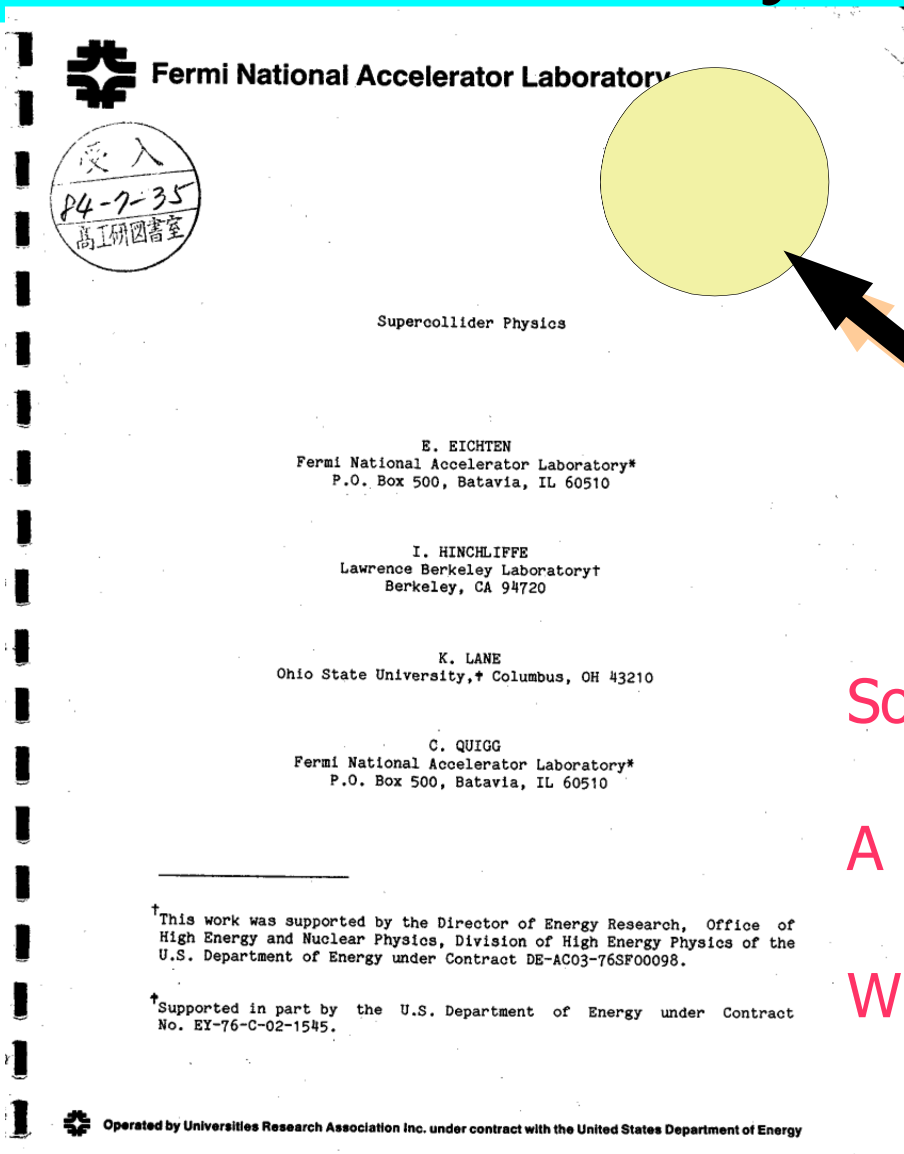
Early Physics at LHC

Ian Hinchliffe
LBNL
SLAC Summer Institute

Thanks to ATLAS and CMS (Plots are from both)

Delays, delays.....


Fermi National Accelerator Laboratory

Supercollider Physics

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Unfortunately this paper was not rendered obsolete yet.

Some of us have waited a while!

A bit more delay we can live with!

When was t=0? 1982? 1988?

Physics marched on.....

