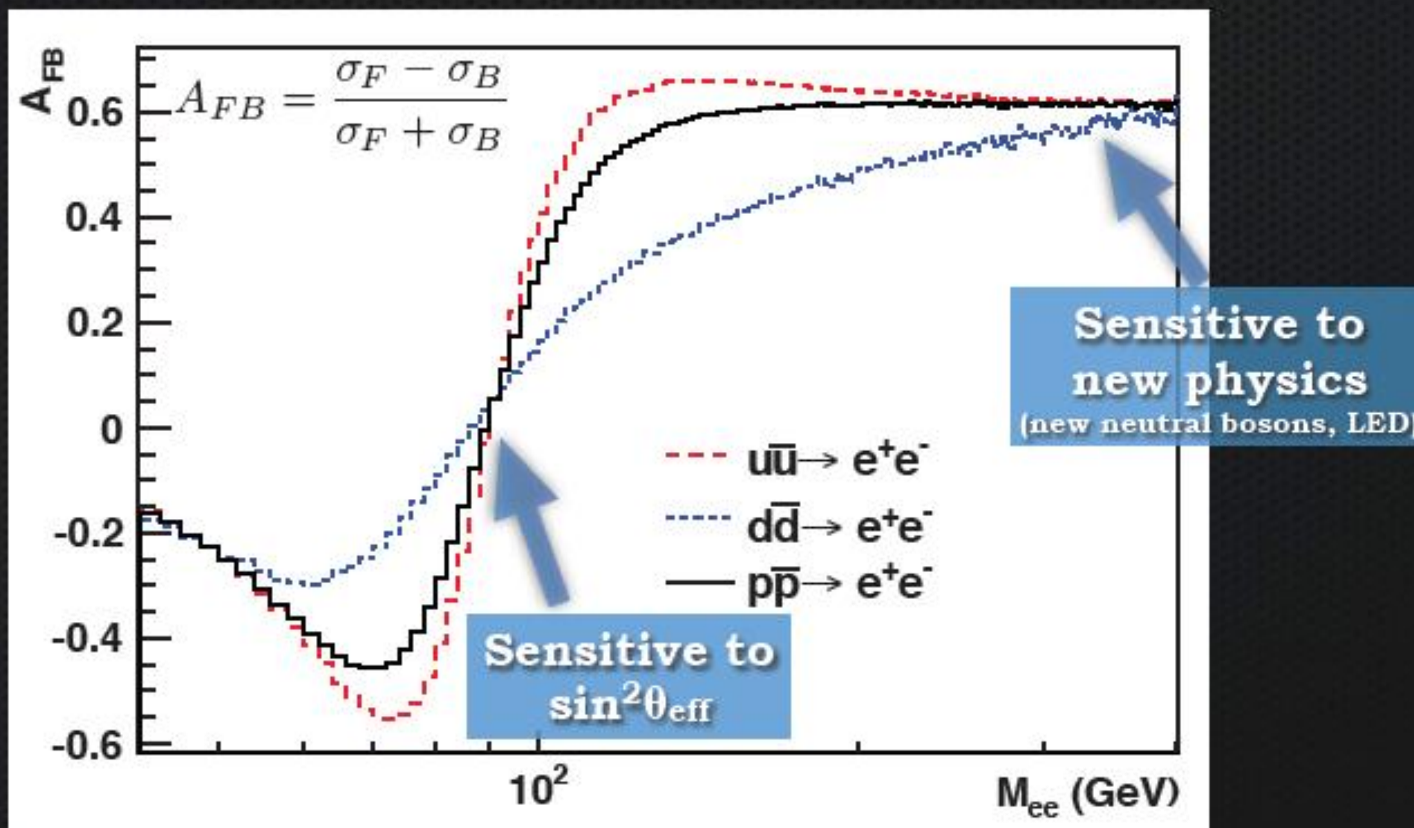
ν masses are BSM physics effects to be put together with *all other NP effects*: from charged LFV, Collider signals, Cosmo-astroparticle… to establish the Next Standard Model

new physics

- **Large Hadron Collider program well underway towards precision physics with W and Z bosons**
  - Stable ground for new physics searches
  - SM physics offers spin-offs into discoveries

Z forward-backward asymmetry
at Hadron Colliders





Z forward-backward asymmetry

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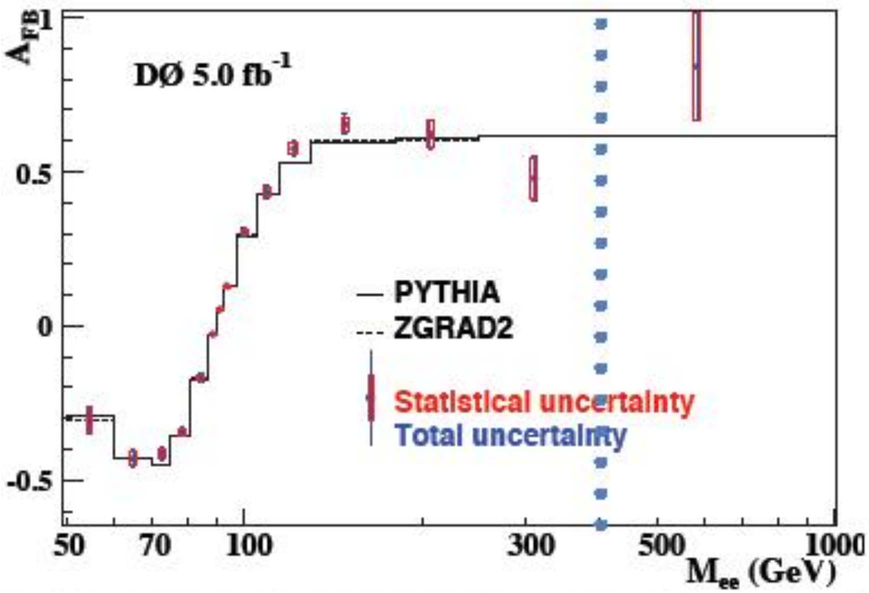
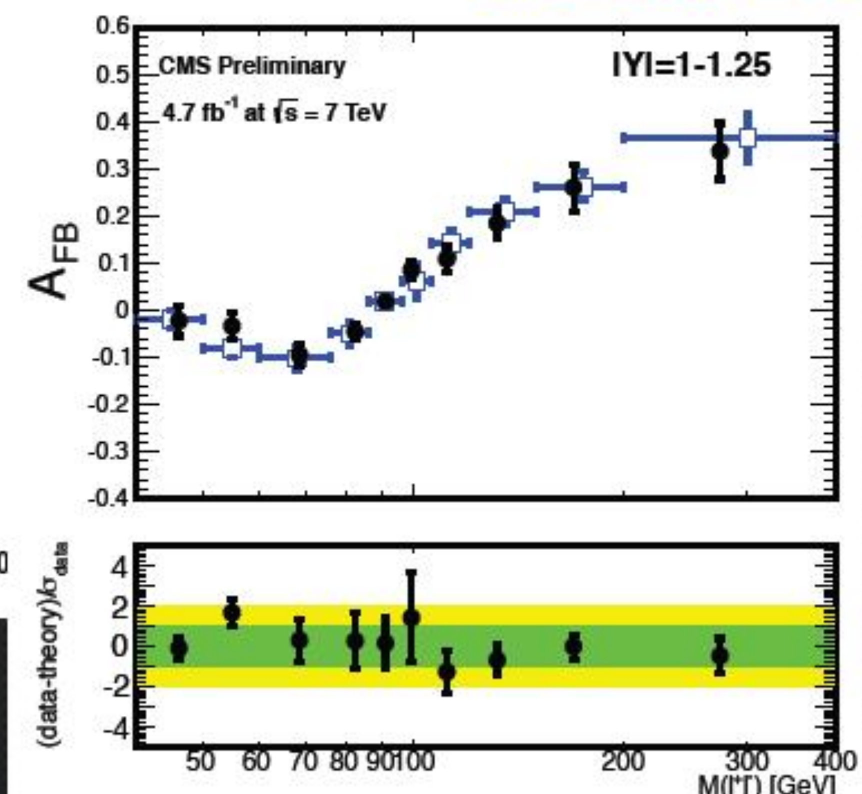
Phys. Rev. D 84, 012007 (2011)



