Interacting with Luciano: personal recollections

MAIANI 70
Roma, September 21-22, 2011

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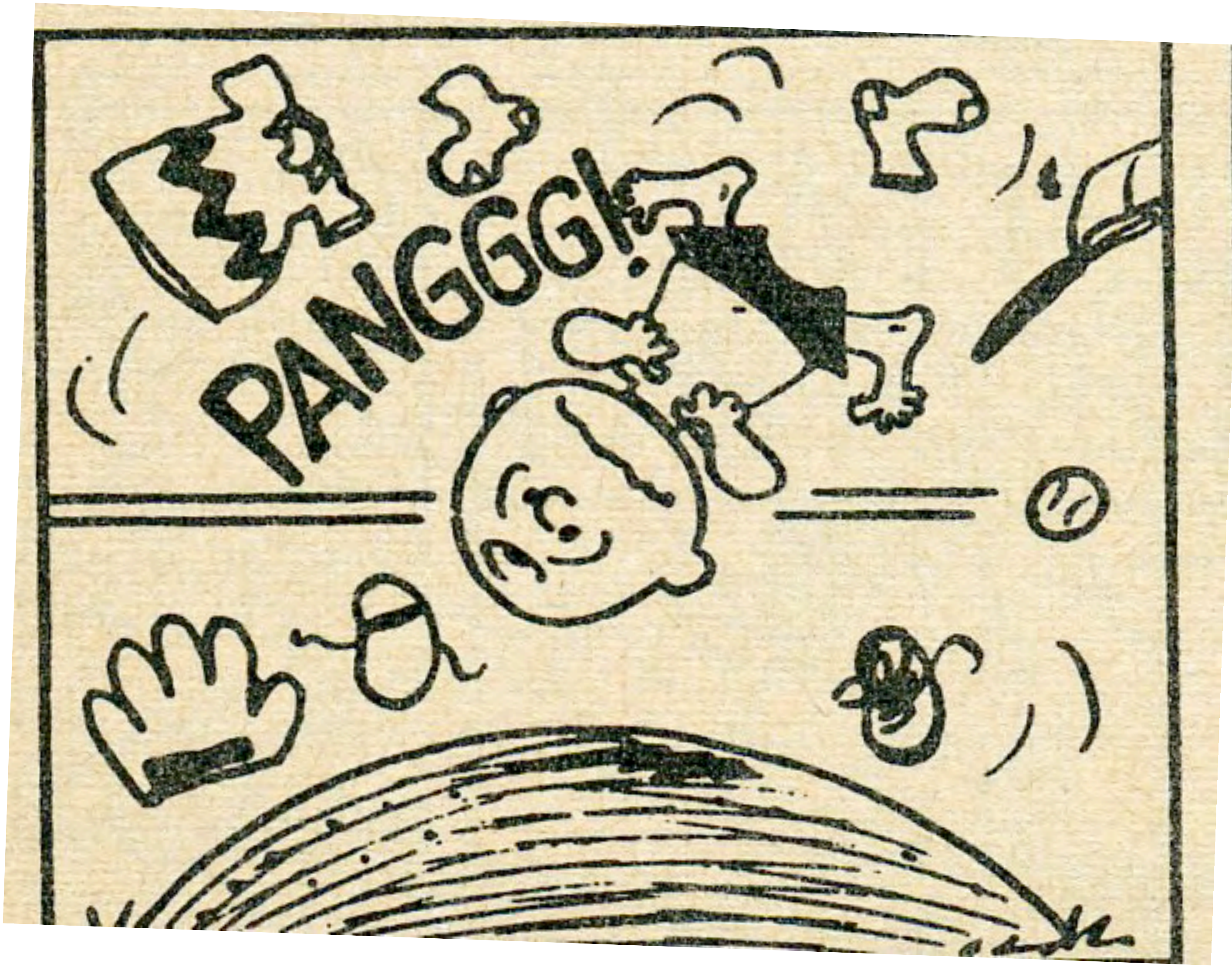
Dipartimento di Fisica, Universita' degli Studi "La Sapienza"

Outline

- The Charm
- The Z lineshape
- The Higgs Search

Interacting with Luciano !

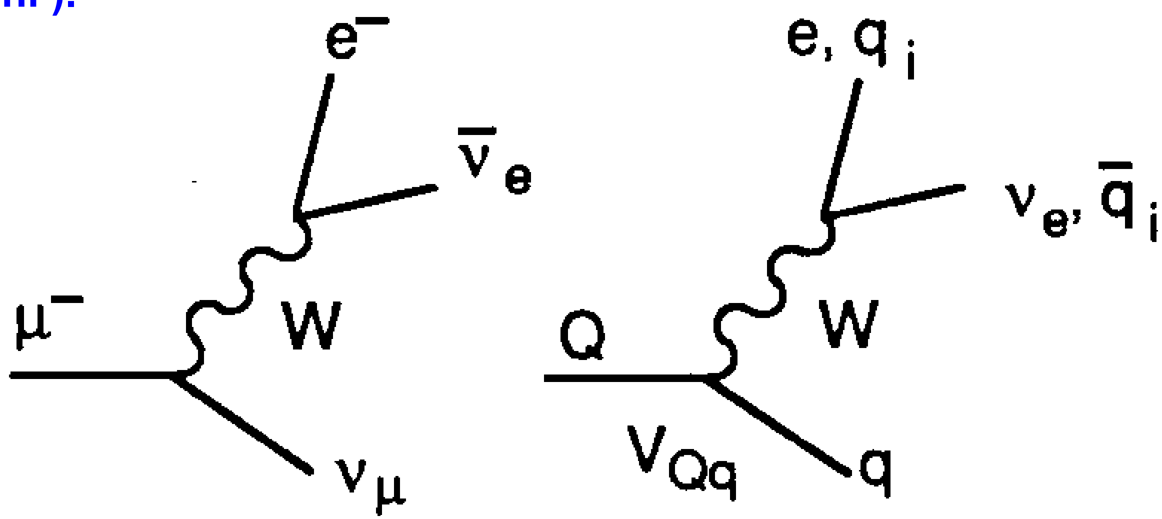


Lifetimes of Charm Mesons: The Physics Case

★ EPS 1979. Conversi

i) "Until recently rather conflicting results have been reported concerning the **lifetime τ_c of charmed particles**… no conclusive answer could be given to the fundamental question of whether or not **the decay rate of charmed hadrons is governed basically by the Fermi weak constant as expected**."

ii) " The theoretical prediction is that charged particles all have lifetimes of the same order of magnitude, essentially determined by the rate of the charmed quark β decay. Including first order gluon effects and correction for the finite mass of the c-quark the value of $\tau_c = 5 \times 10^{-13}$ s has recently been reported (N. Cabibbo, G. Corbo' and L. Maiani).



Diagrams for the β decay of the μ^- and a free heavy quark Q.

The Breakthrough: LEBC

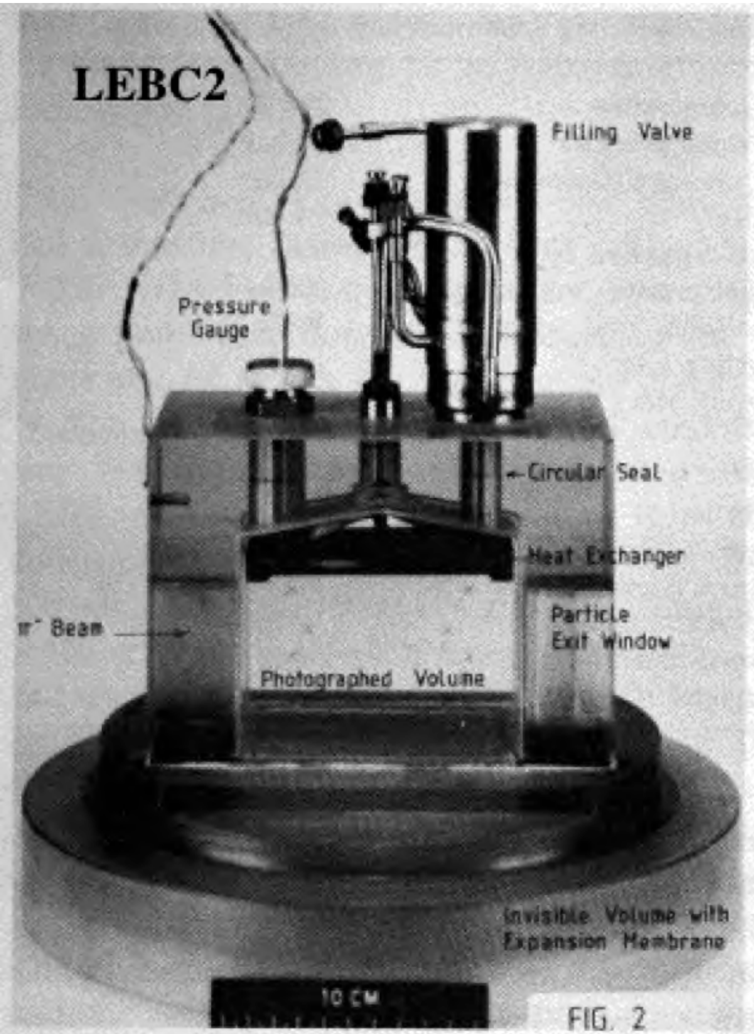


FIG. 2

At CERN H. Leutz and his group had the IDEA

The first (NA13) configuration

Volume = 1 litre , Ø= 20 cm, depth = 4 cm

Axis: horizontal, perpendicular to the beam

No **B** field

Illumination: bright field

Lens: f = 180 mm @ F/11

diffraction limited @ **30 μm**

field depth ≈ **2-3 mm**

Lateral magnification = 1/3.25

Slow spill beam with 1.2 s flat top

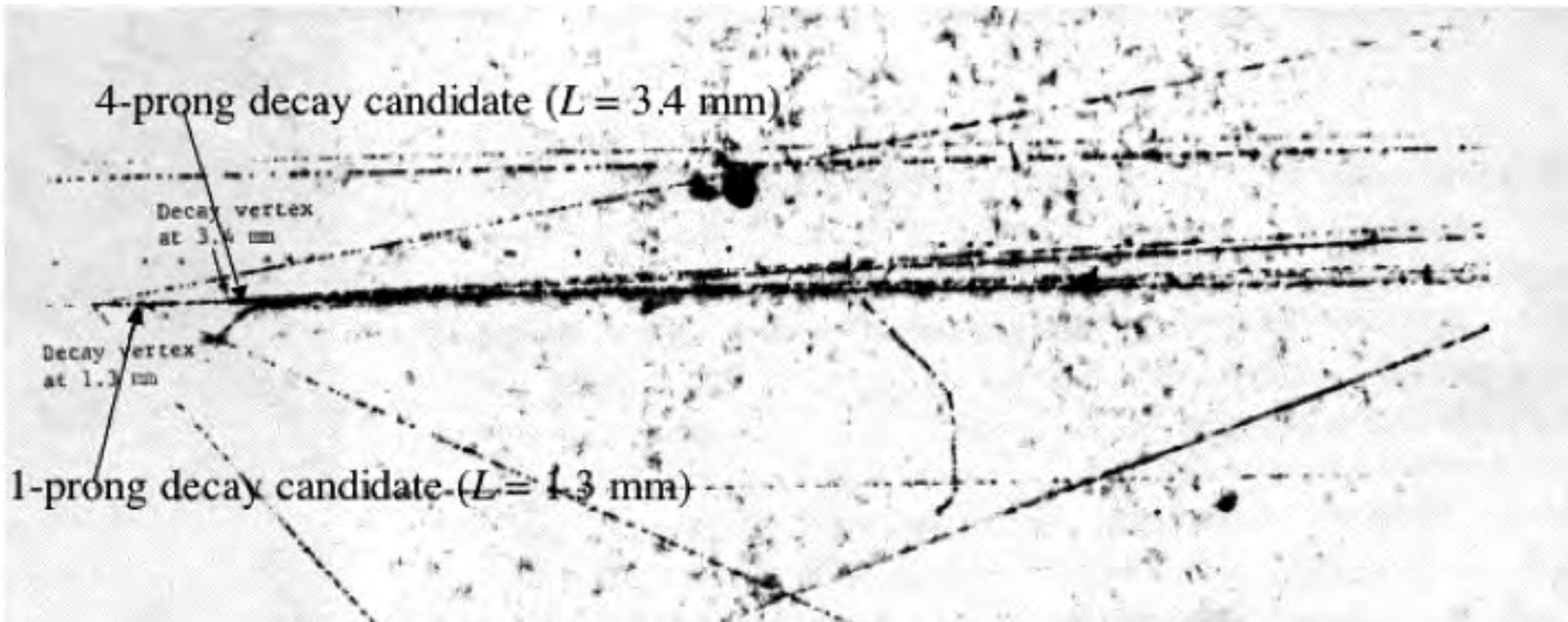
Beam section @ LEBC: 2 mm (H) x 80 mm (V)

Expansion Δp = 4.1 bar (from static 7.4 bar)

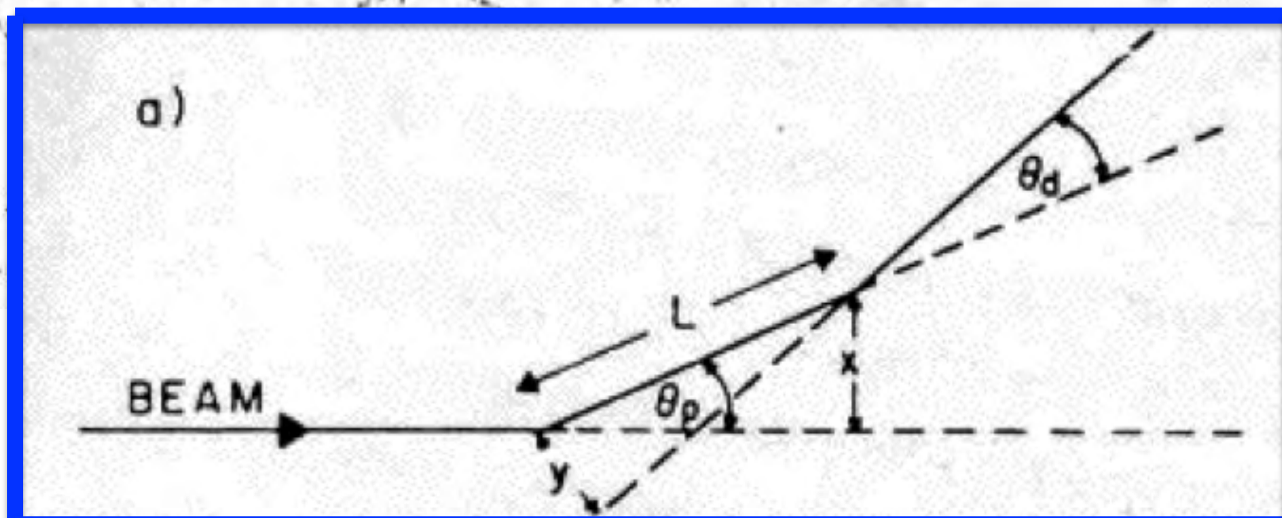
Flash delay = 200 μs for 40-50 μm bubble diameters **and** high (≈70/cm) bubble density

From A. Bettini, 2004

NA13. Example of associated production



$$x = \frac{p_T}{m} tc$$



Expected $x = 60\mu m$ for $t = 0.1$ ps, even if L =several mm

NA16 Main results

16 D°, 15$D^\pm$,

$$\tau(D^0) = \left(4.1^{+1.3}_{-0.9}\right)\times 10^{-13}s \qquad \tau(D^\pm) = \left(8.4^{+3.5}_{-2.2}\right)\times 10^{-13}s$$

$$R = \frac{\tau(D^\pm)}{\tau(D^0)} = 2.1^{+1.4}_{-0.6}$$

Decays of charmed particles had been described in the c quark spectator model. Comparison with μ decay had lead to an universal lifetime for all charmed particles of ≈ 7×10^{-13}s.

