Thirty years of Physics

seen from

Les Rencontres de Physique de la Vallee' d'Aoste

Fernando Ferroni

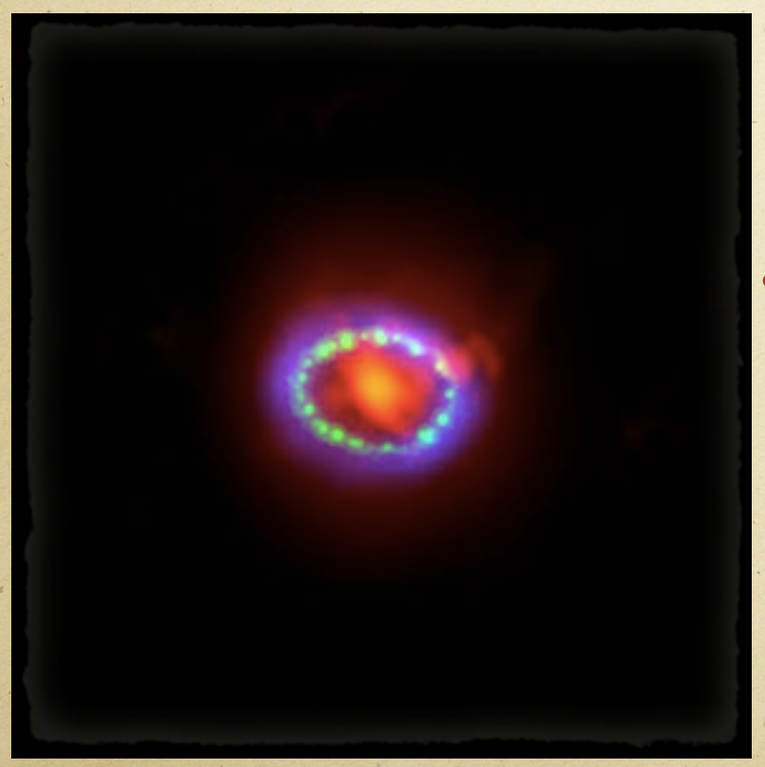
Sapienza University & INFN

I have been here many times, for sure I have seen days like this…..I have also seen things that you humans wouldn't believe (thanks Alvaro if you remember !)

1987: a gold medal (and a bit of luck)

1st Les Rencontres de Physique de la Vallee d'Aoste: Results and Perspectives in Particle Physics

1-7 Mar 1987. La Thuile, Italy



you were born under a very good star !

Supernova type	Type II (*peculiar*)[2]
Host galaxy	Large Magellanic Cloud
Constellation	Dorado
Right ascension	$05^h\ 35^m\ 28.03^s$[3]
Declination	–69° 16′ 11.79″[3]
Galactic coordinates	G279.7-31.9
Discovery date	24 February 1987 (23:00 UTC) Las Campanas Observatory[4]
Peak magnitude (V)	+2.9
Distance	167,885 ly (51.474 kpc)

something remarkable

- astroparticle physics get the center of the stage
- and it is there to stay
- going from a success to another

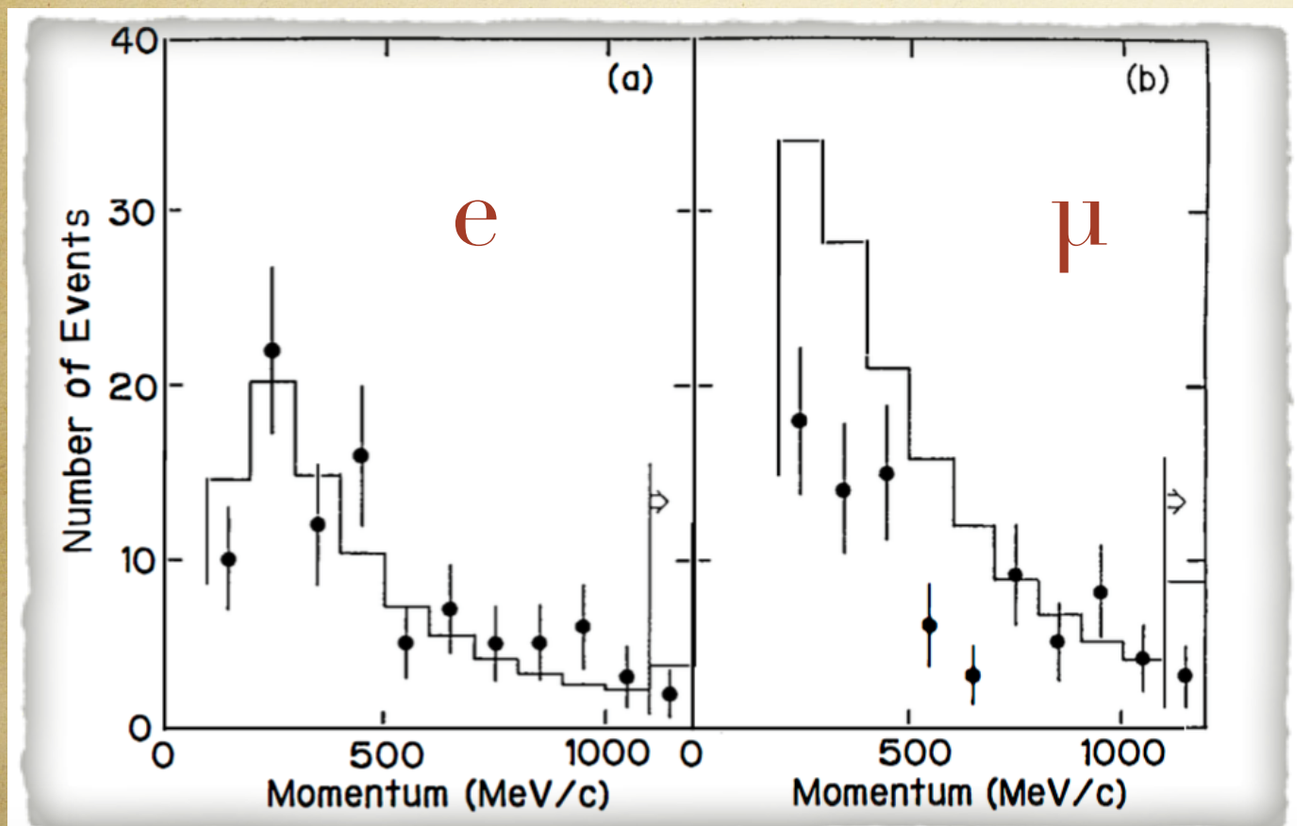
1988

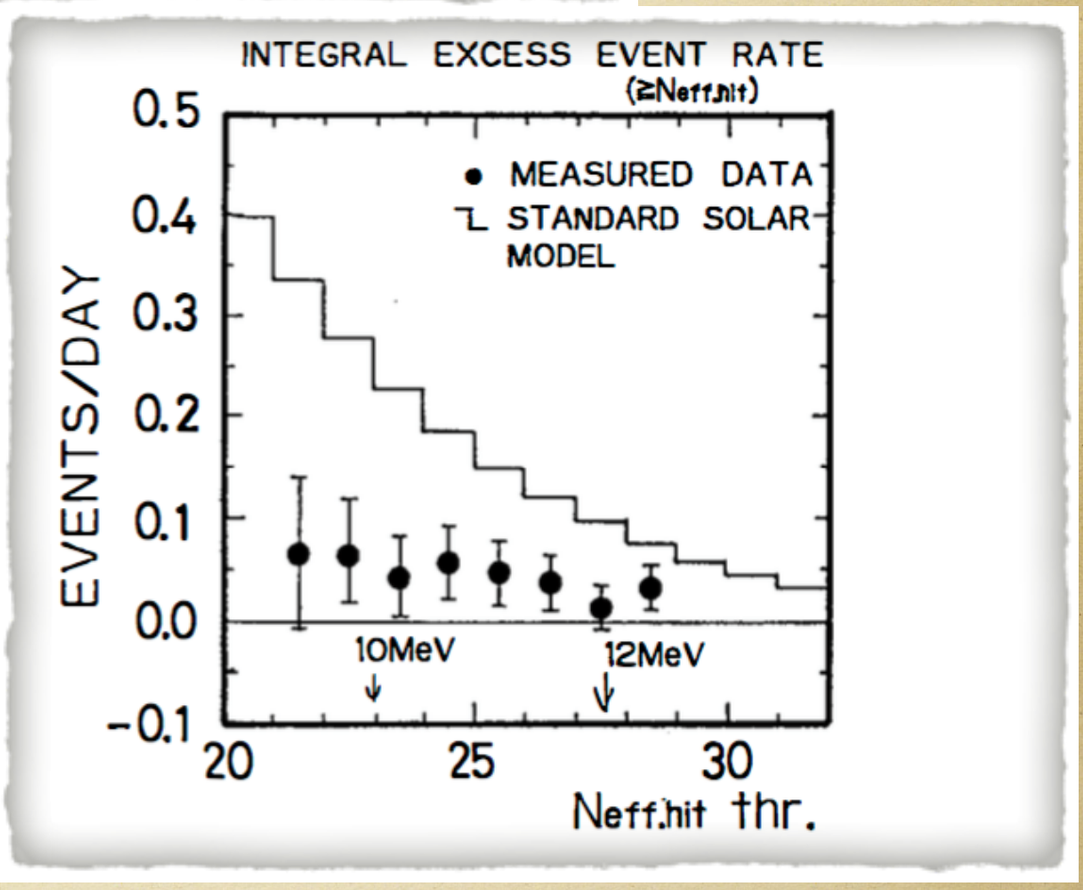
- exploiting the rich harvest of SN1987a
- a lot of emphasis on heavy flavour physics
- possible B-factories presented
- and two results that put neutrino at the center of particle physics (and a couple of Nobel prizes)

1988: news from Kamioka

RECENT ν-RESULTS FROM KAMIOKANDE-II AND FUTURE

M. Koshiba
CERN/TOKAI University*





The natural explanation is obviously the neutrino oscillation

1989

- no discovery but a lot of interesting stuff
- something that will stay on Physics books (or perhaps better in History of Physics books)
- BTW 1989 marks the start of LEP, although too late for La Thuile conference !

from 1989 index

well, both SSC end USSR were terminated !

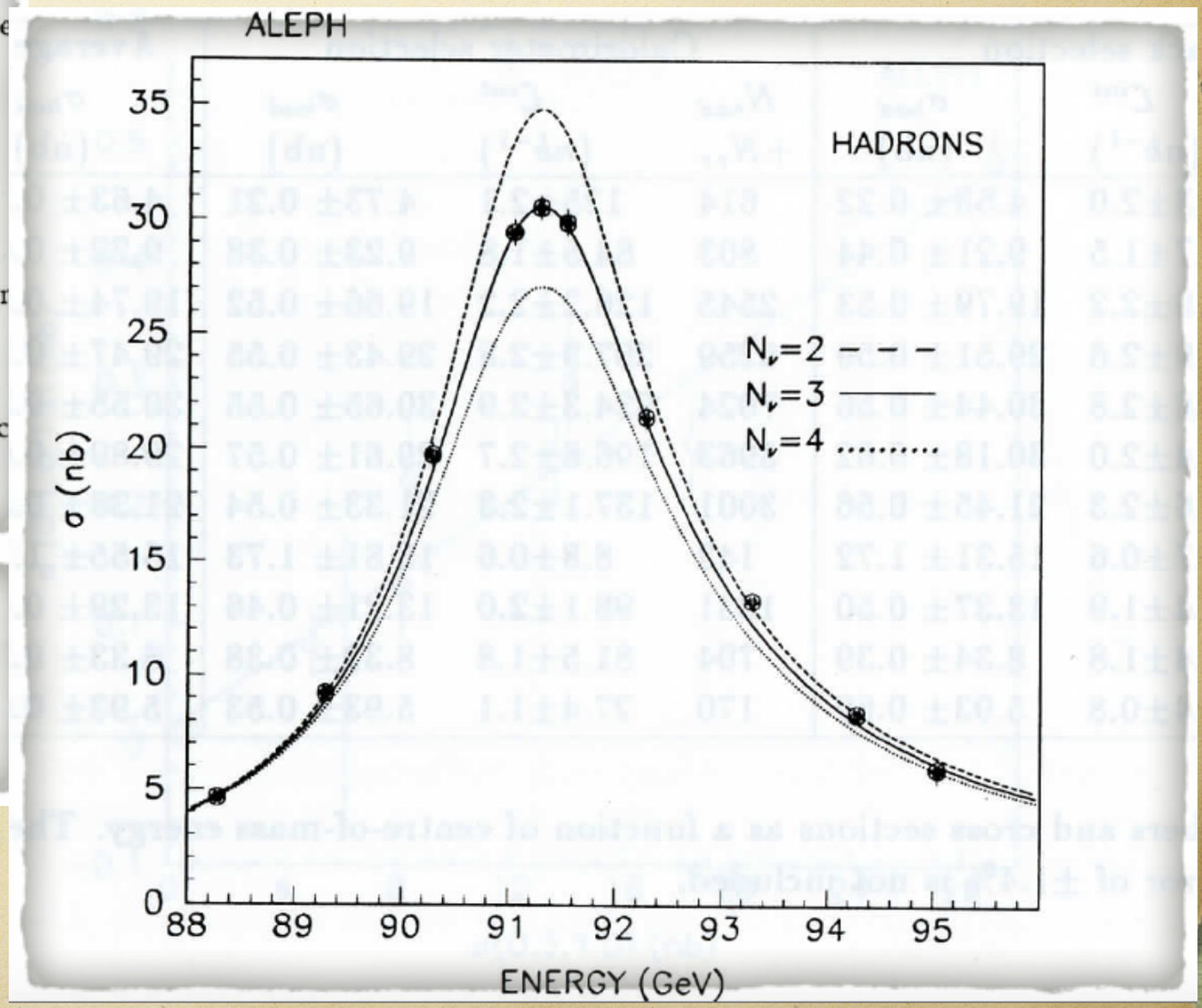
The exploitation of LEP and LHC in the same tunnel is not only compatible, but is of considerable interest for collisions between protons and electrons. Furthermore the current CERN experience in accelerating ions allows to envisage collisions between ions in LHC.

uhmmm !

1990: LEP

S. Gentile	An Overview of the First Results of L3 Experiment.
L. Garrido	Measurement of $\sigma(e^+e^- \rightarrow$ hadrons) with the ALEPH detector and determination of the Z Boson Resonance Parameters.
P. S. Marrocchesi	Preliminary Results on Z Decays into Lepton Pairs and Heavy Quarks in ALEPH.
M. Cattaneo	Search for New Particles with ALEPH.
T. Camporesi	Measurement of the Leptonic Width of the Z° Boson with the DELPHI Detector at LEP.
T. Camporesi	Search for New Particles with the DELPHI Detector at LEP : Standard Higgs Boson and Supersymmetric Particles.

M. Dam	Results of the DELPHI Collaboration from Hadronic Decays of the Z° Boson.	205
J. R. Carter	A Selection of Lineshape and QCD Results from the OPAL Experiment at LEP.	217
T. Tsukamoto	Searches for New Particles by the OPAL Experiment.	227



3-neutrinos-3

1991

the first time
I gave a talk
in LaThuile

- LEP, LEP, LEP, LEP and the frantic search for New Physics starts

Martin Jimack Searches for New Particles at LEP.

- and it is not over yet in spite of Carlo Rubbia predictions

- By 1998 we expect to start the LHC operation, after a one year shut-down in which LHC will be installed. Also LEP will probably be modified in order to increase the luminosity by about one order of magnitude using the "Pretzel scheme". In these conditions LEP will probably run on the Z^0 peak and longitudinal polarization will become an important added parameter.

- By the time the LEP programme is eventually losing momentum, sometime after the turn of the century, one or more beam crossing regions can be converted into electron-proton collisions with 7 times the HERA energies and a good luminosity.

1992: LEP dominance

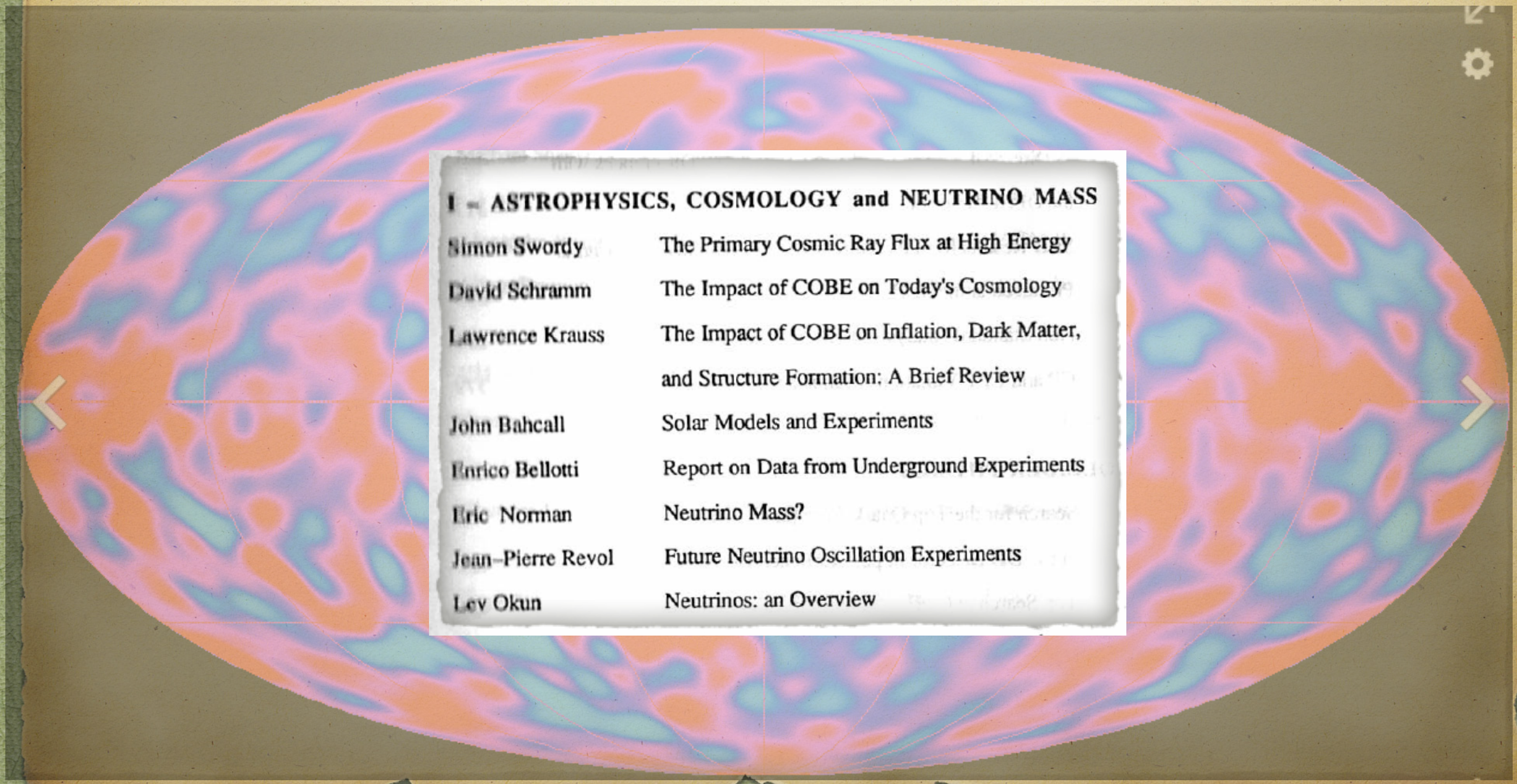
and the start of another saga that is still with us

Ron Settles **Physics at a 500 GeV e^+e^- Collider**

The political challenge is to get the authorization. The economic landscape for the next decade requires the 500 GeV e^+e^- Linear Collider to be a truly world endeavor. The world high energy physicists must begin to convince their governments of this effort.

