The Higgs boson and more

Luciano Maiani
Sapienza Università di Roma

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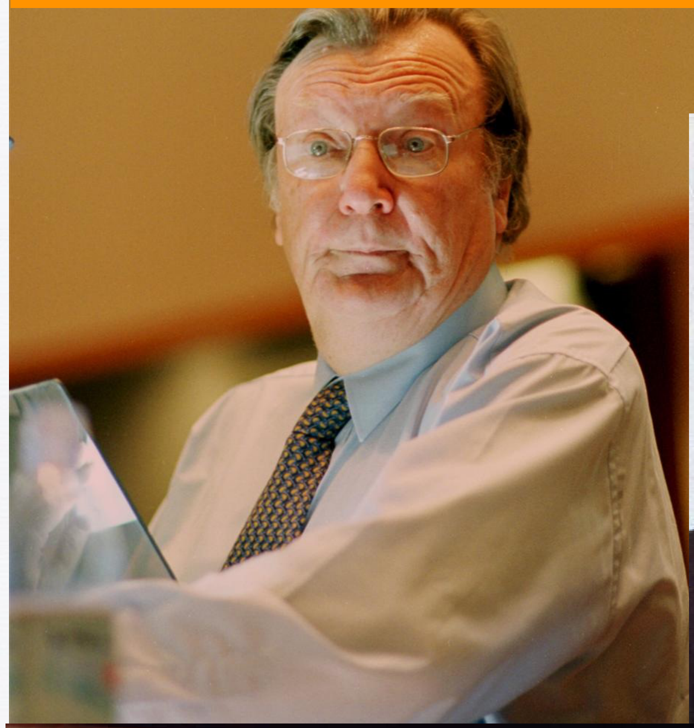
THE EUROPEAN PHYSICAL JOURNAL H

Oral history interview

The LHC timeline: a personal recollection (1980–2012)[⋆]

Luciano Maiani[1] and Luisa Bonolis[2,a]

LHC @ CERN
some protagonists



1. Prologue: the LEP tunnel

- Physicists had thought to make the tunnel wider than what was strictly needed, so as to be able to install later a proton machine with superconducting magnets

- The ECFA study (Roma 1978, chaired by A. Zichichi) had made a recommendation in this direction, nothwitstanding the resistence of those afraid that the implied cost increase would put the LEP project at risk
- A tunnel of 4 meters diameter was accepted, as a compromise. This was not enough for a cryogenic system with two independent magnets (such as was designed for the SSC).
- CERN was forced to develop a new advanced design: "two-in-one", more compact and less expensive
- The choice of tunnel's dimensions, all in all, is a positive story: an admirable compromise that made it possible to prolong the lifetime of CERN well above 20 years.

Two-in-one Dipole Superconducting Magnets

Table 3 : List of Magnets

		Magnetiic Length (m)	Number of magnets
Dipoles	$B_o = 10$ T	9.00	2 x 1792
Quadrupoles	G = 250 T/m	3.05	2 x 642
Tun. quads,	G = 120 T/m	0.72	2 x 400
Sextupoles	B" = 4500T/m^2	1.0	2 x 800
Orbit corr. dipoles	$B_o = 1.5$ T	1.0	2 x 552
Higher-order multipoles			2 x 1600

A more detailed review of the LHC magnets is given in Reference[7]).

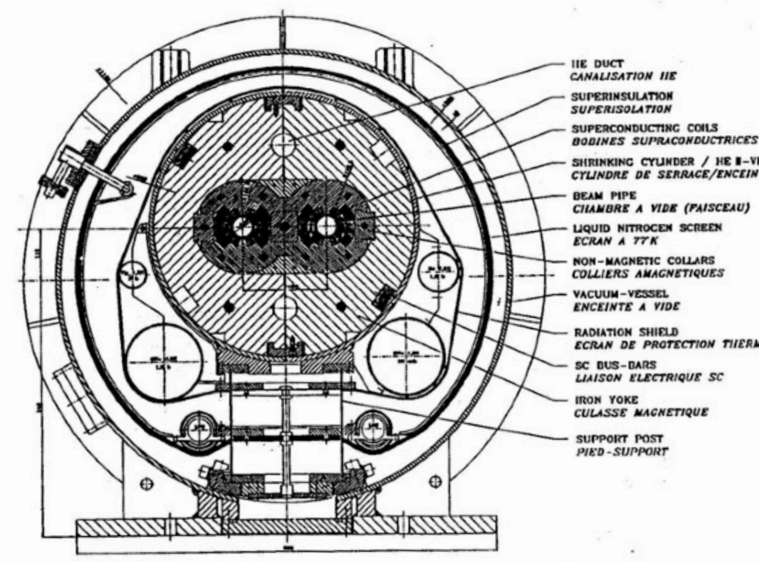


Fig. 3 : LHC dipole standard cross-section

November 1988.
Fermilab loses the competition for hosting the SSC
SSC approved at a new site: Waxahachie, Texas.

10 November 1988. Leon Lederman, wearing a Stetson hat, annoounces to the Laboratory that Fermilab has not been chosen as the SSC site. FNAL Visual Media Service.

Shaft to the SSC tunnel di SSC, located at about10 meters underground. The planned tunnel had a circumference of 87 km.

- **1988** **SSC approved,** proton-proton, 20 TeV/beam, 87 km tunnel, cost 4-5 B US$;
  1989 SSC construction starts.
- **1993** SSC discontinued by the US Congress after a bitter discussion which invested all the scientific community (projected cost >10 B US$)

2. Early LHC chronology

- **1981** Lausanne ECFA workshop: LHC in LEP tunnel
- **1986** La -Thuile workshop: first design (G. Brianti)
- **1988** Feasibility of High Luminosity expts at LHC, Geneve meeting
- **1990** ***Aachen meeting***: main lines are delineated.

- ***G. Kalmus*** (closing remarks): (The Aachen meeting) has marked a watershed, the time, when the LHC project…***graduated*** ..***to being the way forward for European particle physics.***
- ***C. Rubbia: high luminosity makes LHC competitive with the SSC (compensating for an energy ratio 40/16)***
- A lot of wishful thinking:
  - schedule: start civil engineering in 1992, commissioning in 1998 (6 years).
  - ***In reality***…start civil engin. in 1997(+5), commiss. in 2008 (11 years).
  - It was still considered possible to install in the tunnel LHC together with LEP and run LEP and LHC concurrently. This possibility was kept alive until 1995.
  - Need to dismantle LEP was announced by C. Llewellyn Smith in Beijing…I got protests by I. Mannelli
  - no cost mentioned.
- **1992** Council declares that the LHC ***"will be CERN's next facility"***,
- **1992** Expressions of Interest for experiments are presented in Evian; the LHC experiments Committe is created.

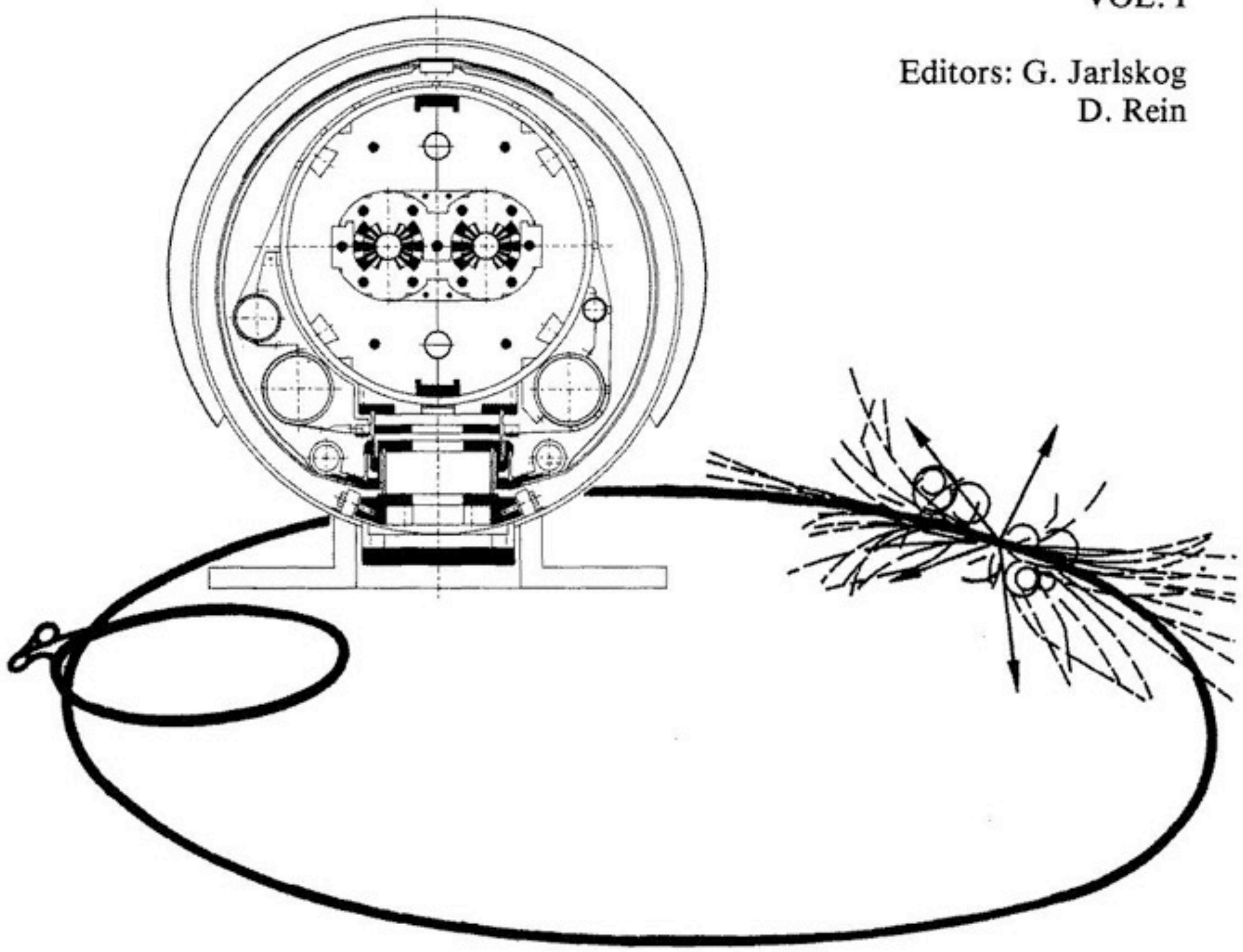
CERN 90-10
ECFA 90-133
Volume I
3 December 1990

EUROPEAN COMMITTEE FOR FUTURE ACCELERATORS

Large Hadron Collider Workshop

PROCEEDINGS
VOL. I

Editors: G. Jarlskog
D. Rein



Aachen, 4-9 October 1990

from LEP to LHC in the same tunnel

LEP, July 1989-
December 2000

LHC, January 2010-

1994: LHC is approved

- the cancellation of the SSC programme made a real shock-wave in Europe, firing back on particle physics and CERN.
- Top quark discovery had a very good balancing effect (as seen from Italy)
- the first prototype of the 11 m superconducting LHC magnets was deliverd to CERN in Dec. 1993 and presented to CERN Council in March 1994, with a very positive effect
- On the basis of the SppbarS and LEP successes, CERN project was approved in December 1994.

First prototype of 15 m superconducting LHC dipole by CERN-INFN-Ansaldo Energia collaboration,1998.

LHC agreements: 1995 to 1997

Chris Llewellyn Smith (right), with Hubert Curien, President of Council (center) receives a Daruma Doll from Kaoru Yosano, Japan Minister of Education, Science and Culture, June 1st 1995 at the signature of the Japan-CERN agreement for Japan participation in LHC (machine and experiments.

CERN personnel protest against budget cuts requested by CERN Council to approve LHC construction. December 1996

Signature of the USA-CERN agreement for the US participation in LHC (machine and experiments), Washington 8 december 1997. From left: Neil Lane, Director NSF, Federico Peña, Secretary for Energiy, Luciano Maiani, President of Council, Chris Llewellyn Smith, Director General of CERN.

The December 1996 resolution

- CERN Council came back to LHC in december 1996
- The new resolution approved to start LHC construction in 1997, in the final stage of full magnets.
- At the same time, Council accepted the request of Germany ***to reduce the annual CERN budget by some 8%, a total of about 700 MCHF over the construction period***
- CERN, accepted the cut, to be reabsorbed by a general reduction of the Laboratory expenses, within 2009.
- ***The starting of LHC was fixed to 2005***.
- LHC had no more contingency and no resources for magnet R&D
- Chris had fulfilled his goal to obtain the approval, at the expense of moving the problems forward in time.
- ***The community, myself included, was anyway satisfied for the approval and physicists of all countries started preparing the detectors, leaving to CERN the problem to make the machine under financial severe conditions.***

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Was to fire back in 2001

3. Normal sufferings...ground freezing at the CMS shaft

..and major crises: LEP

Clean, startling events seen by ALEPH, september 2000

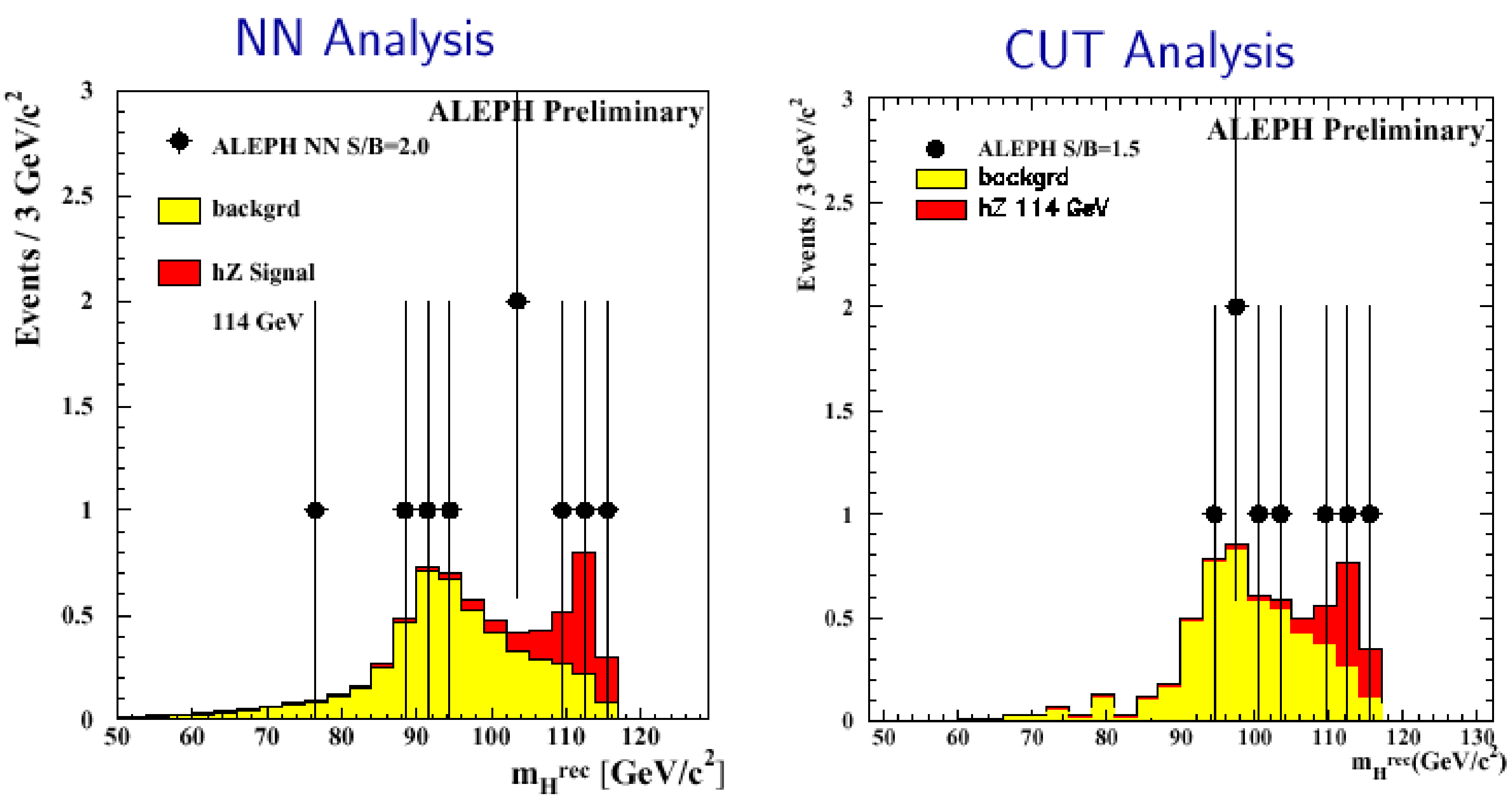
Analysed as:

$$e^+e^- \to Z + H$$

$Z \to 2$ jets;

$H \to 2\ b -$ tagged jets

$M_{2\ b\ jets}$ compatible with M_Z



When cuts are tightened, both accept the same three four jet events with M_H >109 GeV/c²

The survival of these three candidates indicates that they are indeed quite signal-like

Peter McNamara — Status of the Higgs Search at Aleph — November 3, 2000

L.Maiani 9 Februay 2001 — LEP @ICFA — 6

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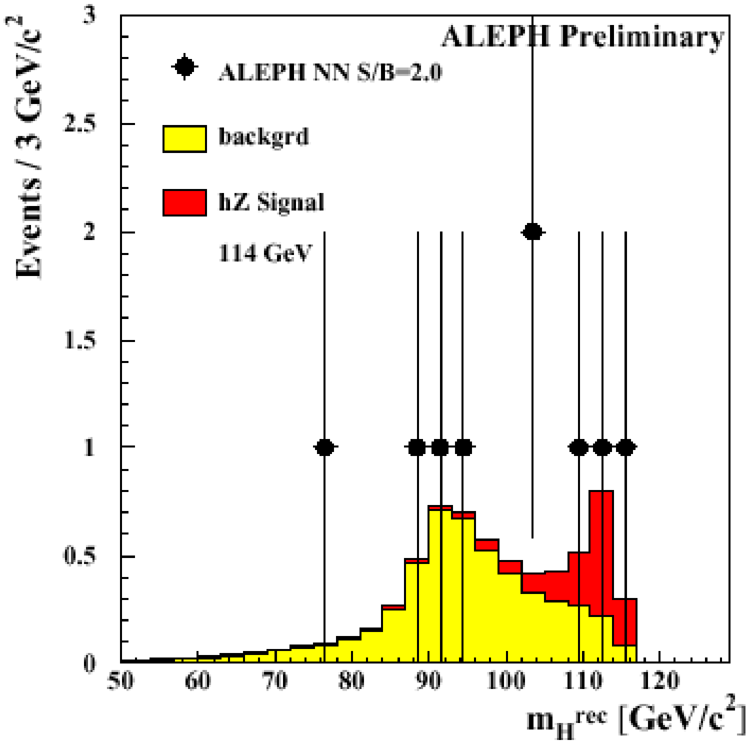
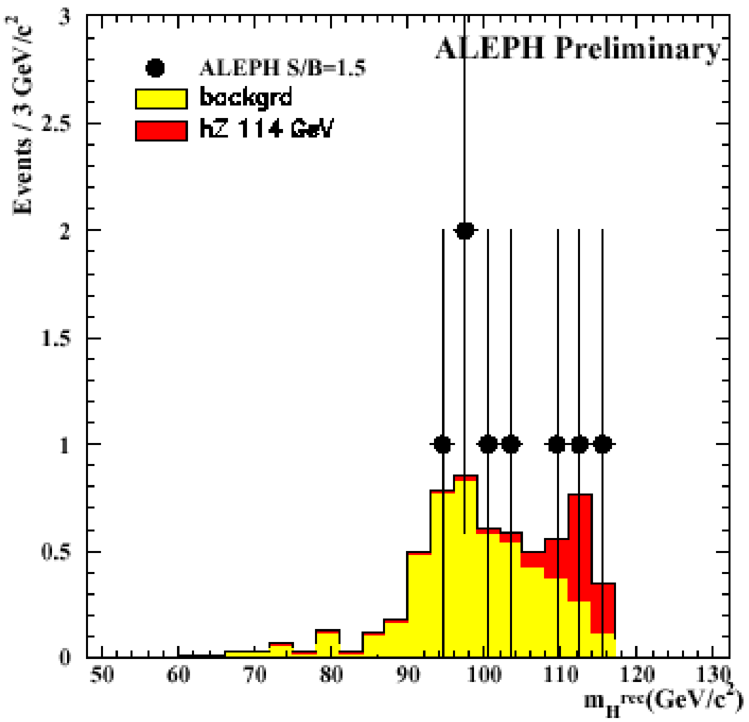
NN Analysis



CUT Analysis



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….The idea that we may find ourselves in September 2001 with 3.5-4 sigmas, CERN's financial position aggravated, LHC delayed and LHC people disbanded is not very encouraging. I am not going to go along this way. (LM to G. Kalmus, SPC Chair, November 4th, 2000)

CERN Council, DG report, Dec. 15, 2000

The future of CERN is in the LHC !!!