But we found that the lifetimes of charmed mesons are different

Table III: Measurements of Lifetimes of Charmed Mesons

Experiment	Ref.	D^+ Decays	D^+ $\tau(10^{-13}$ s)	D^0 Decays	D^0 $\tau(10^{-13}$ s)	D_s^+ Decays	D_s^+ $\tau(10^{-13}$ s)
E-531	9	23	$11.1\pm^{4.4}_{2.9}$	58	$4.3\pm^{0.7}_{0.5}\pm^{0.1}_{0.2}$	6	$2.6\pm^{1.6}_{1.1}$
WA-58	10	27	$5.0\pm^{1.5}_{1.0}\pm 1.9$	44	$3.6\pm^{1.2}_{0.8}\pm 0.7$		
SHF	11	48	$8.6\pm 1.3\pm^{0.7}_{0.3}$	50	$6.1\pm 0.9\pm 0.3$		
➔ NA-16	12	15	$8.4\pm^{3.5}_{2.2}$	16	$4.1\pm^{1.3}_{1.0}$		
NA-18	13	7	$6.3\pm^{4.9}_{2.3}\pm 1.5$	9	$4.1\pm^{2.6}_{1.3}\pm 0.5$		
➔ NA-27	14	149	$11.2\pm^{1.4}_{1.1}$	145	$4.6\pm^{0.6}_{0.5}$		

ii) Tevatron as Charm Factory

Why do we need to trigger on Charm and Beauty at CDF

$\sigma_{b\text{-}bbar} \cong 10^{-3}\,\sigma_{tot} \cong 100\mu b$

Tevatron

In 1998: L.Zanello, S.Giagu, M. Rescigno and I, joined CDF

The challenges were: innovative concepts that permitted the reconstruction of tracks produced in hadron collisions **with sufficient speed and accuracy** for use at trigger level to detect heavy-flavour decays

The Trigger goals were:

1) the pattern recostruction time: order of 20 μs;

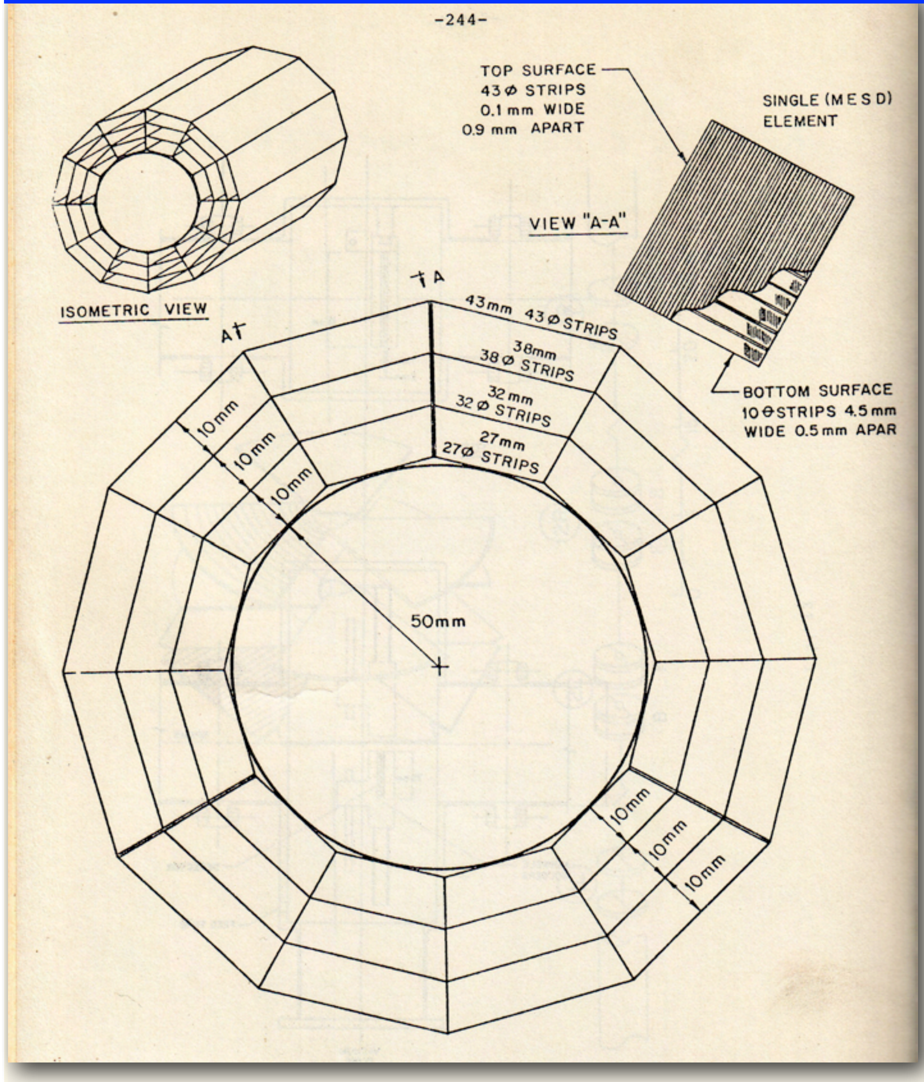
2) **the precision on the impact-parameter: order of a few tens of μm.**

Use of VLSI technology makes it possible to integrate thousands elements on a small silicon chip and implement pattern recognition as a massive parallel algorithm. These ideas led to the invention of a special VLSI system:

The Associative Memory Device

(Dell'Orso M.,**LUCIANO RISTORI** Nucl. Instrum. Methods A 278:436 (1989).

Silicon Vertex Detector for a Hadronic collider



from the
"CDF Technical Design Report"
1981

1981: Aldo Menzione comes forward with the first conceptual design of a *silicon vertex detector* for a collider experiment

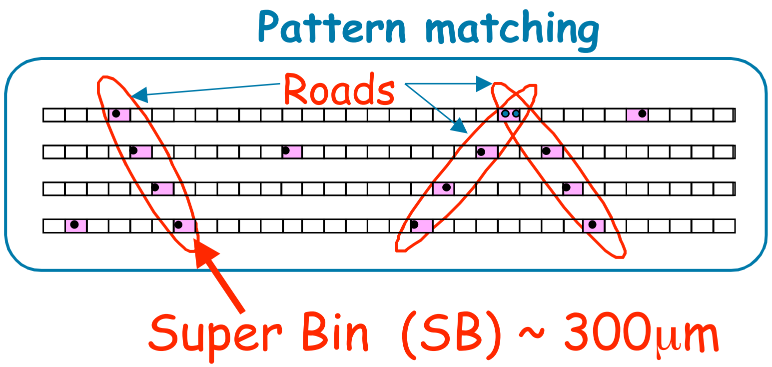
Awarded a Panofsky Price 2009

L. Ristori 2009

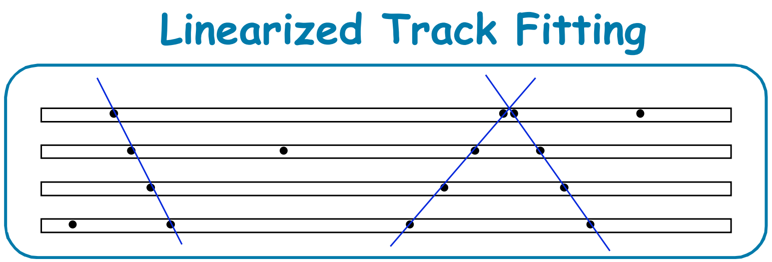
Tracking in 2 steps

Luciano Ristori
Panofsky Prize 2009

1. Find low resolution track candidates called “roads”. Solve most of the pattern recognition



2. Then fit tracks inside roads. Thanks to 1st step it is much easier



The **S**ilicon **V**ertex **T**rigger (**SVT**) was designed and built by CDF between 1990 and 2000.The SVT has been operating without interruption since 2000, and it has allowed CDF to perform important measurements that would otherwise have been impossible.

Physics results at CDF

➔ Observation of B_s^0-$\bar{B}_s^0$ Oscillations

$$\Delta m_s = 17.77 \pm 0.10(stat) \pm 0.07(syst)\ \mathrm{ps}^{-1}$$

The quality of this measuremet is essentially determined by the hadronic decay selected by the SVT trigger

➔ The SVT has also provided CDF with the world's largest sample of D^0 mesons, paving the way to precision measurements of D^0 oscillations and direct CP violation .This could open the way to New Physics.

The present: LHCb

Update! LHCb, 341 pb^{-1}, LHCb-CONF-2011-050

$$\Delta m_s = 17.725 \pm 0.041 \pm 0.026\ \mathrm{ps}^{-1}$$

Unprecedented precision

The future: SuperB

The Z^0 Lineshape

Back to 1989 at LEP

Nuclear Physics B333 (1990) 357–379

MODEL INDEPENDENT ANALYSIS OF THE Z LINE SHAPE IN e^+e^- ANNIHILATION*

A. BORRELLI

INFN-Sezione di Roma, Italy

M. CONSOLI**

CERN, Geneva, Switzerland

L. MAIANI

Dipartimento di Fisica, Università di Roma "La Sapienza", P.le A.Moro 2, 00185 Roma, Italy
and
INFN-Sezione di Roma, Italy

R. SISTO

Dipartimento di Fisica, Università di Roma "La Sapienza", P.le A.Moro 2, 00185 Roma, Italy

Received 7 July 1989

This work paved the way for the Combined Electroweak analysis

MEMORANDUM

TO : The members of the L3 collaboration.

FROM : M. Consoli, L. Ludovici and L. Maiani.

SUBJECT : **Line shape of the Z from SLC/Mark II data and the Standard Theory predictions.**

LEP AND THE STANDARD MODEL(*)

Moriond 1990

M. Consoli[1)], C. Dionisi[2)], L. Ludovici[2)]

Complete table of the published results of the four Collaborations.
The SM predictions and our independent fit are also reported.

	Γ (MeV)	σ^h_{peak} (nb)	Γ_ℓ (MeV)	Γ_h (MeV)	Γ_{inv} (MeV) N_ν
ALEPH	2541 ± 56	41.4 ± 0.8	83.9 ± 2.2	1804 ± 44	495 ± 41 2.97 ± 0.25
DELPHI	2511 ± 65	41.6 ± 1.3	85.1 ± 2.9	1741 ± 61	515 ± 54 3.09 ± 0.32
L3	2529 ± 58	39.8 ± 0.9	82.8 ± 2.4	1744 ± 53	537 ± 48 3.23 ± 0.29
OPAL	2536 ± 45	41.4 ± 1.1	81.9 ± 2.0	1838 ± 46	453 ± 44 2.71 ± 0.25
SM Theory	2488 ± 32	41.45 ± 0.17	83.6 ± 0.6	1737 ± 27	500 ± 5 3
Our fit	2533 ± 26	41.0 ± 0.5	83.1 ± 1.4	1792 ± 29	491 ± 27 2.95 ± 0.16

Higgs Mass Constraints from Experiments

- Fits to electroweak precision data

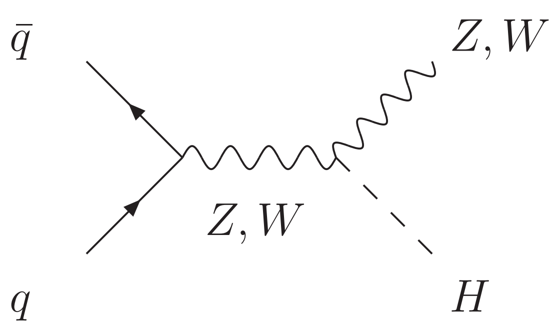
EWWG

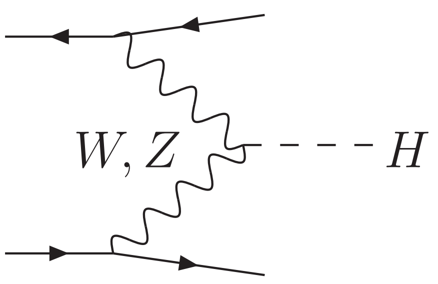
$$M_H = 89^{+35}_{-26} \text{ GeV}, \; M_H \lesssim 185 \text{ GeV @ } 95\% \text{ CL}$$

- Direct search @ LEP:

$$M_H > 114.4 \text{ GeV @ } 95\% \text{ CL}$$

LEP Coll.

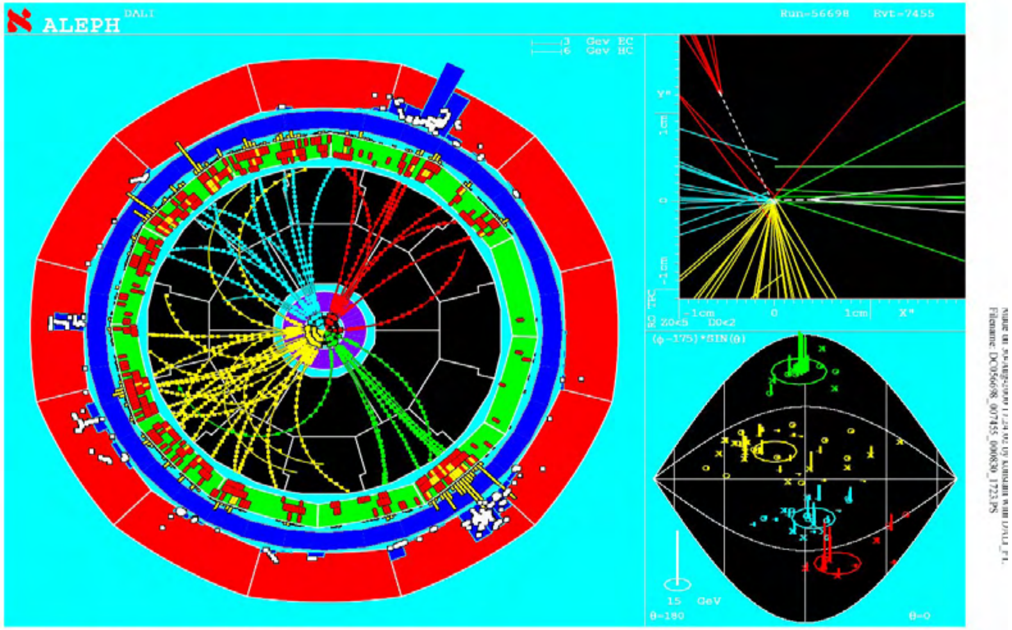




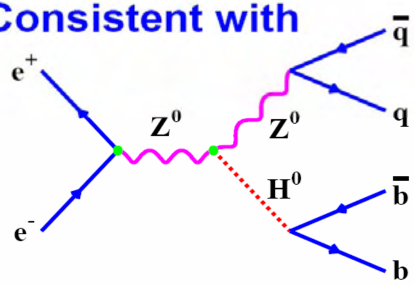
Fall 2000

The Evidence....