There are many indicators at the moment pointing to $\sqrt{s} \sim 0.3 - 0.5\text{TeV}$ being the next range pregnant with new physics: here the Top Quark will and the Higgs Boson may well pop up, and the MSSM has a good chance to. In my opinion any one of these would be worth a 10^9\$ NLC. There are many doubters about this last statement for the Top Quark alone, but they should

1993: COBE and astroparticle on stage



I – ASTROPHYSICS, COSMOLOGY and NEUTRINO MASS

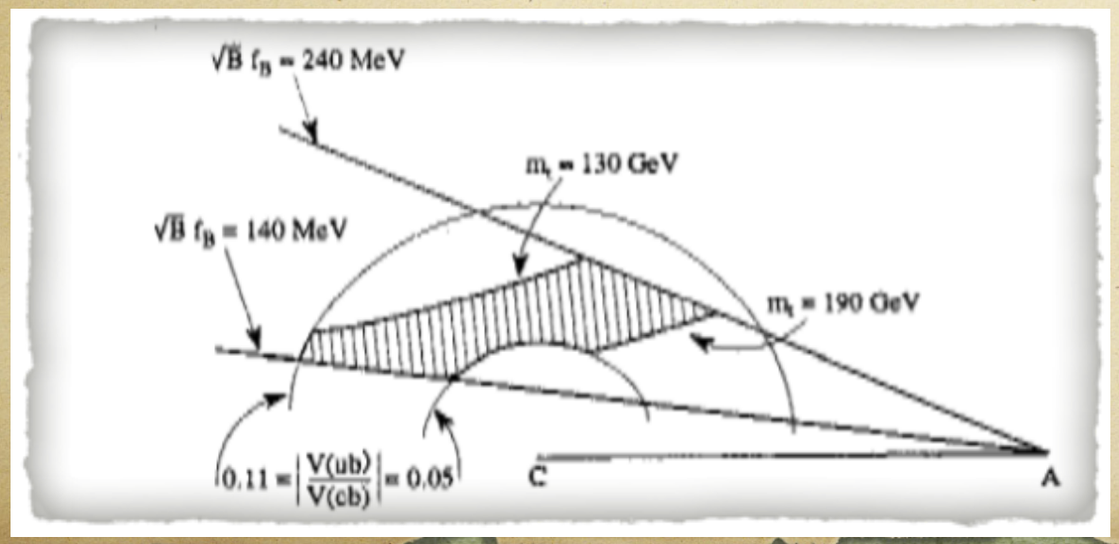
Simon Swordy	The Primary Cosmic Ray Flux at High Energy
David Schramm	The Impact of COBE on Today's Cosmology
Lawrence Krauss	The Impact of COBE on Inflation, Dark Matter, and Structure Formation: A Brief Review
John Bahcall	Solar Models and Experiments
Enrico Bellotti	Report on Data from Underground Experiments
Eric Norman	Neutrino Mass?
Jean-Pierre Revol	Future Neutrino Oscillation Experiments
Lev Okun	Neutrinos: an Overview

1994

a remarkable event: helicopter trip to Rutor glacier
and way back skiing ! 11/3/94 to be precise

B factory at SLAC approved

CP violation in beauty decays: The standard model paradigm of large effects
Ikaros I.Y. Bigi (CERN & Notre Dame U.). Mar 1994. 16 pp.



theorists smell blood !

1995

- the Top quark jumps on the stage although not yet with the (in)famous 5 sigma.

D0

17 events with an expected background of 3.8 ± 0.6 events. The probability for an upward fluctuation of the background to produce the observed signal is 2×10^{-6} (equivalent to 4.6 standard deviations). The kinematic properties of the excess events are consistent with top quark decay. We conclude that we have observed the top quark and measure its mass to be 199^{+19}_{-21} (stat.) ± 22 (syst.) GeV/c^2 and its production cross section to be 6.4 ± 2.2 pb.

CDF

In conclusion, we have observed that a new physics process contributes to the final state with W+$\geq$3 jets. In the context of the Standard Model this process can only be top. Fur-

1996: end of LEP I and the illusion of R_b and R_c

from Guido Altarelli

Table 1

Quantity	Old data (Brussels '95)	New data (La Thuile '96)
m_Z (GeV)	91.1884(22)	91.1884(22)
Γ_Z (GeV)	2.4963(32)	2.4964(32)
σ_h (nb)	41.488(78)	41.490(78)
R_h	20.788(32)	20.788(32)
R_b	0.2219(17)	0.2215(17)
R_c	0.1540(74)	0.1596(70)
A_{FB}^l	0.0172(12)	0.0171(11)
A_τ	0.1418(75)	0.1394(69)
A_e	0.1390(89)	0.1429(79)
A_{FB}^b	0.0997(31)	0.1002(28)
A_{FB}^c	0.0729(58)	0.0756(51)
A_b	SLD direct 0.841(53)	SLD direct 0.842(52)
	LEP indir. 0.910(37)	LEP indir. 0.914(34)
	Average 0.887(30)	Average 0.892(28)
A_c	SLD direct 0.606(90)	SLD direct 0.618(91)
	LEP indir. 0.660(56)	LEP indir. 0.690(50)
	Average 0.645(48)	Average 0.673(44)
$A_{LR} \to \sin^2\theta_{eff}$	0.2305(5)	0.2305(5)
m_W (GeV)	80.26(16)	80.33(15)
m_t (GeV)	180(12)	175(9)

$$R_b^{SM} = 0.2155(4), \qquad R_c^{SM} = 0.1725(3)$$

analyses. On the other hand we look forward to the start of LEP2 in mid '96 to see if some long awaited signal of new physics will finally show up.

1997

- what if I skip it ?

1998

Thanks to Beppo-Sax satellite a real study of the GRB, first observed in the 60's, has started.

2. Observation of High Energy Gamma-Ray Bursts (Enrico Costa, IAS-Roma)

3. Understanding High Energy Gamma-Ray Bursts (Mario Vietri, Roma III)

4. Origin of Gamma Ray Bursts and Cosmic Rays (Arnon Dar, Haifa)

and also the epic fight of Alvaro with all the astrophysicist about the mechanism that generates them

and also a new promising field appears on the screen

5. The LIGO Gravitational Wave Detector (William Kells, CalTech)

1998: neutrino definitely gets a mass

SESSION II MASSIVE NEUTRINOS?

2. Results from the Superkamiokande Experiment (Jeff Wilkes, Washington)

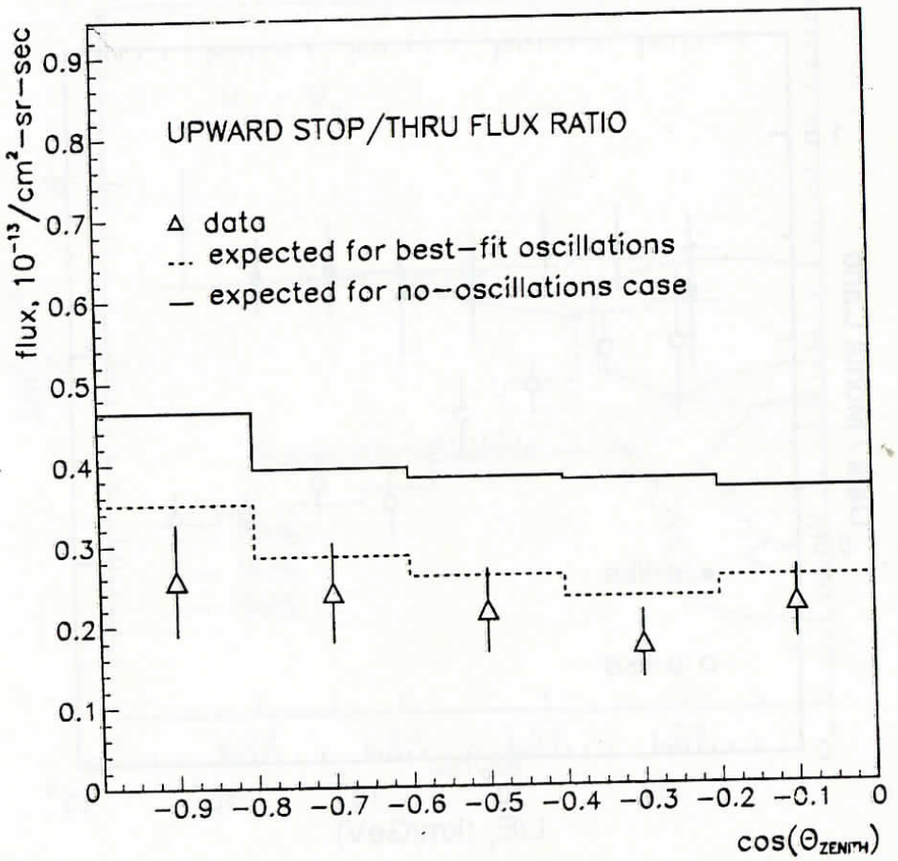
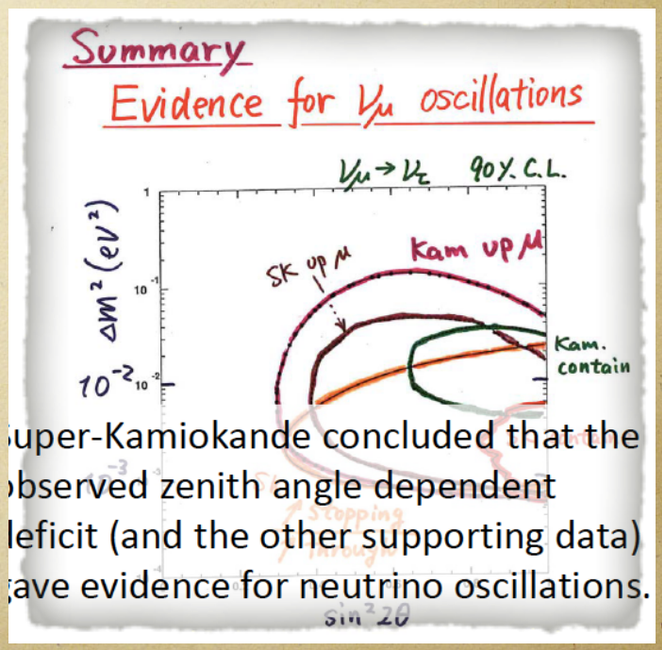


Figure 6: Stop/Through Ratio vs zenith angle



Super-Kamiokande concluded that the observed zenith angle dependent deficit (and the other supporting data) gave evidence for neutrino oscillations.

1999

The flavour-factories take off

Progress of DAPHNE and KLOE *(Paolo Franzini, LNF)*

Progress of BELLE *(Kazunori Hanagaki, Princeton)*

The Start of the Asymmetric e^+e^- SLAC Factory *(Riccardo Faccini, San Diego)*

2000: the millennium year

what strikes me is a talk on side effects of physics

Jean-Pierre Zigrand (London): Basics of Financial Physics

the catastrophe of the finance (that we still suffer)
was very far in time and possibly we (the community)
were even proud of the discovery of the derivatives
and the use of MonteCarlo in the world of Finance

all done by physicists trained by us

The field of finance recently received a lot of attention by physicists, and my hope is that the interaction between financial economists and physicists will lead to new insights into the way financial markets work. A great first step would be to submit research papers to the appropriate finance journals for refereeing and for dissemination among the finance profession. There is a lot to be gained from both sides.

I could not find a better way to conclude than citing Doyne Farmer[11],

> With some justification, many economists think that the entry of physicists into their world reflects merely audacity, hubris, and arrogance. Physicists are not known for their humility, and some physicists have presented their work in a manner that plays into that stereotype.

...

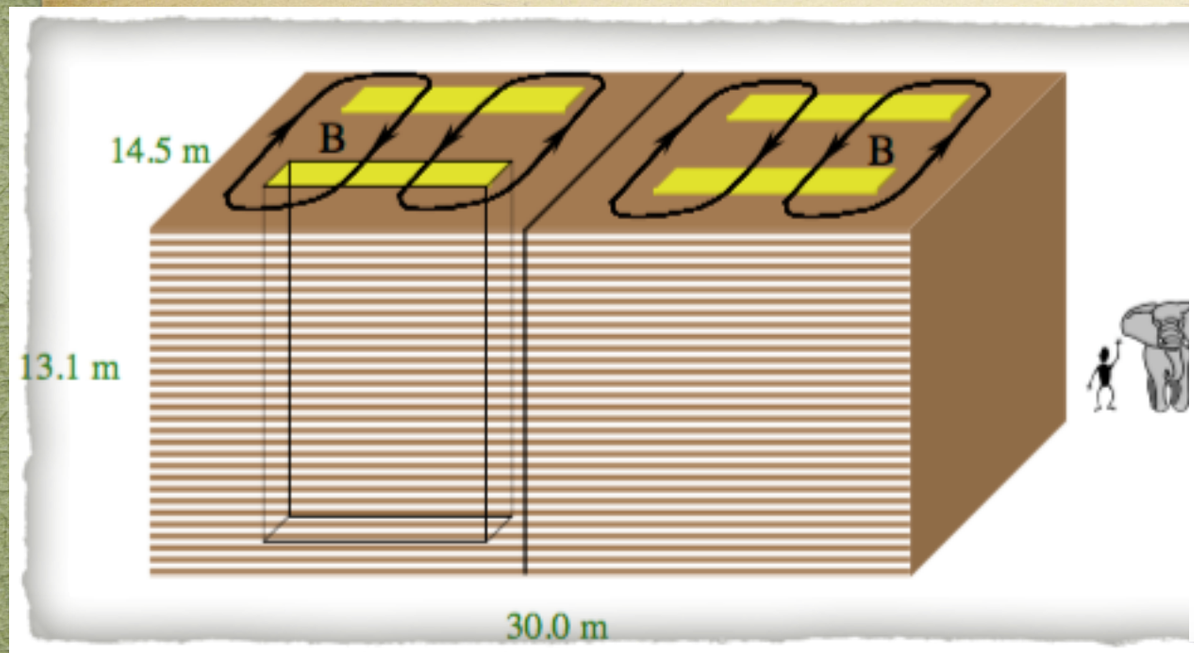
> Many of the physicists know very few empirical facts and are largely ignorant of the literature in economics and finance... Physicists like me should stop reinventing the wheel.

Maybe one could add that financial economists like me should stop presuming that many physicists simply look for a way to have fun and to recycle physics methods, and invite physicists to take part in financial workshops and conferences.

2001: I want to admit a mistake (a big one) done by INFN

MONOLITH: A HIGH RESOLUTION NEUTRINO OSCILLATION EXPERIMENT

Tommaso Tabarelli de Fatis
I.N.F.N. - Sezione di Milano
Piazza della Scienza 3, I-20126 Milano, Italy
for the MONOLITH Collaboration



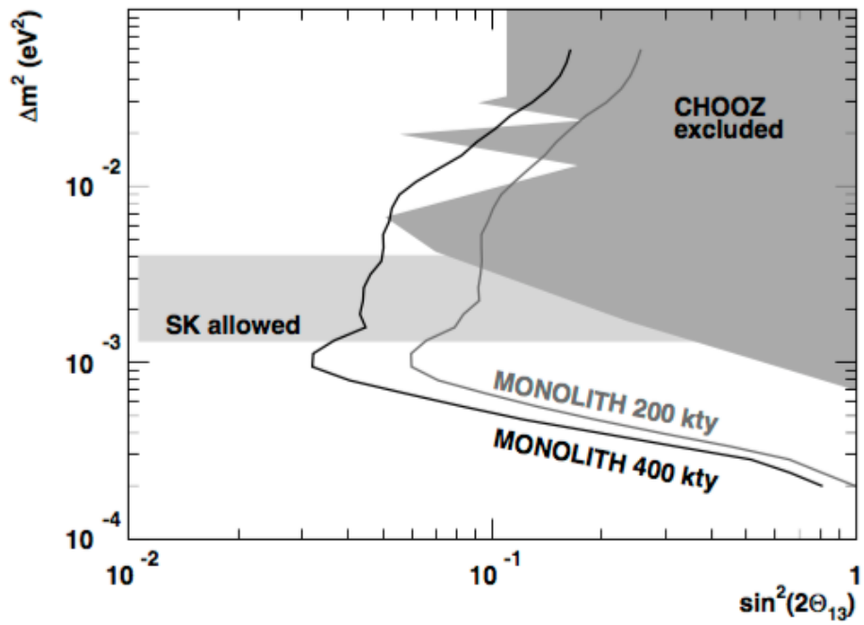
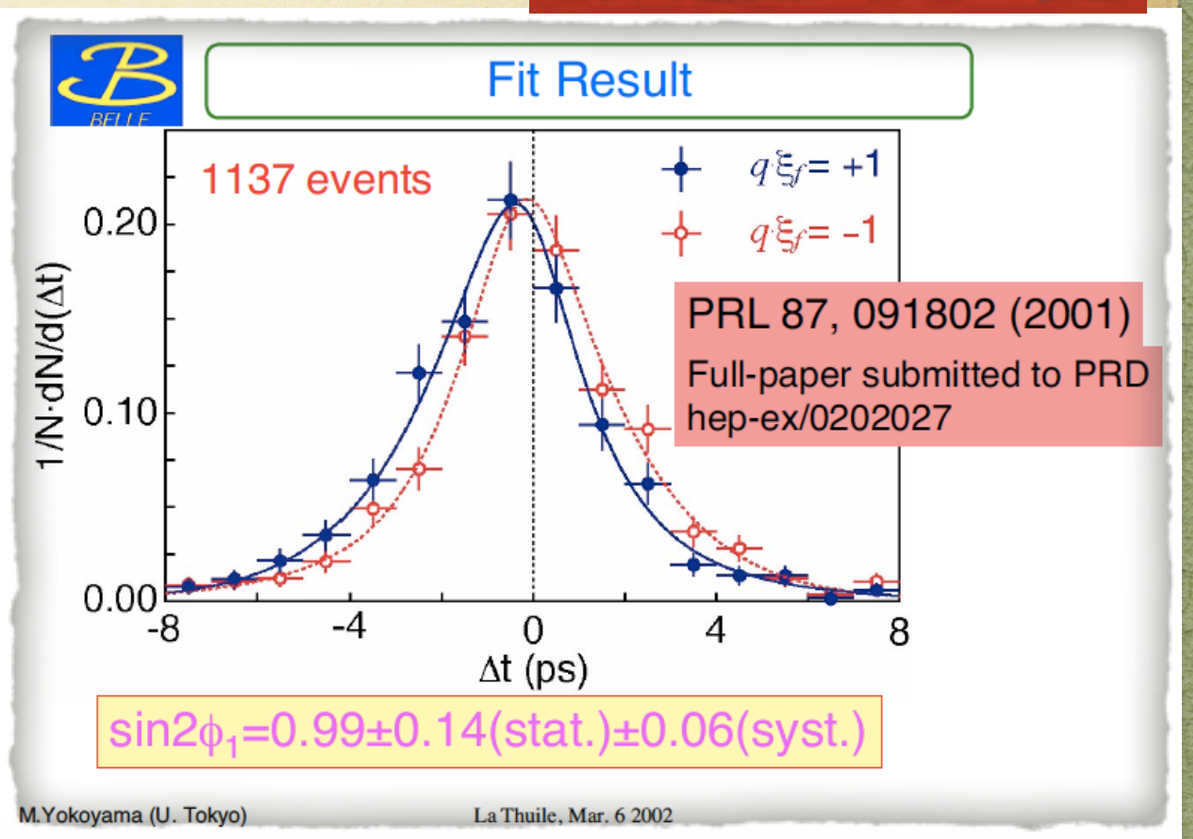
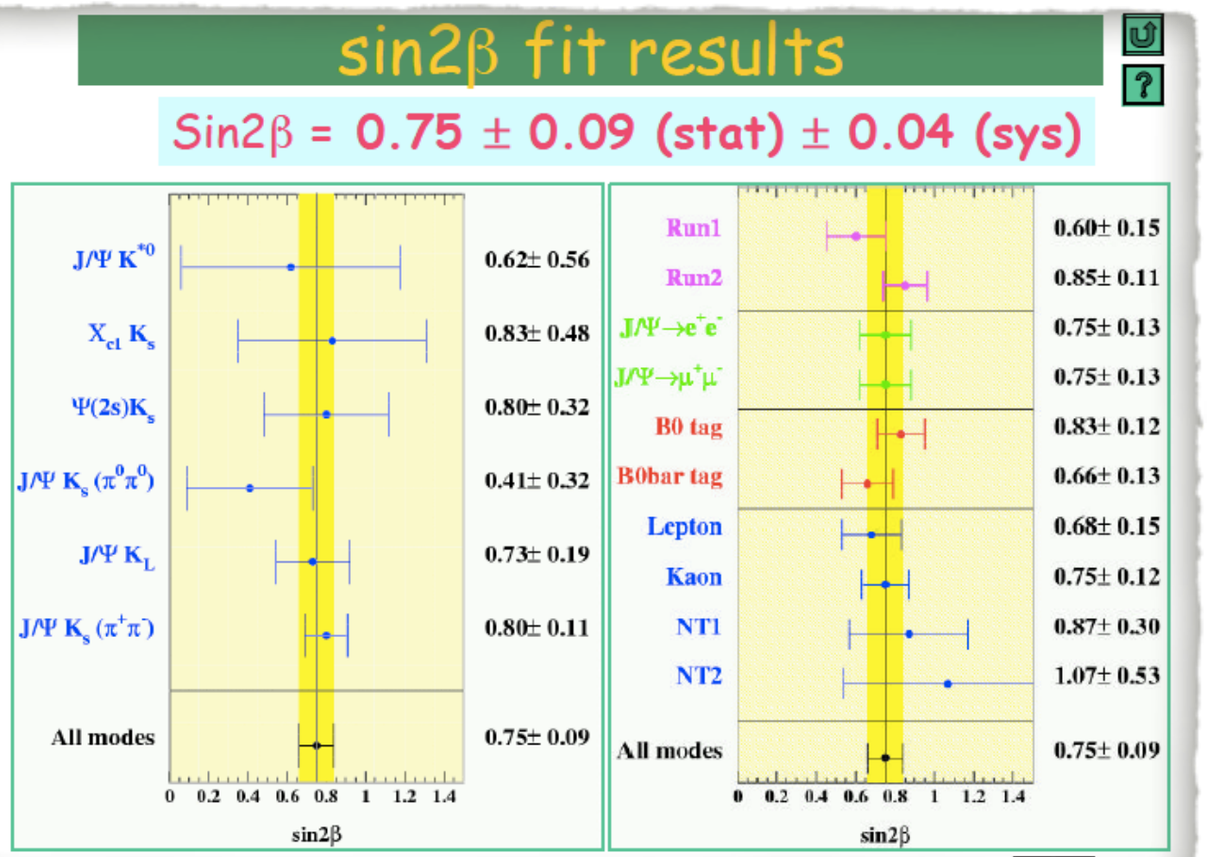


Figure 4: Region of oscillation parameters in the 3ν scenario over which the sign of Δm^2 can be determined at 90% C.L. after 200 kty and 400 kty of MONOLITH exposure. The regions excluded by CHOOZ results and allowed by Super-Kamiokande data are also shown.

