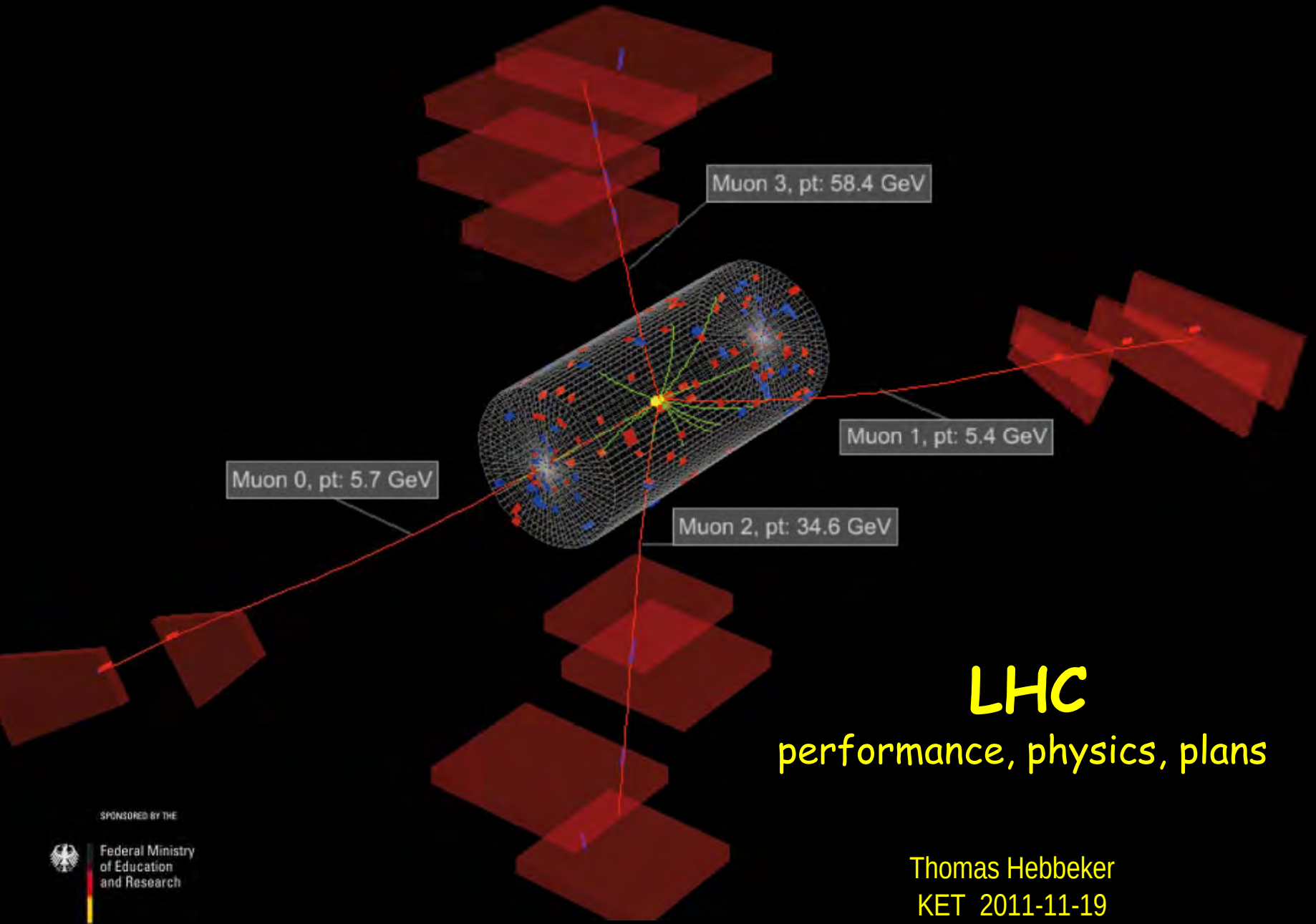


LHC

performance, physics, plans

SPONSORED BY THE
Federal Ministry
of Education
and Research

Thomas Hebbeker

KET 2011-11-19

LHC

CMS

machine
physics
experiments
RESULTS
upgrades

Tevatron

1983 - 2011
(LHC !)

Talk M. Feindt

german contributions !

experience

guide

reference

$p\,\bar{p}$ 2 TeV

L ~ 10/fb per experiment


LHC
machine

Luminosity

CERN Control Center
Nov. 2009

2009:	0.9 TeV	c.m.	p p	~ 10 / μb
	2.36 TeV	c.m.	p p	~ 0.4 / μb
2010:	7 TeV	c.m.	p p	~ 40 / pb
	574 TeV	c.m.	Pb Pb	~ 9 / μb
2011:	7 TeV	c.m.	p p	~ 5 / fb
	574 TeV	c.m.	Pb Pb (and p Pb)	

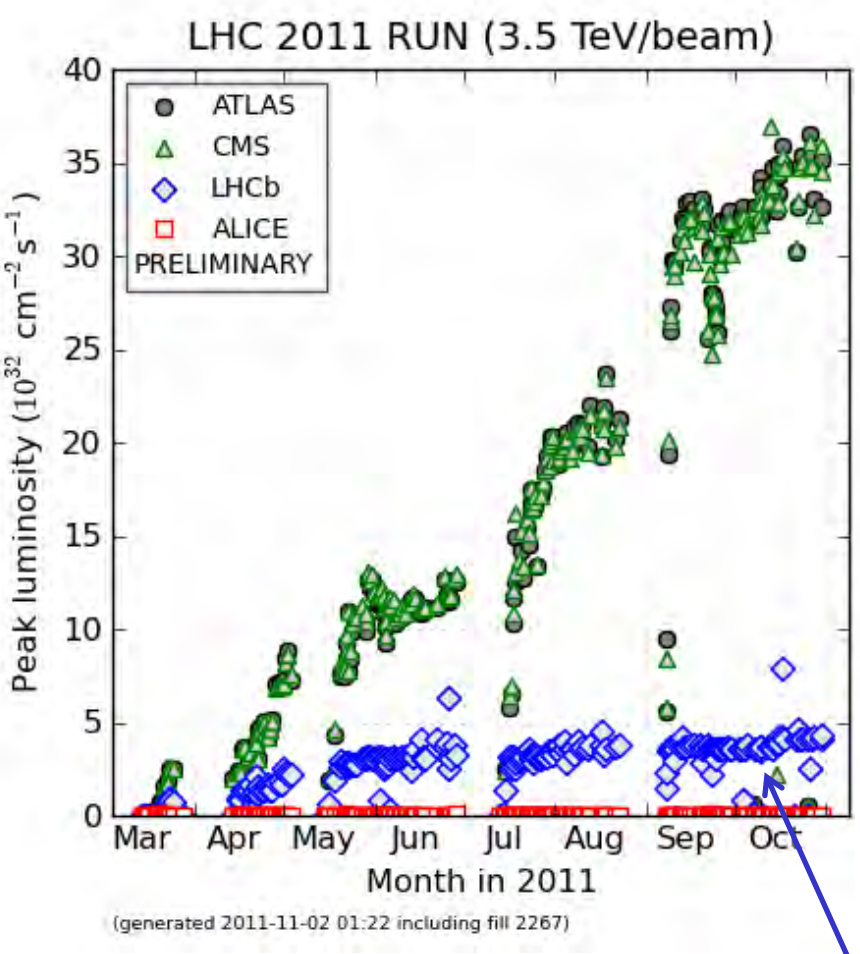
per exp

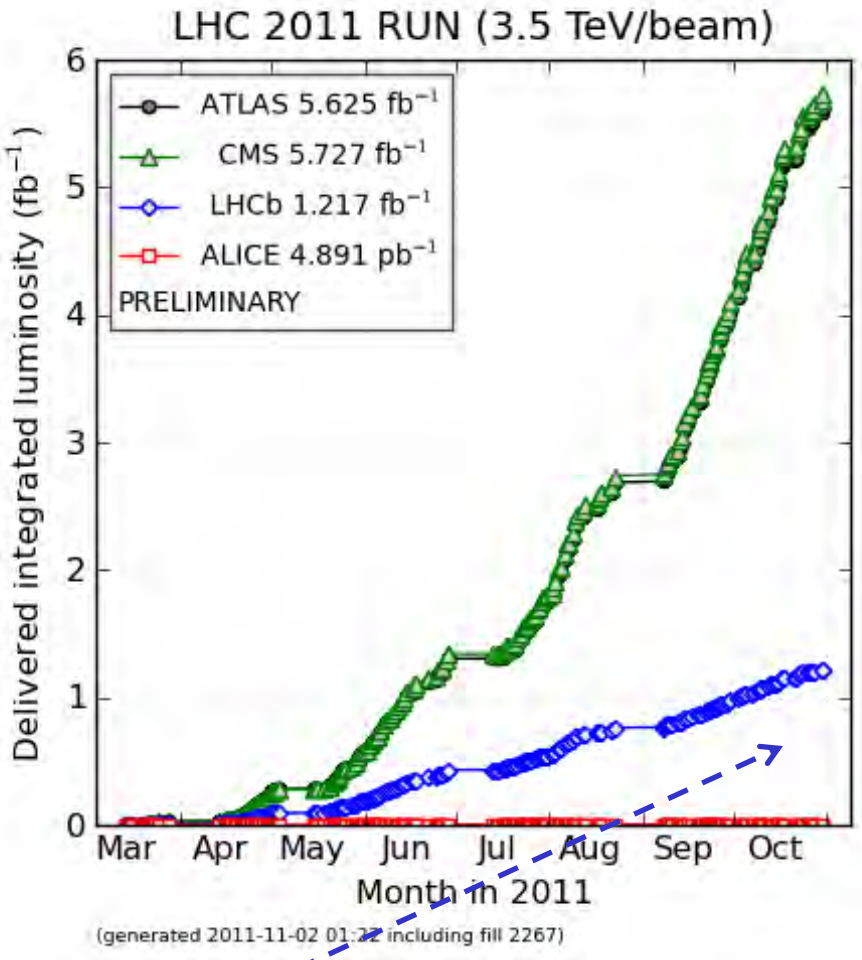
$$1/\ fb = 10^9 / \mu b\ !$$

> 2014:

14 TeV c.m. p p 100 / fb / year

LHC Luminosity evolution





LHCb can cope with 2x higher luminosity than expected !

LHC records

	2010	2011	Nominal
Beam Energy [TeV]	3.5	3.5	7
Bunch population	1.2×10^{11} p	**1.4×10^{11} p**	1.15×10^{11} p
Number of bunches (time)	368	1380 (50ns)	2808 (25ns)
Transverse beam size [μm]	60	28	16.7
Stored energy [MJ]	28	110	360
Peak luminosity [$cm^{-2}s^{-1}$]	2×10^{32}	**3.55×10^{33}**	1×10^{34}
Max delivered lumi (1 fill) [pb^{-1}]	6.23	123	
Longest Stable Beams fill [hrs]	12:09	25:59	

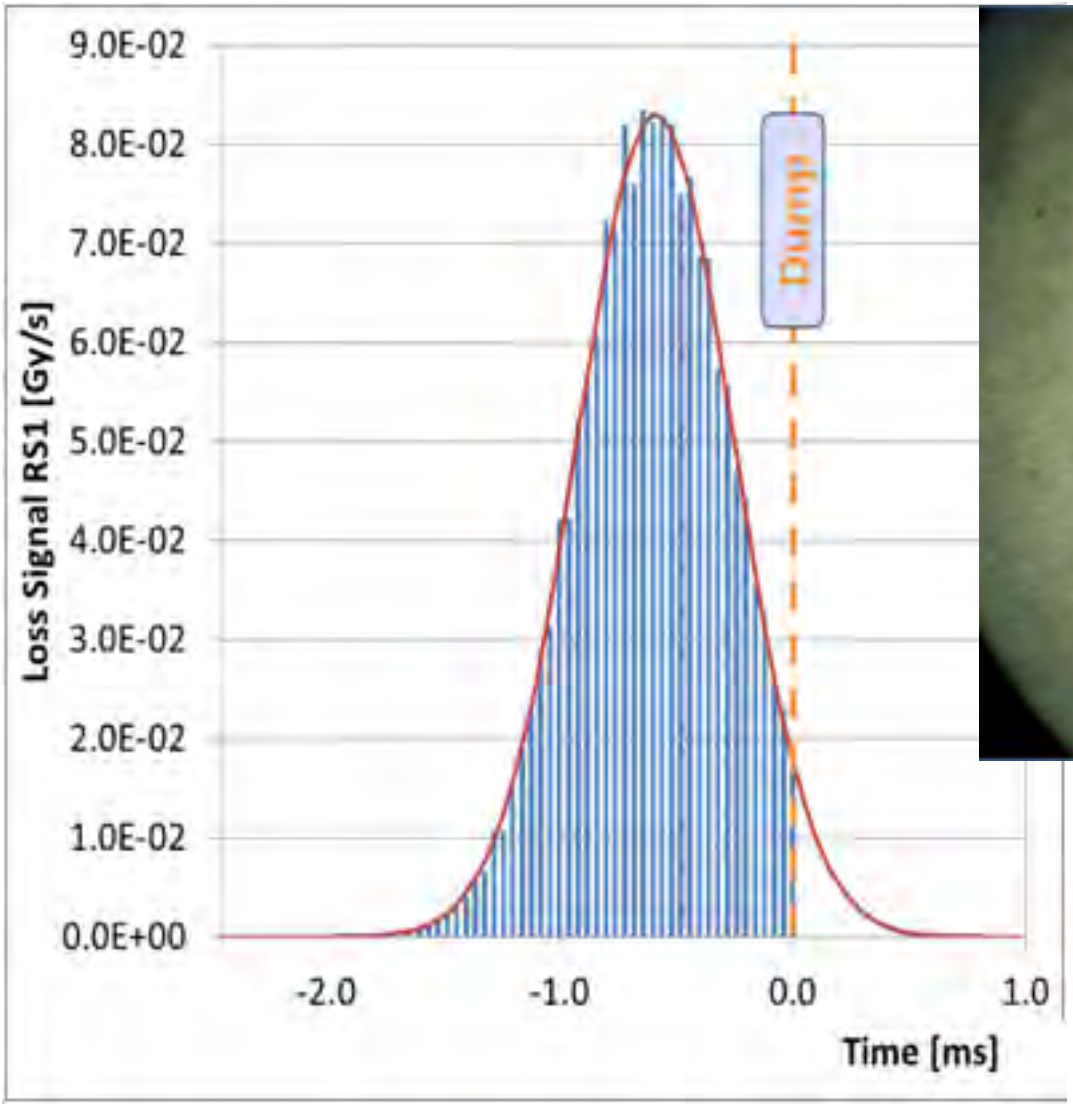
great!

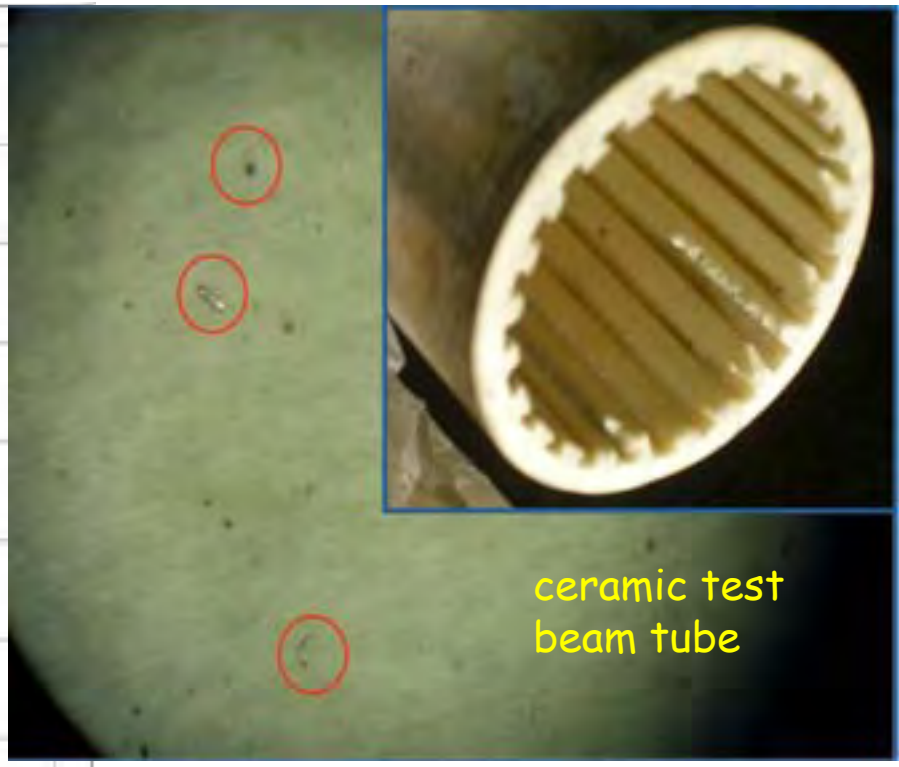
Collier 20110921, Meyers 20111018

LHC problems: UFOs

On average ~ **6 UFOs/hour** during stable beams in the arcs

Jul. 2010 – Sep. 2011: 35 fast loss events led to a beam dump

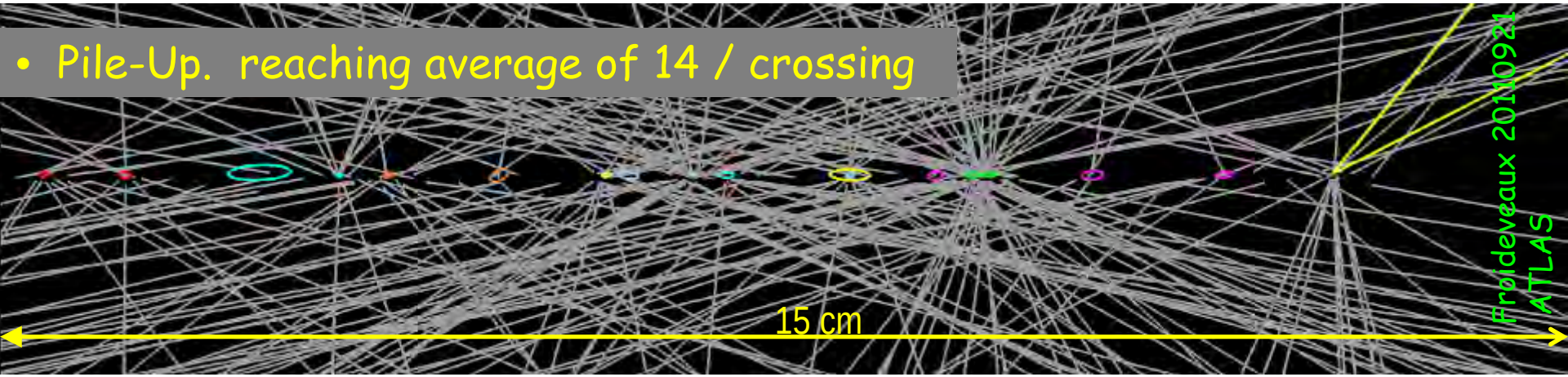




Micrometer sized macro-particles are (still) the most plausible explanation.

Collier 20110921

High Luminosity - drawbacks



- Pile-Up. reaching average of 14 / crossing

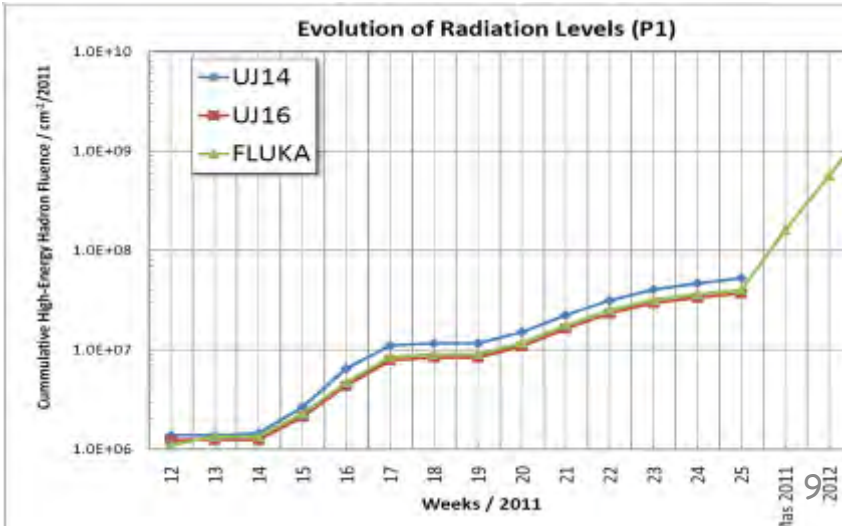
20 σ ellipses

- trigger thresholds / trigger rate / computing

single lepton p_T thresholds: > 30 GeV (HLT, Atlas+CMS)

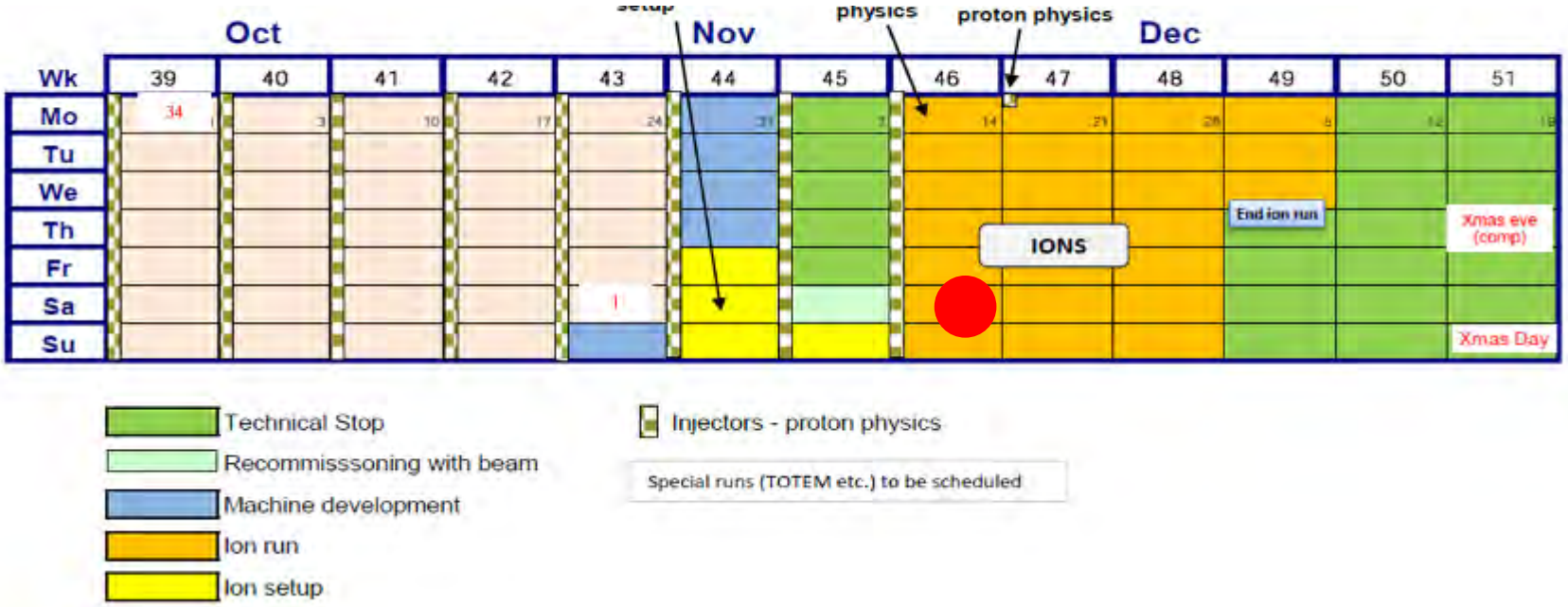
recording 400-500 Hz

- radiation levels in tunnel/caverns/detectors



LHC short term plan

2011



Meyers 20111018

2012

$\sqrt{s} = 7$ TeV (8 TeV ?)