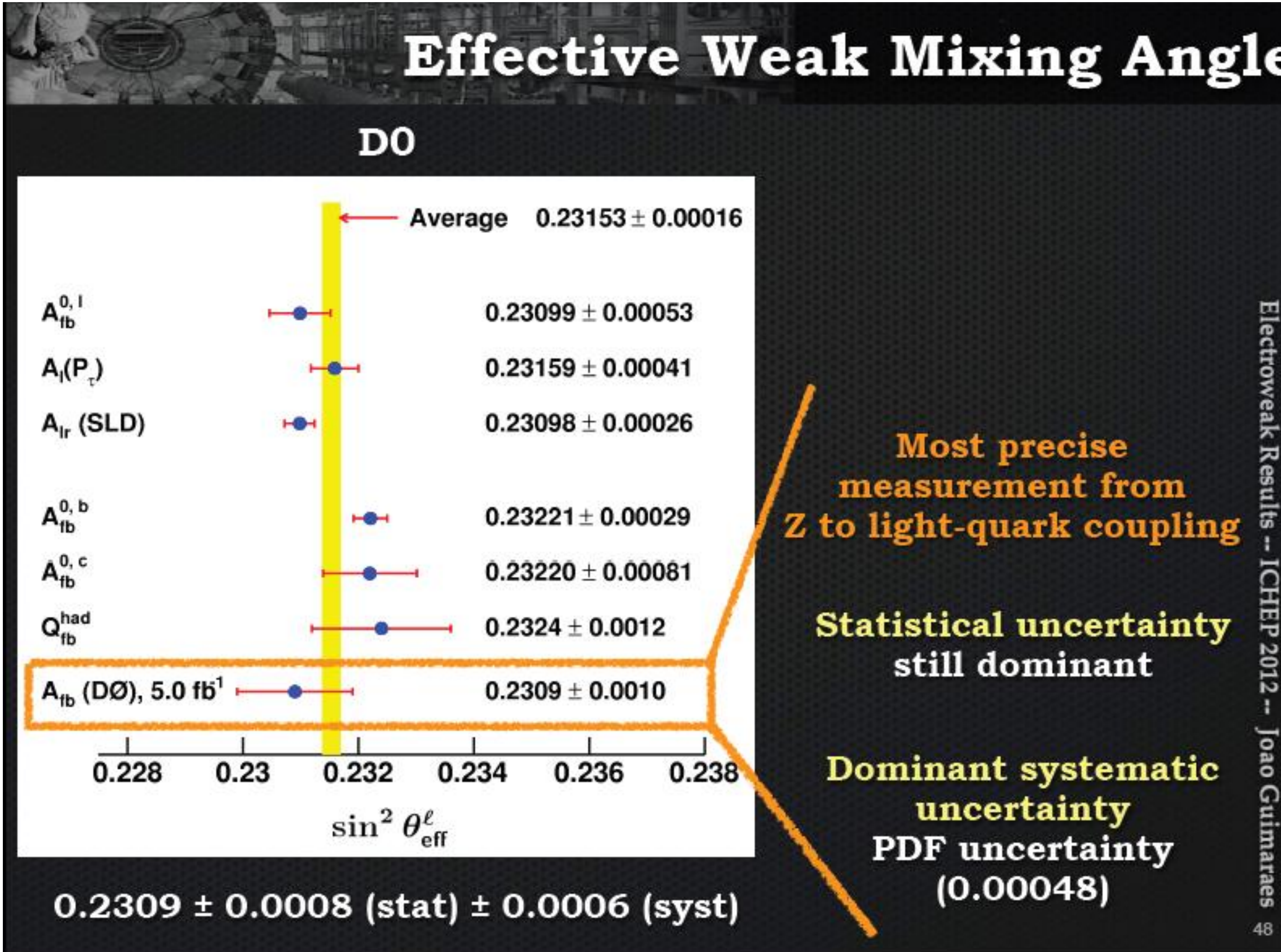
CMS PAS EWK-11-004



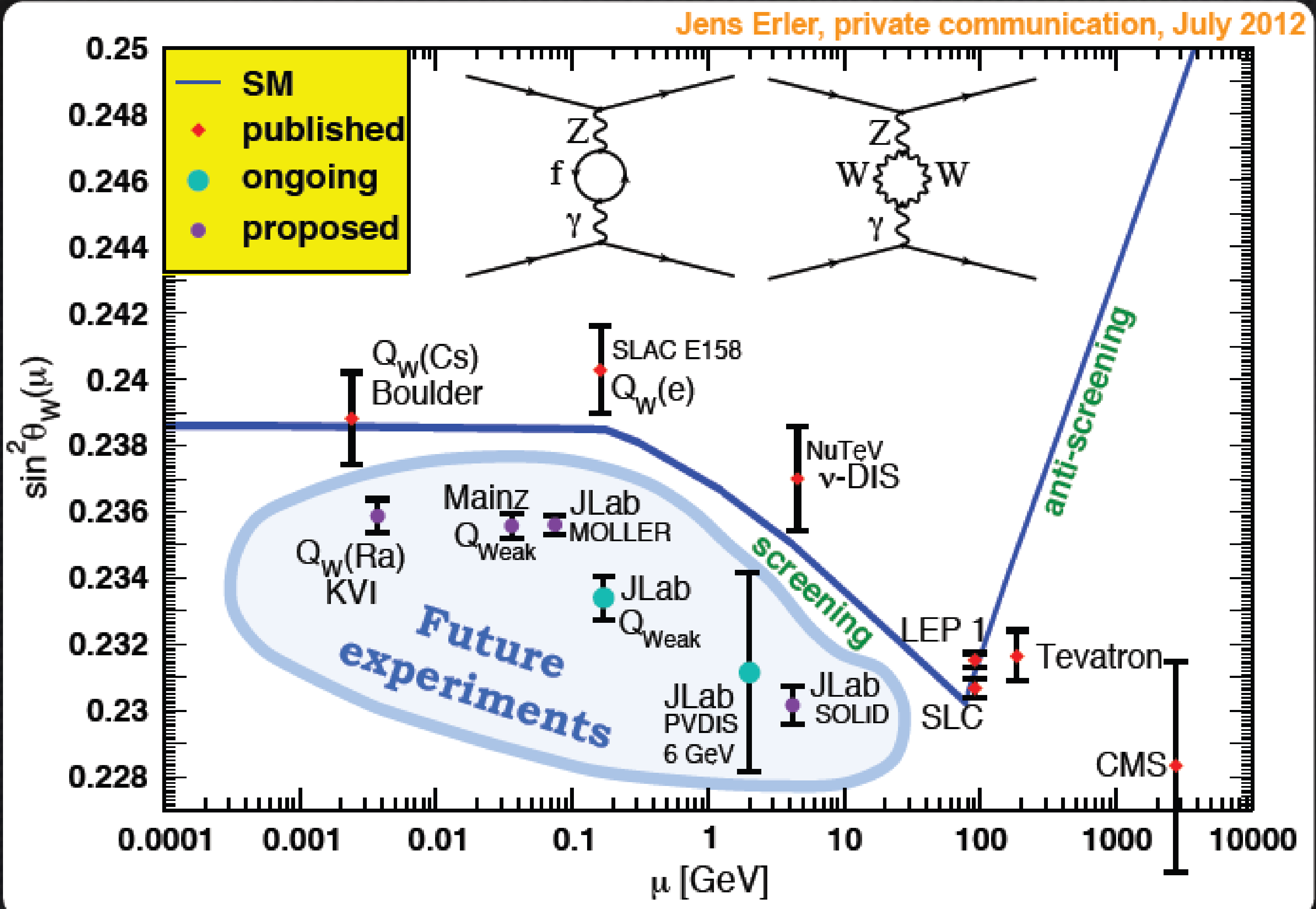
Unfolded AFB agrees well with theoretical predictions