4 Possible $e^+e^- \rightarrow Z^0H^0$ events observed in the final year of LEP operation. *e.g.*



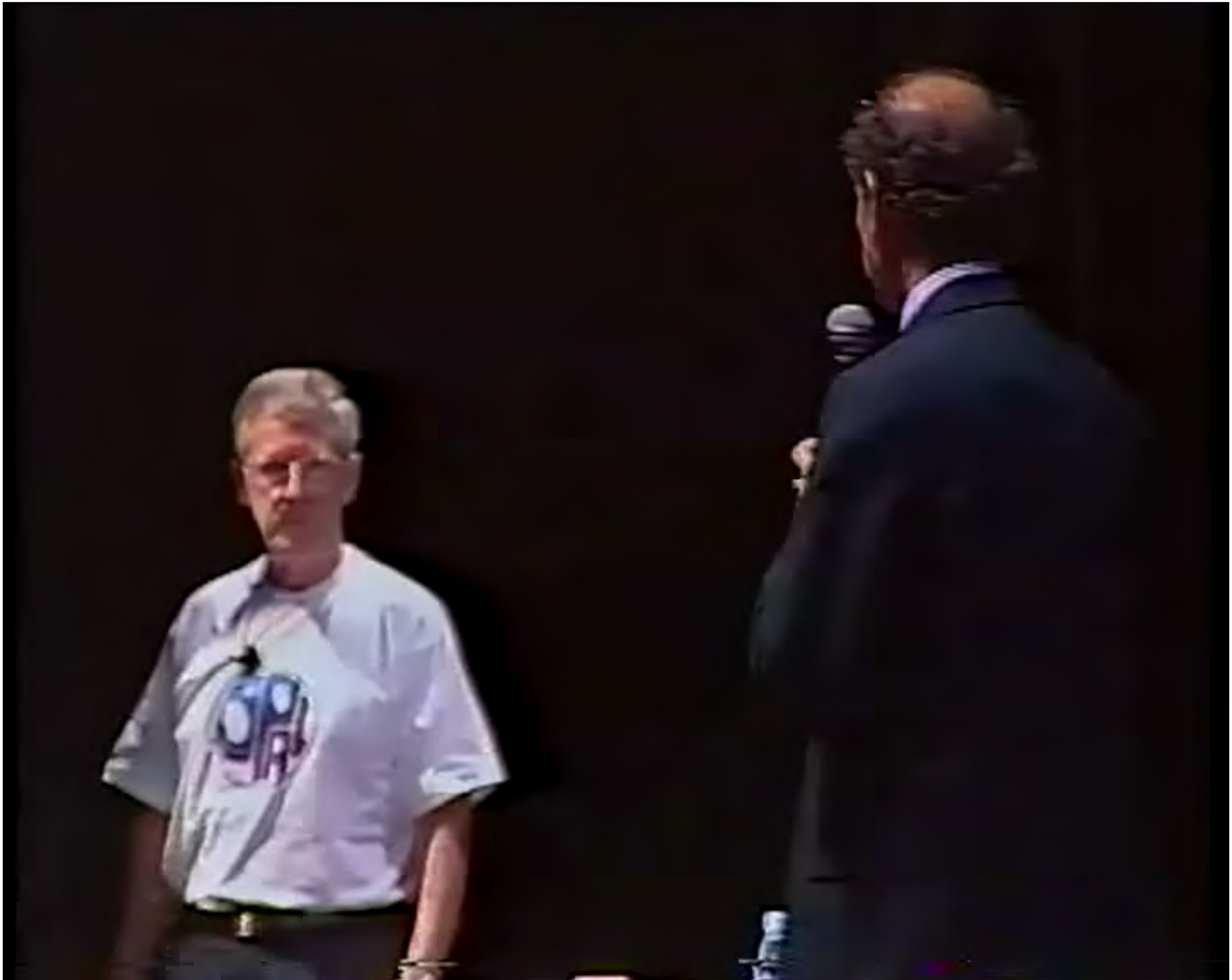
Consistent with



$$m_{H^0} = 115\ \text{GeV}$$

★ **The evidence is tantalizing BUT FAR FROM conclusive**

"LUCIANO's HARDEST CHOICE"

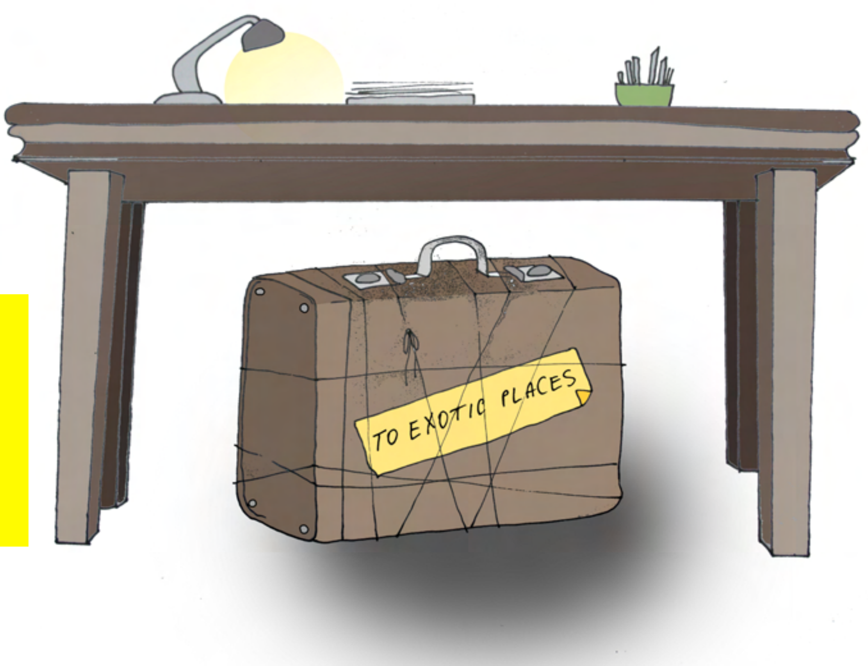


Epilogue: Committee of Council, Nov. 17 2000

. . . . The Committee of Council supports the Director General Luciano Maiani in pursuing the existing CERN programme, (which foresees the decommissioning of the LEP accelerator at the end of the year 2000).

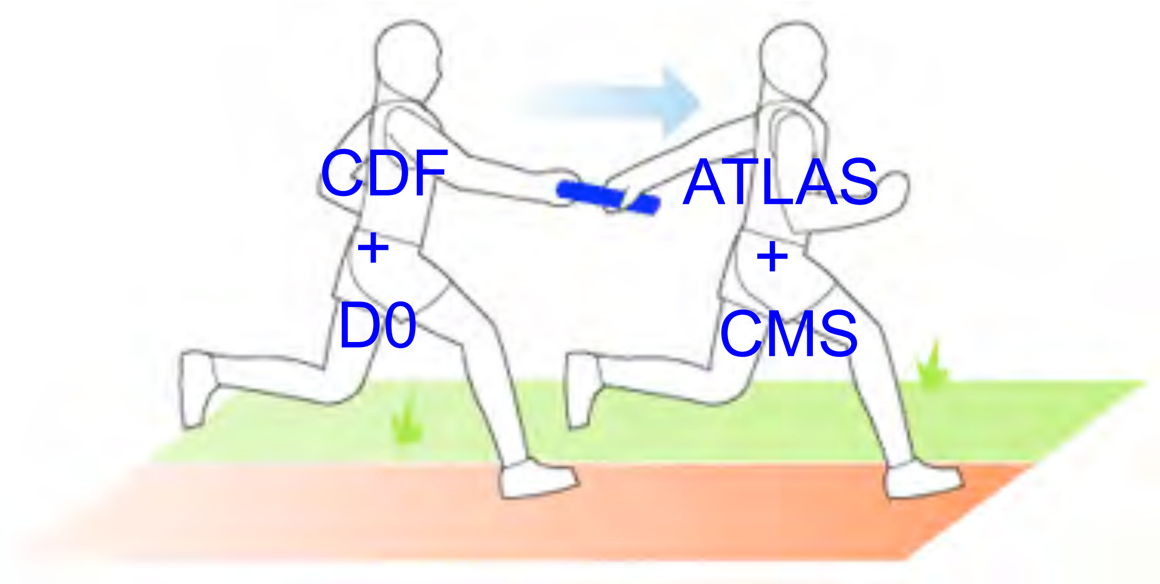
At 8h00 a.m., November 2nd 2000, The LEP collider was shut down forever.

Since then in the Luciano office, I noticed (subliminal) a strange suitcase…….. .



The Higgs Relay Race

The Tevatron "Baton"



Tevatron Higgs Mass Limits

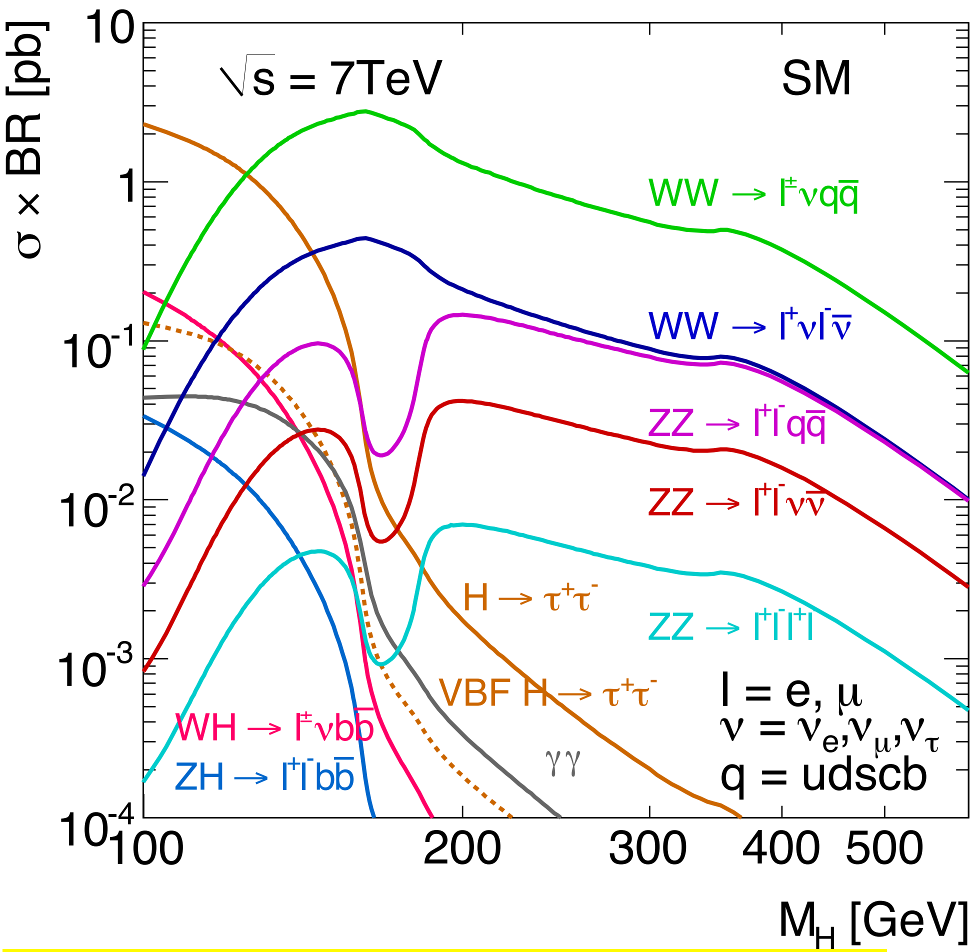
With ≈ 8.5 fb^{-1} each, CDF and D0 together exclude the 100–109 and 156-177 GeV mass range.

- Tevatron running to END on September 30
- ≈ 10 fb-1 available for analysis for both experiments at the end of data taking
- Final results from the Tevatron expected by ICHEP 2012

The LHC

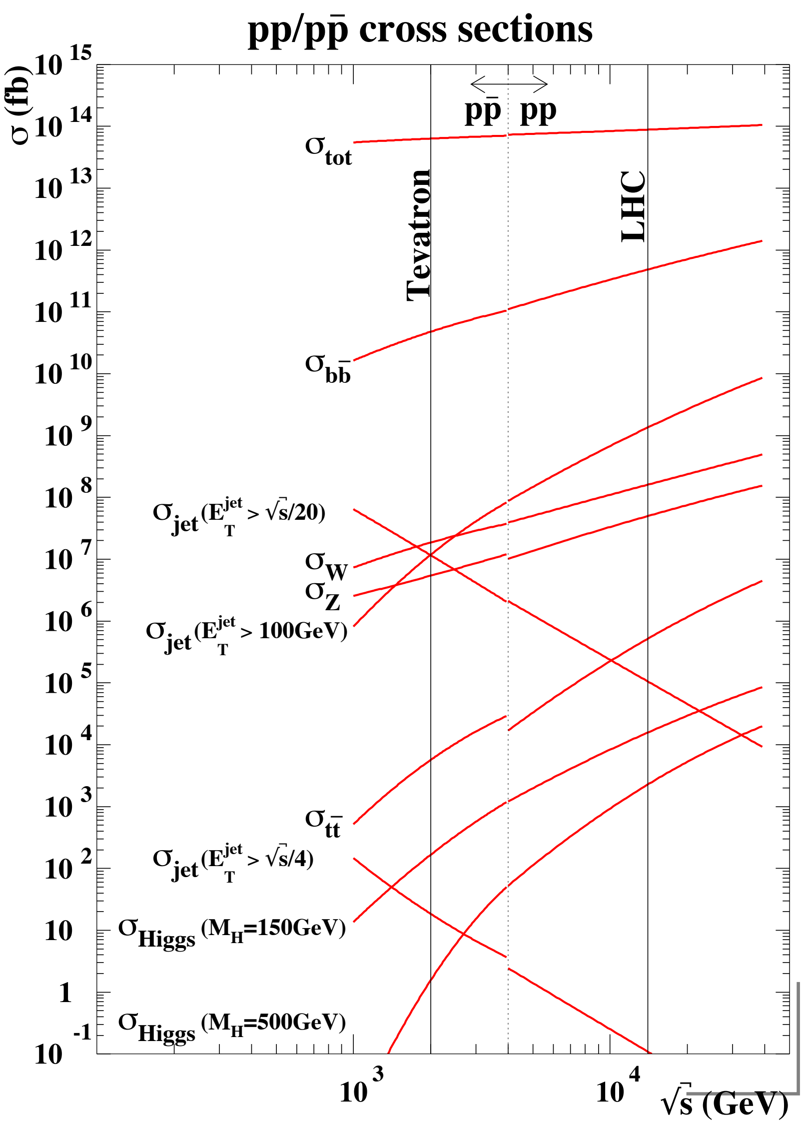
- **The Large Hadron Collider is launched**
- **The machine and its Experiments are performing beyond expectations.**
- **The ground is prepared for major discoveries**