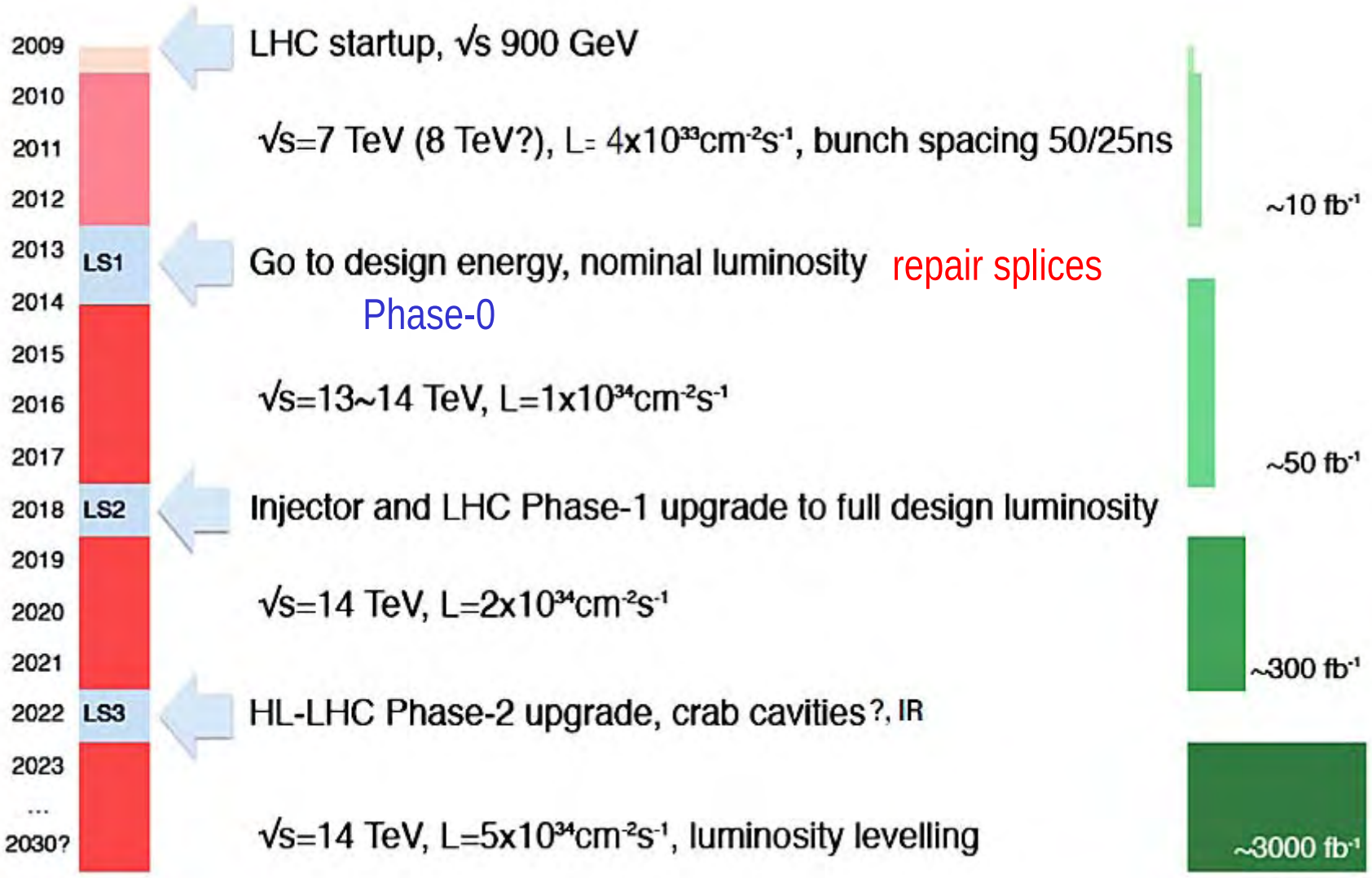
$4 \cdot 10^{33} / cm^2 / s \quad \Rightarrow \quad > 10 / fb\,(?)$

50 ns (25 ns)

restart data taking March

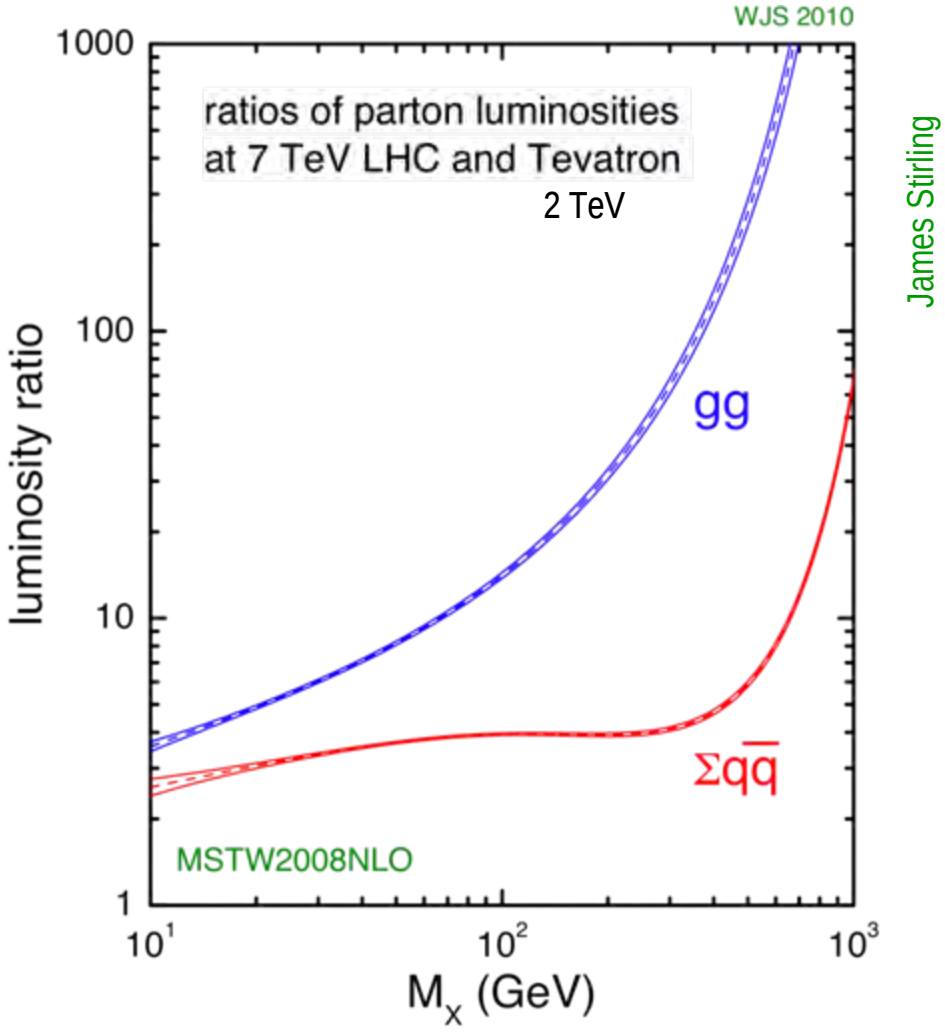
Nessi 20111019

LHC long term plan



Nessi 20111019

Hadron Collider Physics: Tevatron versus LHC

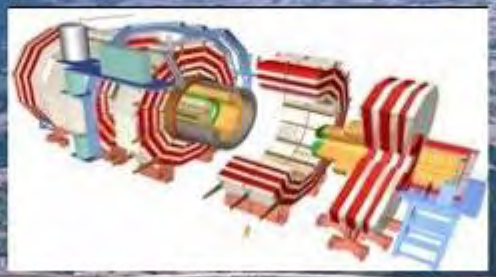


$$\frac{\sigma(t\bar{t},7TeV)}{\sigma(t\bar{t},2TeV)} \approx 25$$

$m(X) > 1TeV$:

$$\frac{\sigma(X,7TeV)}{\sigma(X,2TeV)} > 70$$

LHC Experiments



CMS

+TOTEM…

LHCb

ALICE

ATLAS

ATLAS = FSP 101 = A Toroidal LHC ApparatuS

Germany = 368 authors
= 12.2% = 2nd largest

Berlin
Bonn
Dortmund
Dresden
Freiburg
Gießen
Göttingen
(Hamburg)
Heidelberg
Mainz
München
Siegen
Würzburg
Wuppertal

MPI München

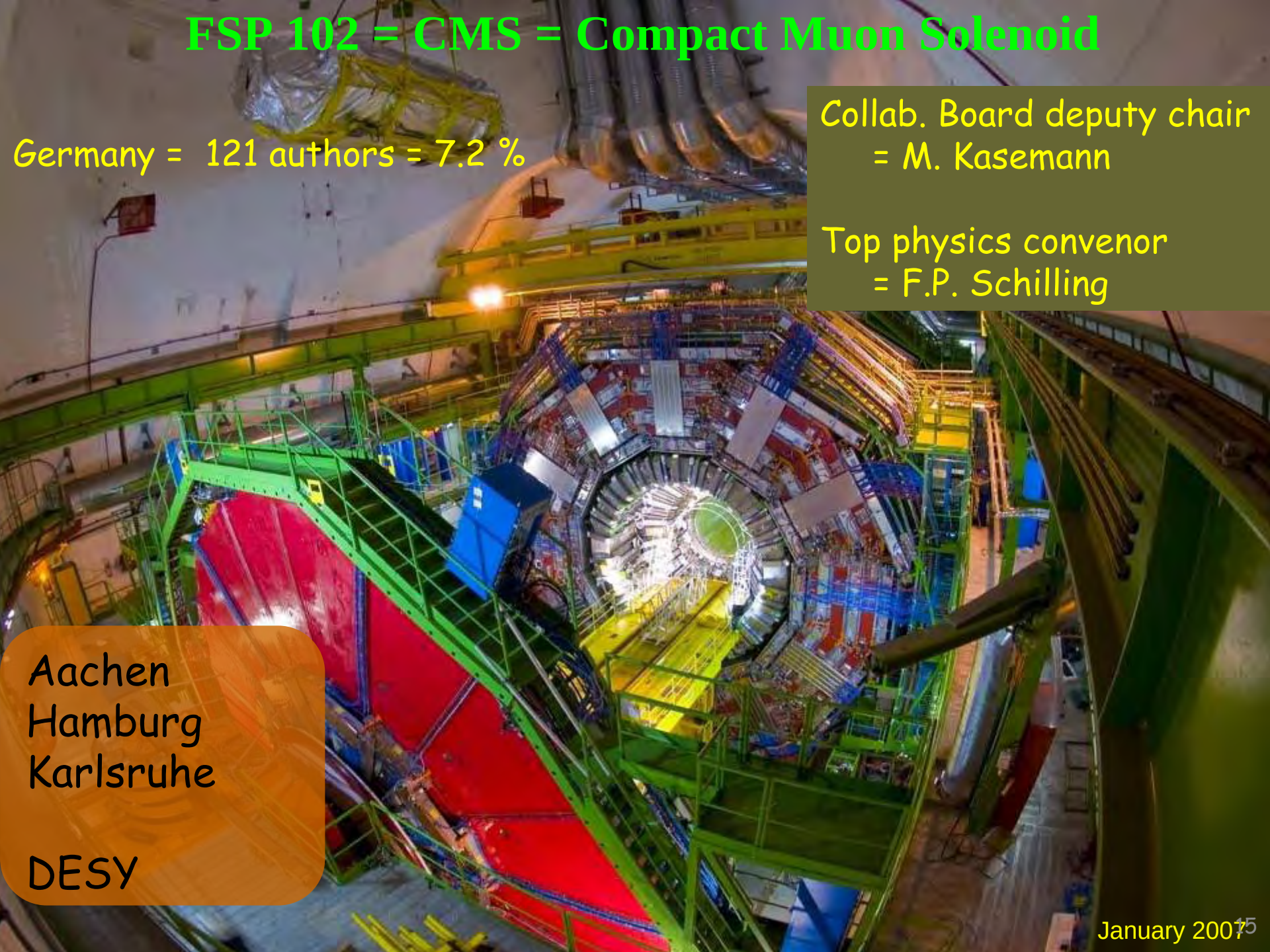
DESY

Collab. Board chair
= G. Herten

Computing coordinator
= H. von der Schmitt

Higgs group convenor
= Sandra Kortner

FSP 102 = CMS = Compact Muon Solenoid



Germany = 121 authors = 7.2 %

Collab. Board deputy chair
= M. Kasemann

Top physics convenor
= F.P. Schilling

Aachen
Hamburg
Karlsruhe

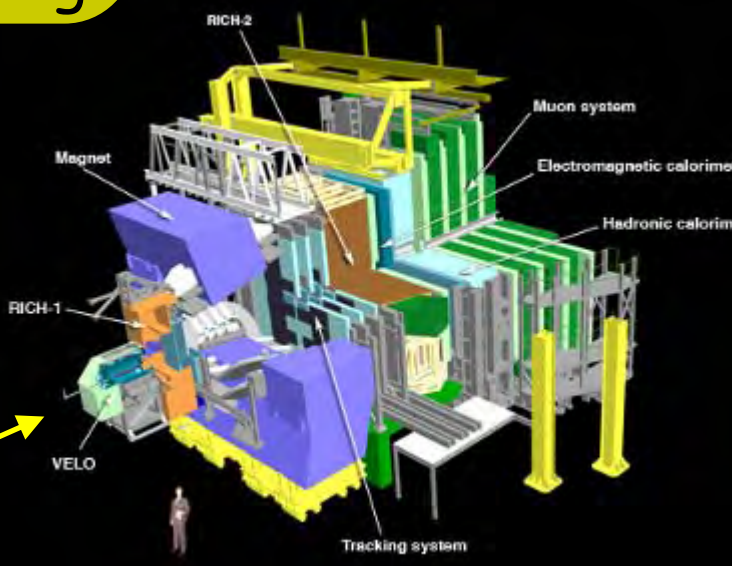
DESY

LHCb = Large Hadron Collider Beauty Experiment

Germany
= 48 authors
= 8.1 %

Dortmund
Heidelberg
Rostock

MPI Heidelberg



Tracking reconstruction
Coordinater =J.v. Tilburg

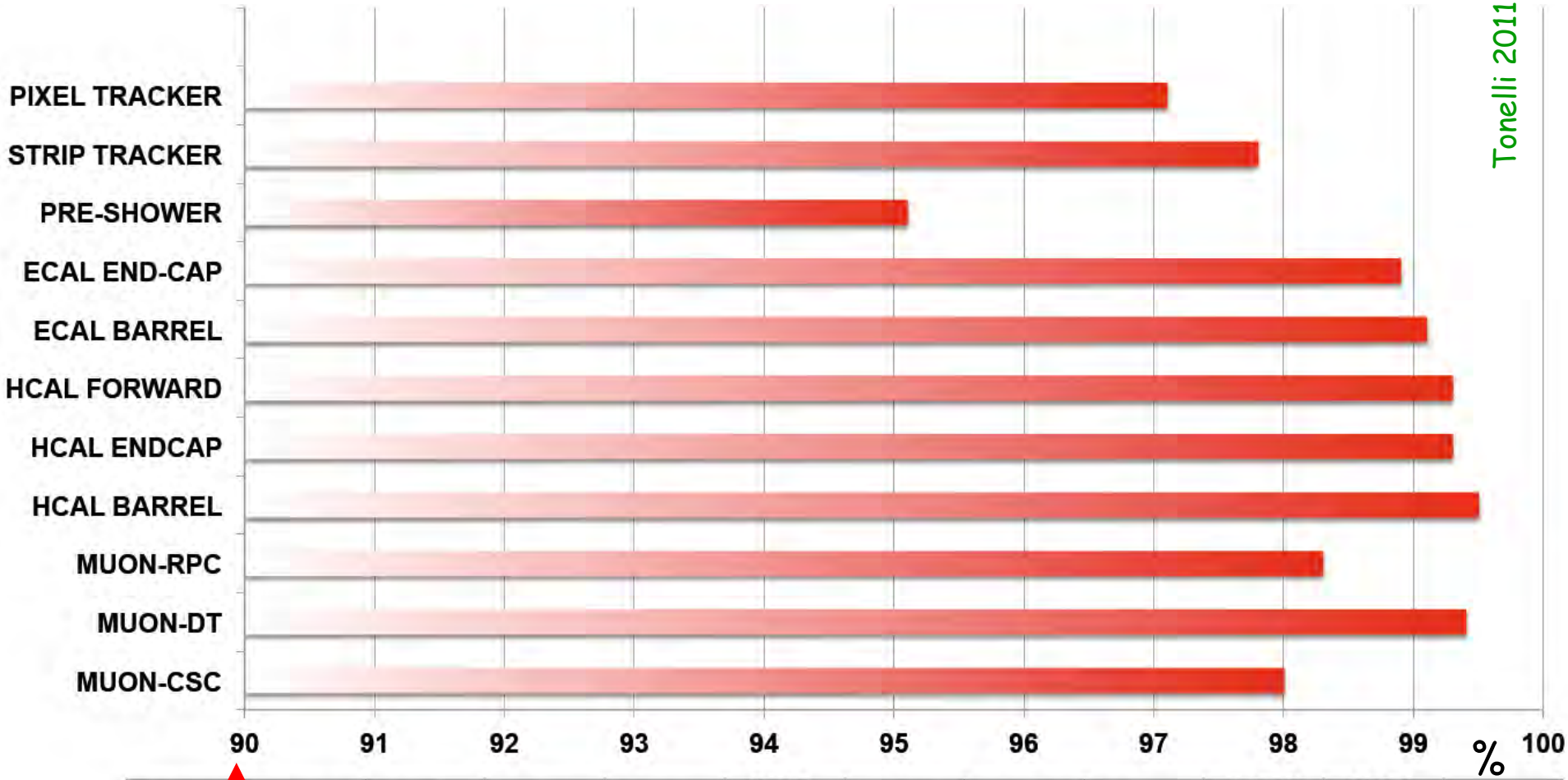
At Work !

lots of work !

often at CERN !

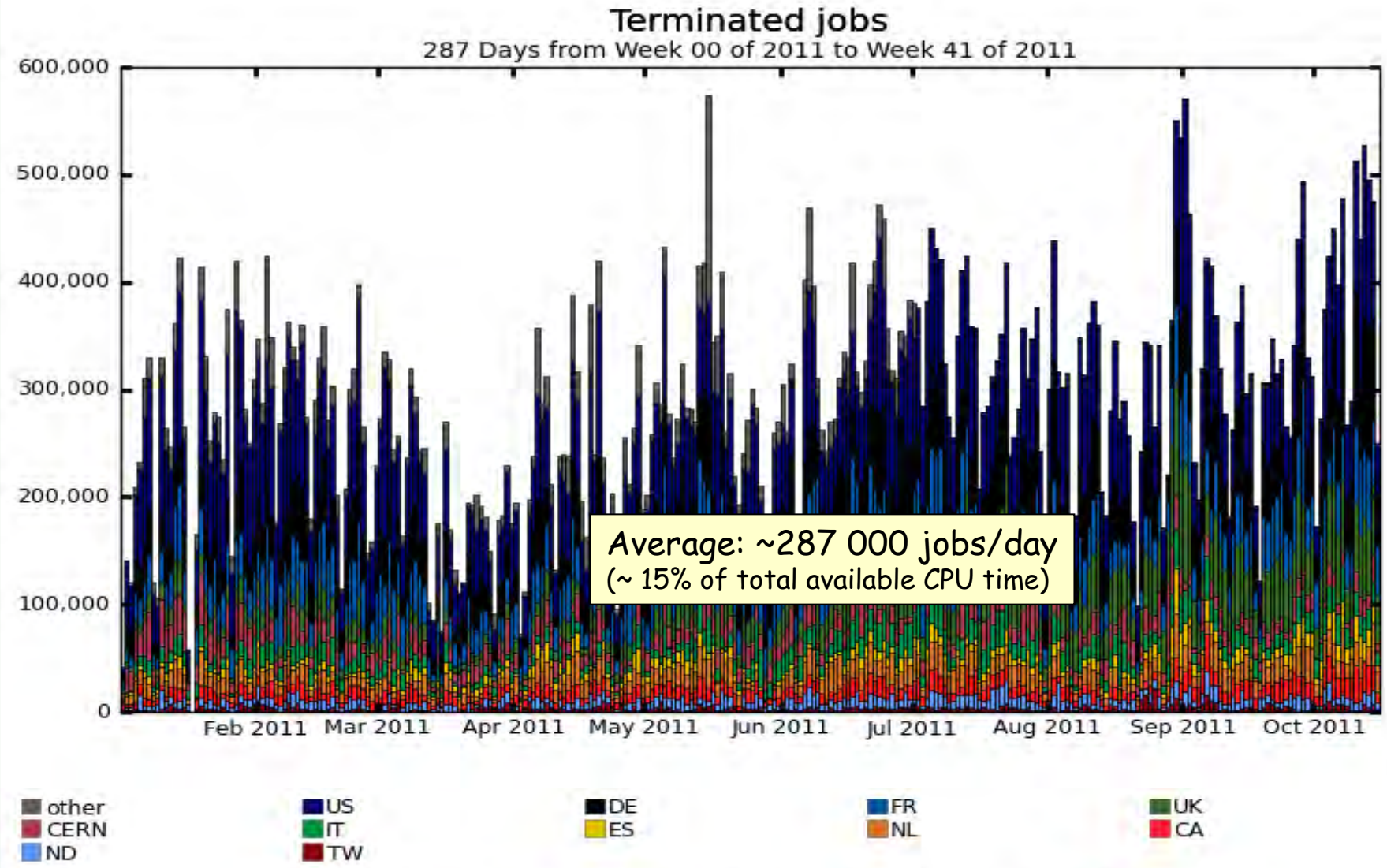
Detector performance – example from CMS

Tonelli 2011-10-18



	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98	99.4	98.3	99.5	99.3	99.3	99.1	98.9	95.1	97.8	97.1	

(Grid) Computing – example from ATLAS



Here only analysis jobs. Most CPU taken by production jobs.

LHC Computing Germany

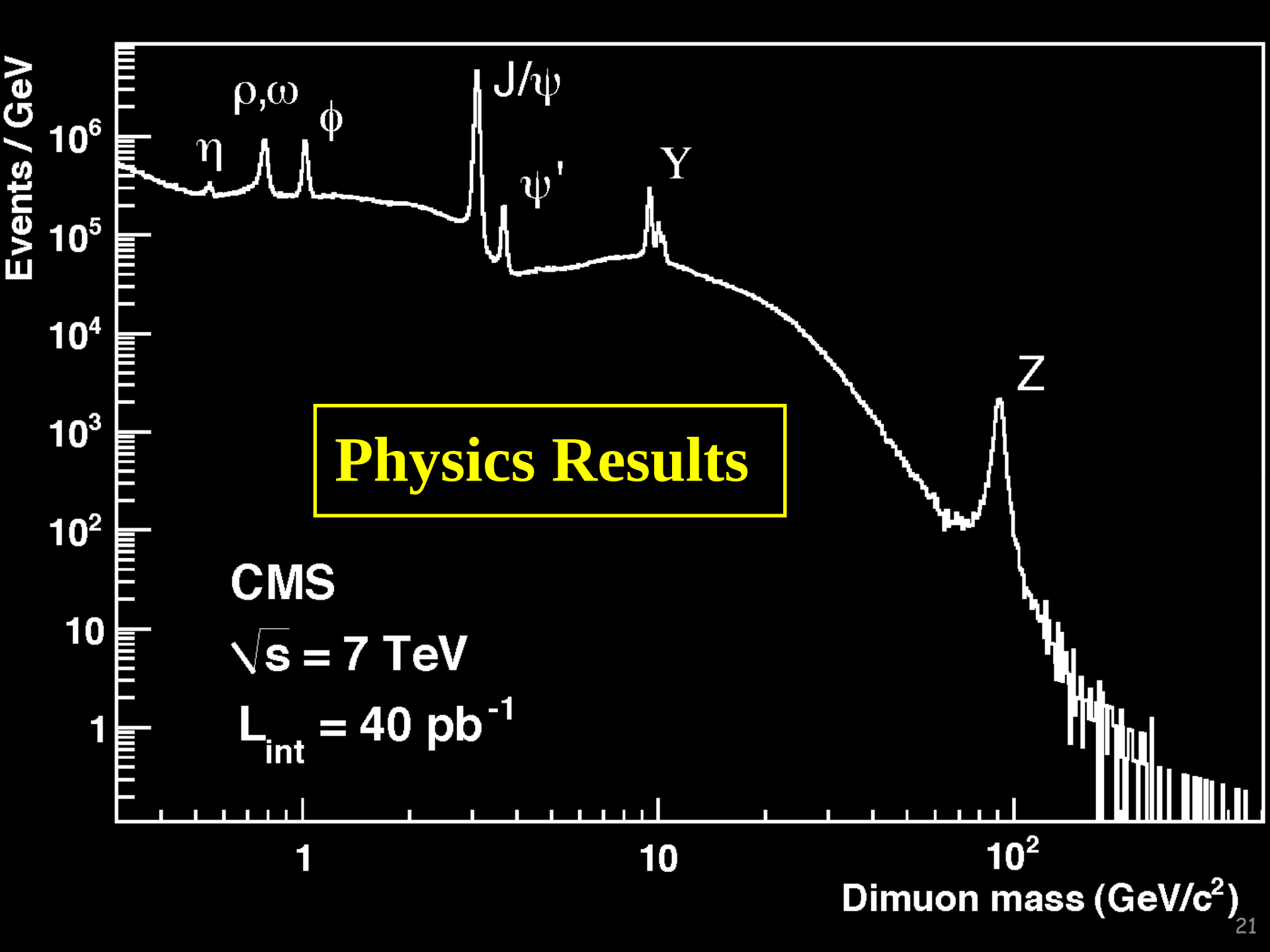
Atlas
CMS
LHCb

Tier 1

Tier 2

Talk G. Quast

Wissing

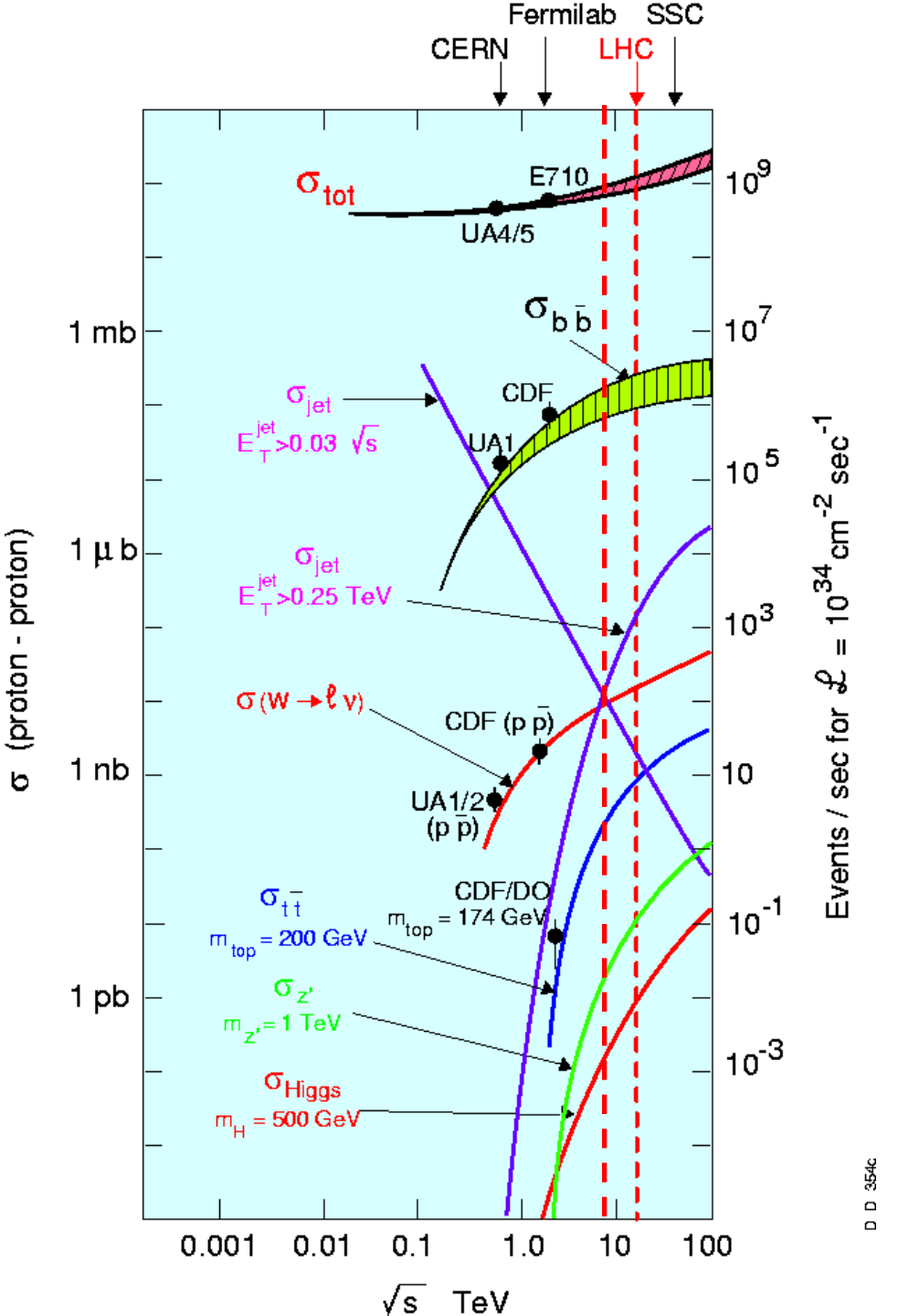

Events / GeV
10^6
10^5
10^4
10^3
10^2
10
1
ρ,ω
η
φ
J/ψ
ψ'
Υ
Z
Physics Results
CMS
$\sqrt{s} = 7$ TeV
$L_{int} = 40\ pb^{-1}$
1
10
10^2
Dimuon mass (GeV/c^2)