CC Statement

"*On 17th November 2000, the CERN Committee of Council held a meeting to examine a proposal by the Director-General concerning the continuation of the existing CERN programme, which foresees the decommissioning of the LEP accelerator at the end of the year 2000.*

The Committee has expressed its recognition and gratitude for the outstanding work done by the LEP accelerator and experimental teams.

It has taken note of the request by many members of the CERN Scientific Community to continue LEP running into 2001 and also noted the divided views expressed in the Scientific Committees consulted on this subject.

On the basis of these considerations and in the absence of a consensus to change the existing programme, the Committee of Council supports the Director-General in pursuing the existing CERN programme."

This decision moves us definitely into the LHC era
A powerful complex, machine and detectors, to fully explore the Higgs and SUSY region

Le Roi est mort
Vive le Roi !!

15/12/2000 L. MAIANI. Status Report 2000

May 2001 TI2 Breakthrough

June 2001
Magnets from Novosibirsk

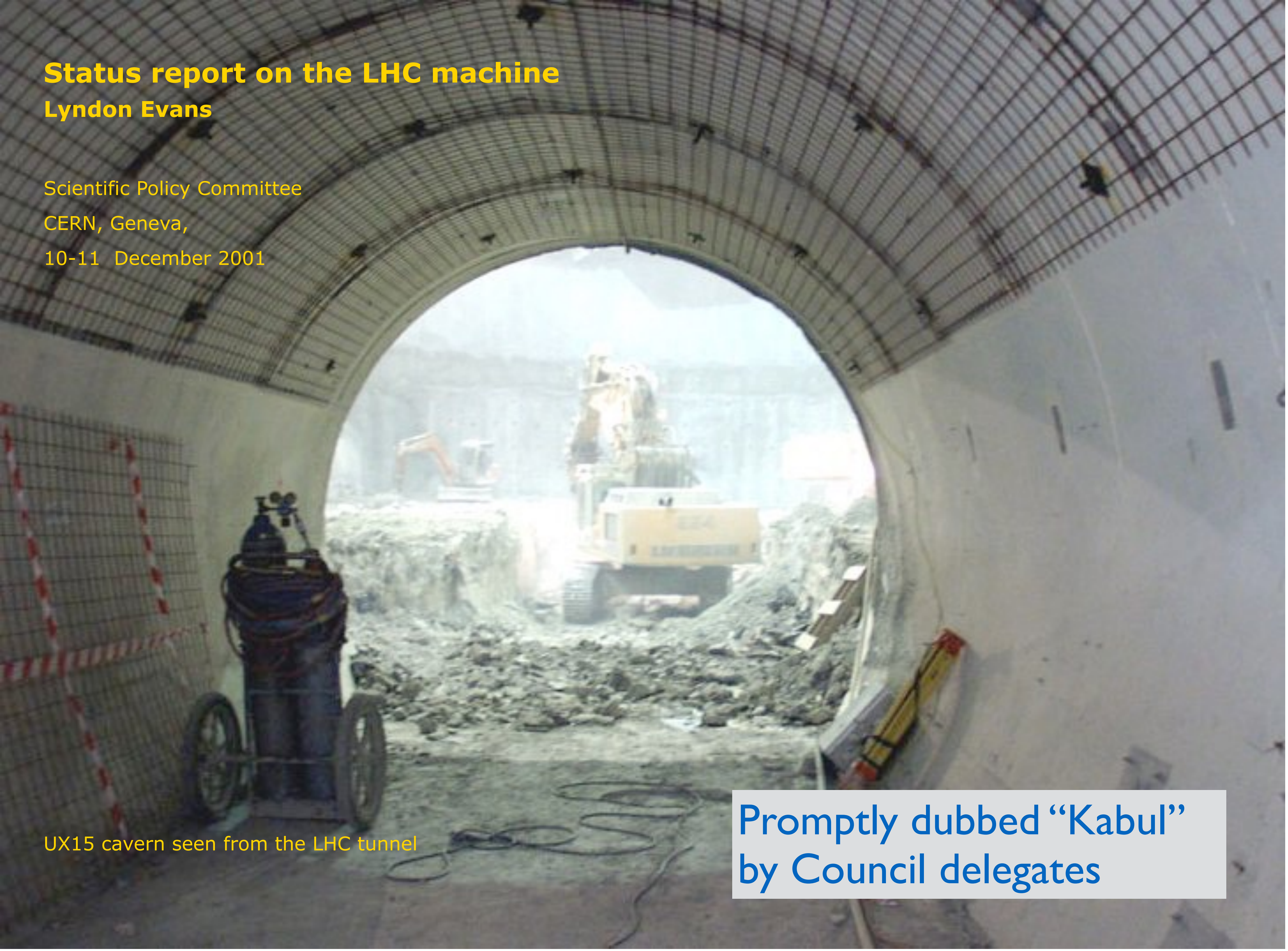
Status report on the LHC machine

Lyndon Evans

Scientific Policy Committee

CERN, Geneva,

10-11 December 2001



UX15 cavern seen from the LHC tunnel

Promptly dubbed "Kabul" by Council delegates

Dipoles in store @ CERN (and LEP magnets)

Dipoles in store @ CERN (and LEP magnets)

Cruising speed: 30-35/month !!

TIME LINE OF LHC CONSTRUCTION

Schedule redifined in March 2002

1.1. LHC Schedule

Contracts for dipole cold mass assembly are being signed;
CERN has a double role: supplier of SC cables, end-customer of the dipoles. We must be prudent in defining the dipole delivery schedule, hence the LHC schedule.

SC cable production to end mid 2005;

last dipole delivered July 1st, 2006;
Machine closed and cold: Oct. 2006;
First beam: April 2007;
First physics: mid 2007;
Very solid foundation of the LHC confirmed by SC cable panel and Machine Advisory Committee.

L. Maiani. March 21, 2002 Committee of Council 8

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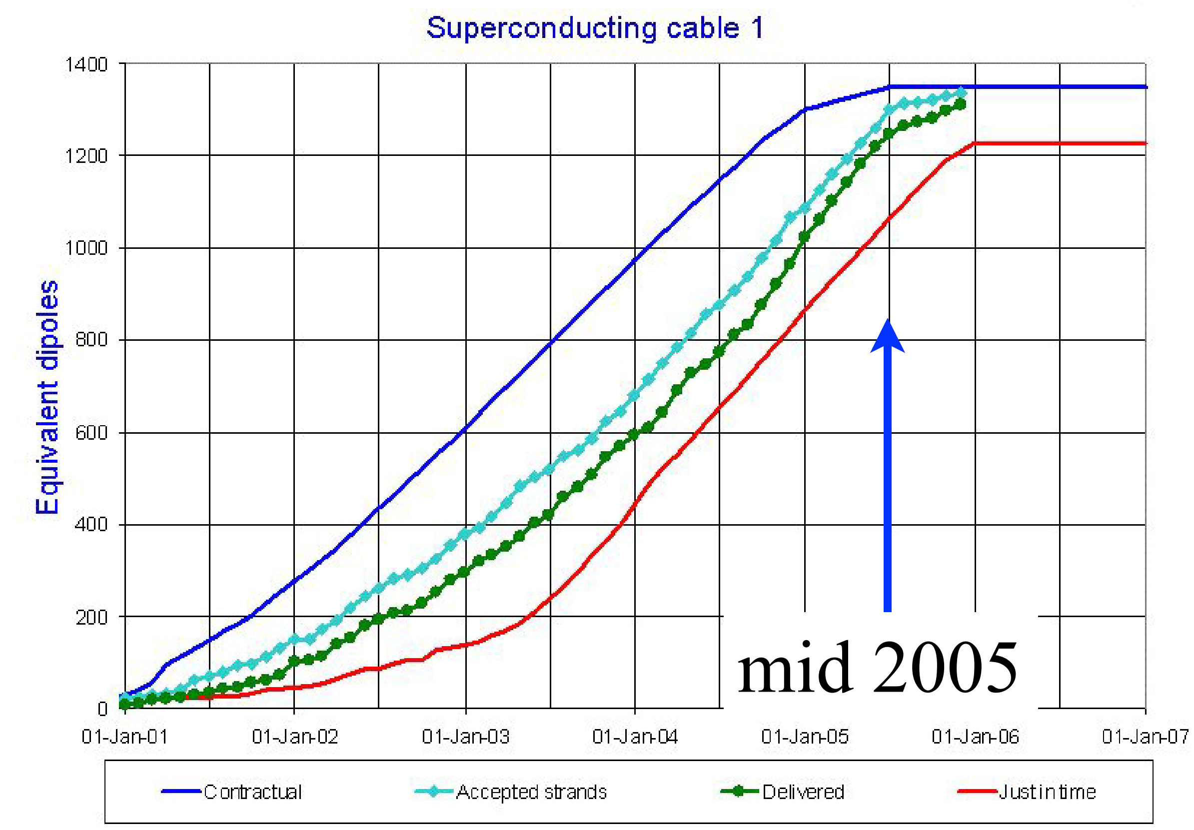

Updated 30 Nov 2005 Data provided by A. Verweij AT-MAS

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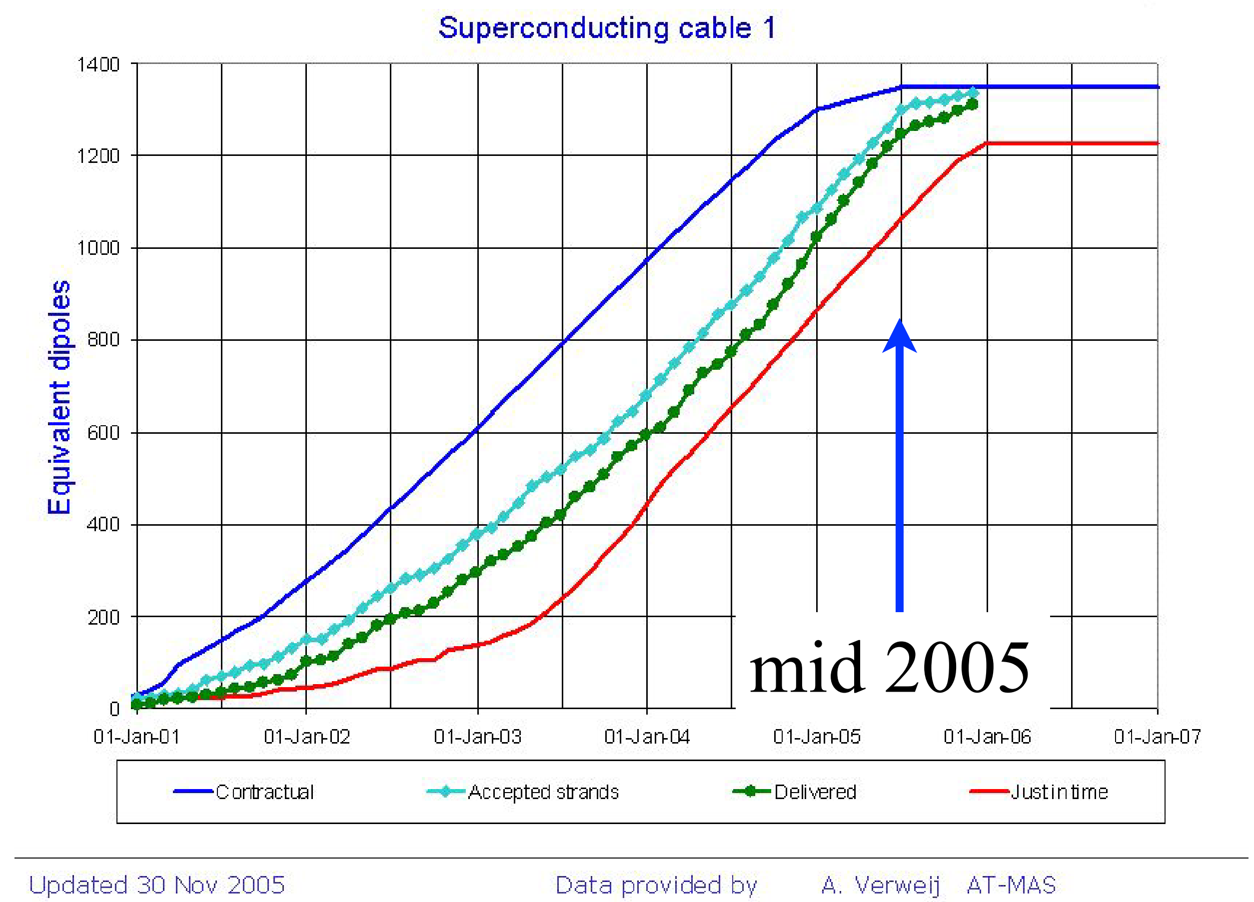

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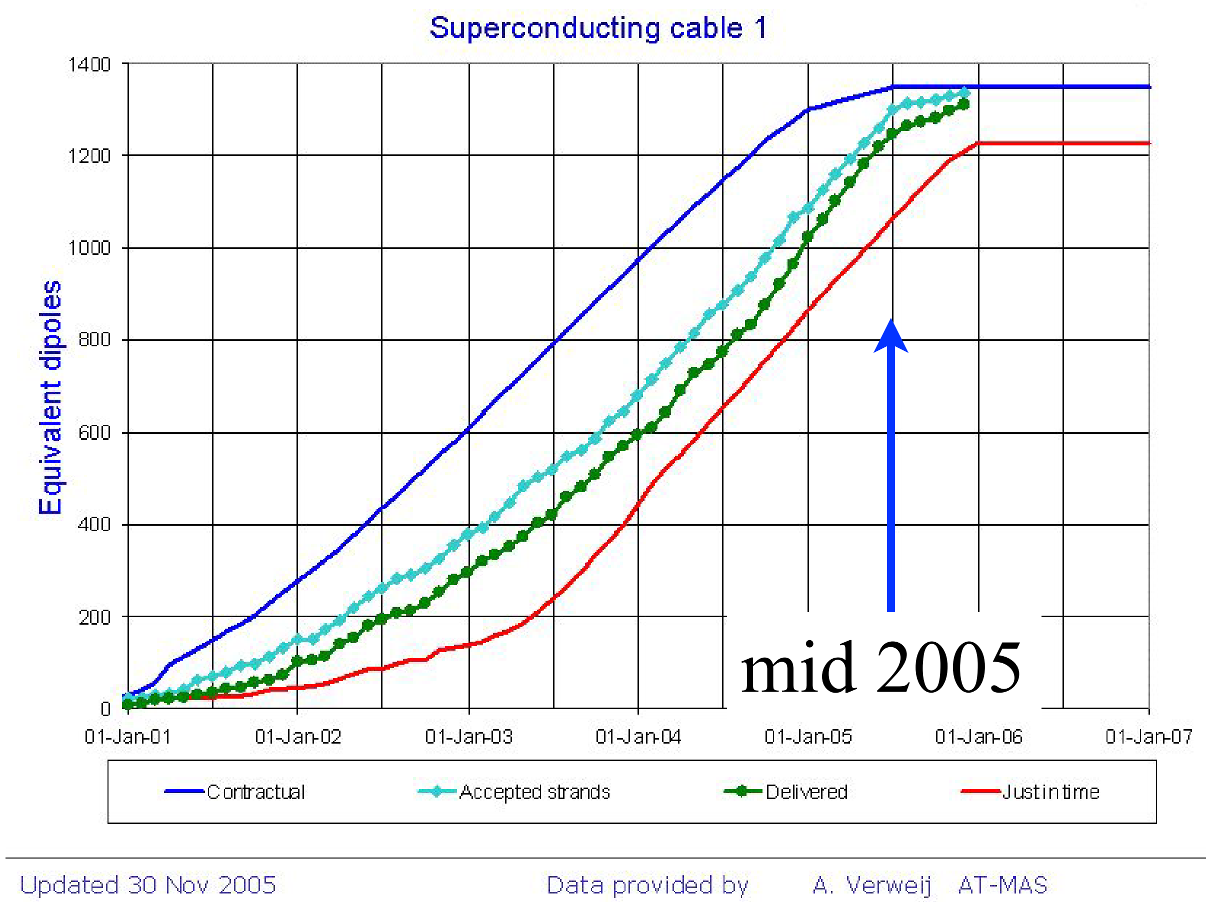

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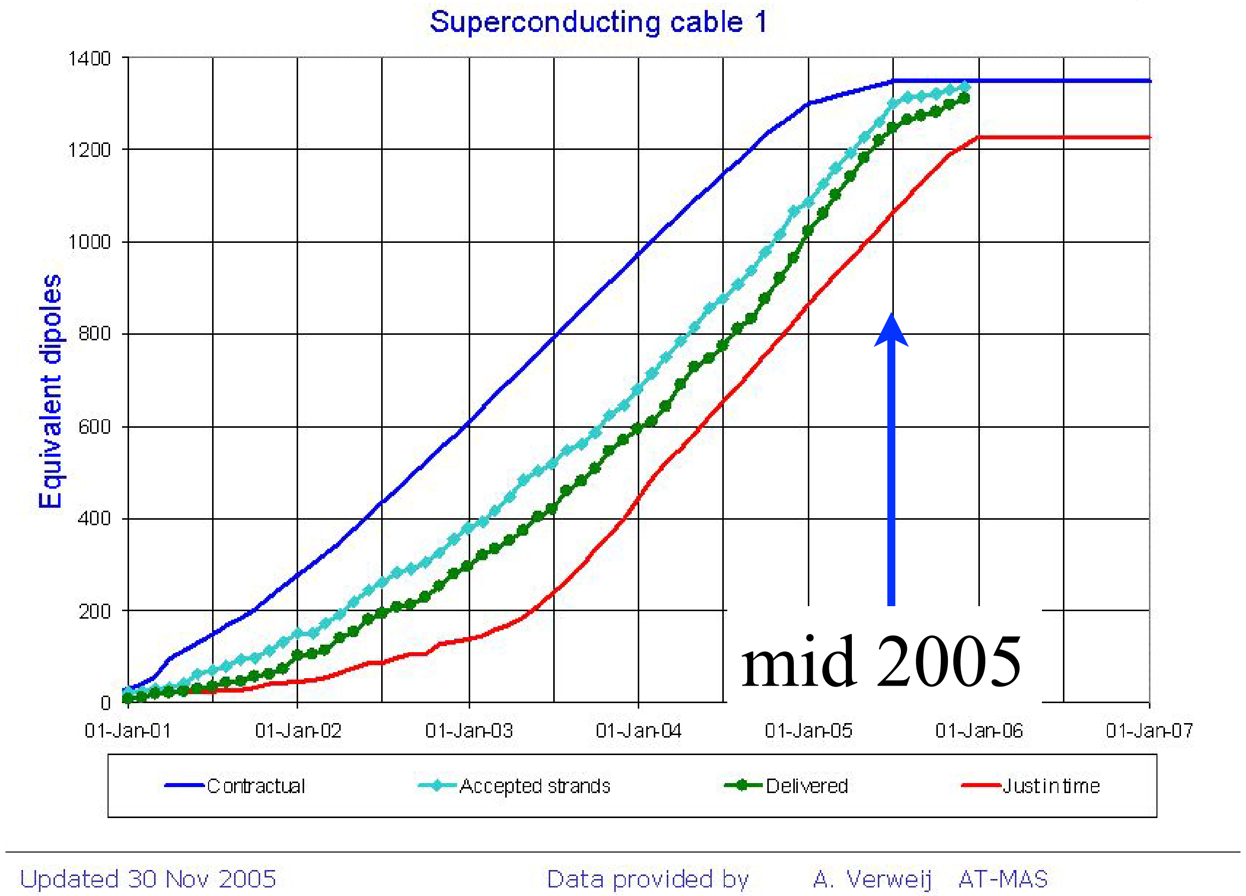