2002: the year of CP violation in B





2002: direct CP violation

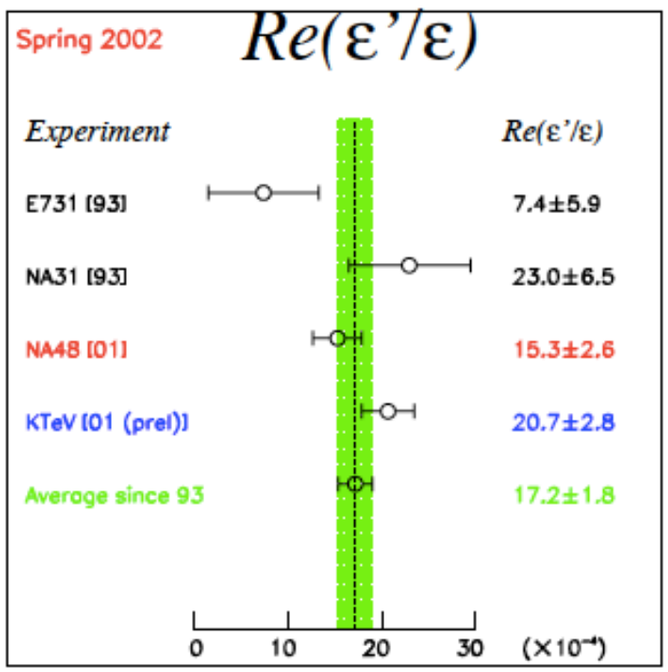
New result of *NA48* on 1998 and 1999 data

$$\epsilon'/\epsilon = (15.0 \pm 2.7) \times 10^{-4}$$

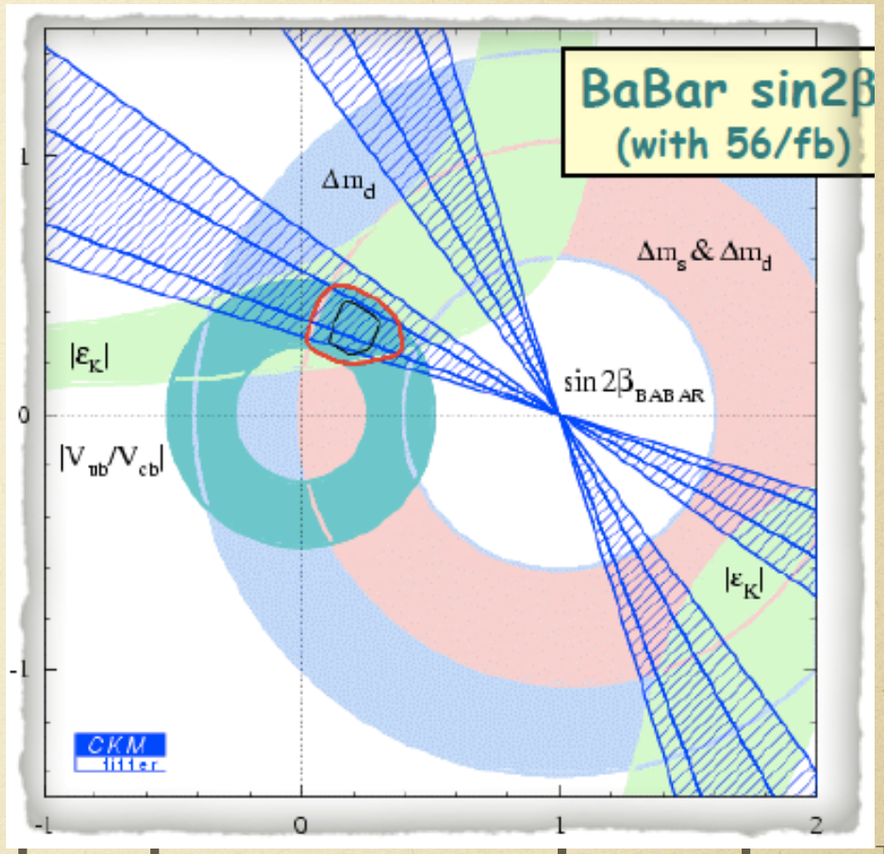
Combining with 1997 result

$$\epsilon'/\epsilon = (15.3 \pm 2.6) \times 10^{-4}$$

roves existence of direct $\mathcal{CP}$ violation at 5.9 σ



☞Direct $\mathcal{CP}$ violation established (at 7.
AND $\chi^2/\mathrm{ndf} = 5.6/3$ (Probability ~ 1



and what was sketched by Bigi in 1994 now becomes a (sad) reality. SM rules !

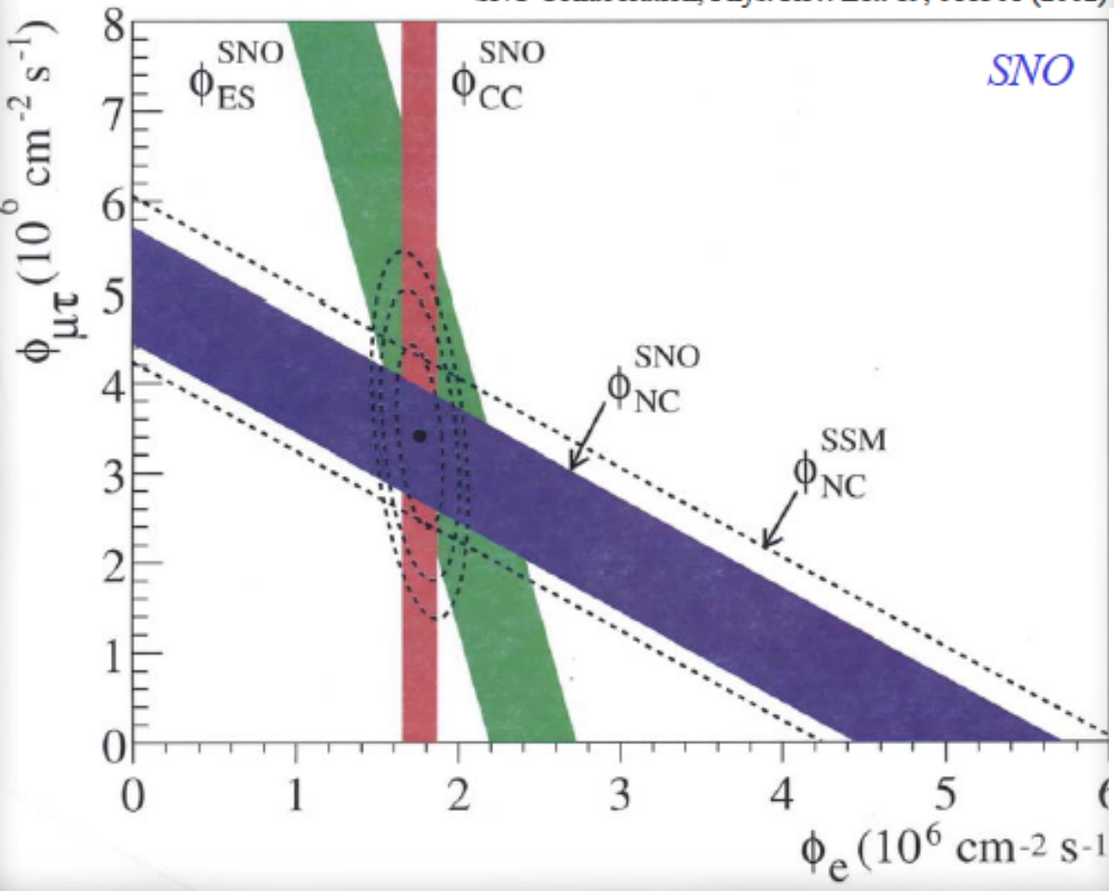
Session V – CP Violation, and Rare Decays

1.	New Measurement of Re(e'/e) by the NA48 experiment at CERN	F. Derue	*Marseille*
2.	The Measurement of e'/e by KTeV Collaboration	A. Glazov	*Chicago*

2003: neutrinos from the sun transform one into another . Do not disappear !

Flavor Content Analysis
of the 8B Solar Neutrino Flux

SNO Collaboration, Phys. Rev. Lett 89, 011301 (2002)



$\phi_{CC}^{SNO} = 1.76 \pm 0.06 \pm 0.09 = 1.75 \pm 0.11$

$\phi_{NC}^{SNO} = 5.09 \pm 0.44 \pm 0.46 = 5.09 \pm 0.64$

$\phi_{ES}^{SNO} = 2.39 \pm 0.24 \pm 0.12 = 2.39 \pm 0.27$

$\phi_{ES}^{SK} = 2.35 \pm 0.02 \pm 0.06 = 2.35 \pm 0.07$

Stat. Sys.

$\phi_{CC}^{SNO} / \phi_{8B}^{SSM} = 0.347 \pm 0.022$

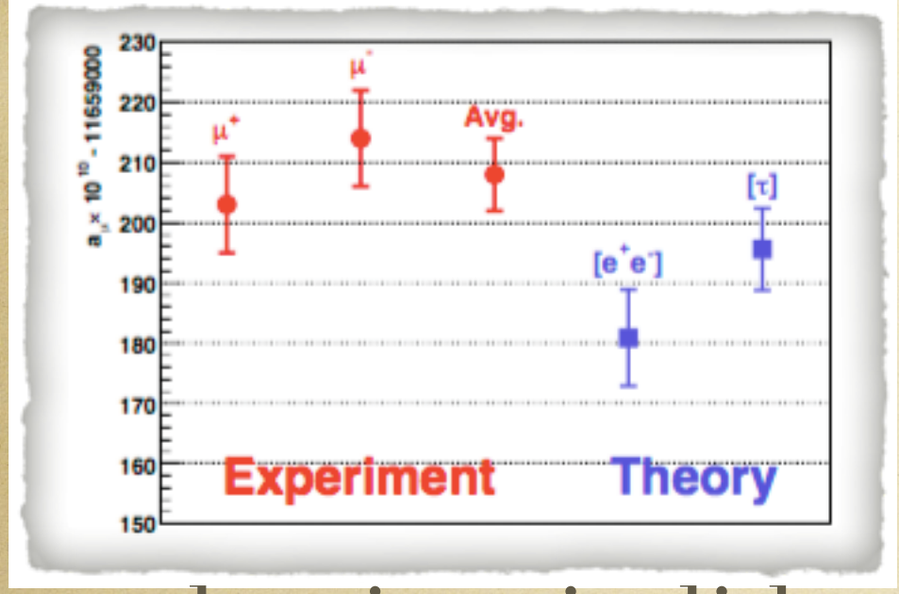
$\phi_{ES}^{SK} / \phi_{8B}^{SSM} = 0.465 \pm 0.014$

$\phi_{NC}^{SNO} / \phi_{8B}^{SSM} = 1.008 \pm 0.127$

2004: (g-2) opens a window (of opportunity ?)

6. New Results on muon g-2 (Ivan Logashenko, Boston/Novosibirsk)

$$a_\mu^{\mathrm{E821}} = (116\,592\,089 \pm 63) \times 10^{-11} \quad (0.54\,\mathrm{ppm})$$



at the time it did not grasp any special attention (2 sigma)

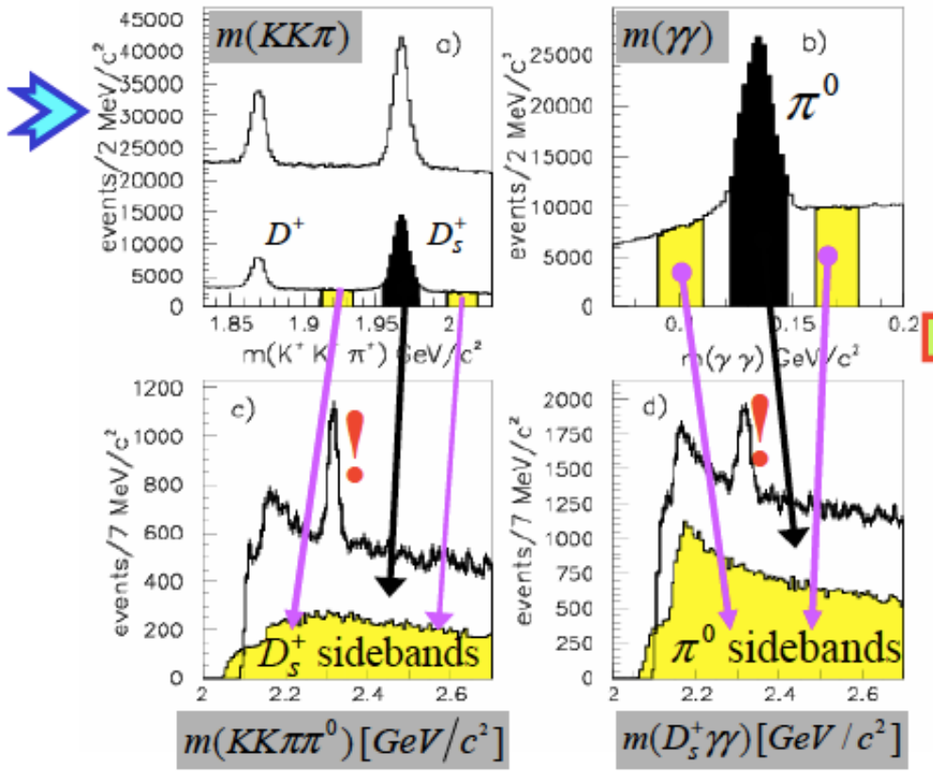
but theory has progressed in the meanwhile and now:

$$\Delta a_\mu(\mathrm{E821} - \mathrm{SM}) = (287 \pm 80) \times 10^{-11} \quad [20]$$
$$= (261 \pm 78) \times 10^{-11} \quad [21]$$

not that 3.6 sigma is anything special but a new exp is planned in FNAL

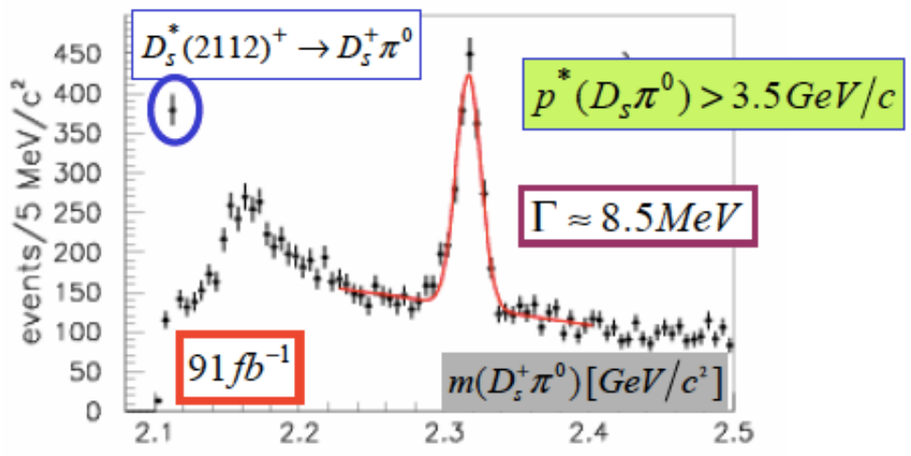
2004: hadrons are not necessarily made by 2 or 3 quarks !

Two surprising new Charmed Mesons : $D_{sJ}^{*}(2317)^{+}$ & $D_{sJ}(2458)^{+}$



[Phys.Rev.Lett. 90,24(2003)]

BaBar discovered a new narrow state in the $D_s^+\pi^0$ invariant mass distribution near 2.32GeV/c²

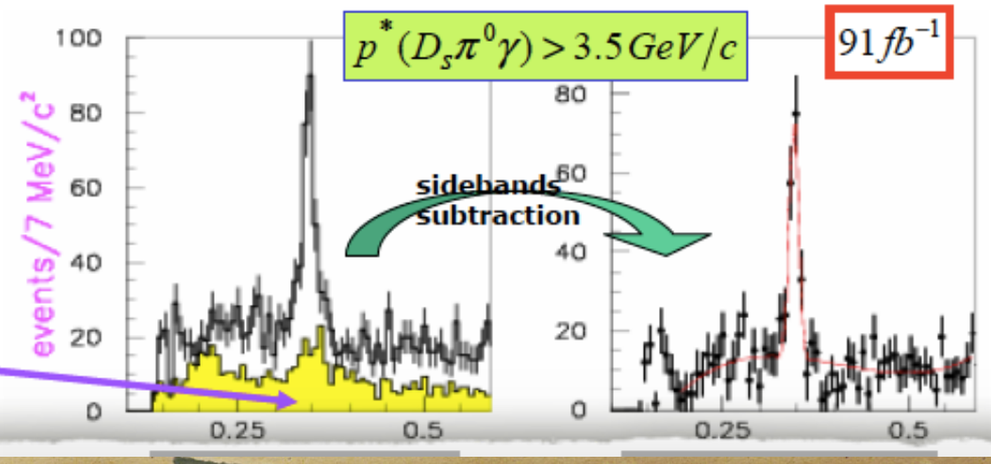


[Accepted by P.R.L. ; hep/ex-0310050]

BaBar observed a second new narrow state in the $D_s^{*+}\pi^0$ invariant mass distribution near 2.46GeV/c²

$$\Delta m(\pi^0) = m(D_s^+\pi^0\gamma) - m(D_s^+\gamma)$$

This state may decay to $D_s^+\pi^0\gamma$ through $D_s^{*+}\pi^0$ or $D_{sJ}^{*+}(2317)\gamma$



2005: Dream Beam

LASER WAKEFIELD ACCELERATION OF HIGH ENERGY QUASI–MONOENERGETIC ELECTRON BEAMS

J. Faure, Y. Glinec, V. Malka
Laboratoire d'Optique Appliqueé, Ecole Polytechnique, ENSTA/CNRS/UMR 7639
Chemin de la Huniere, 91761, Palaiseau, France
A. Pukhov, S. Kiselev, S. Gordienko
Institut fur Theoretische Physik, Heinrich-Heine-Universitat Duesseldorf
40225 Duesseldorf, Germany

We demonstrate the generation of high quality electron beams resulting from the interaction of ultrashort and ultraintense laser pulses with underdense plasmas. The electron energy distribution is quasi-monoenergetic and peaks at 170 MeV.

