LHC: Status and results after the 2011 run

Based on presentations at the 2012 Moriond Meeting

by

G. Dissertori (ETH Zurich): Experimental Summary

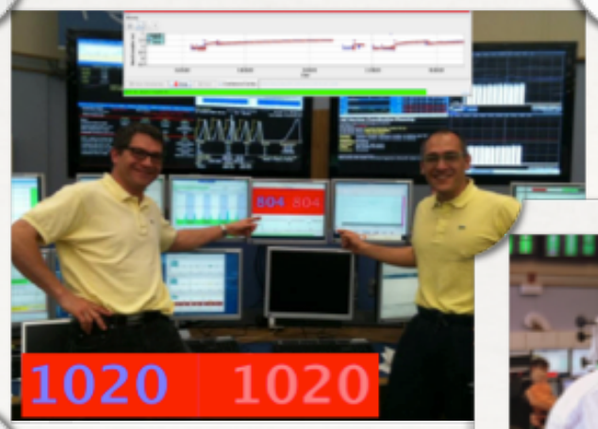
M. Lamont (CERN): LHC Beam Operation

CERN

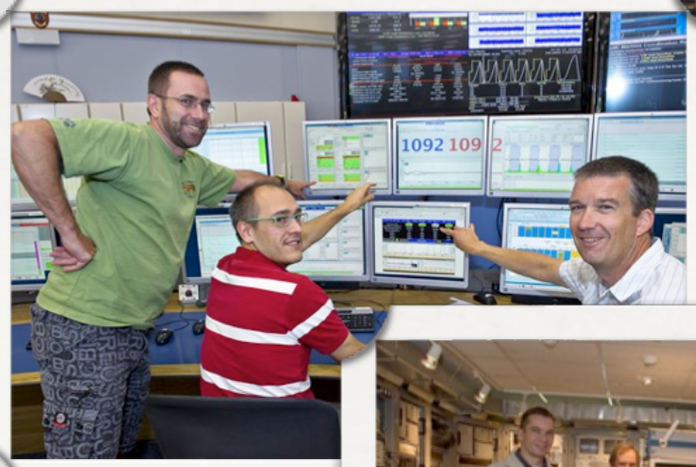
Accelerating Science and Innovation

LHC : A lot to celebrate last year...

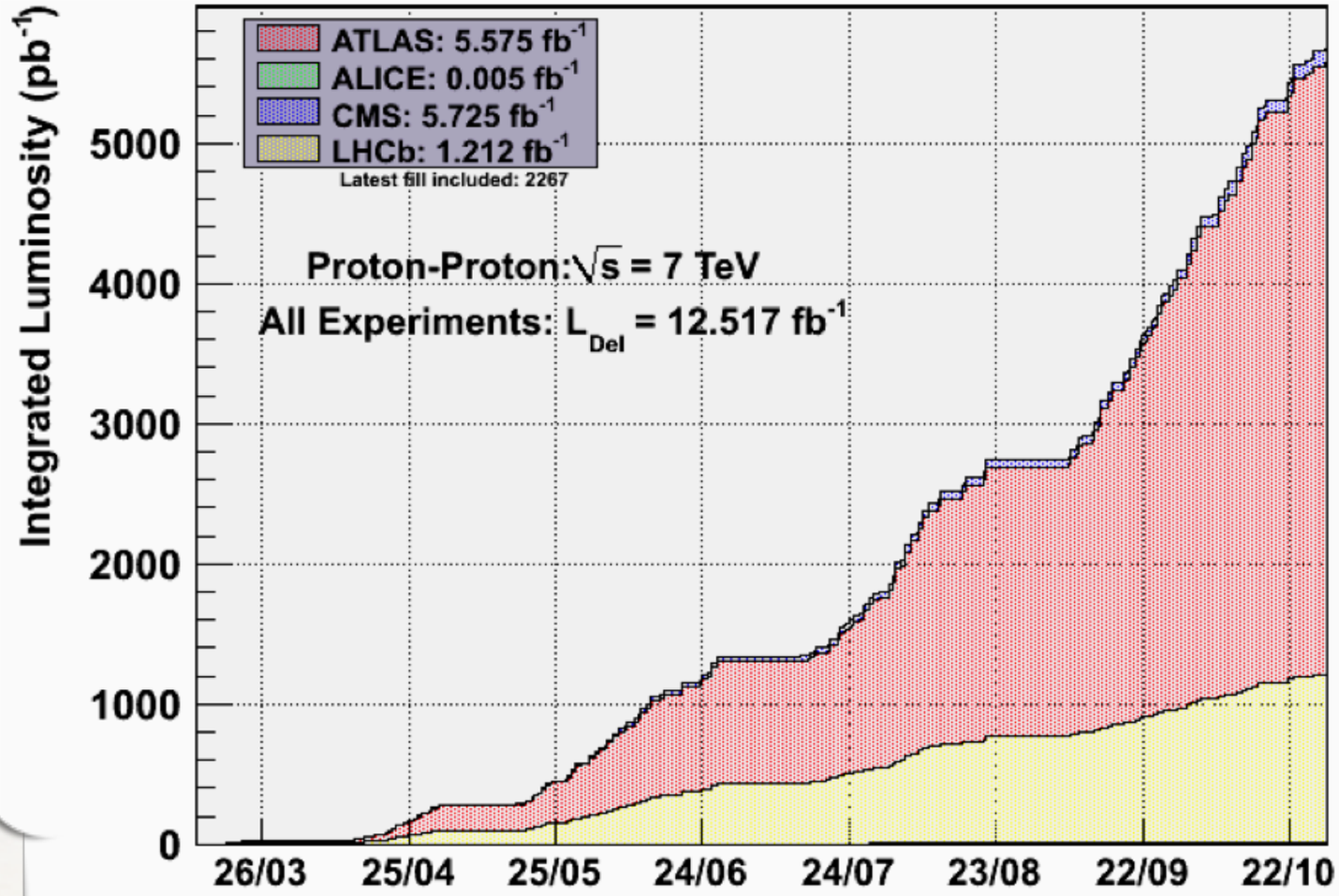
M. Lamont



10^{33}



Ion man



Factor ~20 gain in peak luminosity w.r.t. 2010, mainly thanks to : number of bunches, beta*, emittance
Heavy Ions: 150/microbarn , 20x more in 2011

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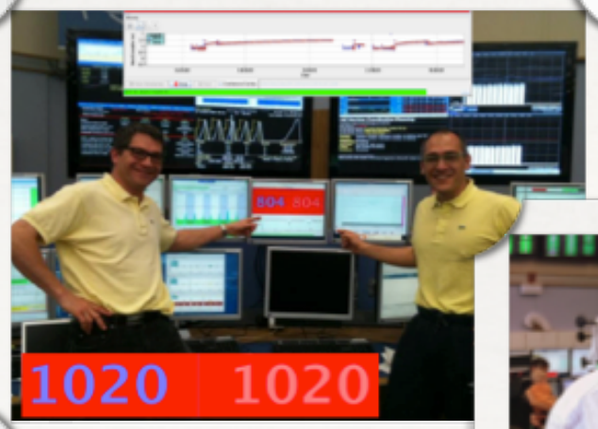

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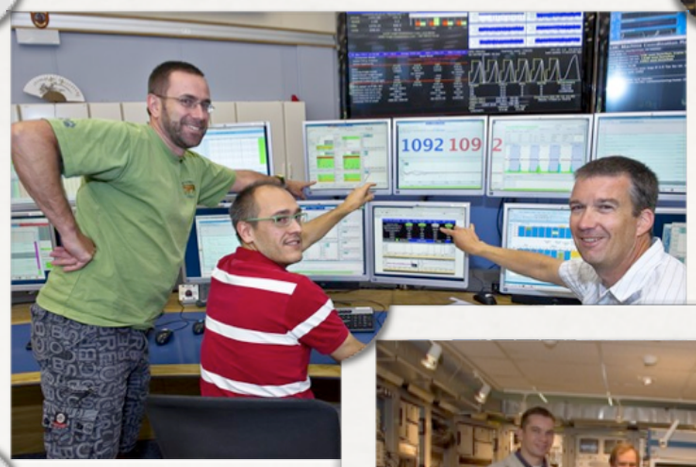

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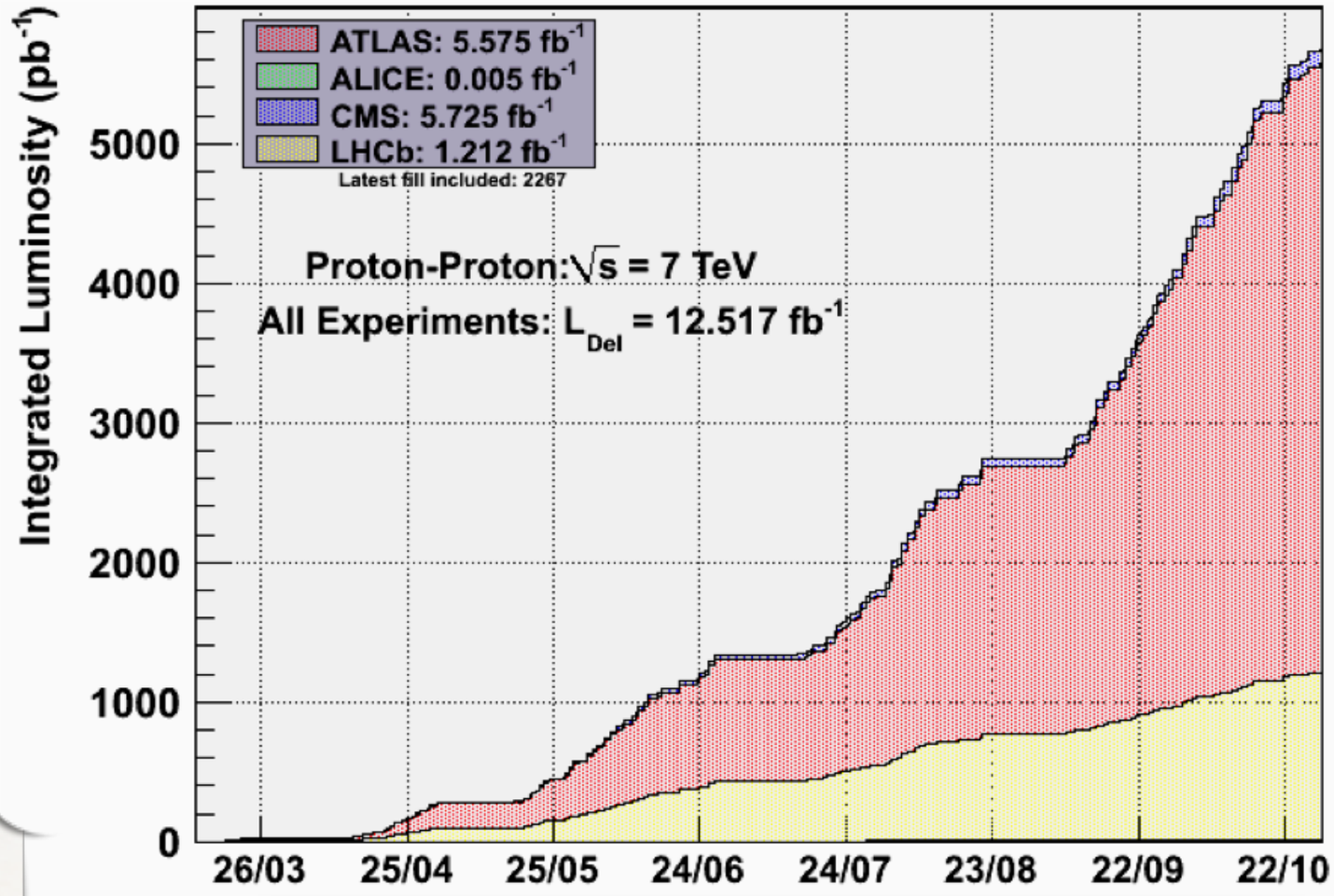

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2012 plan:
- 8 TeV
- 50 ns bunch spacing
- tight collimator settings
- ATLAS/CMS: beta*=0.6 m, peak lumi 6.8e33 $cm^{-2}s^{-1}$
- LHCb/ALICE: beta*= 3 m
- ~126 days proton running, ~22-24 days p-Pb running
- pp : L_{int} somewhere between 12 and 19 /fb

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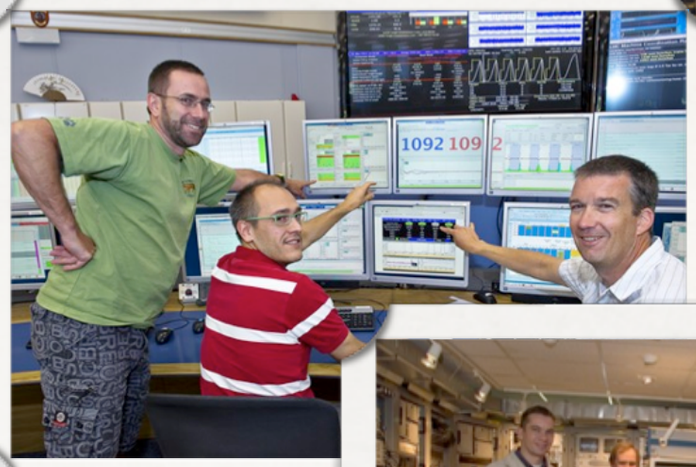