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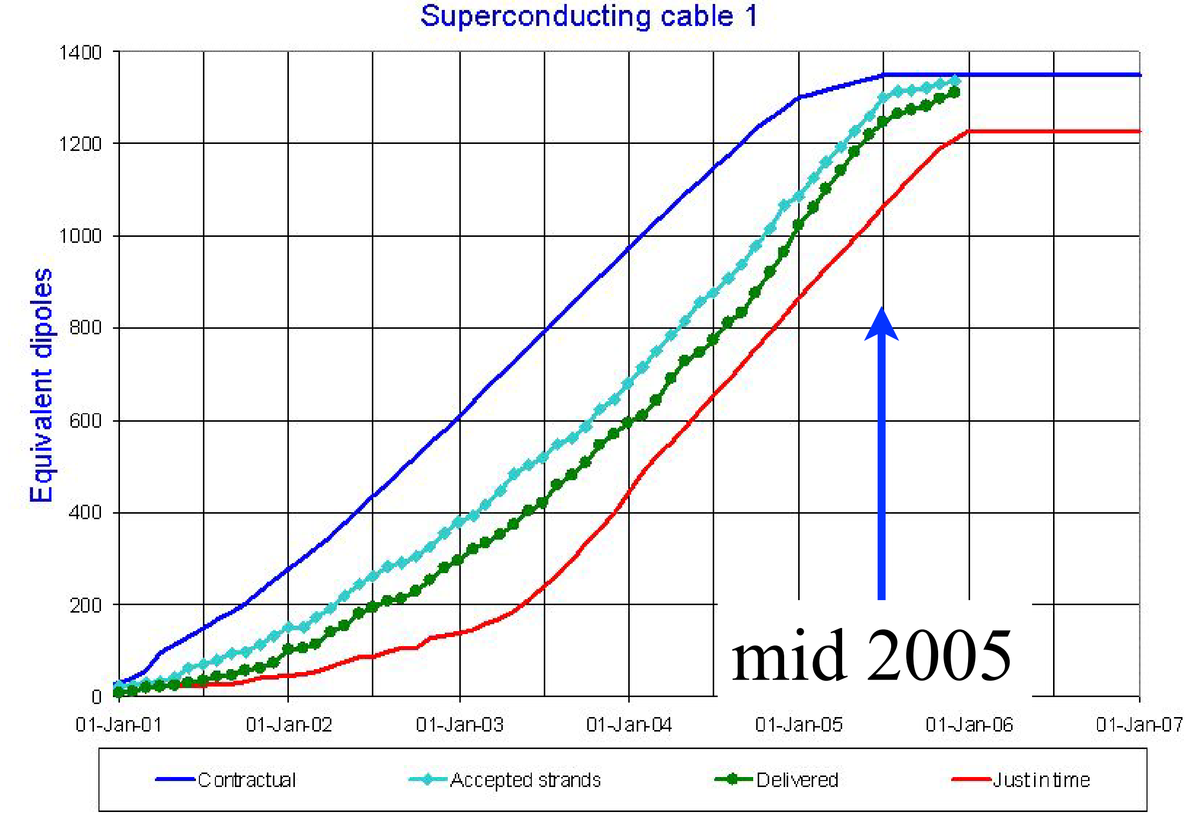

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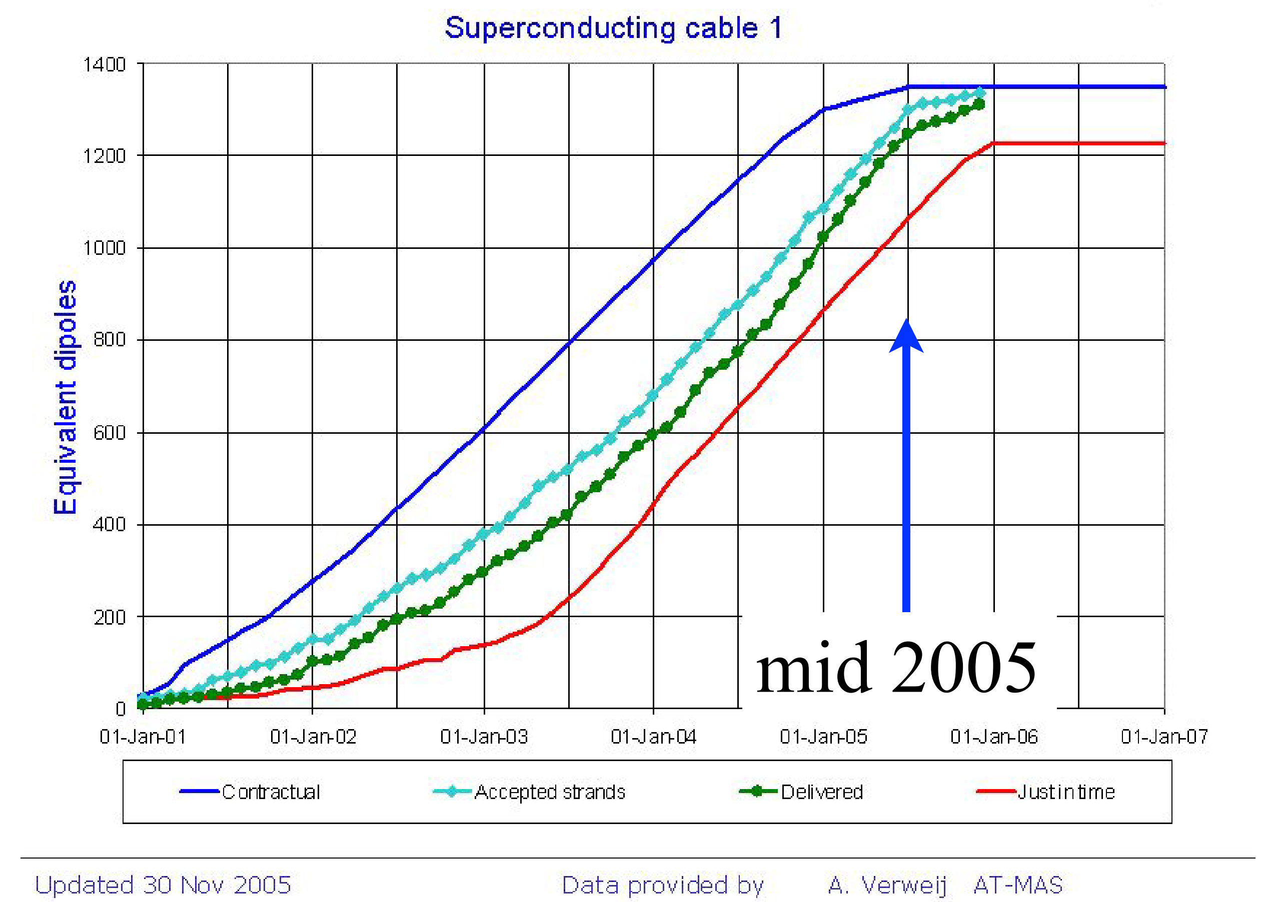

Sept. 10th 2008: first beams

- useful beams: 2010
- Higgs physics: 2011

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MAIANI 70 FEST, Sept. 21, 2011- C.Dionisi comes back to the LEP story

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).

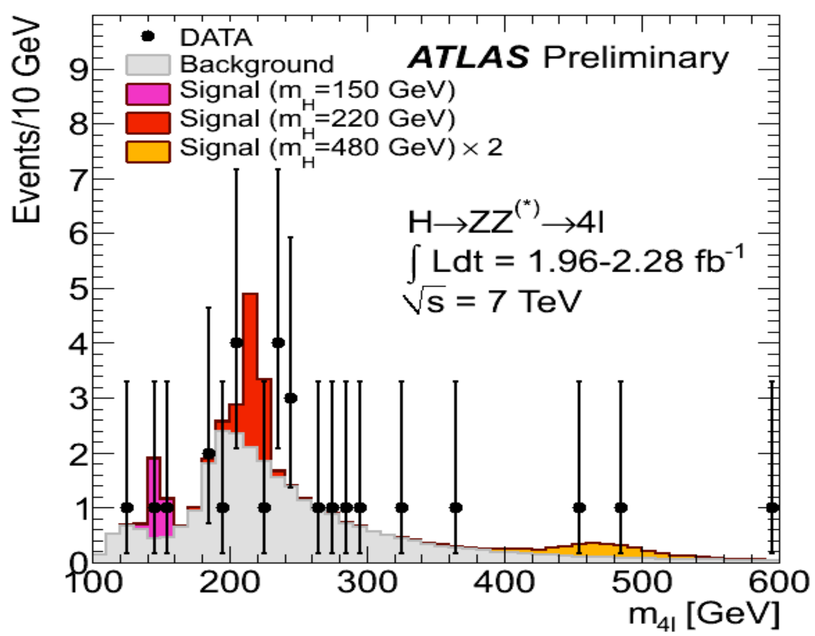
At 8h00 a.m., November 2nd 2000, The LEP collider was shut down forever.

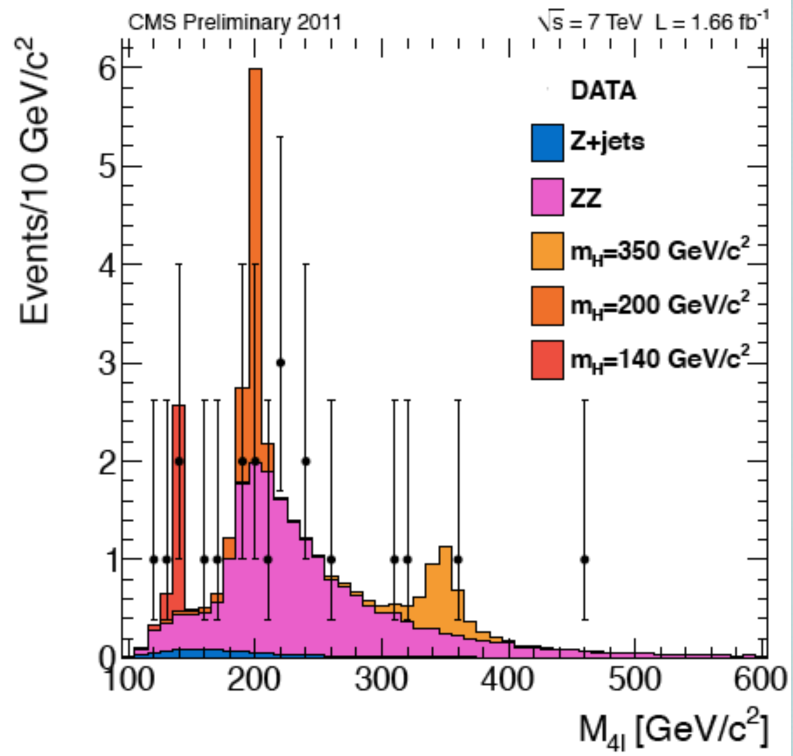
Since then in the Luciano office, I noticed (subliminal) a strange suitcase……..

Higgs hunting: the situation in summer 2011, was summarised by Jim Virdee at the Ellis65 fest, @ ~2 fb^{-1} LHC luminosity

Imperial College London

Search for the SM H → ZZ → 4l





ATLAS
Observe: 27 events
6ee, 9eμ, 12μμ events
Expected: 28 ± 4 events

CMS
Observe: 21 events
5ee, 10eμ, 6μμ events
Expected: 21.2 ± 0.8 events

J. Ellis Colloquium-tsv 14

- Not so different from the situation at LEP, but…
- Luminosity increase to arrive in the coming year…no time limits

- At the same time…Tevatron was making a big effort to increase its luminosity
- Some worry from competition…

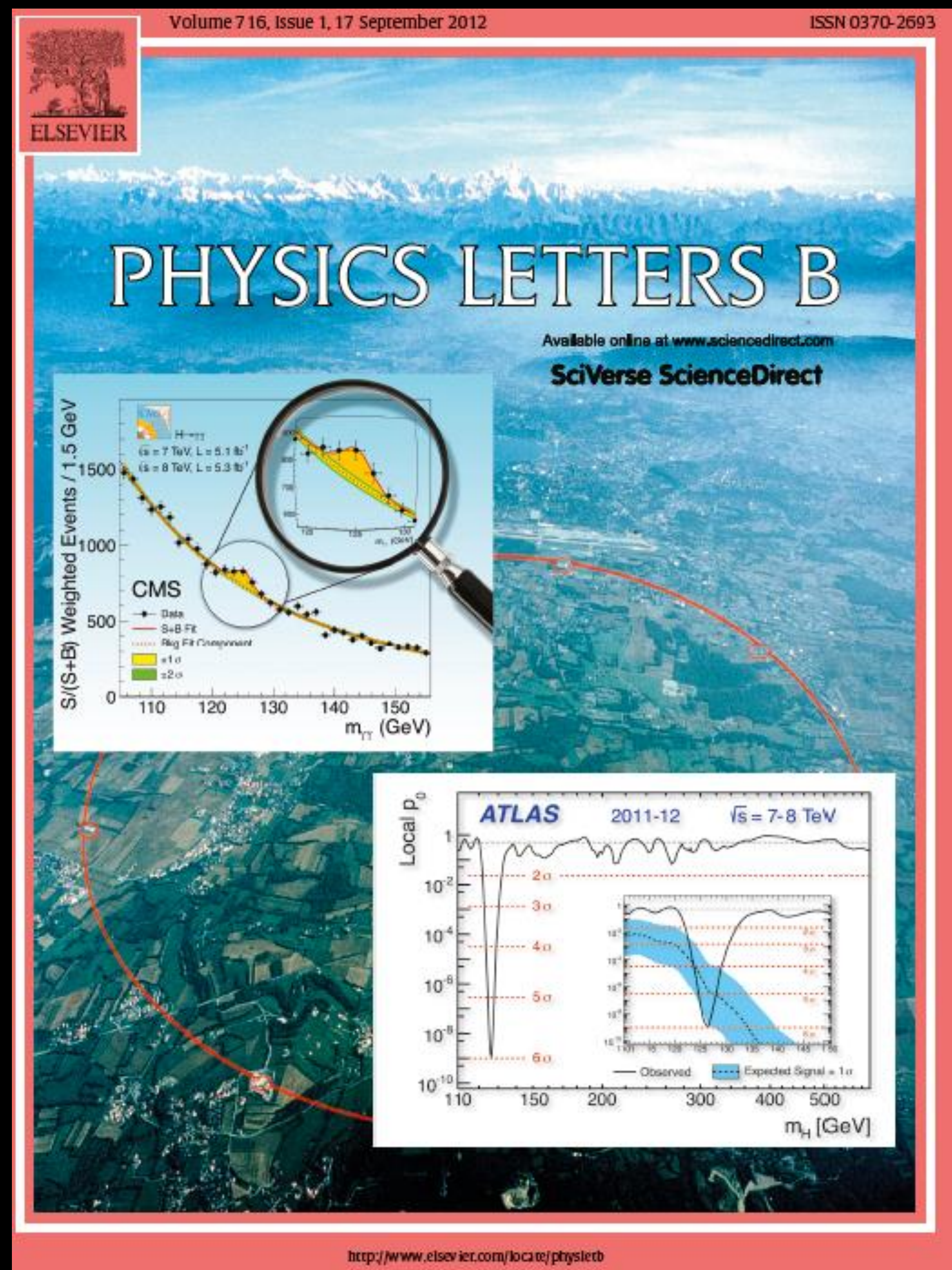
4. Discovery

CERN-4 july 2012

In scientific press

The Discovery

July 2012

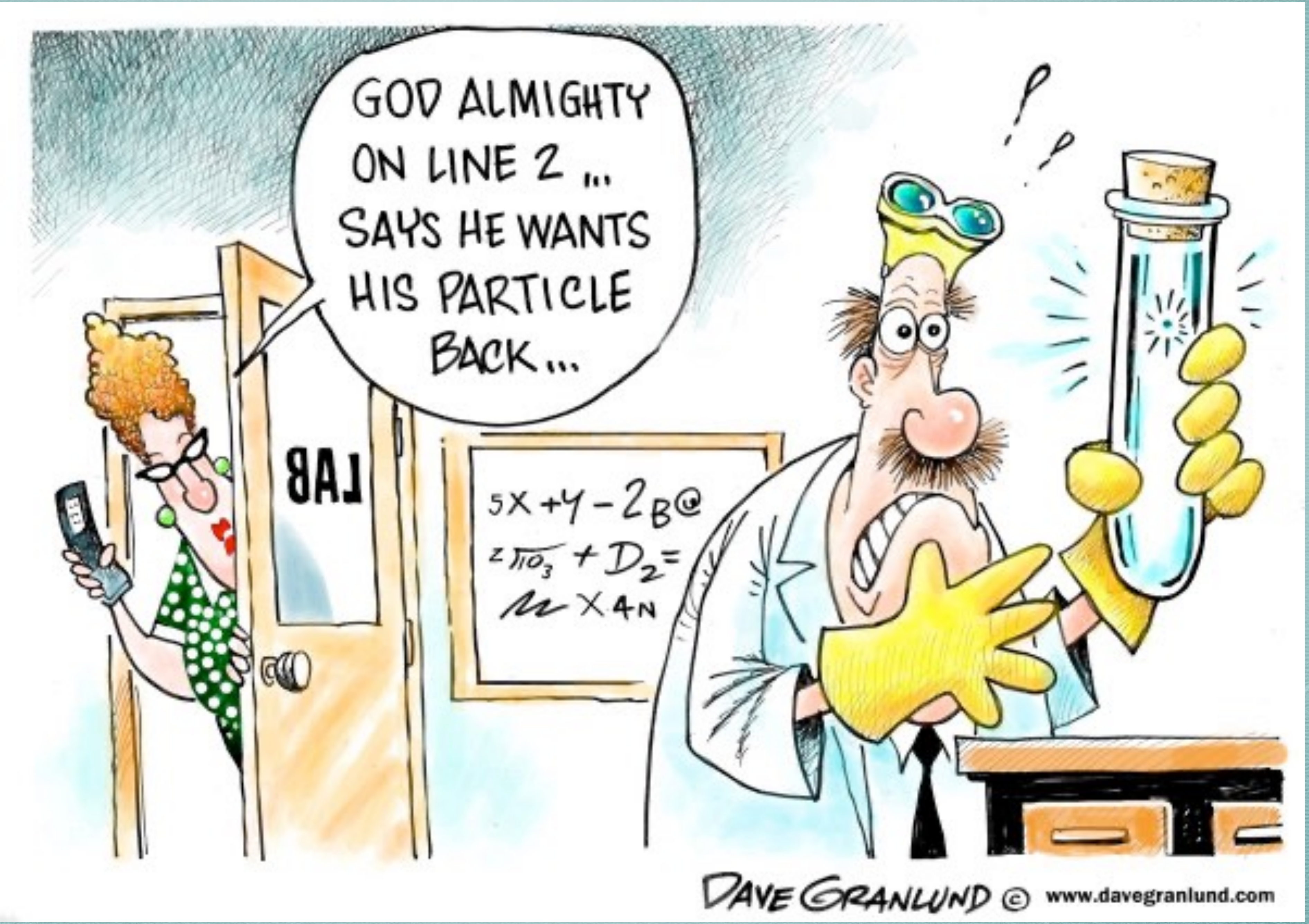


~ 3800 citations / experiment so far

October 2013

"For the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"

The "God particle"



The LHC has been a big industrial enterprise

- LHC used 1200 tons of superconductiong cable, for a total lenght of 7000 km
- during construction, LHC has been the largest single buyer of Niobium-Titanium cables
- one Nb-Ti bar 0 .9m long and 0.2 m diameter gives rise, after extrusion to 9000 filaments of 7 micron diameter and 30 km lenght.
- Magnets prototypes have been developed at CERN in collaboration with European research institutions (INFN for Italy) and European companies (ALSTOM, NOELL, ANSALDO (*))
- in this way it has been possible to transfer advanced technologies to European companies
- that are now using them for Nuclear Fusion facilities like ITER.

(*) now ASG Superconductors SpA, Genova

A few lessons learned

- Do not save on tunnel: a long and large tunnel has a longer lifetime than the first machine you put in;
- A global project, but centralised construction and responsibility: CERN management had the responsibility to stay within cost and, when extracosts were detected, CERN reacted coherently and responsibly;
- Starting from a big lab, already financed, no green grass, helps!
- A full globalised management (e.g. ITER) is more vulnerable to cost increase
- Cost-to-Completion crisis in 2001. CERN has profited from it to enforce real changes: a leaner programme, a well-focused Laboratory.
- LHC final costs to CERN:

	Personnel	Material	Total
Machine and Experimental Areas	**1 150**	**3 685**	**4 835**
Injectors	**86**	**67**	**153**
Detectors: construction, R&D	**879**	**312**	**1 191**
Detectors: test and pre-operation	–	**181**	**181**
LHC Computing	**86**	**93**	**179**
Grand Total	**2 202**	**4 337**	**6 539**

Table 1: Cost to CERN of LHC and associated detectors, in Millions CHF. Source: CERN/2840, May 27, 2009.

- Global collaboration for detectors worked out very well

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The result of more that 25 years of work (1984-2012) is an increadibly robust, upgradable complex, e.g. HL-LHC, that will produce physics for at least two other decades

Particle physics, from Rutherford to the LHC

feature article

August 2011 Physics Today 33

Steven Weinberg

Not the last word

It is clearly necessary to go beyond the standard model. There is a mysterious spectrum of quark and lepton masses and mixing angles that we have been staring at for decades, as if they were symbols in an unknown language, without our being able to interpret them. Also, something beyond the standard model is needed to account for cosmological dark matter.