No evidence for new physics at high-mass

[Joao Guimaraes]

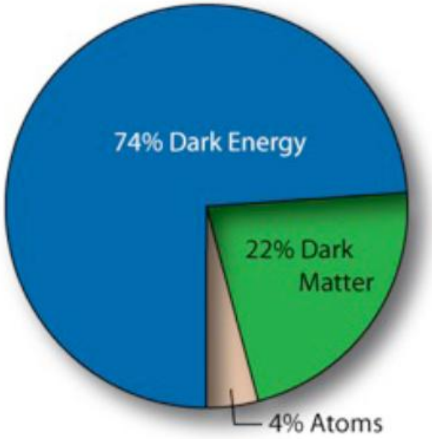


Weak mixing angle: scale dependence

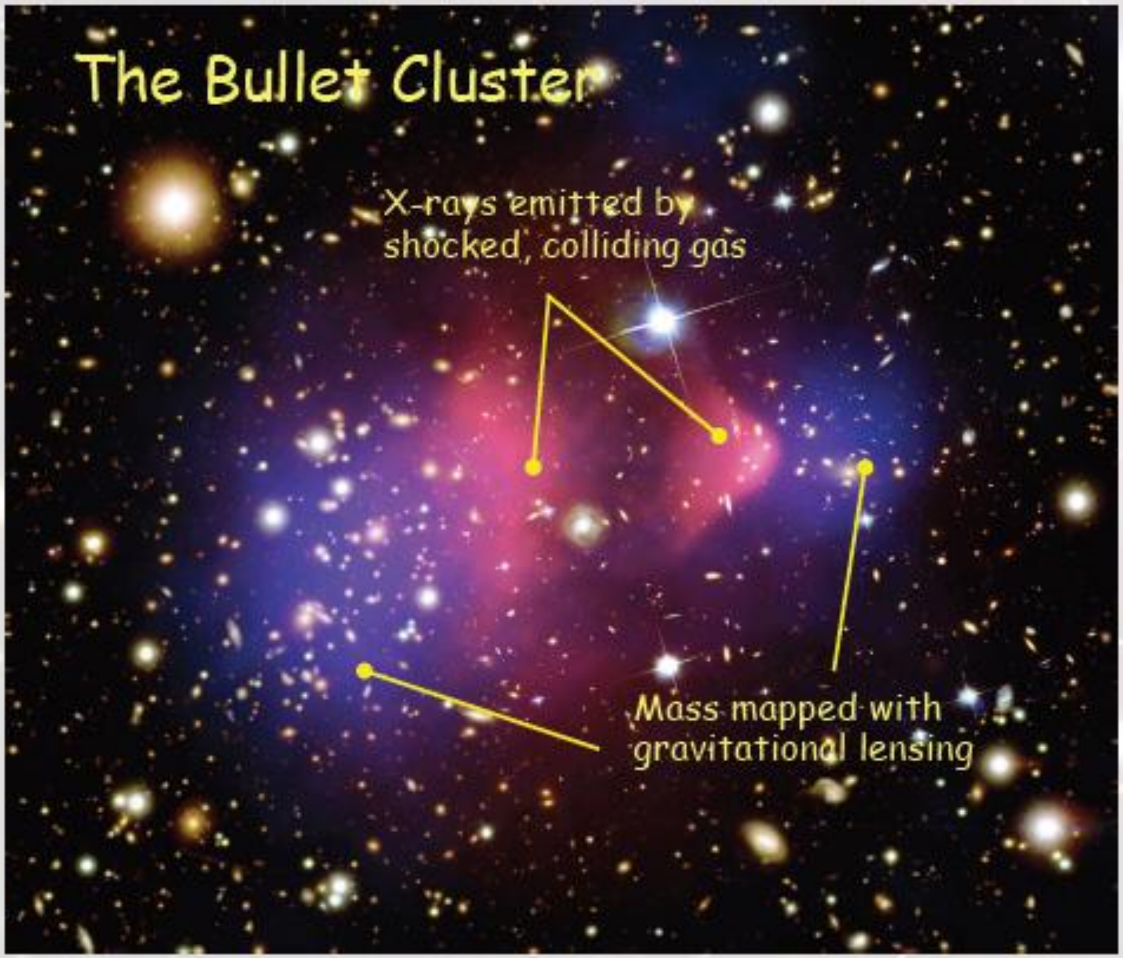


Scale dependence due to radiative effects


SCIENTIFIC AMERICAN
New Ways to Beat Malaria
Brain Control with Light
What Science Gets Wrong
How to Build the Supergrid
Hidden Worlds of Dark Matter
An entire universe may be interwoven silently with our own


74% Dark Energy
22% Dark Matter
4% Atoms

The Dark Matter Problem



What we know:

It's stable, cold, gravitationally interacting, non-baryonic, interacts little with itself (or not at all), composes ~85% of matter in the Universe...

But:

No particle in the Standard Model fits !

Very weakly interacting GeV-TeV particles do...

How to detect WIMPs

[Neal Weiner]

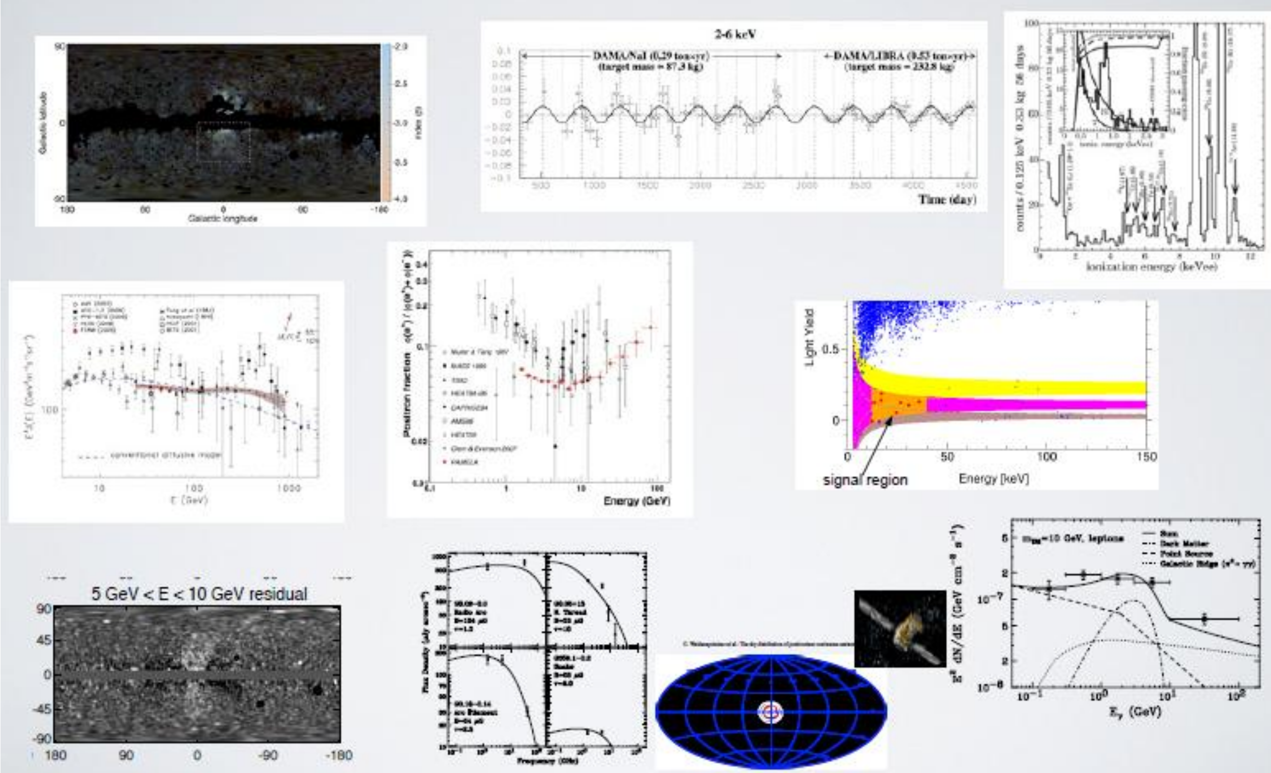
Our ideas of what dark matter is gives us ideas on how to find it