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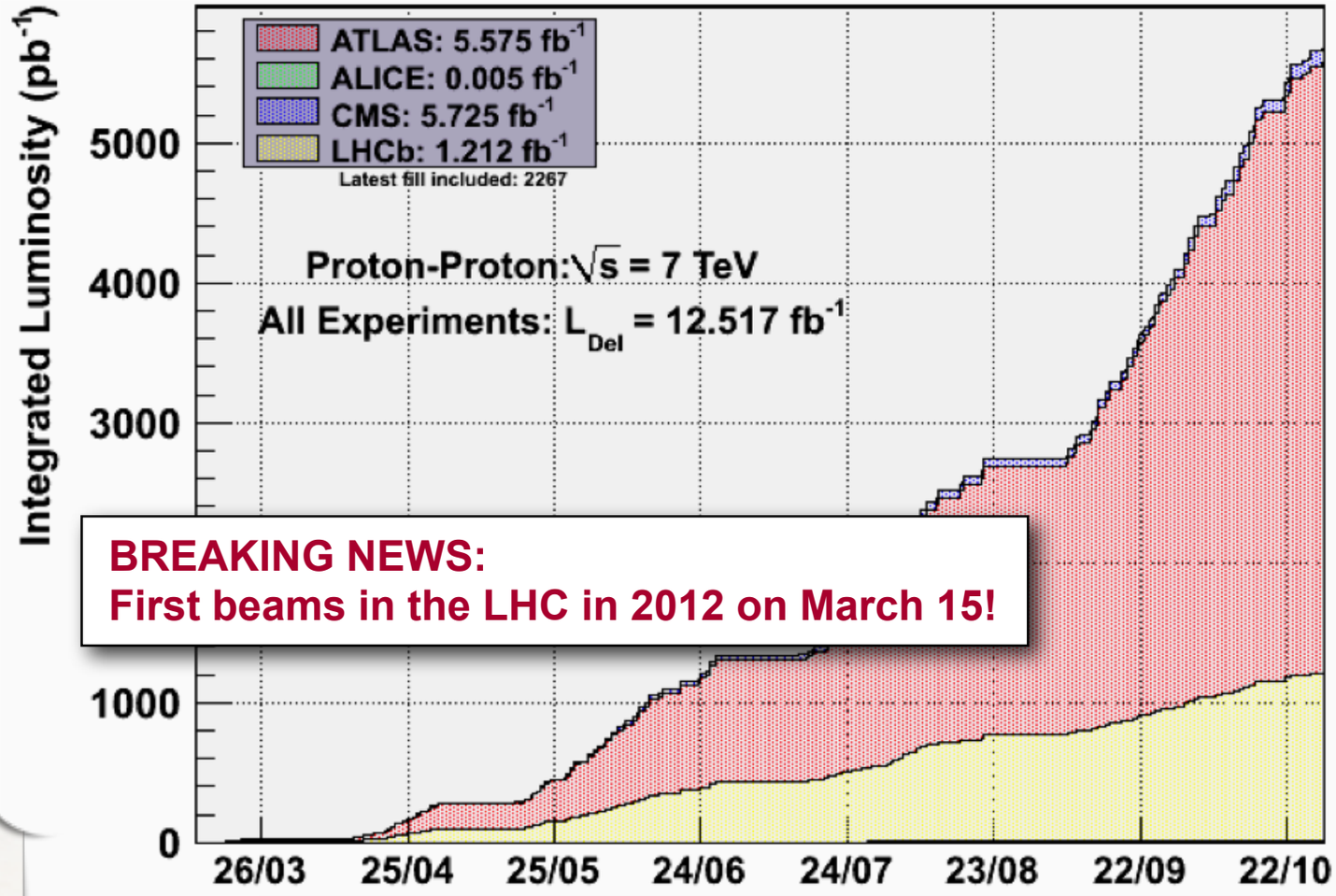

BREAKING NEWS:
First beams in the LHC in 2012 on March 15!

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Heavy Flavours

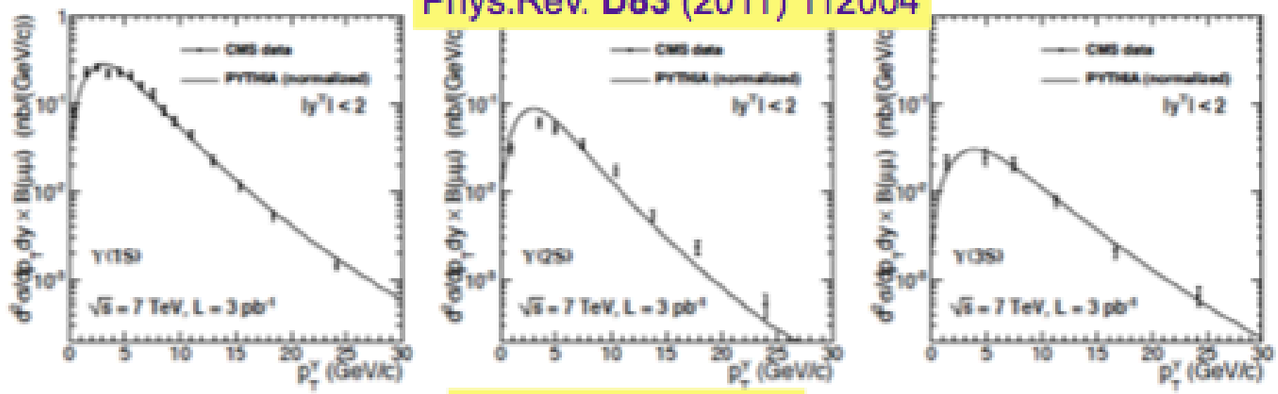
HF production (at the LHC)

ETH Institute for Particle Physics

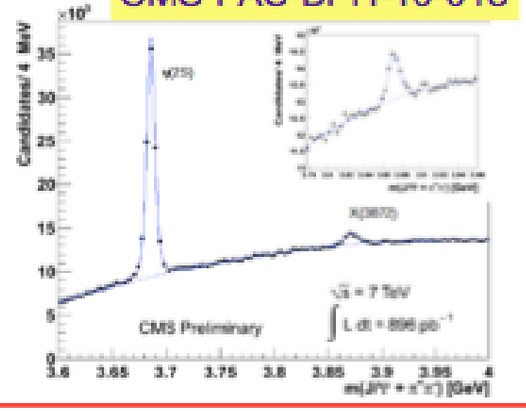
Heavy flavor production results by ATLAS & CMS

- There are many results from ATLAS & CMS that I will not be able to present today!

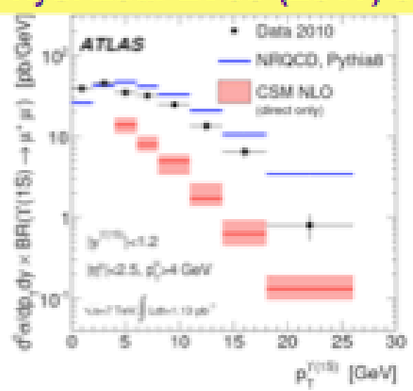
Phys.Rev. **D83** (2011) 112004



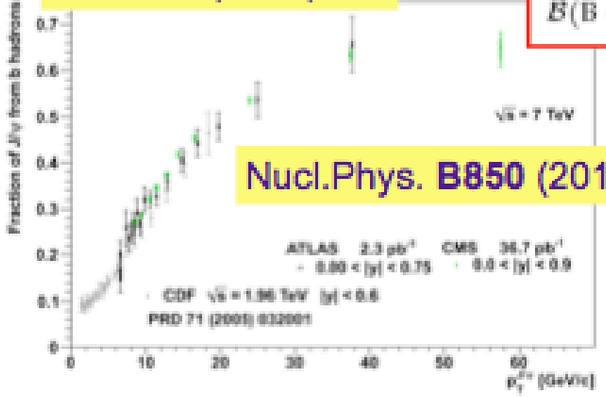
CMS-PAS-BPH-10-018



Phys. Lett. **B705** (2011) 9-27

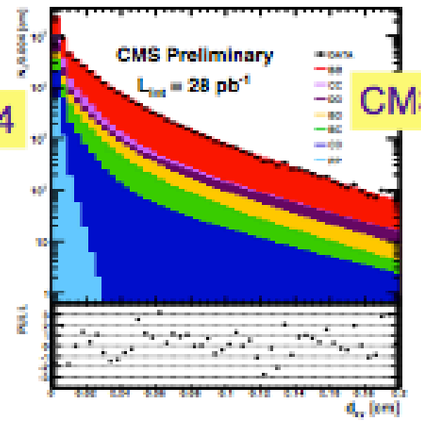


JHEP **02** (2012) 011



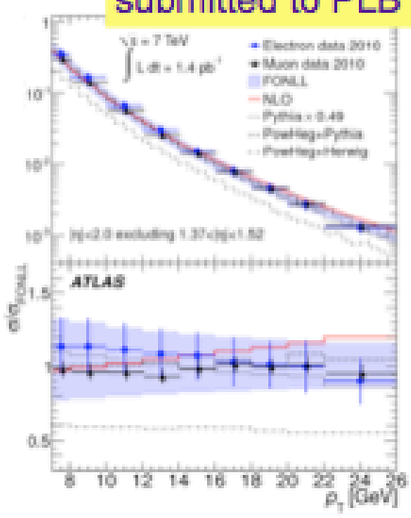
Nucl.Phys. **B850** (2011) 387-444

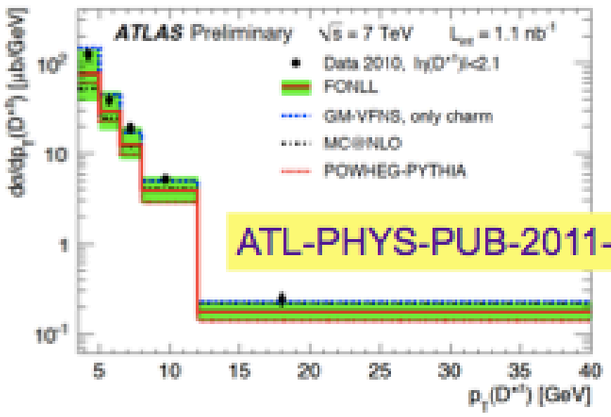
$$\mathcal{B}(\mathrm{B} \to \psi(2S)\mathrm{X}) = (3.08 \pm 0.12\,(\mathrm{stat.{+}syst.}) \pm 0.13\,(\mathrm{theor.}) \pm 0.42\,(\mathcal{B}_{\mathrm{PDG}})) \times 10^{-3}.$$



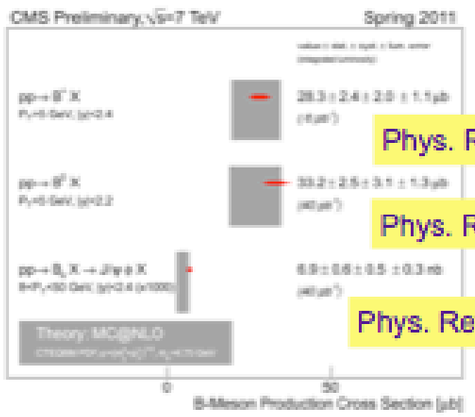
CMS-PAS-BPH-10-015

arXiv:1109.0525
submitted to PLB





ATL-PHYS-PUB-2011-012



Phys. Rev. Lett.**106** (2011) 112001

Phys. Rev. Lett. **106** (2011) 252001

Phys. Rev. **D84** (2011) 052008

Ernest Aguiló (UniZh) 4 March 12th 2012

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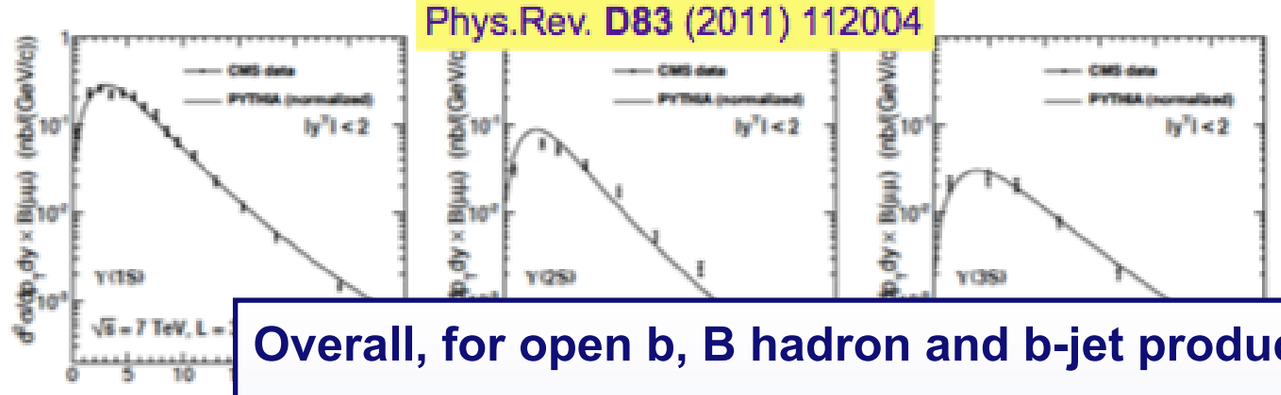
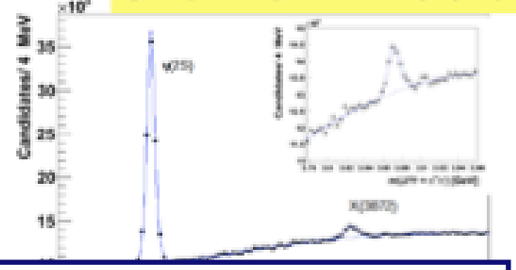
Phys.Rev. **D83** (2011) 112004



CMS-PAS-BPH-10-018



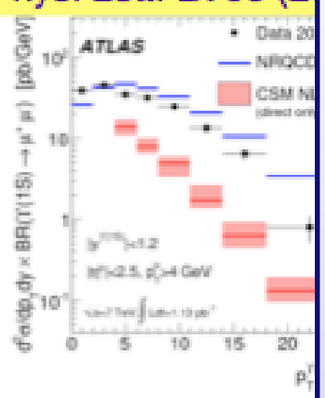
Overall, for open b, B hadron and b-jet production:

- pQCD (and/or MC models) in reasonable agreement, but some discrepancies seen (in p_T and/or eta)
- bb angular correlations studied, low-angle region not well modeled

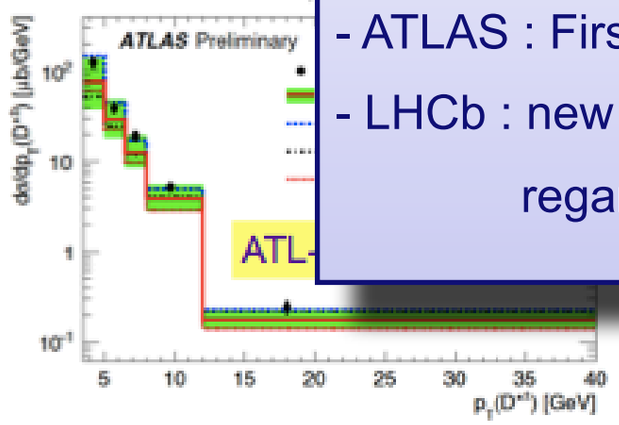
Some highlights :