Results

10 examples:

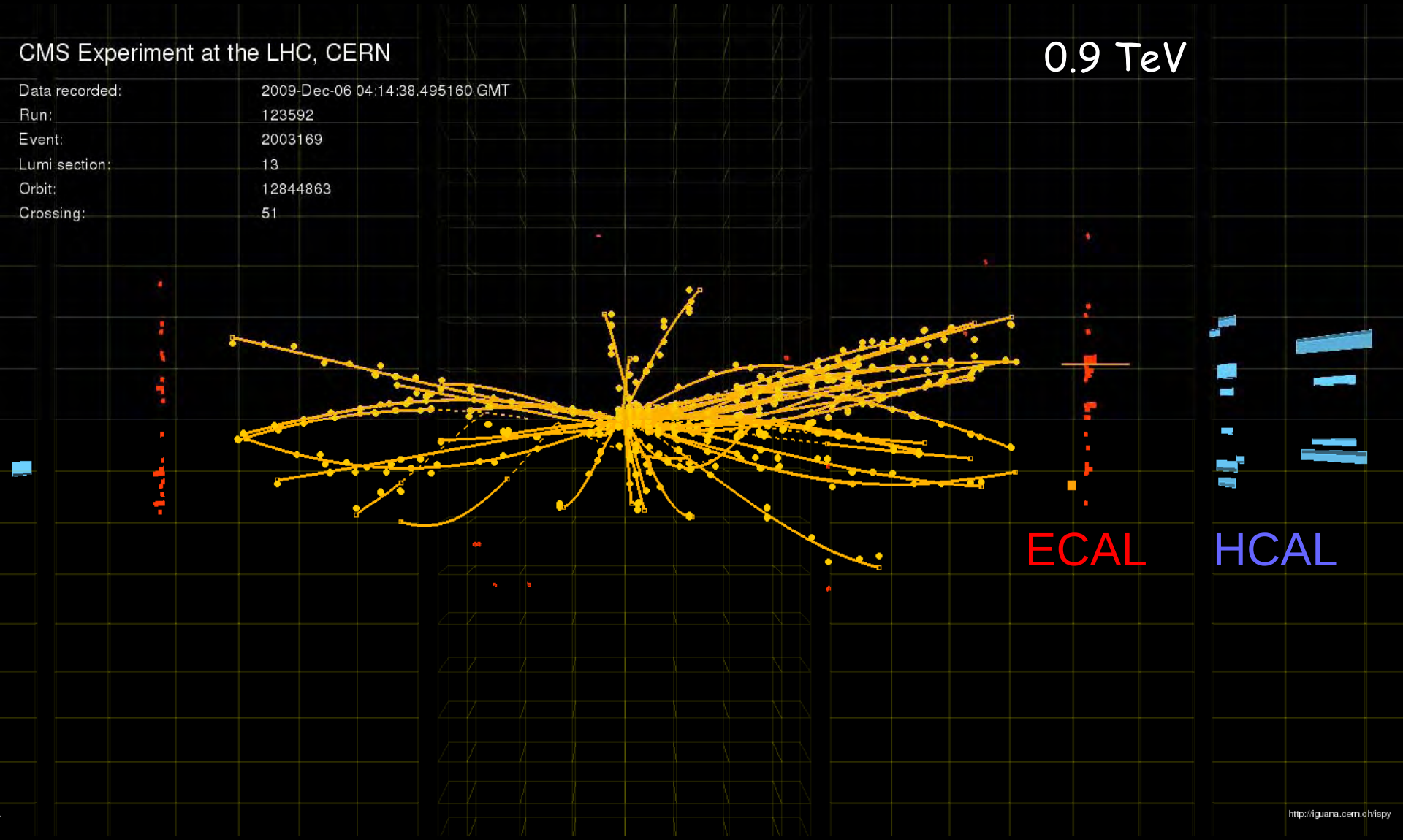
German contributions !

- hadrons
- jets
- b decays
- b oscillation
- top
- W,Z
- higgs
- susy
- W'
- heavy ions

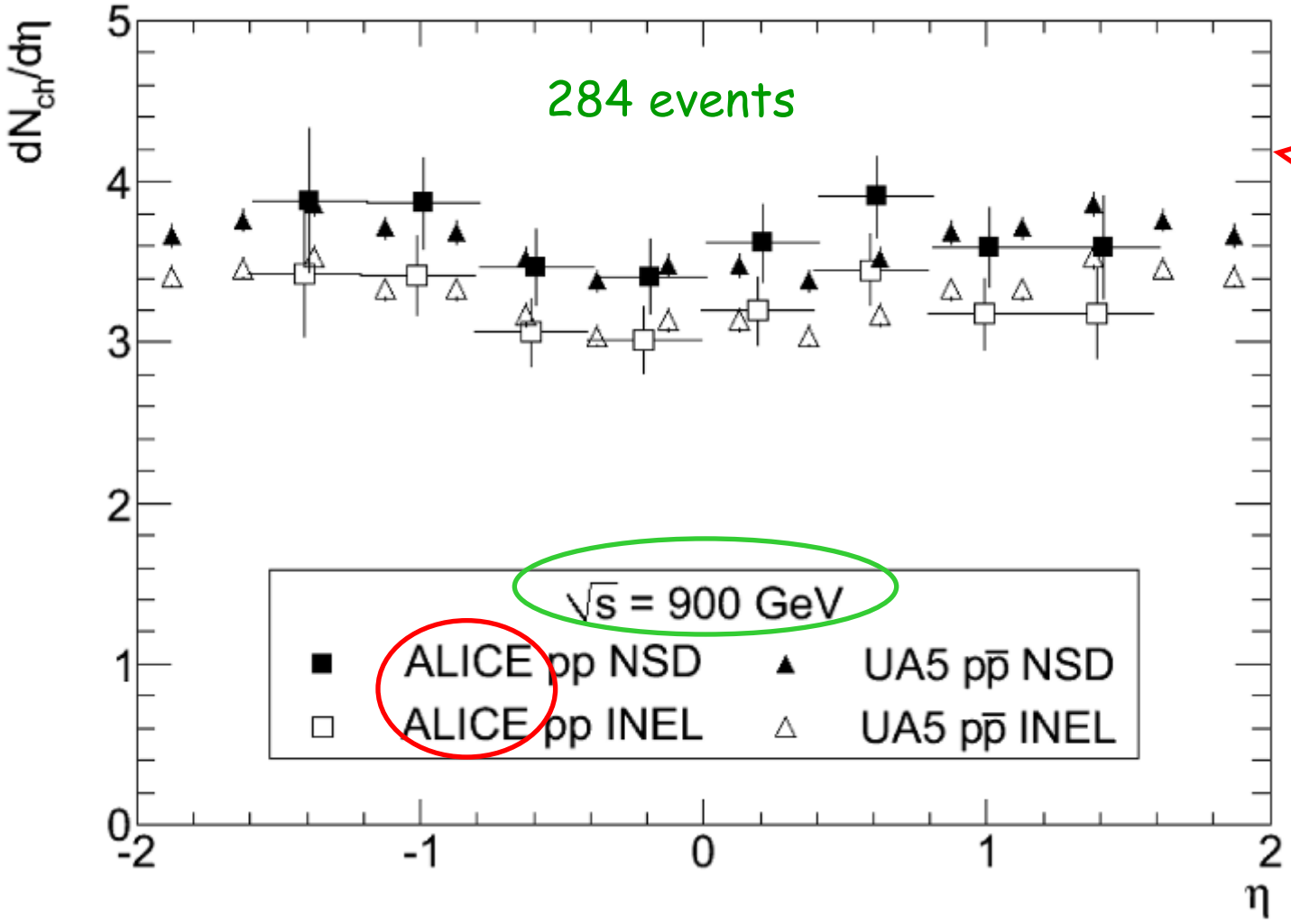


Hadron production

typical minimum bias event



Hadron production in p p



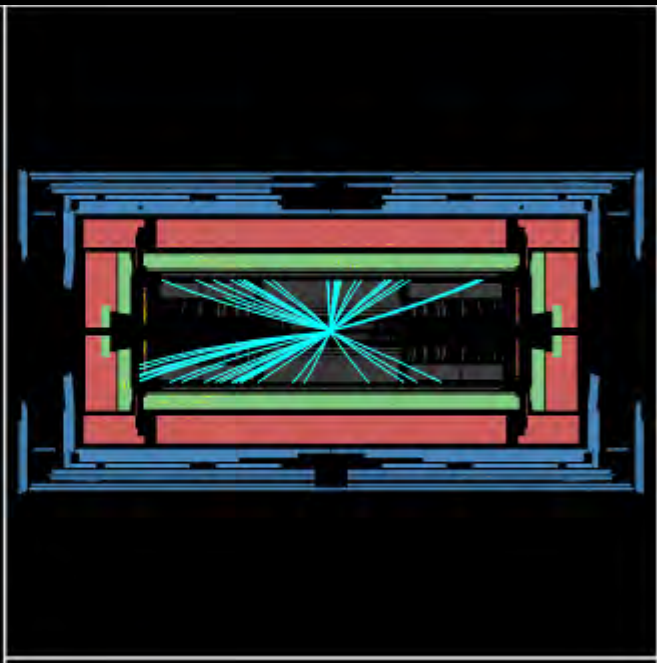
First LHC physics paper

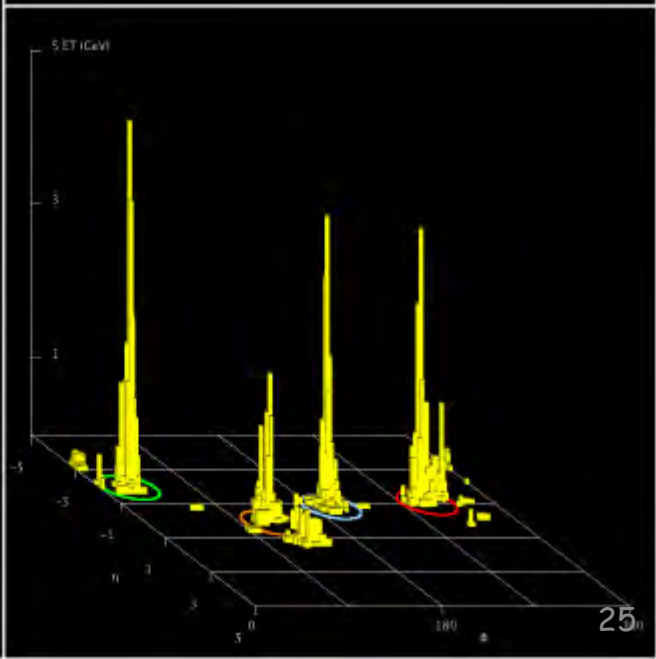
best if pileup low

Measurements at 0.9, 2.36 and 7 TeV:
Rise of multiplicity stronger than anticipated

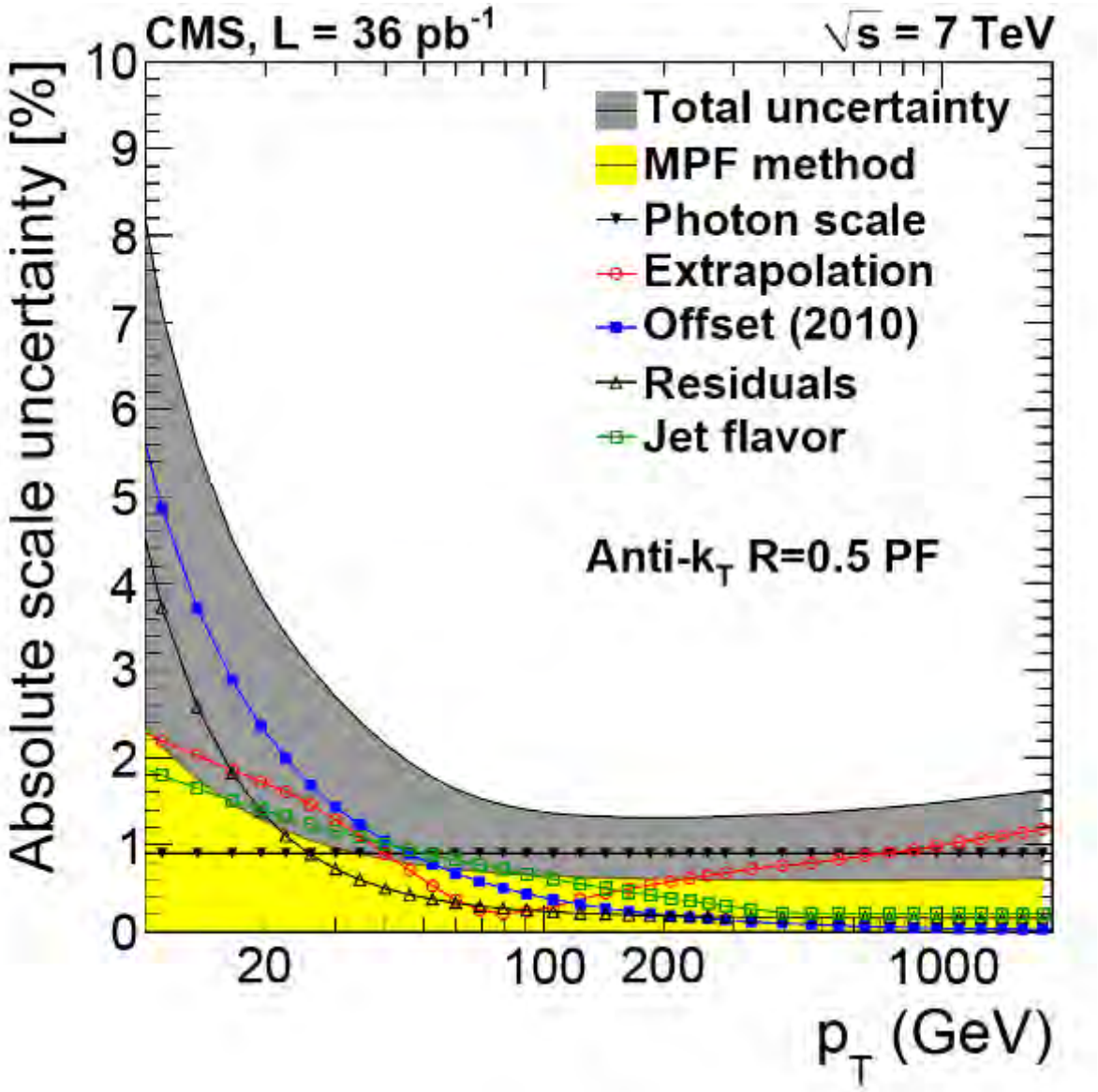
new MC tuning

Jet production



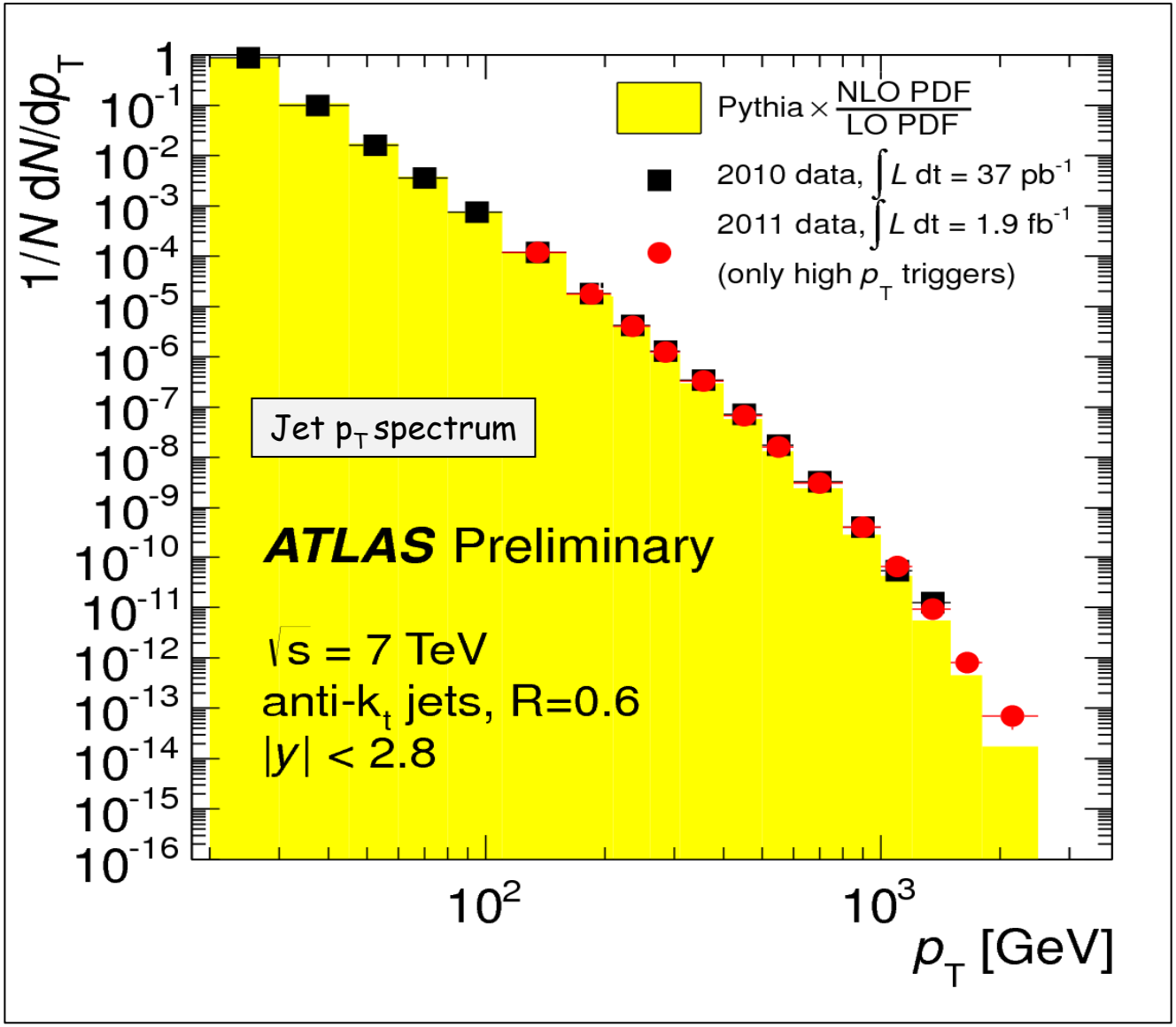


Jet measurements



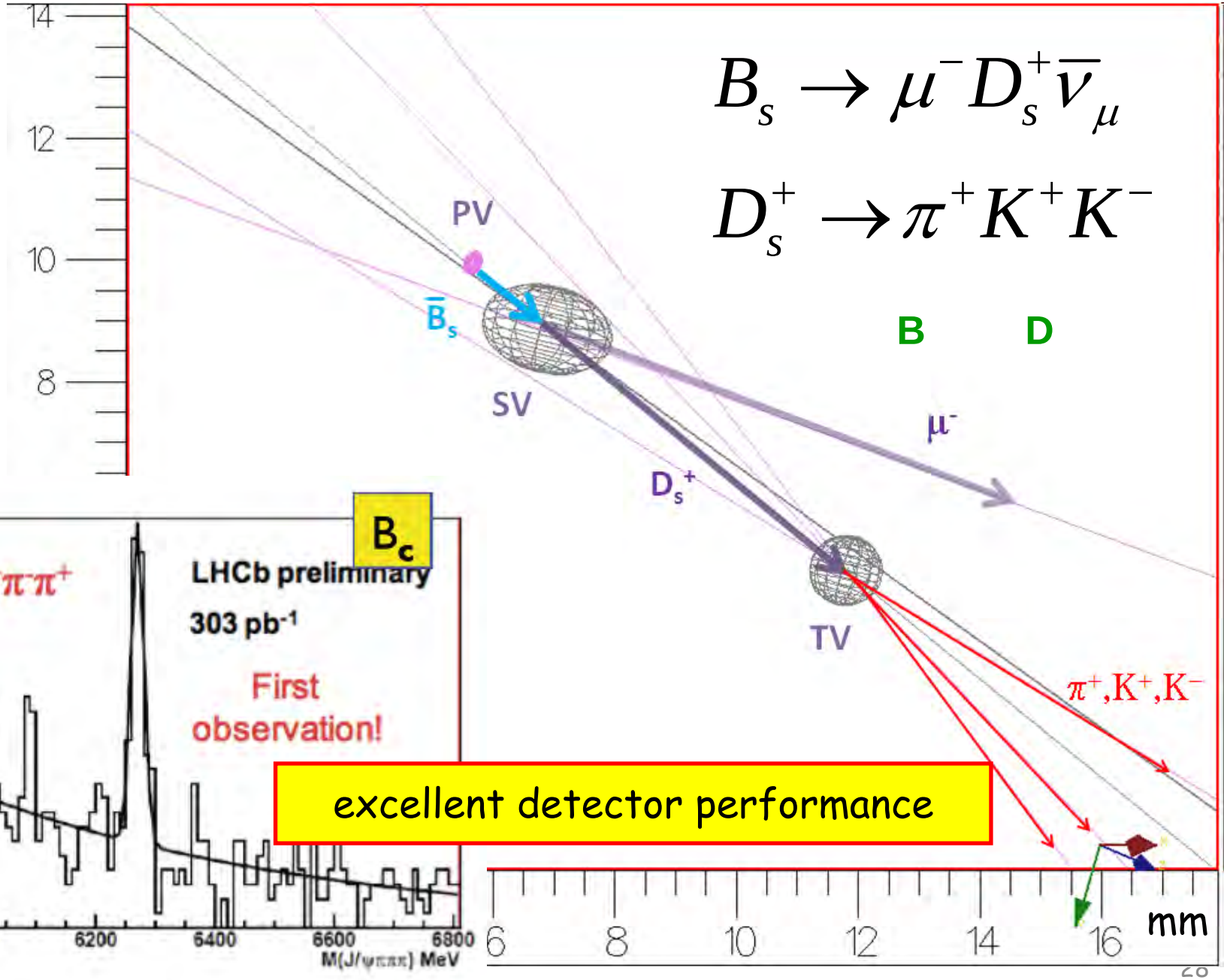
High precision reached „early"