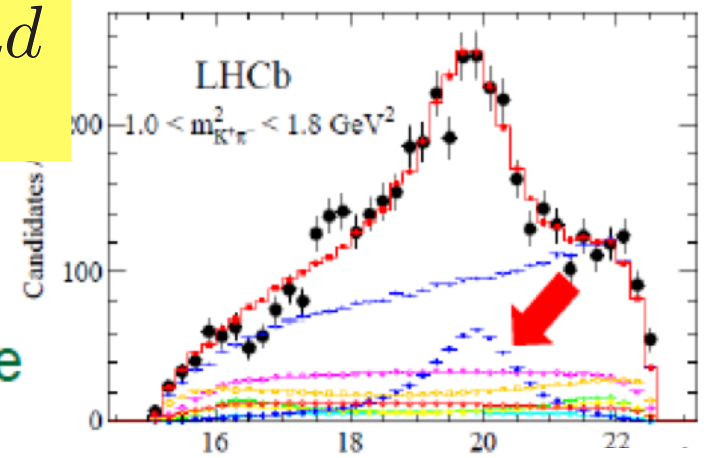
5. Surprises in low energy strong interactions

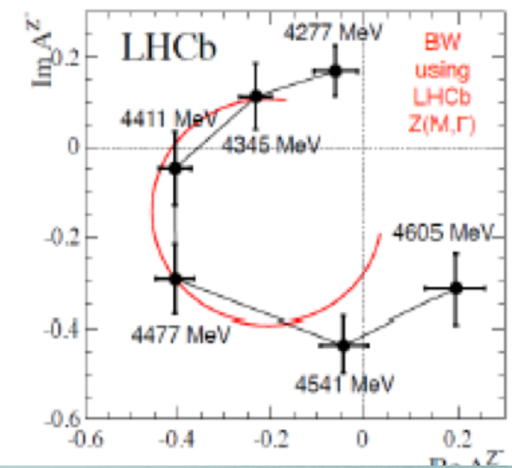
$Z_c(4430)^{\pm} \rightarrow J/\Psi + \pi$

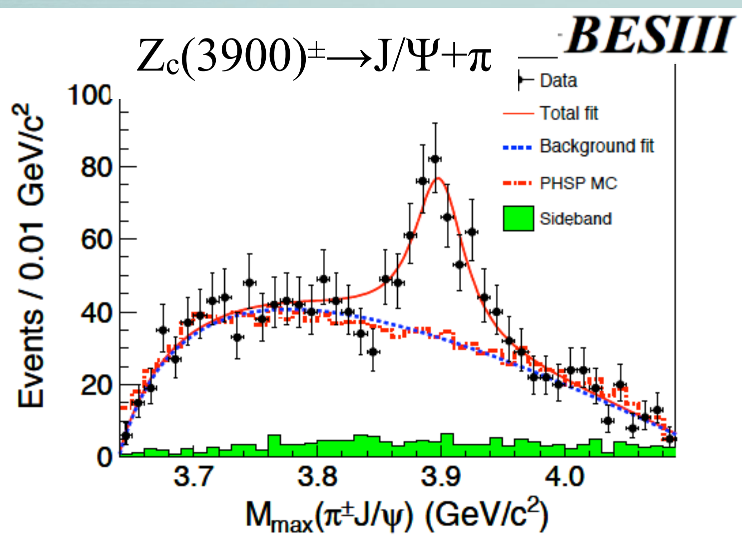
valence quark composition: $c\bar{c}u\bar{d}$

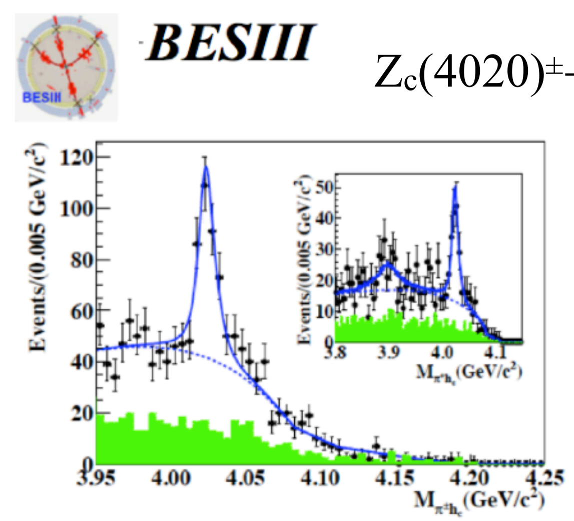
[PRL 112 (2014) 222002]

1. Confirm Belle's observation of 'bump'
2. Can NOT be built from standard states
3. Textbook phase variation of a resonance









$Z_c(4020)^{\pm} \rightarrow h_c + \pi$

BESIII: PRL111, 242001

Simultaneous fit to 4.23/4.26/4.36 GeV data, 16 η_c decay modes. 8.9σ

$M(Z_c(4020))$ = 4022.9±0.8±2.7 MeV;

$\Gamma(Z_c(4020))$ = 7.9±2.7±2.6 MeV

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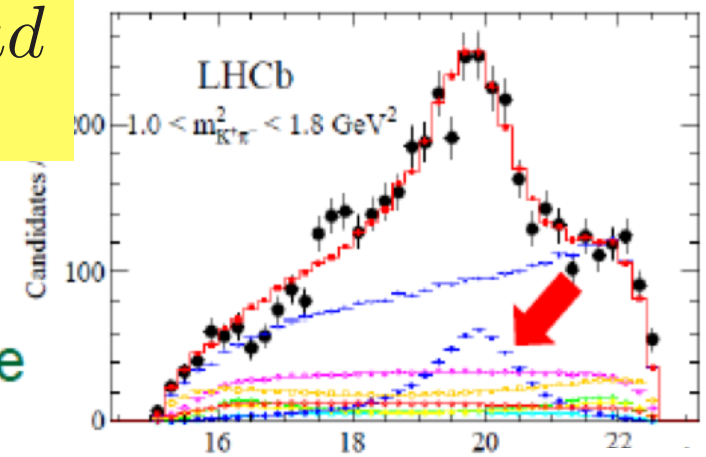
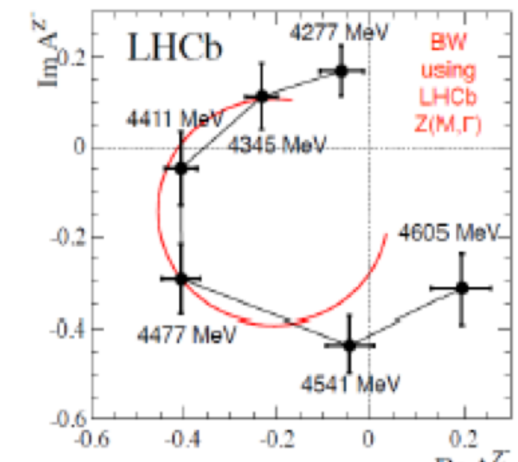
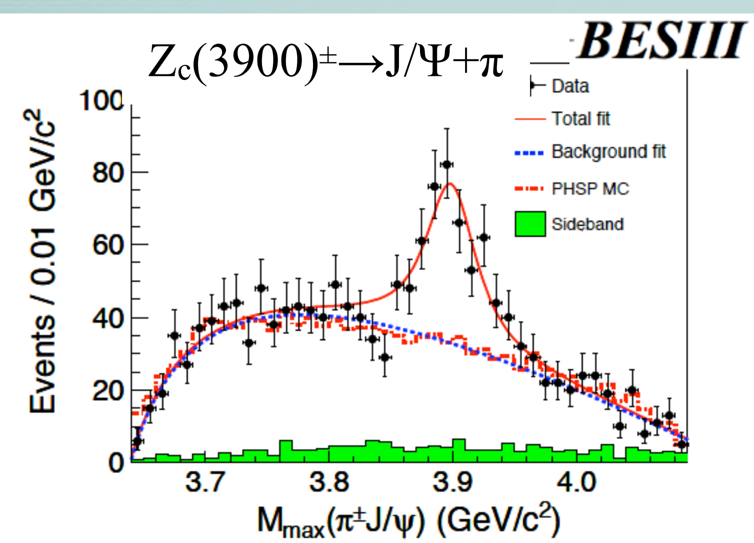
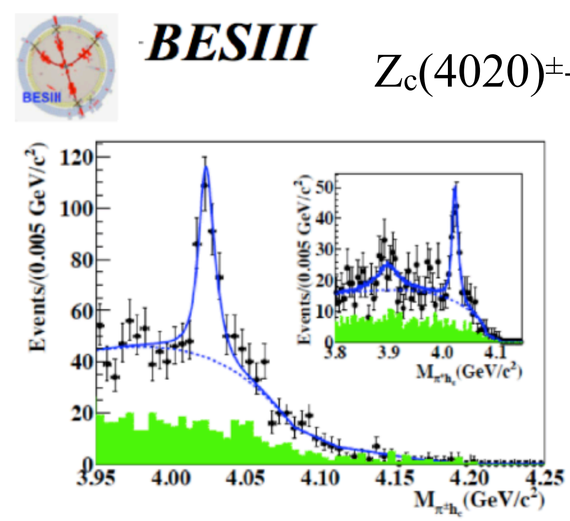








$Z_c(4020)^{\pm} \rightarrow h_c + \pi$

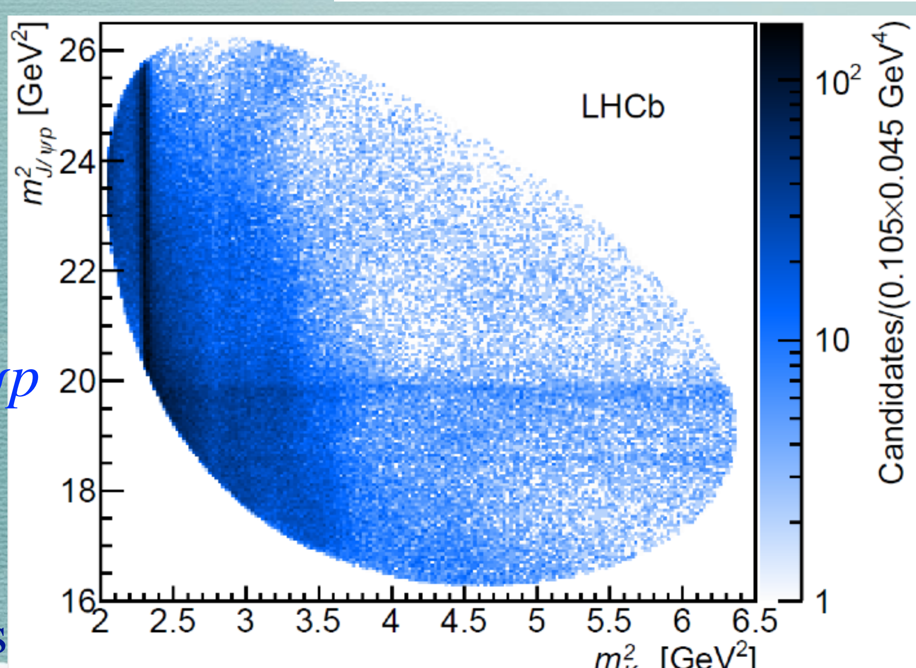
BESIII: PRL111, 242001

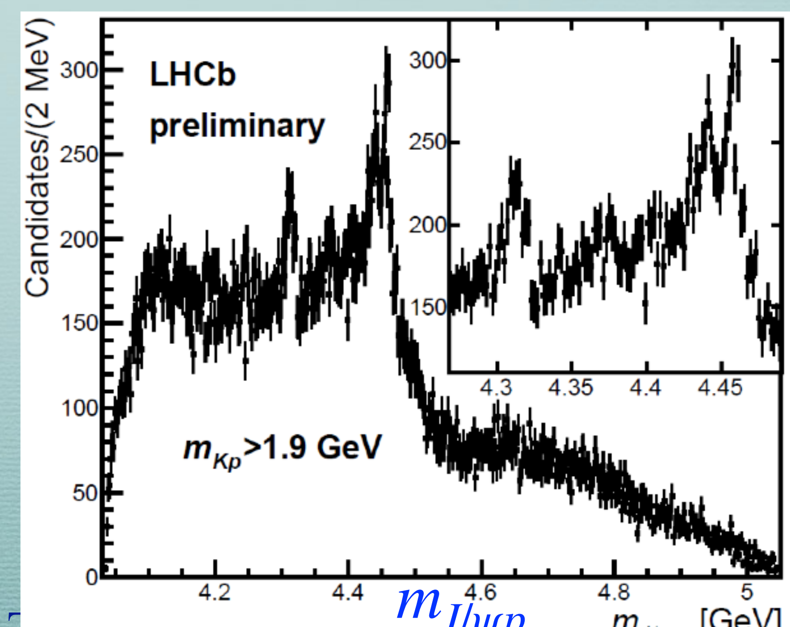
Simultaneous fit to 4.23/4.26/4.36 GeV data, 16 η_c decay modes. 8.9σ

M(Z_c(4020)) = 4022.9±0.8±2.7 MeV;

Γ(Z_c(4020)) = 7.9±2.7±2.6 MeV

$m^2_{J/\psi p}$





$m_{J/\psi p}$

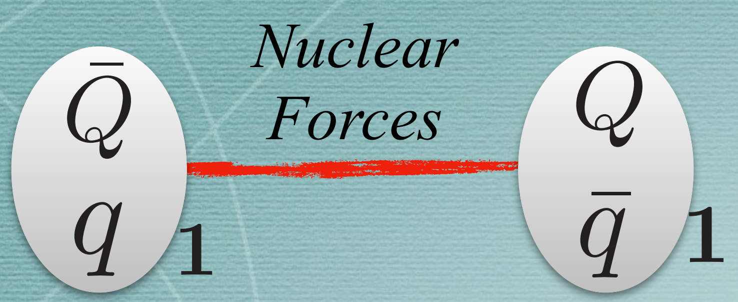
$$\Lambda_b \rightarrow K^- + J/\psi + P$$

LHCb-PAPER-2019-014
PRL 122, 222001

Pentaquarks:

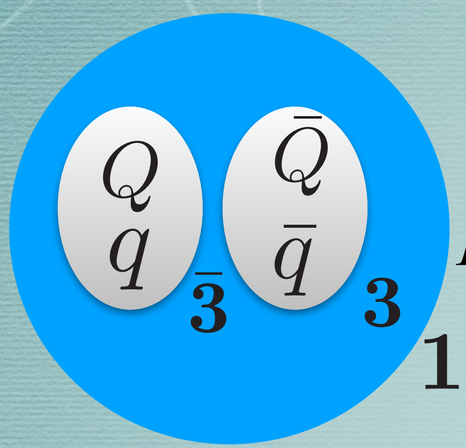
$$\mathcal{P}^+ = c\bar{c}uud$$

No consensus, yet



Hadron Molecule

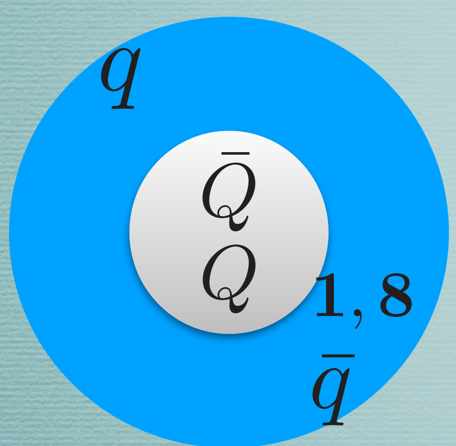
F-K. Guo, C. Hanhart, U-G Meißner, Q. Wang, Q. Zhao, and B-S Zou, arXiv 1705.00141 (2017)



QCD Forces

Compact Diquark-Antidiquark

L. Maiani, F. Piccinini, A. D. Polosa and V. Riquer, Phys. Rev. D 71 (2005) 014028; **D 89** (2014) 114010.



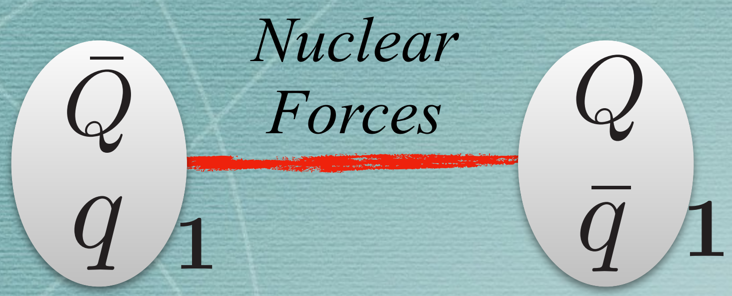
QCD Forces

HadroCharmonium (1)
Quarkonium Adjoint Meson (8)

S. Dubynskiy, S. and M. B.Voloshin, Phys. Lett. **B 666**,(2008) 344.

E. Braaten, C. Langmack and D. H. Smith, Phys. Rev. **D 90** (2014) 01404

No consensus, yet



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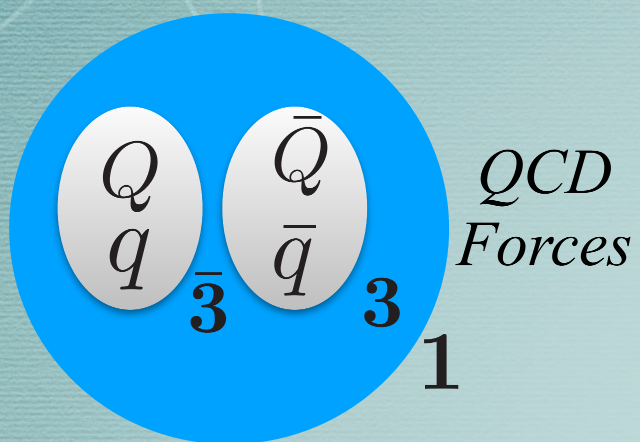

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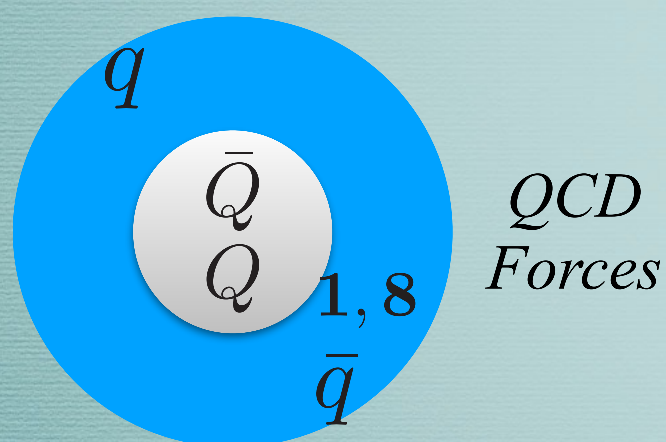

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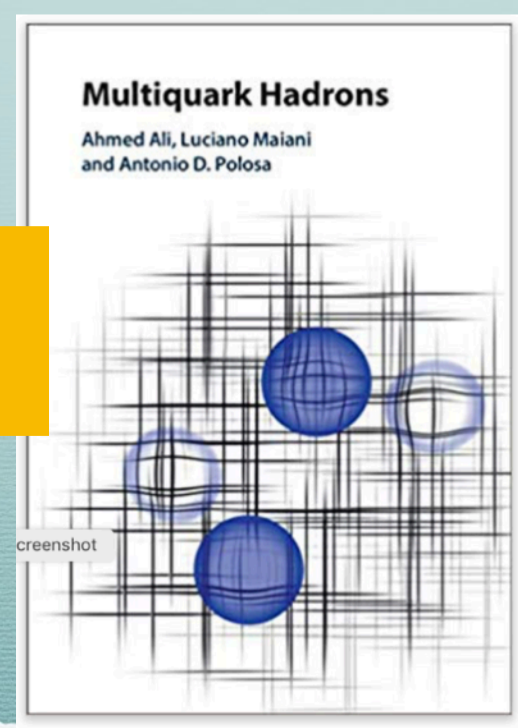
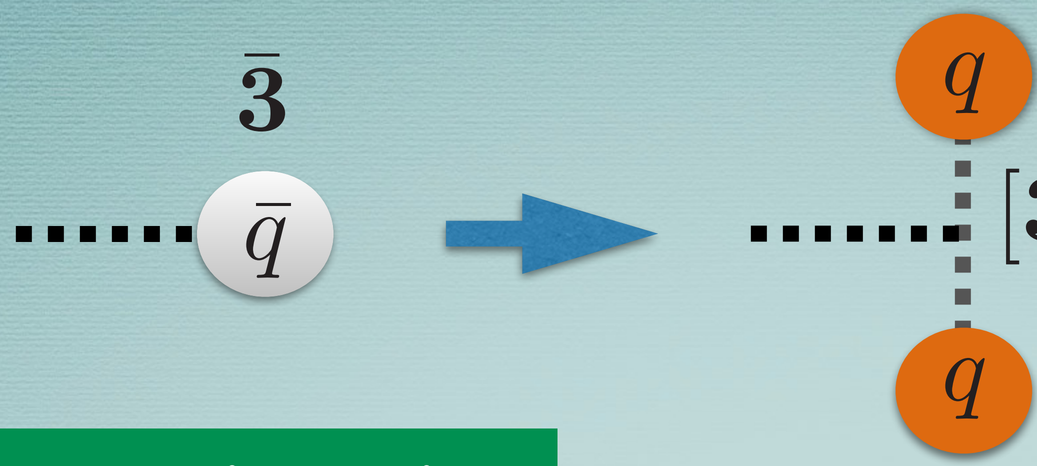
For a review, see:
A. Ali, L. Maiani and A.D. Polosa, *Multiquark Hadrons*, Cambridge University Press (2019)