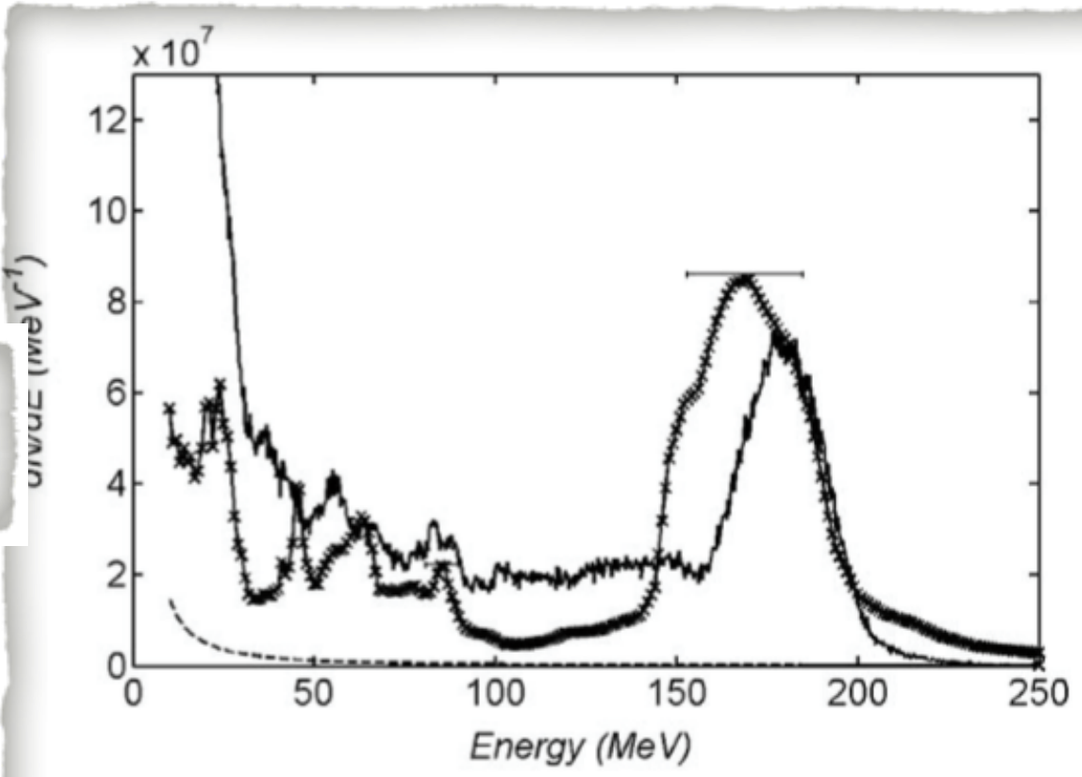
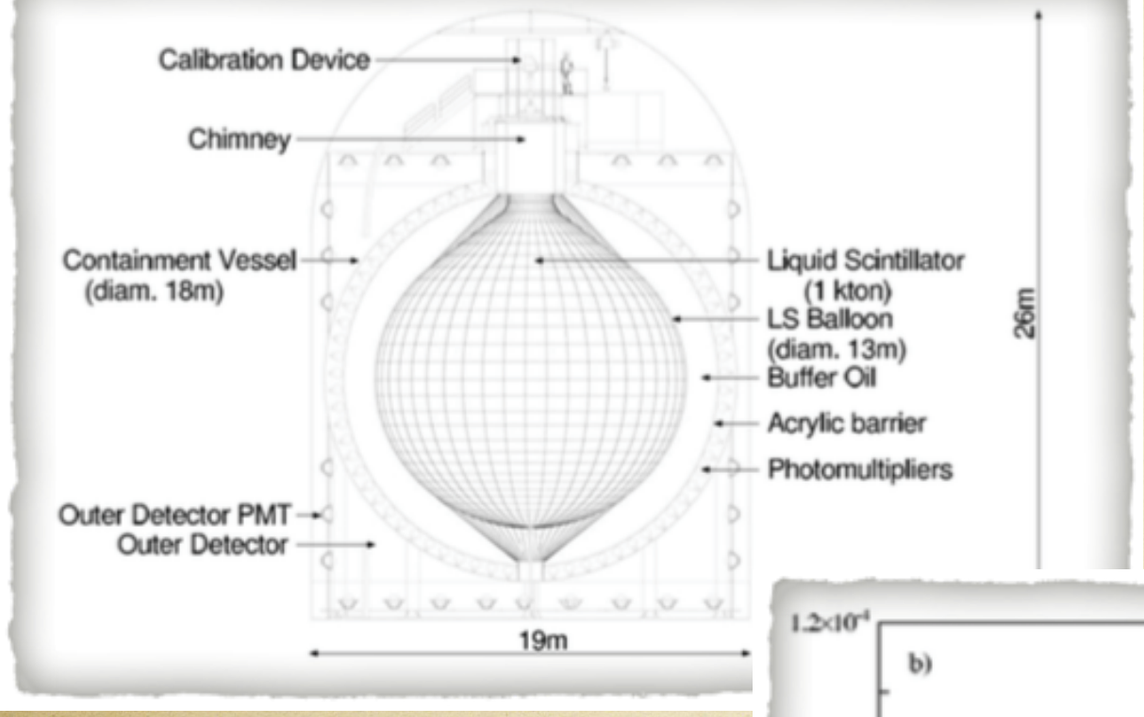


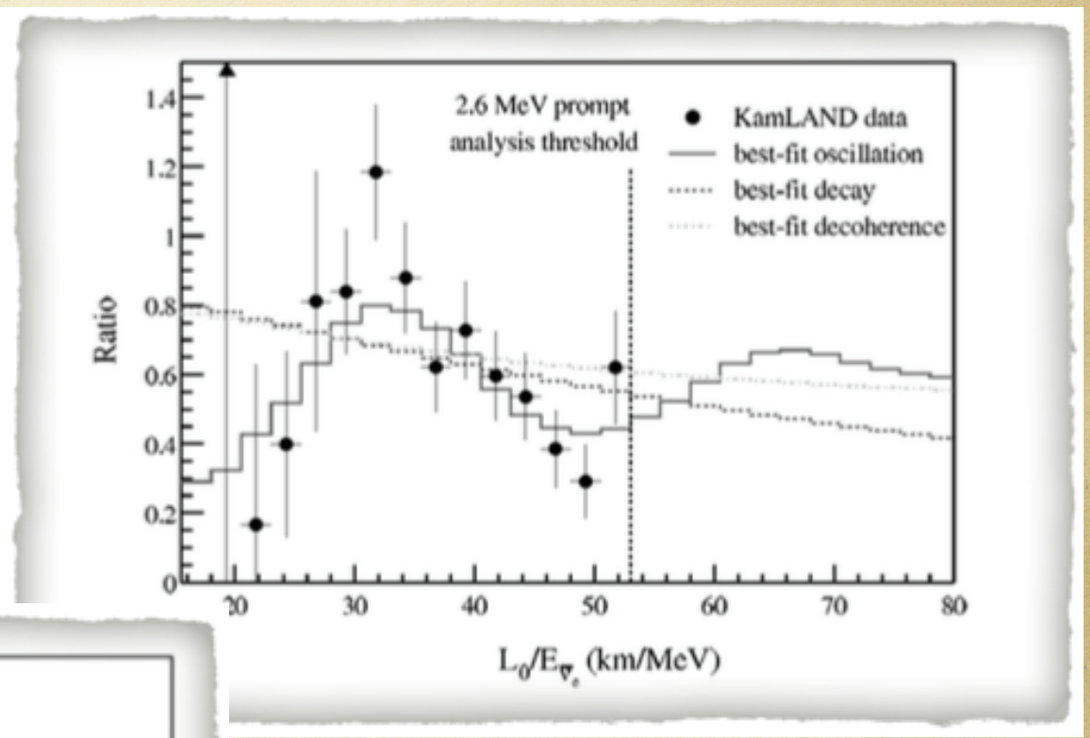
Figure 3: *Electron spectrum corresponding to the deconvolution of the image of figure 2b ($n_e = 6 \times 10^{18} cm^{-3}$. The crosses are the experimental result and the full line represents the result of 3D PIC simulations. The horizontal bars represent the spectrometer resolution.*

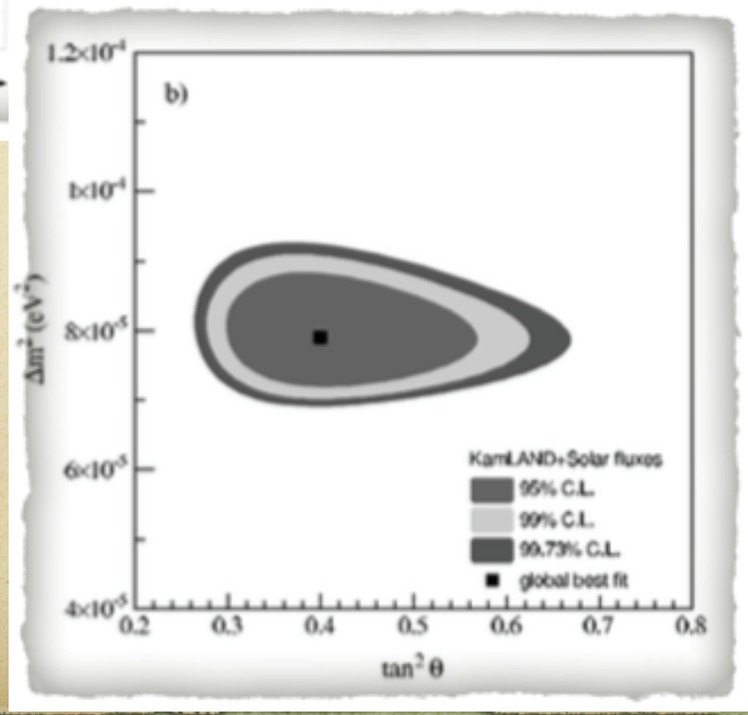
2006: KamLAND

KamLAND: PRESENT STATUS AND FUTURE PROSPECTS

K. Nakajima







2007: I was fascinated by

AN INTRODUCTION TO COSMIC RAYS AND GAMMA-RAY BURSTS, AND TO THEIR SIMPLE UNDERSTANDING

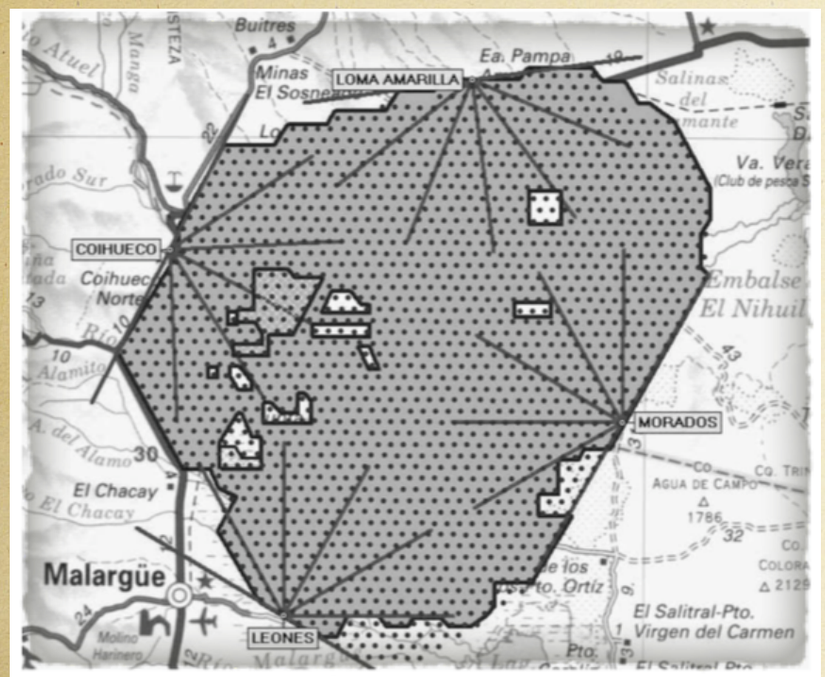
Alvaro De Rújula

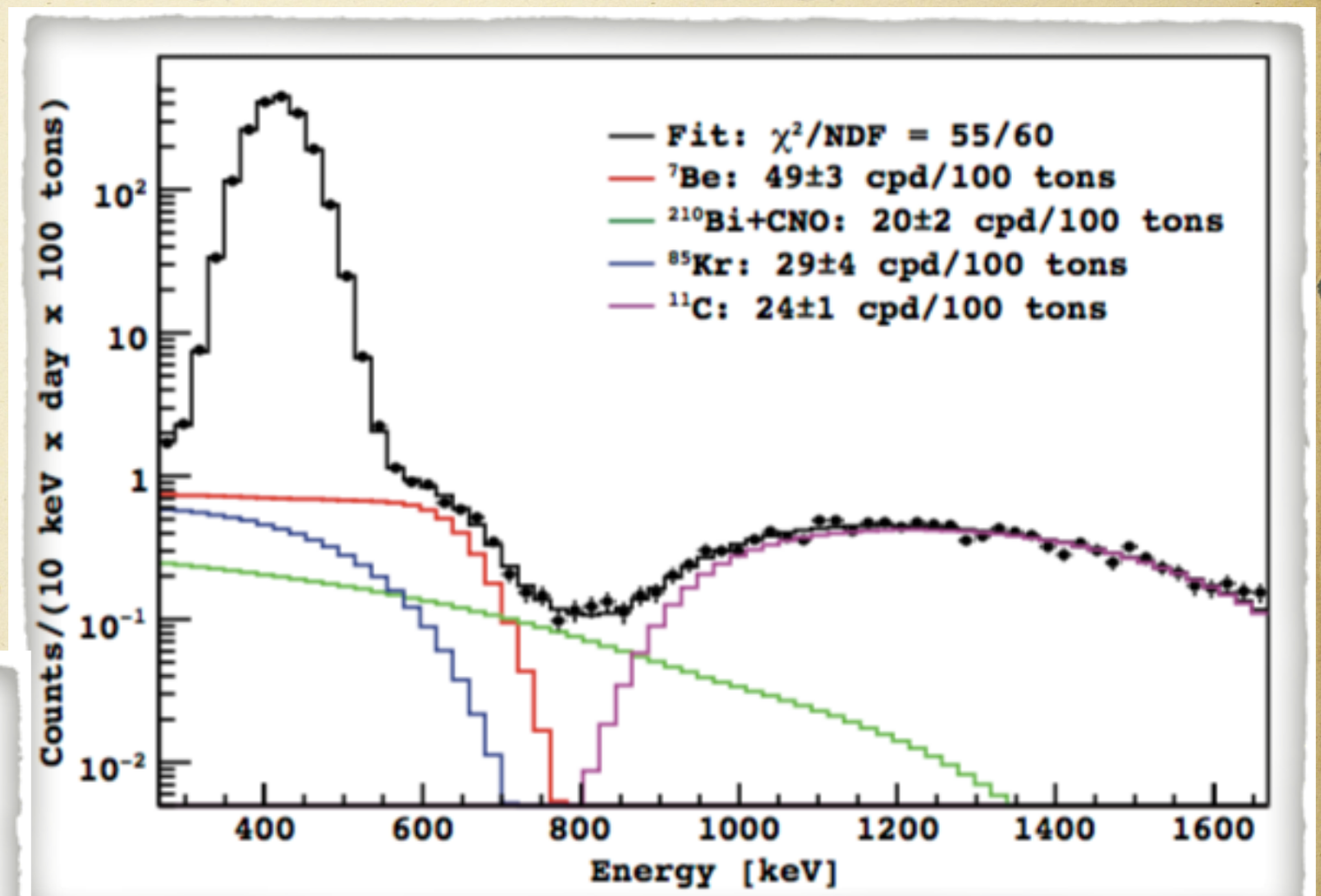
Physicists, unlike ordinary year-counting mortals, live in 'eras'. Many are waiting for the LHC era or the Plank era, GRB astronomers are in their 'Swift era'.

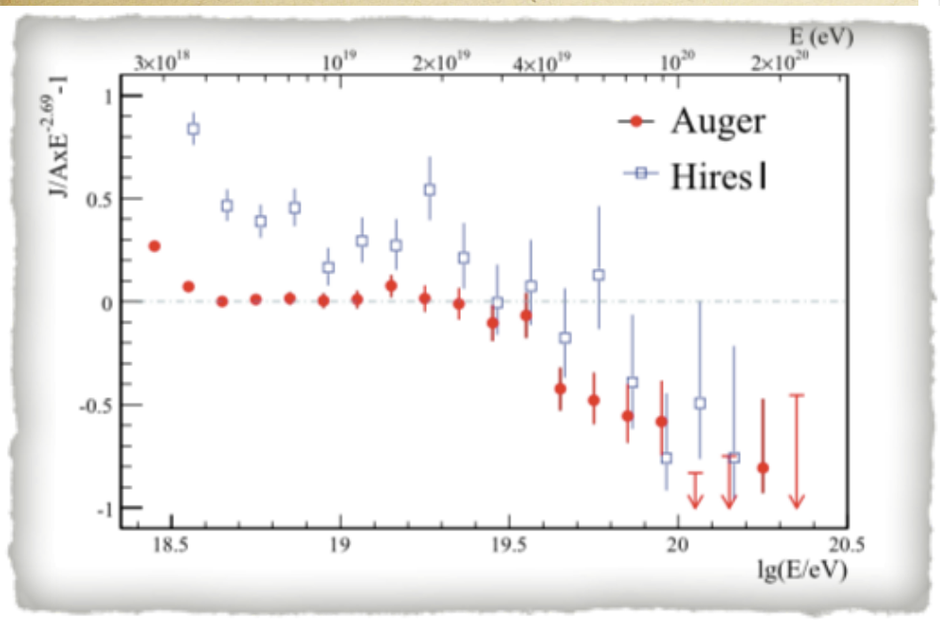
I have shown that the problem of GRBs is convincingly –i.e. predictively– solved and that, on the same simple basis, all properties of CRs can be easily derived. Only an overwhelmed minority recognizes these facts, in contradiction with Popper's and Ockham's teachings. I would conclude with a dictum attributed to Lev Landau: *'In astrophysics, theories never die, only people do.'*

I have to admit that I am somewhat partisan

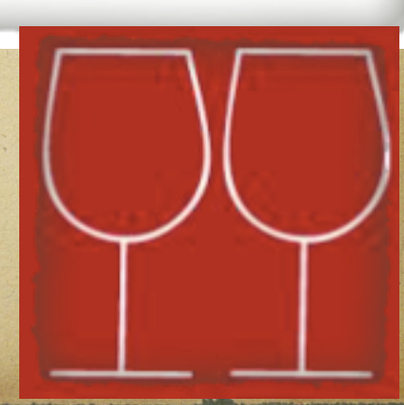
2008: Auger & Borexino





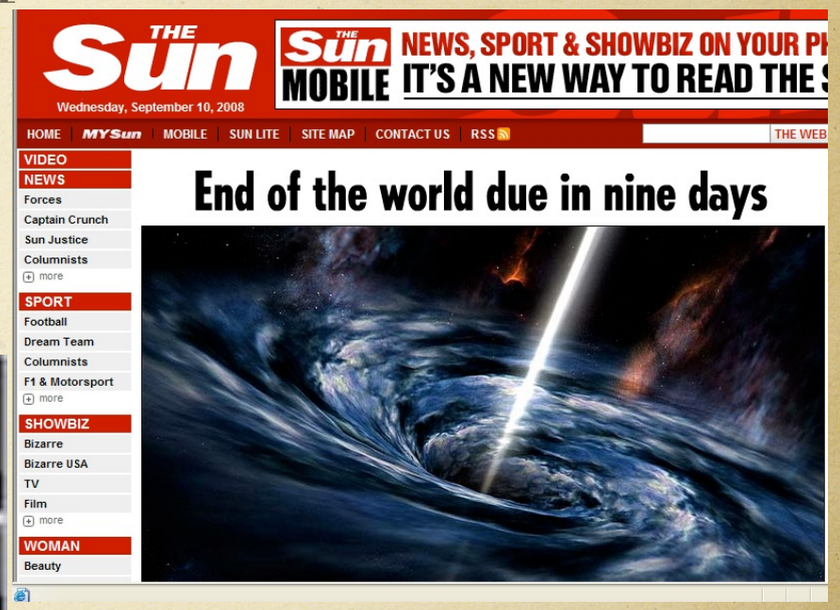


⁷Be finally !