The Higgs Search at LHC



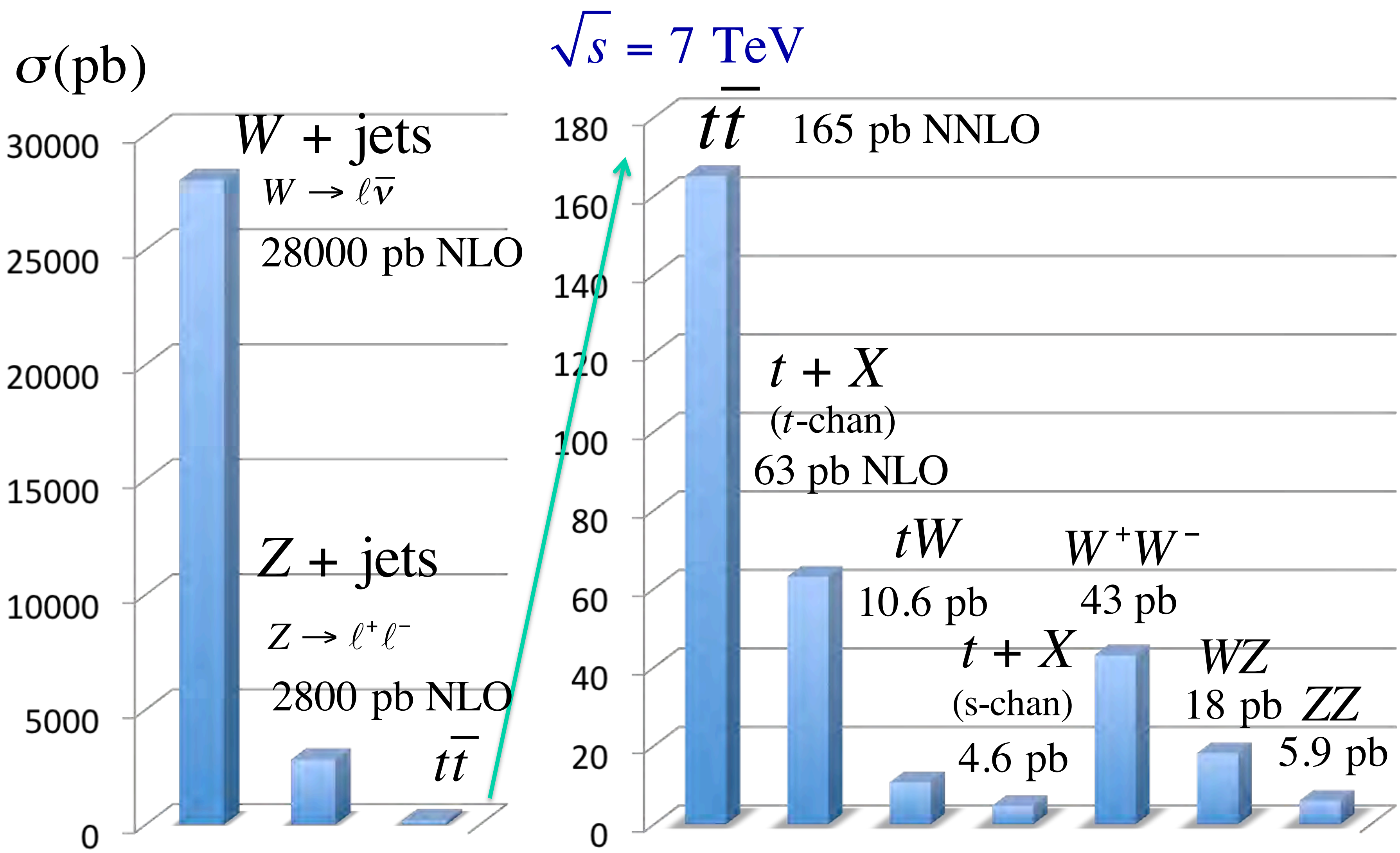
Huge cross section for QCD processes

- S/B ≈ 10^{-10} ➔ a needle in a haystack



- Production rate of the Higgs as well as its decay possibilities ("Signatures"), depend on its mass

Cross Sections of SM Background processes

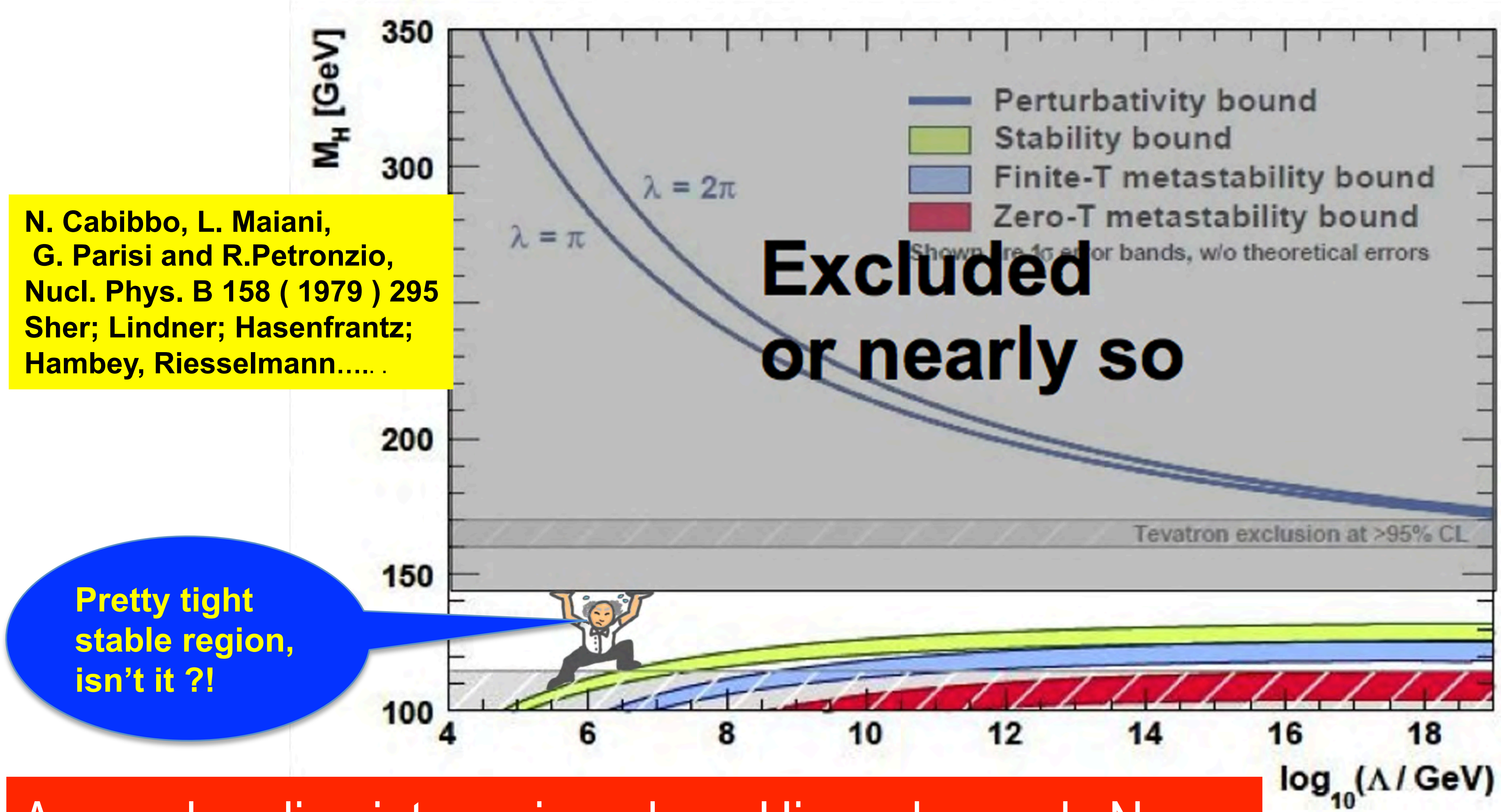


LHC Higgs Mass Limits

➪ **ATLAS and CMS together exclude the 140-460 GeV mass range (there are still islands around 300 GeV...).**

Higgs Stability

N. Cabibbo, L. Maiani,
G. Parisi and R.Petronzio,
Nucl. Phys. B 158 (1979) 295
Sher; Lindner; Hasenfrantz;
Hambey, Riesselmann..... .



Are we heading into region where Higgs demands New Physics ?

We will know very soon !!

❖ H → γγ: a suitable "case for treatment"

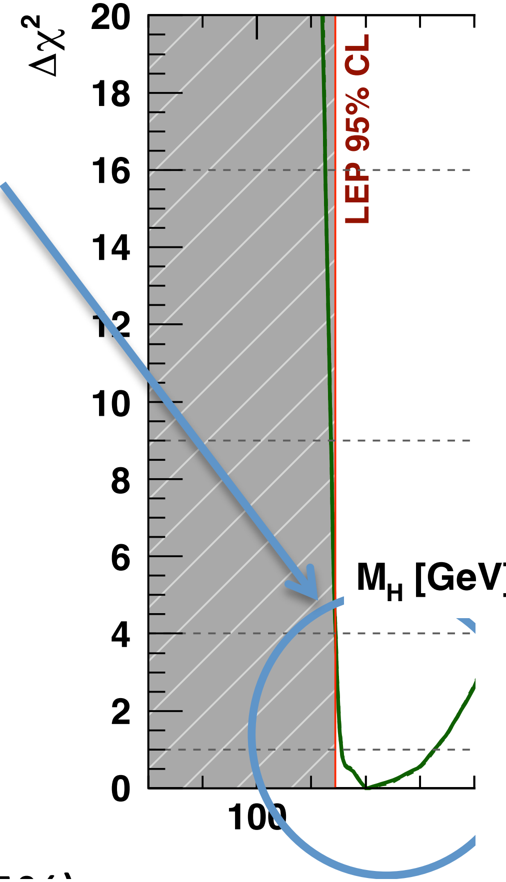
- The focus is now on the region between 114-145 GeV !

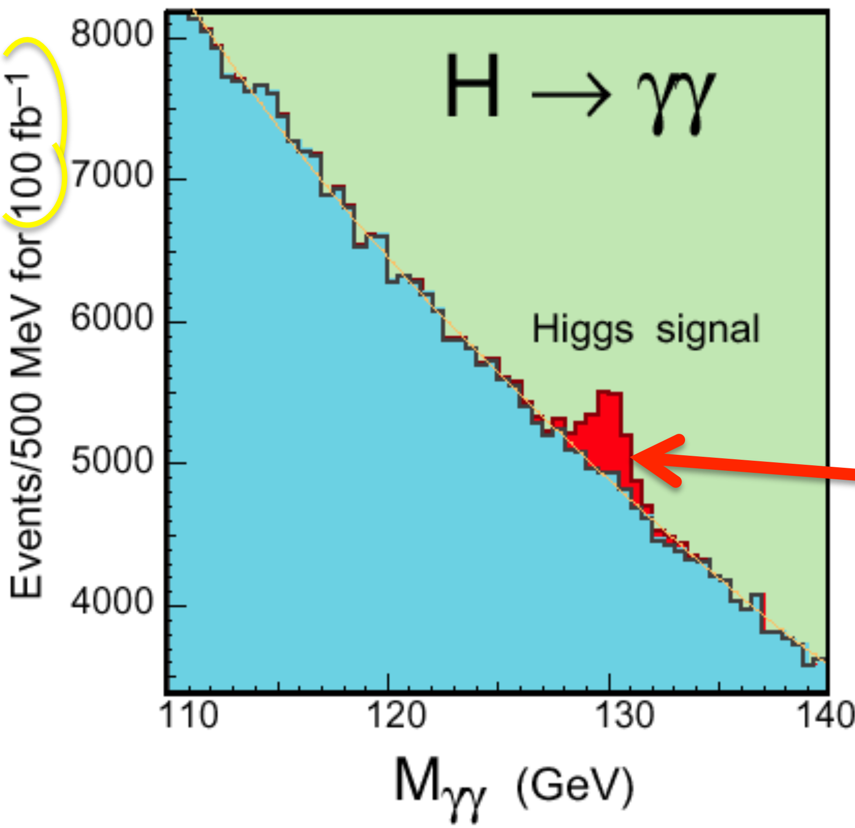
- The lower the mass the harder it is at LHC !

Relevance of the γγ Channel

– Dominant Channel in the very low mass range (110-125 GeV) where the SM Higgs is prefered

– We expect to see a Mass Peak !

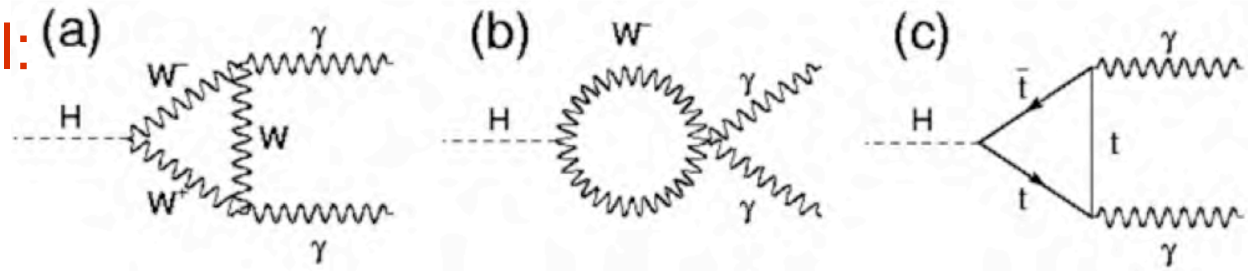




Some years from now……

Signal VS Backgrounds

Signal:

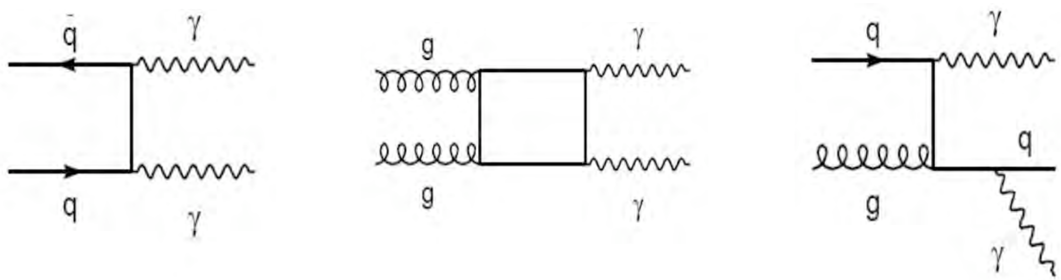


σ = 0.04 pb

Irreducible BG: prompt diphoton (+jets).