Multiquarks! Replacing: antiquark → diquark

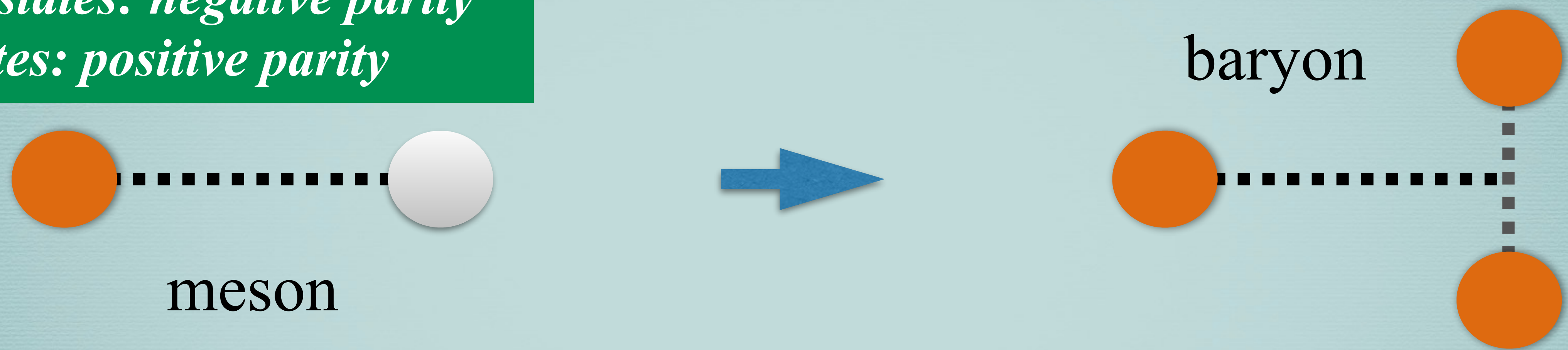
rule:

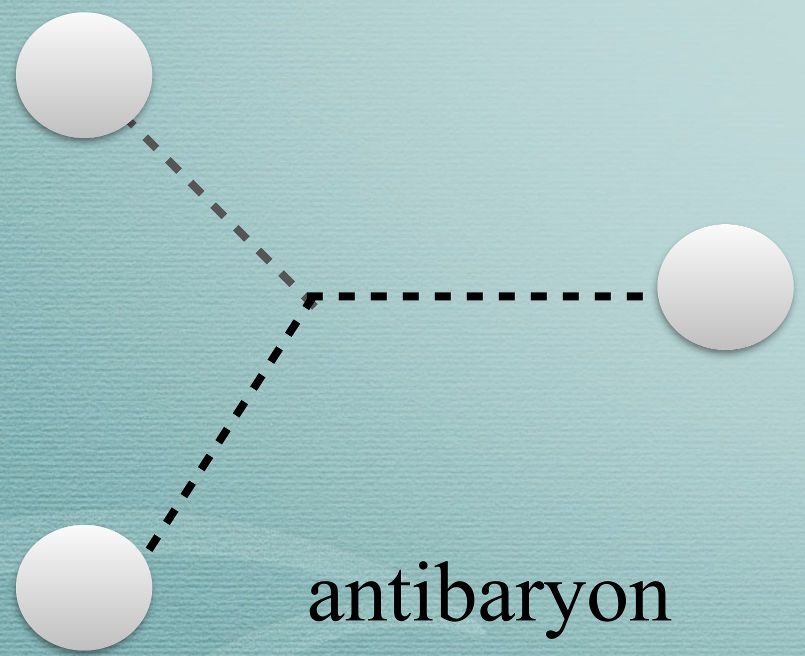


$$[\mathbf{3} \times \mathbf{3}]_{Antisymm} = \bar{\mathbf{3}}$$

S-wave states: positive parity
L=1 states: negative parity

S-wave states: negative parity
L=1 states: positive parity





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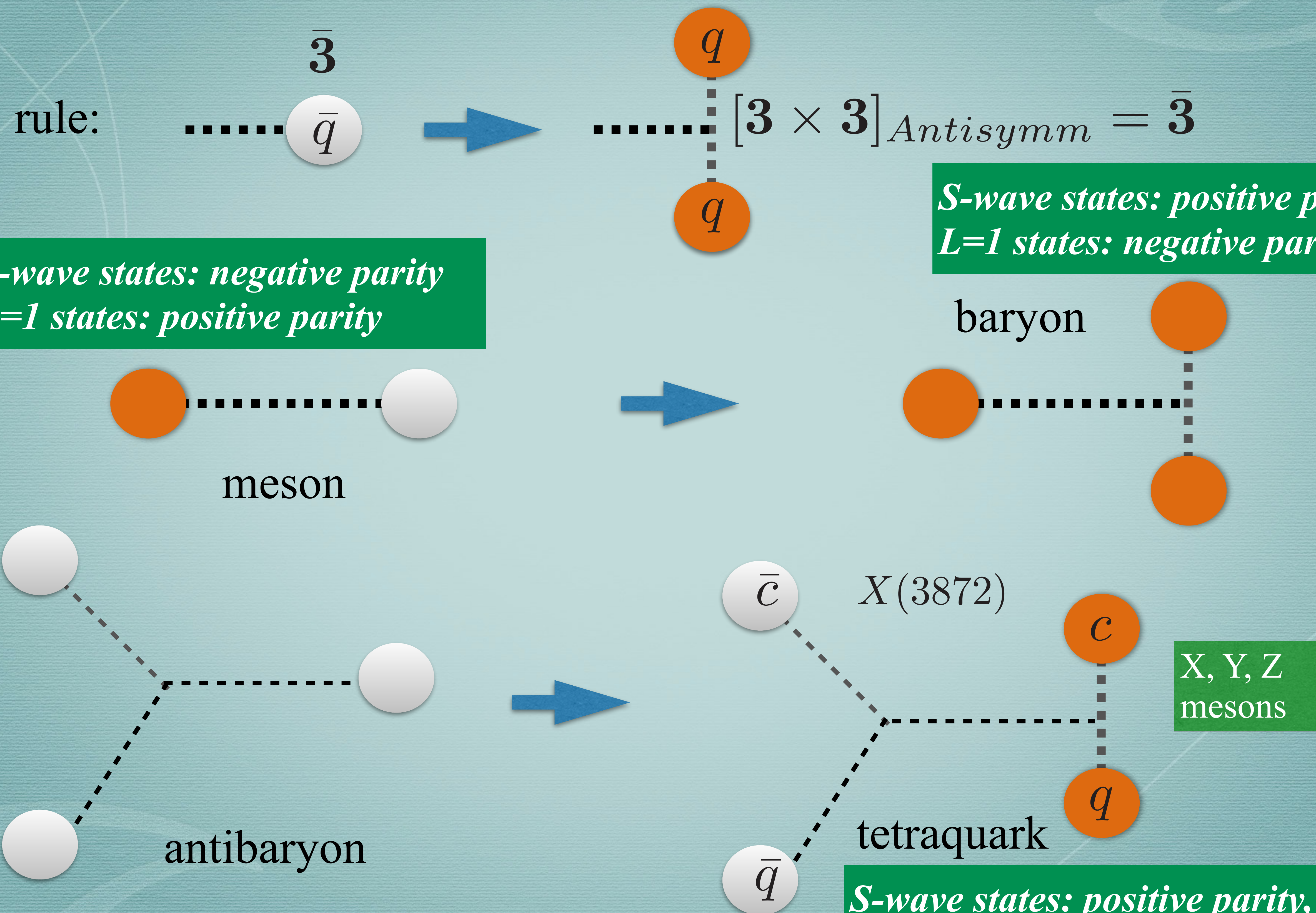

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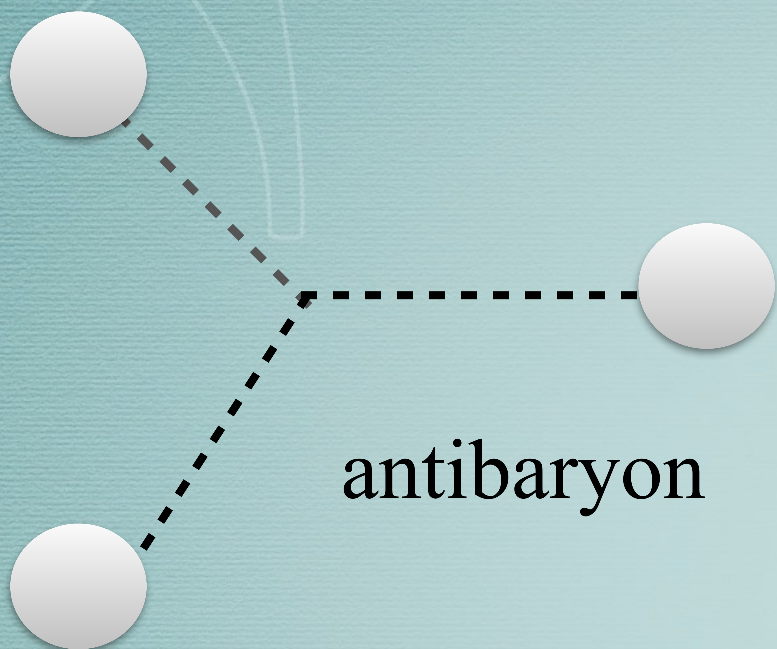
L=1 states: positive parity

S-wave states: positive parity, X,Z
L=1 states: negative parity, Y

A second spectroscopic family ?



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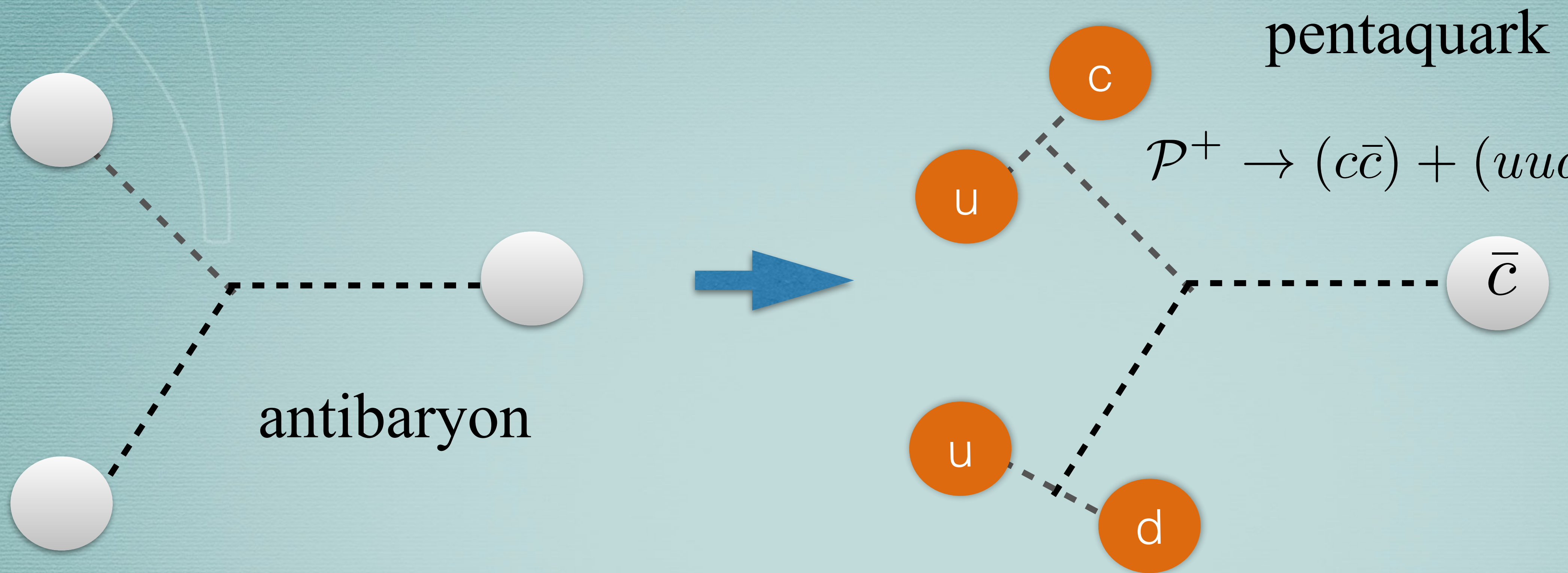
L. Maiani, A. D. Polosa and V. Riquer, PLB **749** (2015) 289



$$\mathcal{P}^+ \to (c\bar{c}) + (uud) = J/\Psi + p$$

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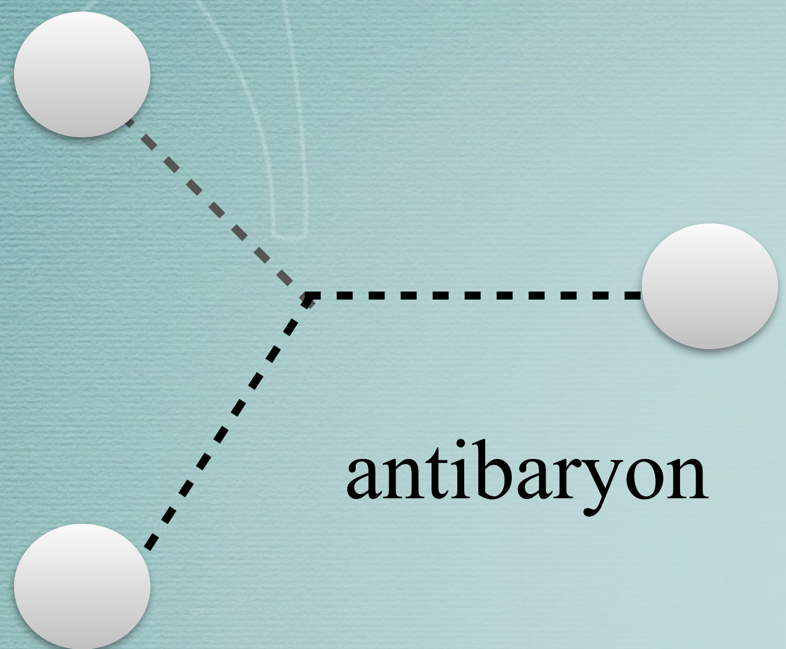
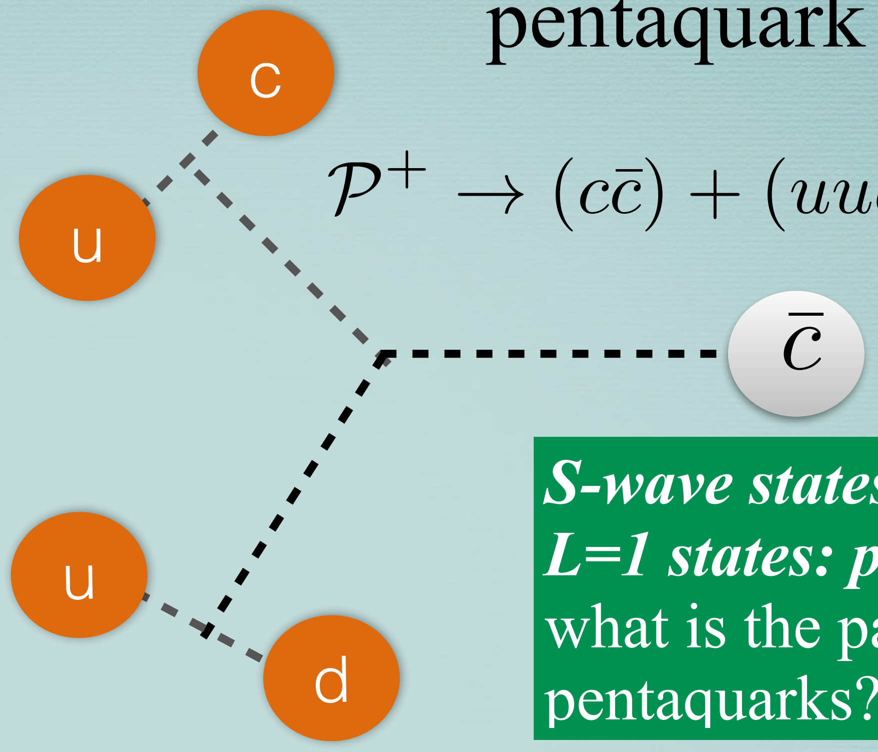
L. Maiani, A. D. Polosa and V. Riquer, PLB **749** (2015) 289



antibaryon

S-wave states: positive parity
L=1 states: negative parity

pentaquark



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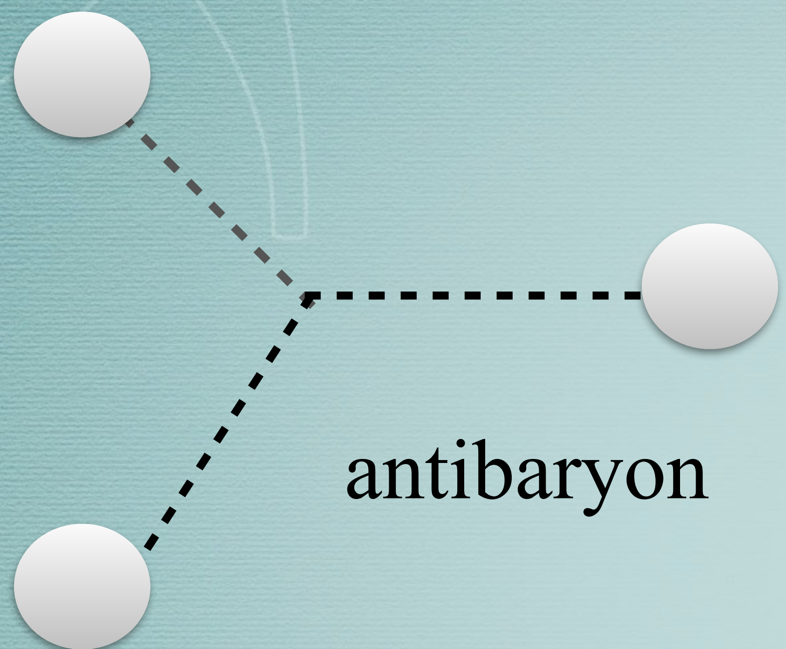