- CMS : Lamba_b (steeper spectrum than B mesons)
- ATLAS : First particle discovered at LHC : $Chi_b(3P)$, just confirmed by Dzero
- LHCb : new measurements of Chi_c, psi(2s) and double charm production, regarding the latter: tests of double parton scattering

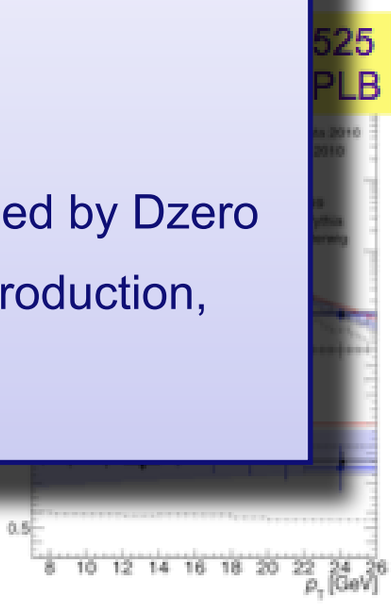
Phys. Lett. **B705** (2



525 PLB



Phys. Rev. **D84** (2011) 052008



Ernest Aguiló (UniZh) 4 March 12th 2012

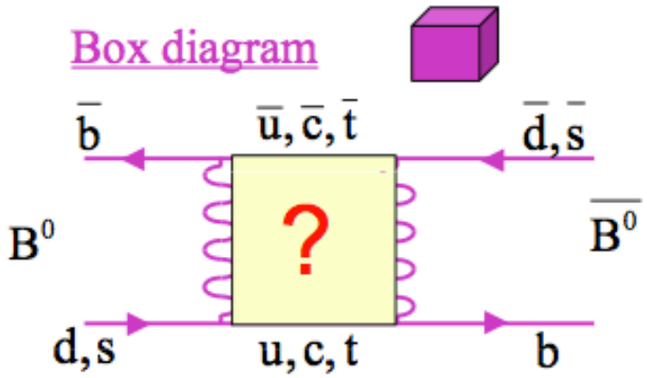
CPV, rare decays, and all that jazz

- If you want to get a beautiful overview, look at A. Schopper's slides

New Physics manifestations in Heavy Flavours

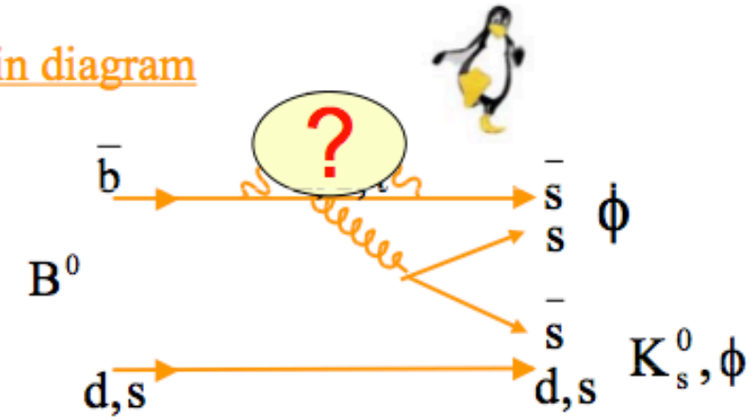
Search for deviations from Standard Model predictions due to
virtual contributions of new heavy particles in loop processes

Box diagram



New Physics

Penguin diagram

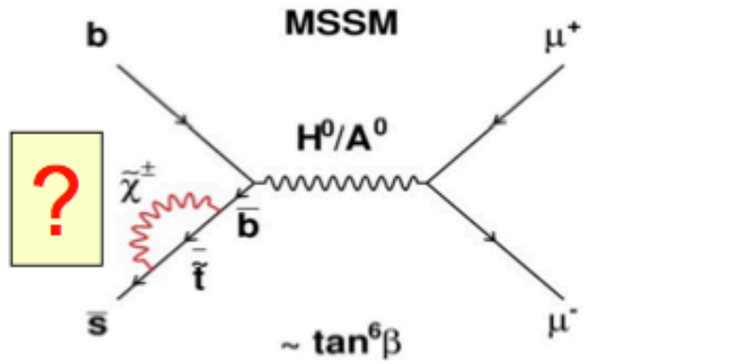


measure:
- ***CP violating phases*** in mixing and decay
- ***Rare Decays*** of heavy quarks

compare:
- to ***very precise predictions*** of the SM

→ discovery potential for ***New Physics*** extending to mass scales far in excess of the LHC centre-of-mass energy

$B_s \rightarrow \mu^+\mu^-$ "s-channel penguin"



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Probing New Physics with Heavy Flavours

A highly biased selection of a few exciting topics:

Based on summer conferences:
LP2011, EPS2011, HCP2011…

- CKM metrology:
  - the tension between sin(2β) and B→ τν
  - the need for improved measurement of angle γ
- Direct CP violation:
  - first evidence for direct CP violation in $B_s \rightarrow K\pi$
  - $B^0 \rightarrow K^+ \pi^-$ and $B^+ \rightarrow K^+\pi^0$ CP asymmetry puzzle
- Mixing induced CP violation:
  - dimuon charge asymmetry A_{sl}
  - weak phase Φ_s
- Rare decays:
  - A_{FB} in $B_d \rightarrow K^*\mu\mu$
  - $B_s \rightarrow \mu\mu$ (and $D^0 \rightarrow \mu\mu$)
- A charming surprise…

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Some of the important new results / updates shown in these last weeks in La Thuile:

- direct CPV in B to hh' (LHCb)

- CPV in Bs mixing (LHCb, CDF)

- Bs to mumu (LHCb, CMS, ATLAS, CDF)

- B to K* mumu (LHCb)

- a number of further rare decays (LHCb)

- delta-A_{CP} in charm (LHCb, CDF)

TOP

Everybody says: “... the top quark is special!”

By now, all the other quarks must suffer psychological damage

TOP production

Aracena
Suarez
Wu

ETH Institute for Particle Physics

- Amazing amount of new results, both from LHC and Tevatron

	ATLAS	CMS
Lepton + jets	0.70 fb^{-1}	0.80-1.09 fb^{-1}
Dilepton	0.70 fb^{-1}	1.14 fb^{-1}
Tau + μ	1.08 fb^{-1}	1.09 fb^{-1}
Tau + jets	1.67 fb^{-1}	n/a
All hadronic	4.70 fb^{-1}	1.09 fb^{-1}

Current ATLAS combination:

$$\sigma_{t\bar{t}} = 177 \pm 3(\text{stat.})^{+8}_{-7}(\text{syst.}) \pm 7(\text{lumi.})\ \text{pb}$$

Current CMS combination:

$$\sigma_{t\bar{t}} = 165.8 \pm 2.2(\text{stat.}) \pm 10.6(\text{syst.}) \pm 7.8(\text{lumi.})\ \text{pb}$$

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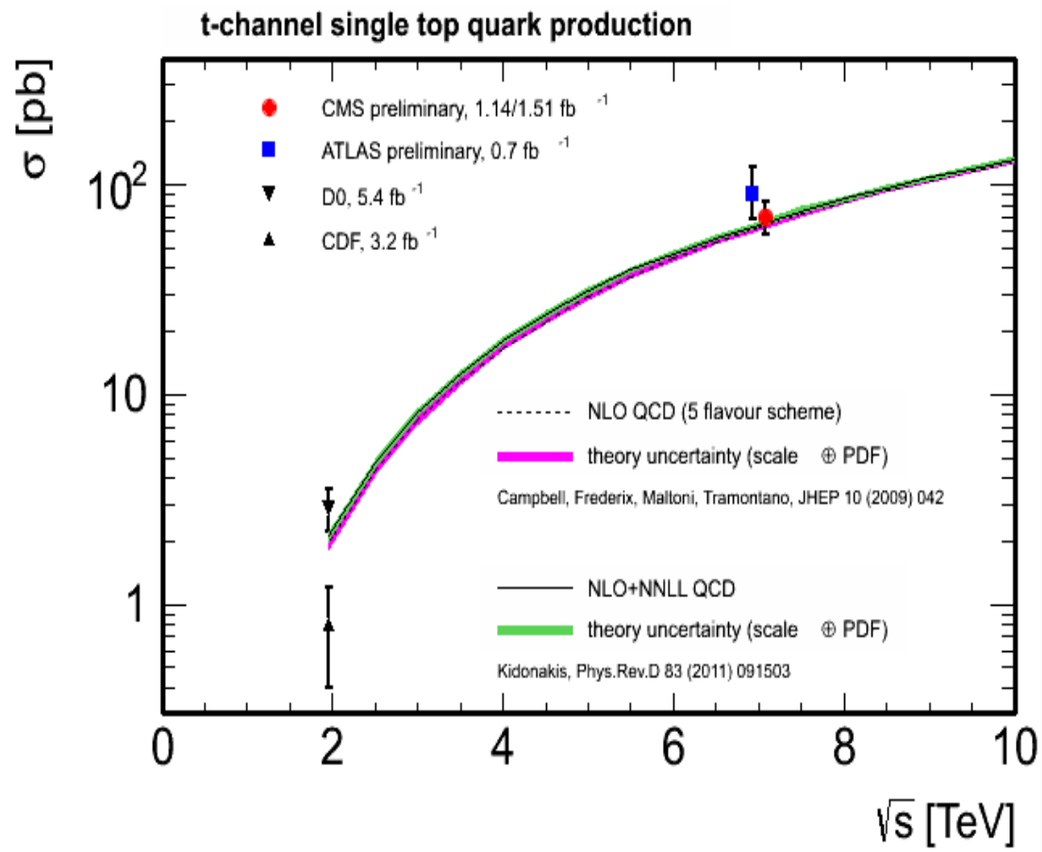

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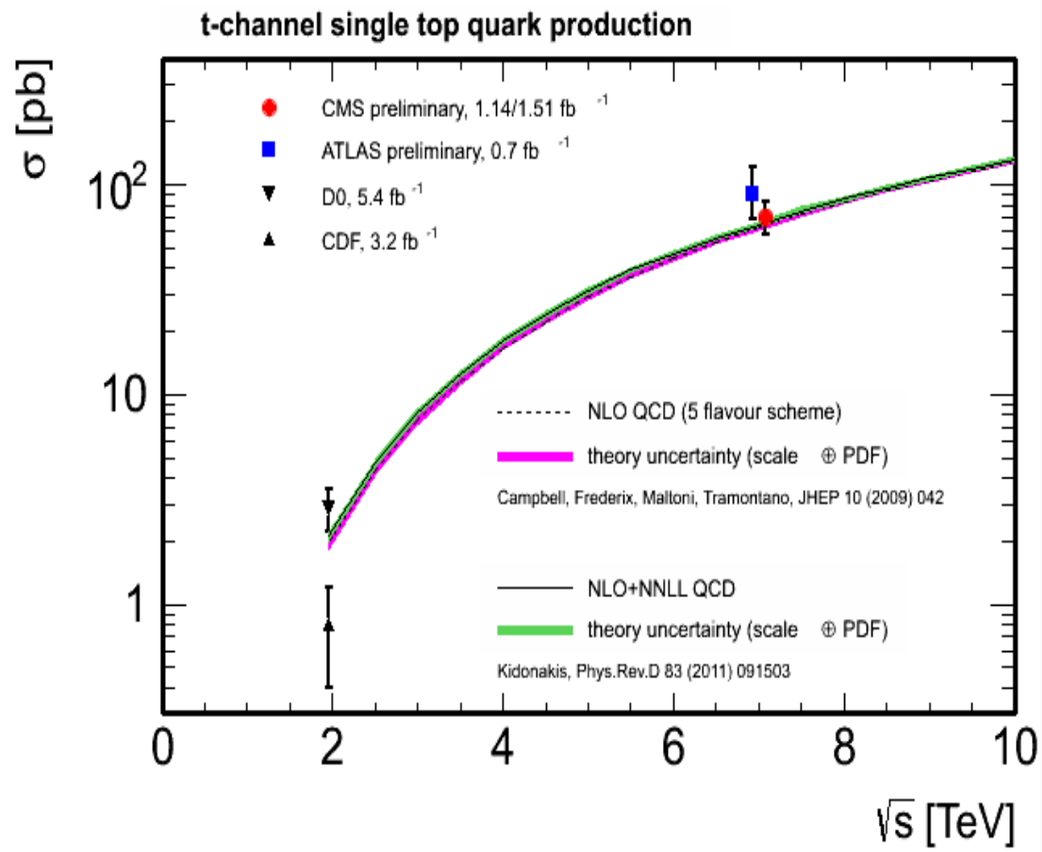


Top pair production:

- exp. uncertainty reached 6% (!) level, smaller than theory uncertainty.
- overall impressive agreement with pQCD pred. ATLAS-CMS consistency? LHC combination?
- top pair xsec useful to constrain pdfs? see also talk by Schwinn

Single top production:

- Better than 20% accuracy reached. “Harmonization” of theory uncert. needed between ATLAS and CMS
- CMS : $|V_{tb}|$ extracted at the 10% level!
- closing in on tW and s-channel prod.