Born, box or fragmentation processes

qqbar, qg, $\sigma \approx$ 21 pb
gg $\sigma \approx$ 8 pb



γ-jet $\sigma \approx 1.8\times10^5$ pb
jet-jet $\sigma \approx 4.8\times10^8$ pb

Reducible backgrounds: γj, dijet (jj)

Drell-Yan BG also contributes (misidentified e)

γ-jet need rejection R~O(10 ^{4})

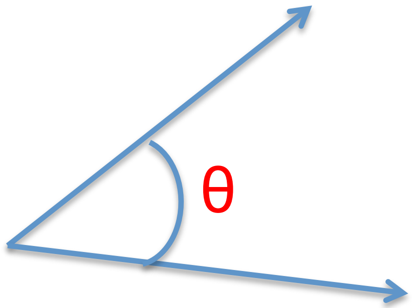
jet-jet need rejection R~O(10 ^{7})

Experimental Issues

➩ H → $\gamma\gamma$ mass reconstruction: the discovery potential depend on the di-photon invariant mass resolution:

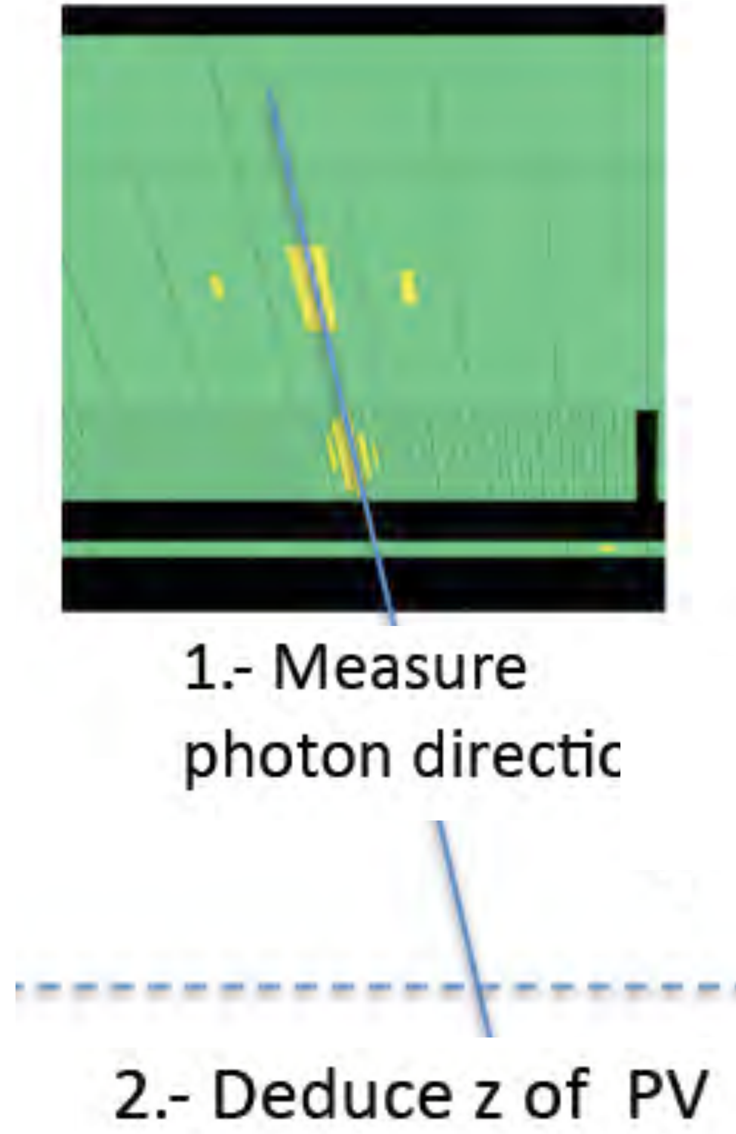
- Energy resolution via calibration
- Photon reconstruction
- Vertex reconstruction
- Pile Up condition
- $\pi^0 - \gamma$ rejection

H➔γγ mass reconstruction



$$m^2 = 2p_1p_2(1-\cos\theta)$$

$$\delta m/m = \frac{1}{\sqrt{2}}\frac{\delta p}{p} \oplus \frac{\delta\theta}{\theta}$$

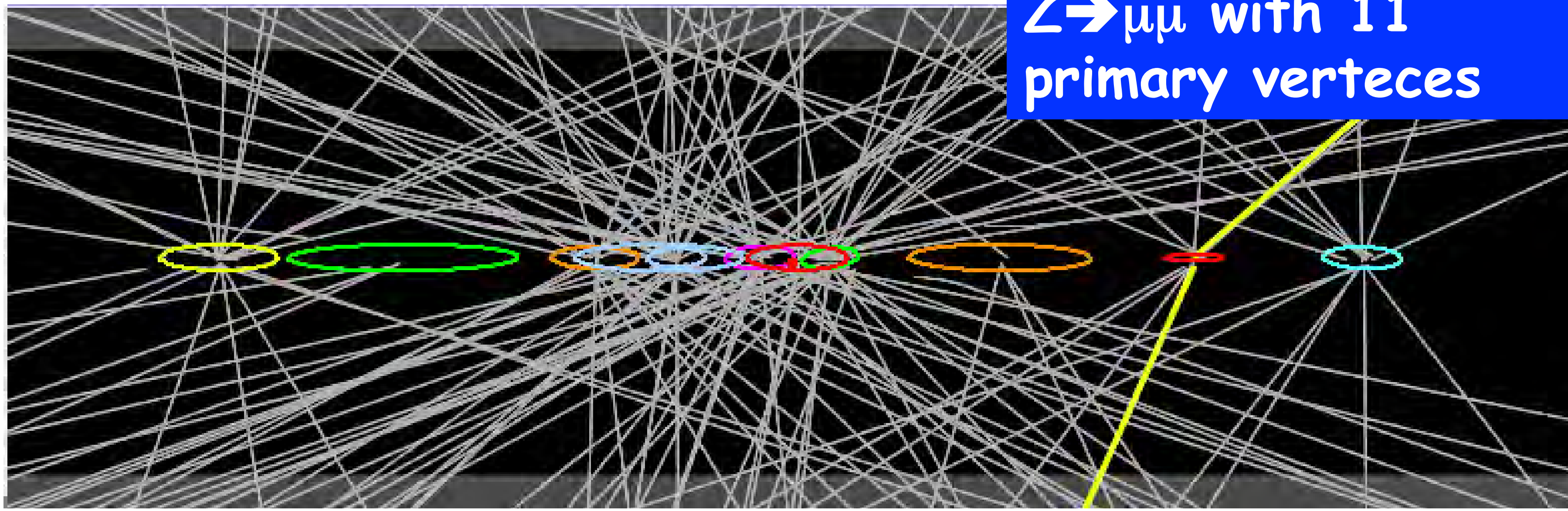


- **Energy resolution contribution δp ≈ 1.3 GeV**
  - **energy scale calibration from Z ➔ e+e-**
- **Interaction point spread:**
  - **σ(z) ≈ 5.6 cm ➔ δm(θ) ≈ 1.4 GeV**
- **Resolution with pointing: σ(z) ≈ 1.5 cm;**
  - **Use of recoil tracks less effective with large number of pile-up collisions**
- **Use conversion tracks as well**

ATLAS

Pile Up Event

Z→μμ with 11 primary verteces



Pile-up challenge:

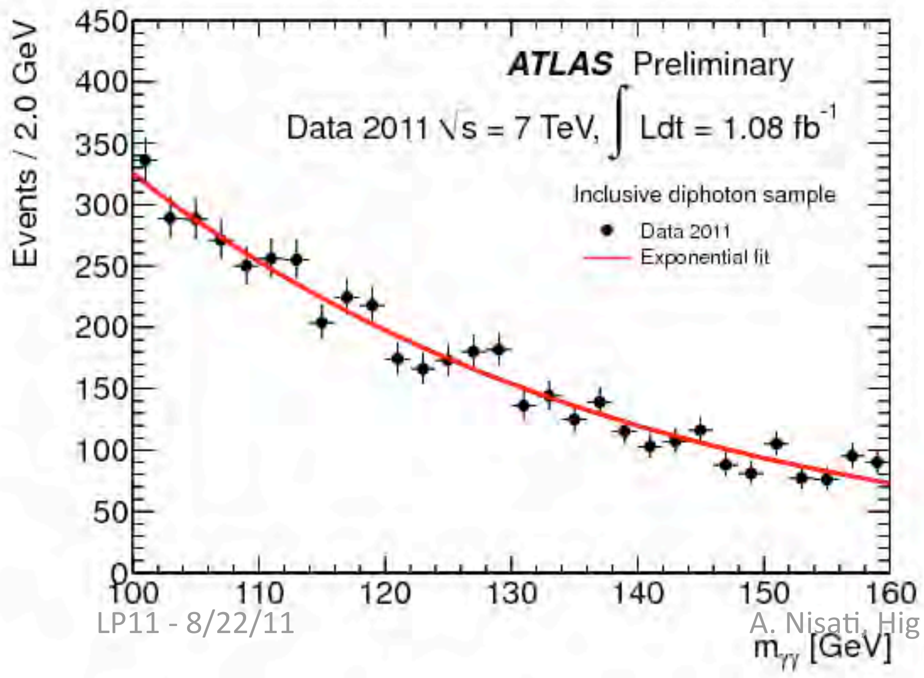
- 50 ns bunch trains for ~all 2011 data

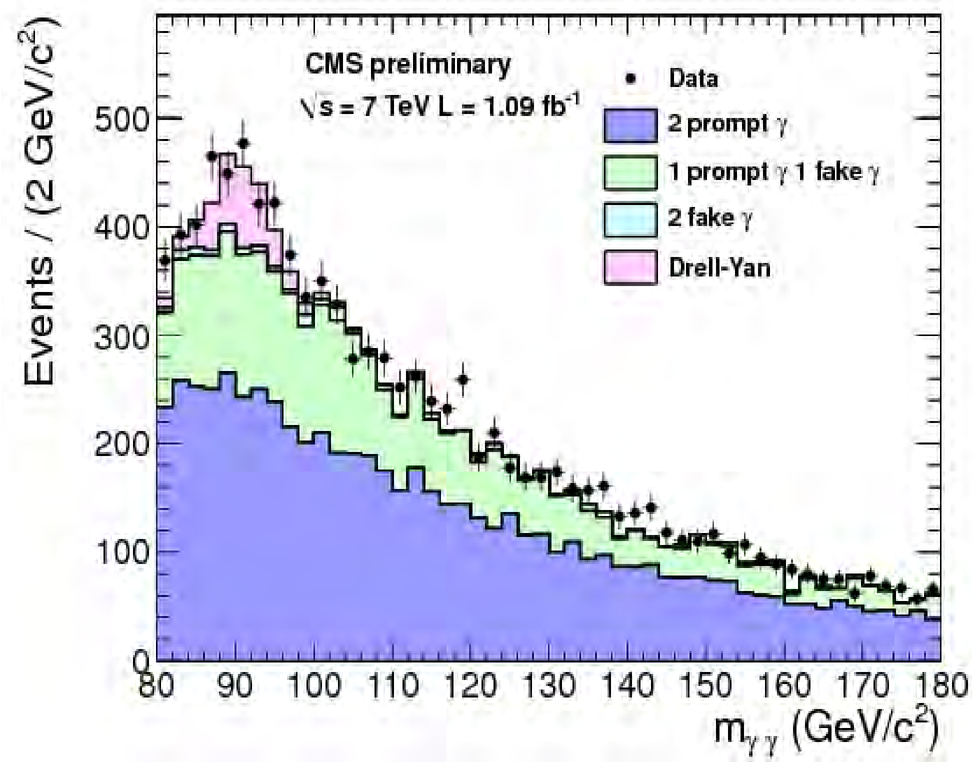
→ Substantial in- and out-of-time pileup: μ ≈ 6

→At 5 × e[33] two possible scenarios: i) <μ> ≈ 21

ii) <μ> ≈ 11

H→γγ: results





no indication of a significant excess is found

Perspective for low mass Higgs

- **Many channels contribute to low mass discovery**

$H \rightarrow \gamma\gamma$

- resolution is the key work area for both experiments
- Pile Up could be a serious Issue

$H \rightarrow ZZ$; $H \rightarrow WW$

Gluon fusion

$H \rightarrow \tau\tau$

Gluon fusion

$H \rightarrow bb$

VBF

My educated guess from ATLAS simulations at $\sqrt{s}$ = 7 TeV

- **8-9 fb^{-1}/per Exp for SM exclusion**

≈ 15 fb^{-1}/per Exp for 3.5 σ discovery

Scenario Envisaged

Year	Luminosity (fb-1)	Total (fb-1)	Beam Energy (TeV)
2011	4-5	4-5	3.5
2012	10	15	3.5/4
2013	0	15	----

Where is Higgs hiding ?

Summary

As a result of the work done at LEP, Tevatron and LHC, the window for the Standard model Higgs is becoming very narrow.

- **Thus, there is strong evidence that:**

  either

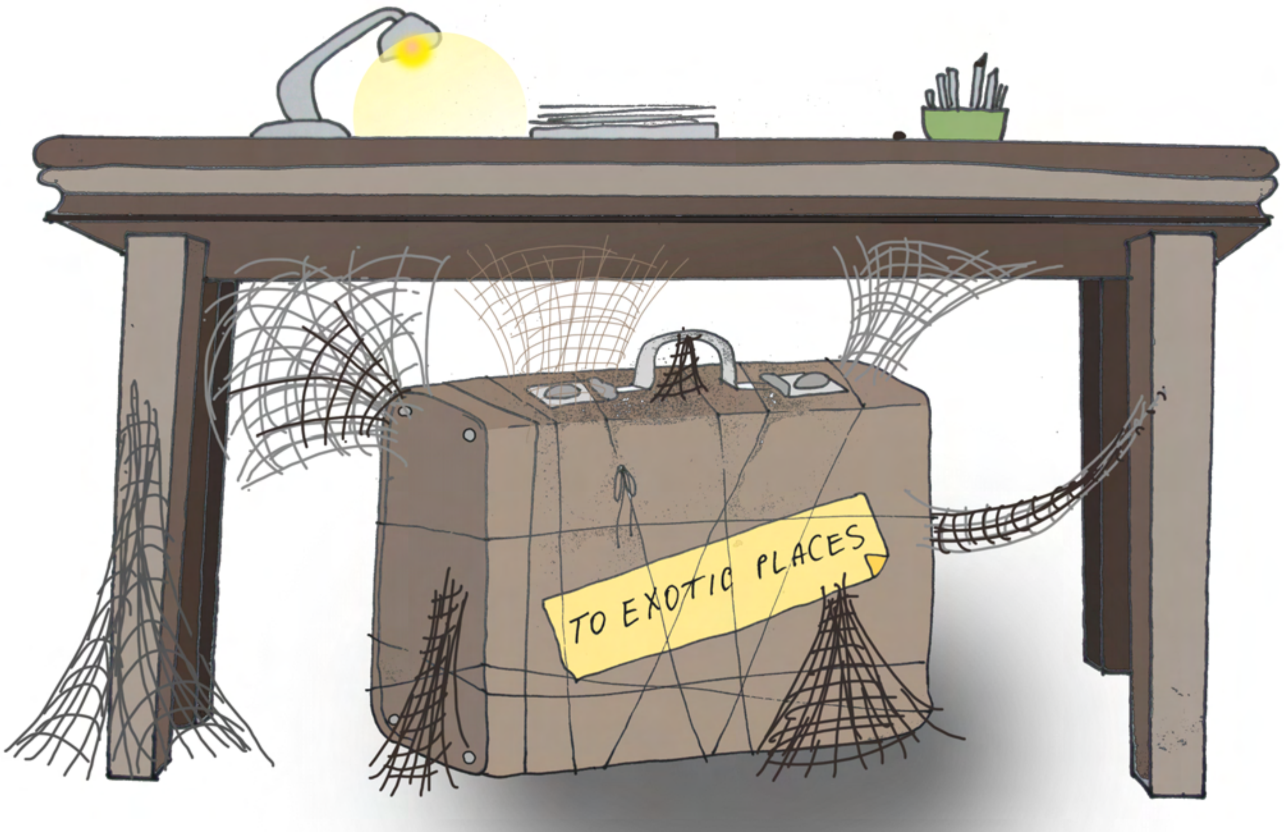
  the Higgs Boson is light, consistent with precision electroweak predictions, and with theoretical prejudice

  or,

  ....?