How to detect WIMPs

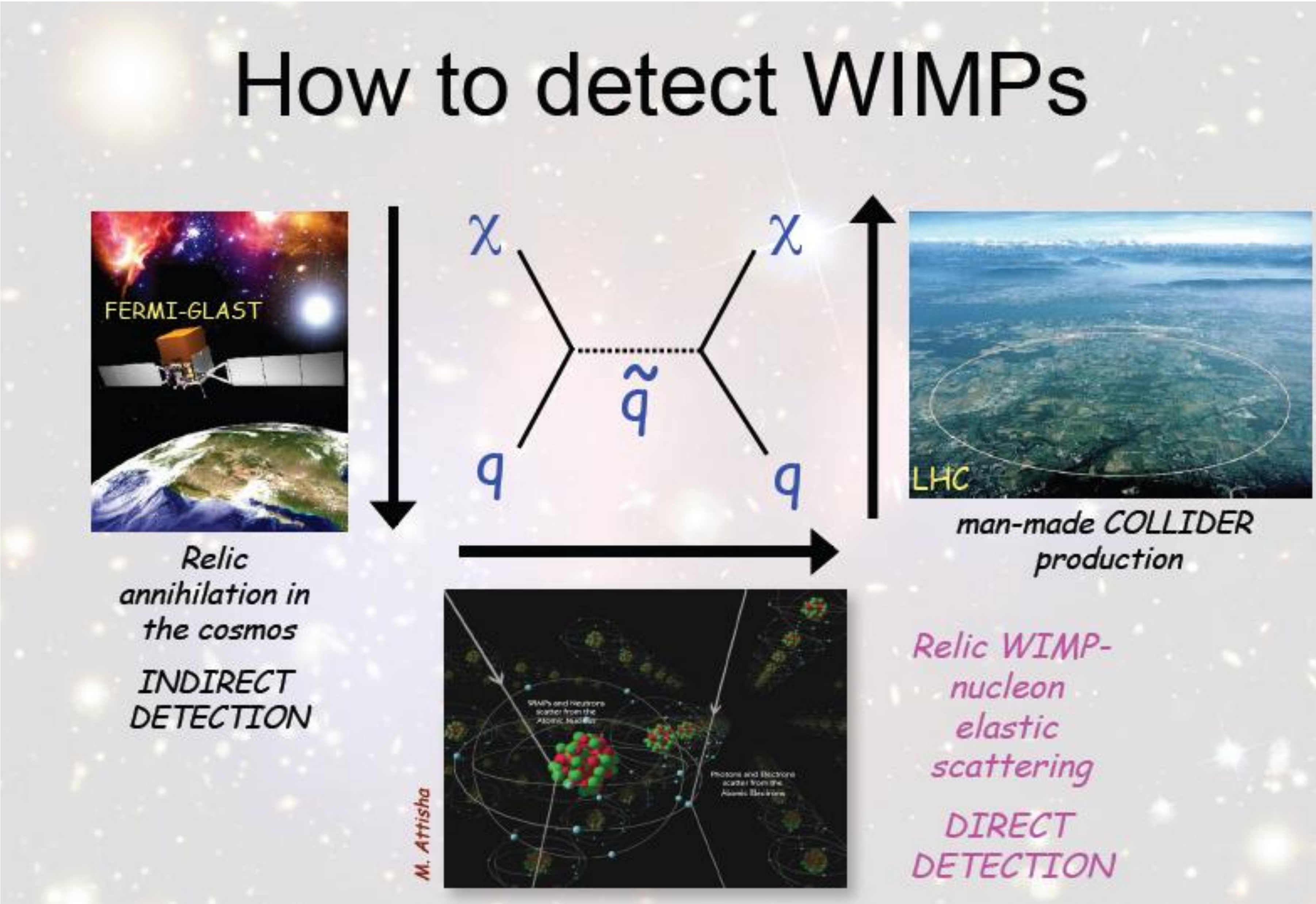
[Neal Weiner]

Our ideas of what dark matter is gives us ideas on how to find it

- Unlike the Higgs DM has been discovered many times



[Lauren Hsu]


How to detect WIMPs
FERMI-GLAST
Relic annihilation in the cosmos
INDIRECT DETECTION
χ
χ
q
q
q̃
LHC
man-made COLLIDER production
M. Attisha
Relic WIMP-nucleon elastic scattering
DIRECT DETECTION

[Lauren Hsu]

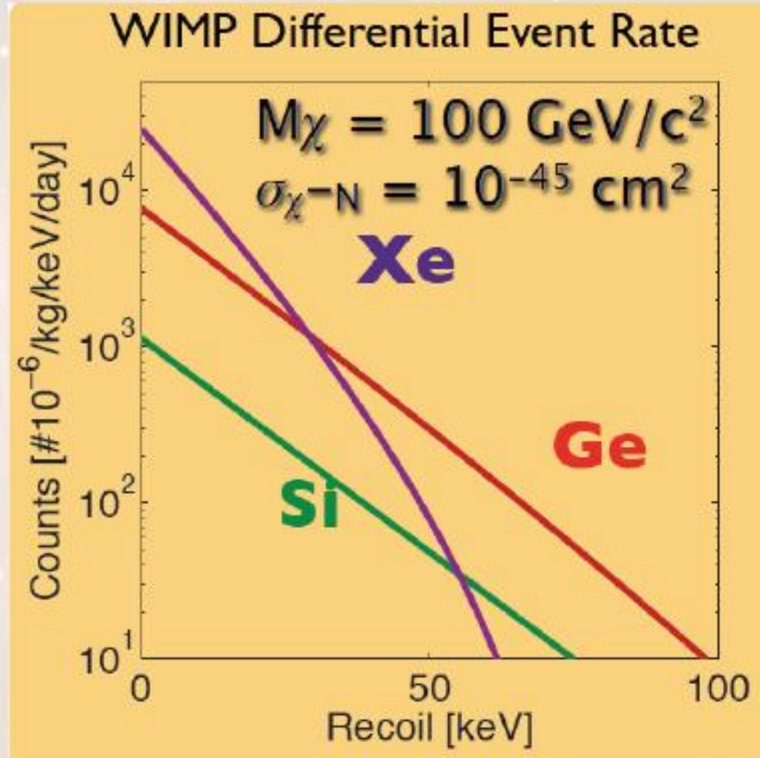
direct searches:

Expected signal:

- nuclear recoil (from elastic scattering of WIMPs)
- featureless exponential
- rates <<0.1 events /kg/day

Challenges:

- low energy thresholds (≤10 keV)
- mitigation of natural radioactive background (by factors >10^7)
- long exposures, underground operation



[Lauren Hsu]