Inclusive jet production



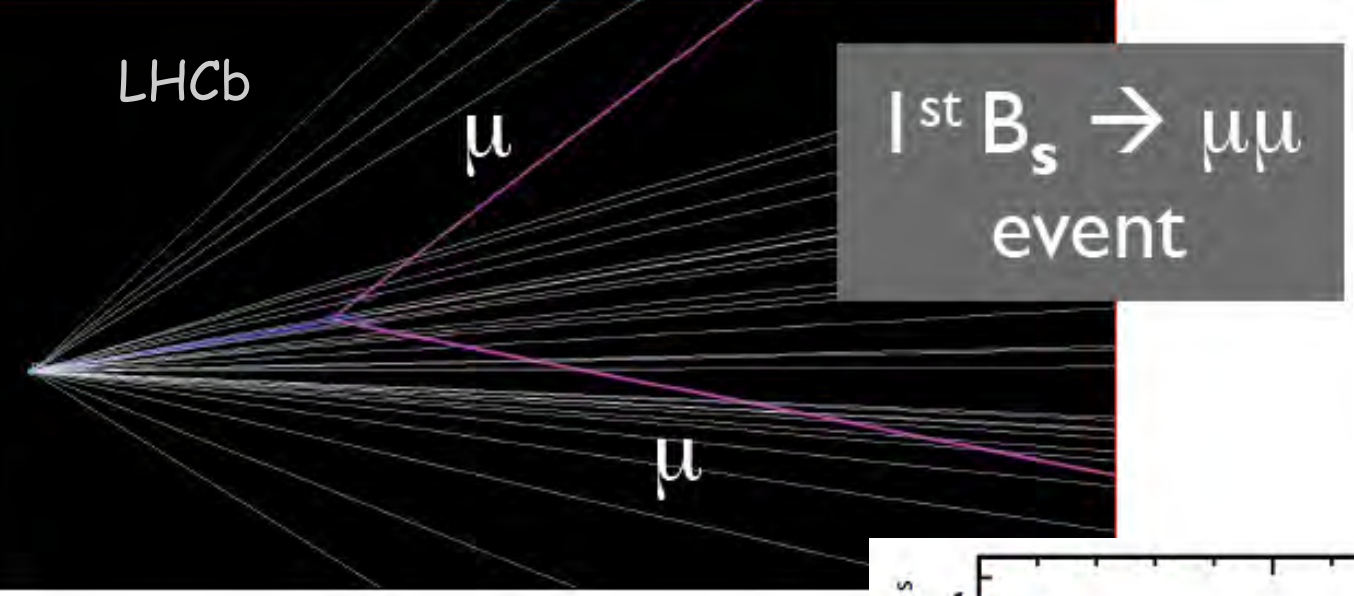
Agreement with QCD prediction over several orders of magnitude

LHCb b production and decay



excellent detector performance

$B_s \to \mu\mu$



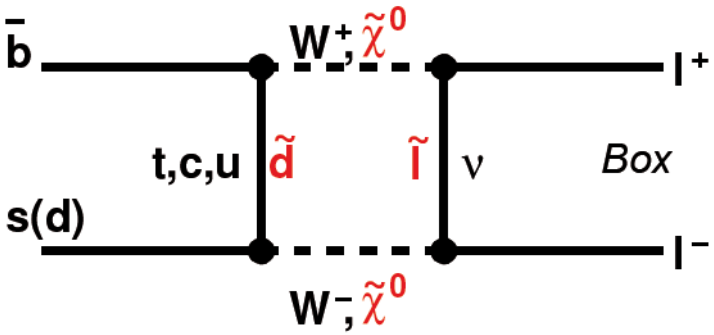
Campana 2011-10-19

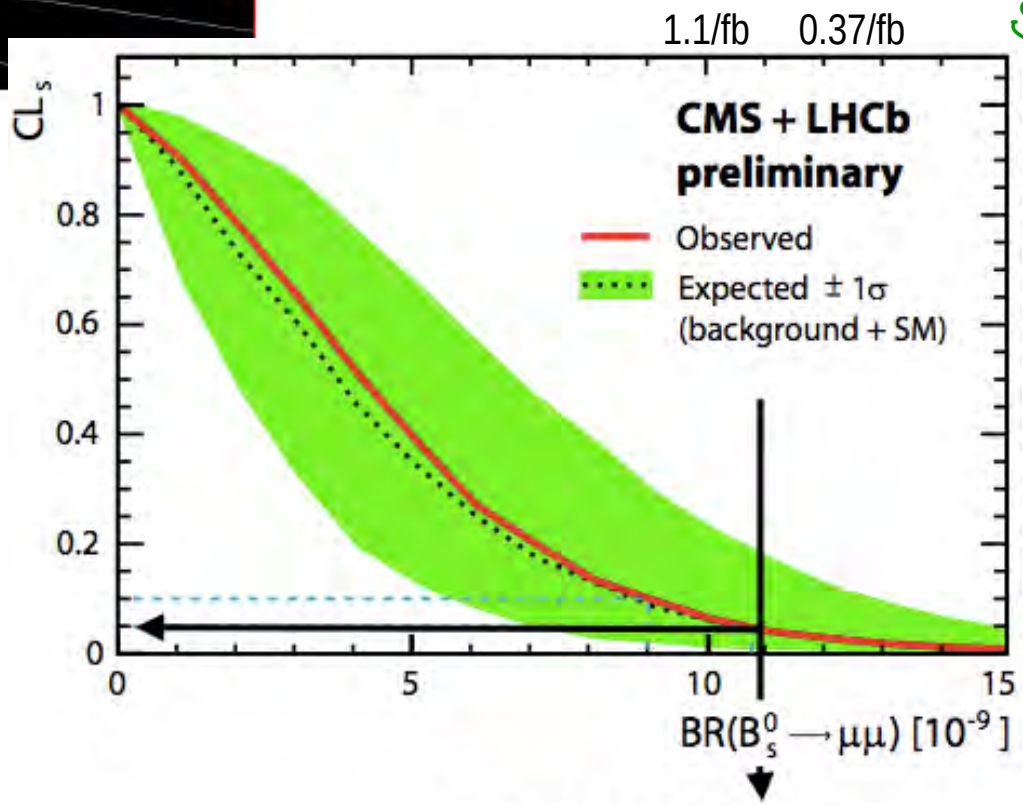
Standard Model:

$\mathcal{B}(B_s \to \mu\mu) = (3.2 \pm 0.2) \times 10^{-9}$

within reach 2012

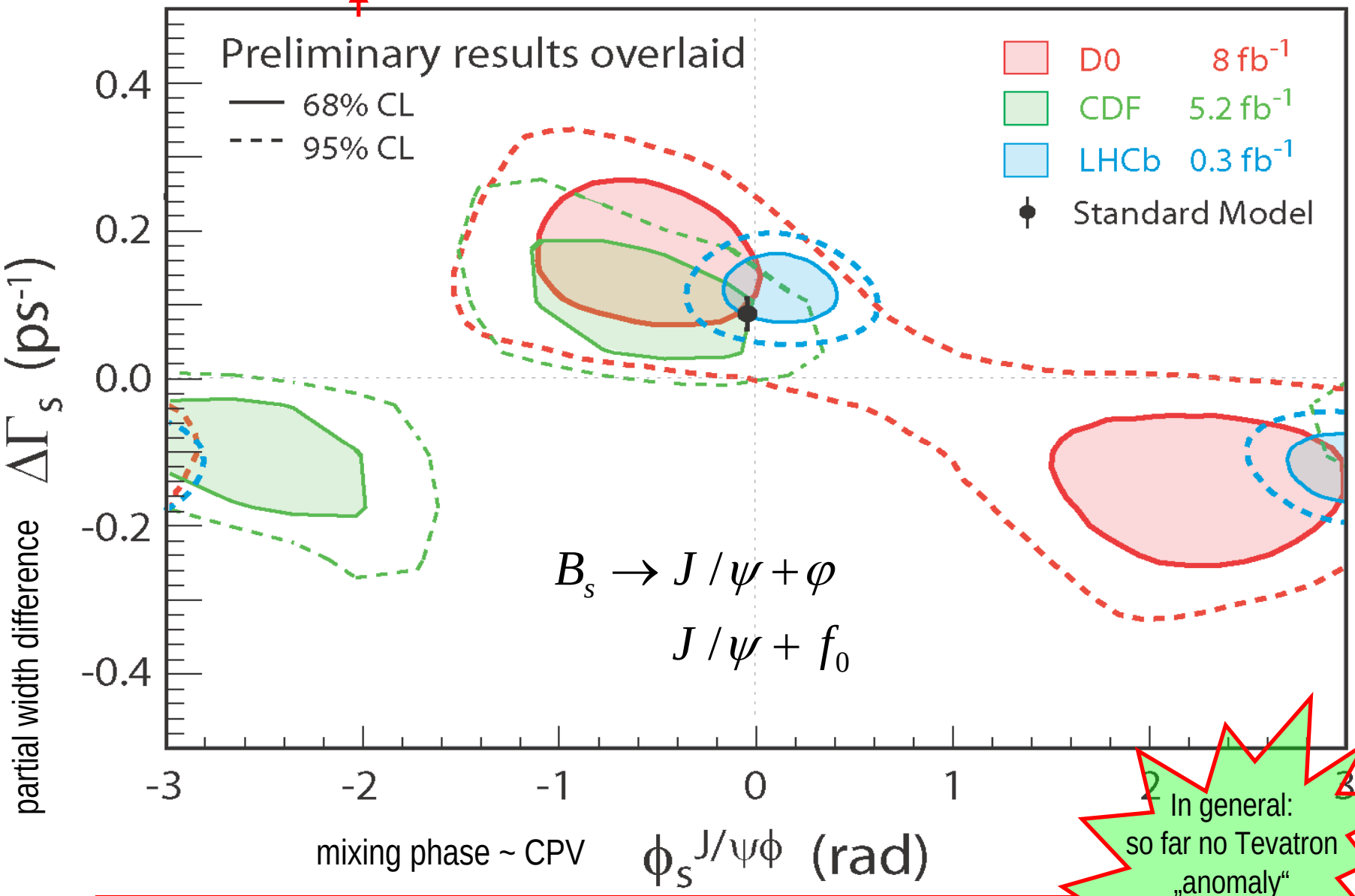
SUSY: possible enhancement:





$BR < 11 \cdot 10^{-9}$ (95%CL)

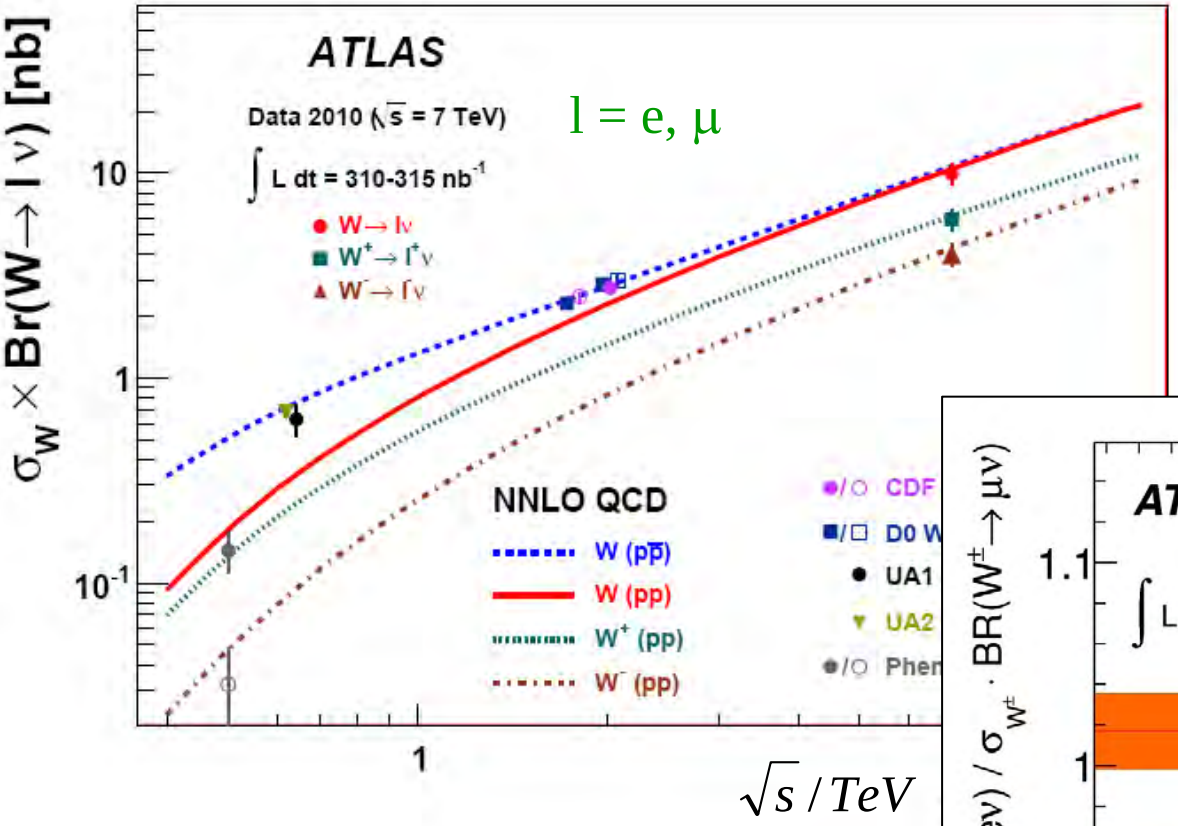
B_s system properties



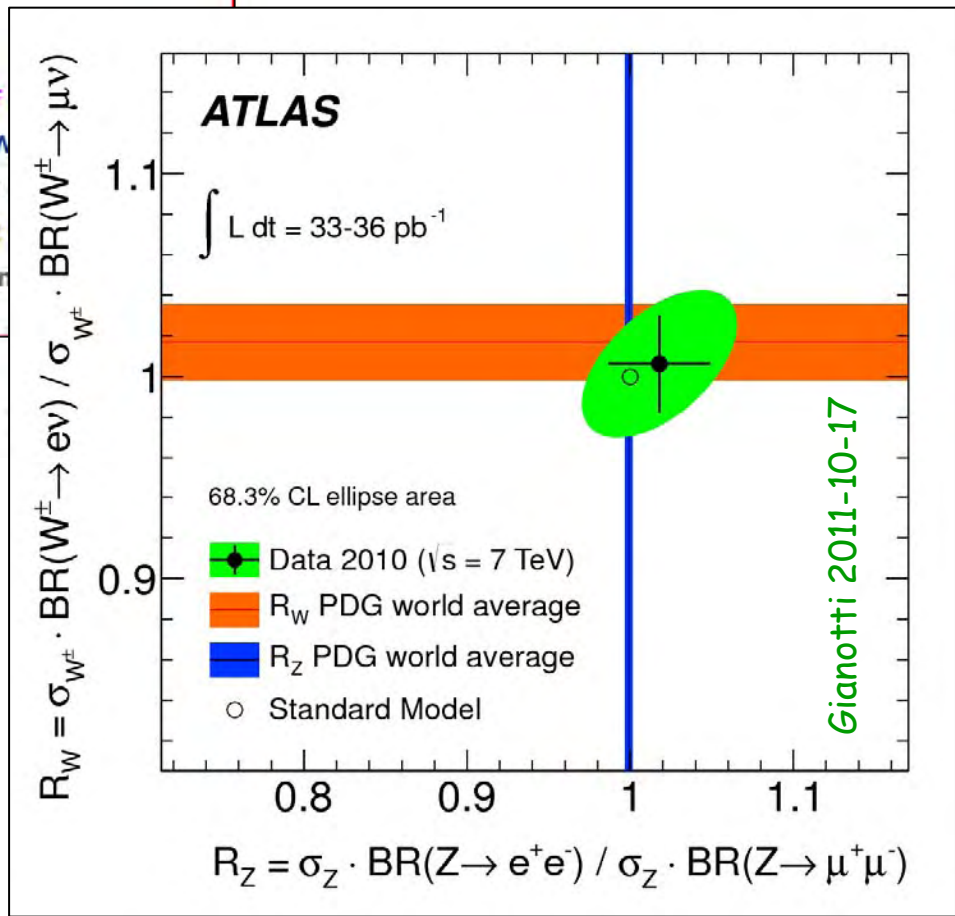
In general:
so far no Tevatron
„anomaly“
seen at LHC

SM ok! - Tevatron results not confirmed

W and Z production and decay

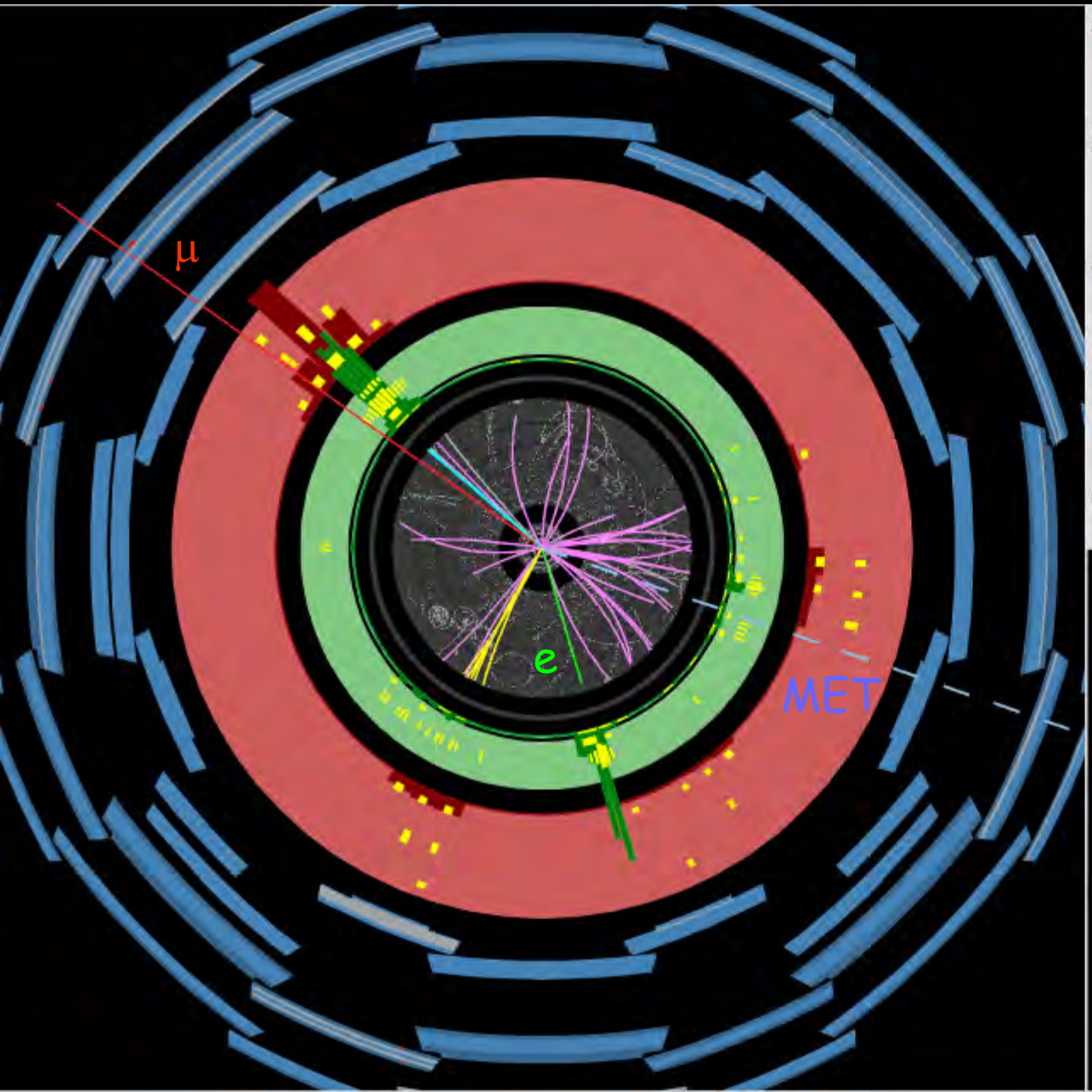


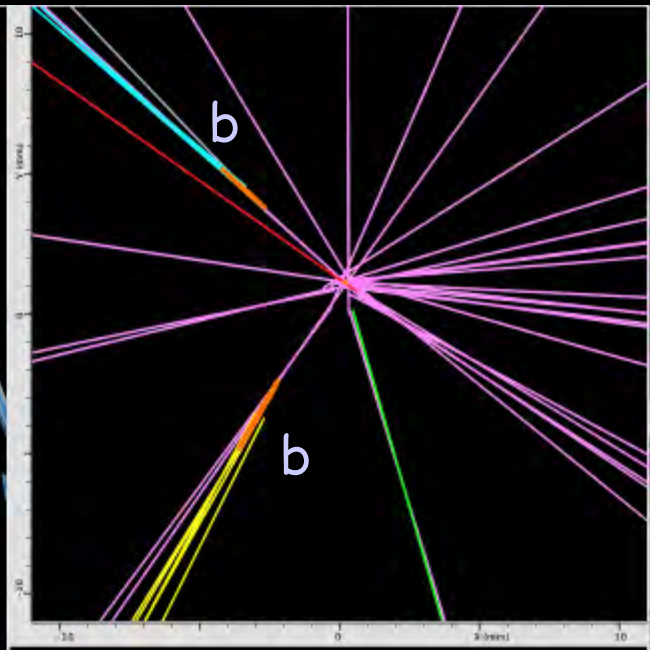
millions of Z, W events !