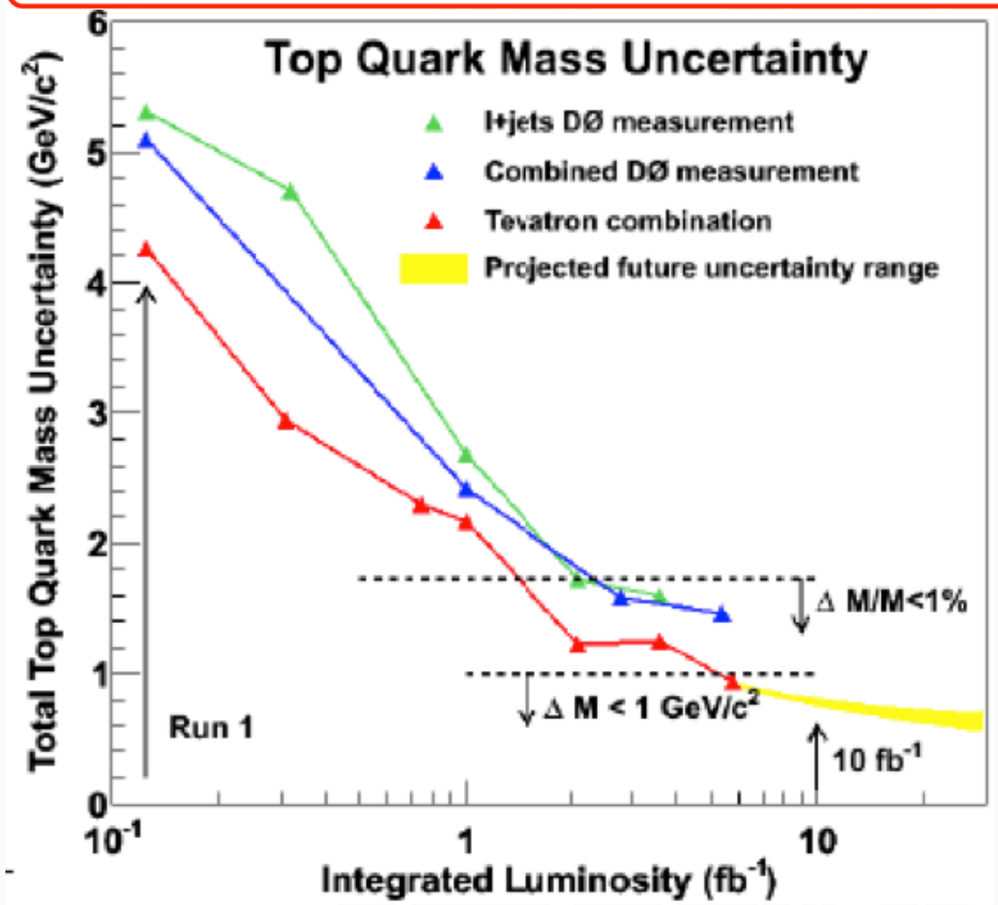
TOP mass

Brandt
Blyweert

ETH Institute for Particle Physics

- Tevatron is leading, with LHC catching up....

$$m_{\mathrm{top}} = 173.2 \pm 0.6\,(\mathrm{stat}) \pm 0.8\,(\mathrm{syst})$$



Relative uncertainty: 0.54%
Expect this limit to be improved…

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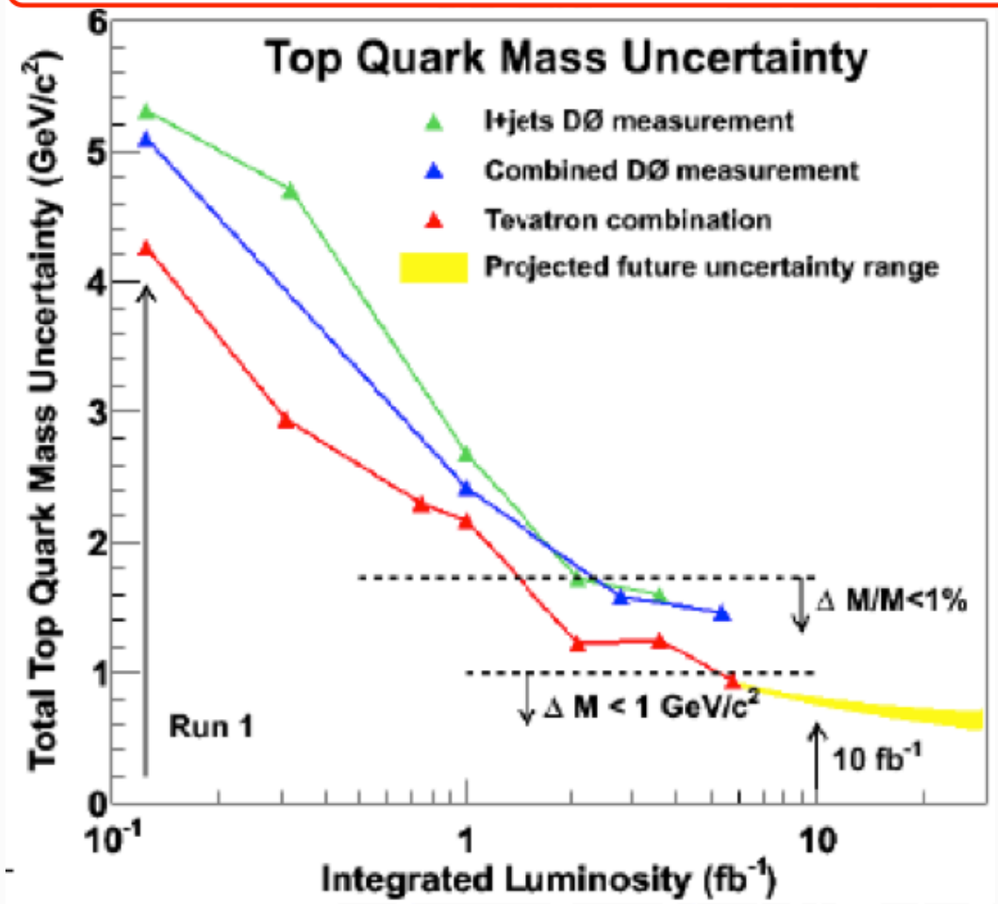

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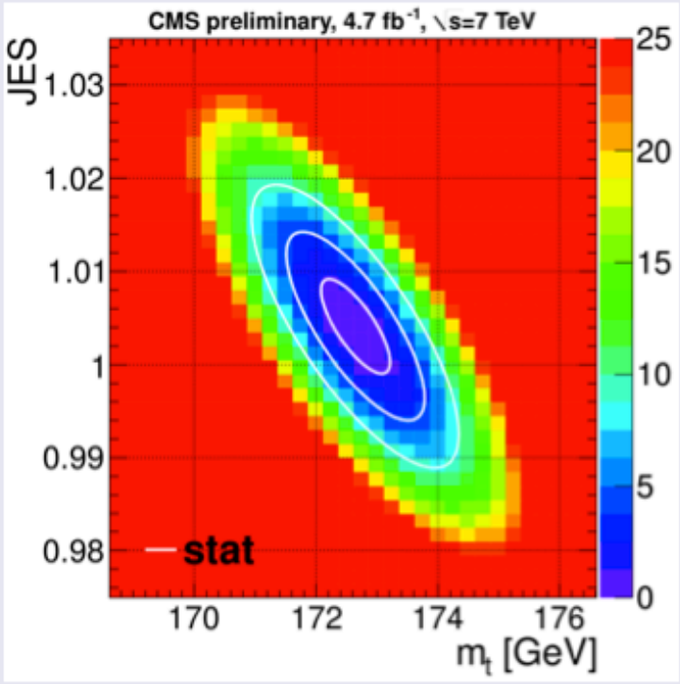
Results on data (4.7 fb^{-1})



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- Most precise LHC measurement

Systematics not yet included: colour rec, UE

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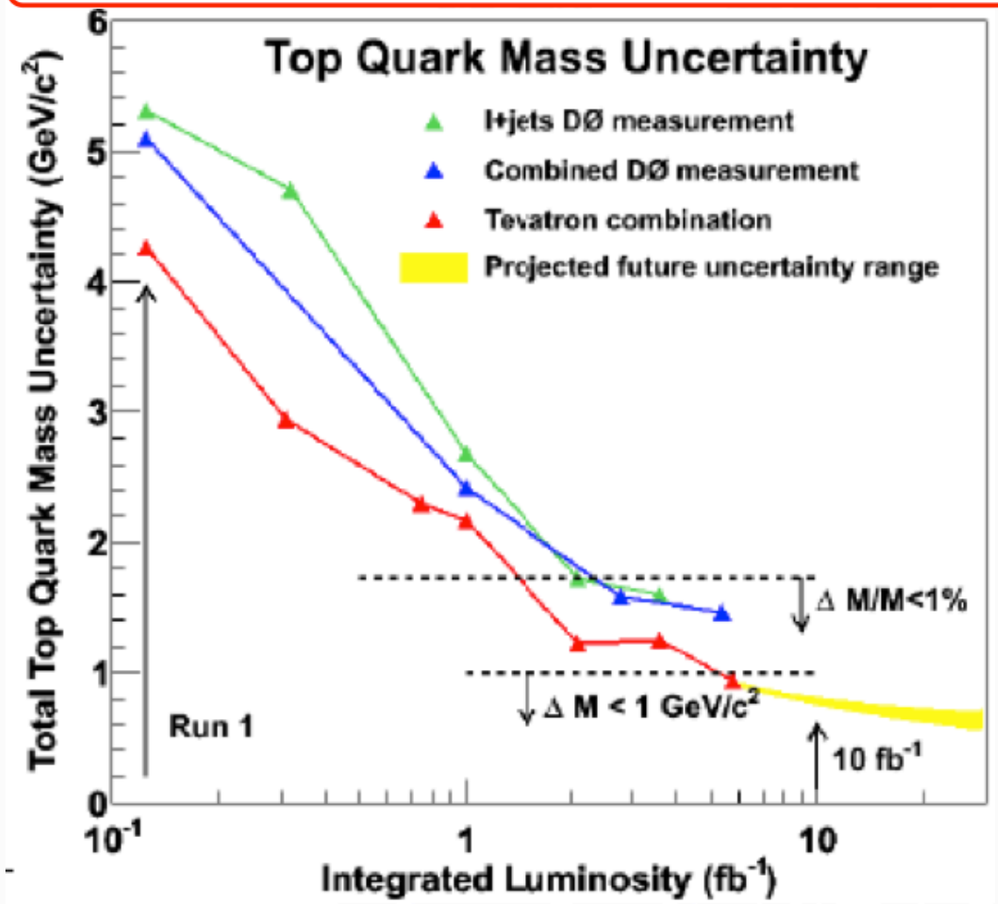

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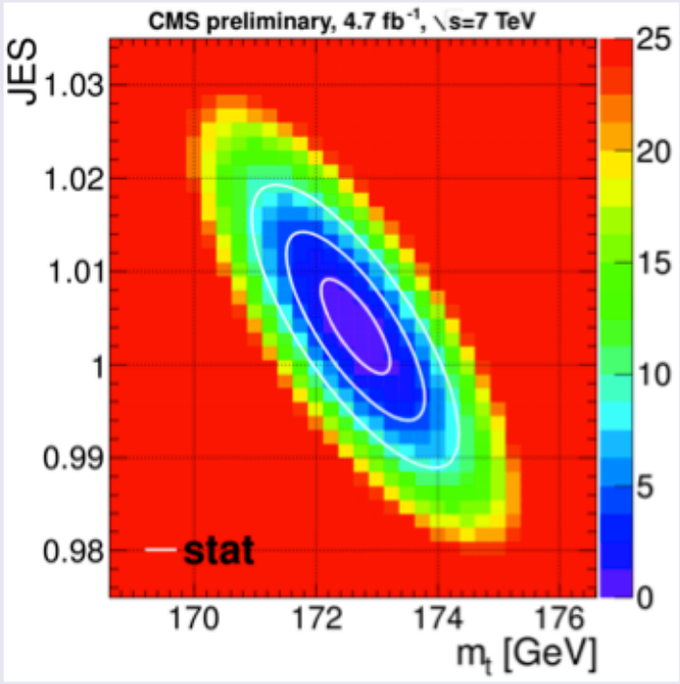

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Important observations made:

- M_W is used as constraint in m_{top} measurements. This has to be considered in EWK fits (see later) !
- working towards LHC combination. Again, “synchronization” of systematics treatment needed.
- When will we get an LHC-TEVATRON combination?
- m_{top} from the cross section: O(5 GeV) reached. PDF dominated.

New Phenomena

New Phenomena

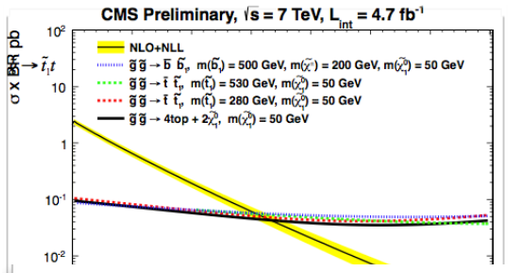
LHC by now “flying over”
everybody else...
but still nice results coming out
from HERA and the TEVATRON

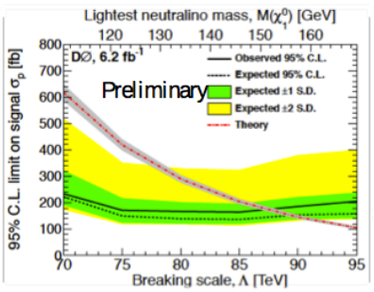
SUSY searches

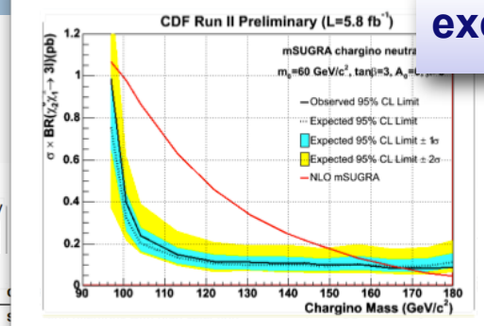
Zivkovic
Karapostoli
Duflot

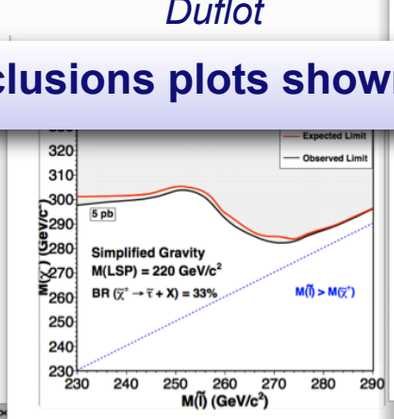
ETH Institute for Particle Physics

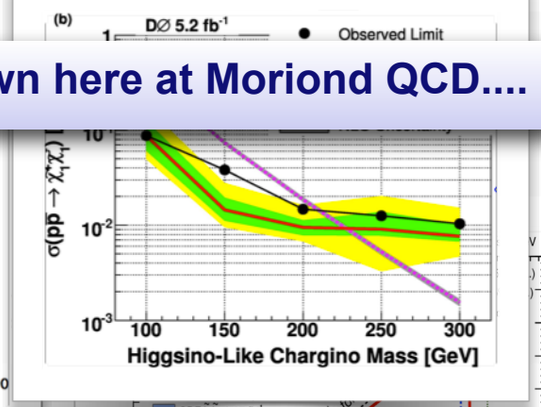
exclusions plots shown here at Moriond QCD....