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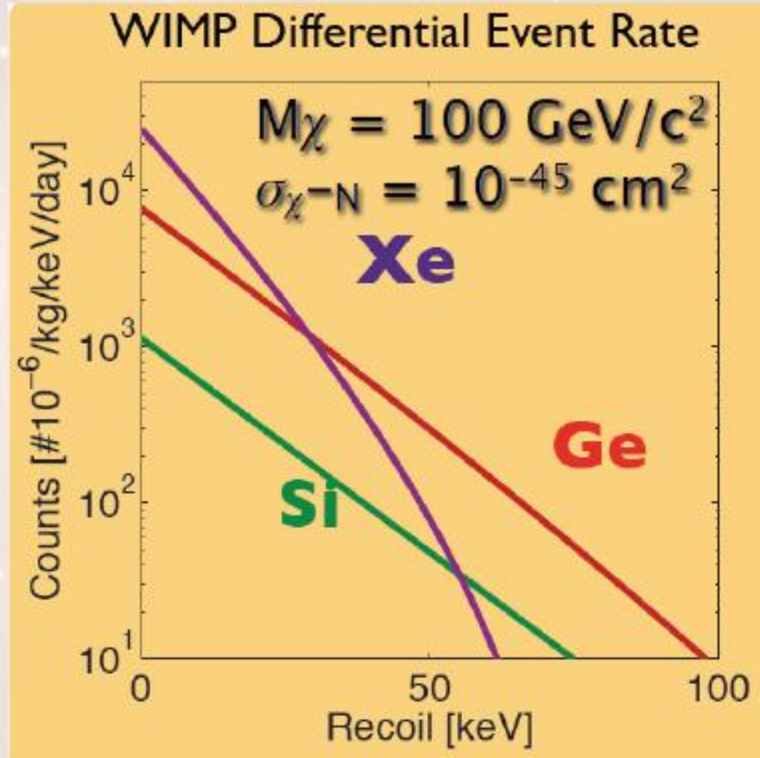
- mitigation of natural radioactive background (by factors >10^7)
- long exposures, underground operation



Strangeness and Dark Matter

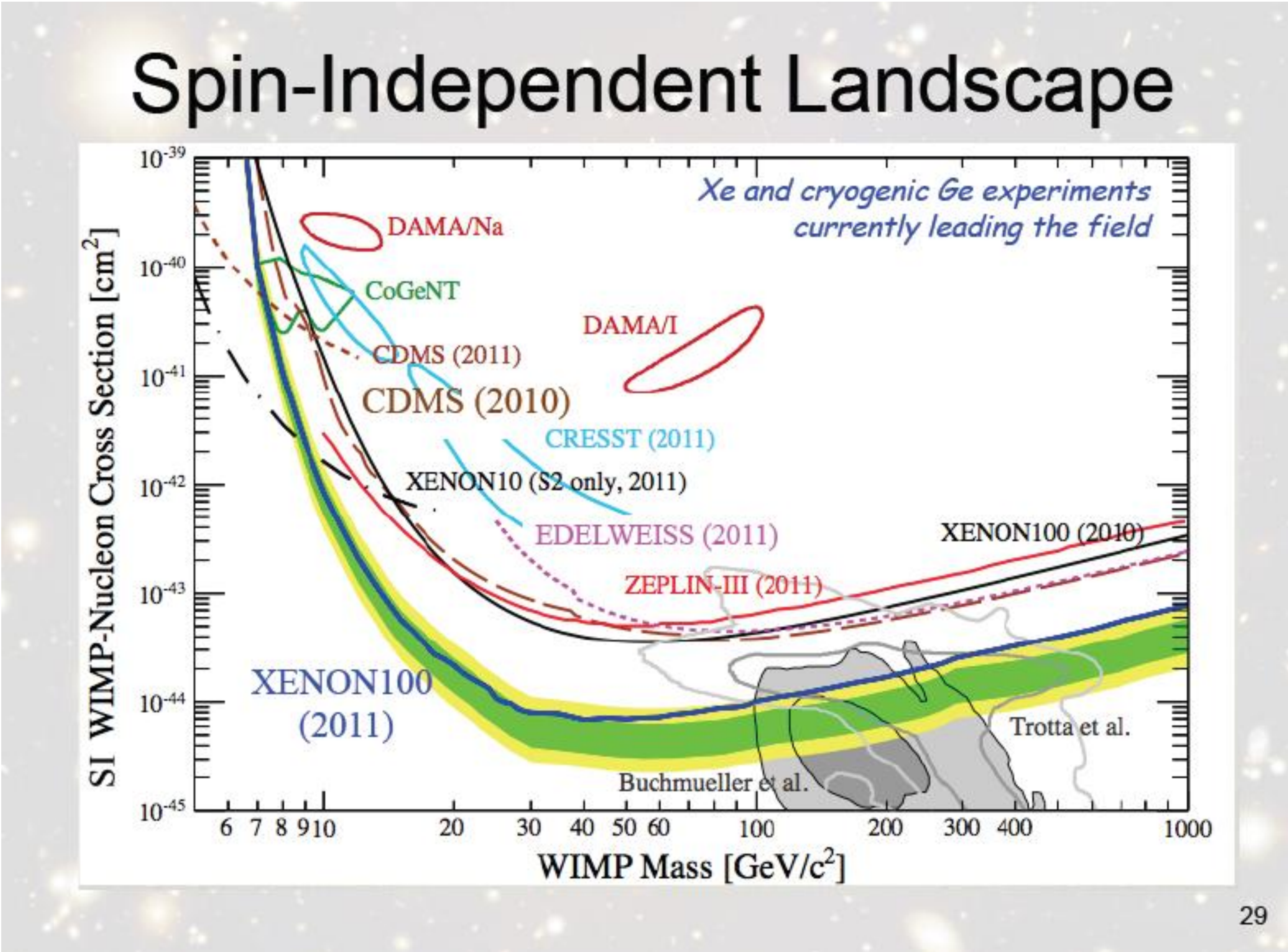
- Significant uncertainty coming from nucleon "sigma" terms

$$\sigma_q = m_q \langle N|\bar{q}q|N\rangle$$

lattice info

[James Zanotti]

direct searches:



[Lauren Hsu]

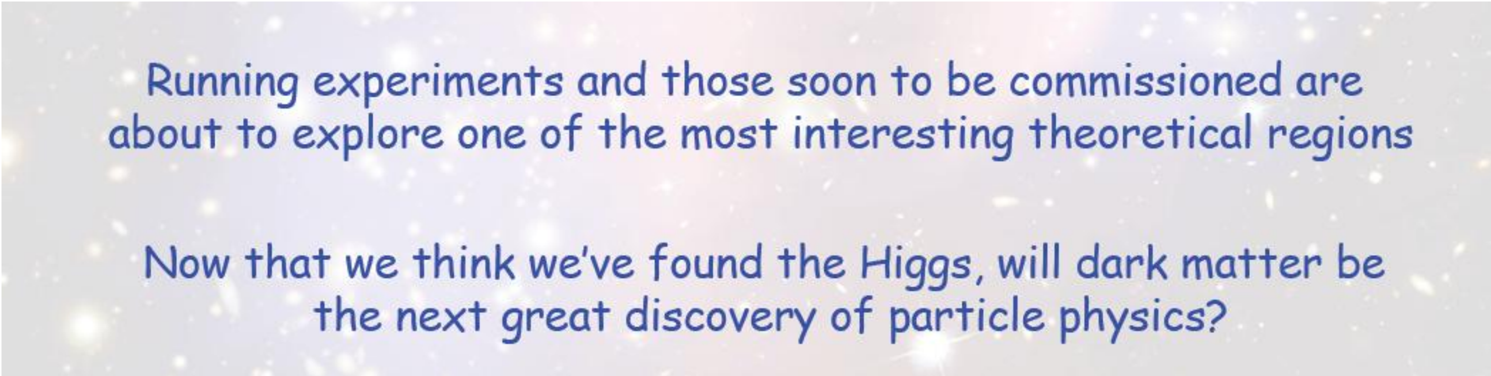
direct searches:

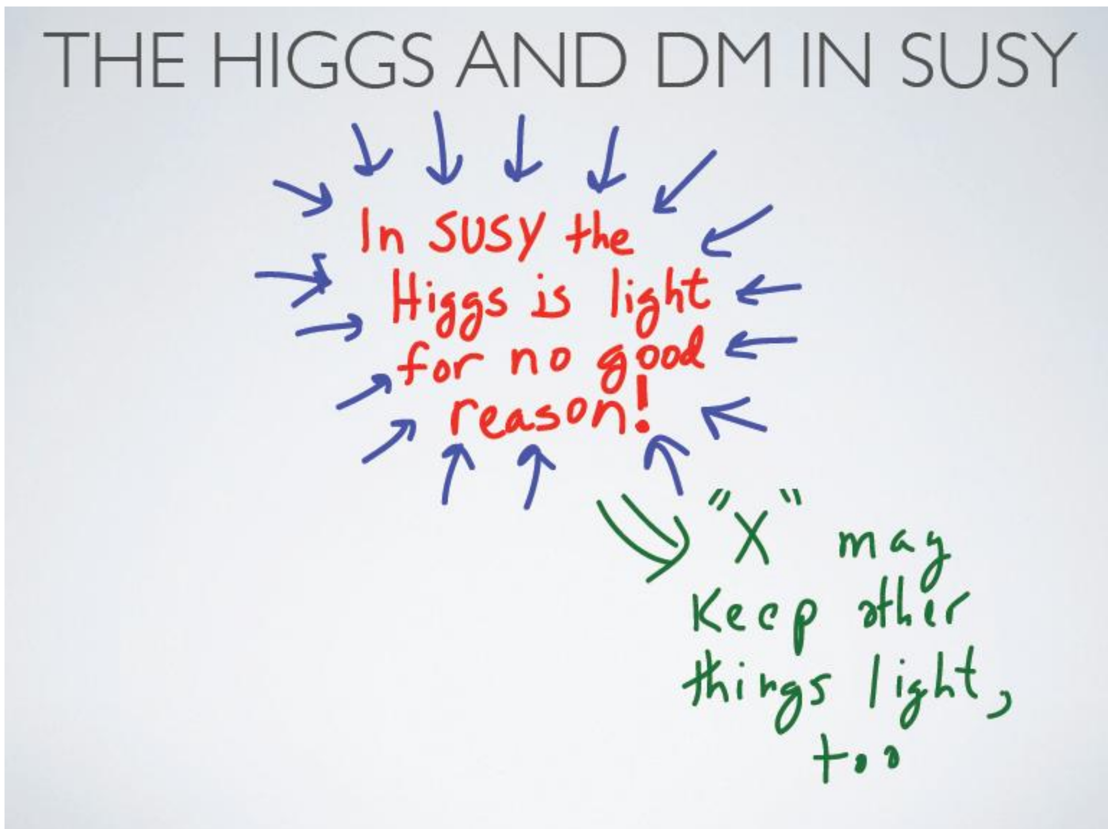
Running experiments and those soon to be commissioned are about to explore one of the most interesting theoretical regions

Now that we think we've found the Higgs, will dark matter be the next great discovery of particle physics?

[Lauren Hsu]

direct searches:

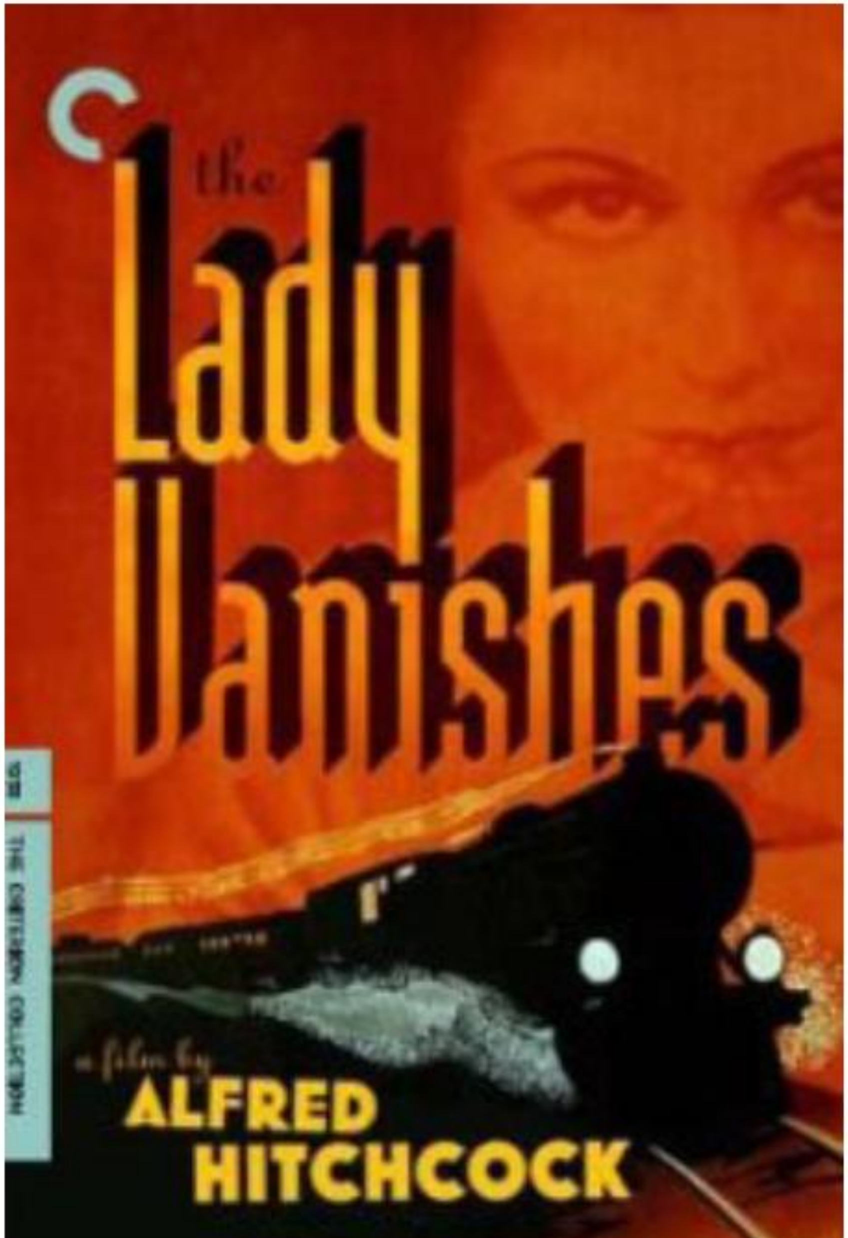




[Neal Weiner]

and finally also a word about SUSY

[Andy Parker]



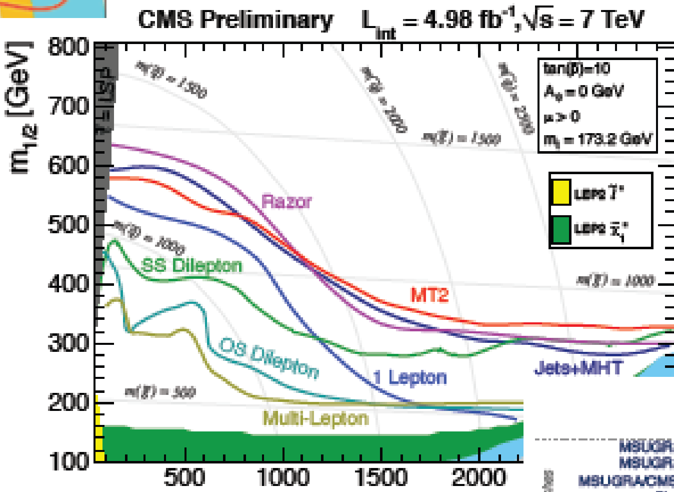
SUSY has been expected for a long time, but no trace has been found so far…

Like the plot of the excellent movie “The Lady Vanishes” (Alfred Hitchcock 1938).