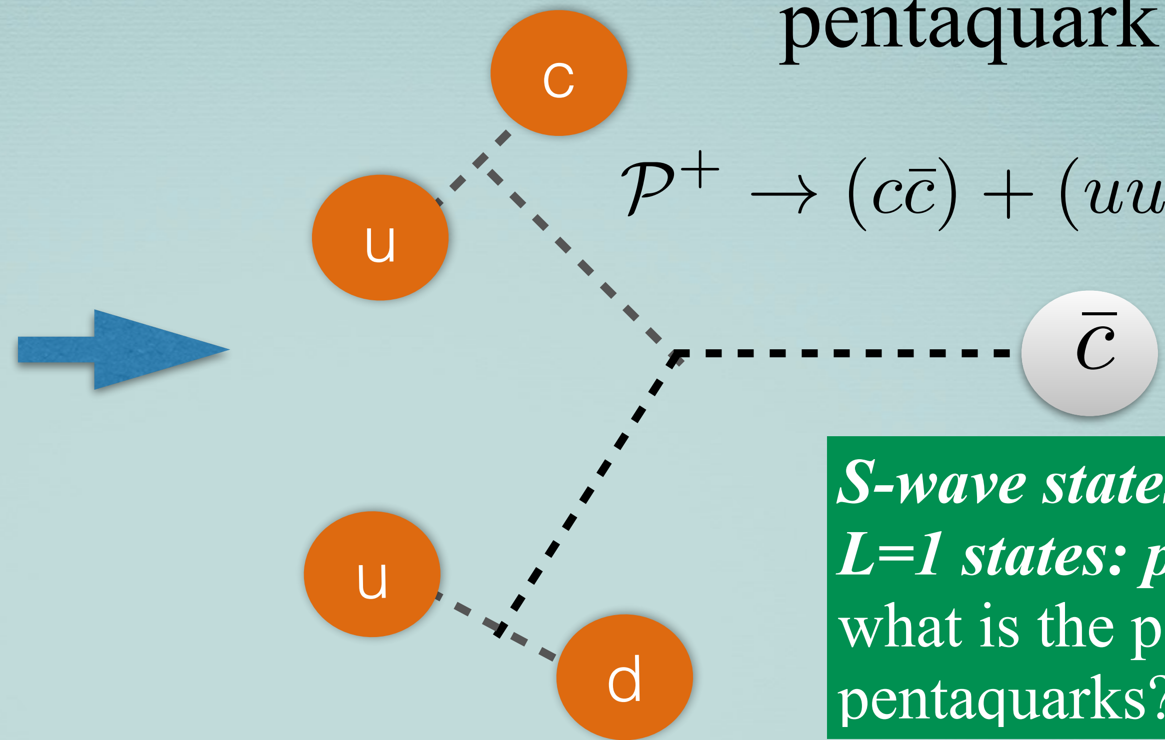

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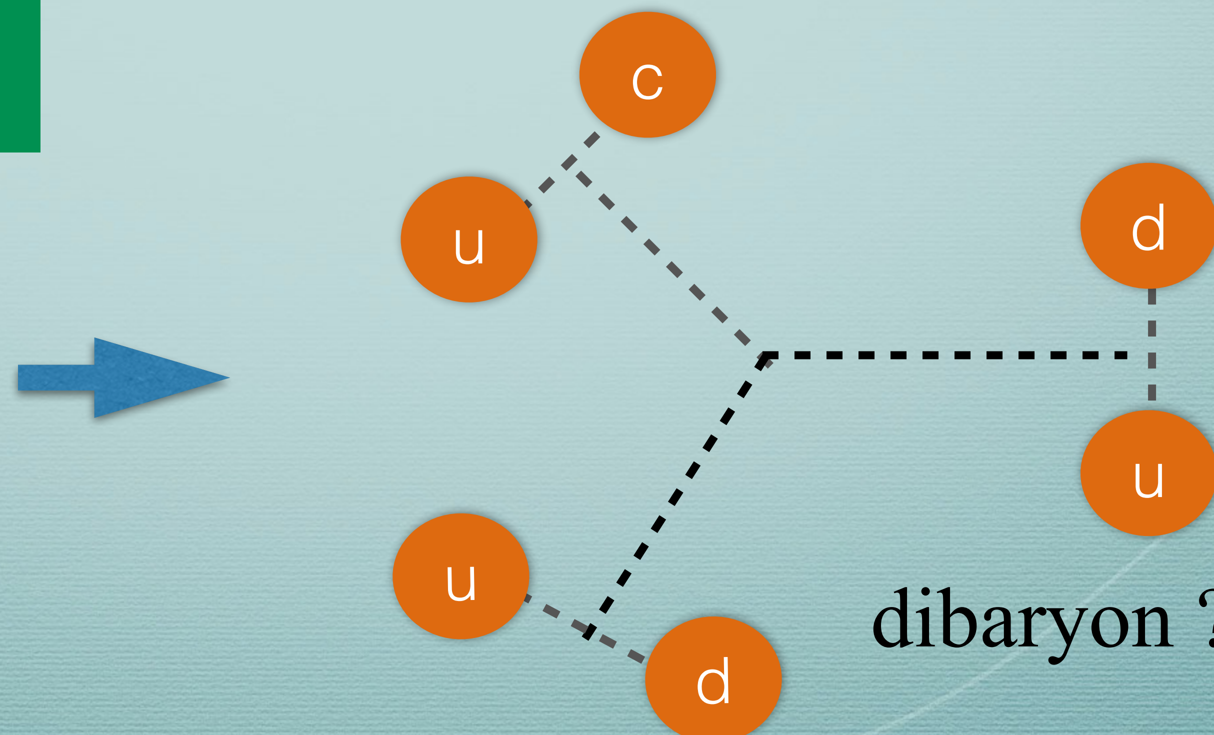

dibaryon ???

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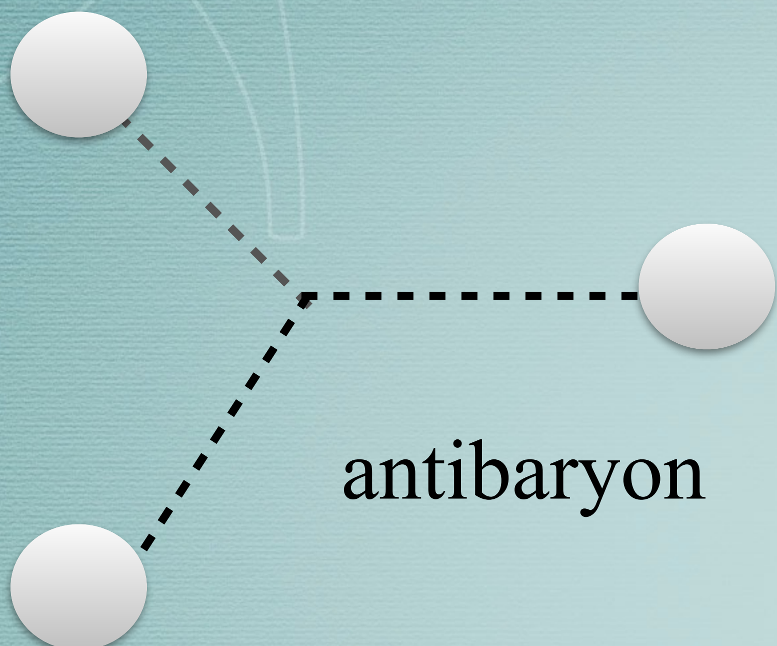
L. Maiani, A. D. Polosa and V. Riquer, PLB **749** (2015) 289



antibaryon

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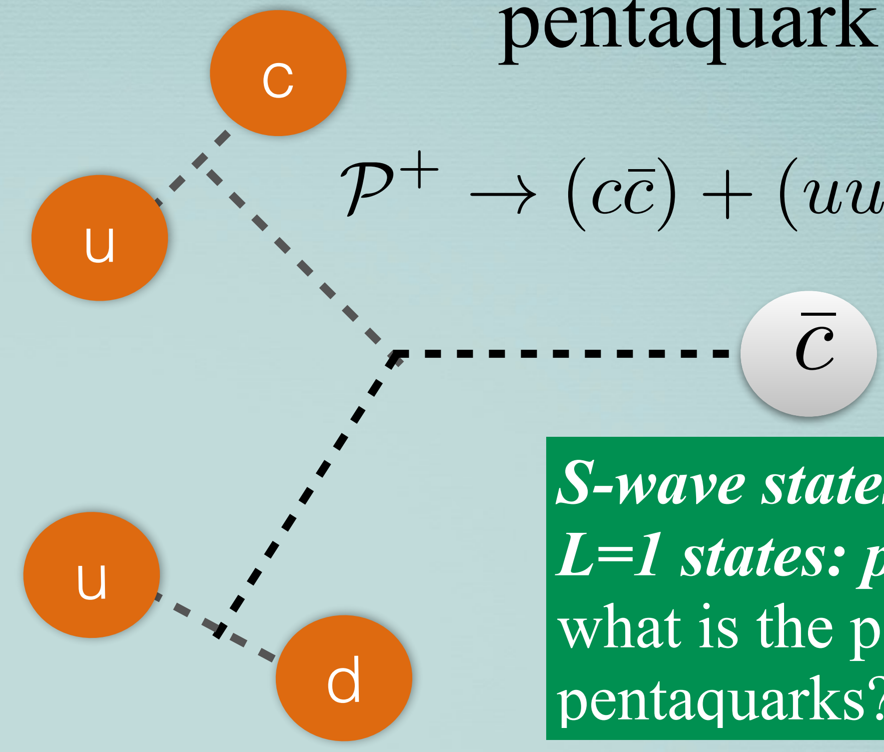

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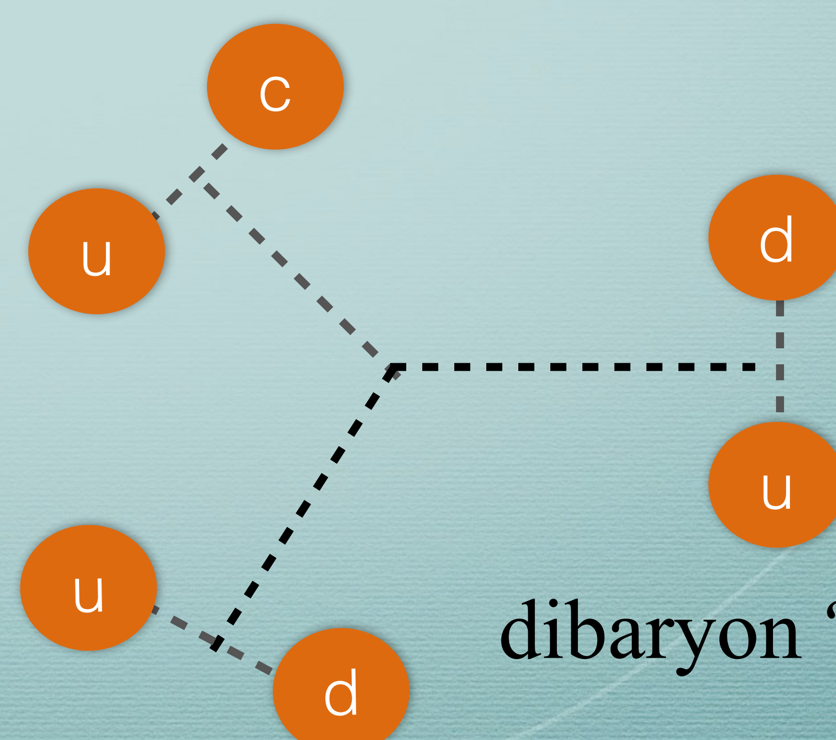
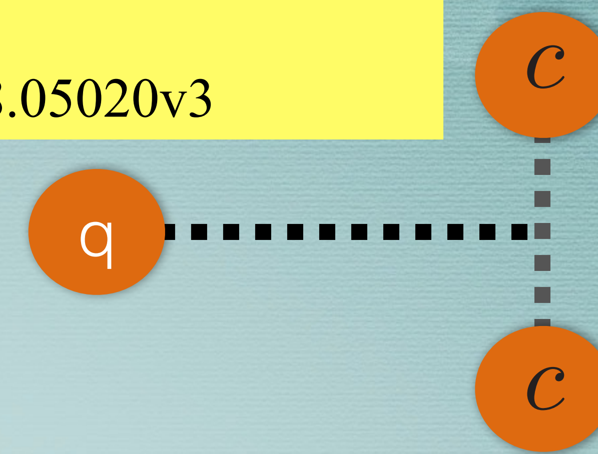


dibaryon ???

Substitution with diquark (antidiquark) reproduces qualitatively ***all we have seen in Exotic Hadrons until now***… and more

A new sensation (2017): doubly heavy baryons

M. Savage, M. B. Wise, PL**B 248**,1990;
N. Brambilla, A. Vairo and T. Rosch, PRD **72,** 2005; T. Mehen, arXiv:1708.05020v3

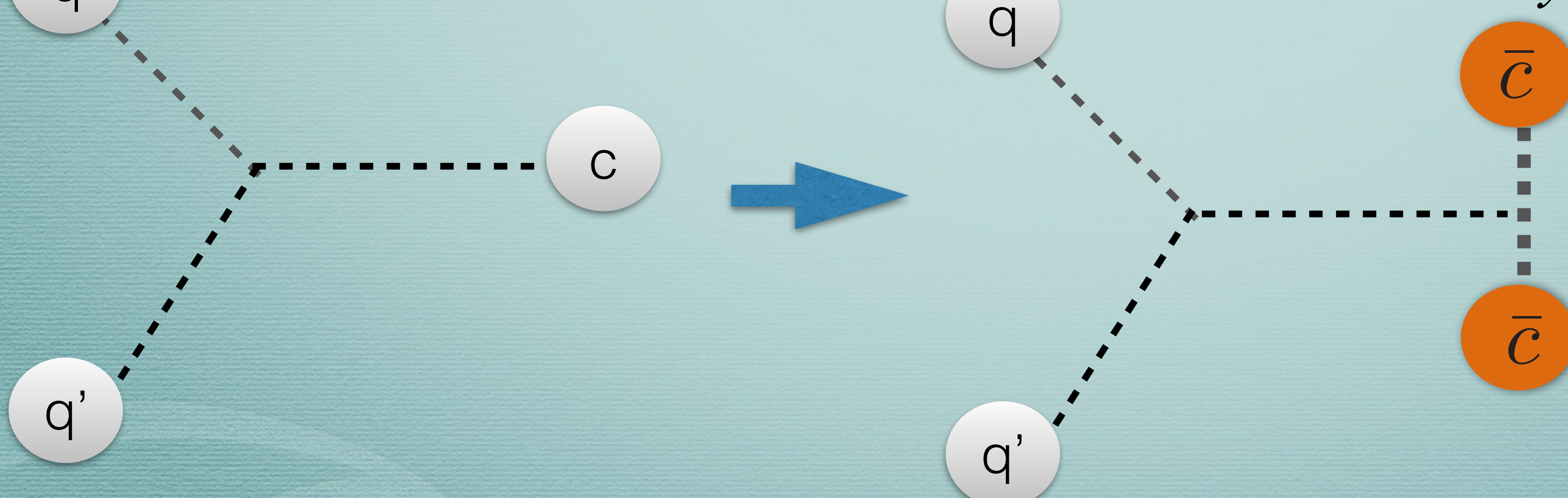


- Doubly heavy baryons are related to single quark heavy mesons
- QCD forces are mainly spin independent, so there is an approximate symmetry relating masses of *DH baryons* to *SH mesons*: e.g.

$$M(\Xi_{cc}^*) - M(\Xi_{cc}) = \frac{3}{4}[M(D^*) - M(D)]$$

similarly: *single heavy quark baryons*….

…. are related to *doubly heavy tetraquark*



Esposito, M. Papinutto, A. Pilloni, A. D. Polosa, and N. Tantalo, Phys. Rev. D88, 054029 (2013)
M. Karliner and J. L. Rosner, arXiv:1707.07666 [hep-ph].
E. J. Eichten and C. Quigg, arXiv:1707.09575 [hep-ph].

Double Beauty tetraquarks $[bb]_{\bar{\mathbf{3}}}[\bar{q}\bar{q}']_{\mathbf{3}}$ may be stable under strong decays !!

predicted :
M. Karliner and J. L. Rosner, arXiv:1707.07666 [hep-ph].
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- Different quark model calculations: ***negative*** Q-value for the decay $T_{bb} \to BB\,\gamma$!
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$QQ'\bar{u}\bar{d}$	B-O	Karliner:2017qjm	Eichten:2017ffp	Luo:2017eub	Lattice QCD
$cc\bar{u}\bar{d}$	$+7(-10)$	$+140$	$+102$	$+39$	-23 ± 11 Junnarkar:2018twb
$cb\bar{u}\bar{d}$	$-59(-74)$	~ 0	$+83$	-108	$+8 \pm 23$ Francis:2018jyb
$bb\bar{u}\bar{d}$	$-138(-156)$	-170	-121	-75	-143 ± 34 Junnarkar : 2018twb $-143(1)(3)$ Francis : 2016hui $-82 \pm 24 \pm 10$ Leskov : 2019ioa

B-O: L. Maiani, A. D. Polosa and V. Riquer, *The Hydrogen Bond of QCD in Doubly Heavy Baryons and Tetraquarks*, Phys. Rev. **D 100** , 074002 (2019).

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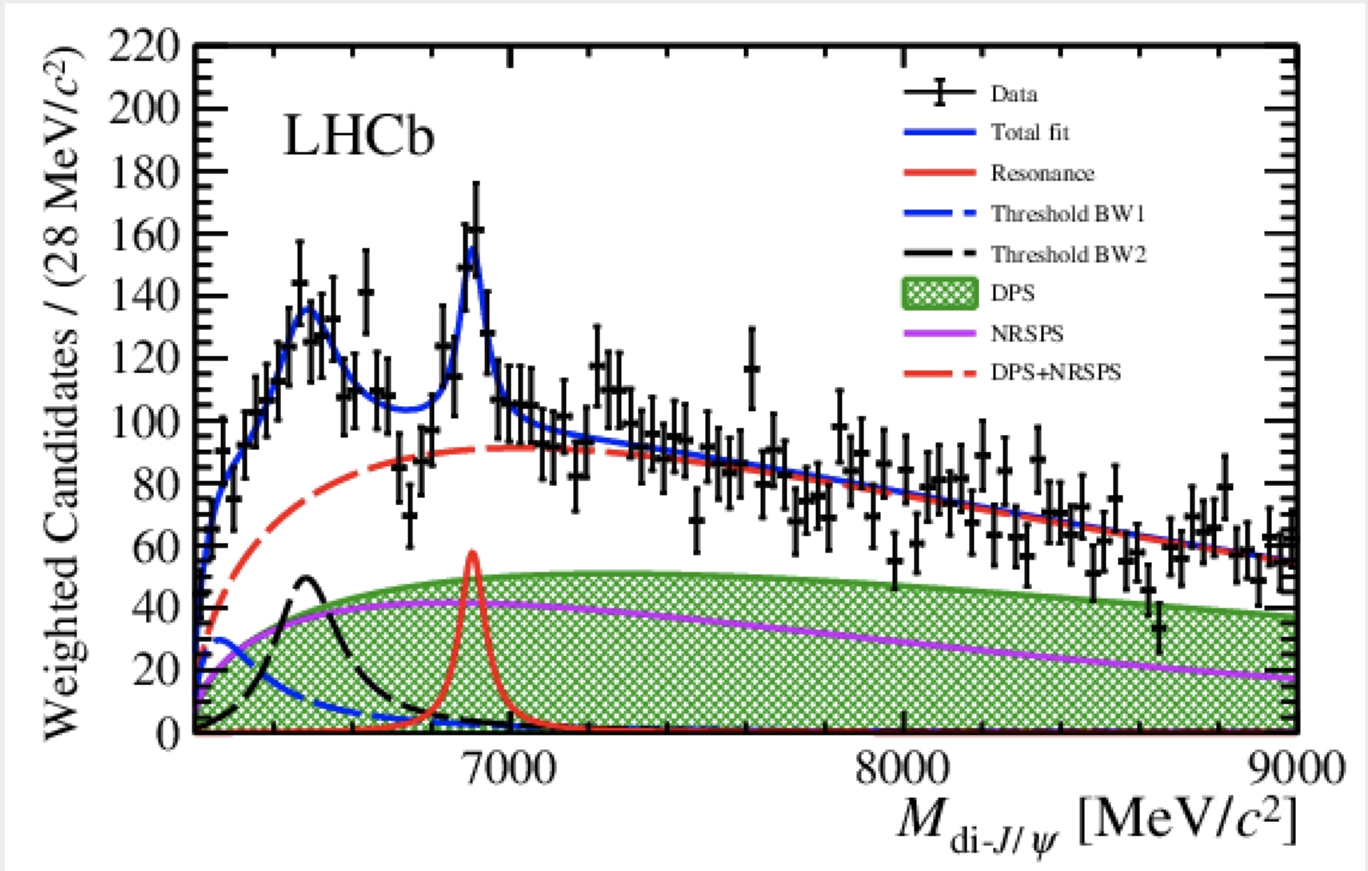
Spectacular new physics to be expected at a high luminosity Z^0 factory

A game changer! LHCb has observed J/ψ- pair resonances

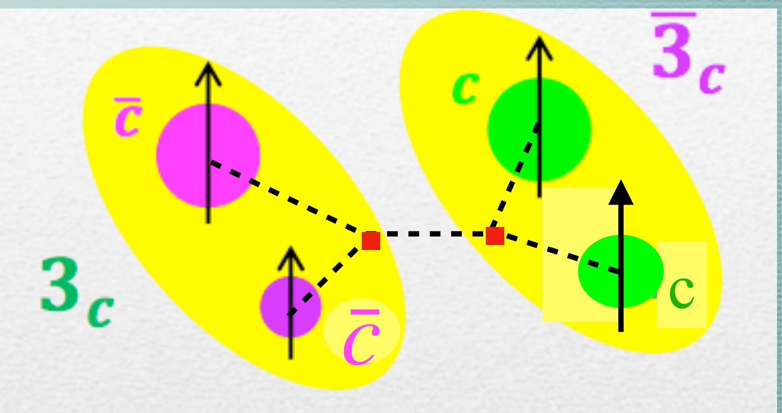


R. Aaij, C. Abellan Beteta, T. Ackernley, et al. (LHCb Collaboration). Observation of structure in the J/ψ pair mass spectrum. arXiv:2006.16957, 2006.