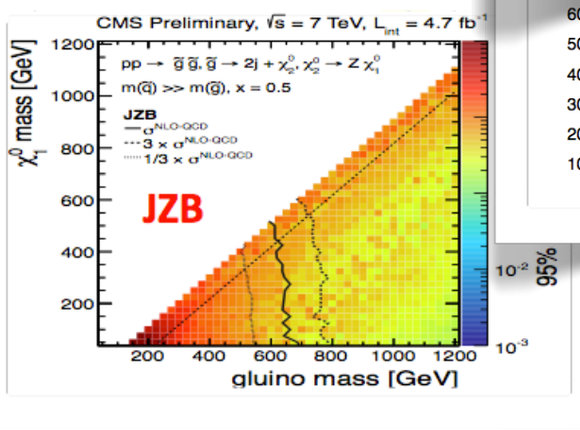


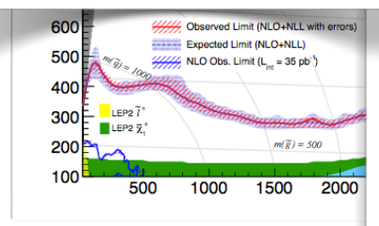


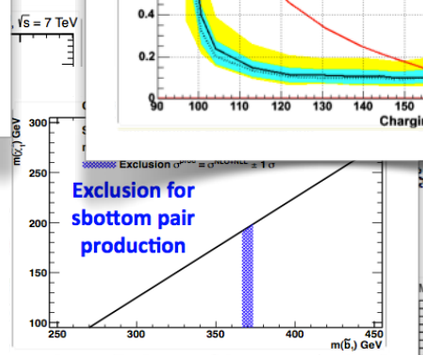


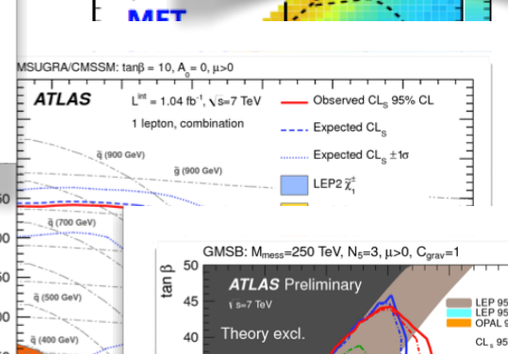


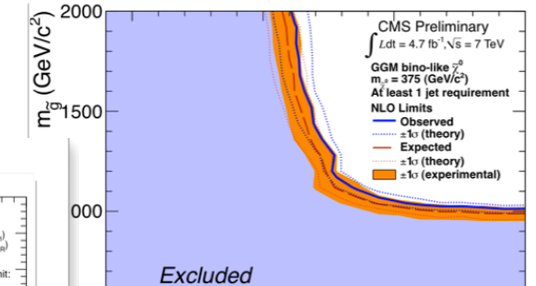


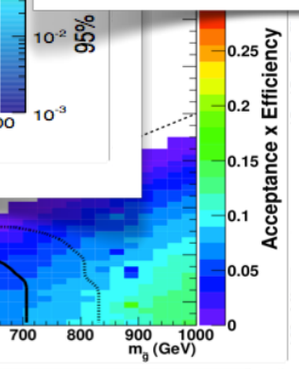


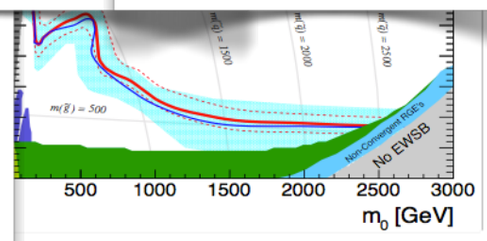


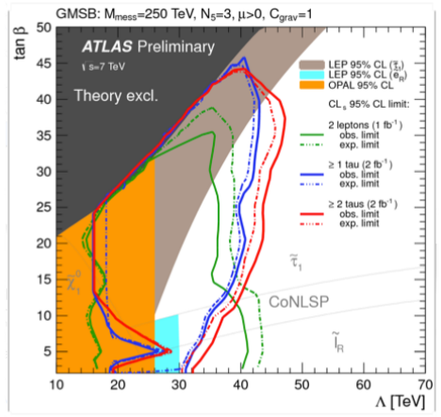


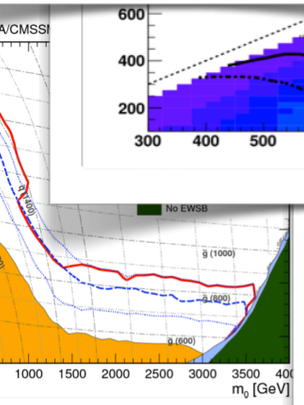


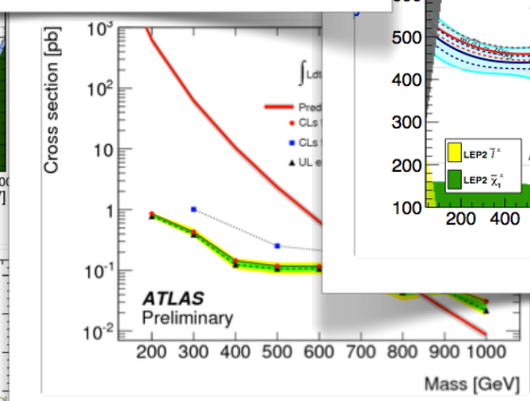


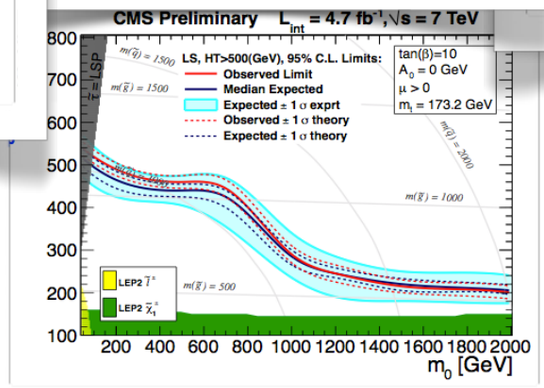


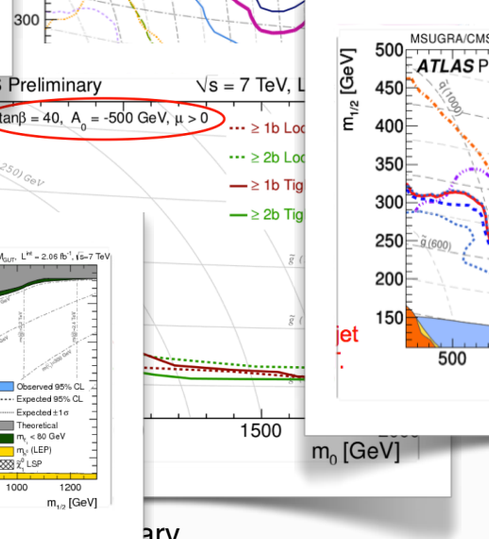


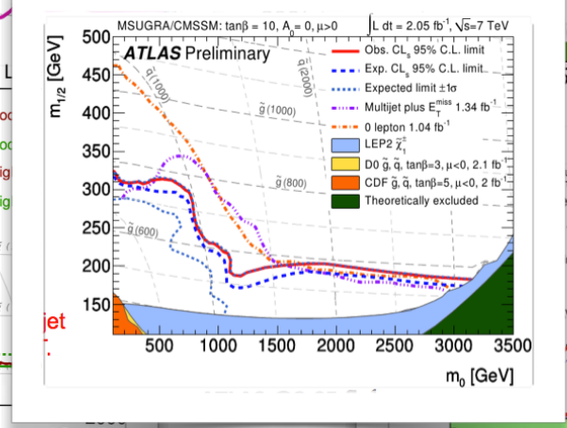


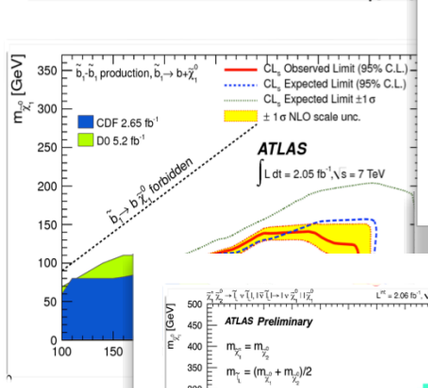


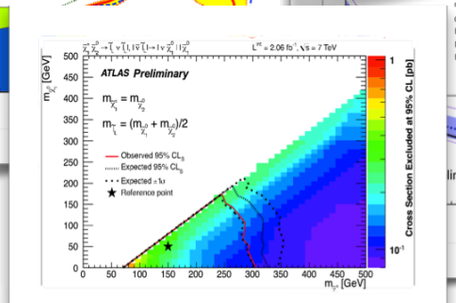


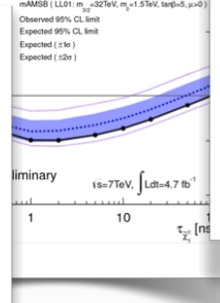


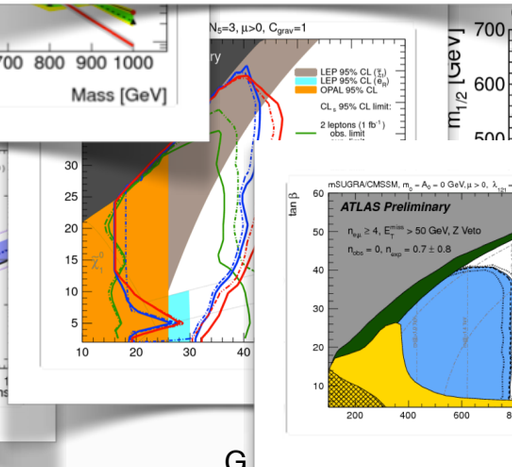


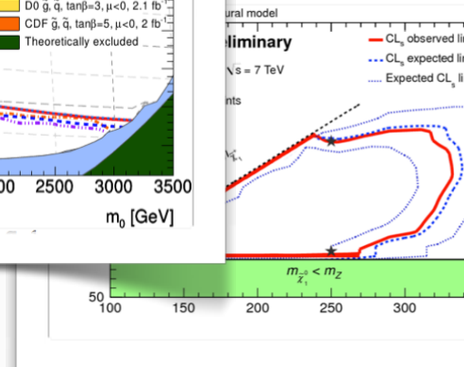












Executive summary

ETH Institute for Particle Physics

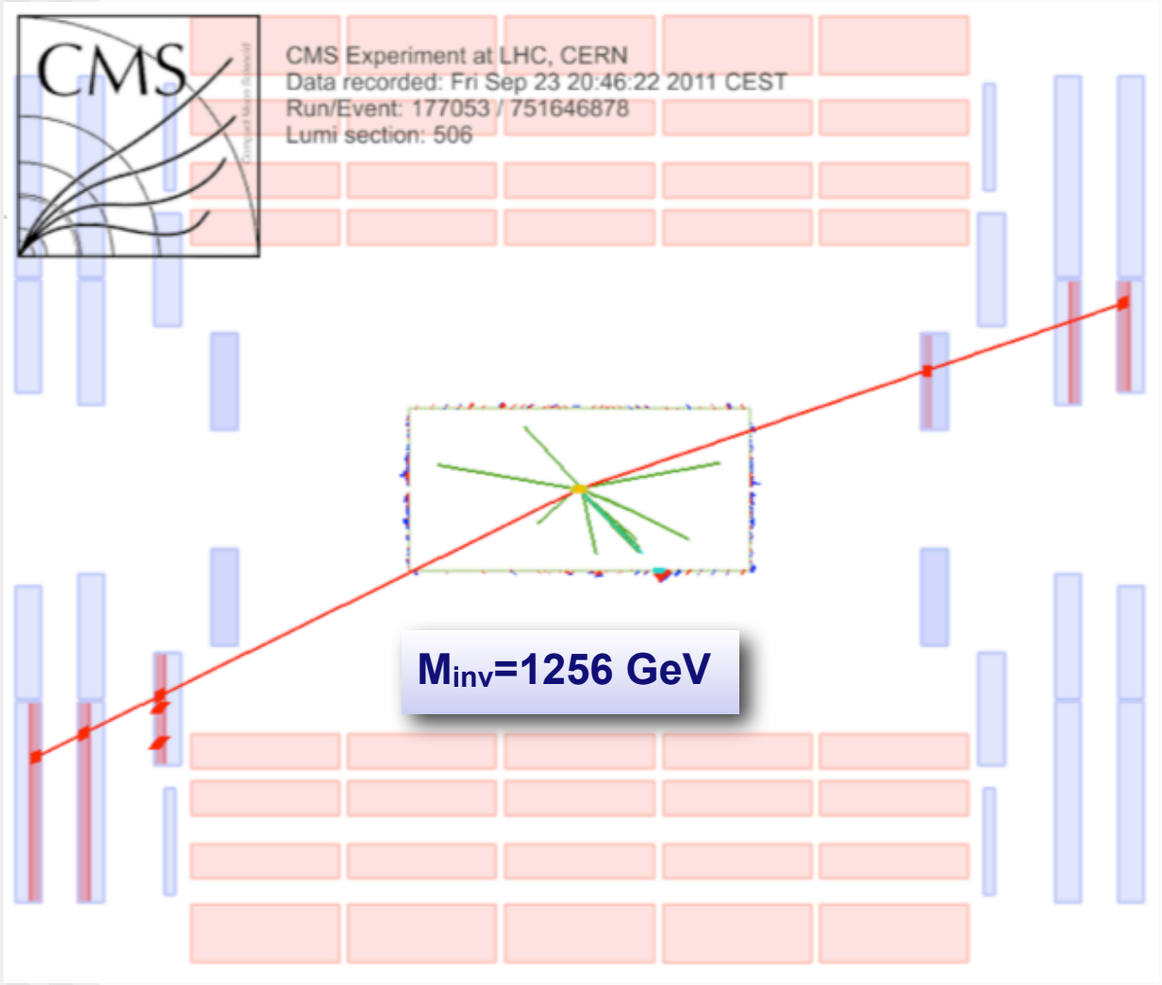
L. Duflot

- Still digesting the wealth of data delivered in 2011 but current results show great improvements in excluded phase space.
- Attacking the spectrum from above, generic squark and gluino searches allow to set limit around the TeV scale for "easy" scenarios like CMSSM.
- The delivered luminosity now allows us to attack the spectrum from below (single squark flavor production) and in particular to focus on the 3rd generation squarks (see also previous talk) directly connected to the EWSB and naturalness (see Higgs talks).
- 2012 promises vastly more data and as a bonus an increased center-of-mass energy.