Perfect agreement with SM

Top $t\bar{t} \rightarrow bW\,bW \rightarrow b\mu\nu\,be\nu$





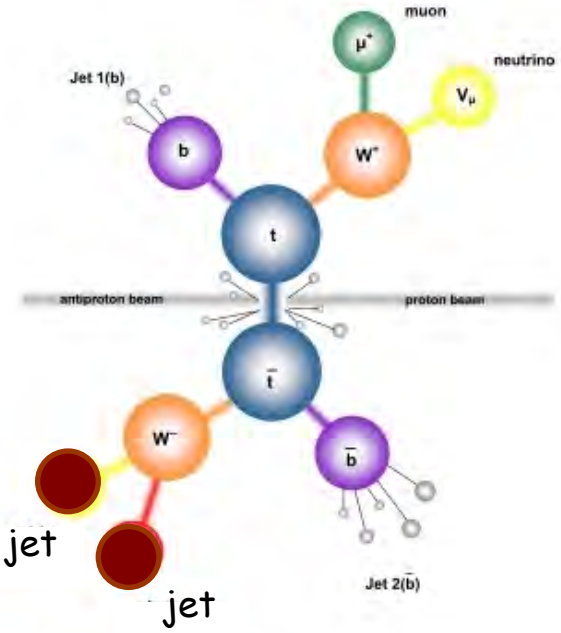
ATLAS EXPERIMENT

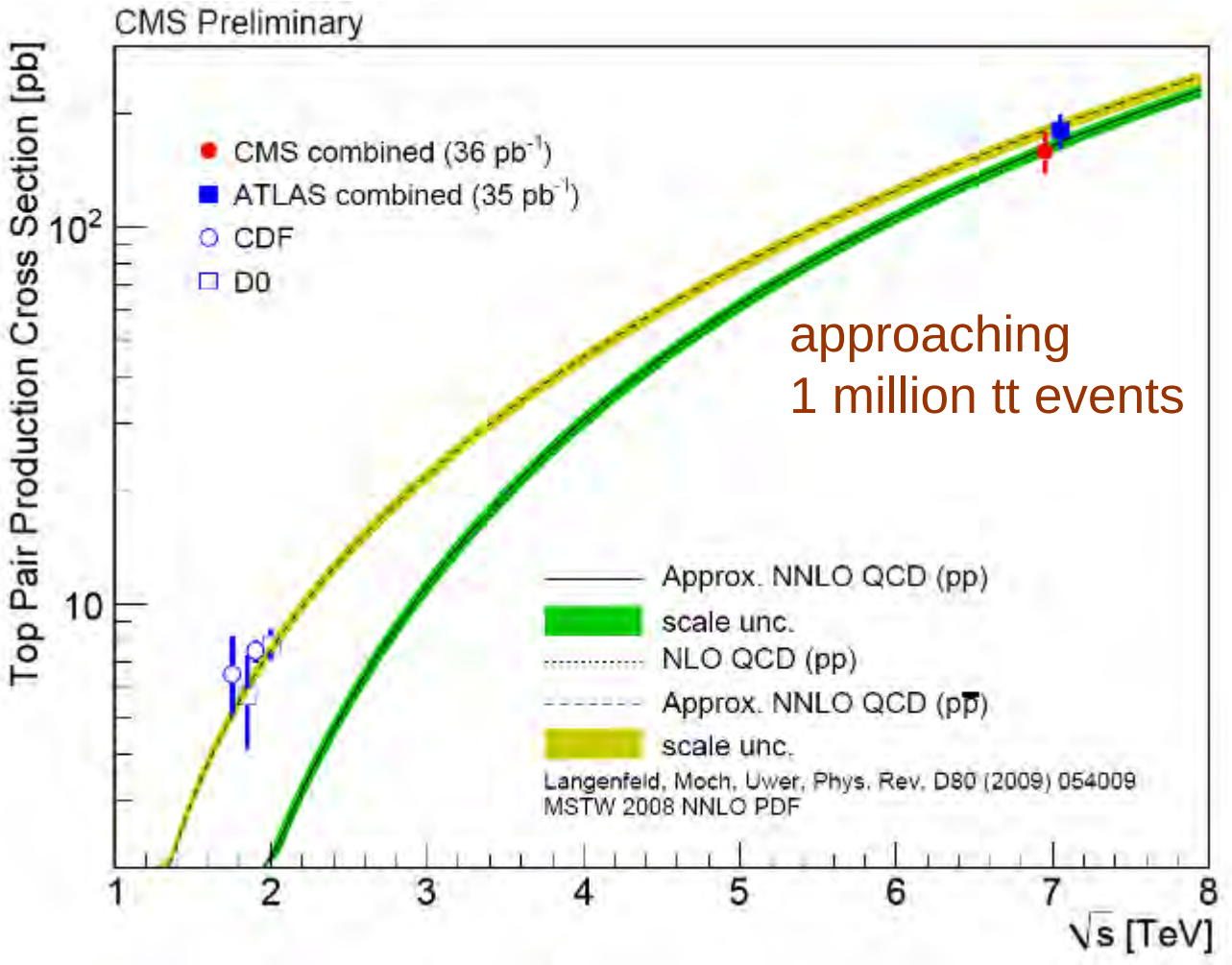
Run Number: 160958, Event Number: 9038972

Date: 2010-08-08 11:01:12 BST

7 TeV c.m.

Top production





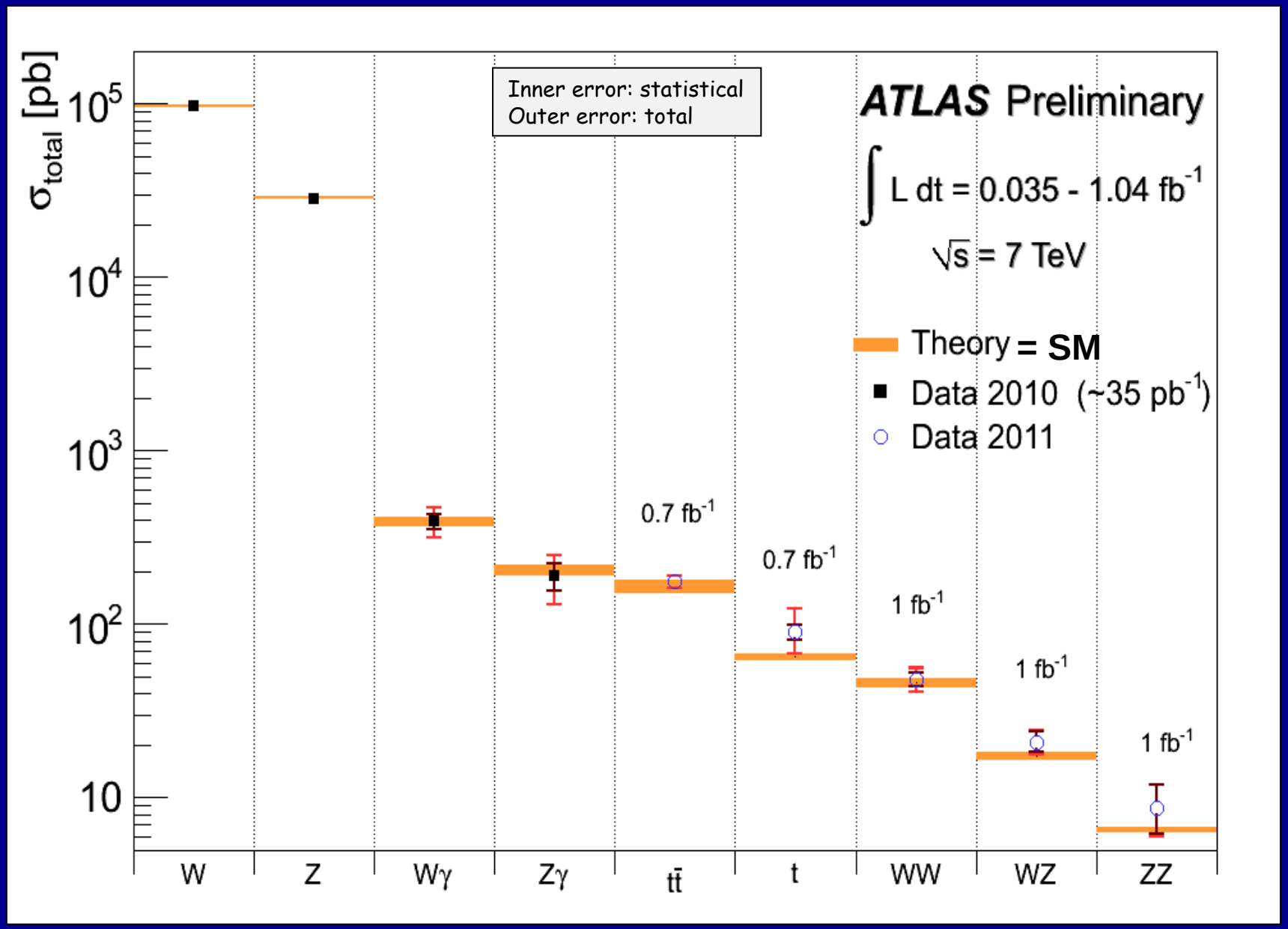
End of 2011: LHC has already produced 15 times more tops than Tevatron !

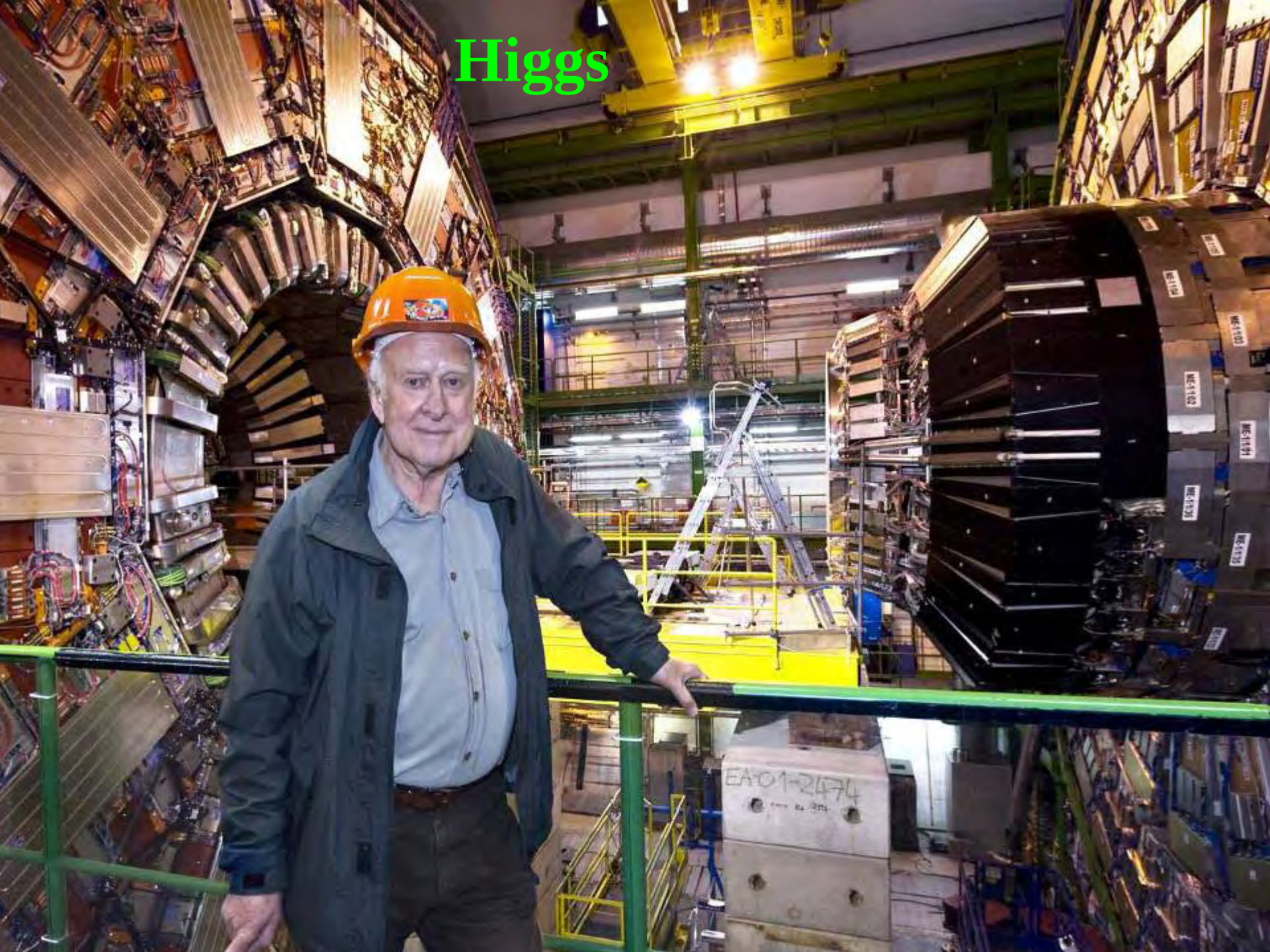
$$\sigma = 171 \pm 20 \pm 14 + 7\,pb$$ agreement with SM

(ATLAS 2010 dileptons)

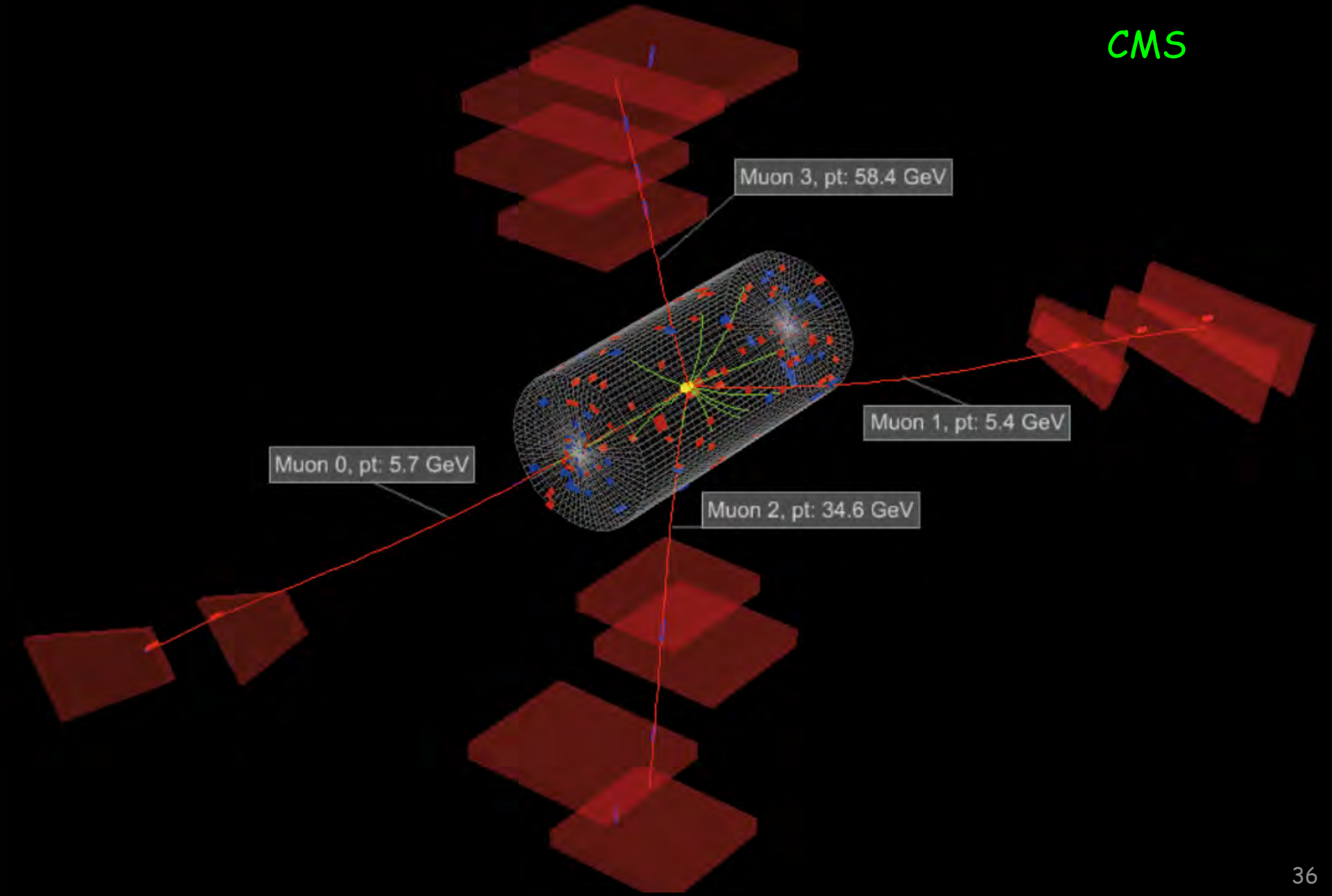
Summary of weak boson production

T.Hebbeker

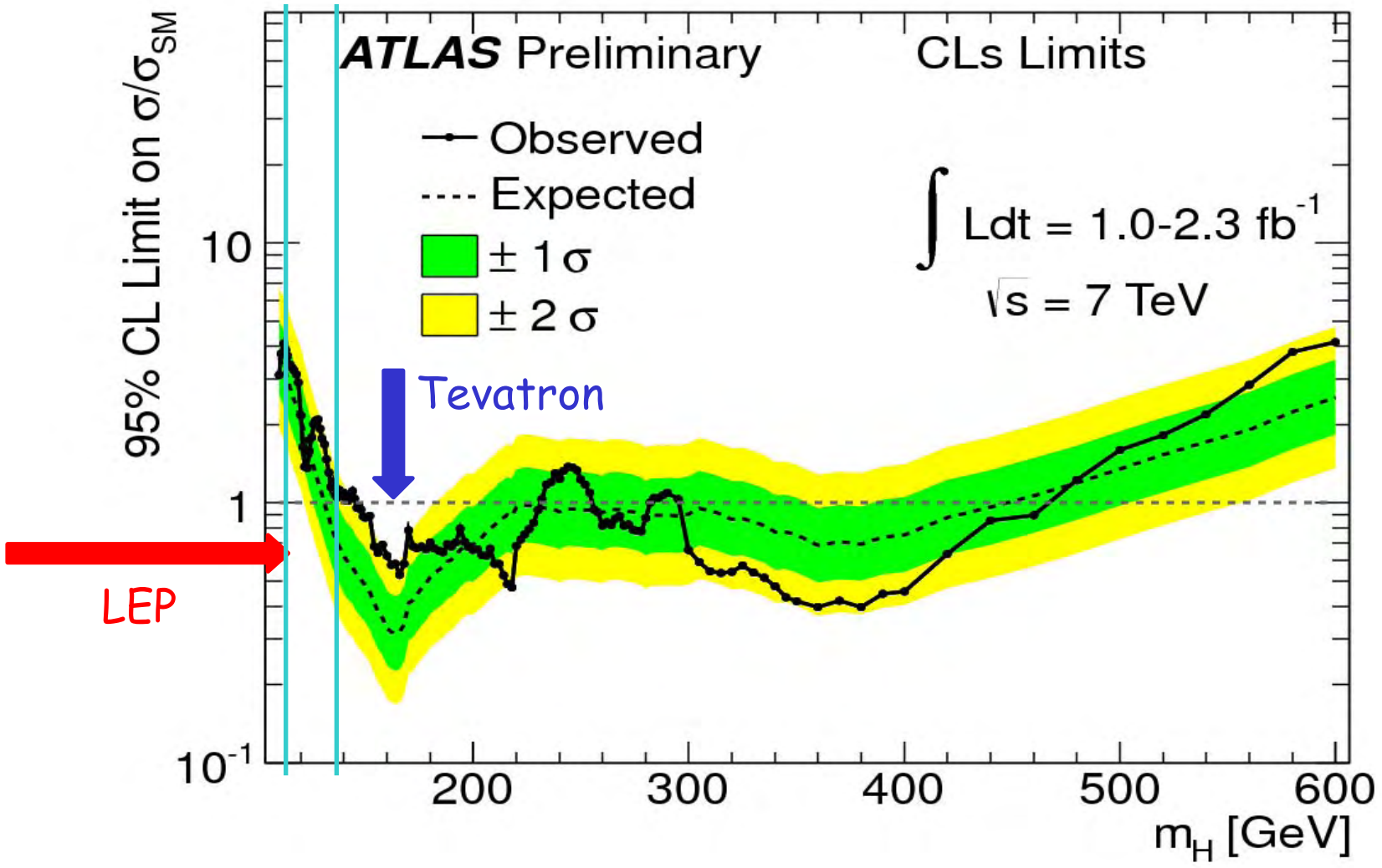



Higgs

Higgs candidate event



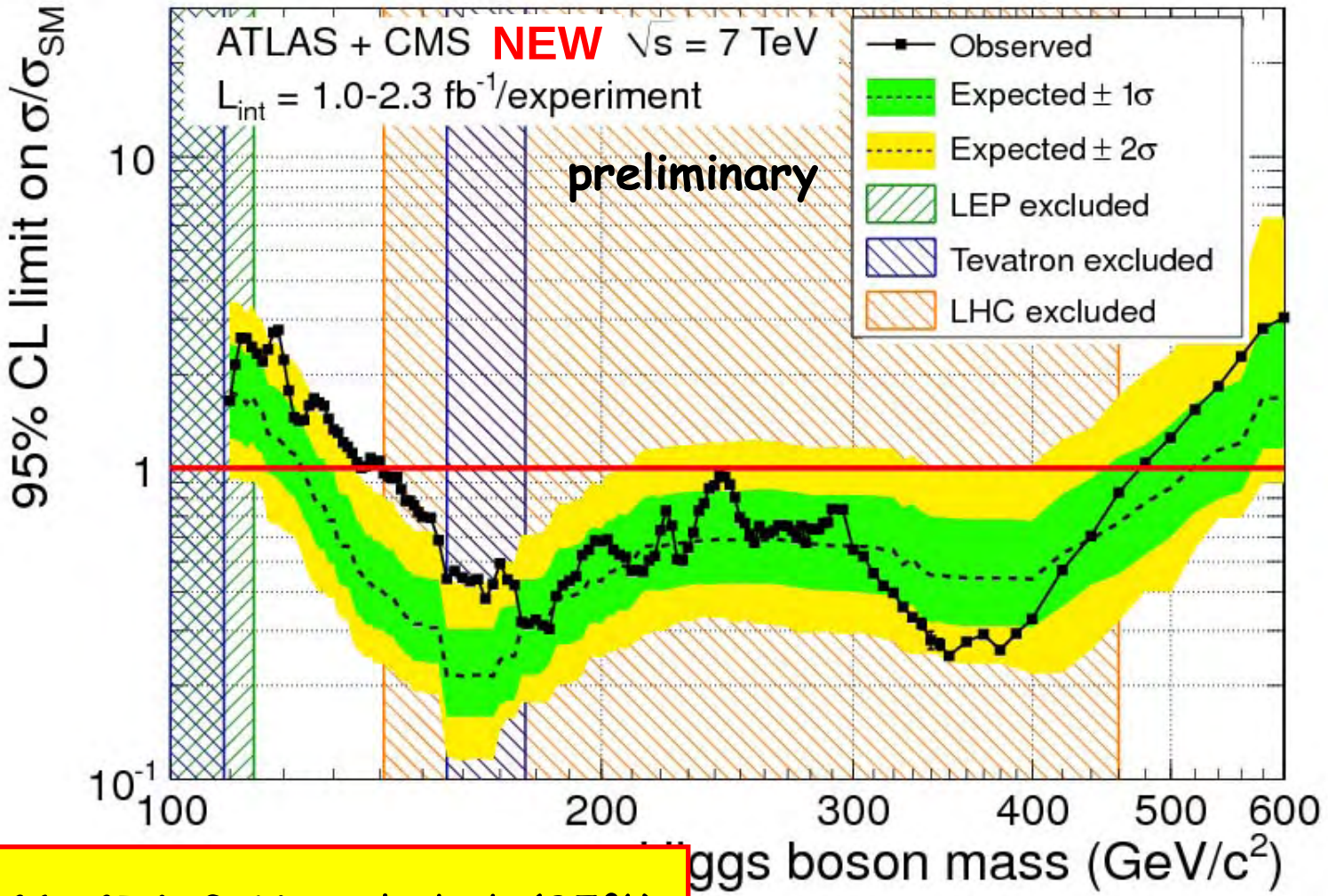
Standard Model Higgs limits



High mass region 300-450 GeV excluded

(not accessible by Tevatron)

ATLAS+CMS Combination: limit on σ/σ_{SM}

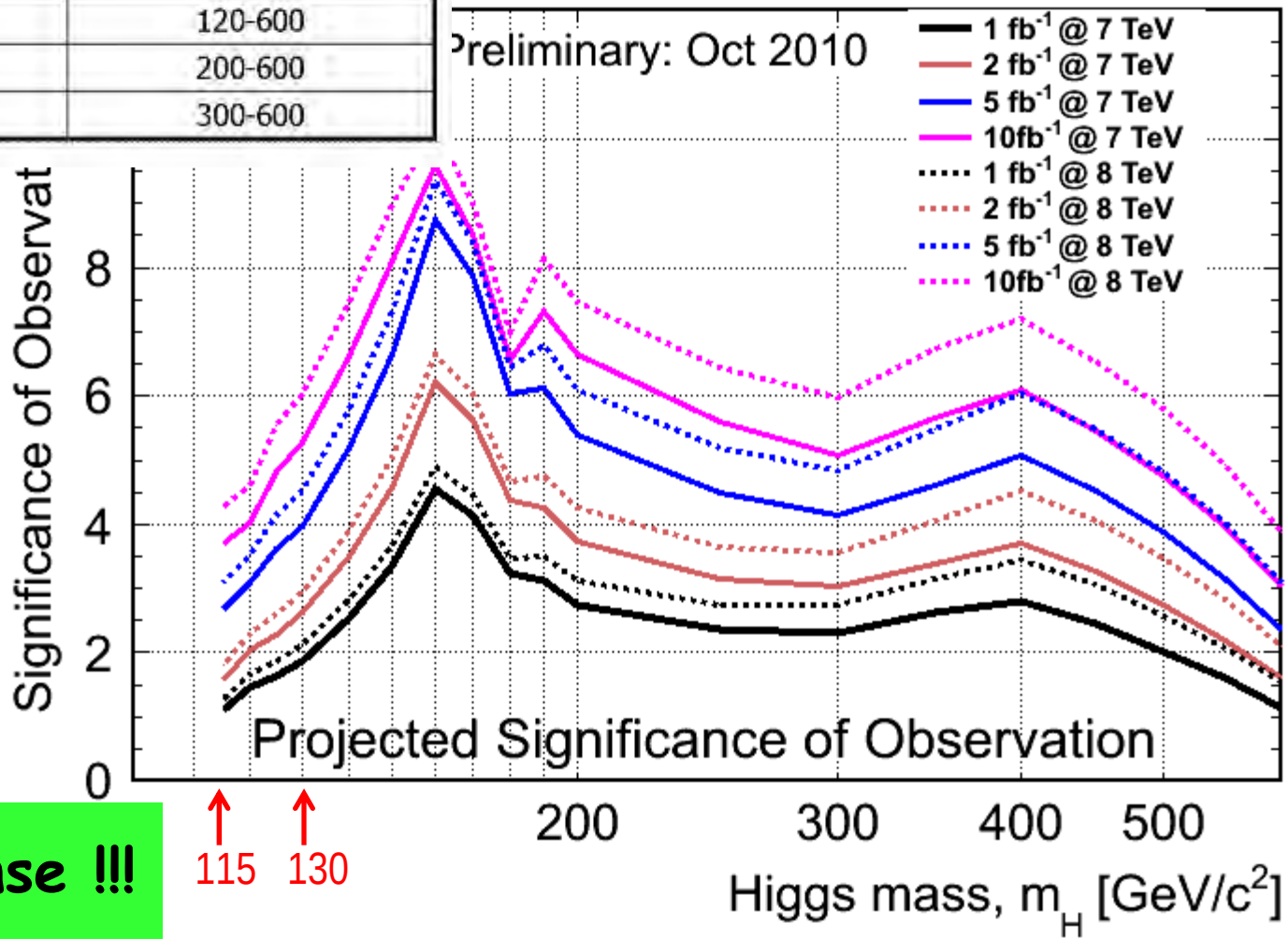


High masses **141-476 GeV** excluded (95%)

mass range 115-135 GeV most interesting

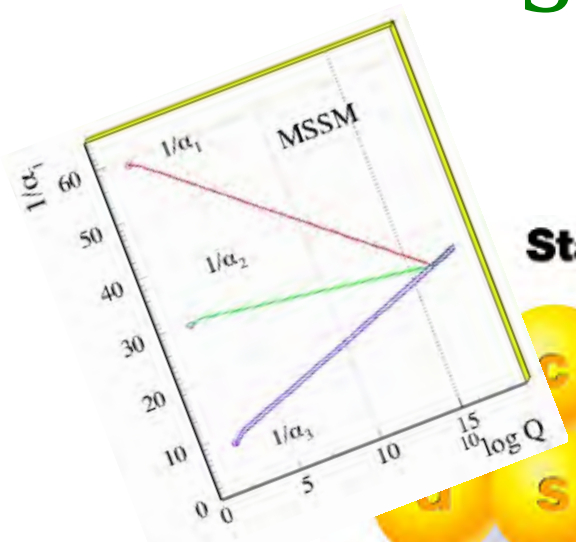
SM Higgs prospects discovery

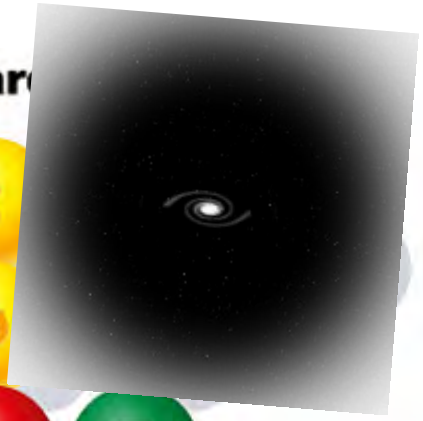
Channels included CMS	Higgs mass range used in analyses (GeV)
H→γγ	115-150
VBF H→ττ	115-145
VH, H→bb (highly boosted)	115-125
VH, H→WW→lνjj	130-200
H→WW→2l2ν + 0/1 jets	120-600
VBF H→WW→2l2ν	130-500
H→ZZ→4l	120-600
H→ZZ→2l2ν	200-600
H→ZZ→2l2b	300-600