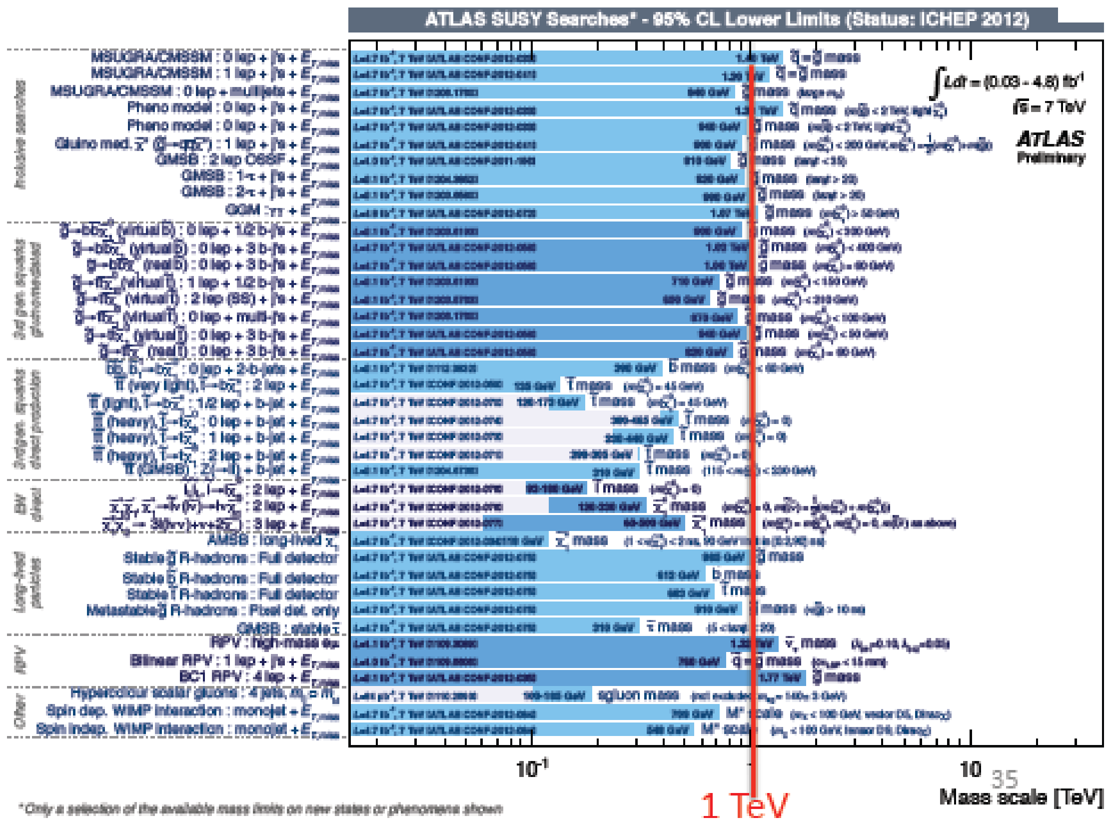
A lady is seen, then disappears on a train:

- is she imaginary?
- has she been kidnapped and hidden?
- is she in disguise?
- is she dead?

Both experiments provide nice search summaries



cMSSM



Larger versions in backup slides

[Andy Parker]

Is SUSY Dead?

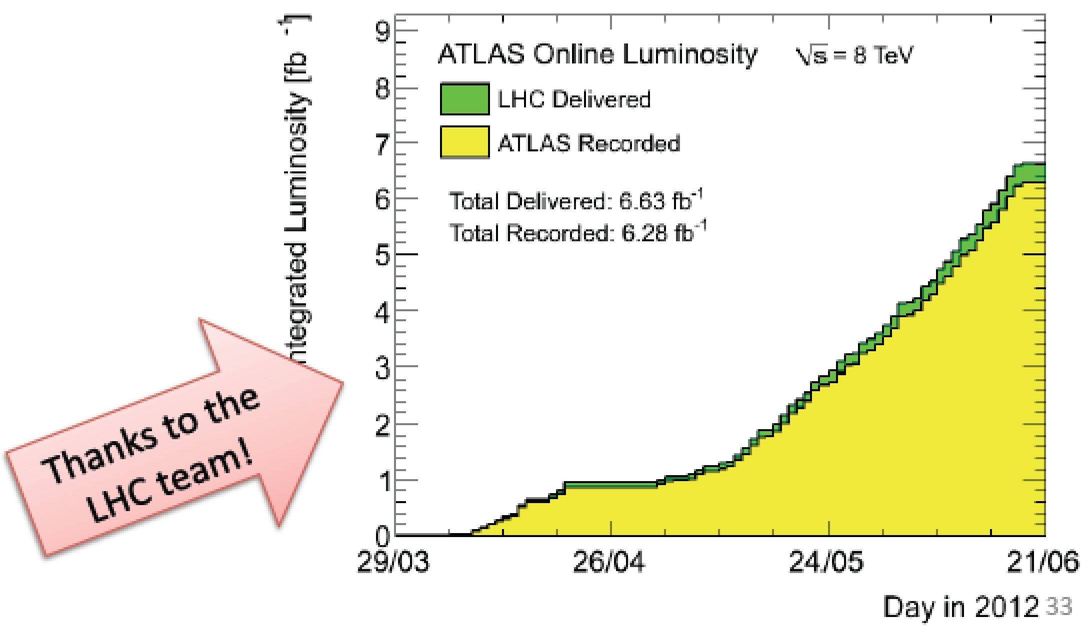
- The searches leave little room for SUSY inside the reach of the existing data.
- But interpretations within SUSY models rely on many simplifying assumptions, and so care must be taken when making use of the limit plots

[Andy Parker]

Is SUSY Dead?

- The searches leave little room for SUSY inside the reach of the existing data.
- But interpretations within SUSY models rely on many simplifying assumptions, and so care must be taken when making use of the limit plots

Maybe a happy ending....?



[Andy Parker]

Is SUSY Dead?

The lady is found alive and well in the final scene…

I apologize for not having covered your favourite topic

lattice: information from first principles

B-physics : unitarity triangle & NP

no time to cover any detail of...

flavour-physics : CPV

HIC : the quest for the QGP

please consult: `www.ichep2012.com.au/Program/`

… in summary

[Alex Pomarol]