Spectacular events...

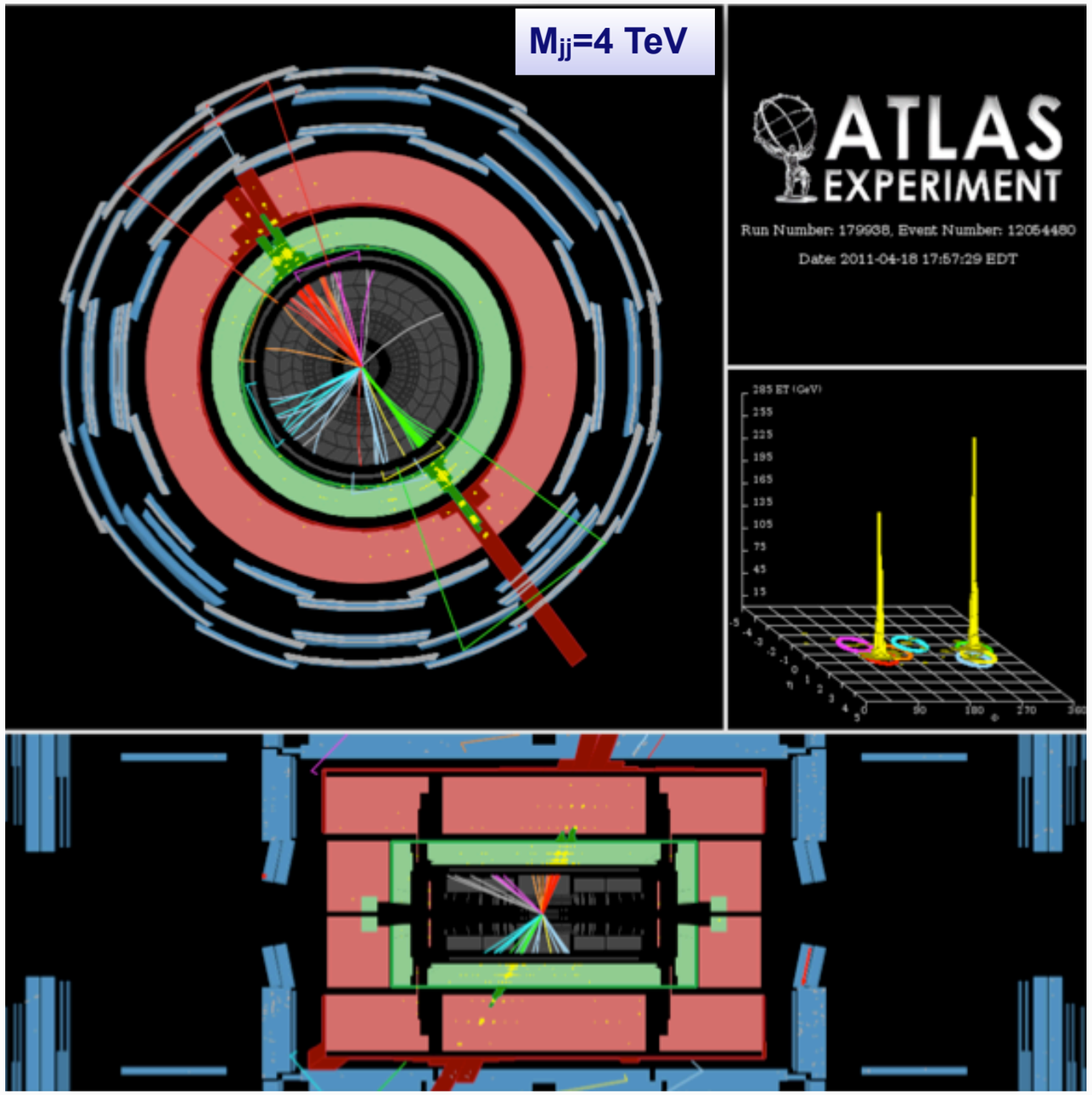
E. Moyse

ETH Institute for Particle Physics



- Exclude masses (ATLAS) NEW!
  - excited quarks < 3.35 TeV
  - colour octet scalars < 1.94 TeV

- Exclude masses (CMS):
  - string resonances < 4 TeV,
  - excited quarks <2.49 TeV,
  - axigluons/colorons < 2.47 TeV
  - W' bosons<1.51 TeV. + more

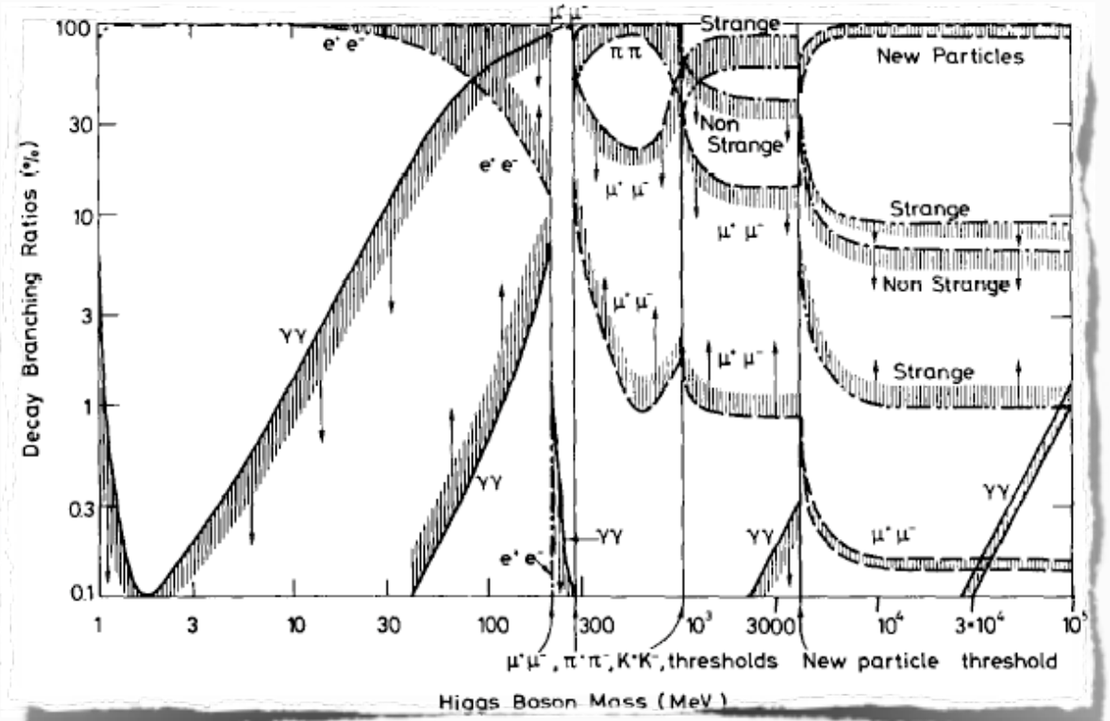


	mass Z'_{SSM} (TeV)	mass RS G_{KK} (TeV)
ATLAS	<2.21	<2.16 for $k/\bar{M}_{PL}$ =0.1
CMS	<2.32	< 1.81 (2.14) for $k/\bar{M}_{PL}$=0.05 (0.1)

~~Higgs~~
The Scalar

“The scalar” : Direct searches

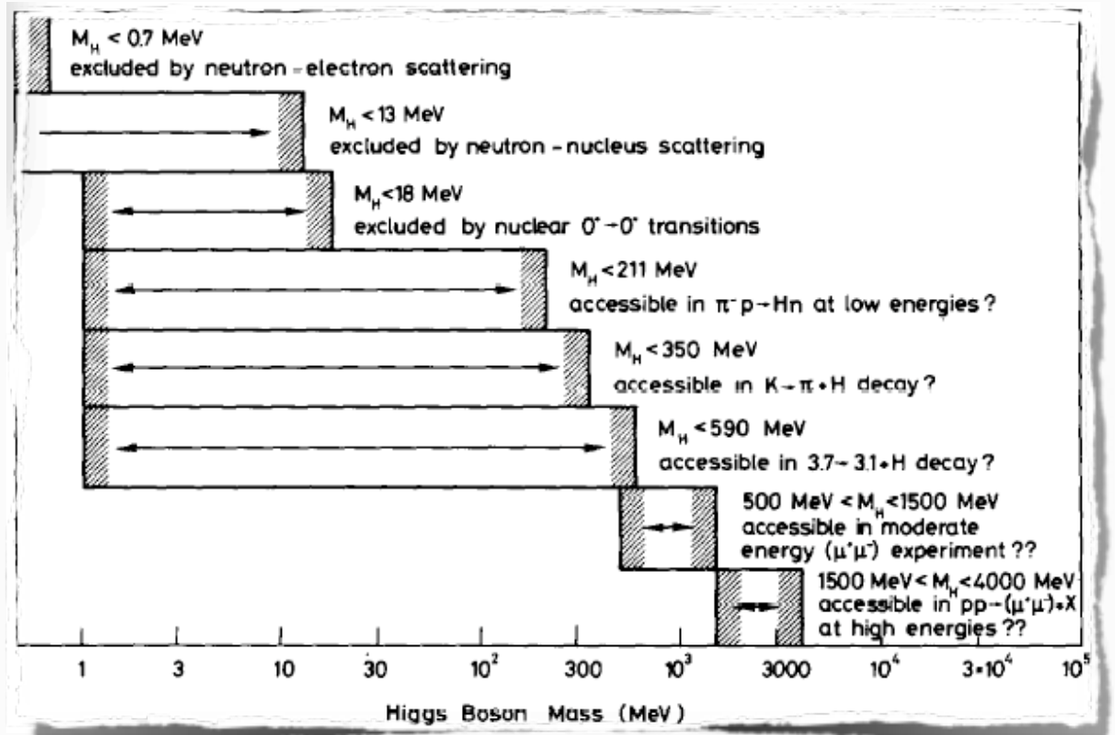
- some history, back in 1975...



A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John ELLIS, Mary K. GAILLARD * and D.V. NANOPOULOS **
CERN, Geneva

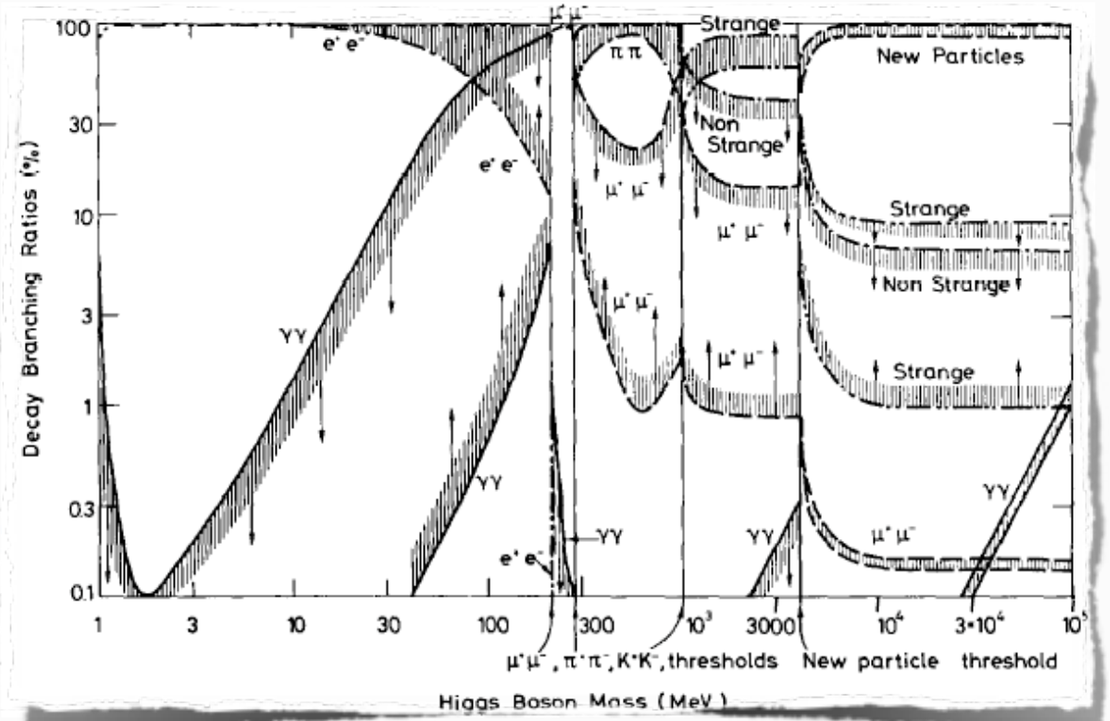
Received 7 November 1975



We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

“The scalar” : Direct searches

- some history, back in 1975...