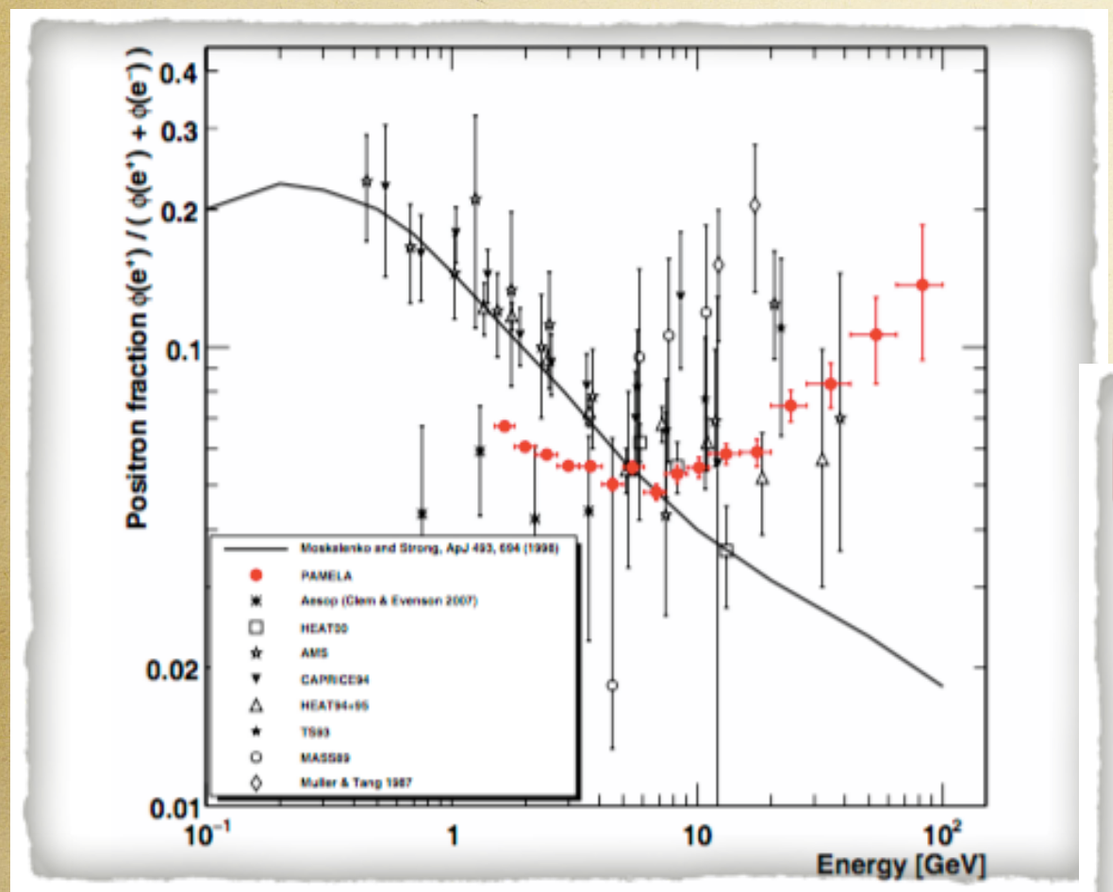


2009

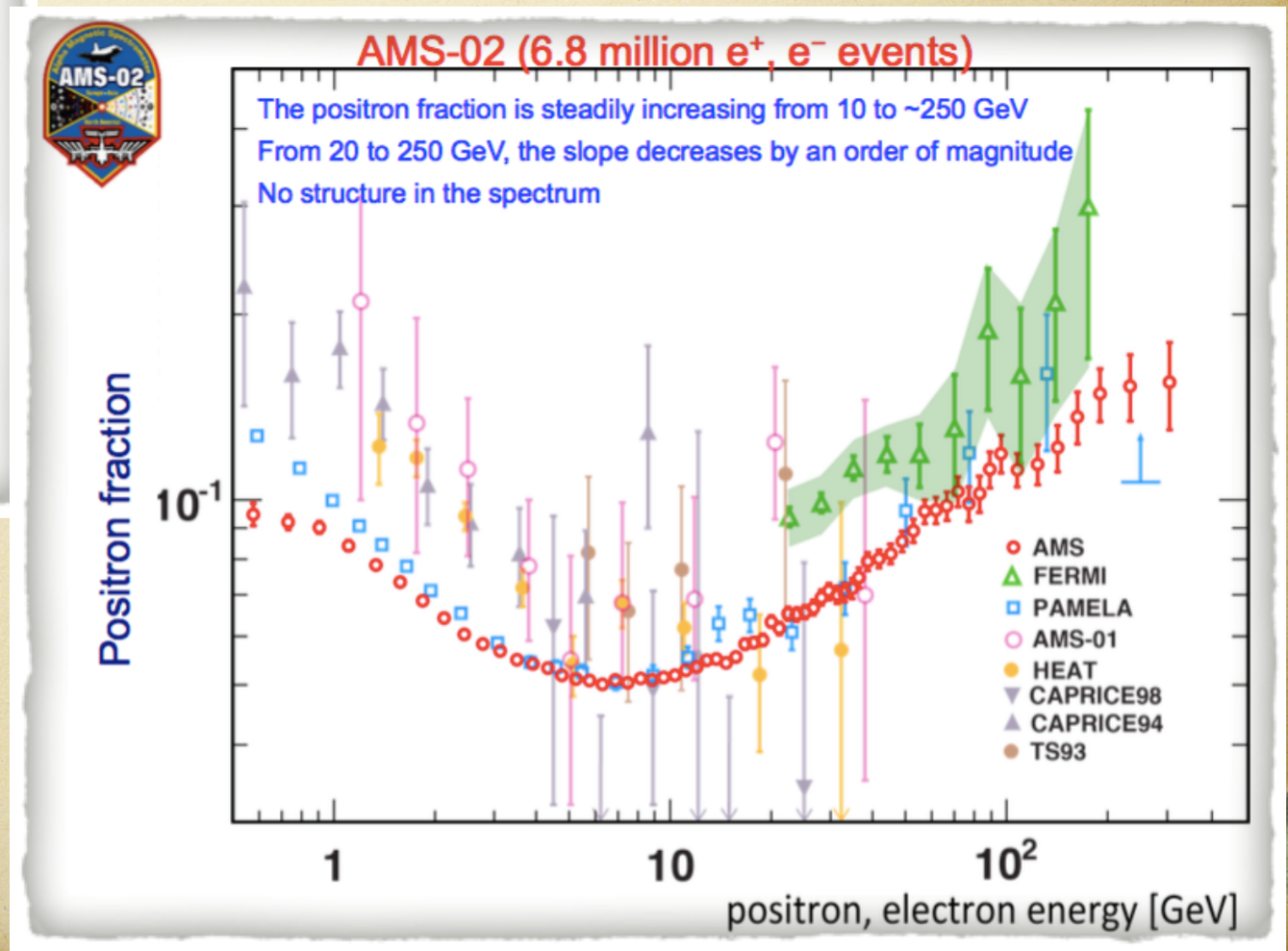
- LHC started in 2008, however in a peculiar unlucky way



2009: PAMELA positrons

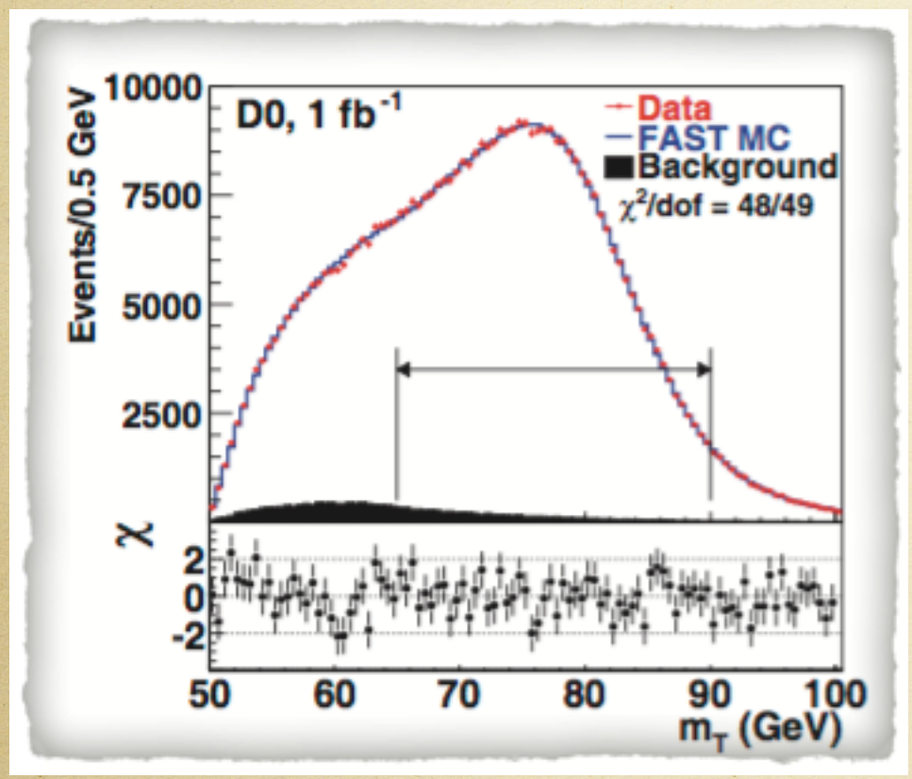


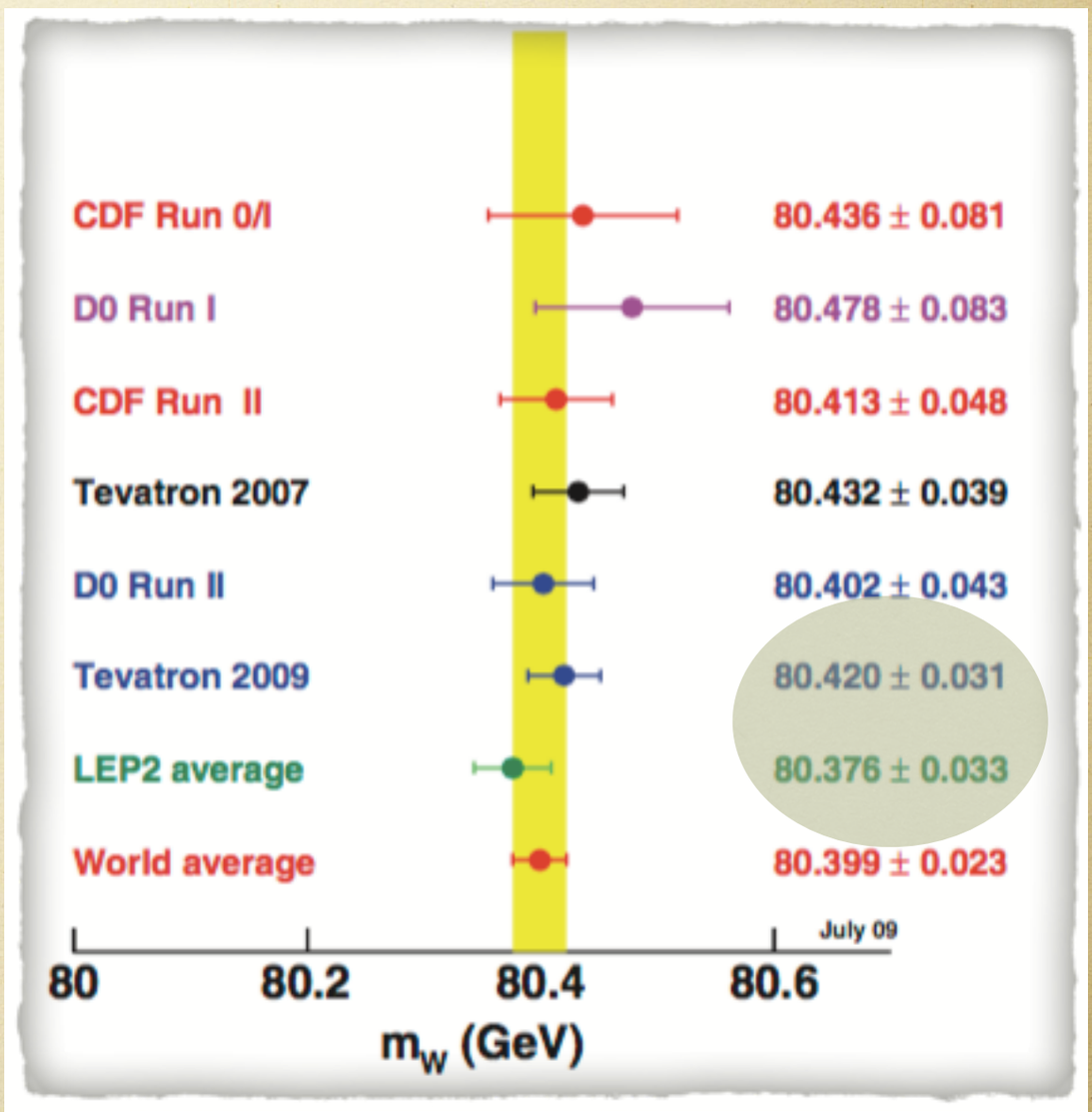
that NOW is a possibility for a discovery



an interesting feature !

2010: Tevatron W mass eventually wins over LEP





2011: let me remember a Master of Science

The early days of QCD (as seen from Rome)

G. ALTARELLI

Dipartimento di Fisica "E. Amaldi", Università di Roma Tre and INFN
Sezione di Roma Tre - I-00146 Rome, Italy and
Department of Physics, Theory Unit, CERN - CH-1211 Geneva 23, Switzerland

No secret revealed
It was 70th birthday
of Mario

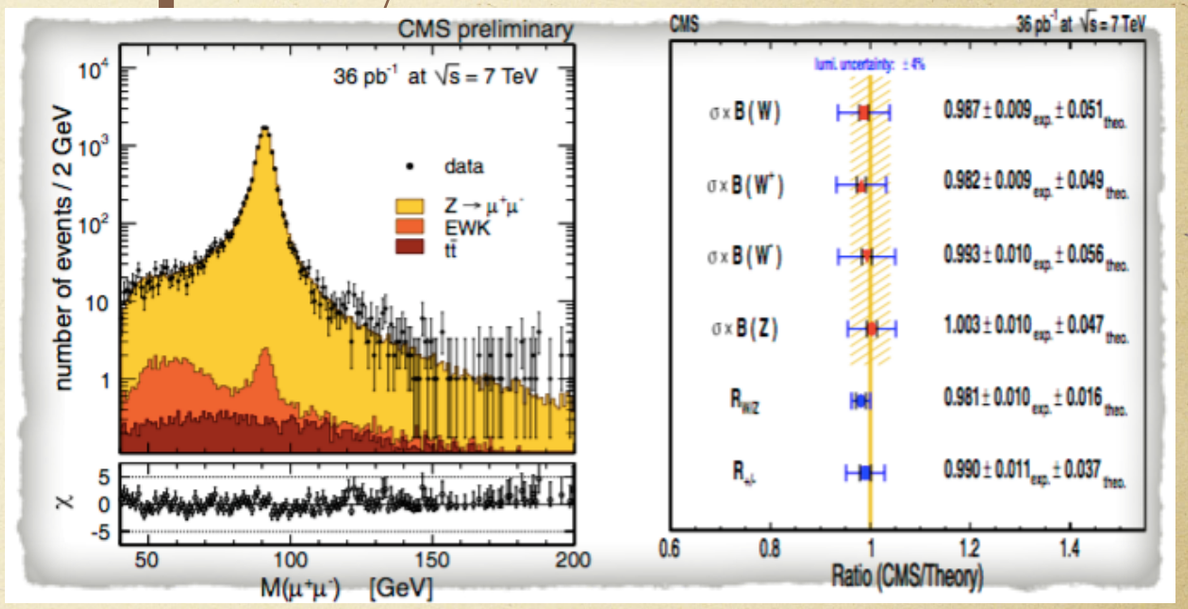
om the left: Mario Greco, Yogi Srivastava and Guido Altarelli in 1979

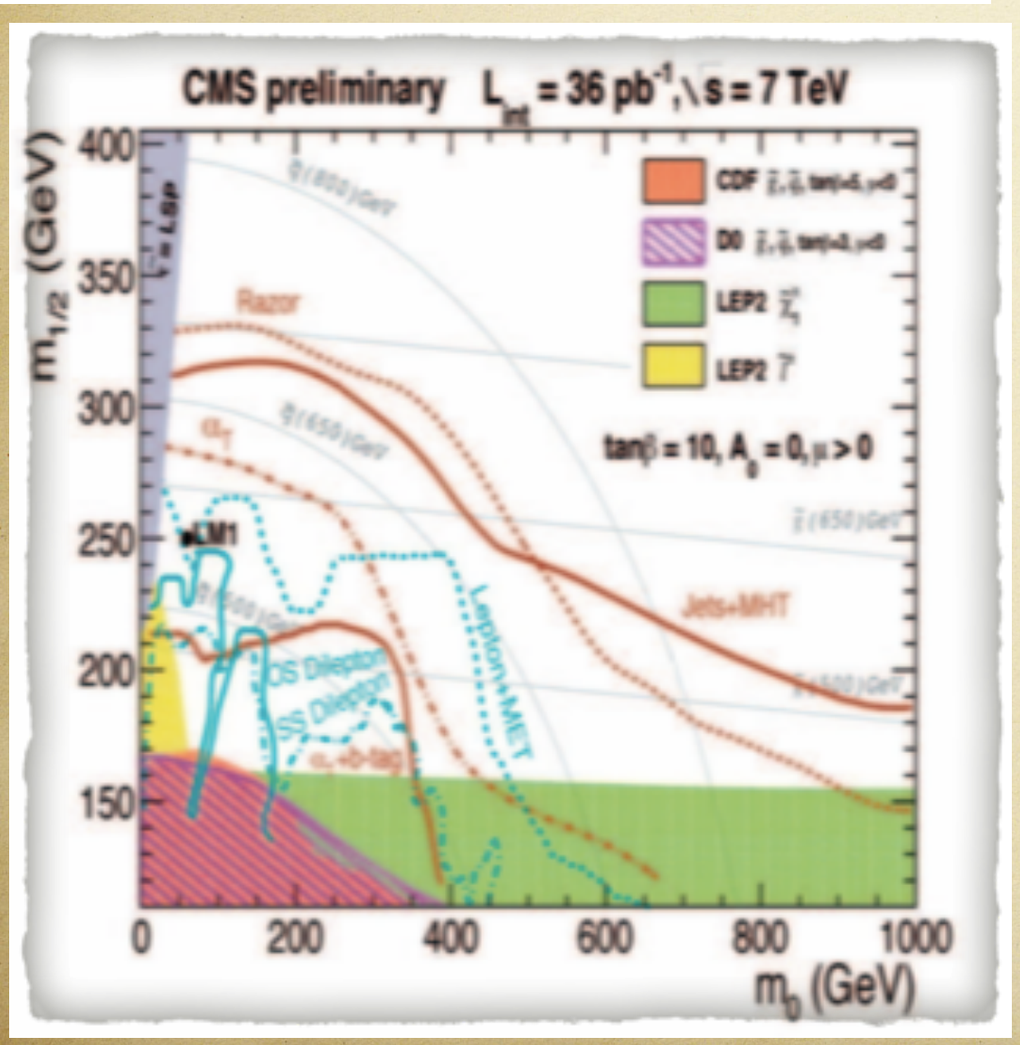
2011: LHC starts to produce physics

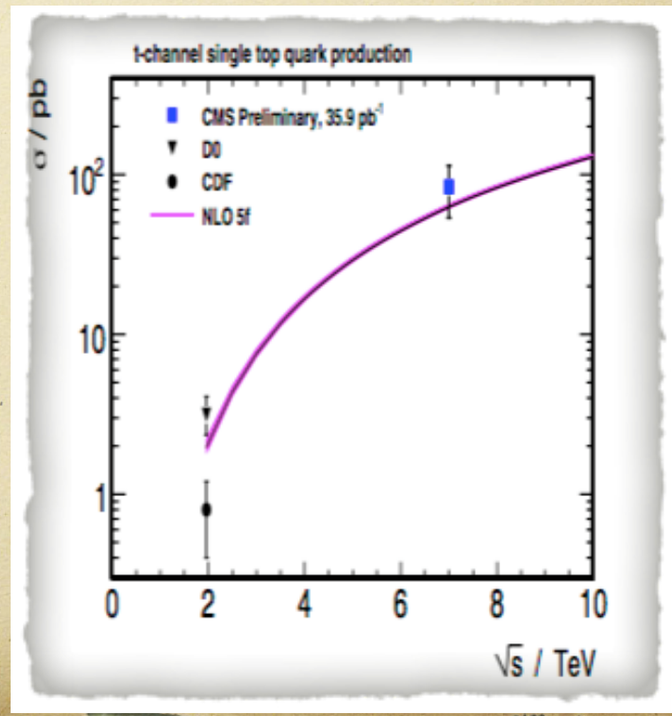
First physics results from the CMS experiment at the LHC