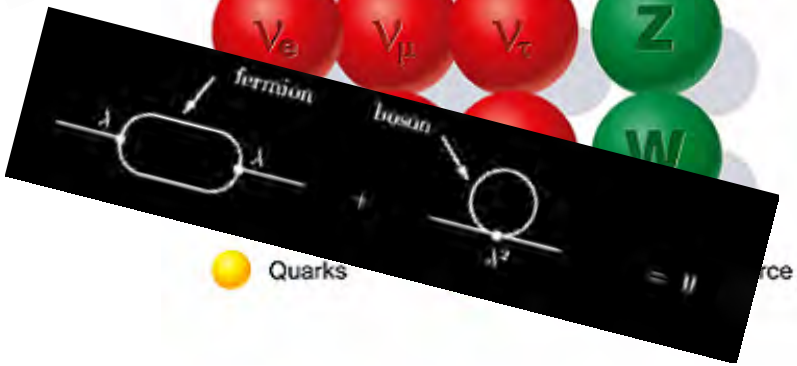


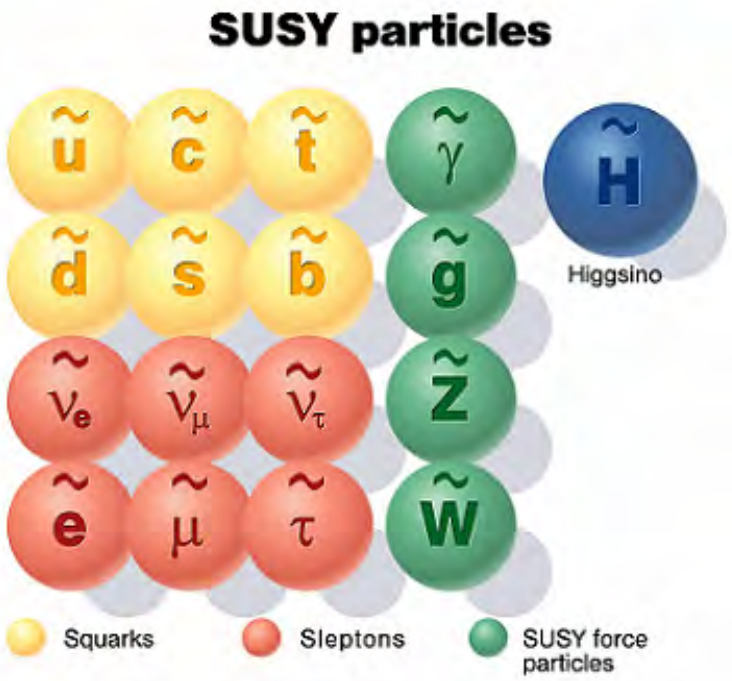
2012 – suspense !!!

Supersymmetry ?





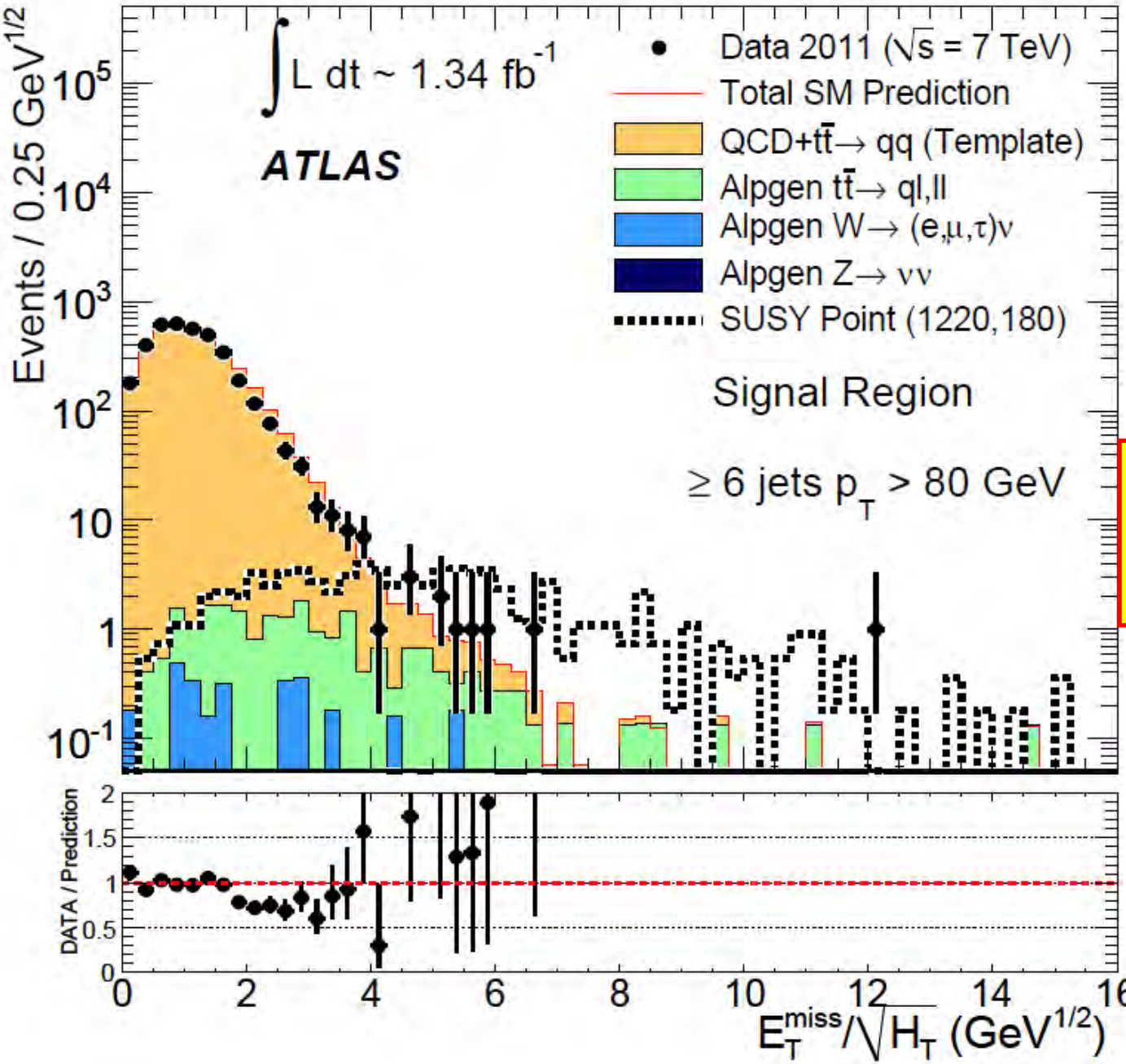




Lightest MSSM higgs ~ SM higgs **mass < 135 GeV** !
higgs limits = strong constraints in SUSY parameter space

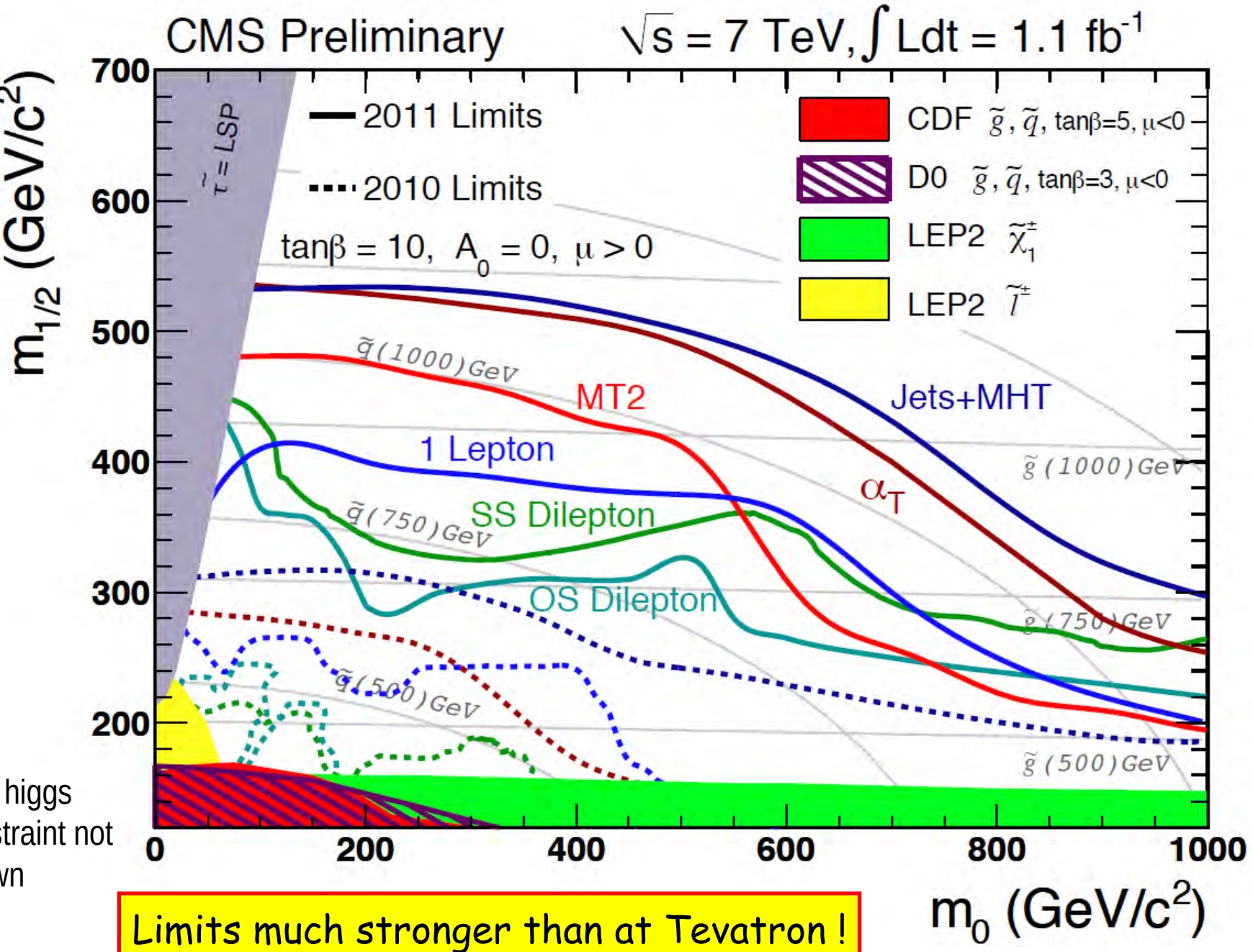
Excluding MSUGRA does not rule out Supersymmetry !

Example: MSUGRA search in jet events



no indication for SUSY (yet)

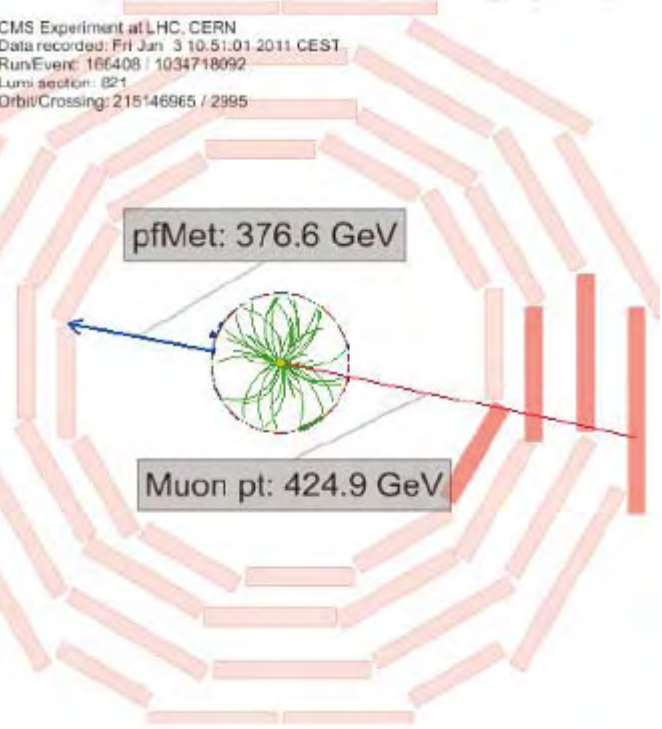
MSUGRA Limits

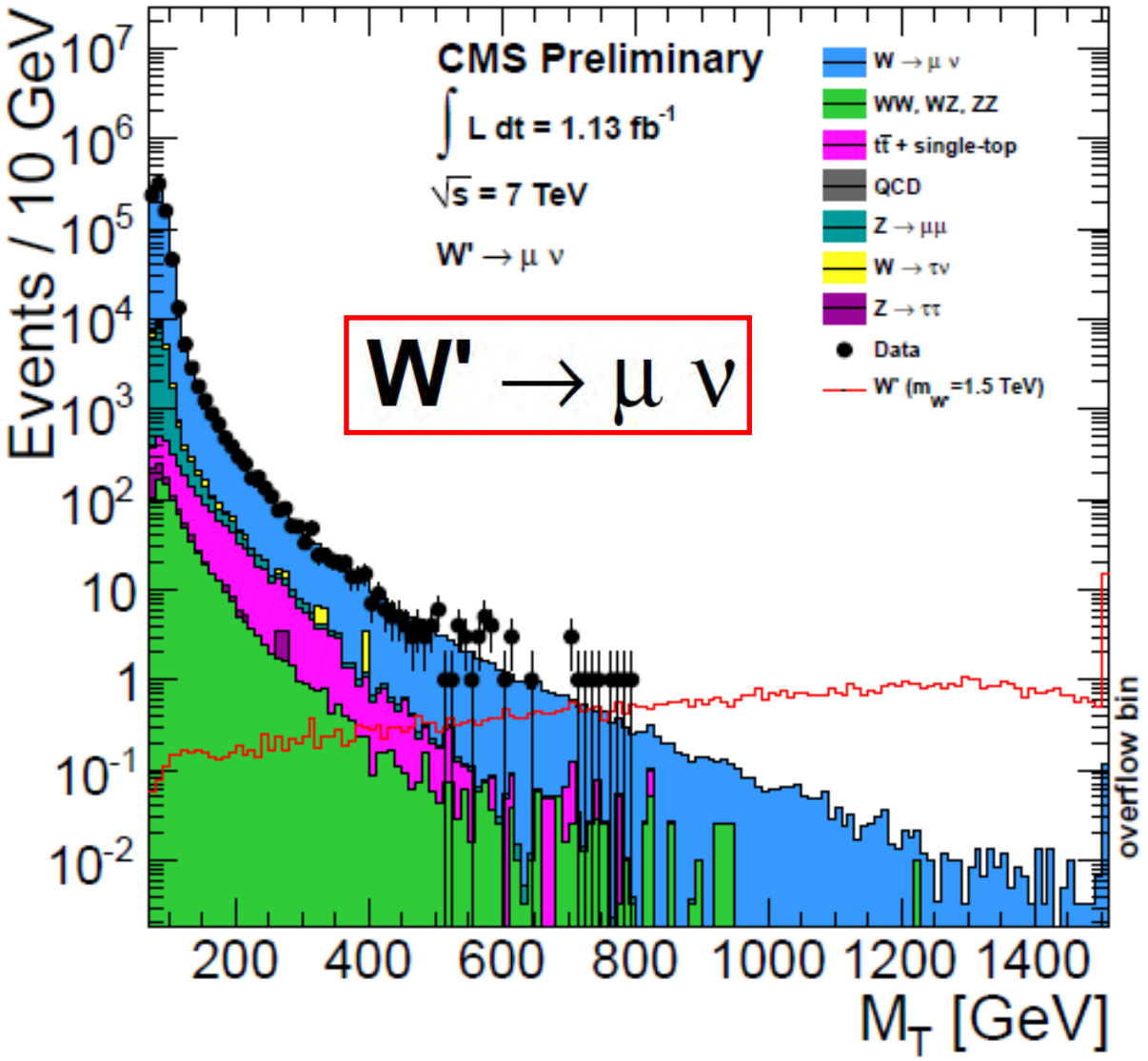


LEP higgs constraint not shown

Limits much stronger than at Tevatron !

Search for W´

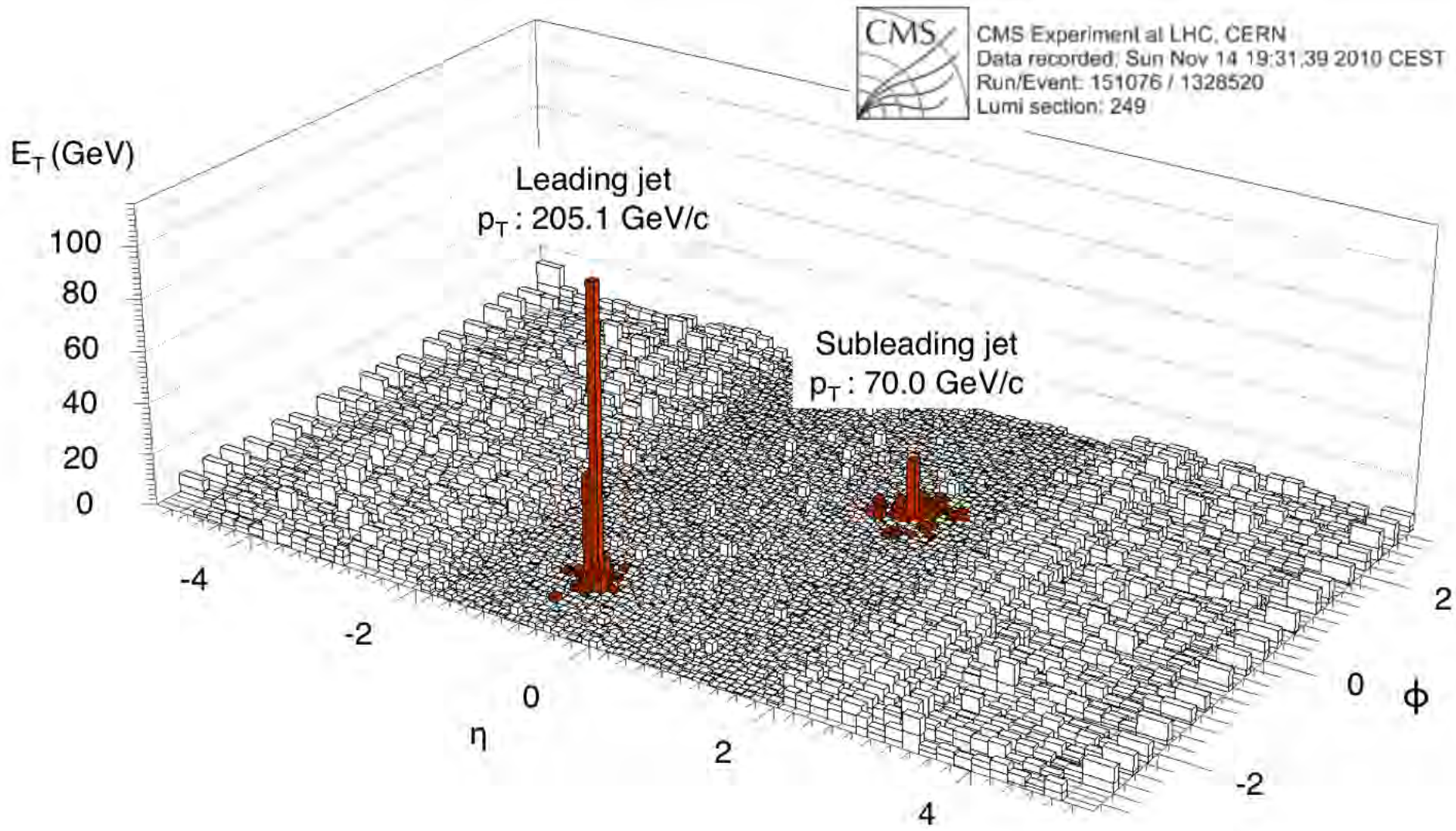




W' excluded up to m = 2.27 TeV

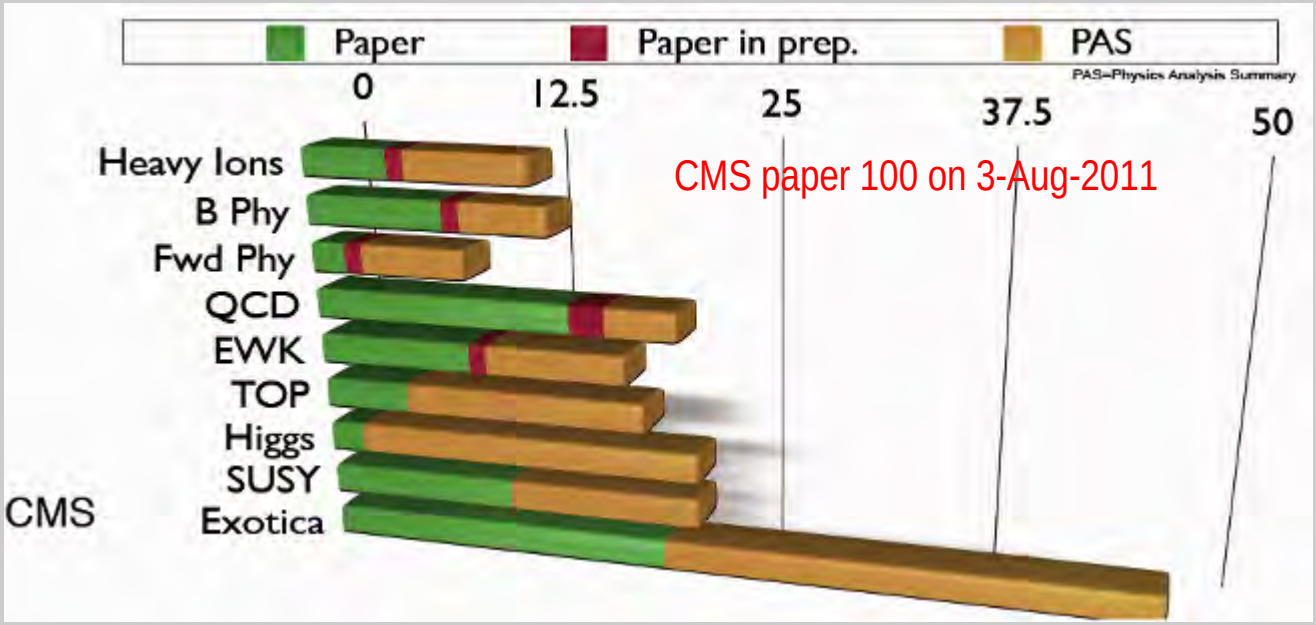
(Tevatron limit: 1 TeV)

Heavy Ions – Jet quenching

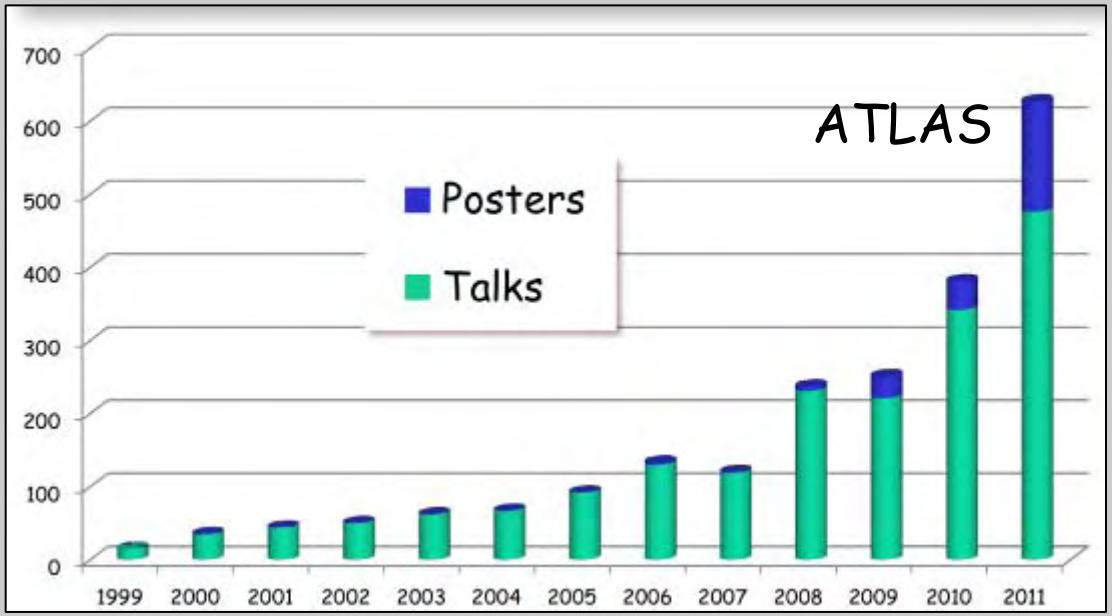


jet suppressed by dense medium (QGP)