4th of July 2012

A very stirring day for the EWSB practitioners

We've been more than 40 years of mainly wandering in the desert…

ICHEP2012 Melbourne

36th International Conference on High Energy Physics

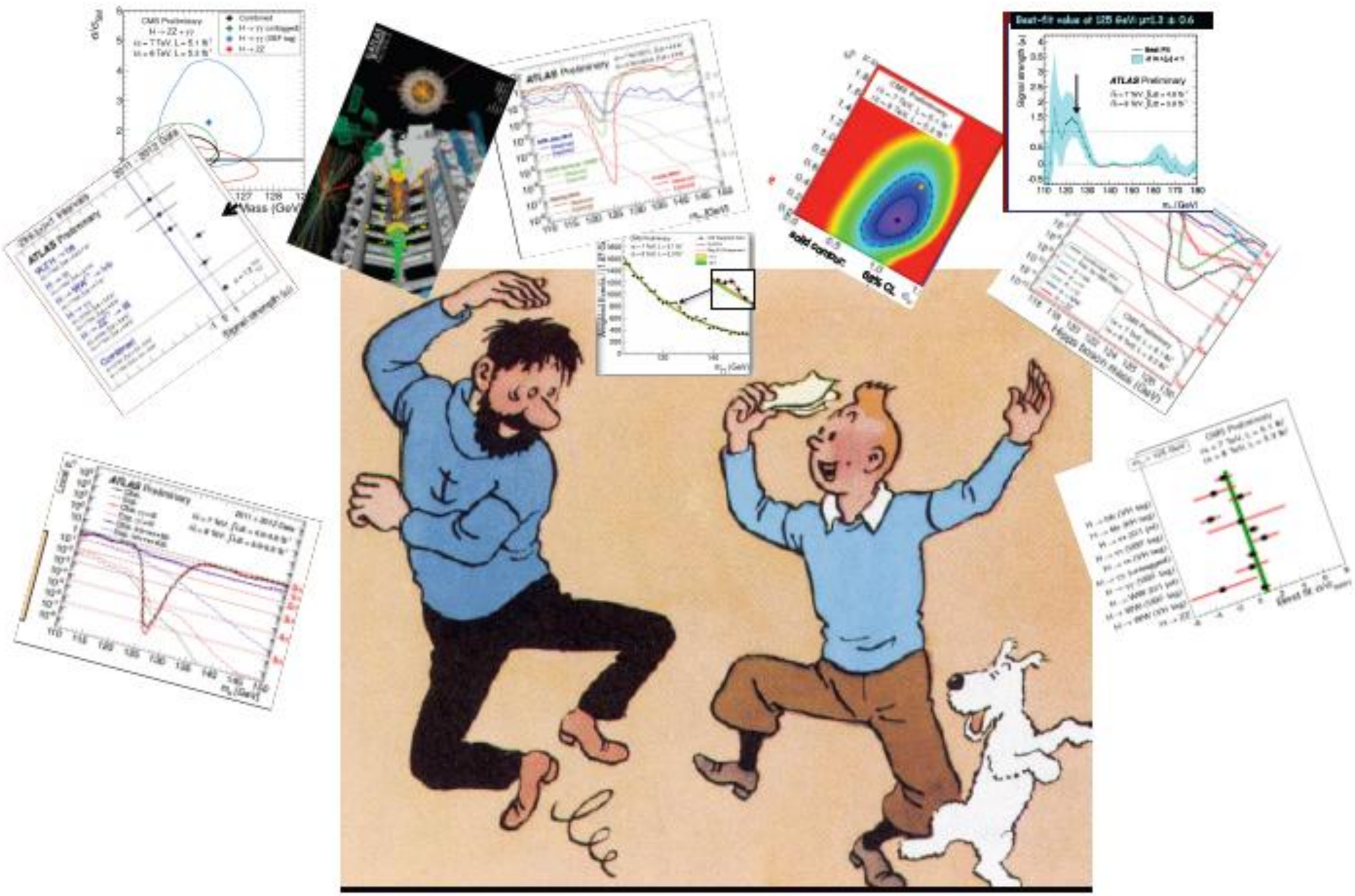
4 – 11 July 2012

Melbourne Convention and Exhibition Centre

… in summary

[Alex Pomarol]

… and finally plenty of new relevant data has begun to fall over us!



ICHEP2012 Melbourne

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exciting news from the high energy & high intensity frontiers

base line: **QCD**
→indispensable input for hadron machines (the 'discovery' machines)

lattice: information from first principles

EW: symmetry breaking, higgs, ...

HERA
Tevatron
Rhic
LHC
neutrinos
cosmology
high intensity exp.

flavour-physics : CPV

B-physics : unitarity triangle & NP

DM&DE: (in)direct searches & cosmology

HIC : the quest for the QGP

neutrino: numbers & masses

BSM: SUSY, new physics, exotics

- *new technologies & facilities*
- *communicating science*

for more details: www.ichep2012.com.au/Program/

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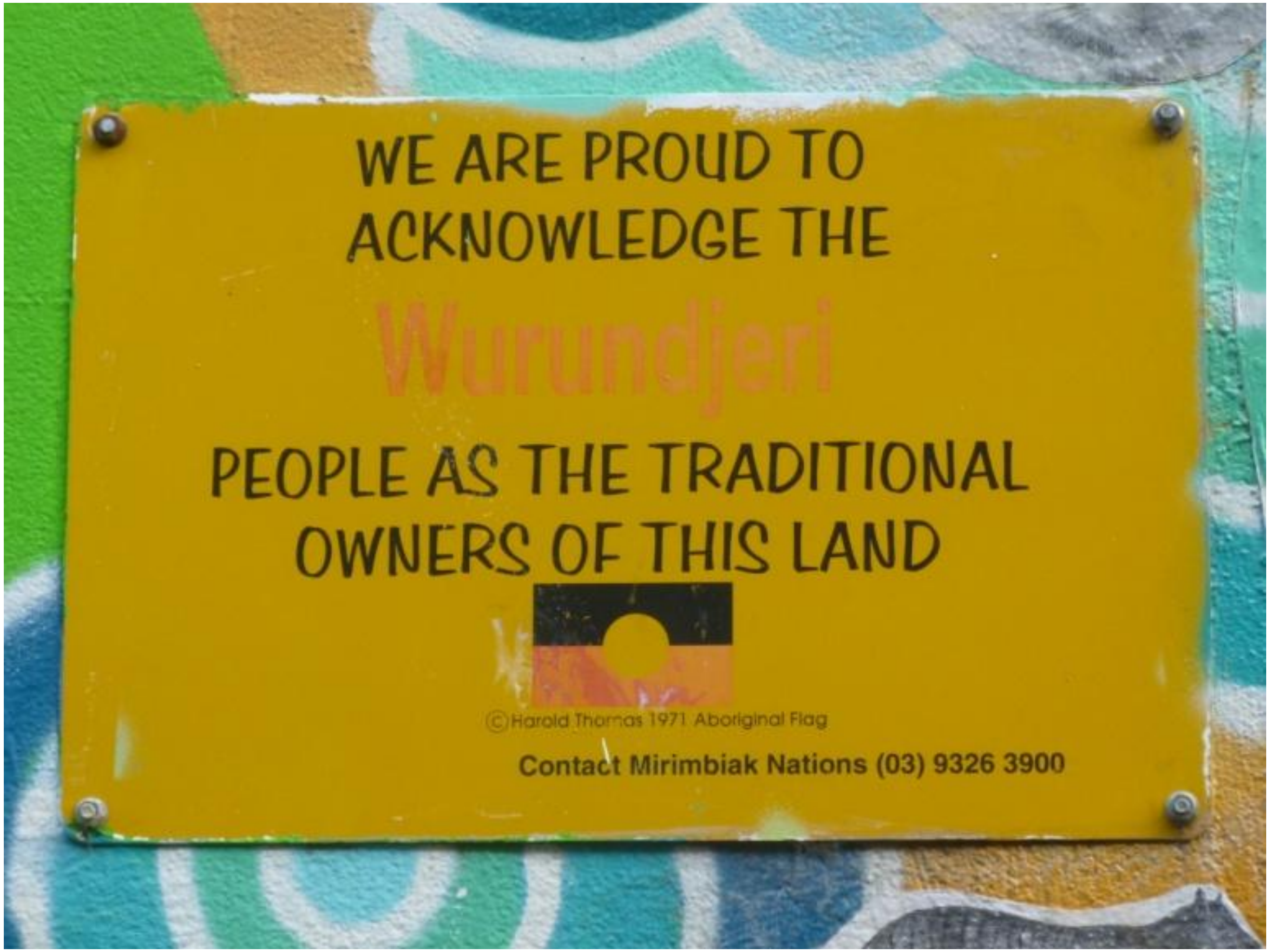
very stimulating conference

& amazing new results

still many ways to go ...

[Maringka Baker: Pukara]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