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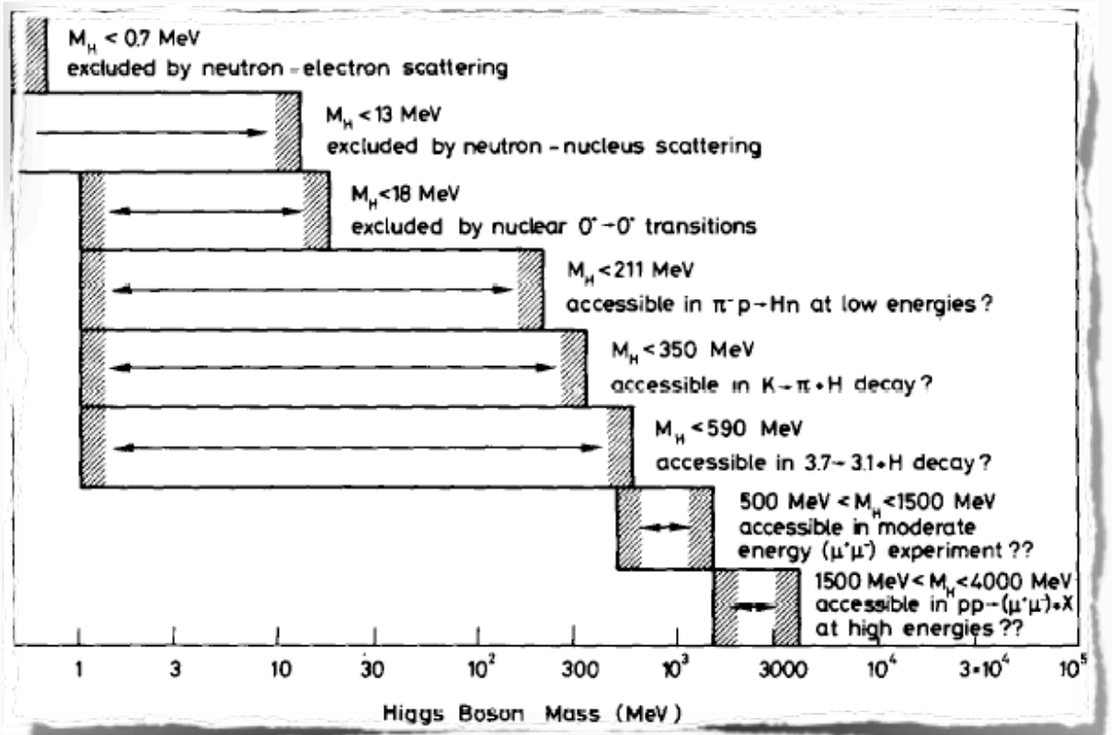

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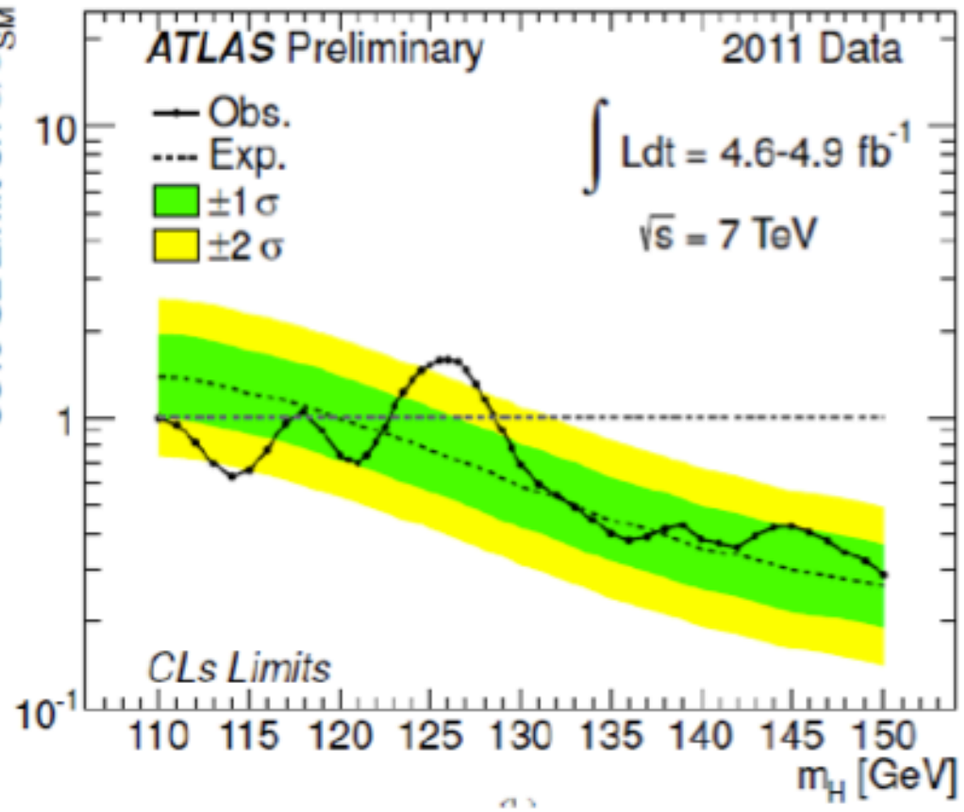
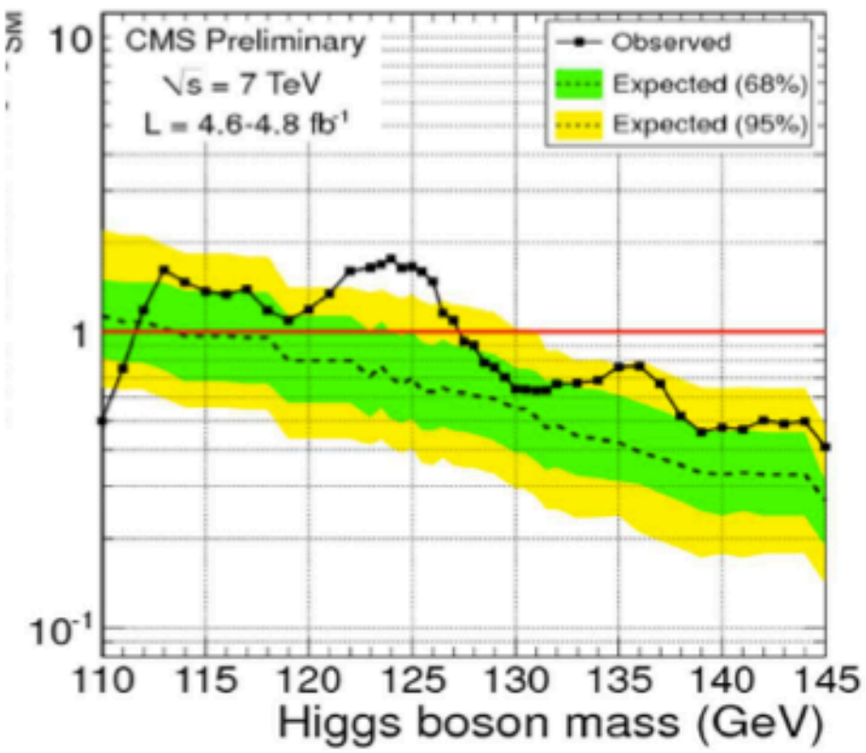
Fortunately politicians and funding agencies don’t seem to read the papers of J. Ellis et al...

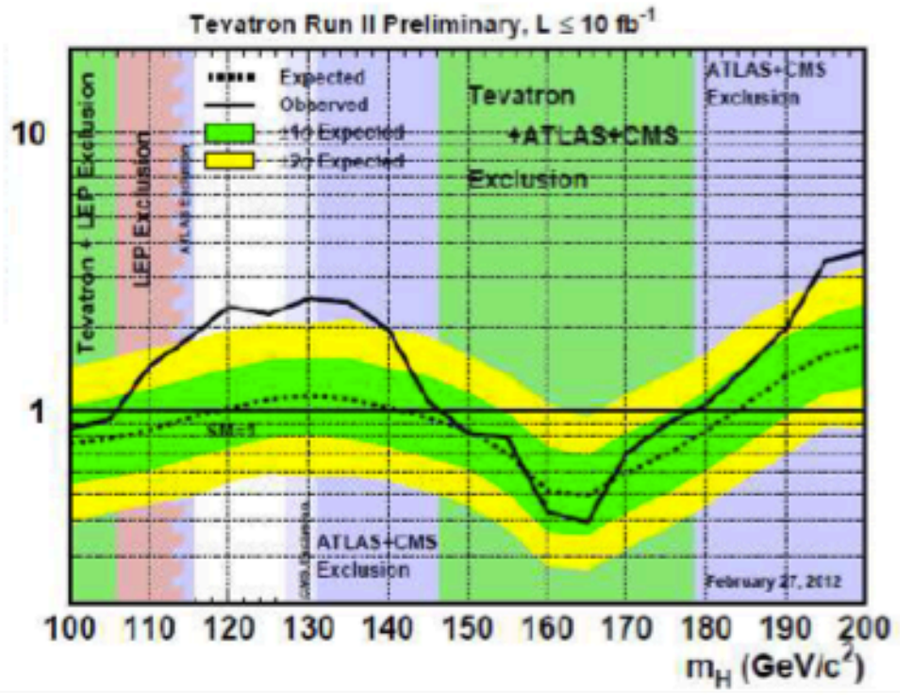
Executive summary

G. Altarelli

The Higgs







95% exclusion
ATLAS:
110-117.5, 118.5-122.5, 129-539 GeV
CMS:
127.5- 600 GeV

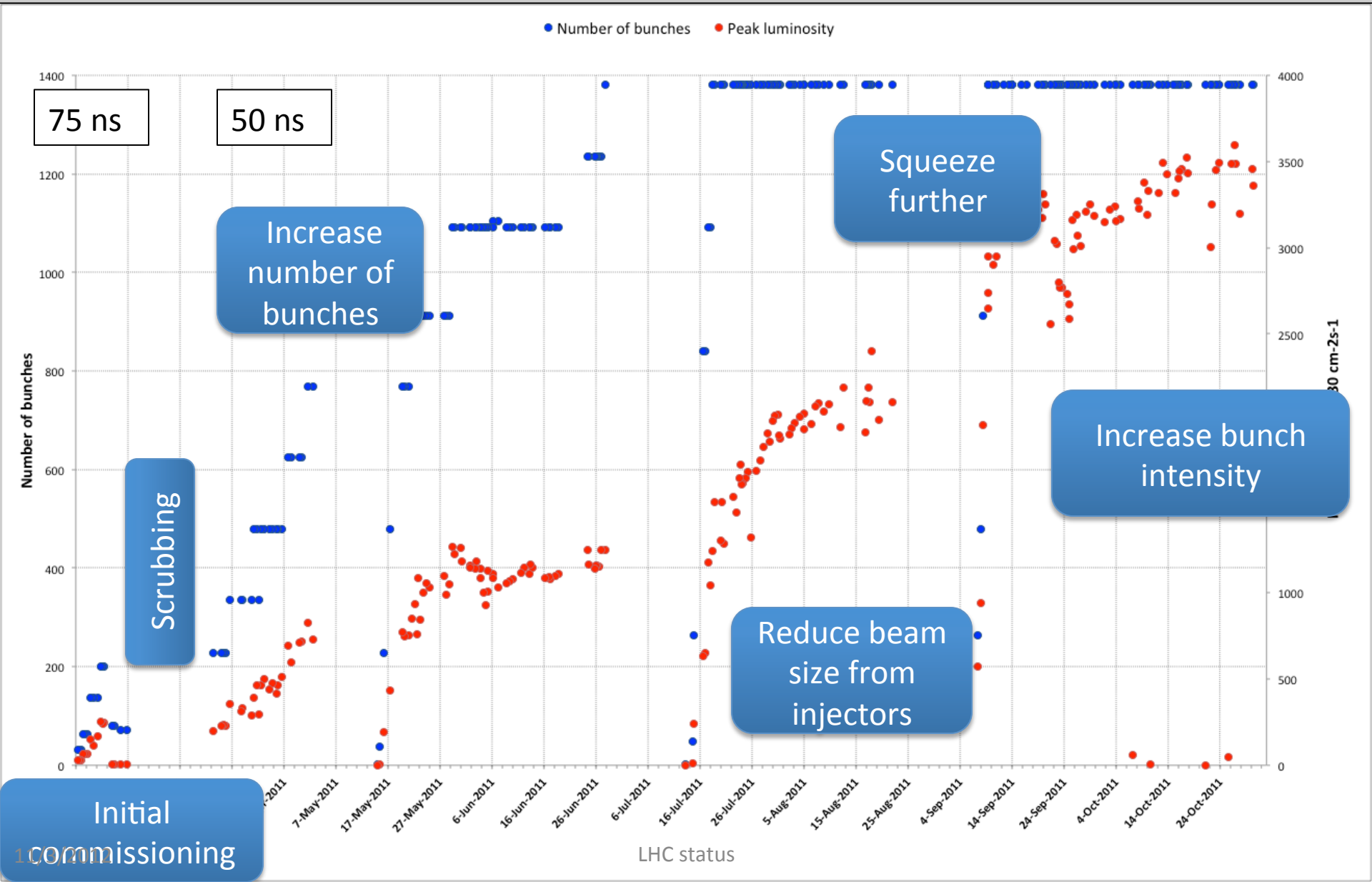
All experiments see some excess at ~ 122 - 128 GeV