G. Tonelli

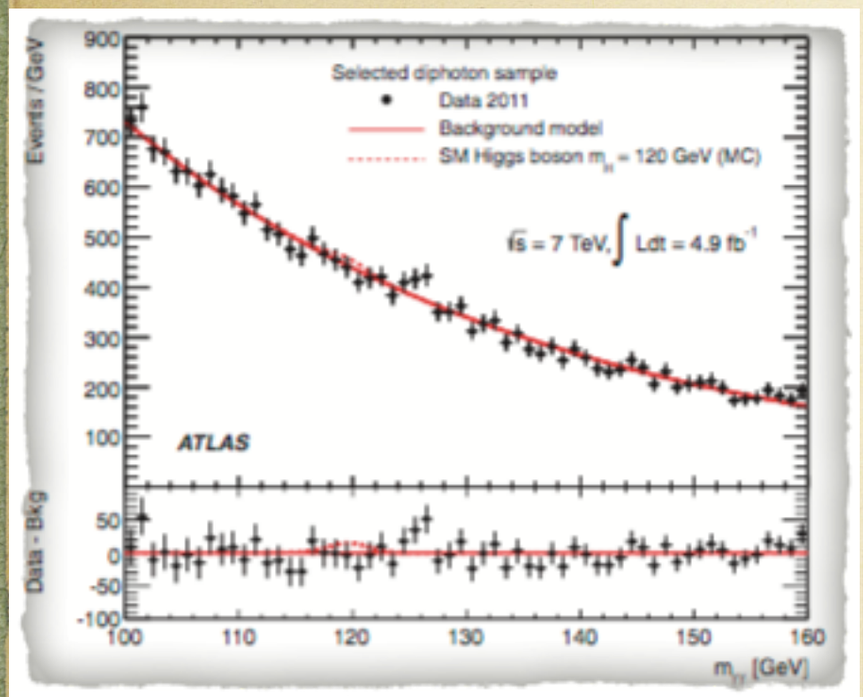
CERN - Geneva, Switzerland and
INFN, Sezione di Pisa and Università di Pisa - Pisa, Italy

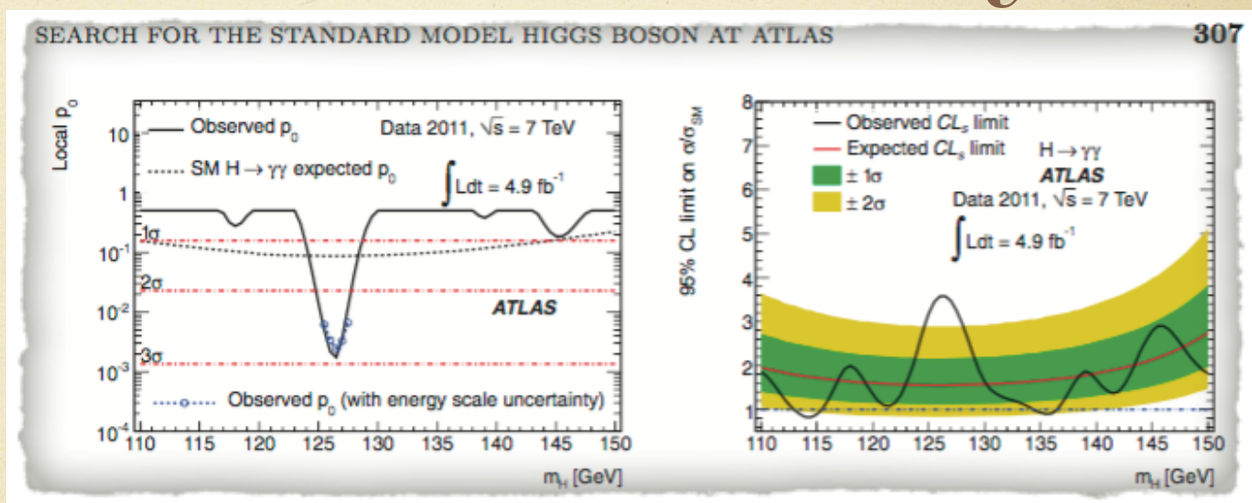






2012: this time LaThuile was a bit too early





Interpreting the 125 GeV Higgs

D. Carmi[1], A. Falkowski[2], E. Kuflik[1] and T. Volansky[1]

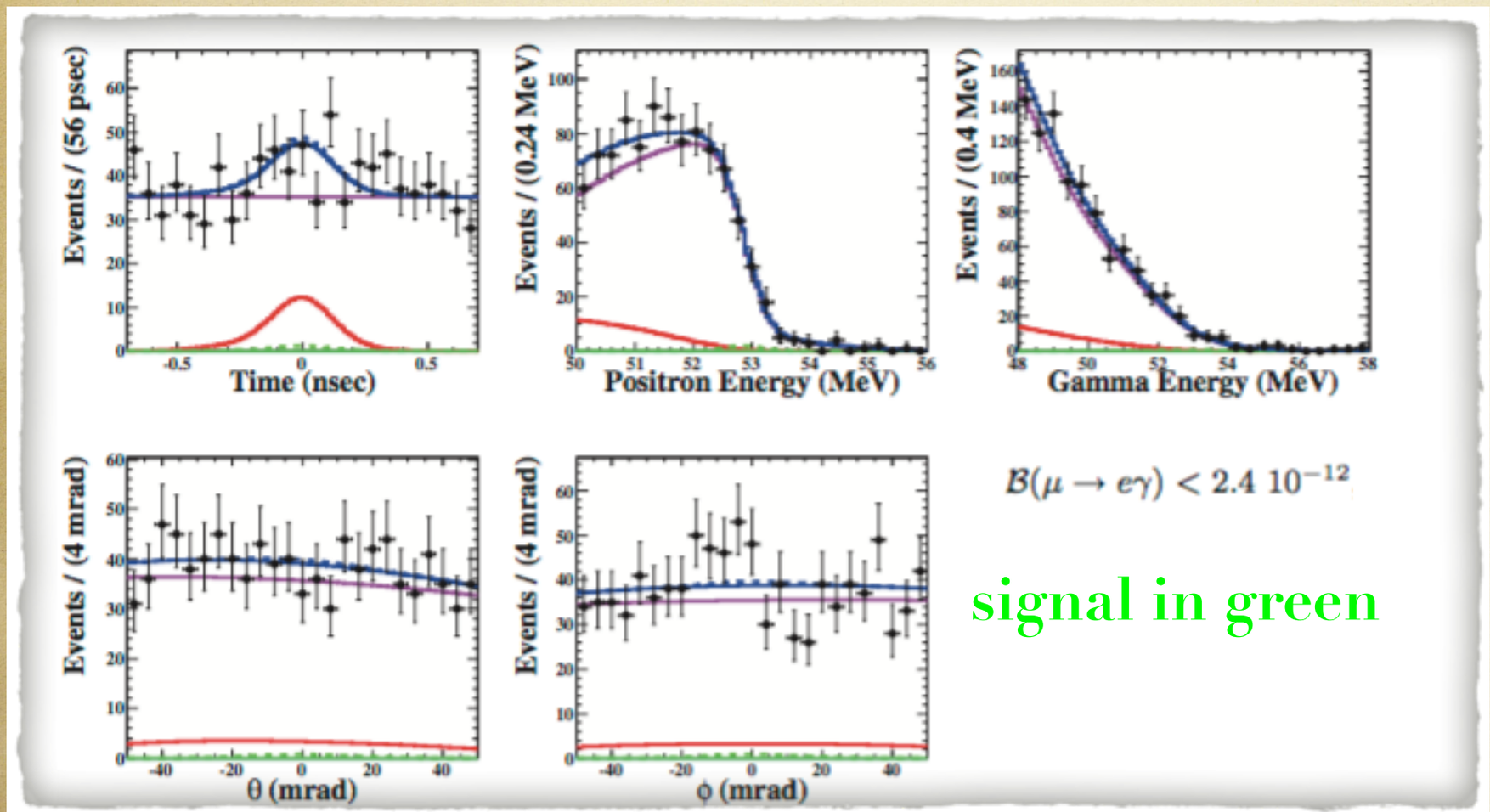
([1]) *Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University Tel-Aviv 69978, Israel*

([2]) *Laboratoire de Physique Théorique d'Orsay, UMR8627–CNRS Université Paris–Sud - Orsay, France*

something not discovered yet gets interpreted.
Theorists have a competitive advantage !

2012: the normal year

Searching for $\mu \to e\gamma$ with MEG



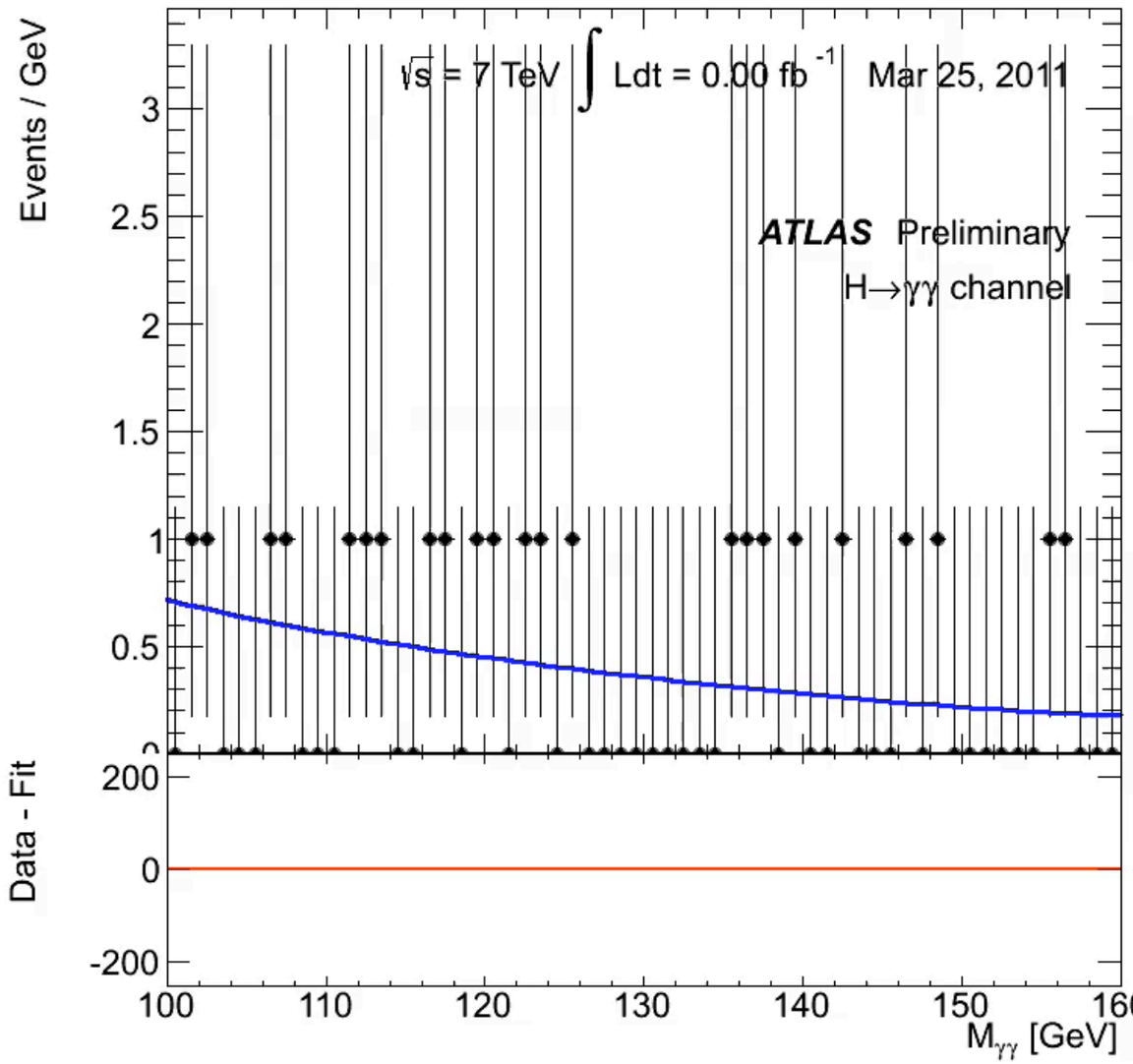
$\mathcal{B}(\mu \to e\gamma) < 2.4\ 10^{-12}$

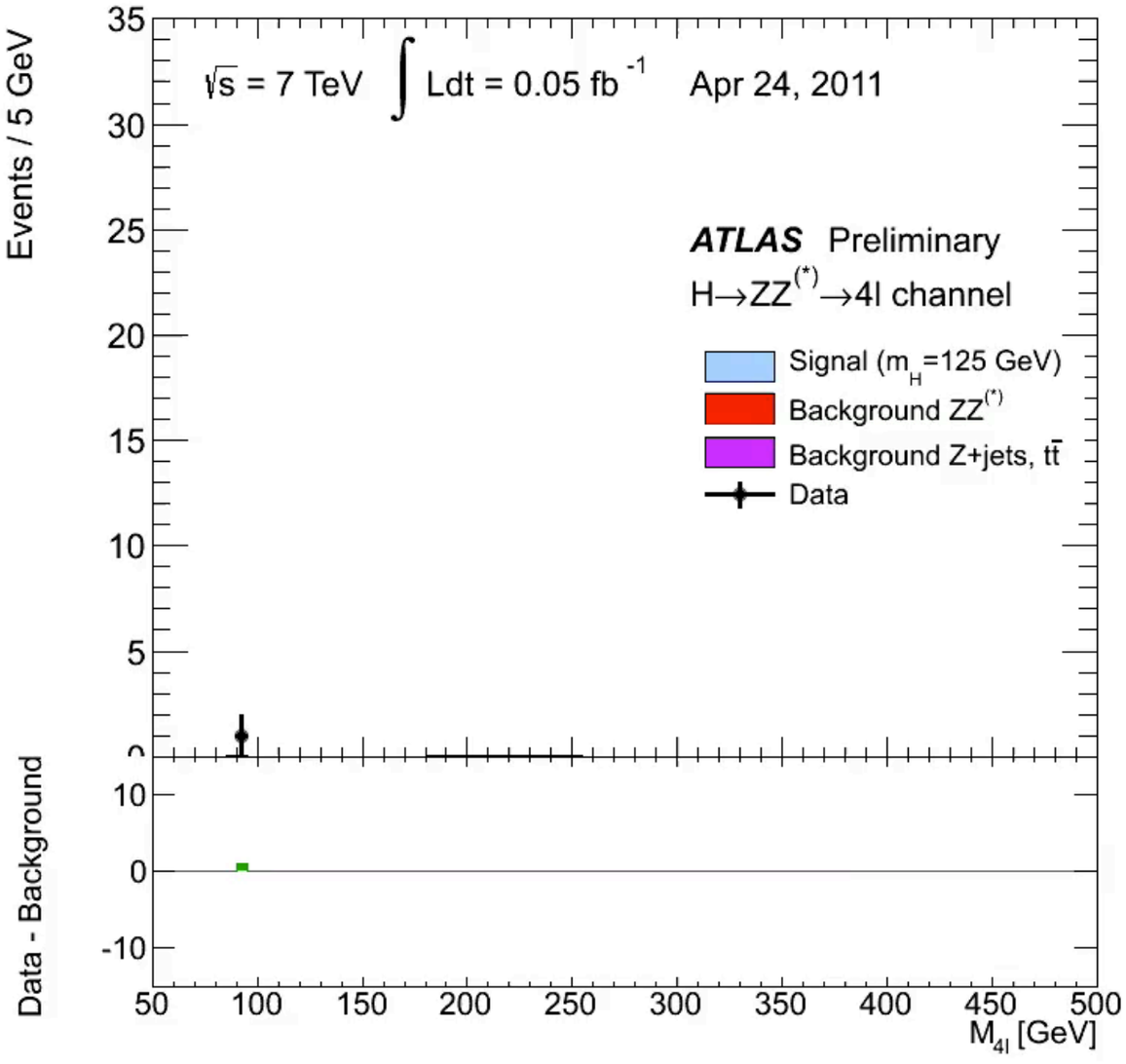
signal in green

End of an illusion

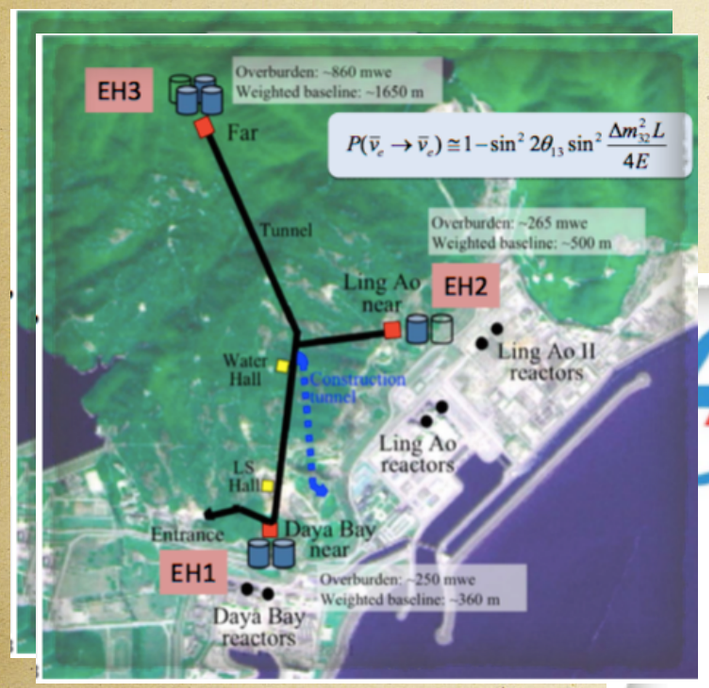
remember that in 2009 they had seen some hint of a signal (well 3 events in the ROI)