Publications and Presentations

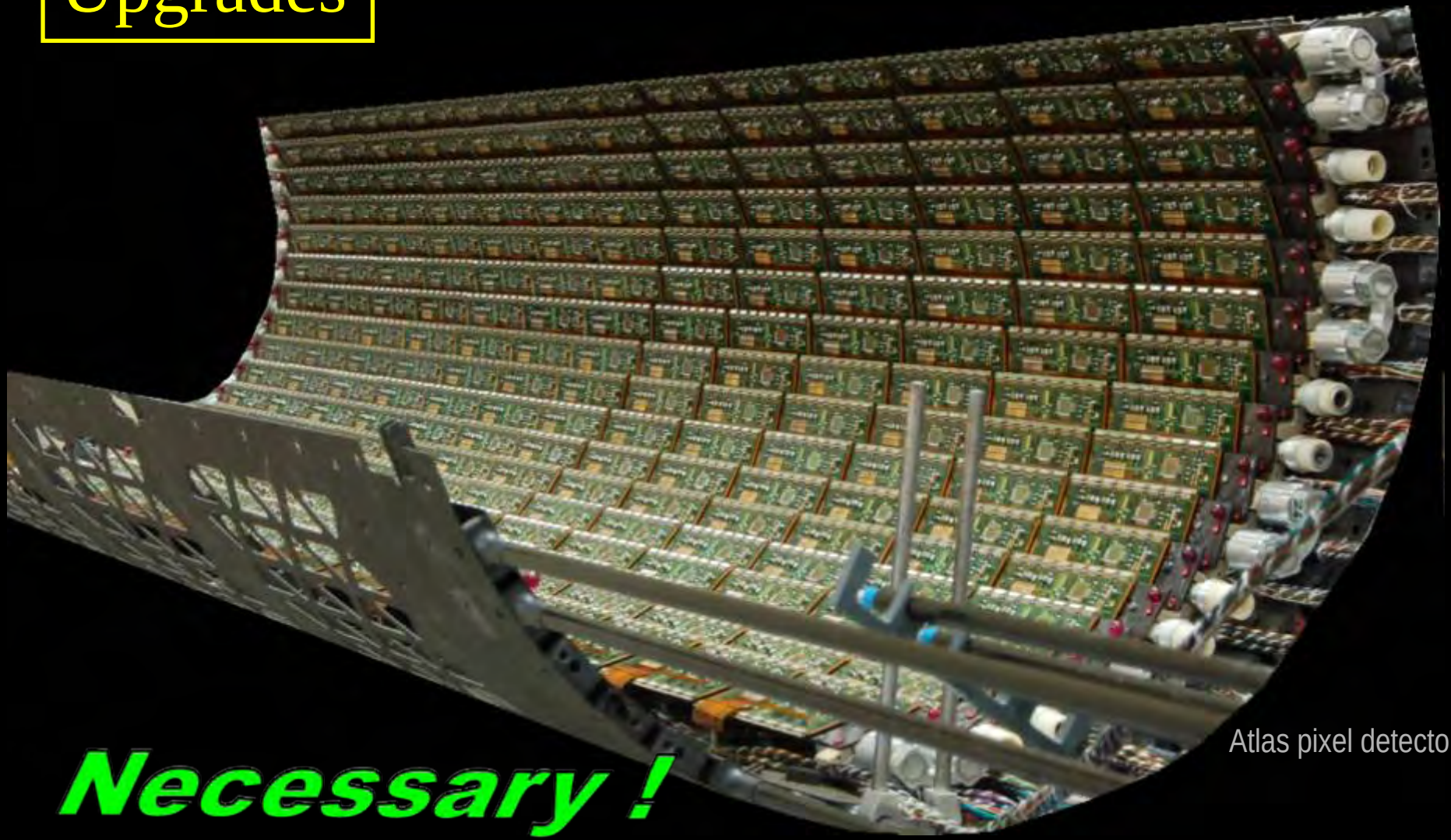


Tonelli 2011-10-18



Gianotti 2011-10-17

Upgrades



Atlas pixel detector

Necessary !

Huge effort !

ATLAS Upgrades

Steps for ATLAS upgrade (major German contributions):

Phase 0 (2013/14):
New: inner pixel layer (IBL) , new forward detector
level 1 topological calorimeter trigger
additional drift tubes in muon system

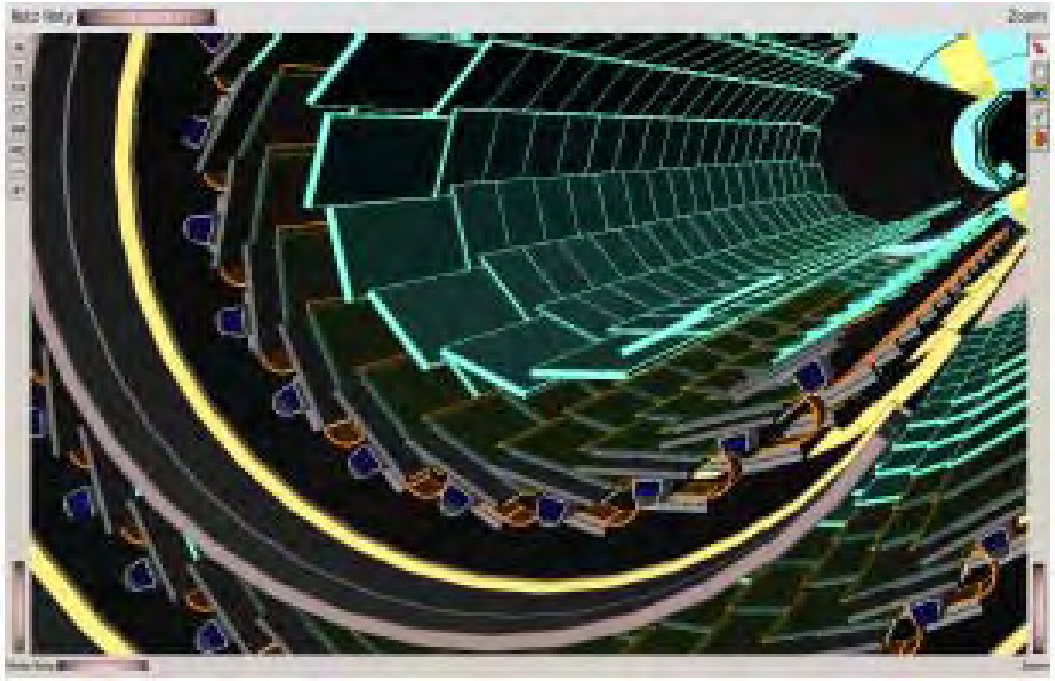
Phase 1 (2018):
New: muon chambers,
calorimeter & track trigger

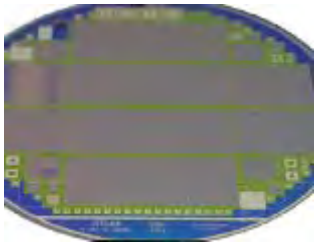
Phase 2 (~2022):
New: completely new Inner Tracker (full silicon: strips & pixel)
electronics in calorimeter, muon chambers
trigger upgrade

From P. Mättig

IBL: innermost pixel layer to be installed 2013/14

3,3 cm from IP ➔ significant improvement in B - Tagging





IBL: Strong German involvement
Components produced in German industry/institutes

From P. Mättig

Muon chambers

From P. Mättig

German contribution :

Aims: reduce occupancy in high intensity environment,
prepare for more precise trigger information

Technologies: smaller drift tubes (reduce diameter 30 ➔ 15 mm)
higher bandwidths (opto) - electronics

Phase 0: additional drift tubes
close acceptance holes
Phase I: ‚small wheels' close to beam
= endcap first layer
improve rate capability
(also for trigger)
Phase II: new read out/trigger electronics
replacement of inner chambers
improve trigger, bandwidth, radiation hardness

CMS Upgrades - up to phase 1

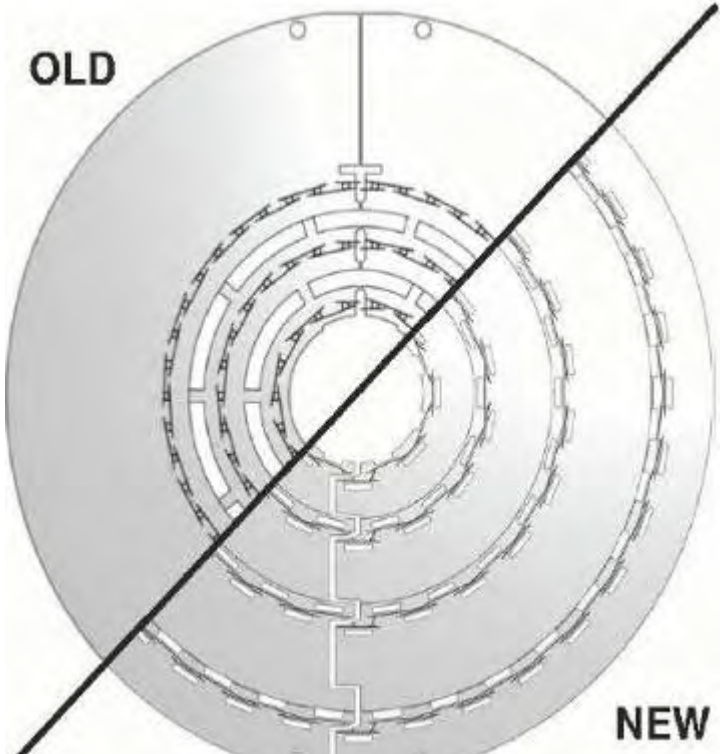
Germany

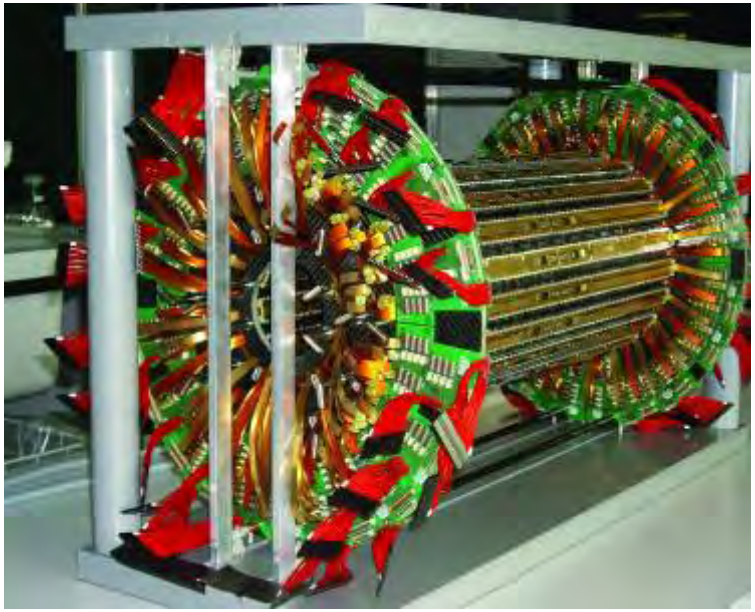
- DT muon / trigger system upgrade LS1 2013/14
- replacement of pixel detector LS2 ~ 2018

From P. Schleper

Current Pixel detector:

- Inefficient at 2 x 10^{34} cm^{-1} s^{-1} buffers too short
- Radiation damage ~200 fb^{-1}





New Pixel detector

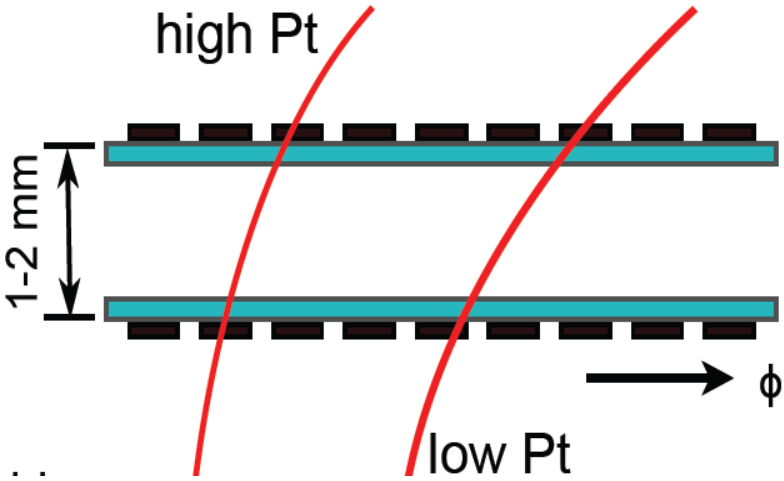
- 4 layers, smaller radius,
- Longer buffers, digital R/O,
- CO_2 cooling, new powering
- Less material

CMS Upgrades - phase 2

Germany

- new inner tracker
- new muon trigger

LS3 ~ 2022



new tracking: strips - strixel – pixel

- ongoing R&D within CEC consortium
- Sensor materials and design, radiation & measurement campaign,
- Build module prototype 2 sensors, e.g. Hybrid correlation for testbeam
- DC-DC power converter (as for phase-1)

Myon track trigger: MTT

- Szintillators with SiPM R/O, between HO and Muon system

From P. Schleper

Upgrade Plans LHCb

From U. Uwer

LHCb upgrade-plans:

Luminosity increase for LHCb to >10^{33} $cm^{-2}s^{-1}$ 2.5 events / bunch crossing = 5 x design

Detector readout at 40 MHz, no Hardware-Trigger.

LS2 ~ 2018

Implication for Tracking System

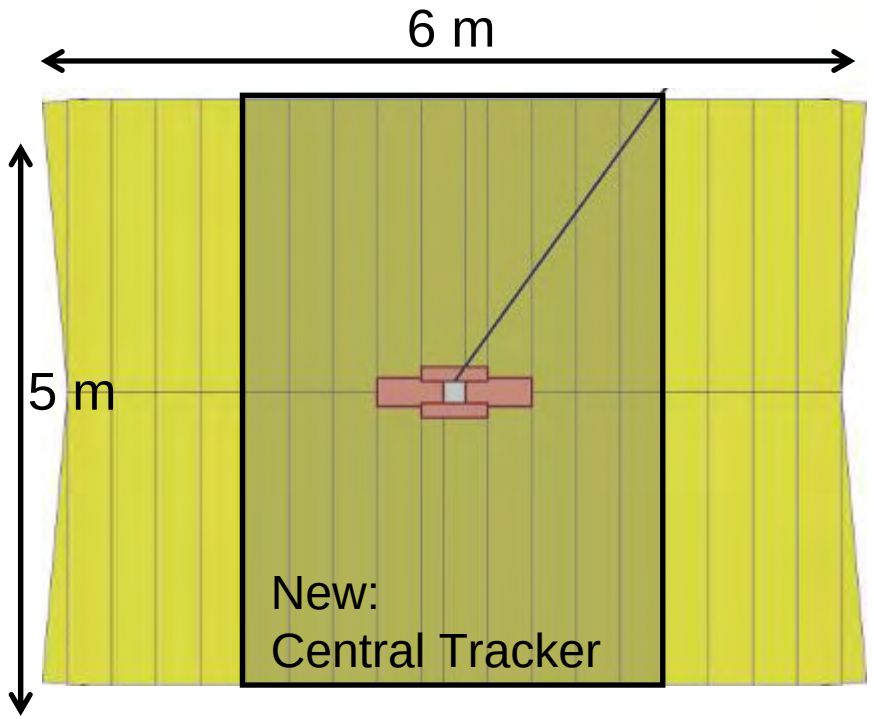
- Granularity in inner part too low:

  New Central-Tracker
  to replace IT and the inner part of OT.

- New 40 MHz Readout-Electronics for remaining OT modules.

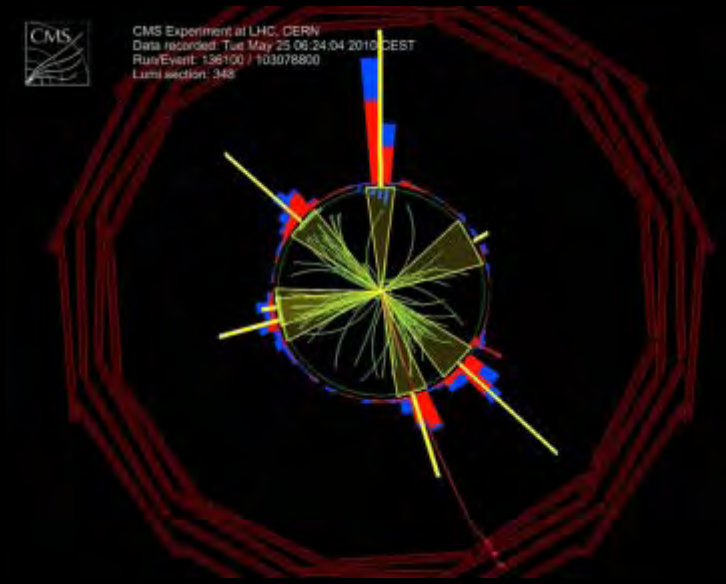
- Proposed Central Tracker:
  Scintillating fibers + SiPM
  (R&D needed to confirm feasibility)

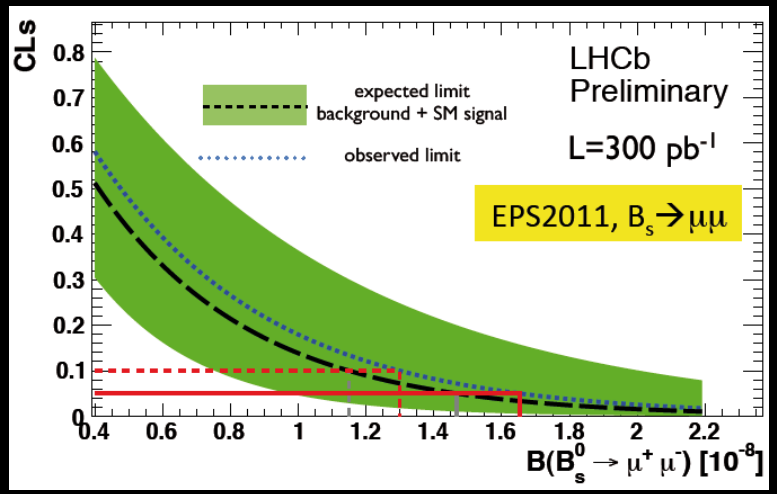
- German groups would like to contribute to Central Tracker and to 40 MHz readout.



Outer Tracker: straw tubes
Inner Tracker: Silicon strips

Summary


CMS Experiment at LHC, CERN
Data recorded: Tue May 25 06:24:04 2010 CEST
Run/Event: 136100 / 103078800
Lumi section: 348

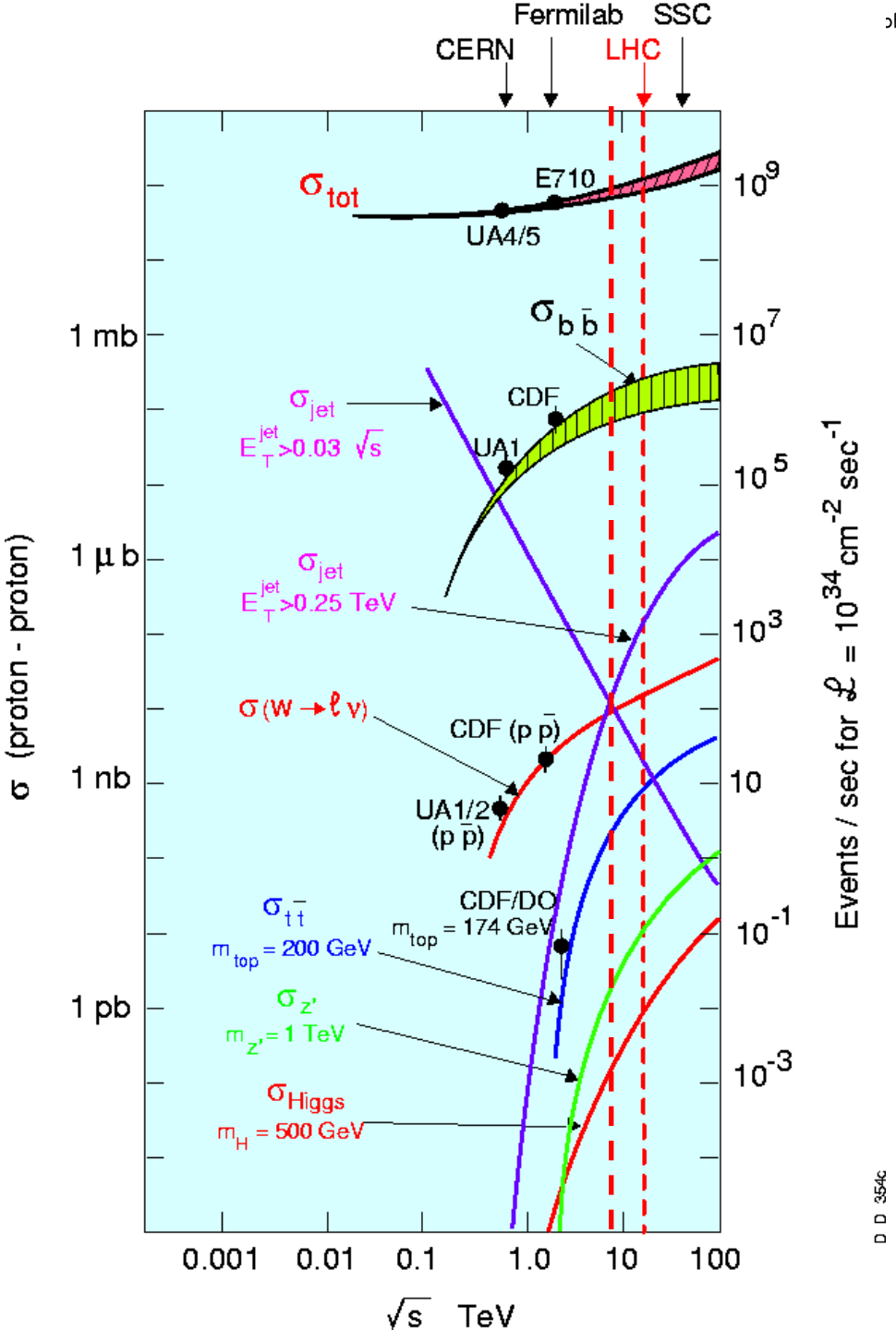

CLs
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
expected limit
background + SM signal
observed limit
LHCb
Preliminary
L=300 pb-1
EPS2011, Bs→μμ
B(B0s → μ+ μ-) [10-8]