Little doubt that these resonances are tetraquarks

Tetraquark constituent picture of 2 J/Ψ resonances

$$[cc]_{S=1}[\bar{c}\bar{c}]_{S=1}$$



- [cc] in color $\bar{\mathbf{3}}$
- total spin of each diquark, S=1 (color antisymmetry and Fermi statistics)

Tetraquark 2 J/Ψ resonances (cont'd)

- S-wave: positive parity
- C=+1 states: $J^{PC} = 0^{++}$, 2^{++}, decay in 2 J/Ψ
- C= -1 states: $J^{PC} = 1^{+-}$, decays in $J/\psi + \eta_c$
- masses and decays can be computed,

spectrum
see e.g. M.A.Bedolla, J.Ferretti, C.D.Roberts and E.Santopinto, arXiv:1911.00960 [hep-ph] ;
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decays: C. Becchi, A. Giachino, L. Maiani and E. Santopinto, [arXiv:2006.14388 [hep-ph]]

- new methods may be found
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- spectrum, quantum numbers...really exciting !!!

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$D^- K^+ = \bar{c}\bar{s}ud$, valence quarks

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arXiv:2009.00025 [hep-ex]

good news for HL-LHC. A lot of resonances to find:
tetraquarks with open charm&strageness, full charm, full beauty…

6. Challenges at High Energy

•Standard Theory is unnatural ('t-Hooft, 1979): if it has to be completed at a large energy scale Λ, we would expect $M^2_{Higgs} \sim g^2\Lambda^2$. We know of two alternatives:

- ***Low energy supersymmetry.*** Relates scalars and fermions, whose mass is protected by chiral symmetry, and reduces Λ to M_{SUSY}, needed to be O(1TeV) for not too unnatural tuning, ... or
- ***No elementary scalars***. The Higgs boson is composite of fermion fields, tied together by forces at a scale O(1 TeV), called generically Technicolor forces.
- H could be much lighter than the high energy strong interactions scale, if it is a ***would-be-Goldstone boson*** of some symmetry.

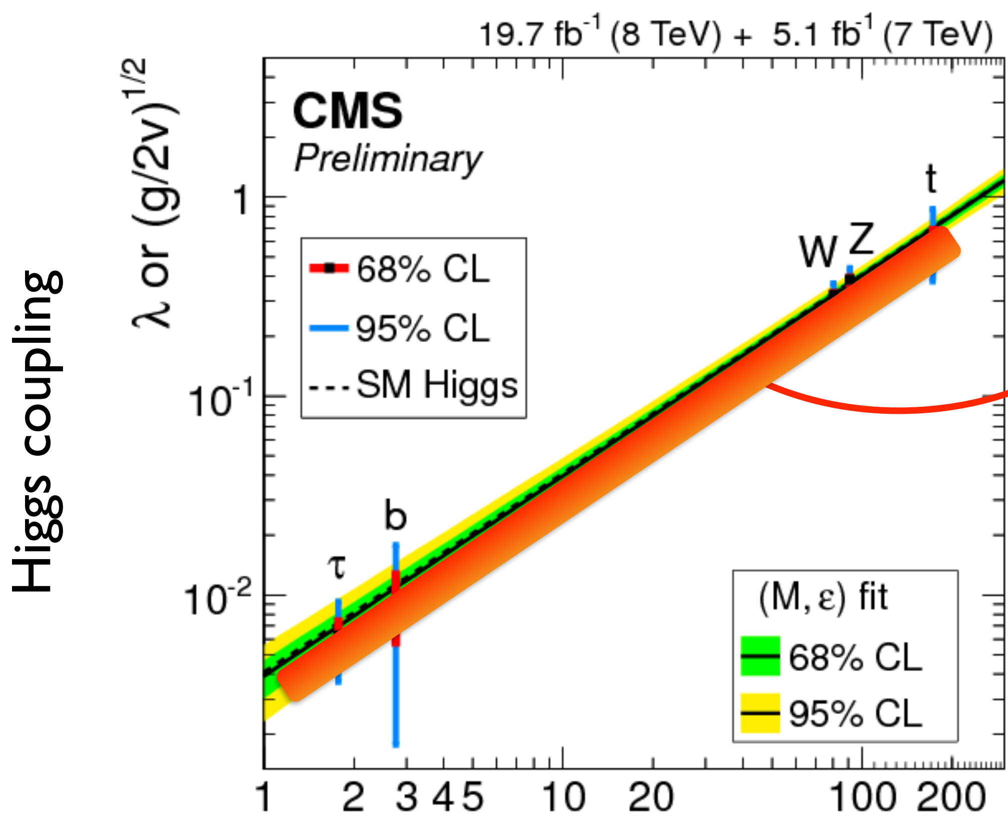
• we should keep ***all options*** open...for the time being.

• LHC , HL-LHC or a Higgs factory (see later) could search for precursor signals of high energy new physics in deviations from ST of Higgs decays;

• or find SUSY particles and /or other Higgs bosons and/or Techicolor bound state

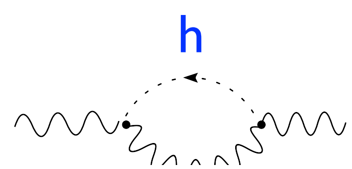
A better perspective to understand how close to a SM Higgs:

A. Pomerol @ Higgs Hunting 2014



Composite Higgs
(reduction of couplings)

small effects already expected,
as EWPT (LEP1) put strong limits
to the coupling hVV
since it affects the Z propagator:



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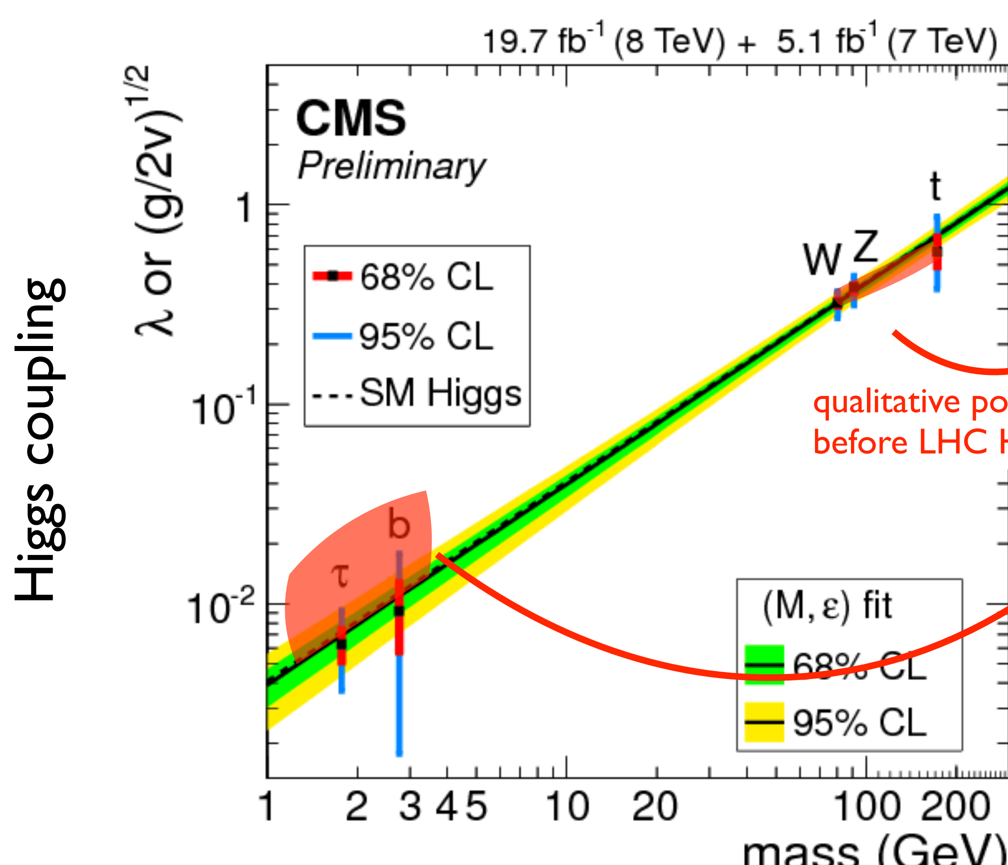
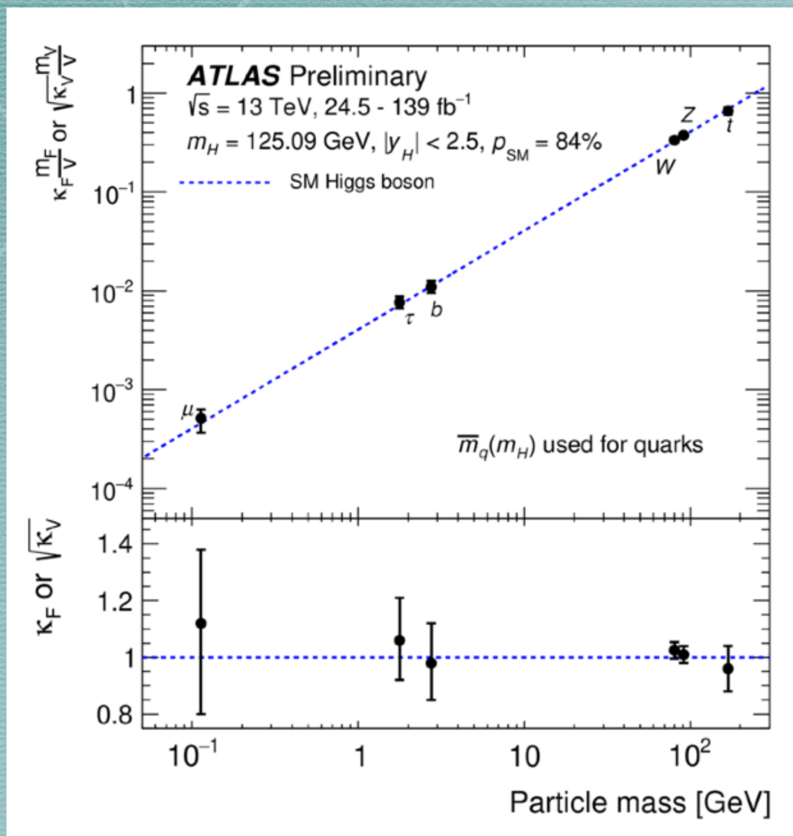
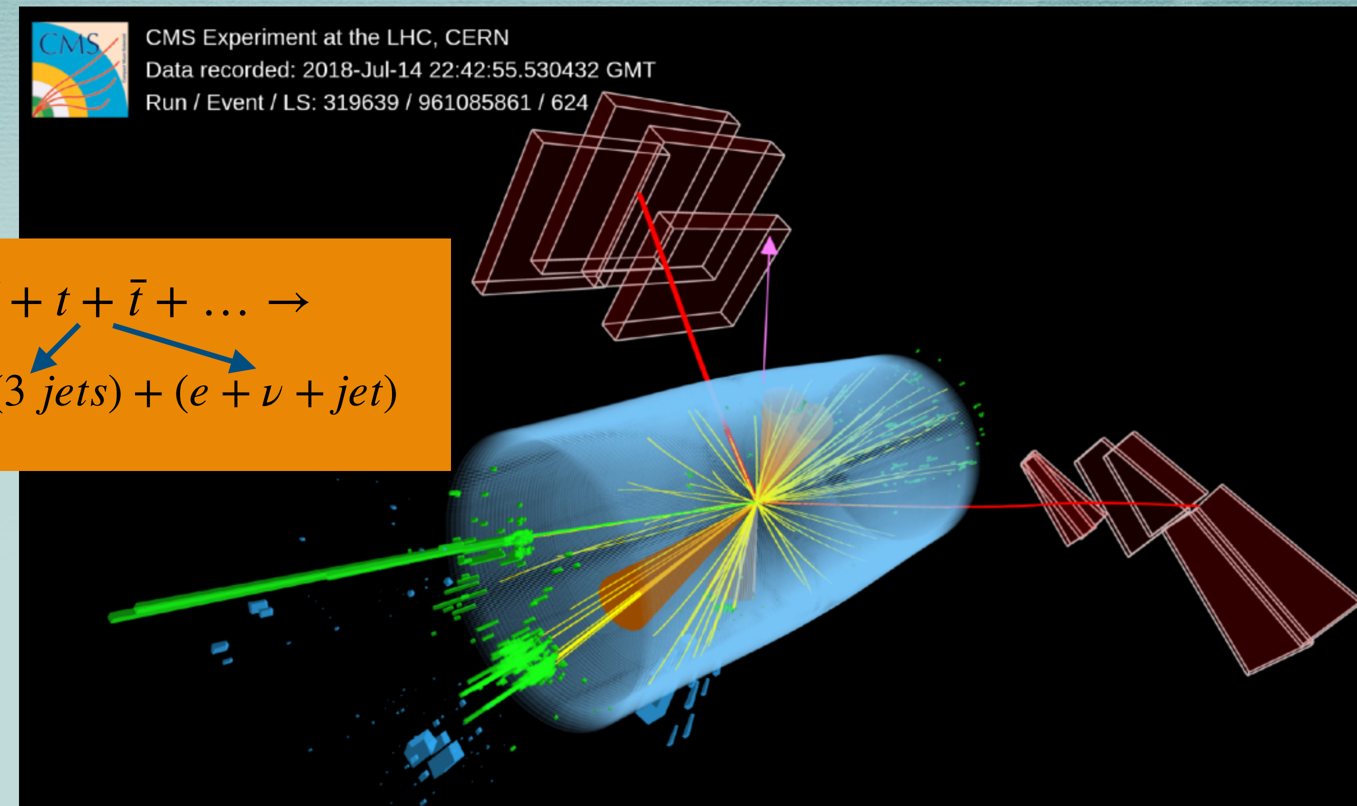


MSSM light Higgs

qualitative possible ranges
before LHC Higgs data

No deviations from ST or SUSY particles seen by ATLAS or CMS

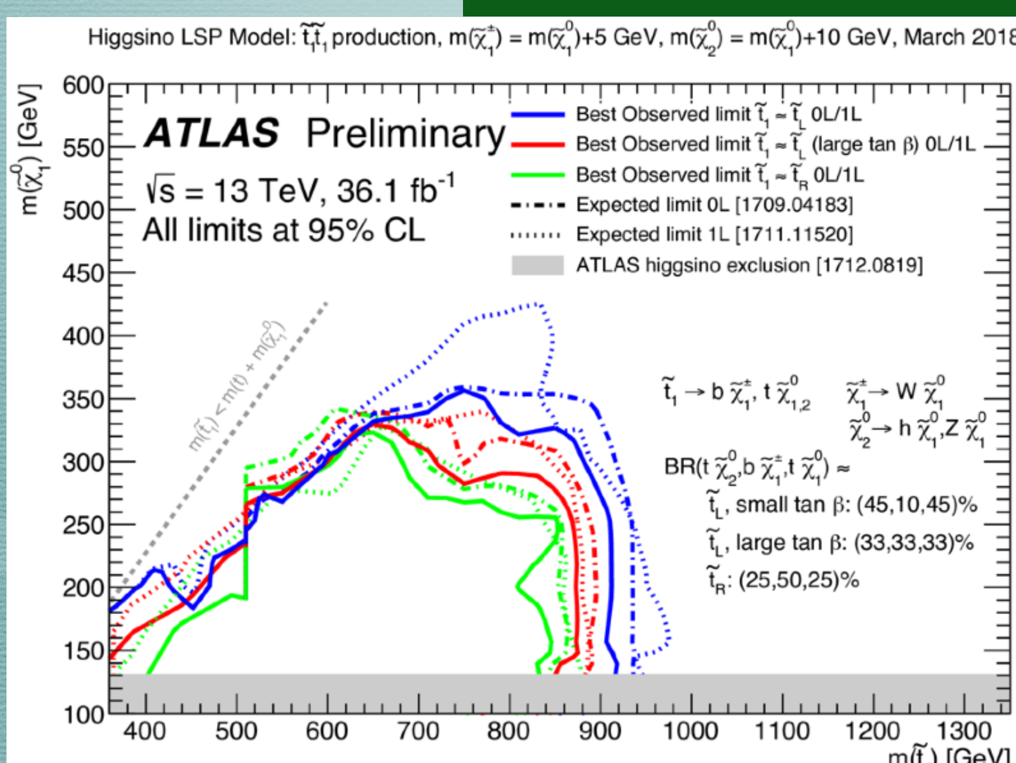


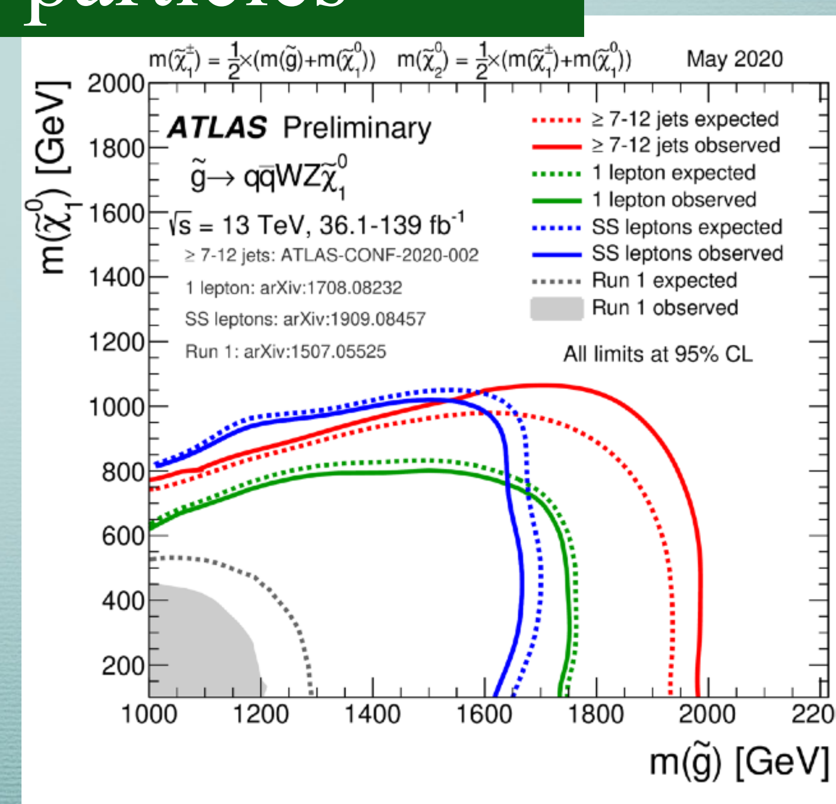


$$p + p \to H + t + \bar{t} + \ldots \to$$

$$\to (\mu^+\mu^-) + (3\ jets) + (e + \nu + jet)$$

Limits on SUSY particles





Probing SUSY in the Higgs Sector

- Two Higgs doublets required (Dimopoulos & Giorgi): H_u, H_d

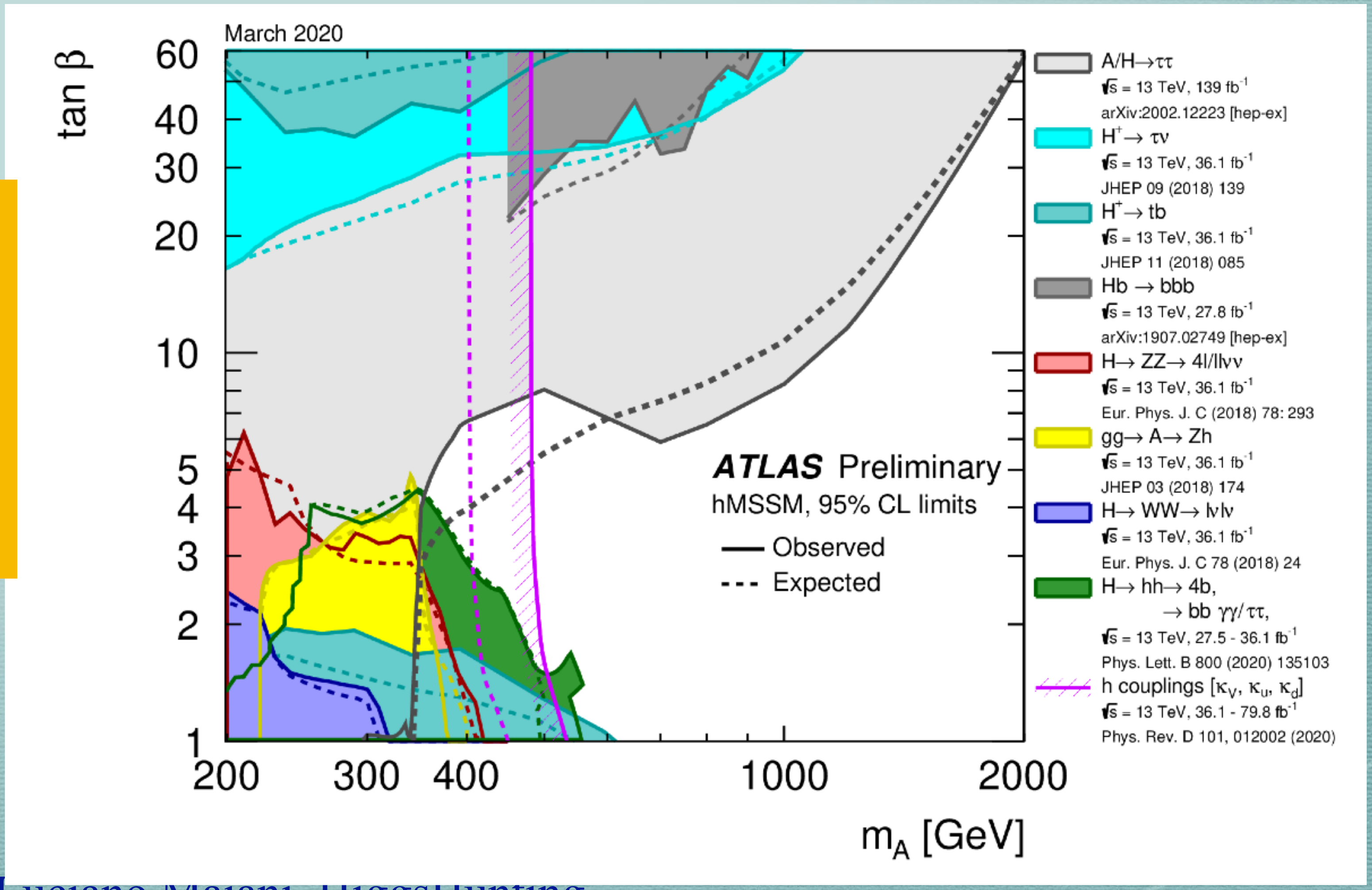
$$\langle 0|H_u^0|0\rangle = v\sin\beta;\quad \langle 0|H_d^0|0\rangle = v\cos\beta;\quad 0 < \tan\beta < +\infty$$
$$v^2 = (2\sqrt{2}G_F)^{-1} = (174\ \text{GeV})^2$$

- Physical H bosons:

$$h:\ 125\ \text{GeV}$$
$$H,\ A,\ H^{\pm}\ \ ???$$

- ATLAS ad CMS search for A has given, so far, lower bounds to M_A in the $M_A - \tan\beta$ plane

ATLAS, March 2020
Data analysed in the hMSSM model of A. Djouadi, L. Maiani, A. Polosa, J. Quevillon and V. Riquer, JHEP **06** (2015), 168, [arXiv:1502.05653 [hep-ph]].