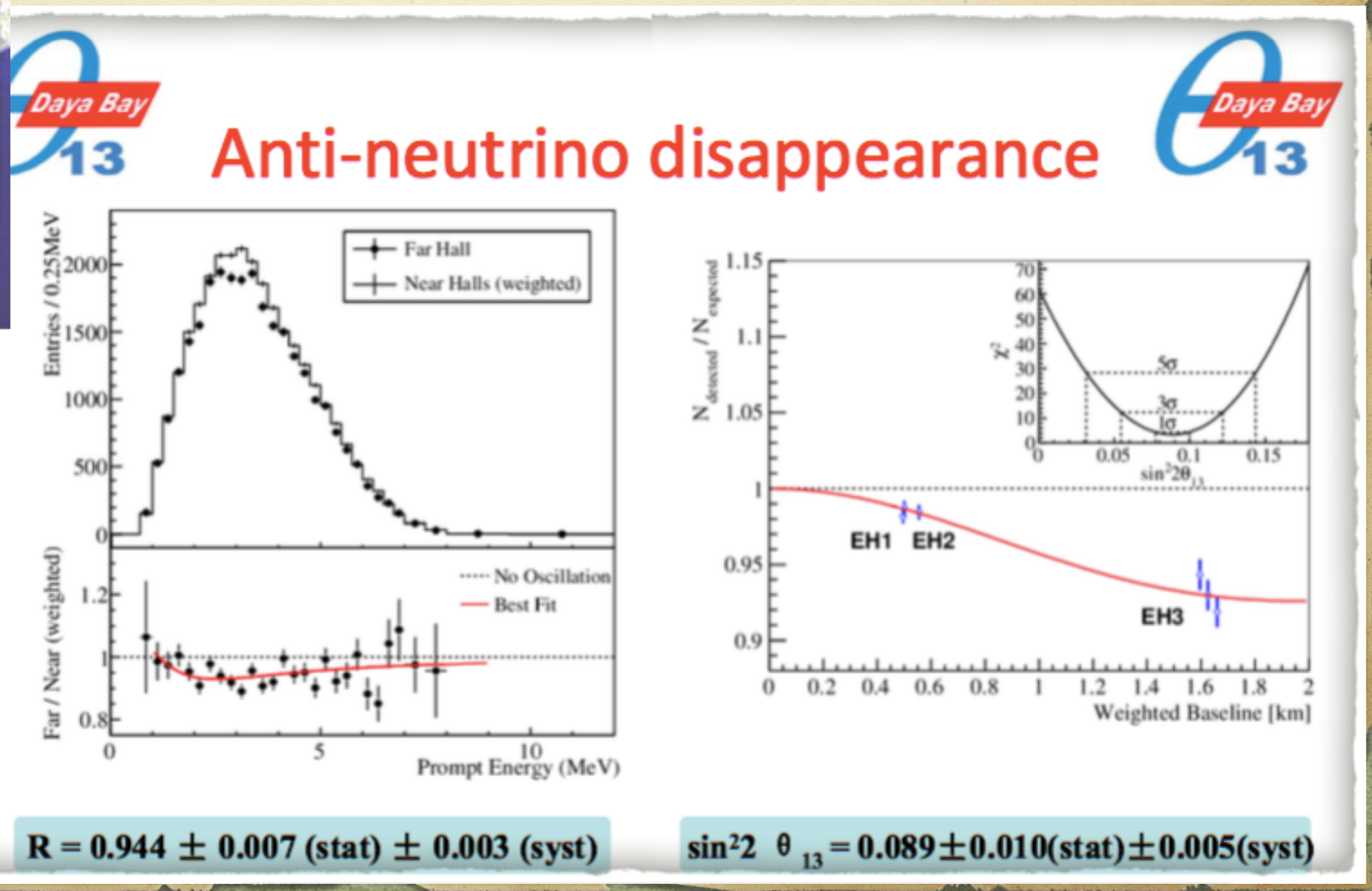
2013: here it is
Higgs boson in its full glory



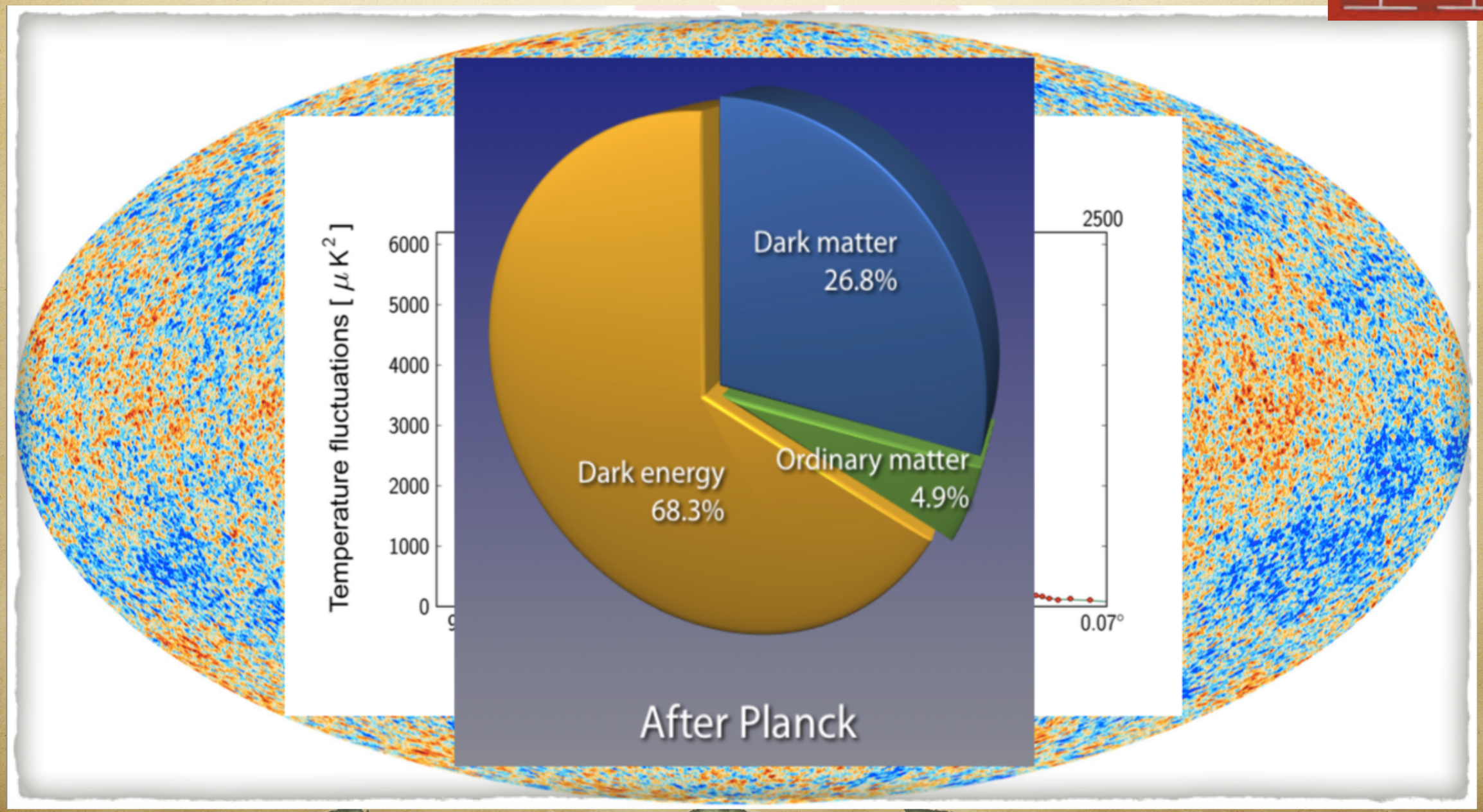


2013: $\sin^2\theta_{13}$

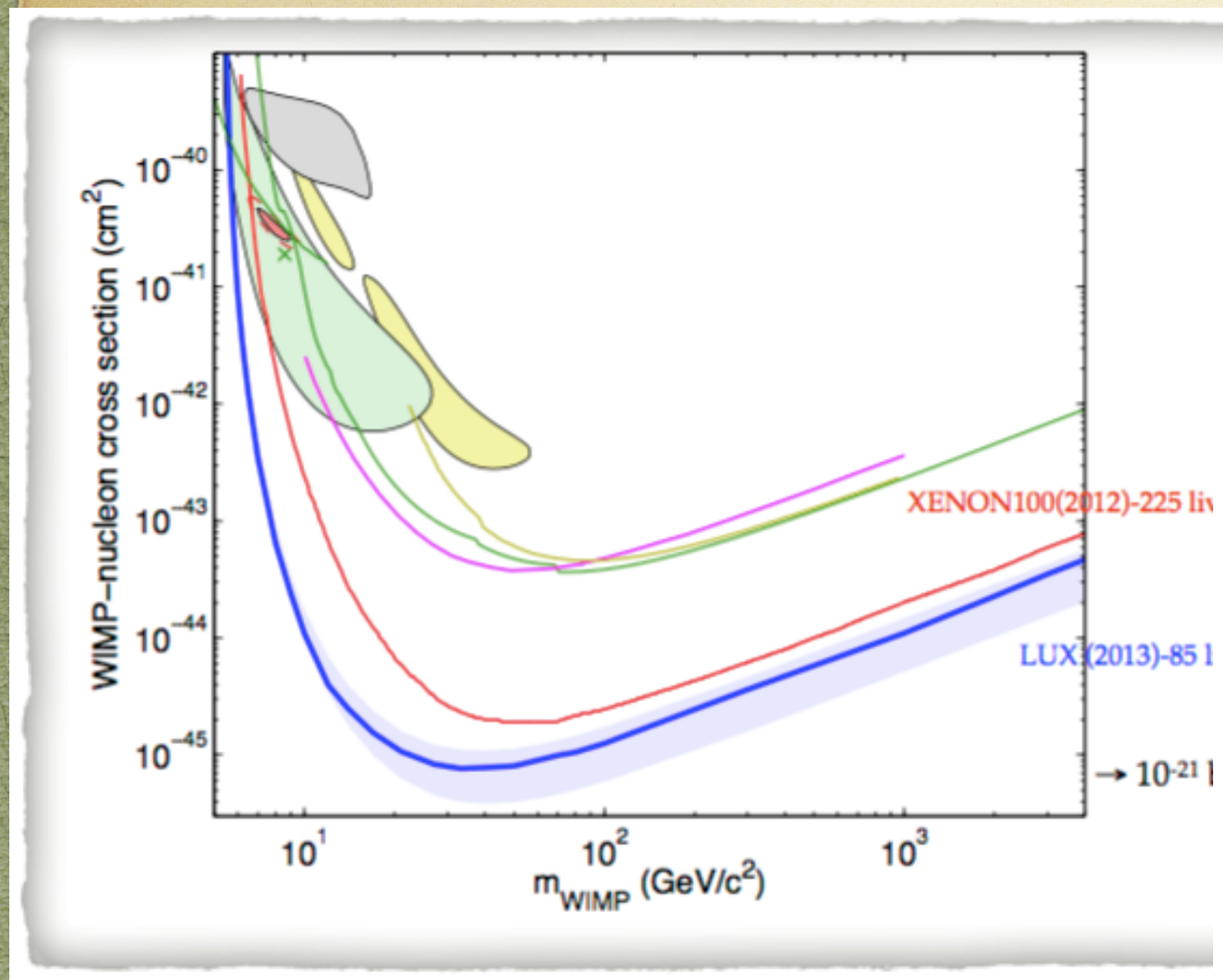


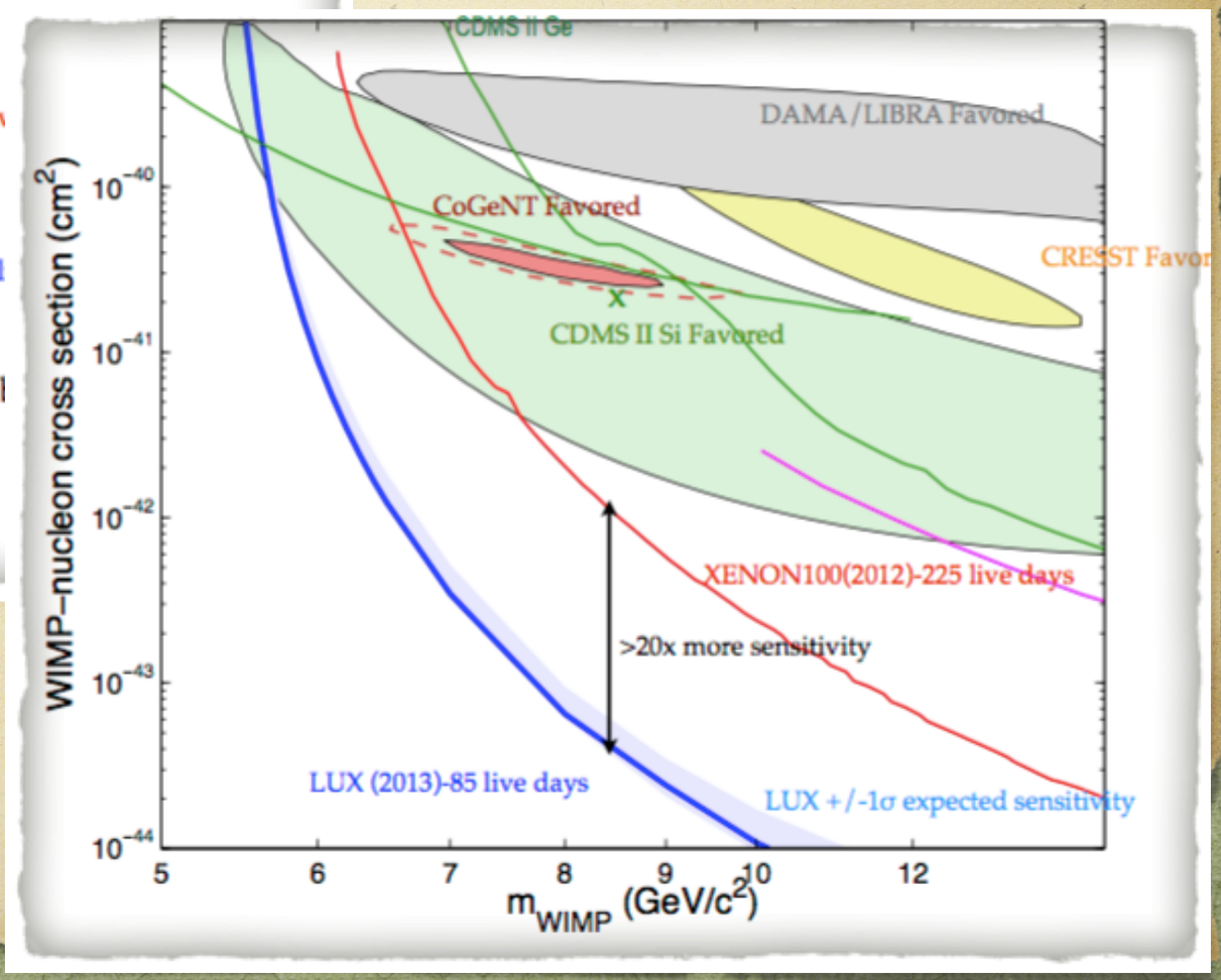


2014: Planck corrects the Universe composition



2014: Looking for Dark Matter (and getting a conflict with DAMA/LIBRA)





2014: yet another confirmation of the almighty SM

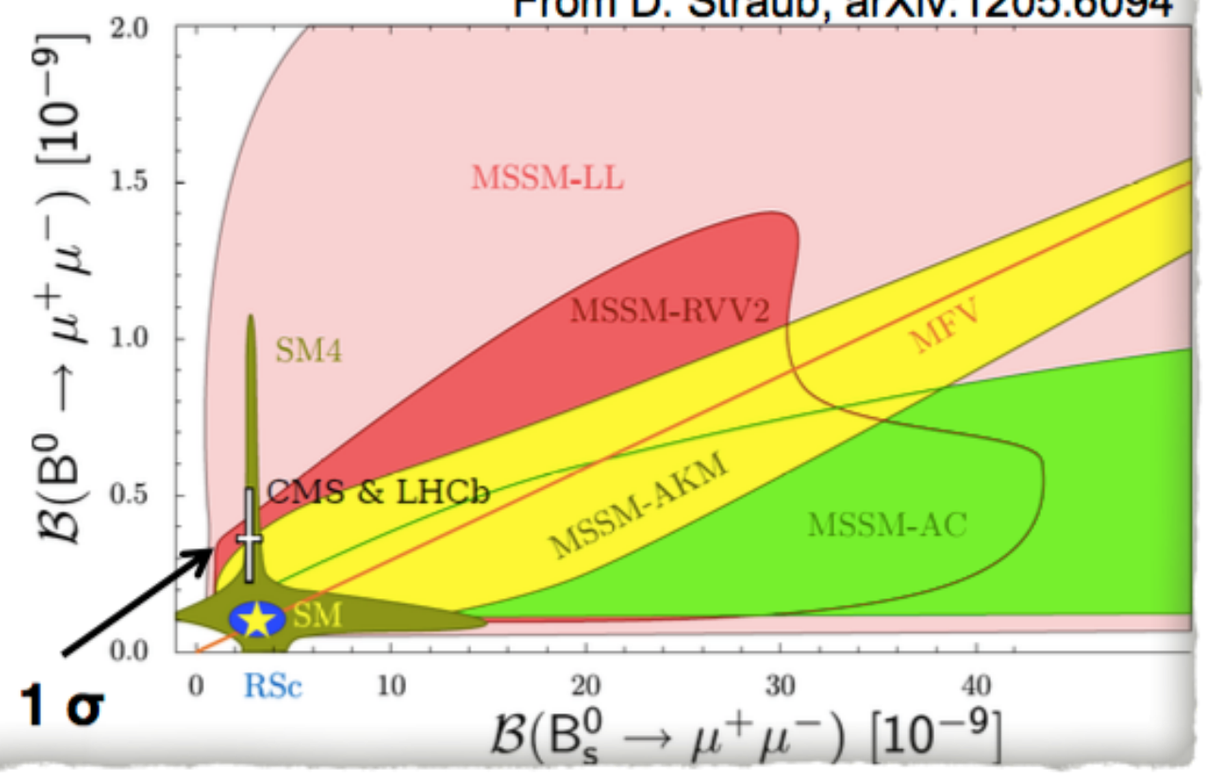
- CMS (25 fb^{-1}) and LHCb (3 fb^{-1}) both found evidence for the very rare decay $B_s \to \mu^+\mu^-$, in agreement with SM
- Combining CMS and LHCb: first observation of $B_s \to \mu^+\mu^-$

$$BR(B_S^0 \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}$$

$$BR(B^0 \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}$$

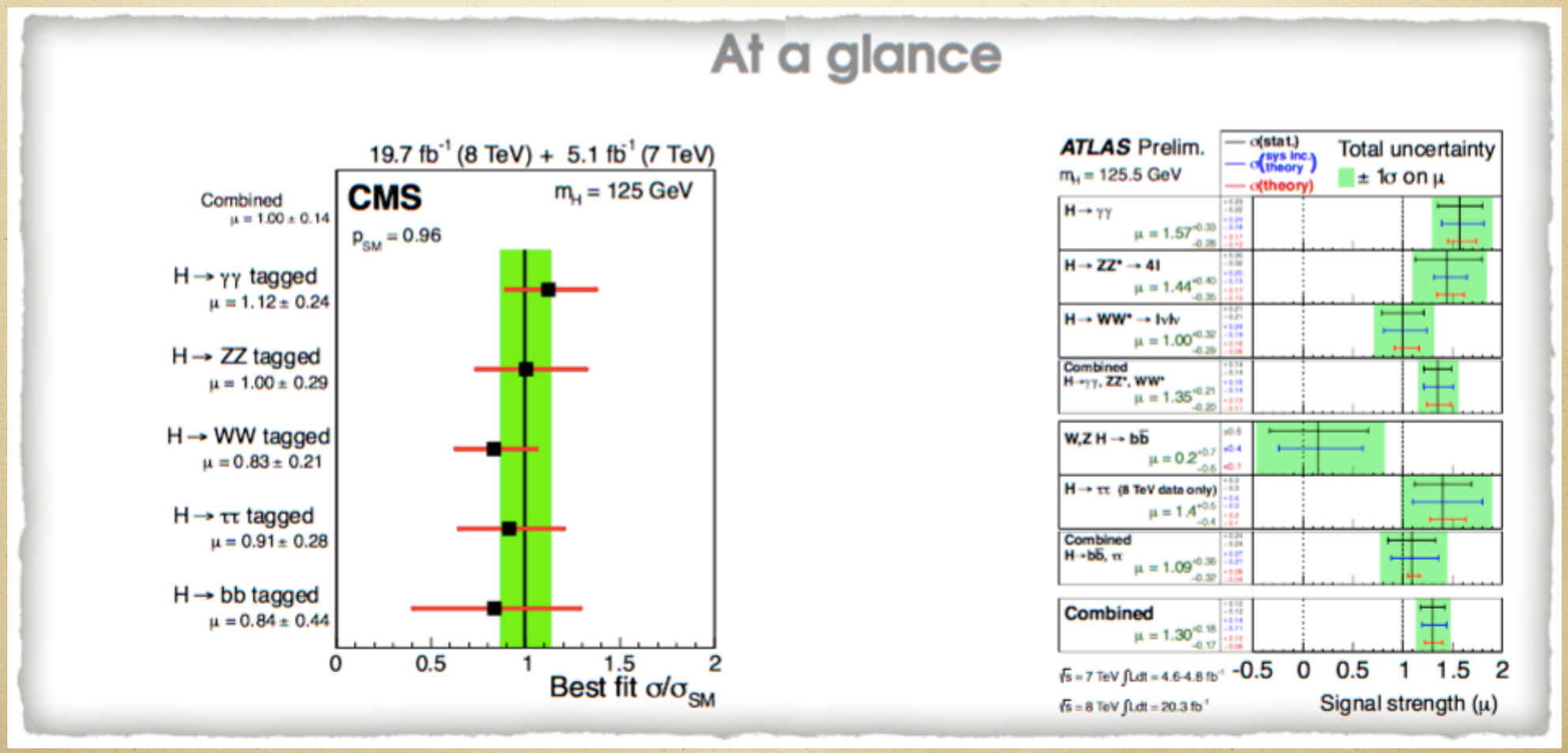
- We are entering the precision era
- The current SM BR($B_s \to \mu^+\mu^-$) has a 10% uncertainty ⇒ crucial to improve theoretical errors