My own conclusions

ETH Institute for Particle Physics

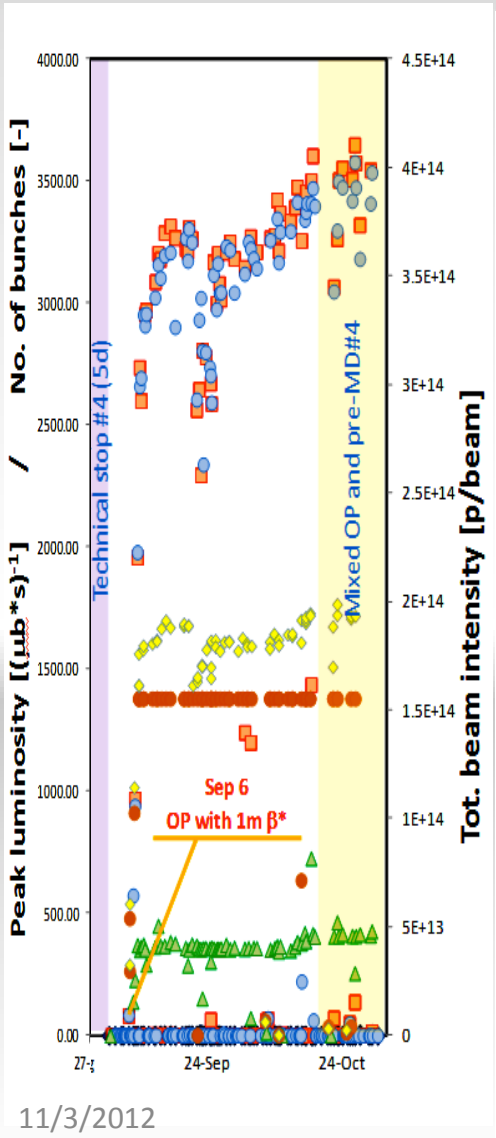
- Simply impressive, what the LHC and TEV exps. have delivered on such a short timescale! Chapeaux!
- A really (rock?)solid conclusion: m_H >~ 128 GeV excluded, up to ~600 GeV where the current searches stop.
- in the ~120-130 GeV region: all actors see some excess.
  You may call it “tantalizing”, if you like...
- but, let’s not forget about the statistics involved and let’s not get carried away (see fluctuations in the Hgg curves)
  - would be really interesting now to see a combination of the experiments, especially concerning the consistency among channels
- also many non-SM Higgs searches performed, fermiophobic, (N)MSSM, double-charged, ... : nothing significant seen
- the upcoming 8 TeV run will help to shed light (in one or the other direction)
  - unfortunately, we are all biased now (admit it or not). So the challenge is with the experimenters, be careful with the upcoming 8 TeV analyses

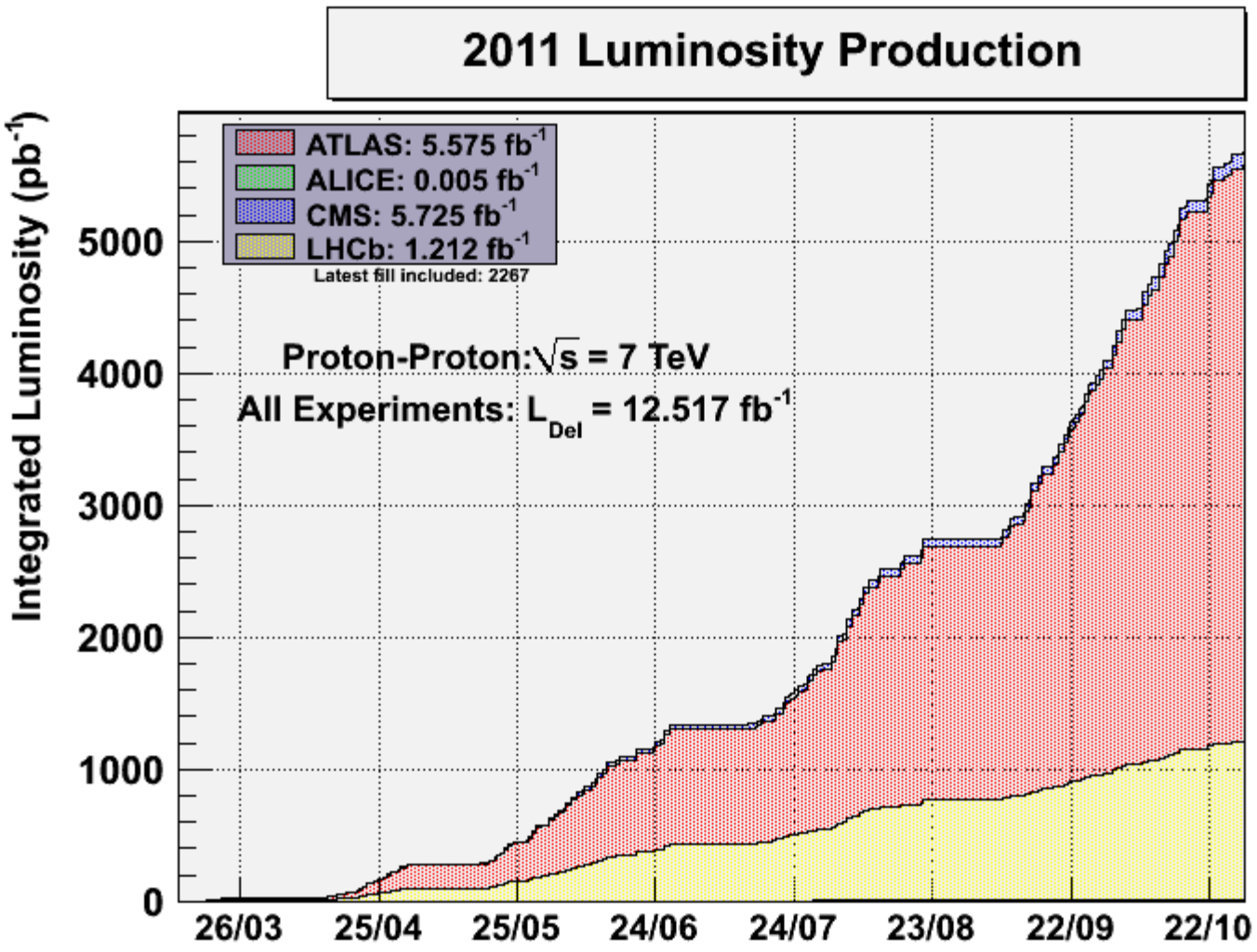
2011 – recap


Number of bunches
Peak luminosity
75 ns
50 ns
Increase number of bunches
Squeeze further
Increase bunch intensity
Scrubbing
Reduce beam size from injectors
Initial commissioning
Number of bunches
1400
1200
1000
800
600
400
200
0
4000
3500
3000
2500
1000
500
0
7-May-2011
17-May-2011
27-May-2011
6-Jun-2011
16-Jun-2011
25-Jun-2011
6-Jul-2011
16-Jul-2011
26-Jul-2011
5-Aug-2011
15-Aug-2011
25-Aug-2011
4-Sep-2011
14-Sep-2011
24-Sep-2011
4-Oct-2011
14-Oct-2011
24-Oct-2011

Impressive final run in

Mirko Pojer



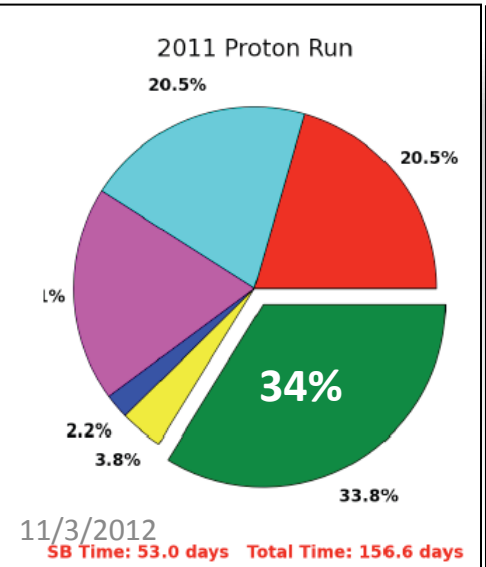


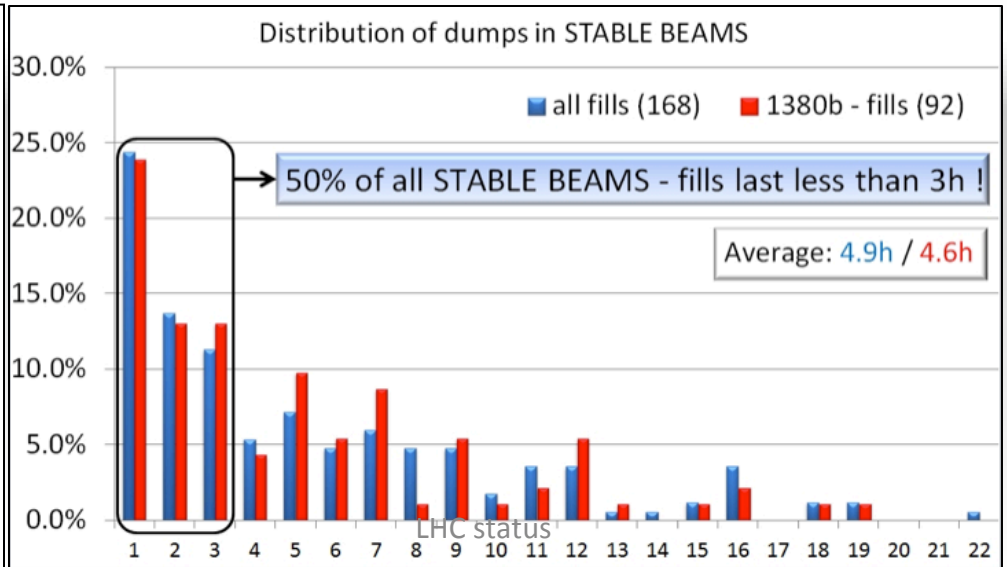
Of note

- Operational robustness
  - Precycle, injection, 450 GeV, ramp & squeeze & collisions
- Machine protection
  - Unpinned by superb performance of machine protection and associated systems
  - Rigorous machine protection follow-up, qualification and monitoring (Post Mortem analysis, MPP, rMPP)
- **Routine collimation of 110 MJ LHC beams** without a single quench from stored beams.

Operation efficiency

- Overall efficiency
  - Pretty good considering that this is the LHC
  - Overall time in stable beams 34%
- Premature dumps
  - 50% of all STABLE BEAMS fills lasted less than 3 hours





2012 strategy

4 TeV

β*=0.6m→0.7m→0.9m

50 ns

∫Ldt = 5 fb^{-1} in June?

∫Ldt = 15-19 fb^{-1}

Dumps=30-50

Pile-Up=26-35

LHCb ∫Ldt=1.5 fb^{-1}

L_{peak}=5-6.8 10^{33} cm^{-2}s^{-1}

TCP gap=2.2mm

IP1 β*=500m

SPS ε= 2 μm

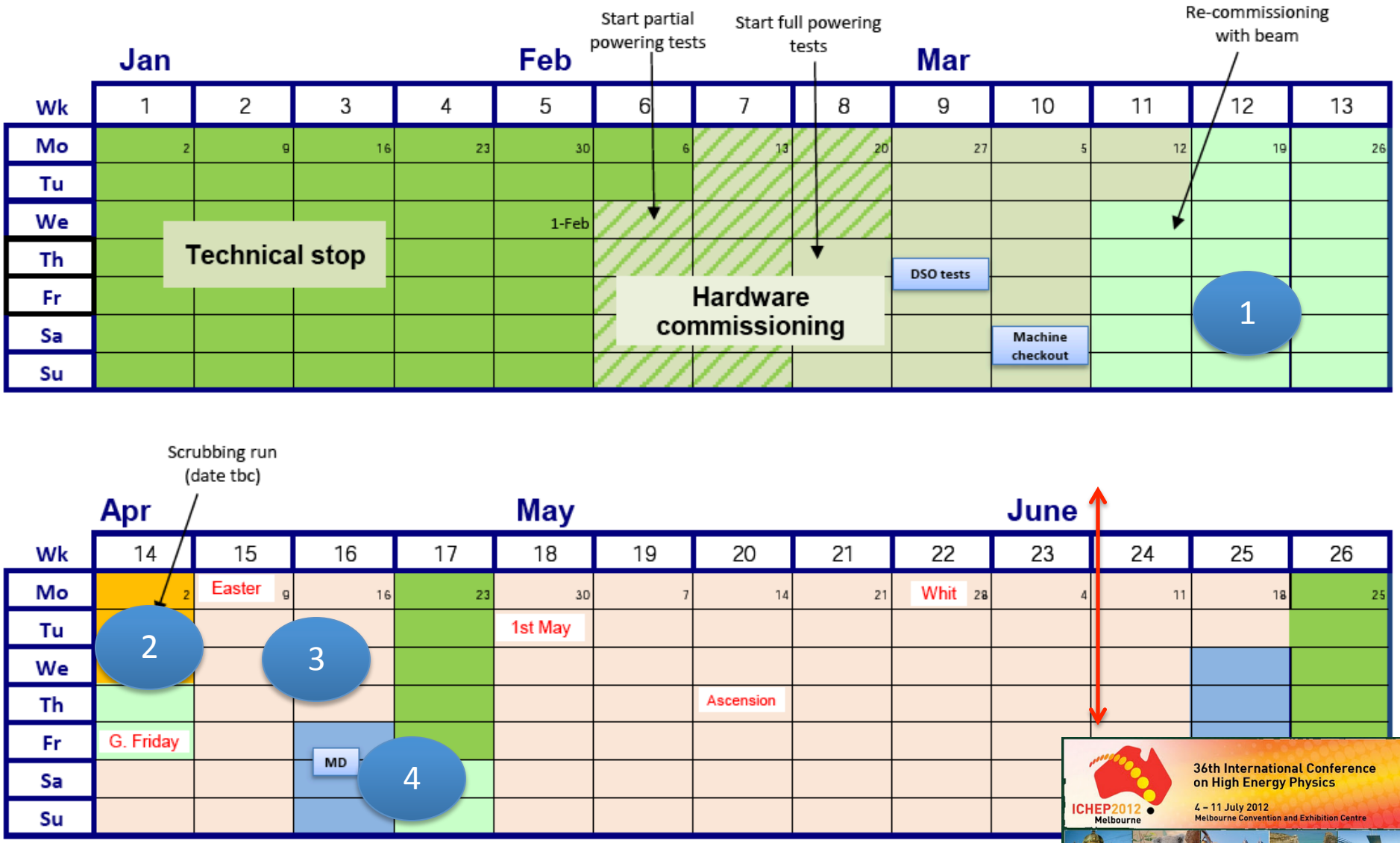
SPS N_p= 1.6 10^{11}

p-Pb: 3.5 TeV or 4 TeV

∫Ldt = 15- 23 nb^{-1}

β*=(0.6,0.6,0.6,3)m

2012 LHC schedule Q1/Q2



2012 LHC schedule Q3/Q4