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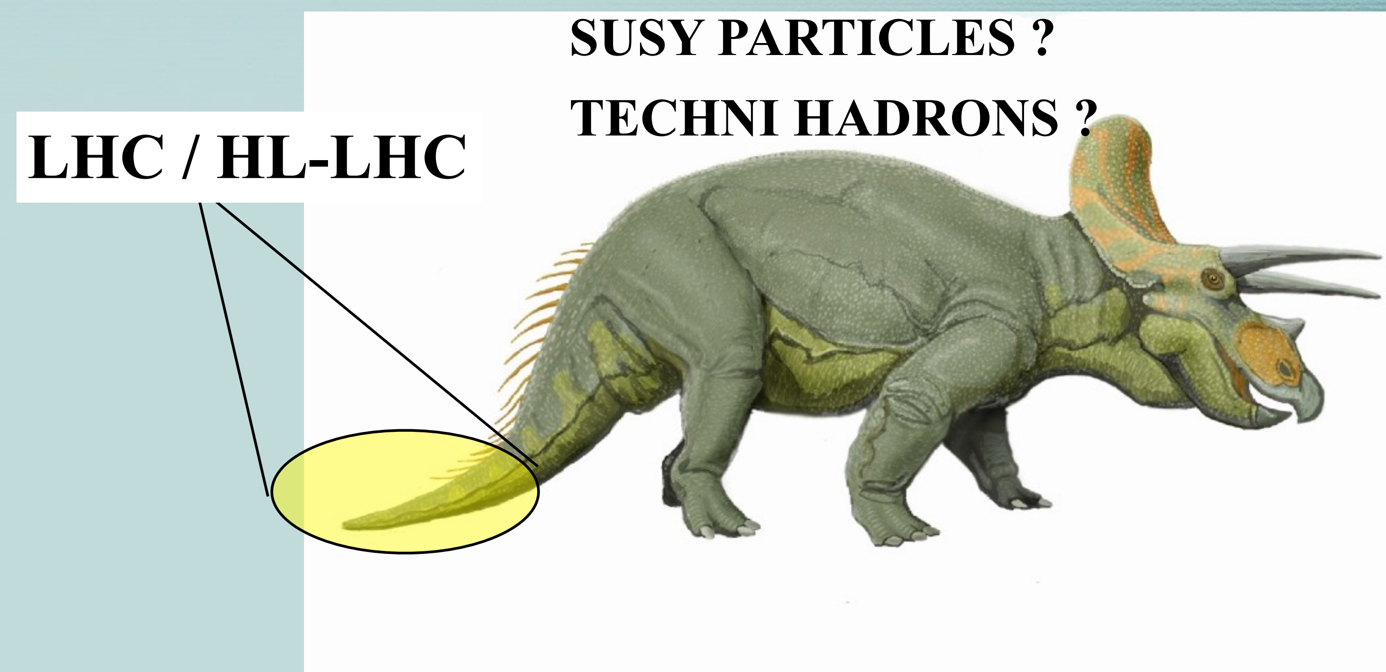

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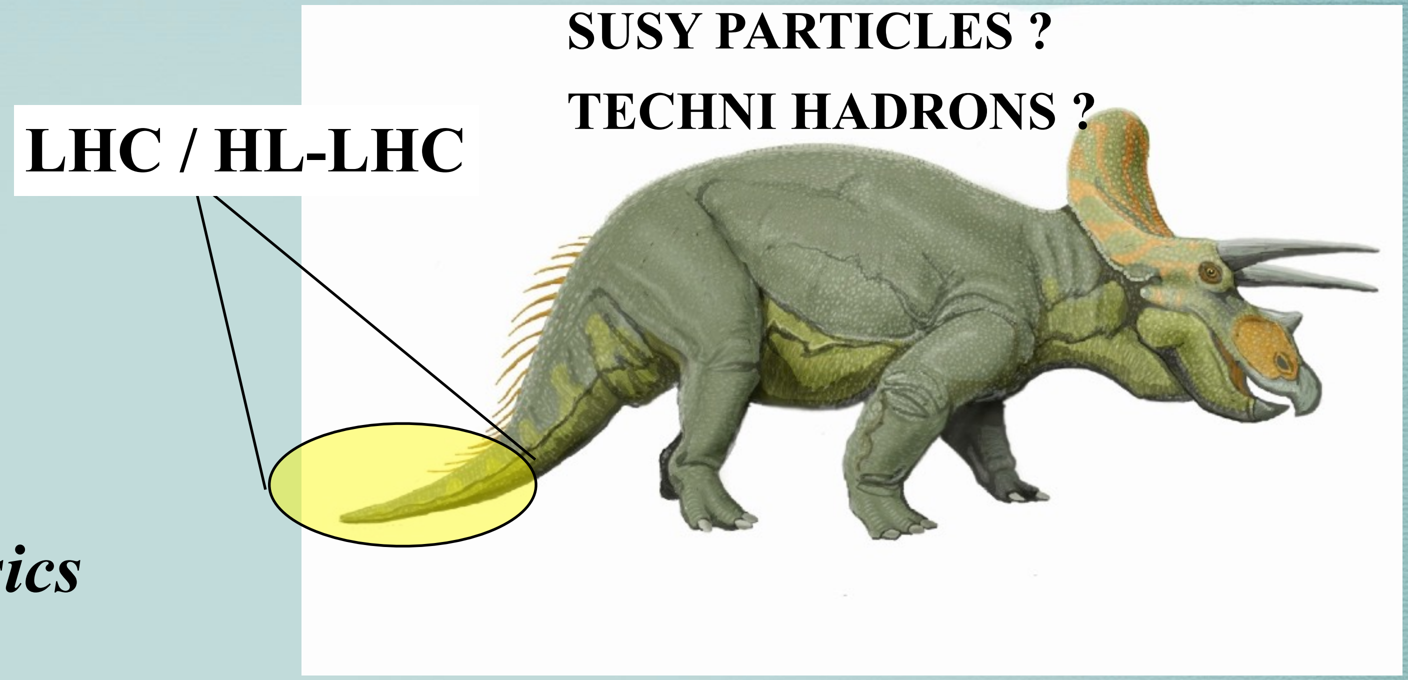

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- ***Can we really guess what New Physics at High Energy is?***

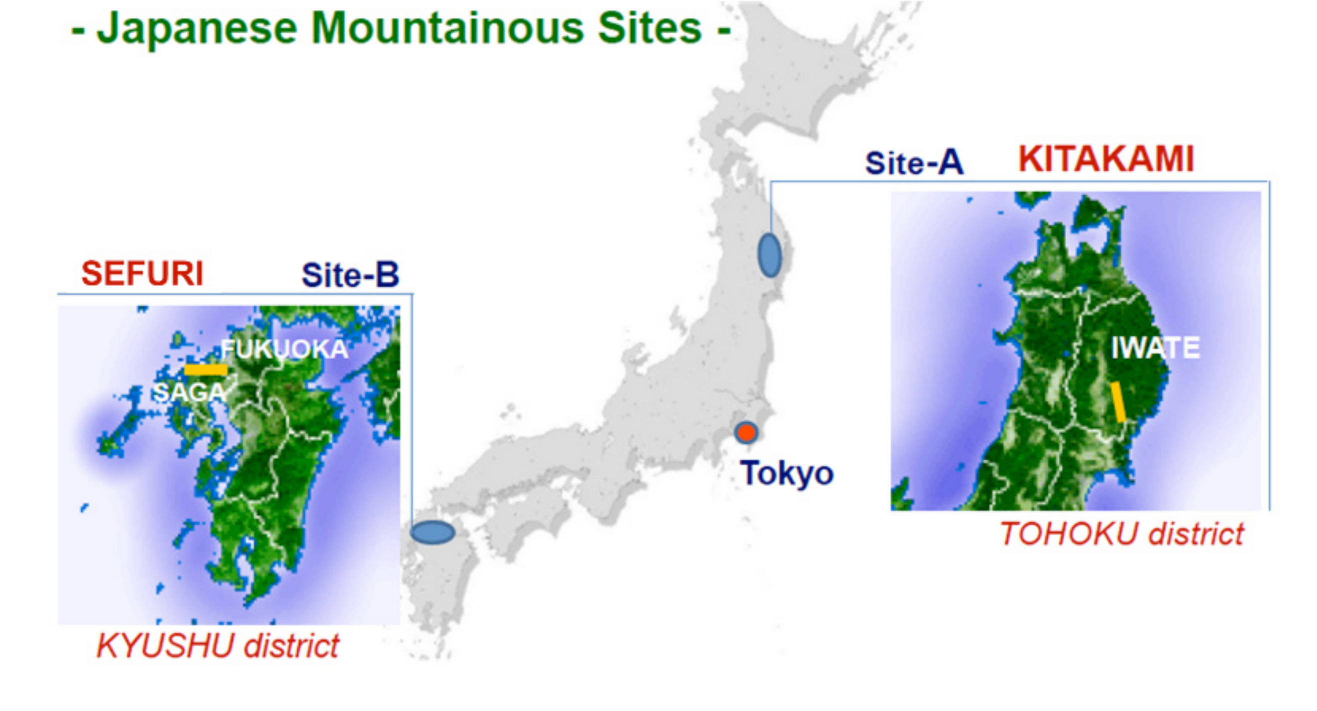
- In the 80s we thought that the unnaturalness of ST could give the key to a complete theory of what is Beyond the Standard Theory (SUSY, GUT, then Gravity…)
- we may have guessed some real point…. compositeness, supersymmetry …but there are so many things we do not fully understand (which kind of SUSY, dark matter, hierarchy, strong interactions) that the physics we will find there will be, most likely, ***entirely new, strange and unexpected***.
- Only direct experiments will tell.

Asia gets in

The electron-positron step

An $e^+ e^-$ Higgs boson factory, could aim at high precision to probe Higgs physics at high energies

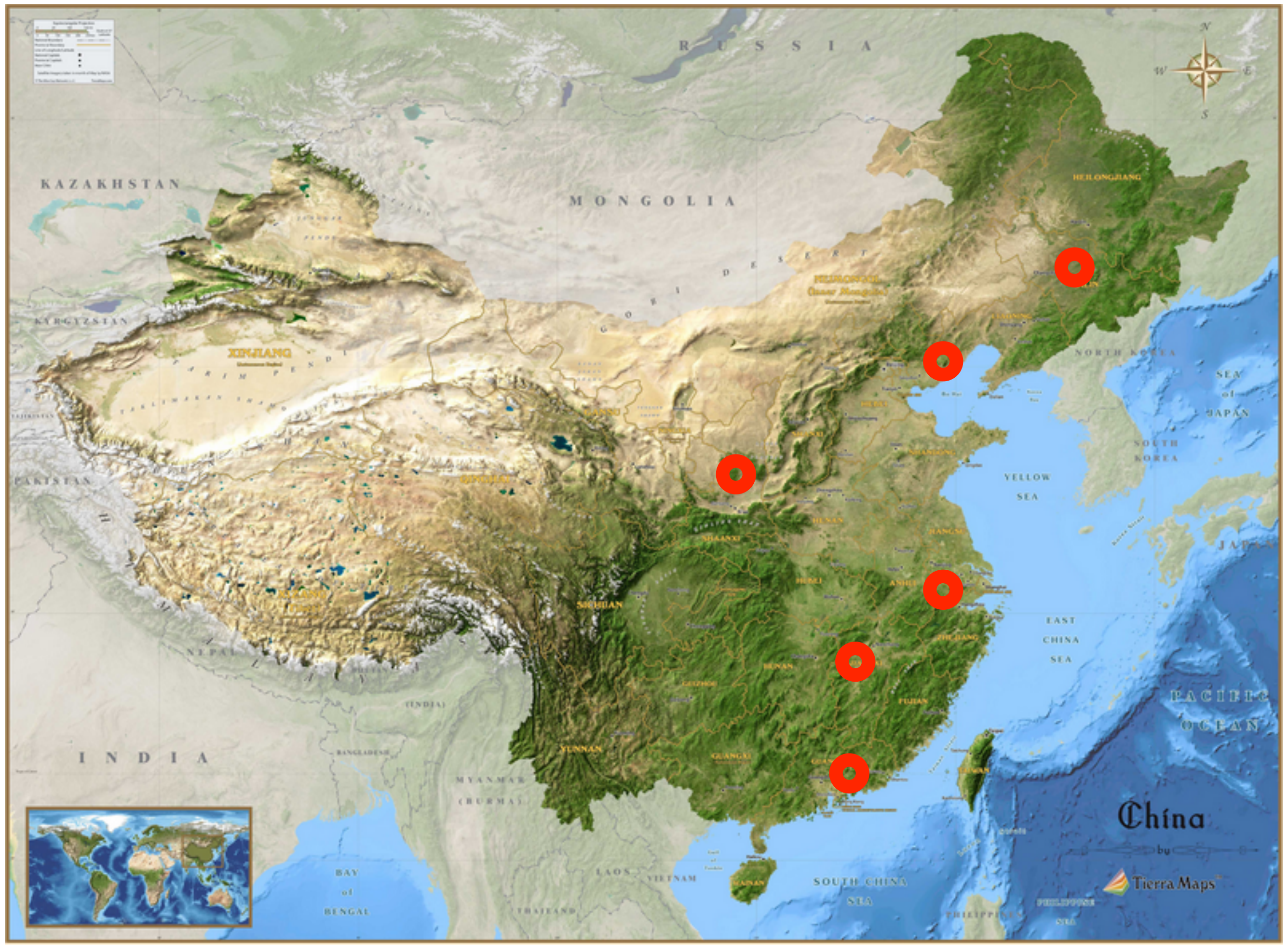
- International Linear Collider, e^+e^- @ 0.5 TeV:
  - site approved in Japan: (Kitakami)
  - a reserve site (Sefuri)



An alternative…

- Go for a circular e^+e^- @ 250-300 GeV in a large tunnel (Higgs factory)
- 70-100 km to make radiation losses acceptable,
- tunnel may host later a p-p collider @ 80-100 TeV, to explore the region left by LHC, 3 to 10 TeV
- projects are being made at CERN, (FCC-e^+e^-), and in China at IHEP (CepC)

CEPC site investigation and facility study

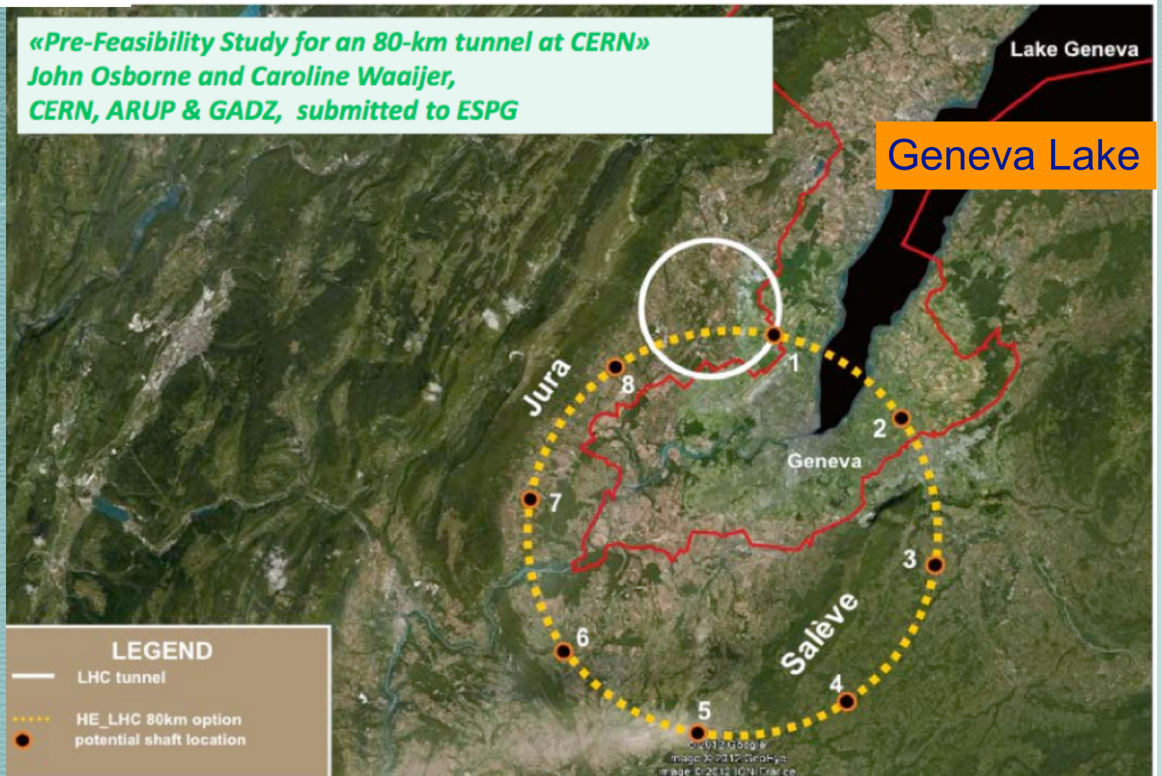


- Site selection based on geology, electricity supply, transportation, environment for foreigners, local support & economy,…
- North are better for running cost savings
- CDR study is based on Qing-Huang-Dao, 300 km towards the east of Beijing

- More invitations from local governments: Changsha, Changchun, …
- Recent visit to Shangsha: best for geology & transportation(20 km from a large city & an international airport)

Dreams about the future

FCC tunnel in the Geneva area – "best" option



A good example is Qinghungdao (秦皇岛)

Feb. 24, 2014

- 100 TeV proton Collider is a fantastic challenge
- new innovative technologies: material science, low temperatures, electronics, computing, big data
- an attraction for new physics ideas and young talents to solve the hardest scientific problem which we have been confronted in the last 100 years

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1950's: National Laboratories in IT, FR, UK, DE... united forces to make CERN-Europe
2030's: Regional Laboratorie in Europe, America, Asia … will unite in a
Global Accelerator Network - The World ??