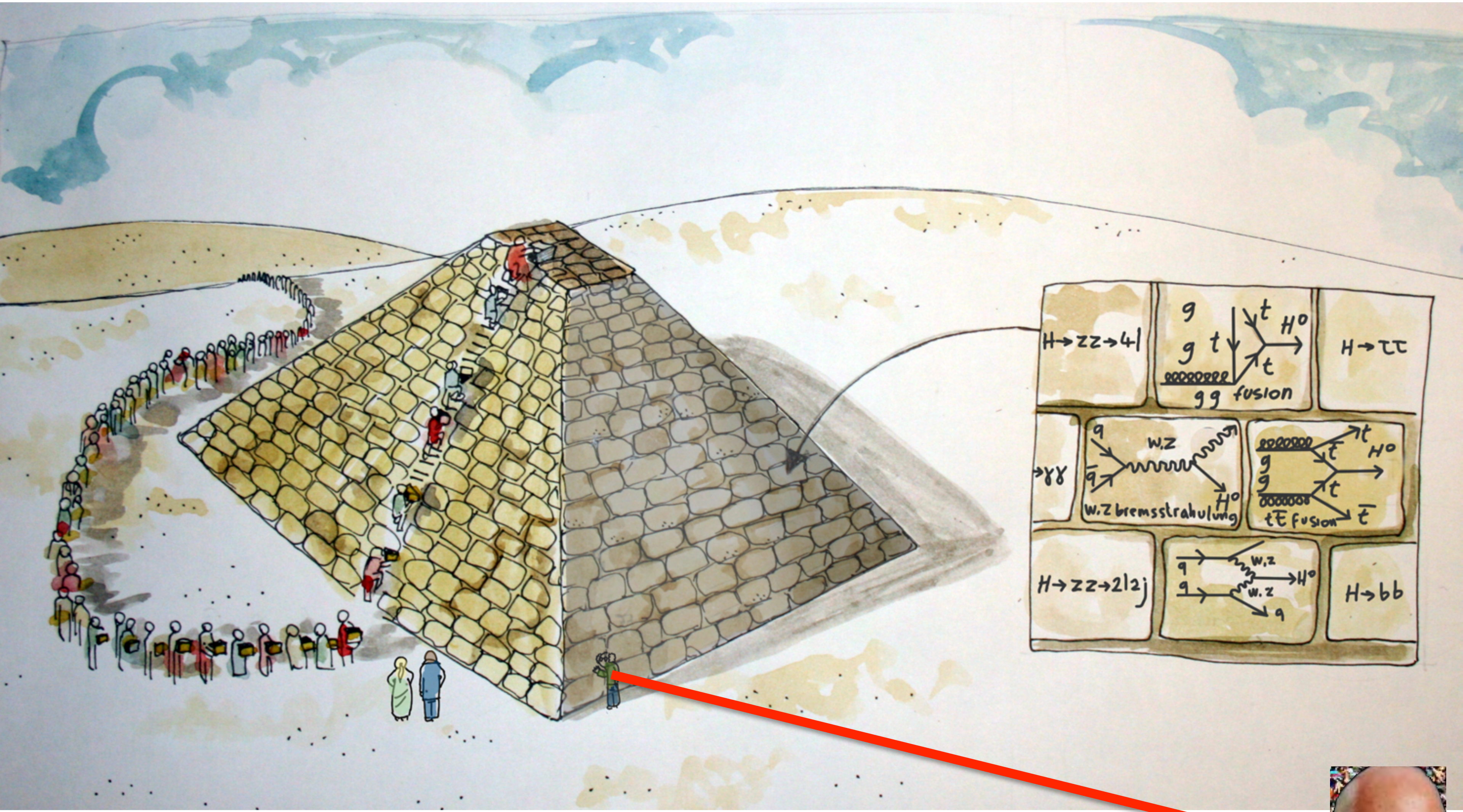
- **The luminosity from 2011+2012 runs, will allow exploration up to the TeV scale, thus giving a better picture of the way ahead.**

Today 22nd of september 2011 in the Luciano office…after 11 years



Luciano was right: The mysterious suitcase will stay there forever ! (no longer subliminal !)

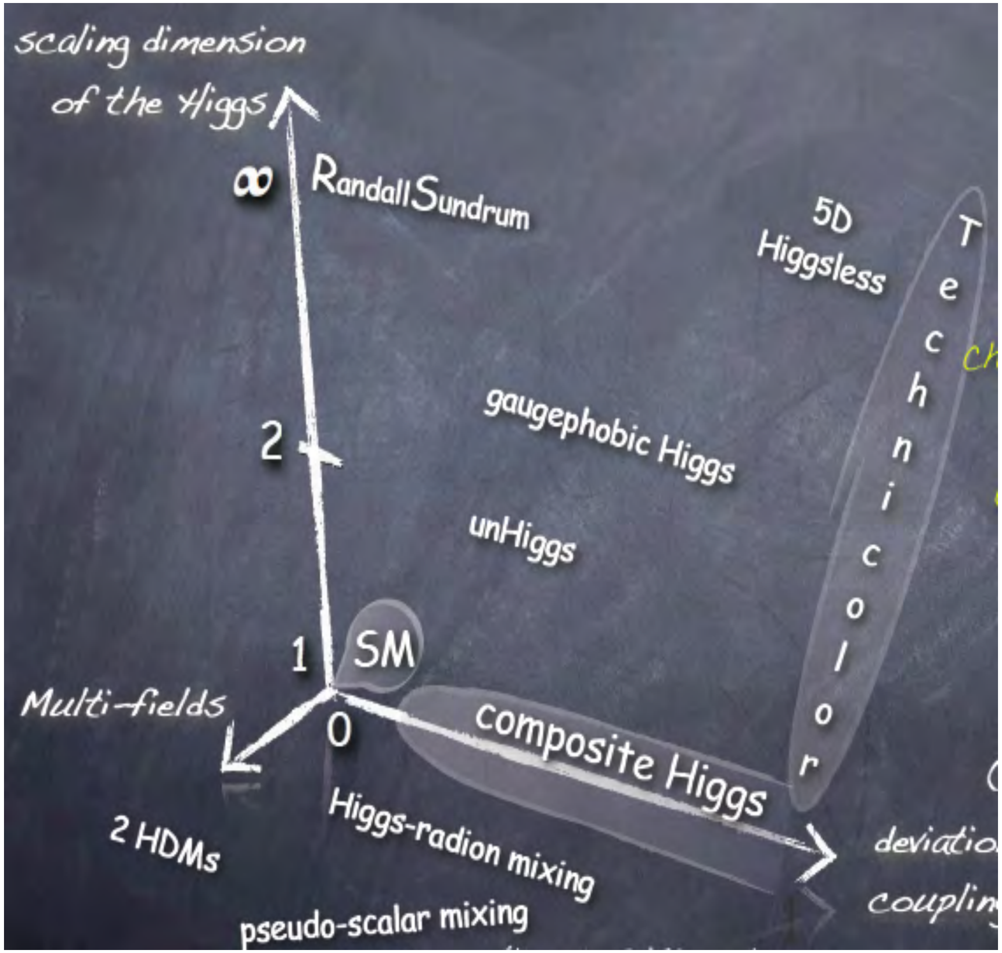
ATLAS and CMS at Work



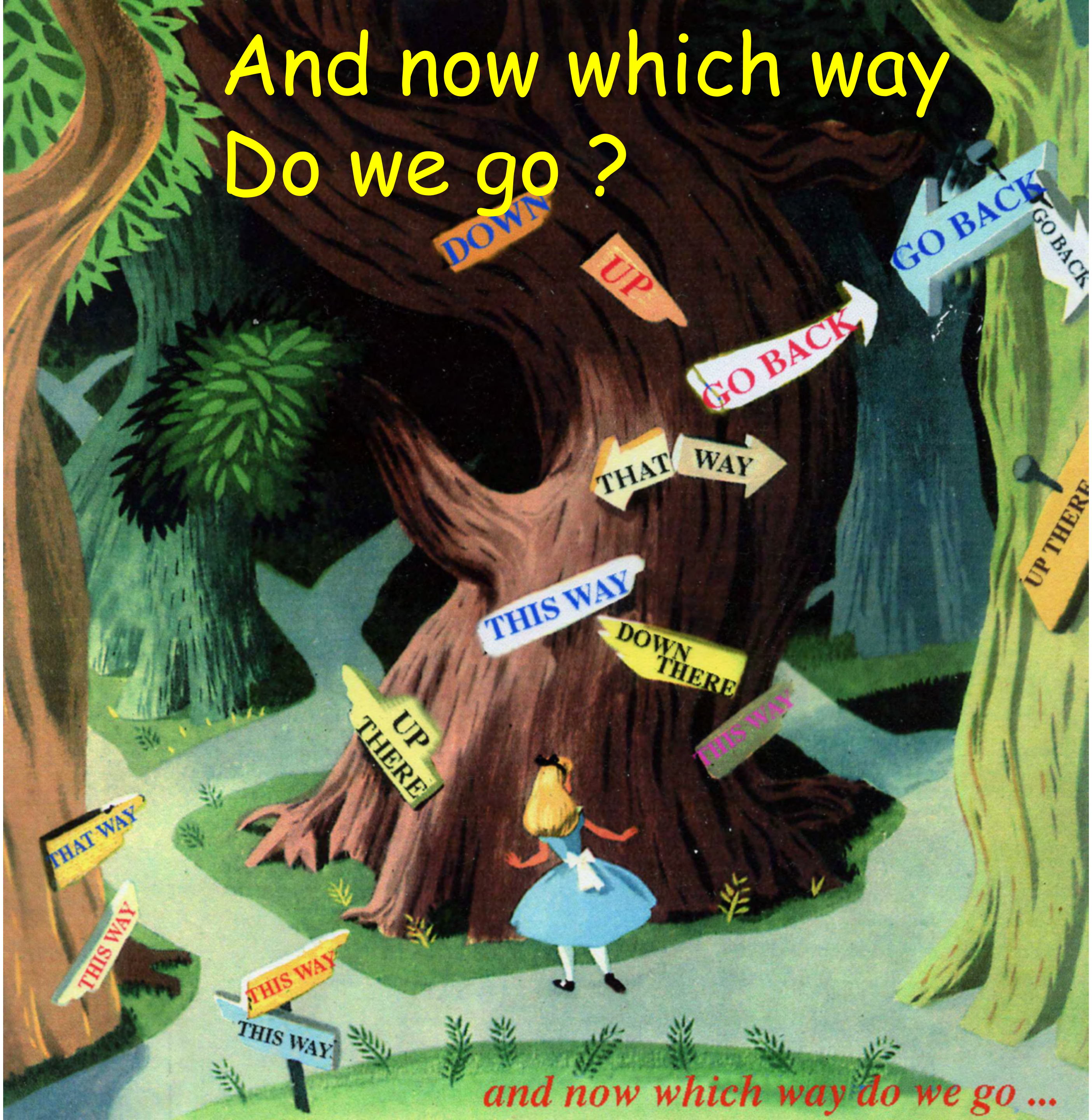
May be we are almost done…..

If no Higgs then what?

Beyond the SM Higgs



And now which way Do we go ?



A Very Good News

Luciano will help us to figure out the way to go !

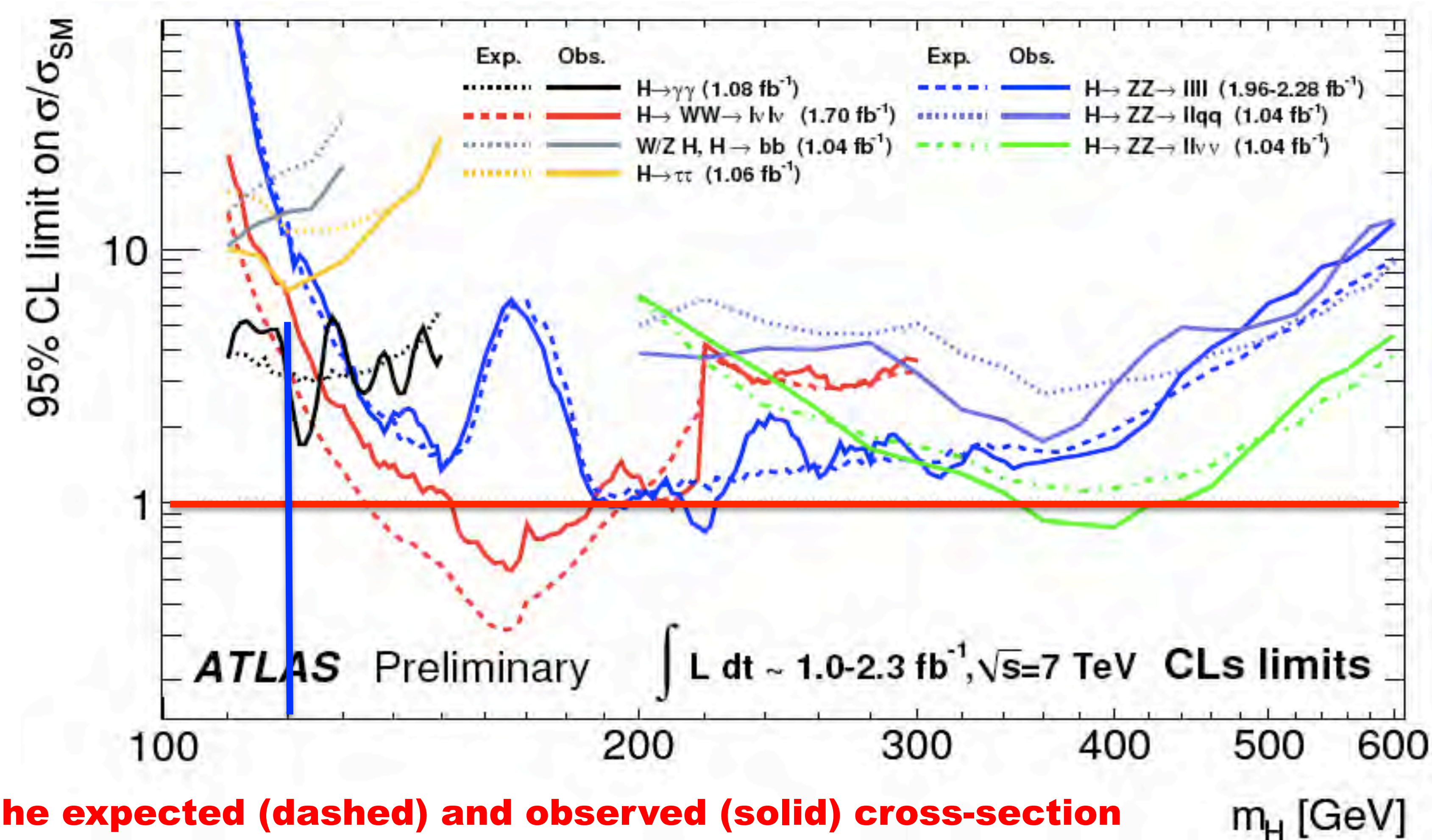
Tanti Carissimi Auguri

Acknowledgments

- Thanks to Federica Fruhwirth for the nice drawings
- Thanks to Alessandro De Salvo for the support

BACKUP

Standard Model Higgs Combination (ATLAS)