APPENDIX

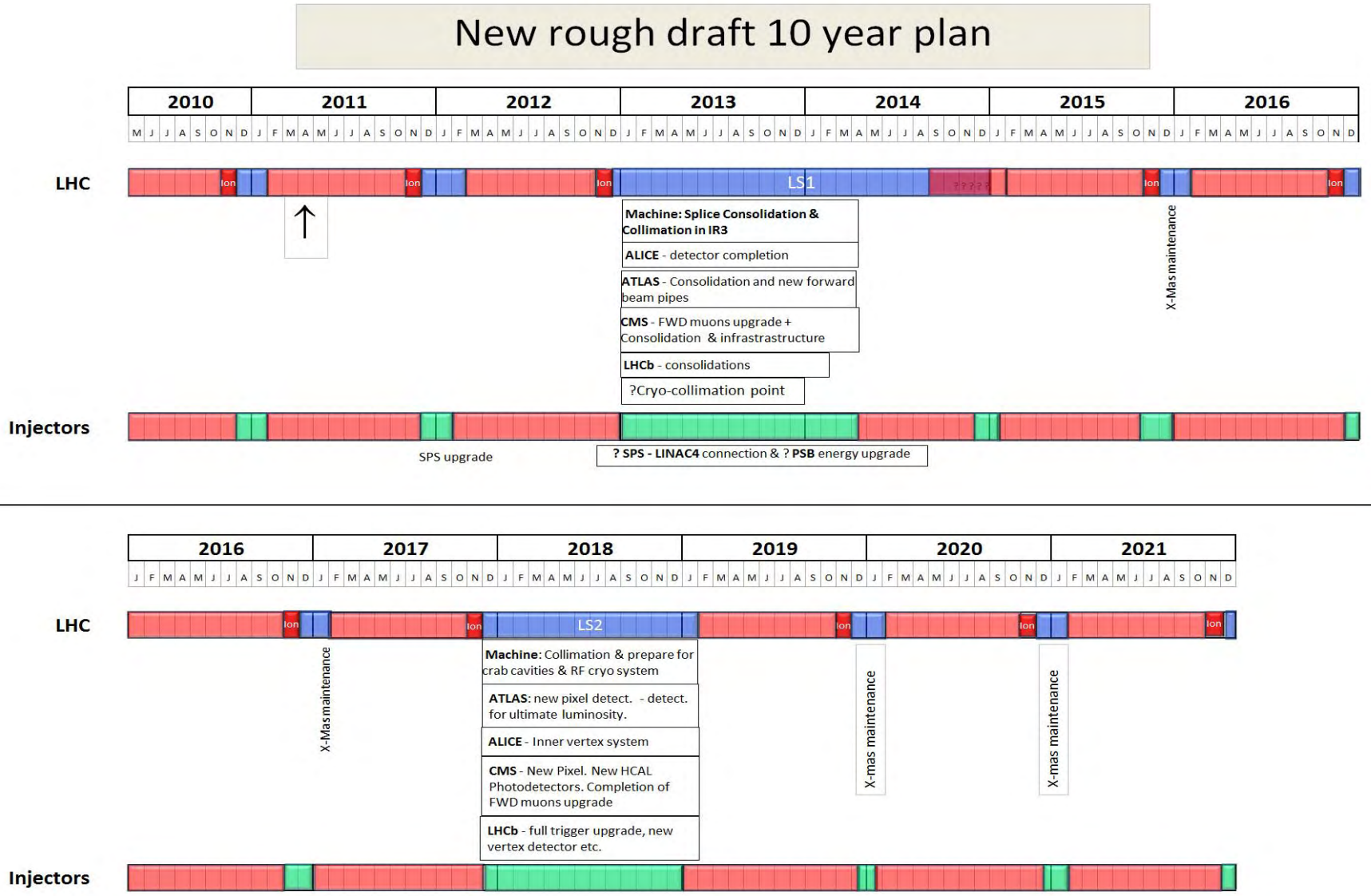
Hadron Collider Physics

SM

Higgs
Supersymmetry
xxx



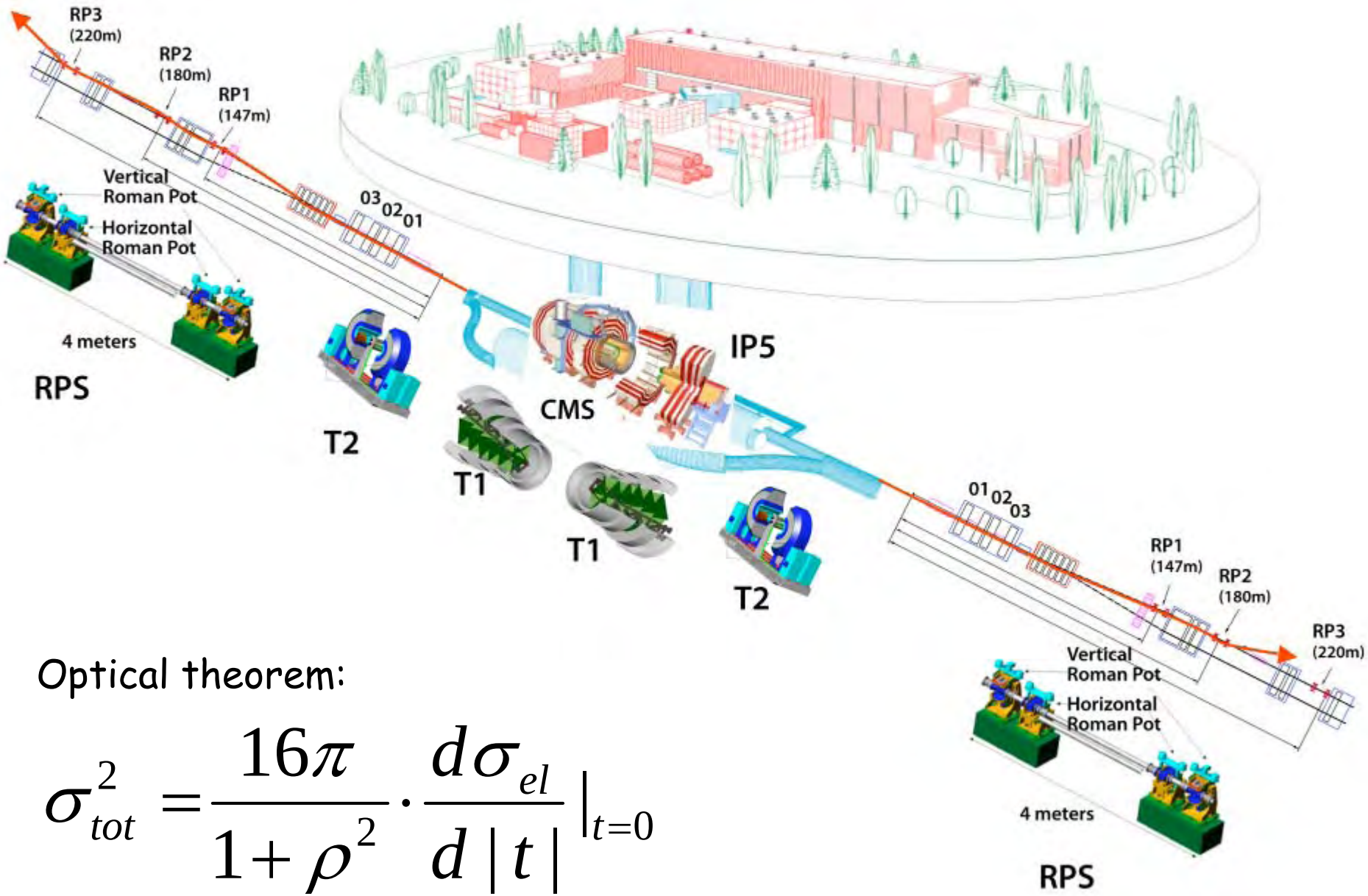
LHC plans



LHCC, Sep. 21 2011, Paul Collier + update

pp cross section (TOTEM)

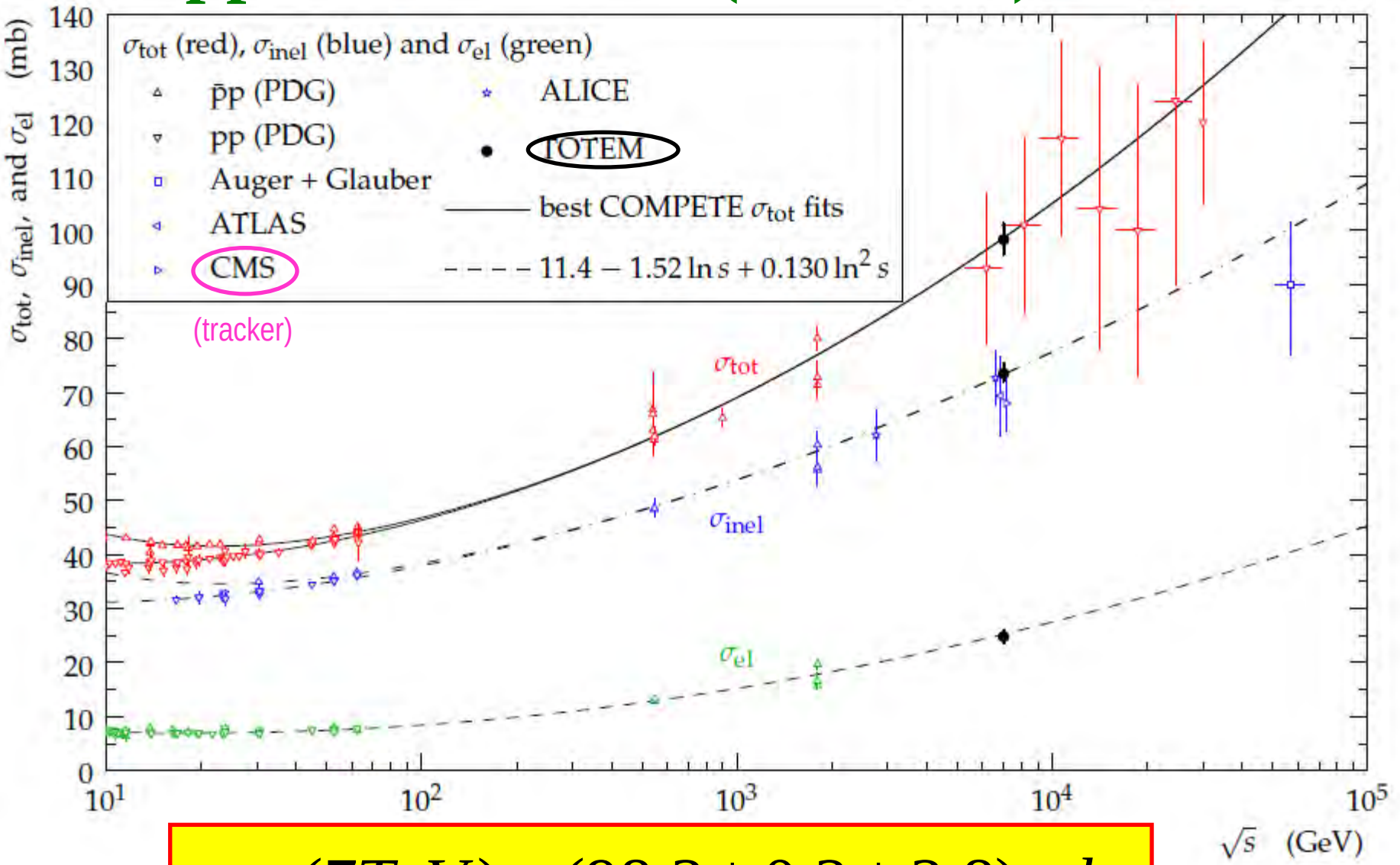
TOTal cross section, Elastic scattering and diffraction dissociation Measurement at the LHC



Optical theorem:

$$\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \cdot \frac{d\sigma_{el}}{d|t|}\Big|_{t=0}$$

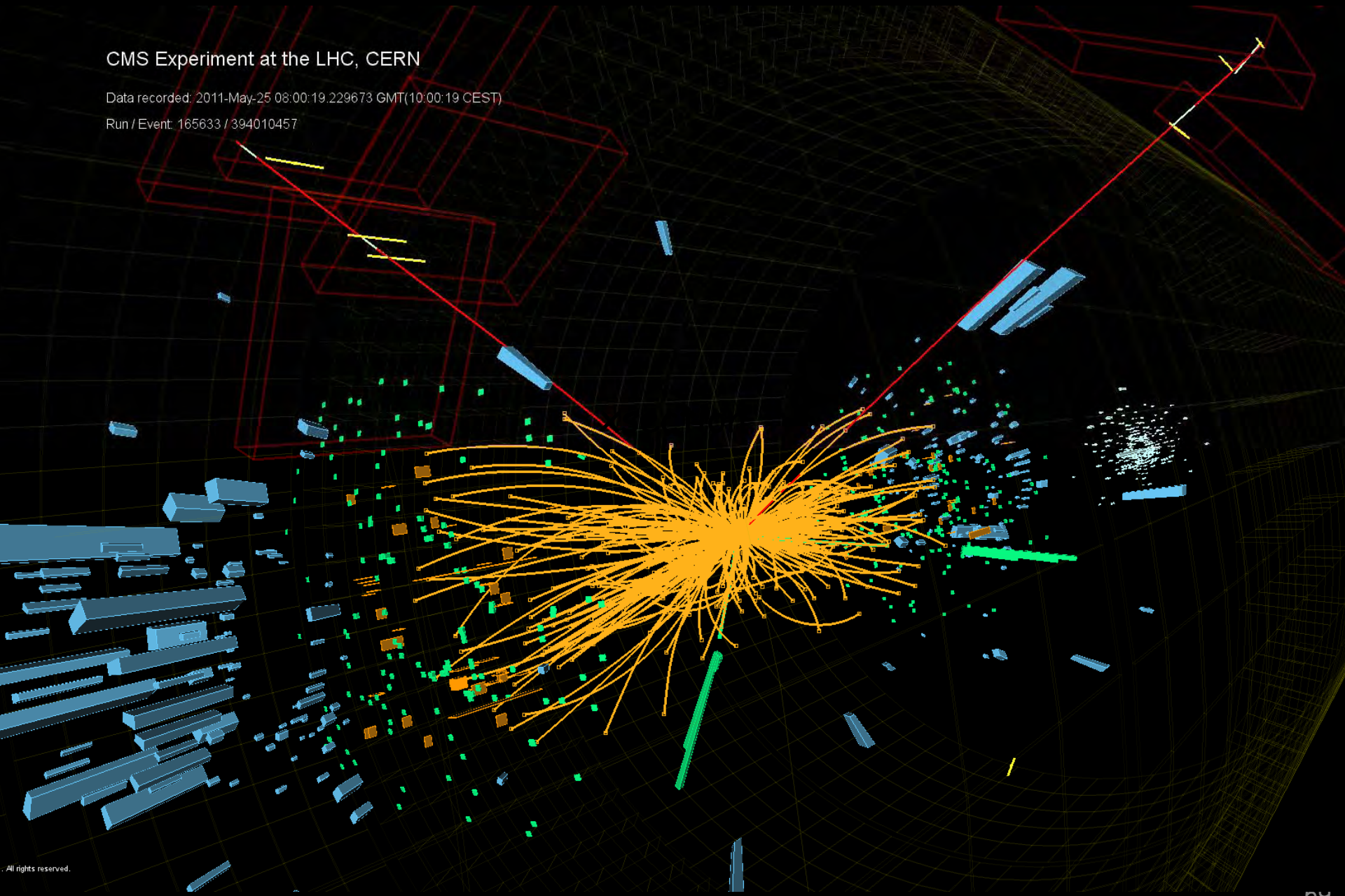
pp cross section (TOTEM)

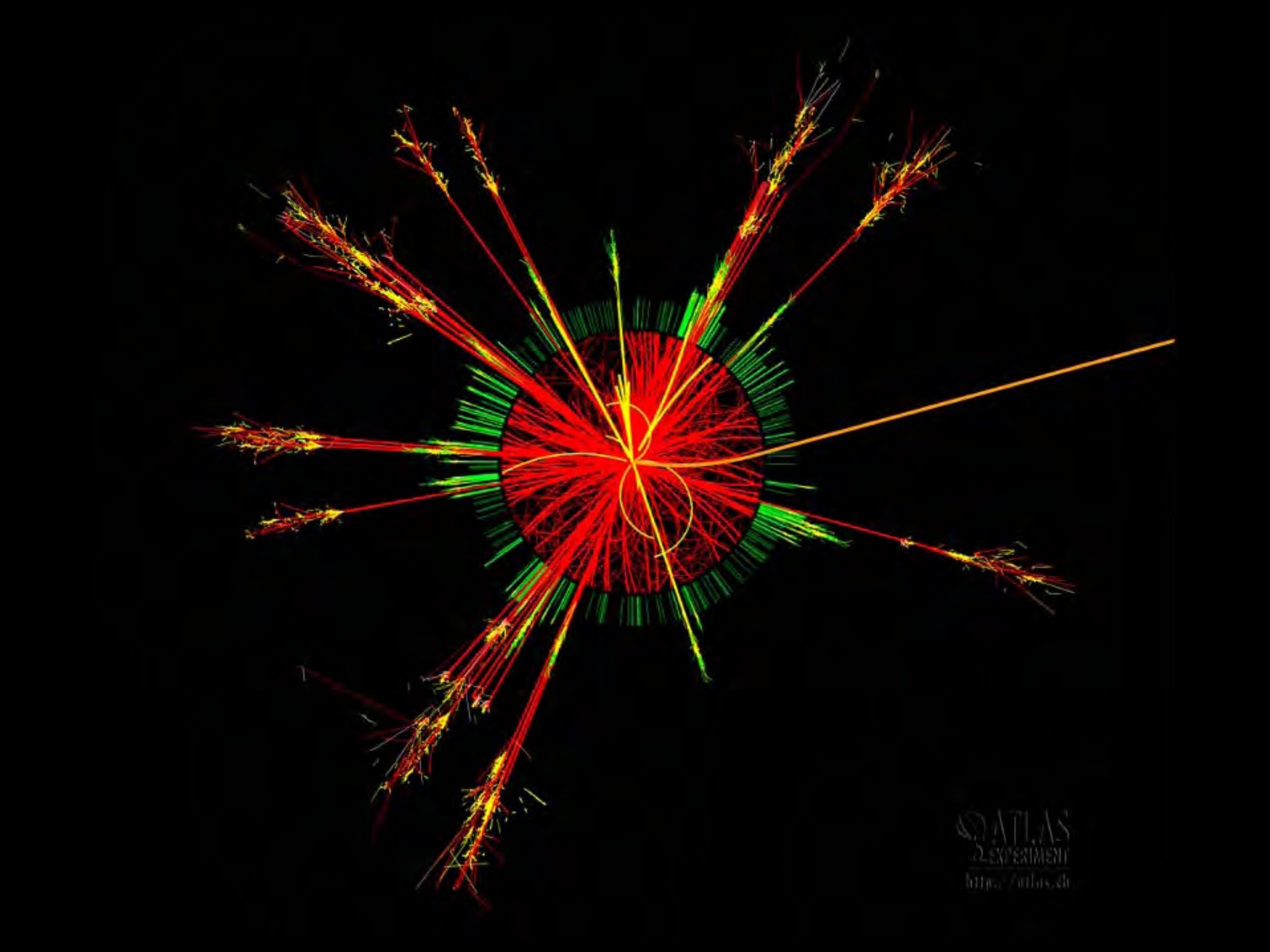


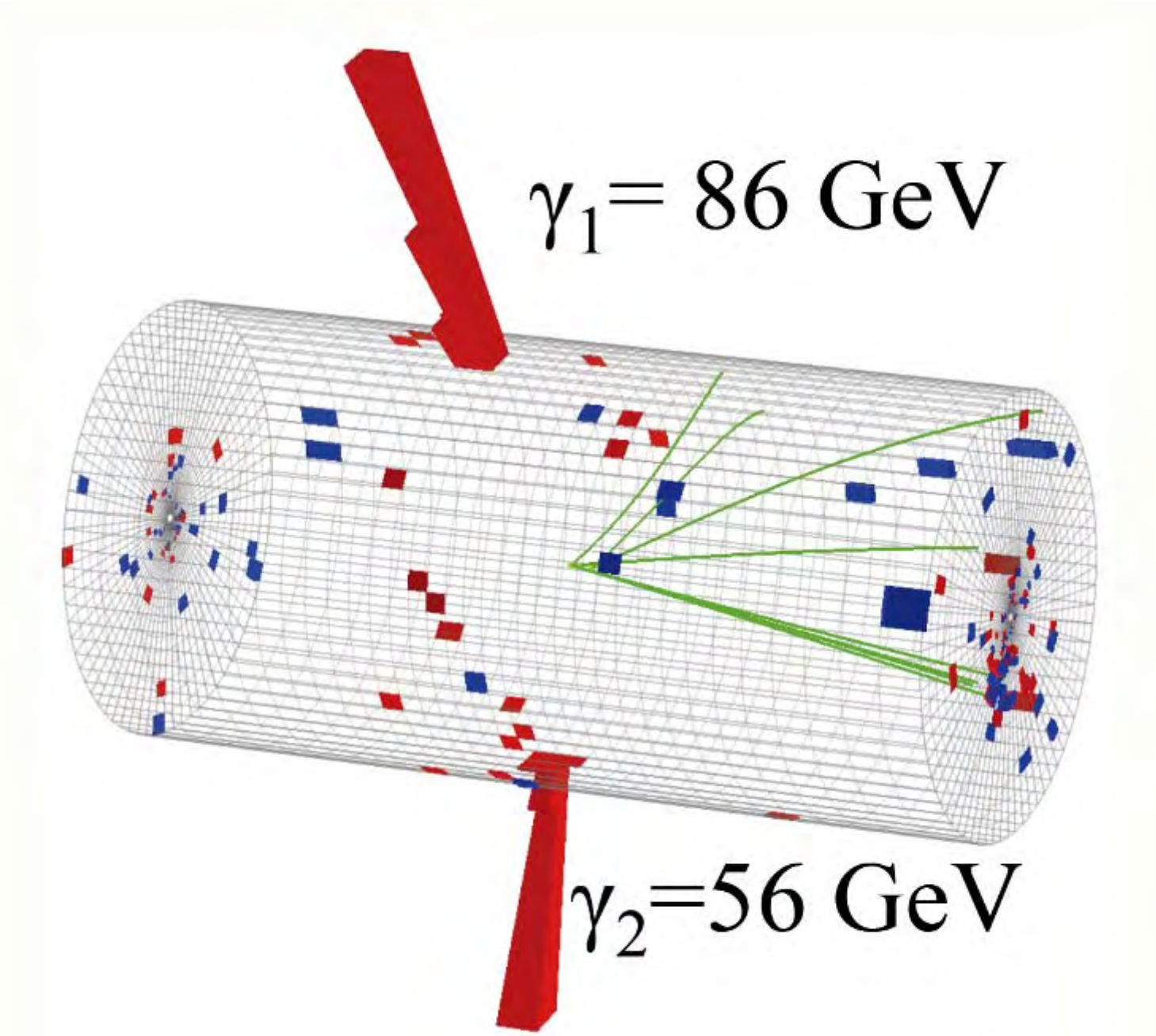
$$\sigma_{tot}(7TeV) = (98.3 \pm 0.2 \pm 2.8)\, mb$$

(can not be calculated from first principles)

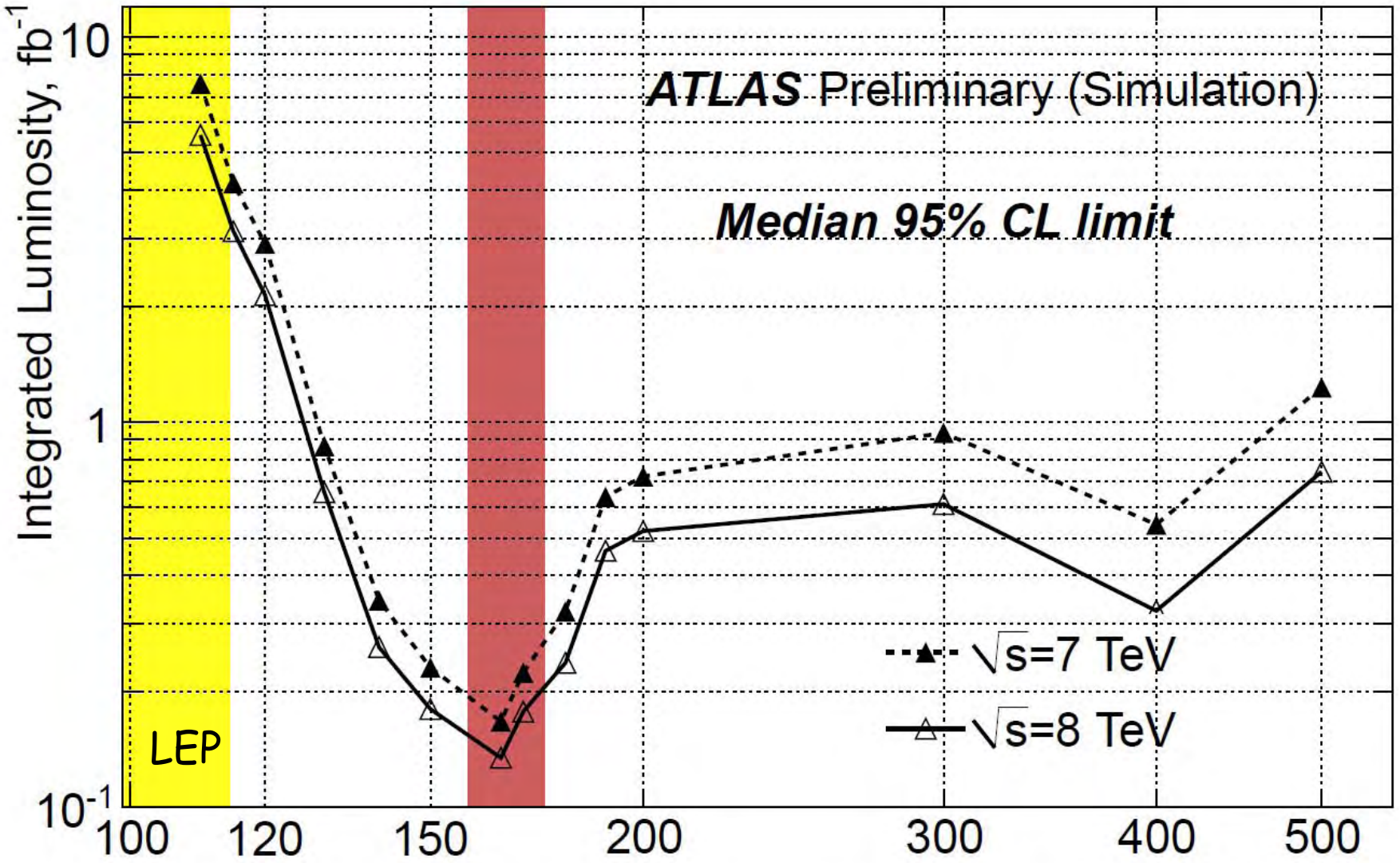
Higgs candidate event




ATLAS
EXPERIMENT


γ_1= 86 GeV
γ_2=56 GeV

SM Higgs prospects - exclusion



2012 – suspense !!!