From D. Straub, arXiv:1205.6094

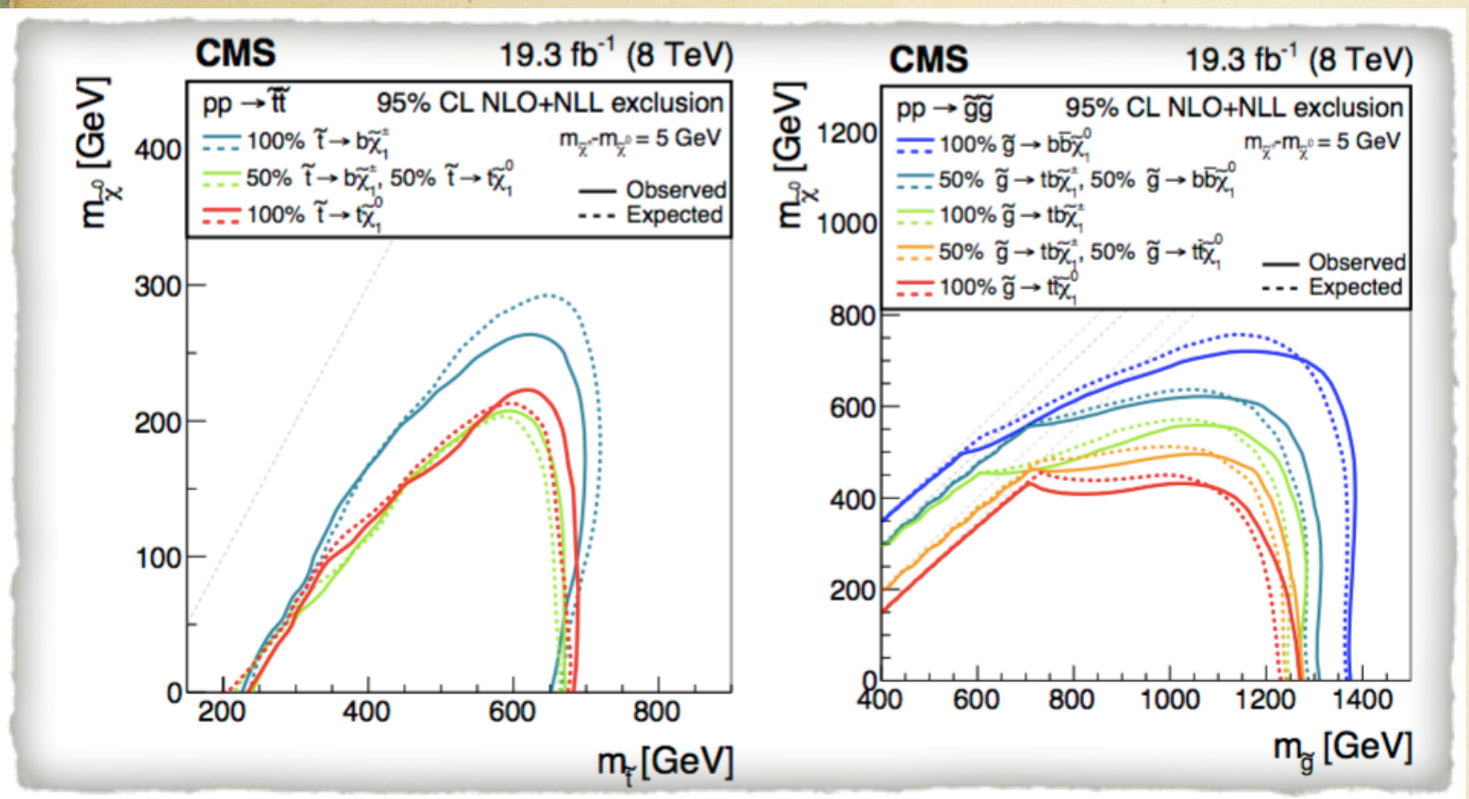


2015: waiting for the 13 TeV fireworks

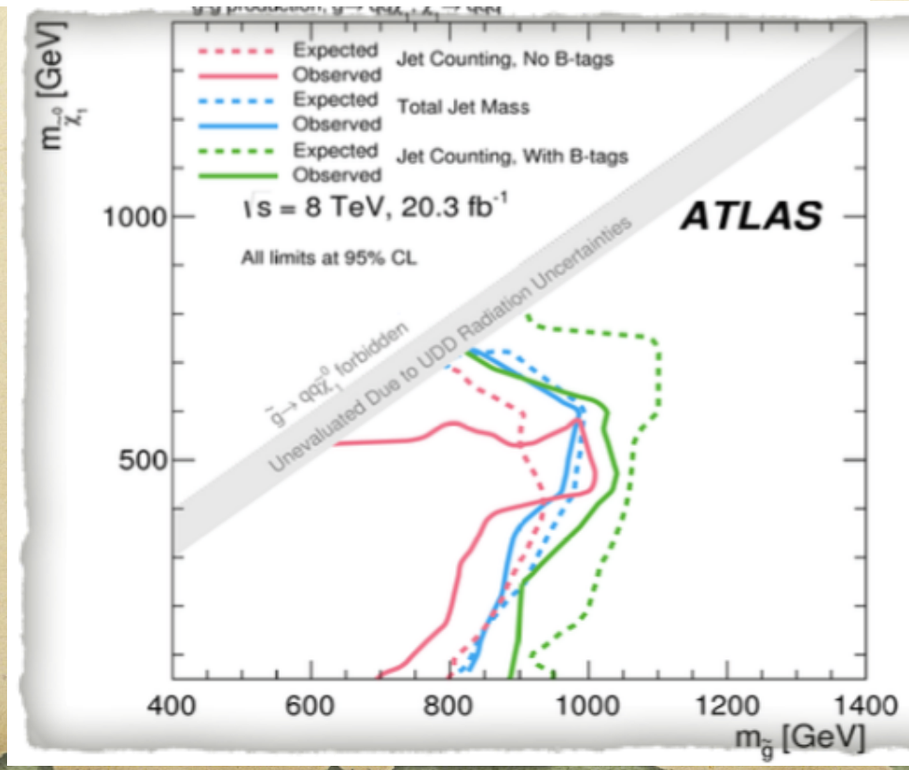
Higgs boson looks very standard

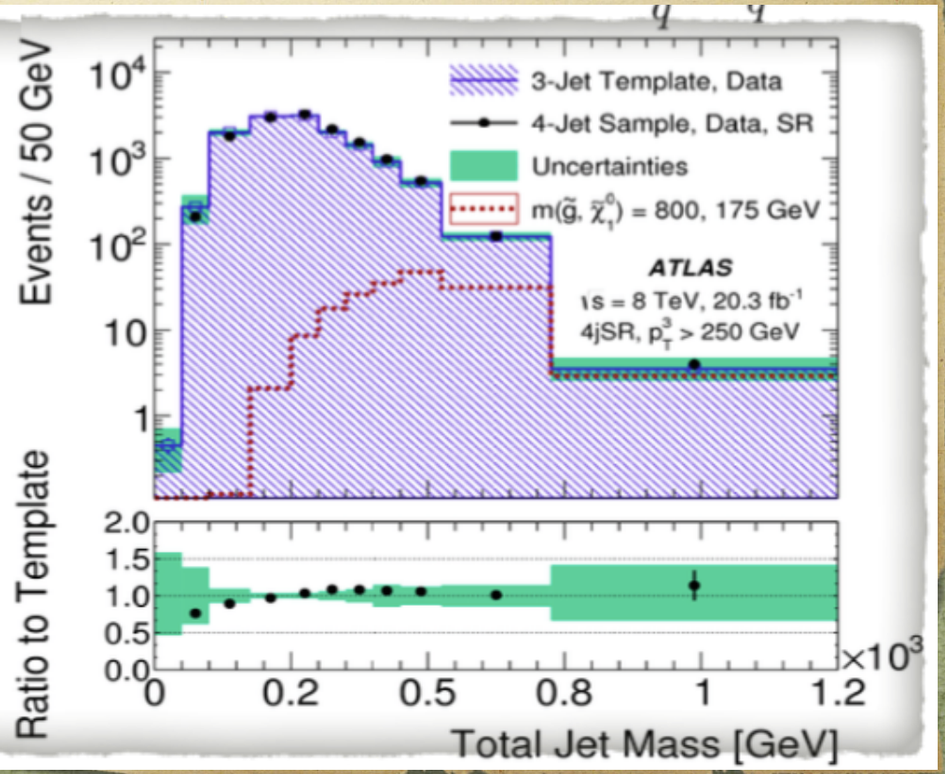


2015: and…

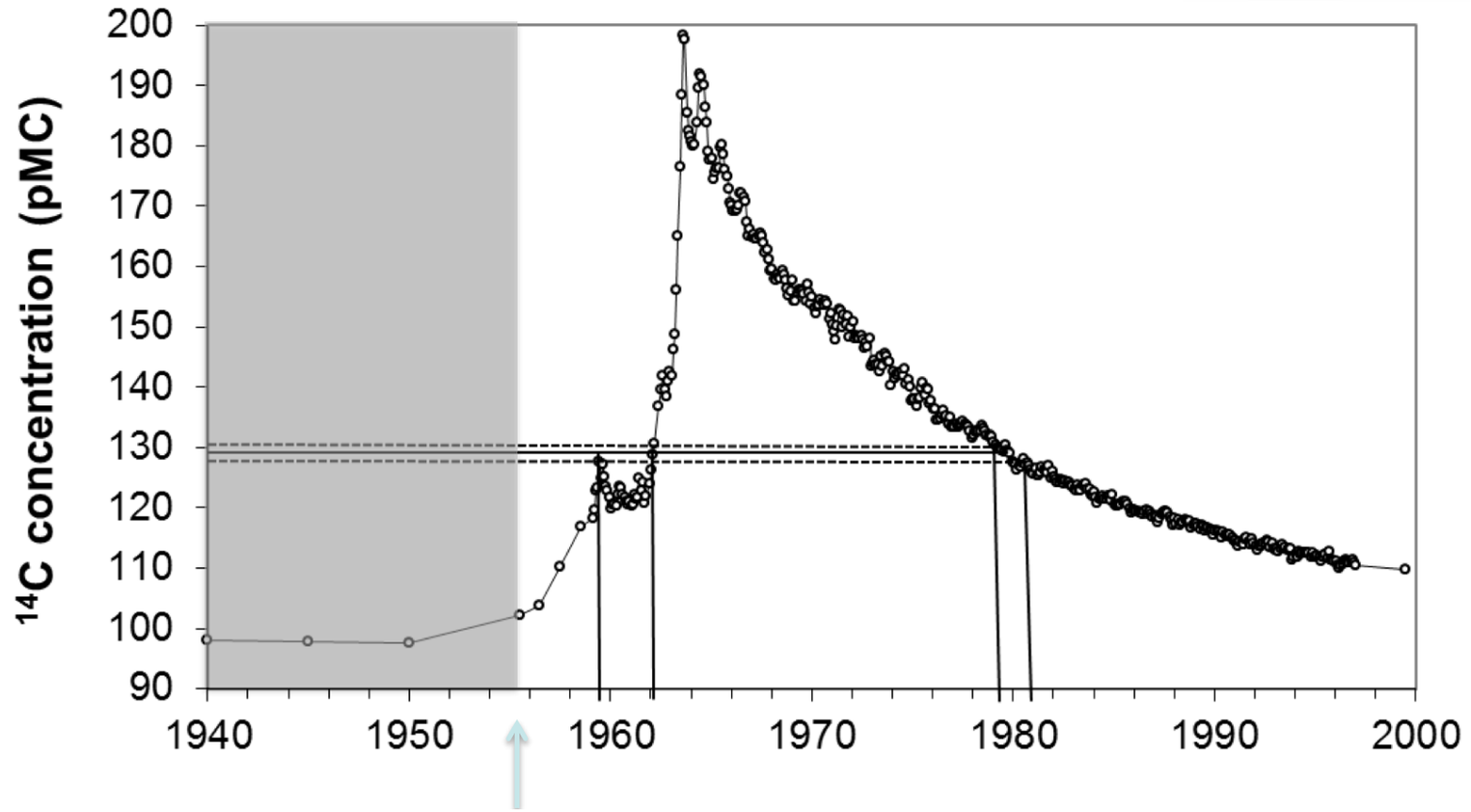


Susy is still waiting for a prince to kiss her. By now is still a toad.





2015: in the meanwhile…



Léger's death → the painting is a fake

P.A. Mandò

Department of Physics&Astronomy of the University

and

Istituto Nazionale di Fisica Nucleare

Florence, Italy

we have learnt that if you want to buy modern art you better know particle physics !

2016: strike !

Selected for a Viewpoint in *Physics*

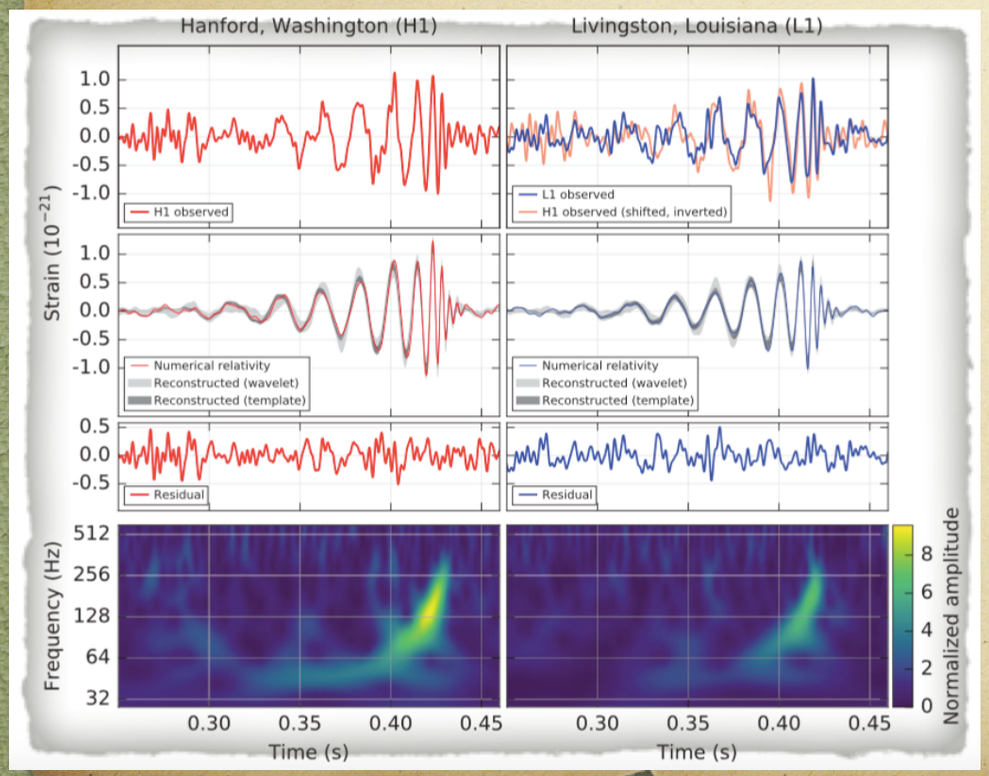
PRL **116,** 061102 (2016) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2016

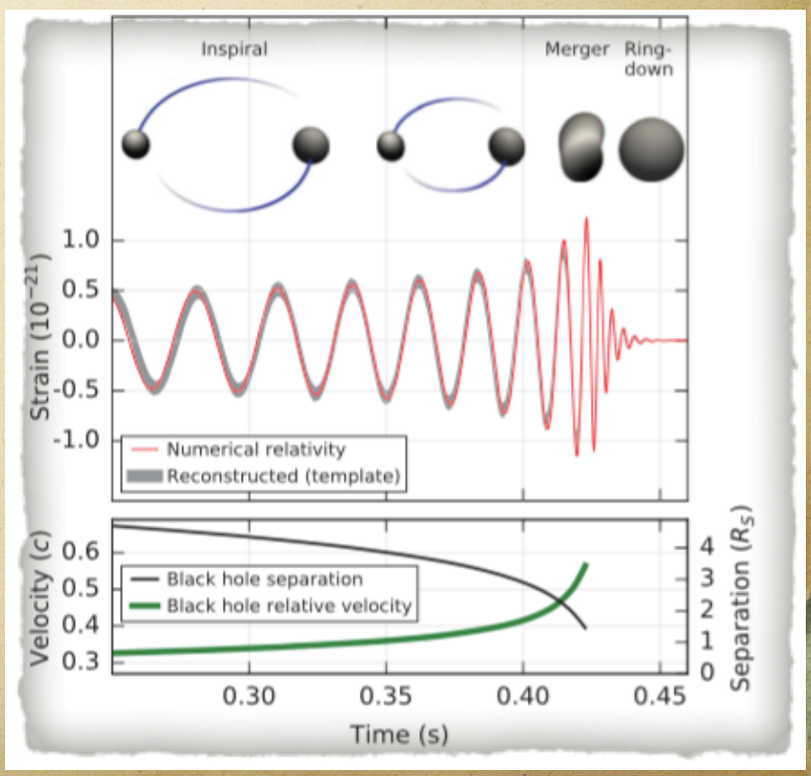
Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.**

(LIGO Scientific Collaboration and Virgo Collaboration)

(Received 21 January 2016; published 11 February 2016)





happy birthday and another 30 of these years