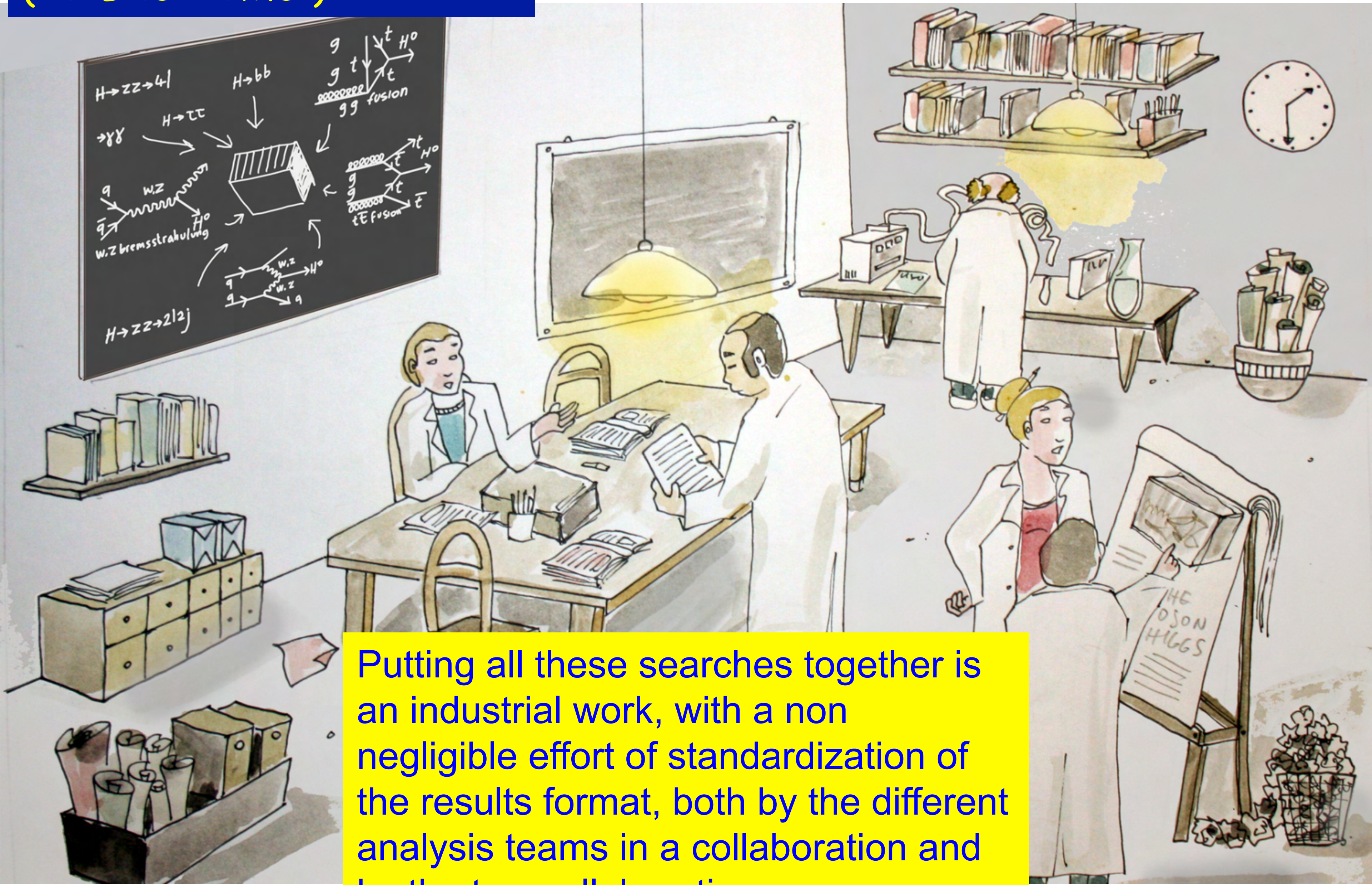


The expected (dashed) and observed (solid) cross-section limits for the individual search channel, normalized to the SM Higgs boson cross section, as a function of the Higgs boson Mass.

The black line is for the H → γγ channel.

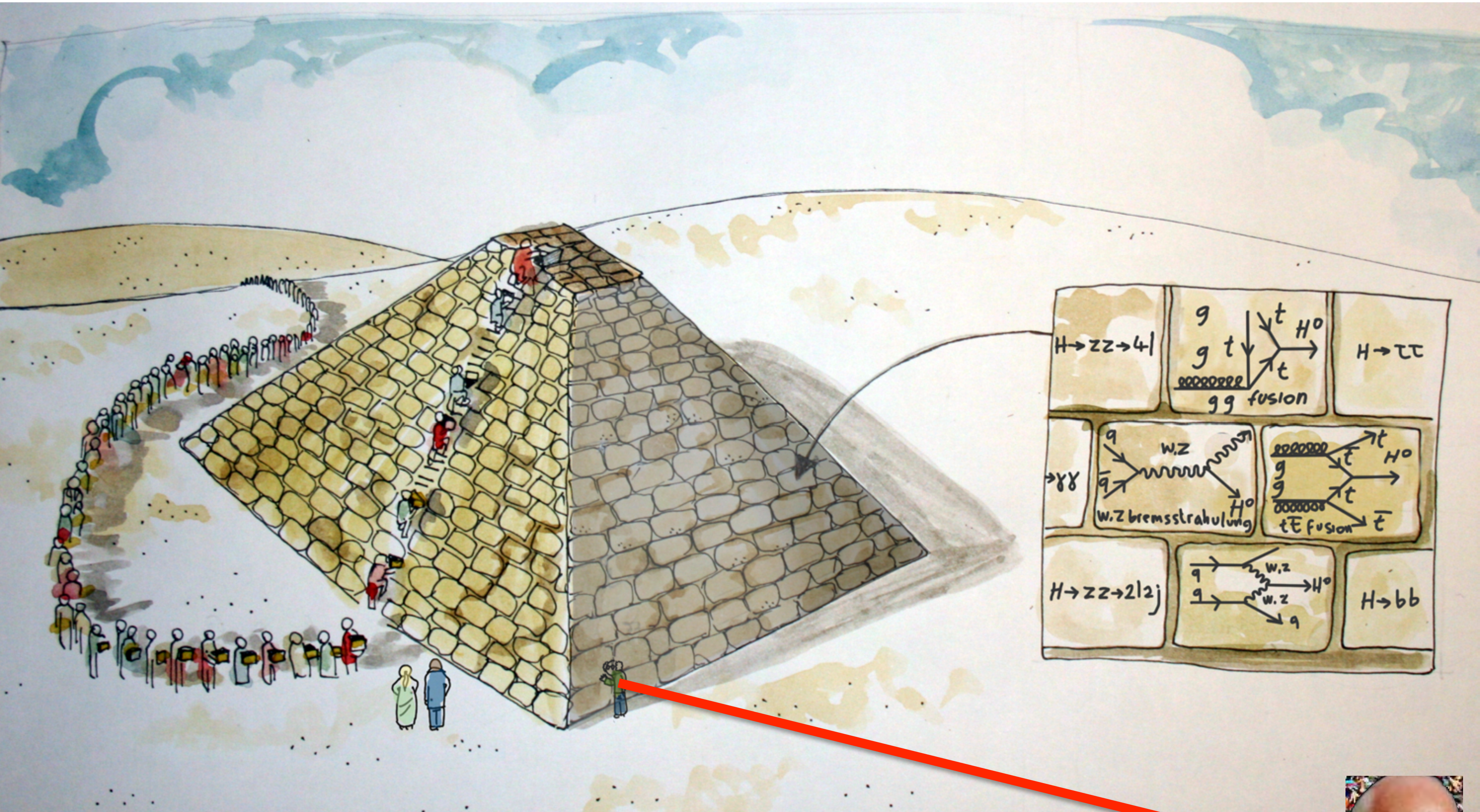
SM Higgs Combination
(ATLAS + CMS)

ATLAS and CMS at Work



Putting all these searches together is an industrial work, with a non negligible effort of standardization of the results format, both by the different analysis teams in a collaboration and by the two collaborations.

ATLAS and CMS at Work



May be we are almost done…..

Simple Signature Channel

Very simple signature (and analysis selection):

Two tightly identified and isolated photons with:

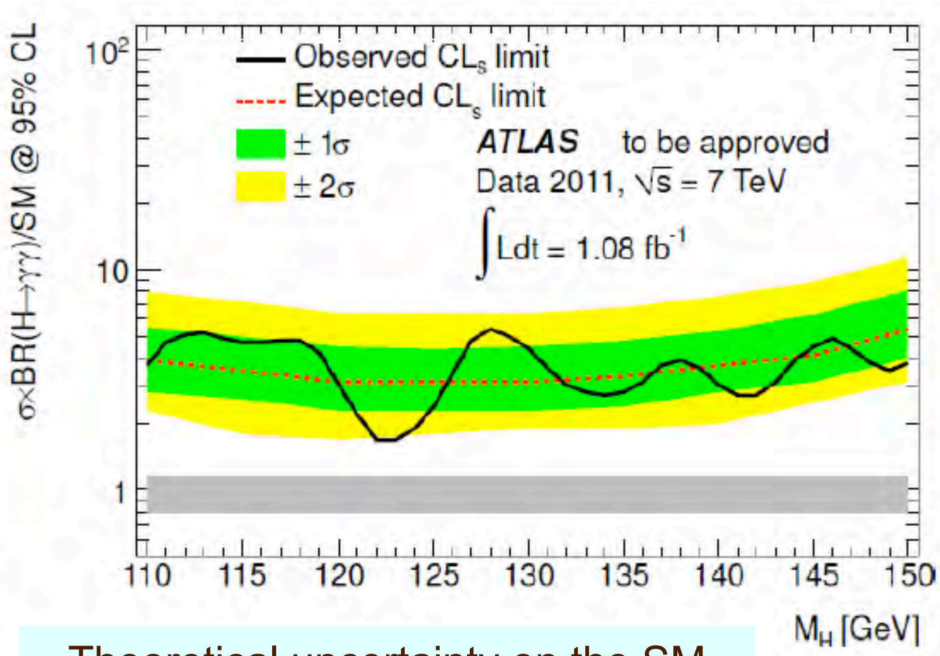
$P(\gamma_1)_T > 40$ GeV/c

$P(\gamma_2)_T > 25$ GeV/c

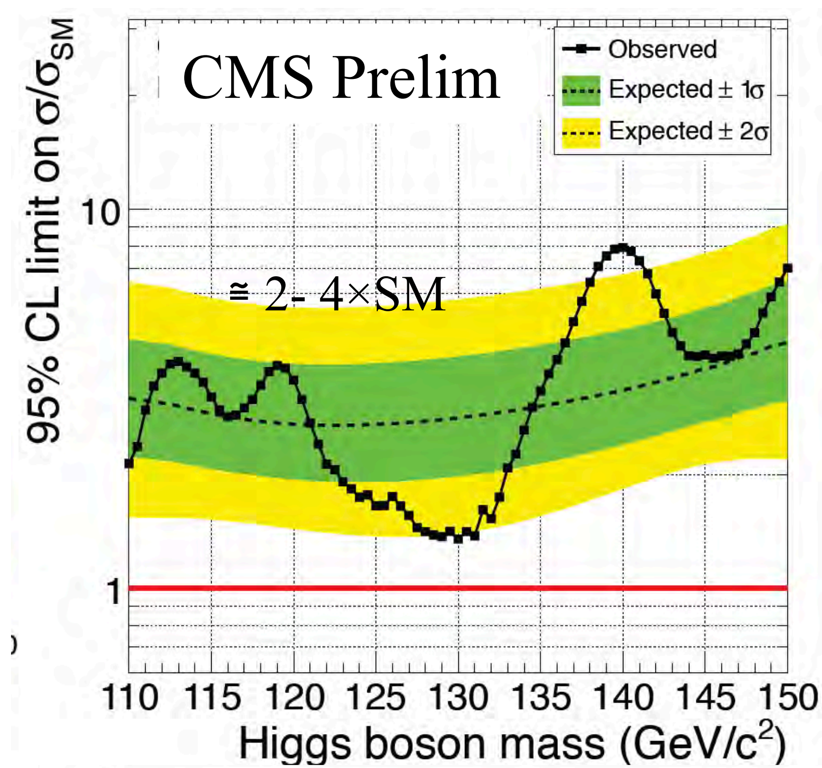
- $|\eta(\gamma_1,\gamma_2)| < 2.37$, excluding [1.37,1.52]

- Calorimetric isolation < 5 GeV

Photon identification based both on the longitudinal and the lateral segmentation of the calorimeter

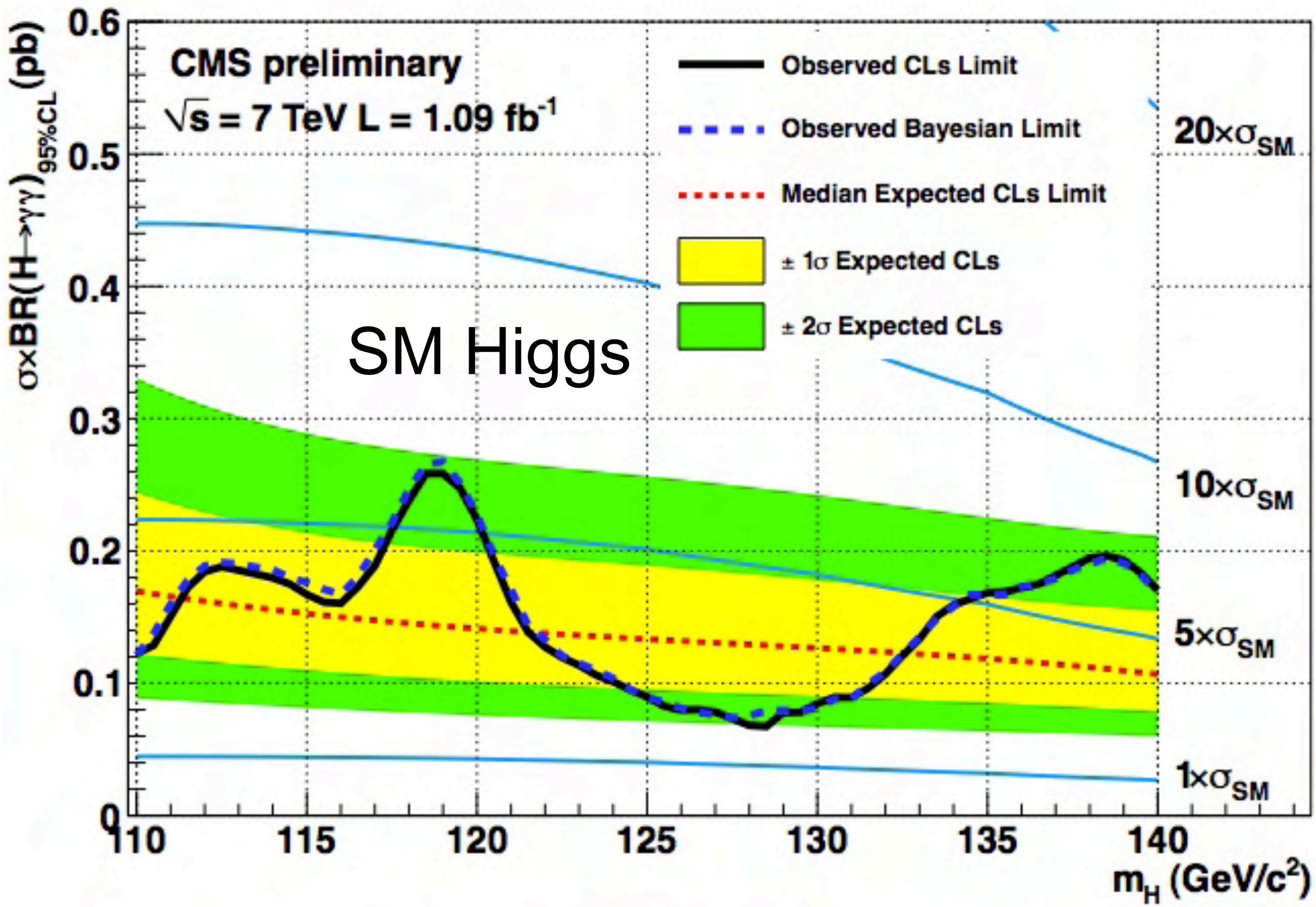


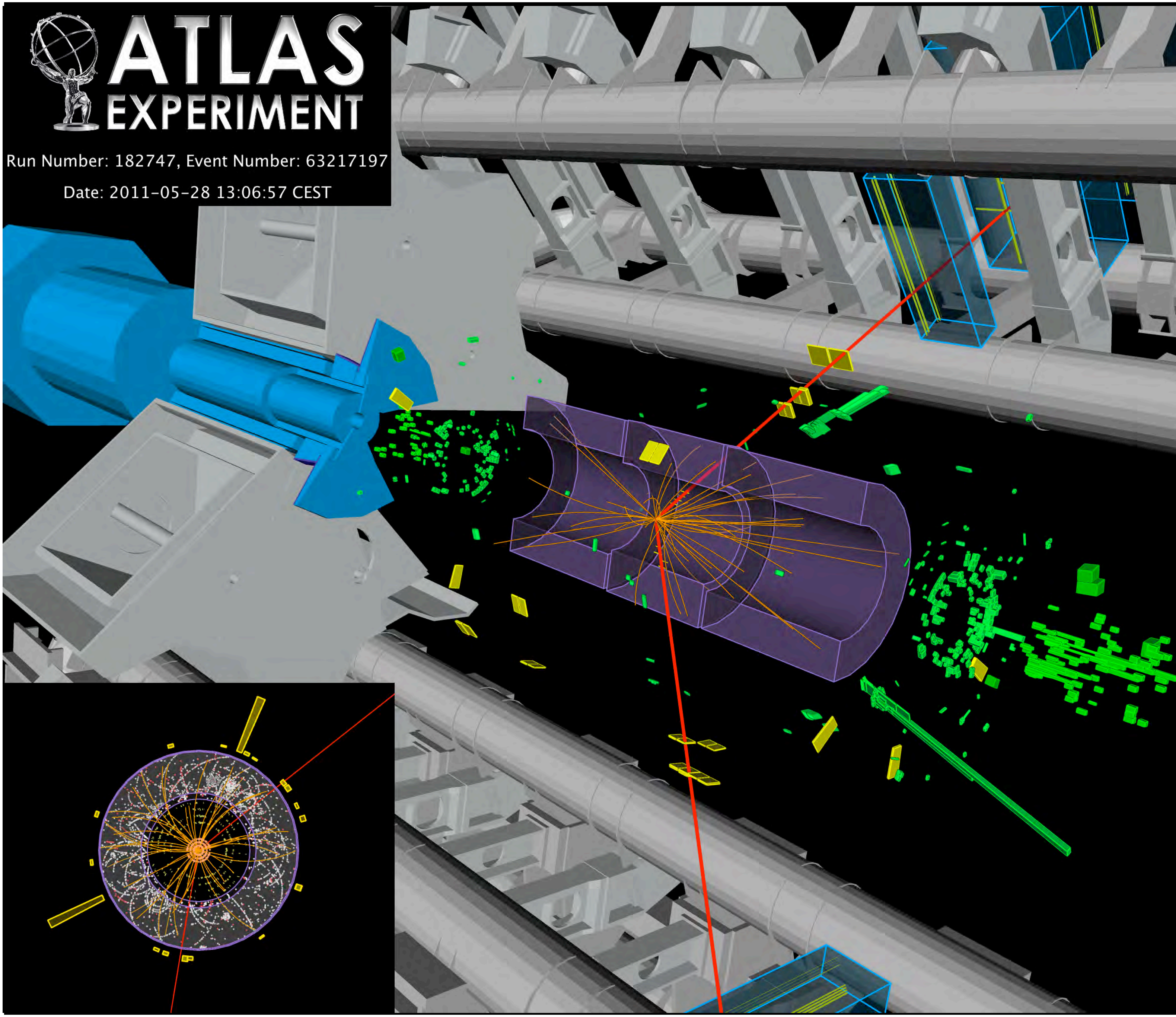
Theoretical uncertainty on the SM Higgs cross section is not included in the limit, but shown as a gray band at 1xSM value. Limit is calculated using a frequentist approach (CLs).



Exclusion (@95% CL) 0.06 pb < σ×BR < 0.26 pb

- **×2 ÷ ×6 SM** for **110 GeV < m(H) < 135 GeV**
- observed limit within 2σ from expected value





2μ2e candidate:

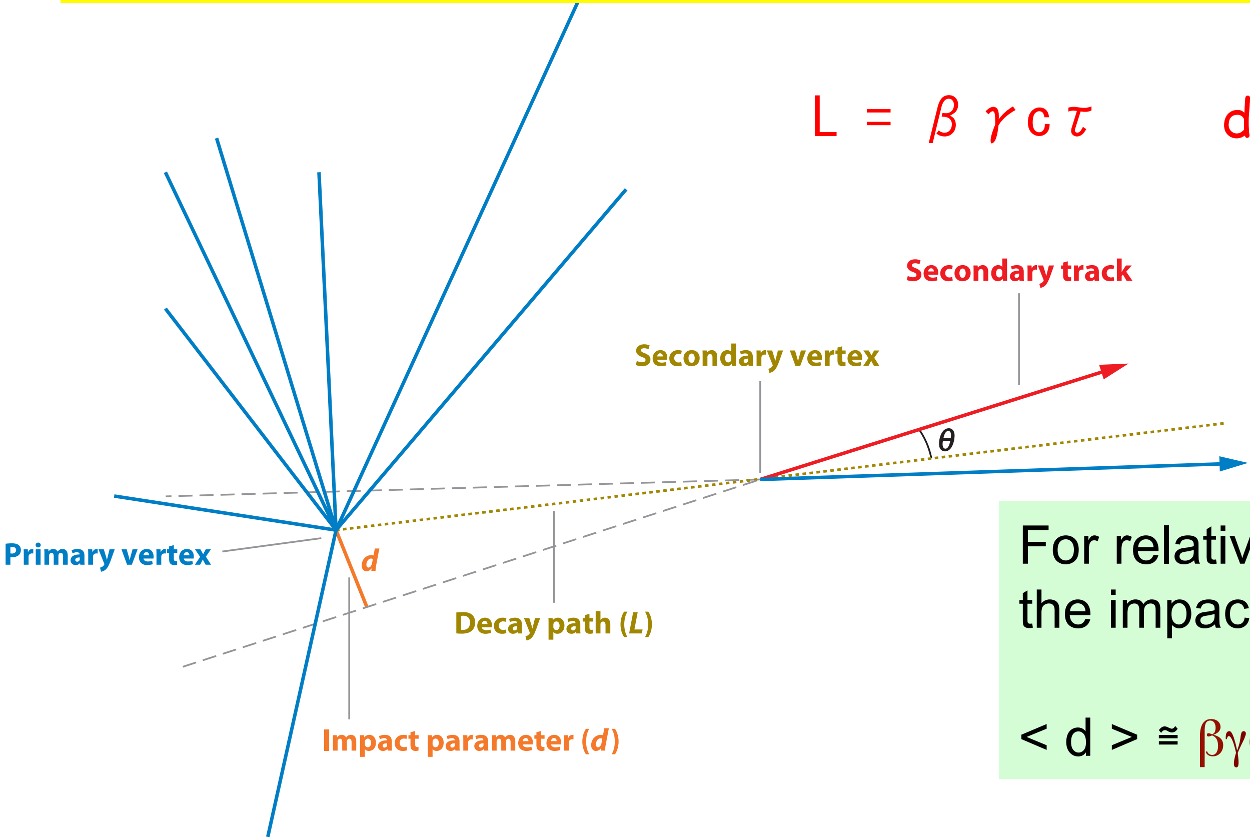
m_{lead}: 85.9 GeV

m_{subl}: 85.5 GeV

m_{4l}: 210 GeV

Needed Precision on the impact parameter measurements

$L = \beta \gamma c \tau \qquad d = L \sin\theta$



For relativistic particles, the impact parameter is:

$< d > \cong \beta\gamma c\tau\,(1/\gamma) = \beta c\tau \cong c\tau$

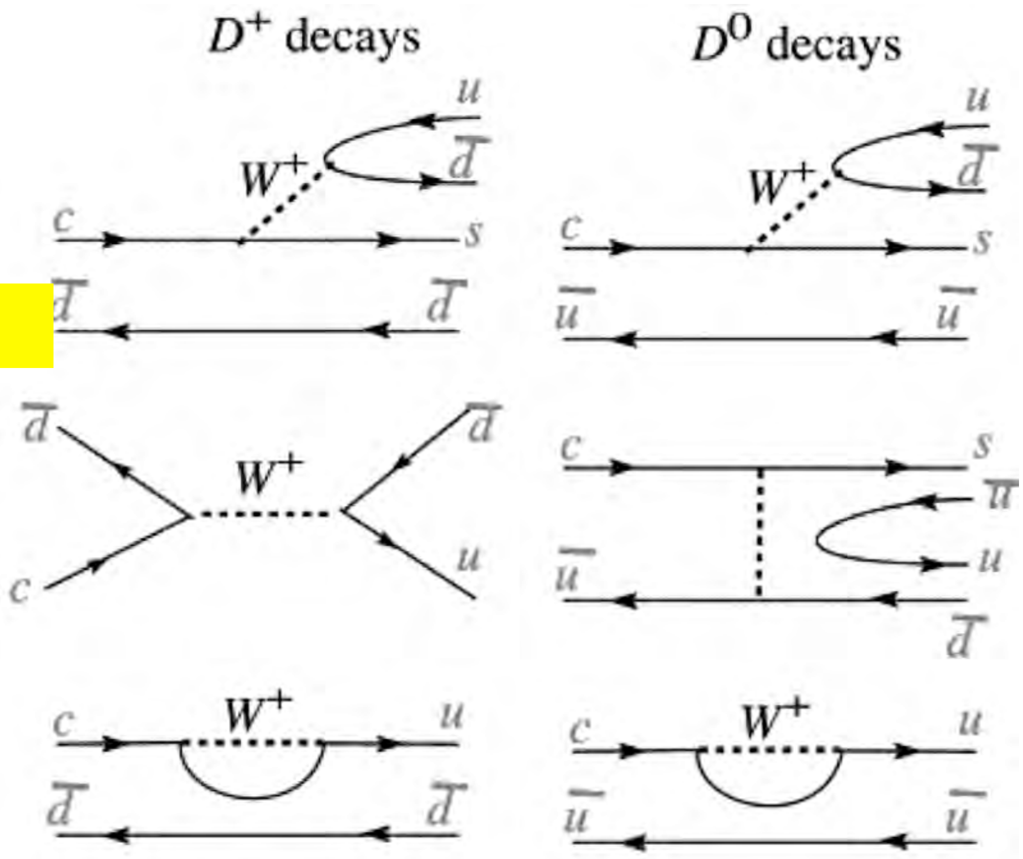
- For particles containig the **b quark, cτ is of the order of 450 μm,** and for particles containing the **c quark,cτ can be as small as 123 μm.**

- **These values set the scale for the precision of the impact-parameter measurement needed to detector secondary vertices from heavy-flavor decay to the order of a few tens of micrometers.**

❖Charm decays had been believed to be dominated by the “spectator” graph, hence that lifetimes of all charmed hadrons were nearly identical.

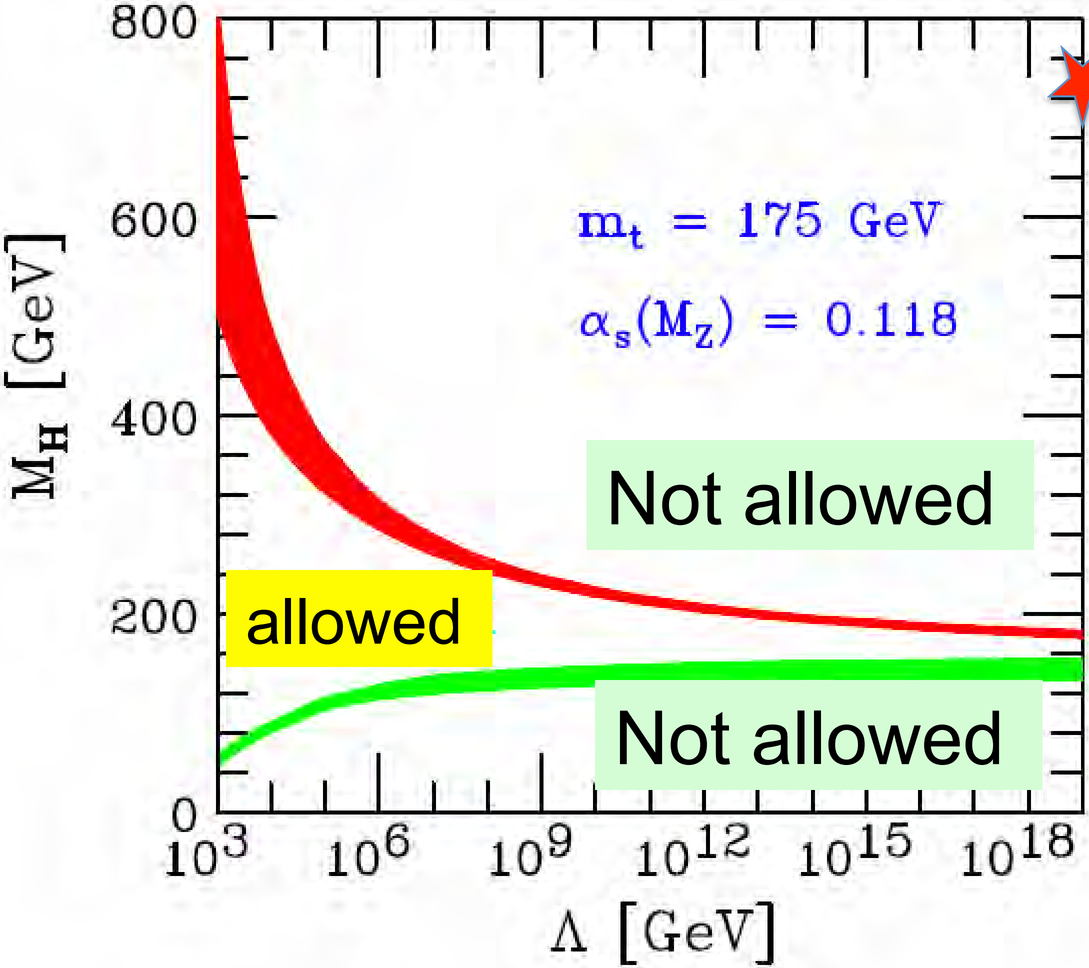
Sources of possible differences

- Two identical d’s in the D^+, not in the D^0 decay [Pauli effect];
- D^+ but not D^0 has an annichilation channel open, but it is Cabibbo-suppressed;
- D^0 W exchange is suppressed by helicity;
- Penguins are Cabibbo and helicity suppressed.



We were only at the beginning. To disentangle the contributions of the different graphs and their possible interferences, the lifetimes of all charmed hadrons, both mesons and baryons, had to be accurately measured. [This has been achieved in ≈ the year 2000].

Higgs Mass Constraints from Theory



N. Cabibbo, L. Maiani, G. Parisi and R.Petronzio,
Nucl. Phys. B 158 (1979) 295
Sher; Lindner; Hasenfrantz; Hambey, Riesselmann..... .

Triviality ➔ upper bound

Vacuum stability ➔ lower bound

$\Lambda = 1$ TeV : 55 GeV $\lesssim M_H \lesssim$ 700 GeV

$\Lambda_{GUT} = 10^{16}$ GeV: 130 GeV $\lesssim M_H \lesssim$ 190 GeV