- **W/Z measured**
- **Top found**
- **SM proved correct at quantum level**
- **CKM accounts for CP violation**

No big surprises but a huge achievement for both theory and experiment

- Individual lepton number not conserved
- Dark matter/energy

Unexpected, don't fit comfortably in Standard Model

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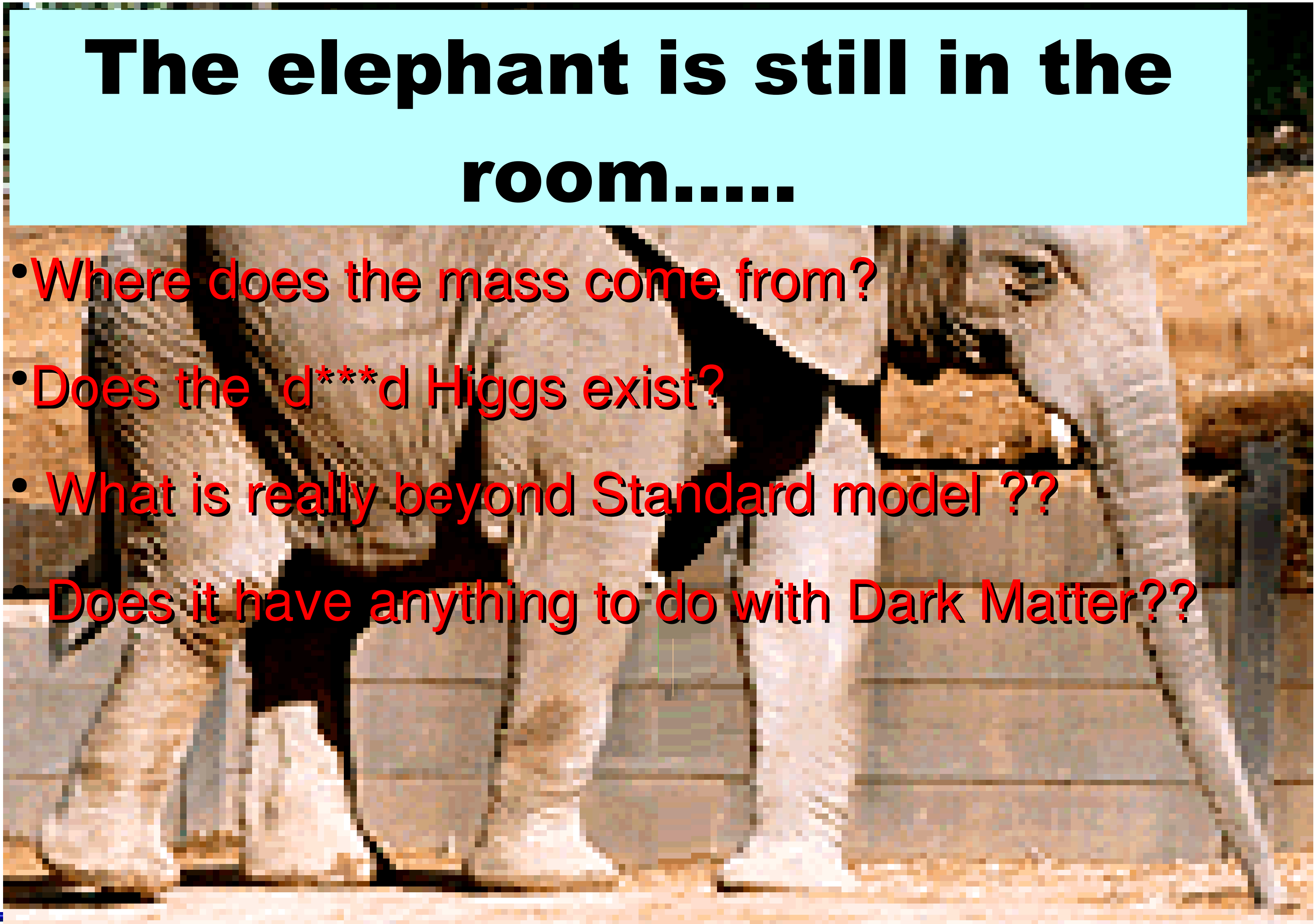
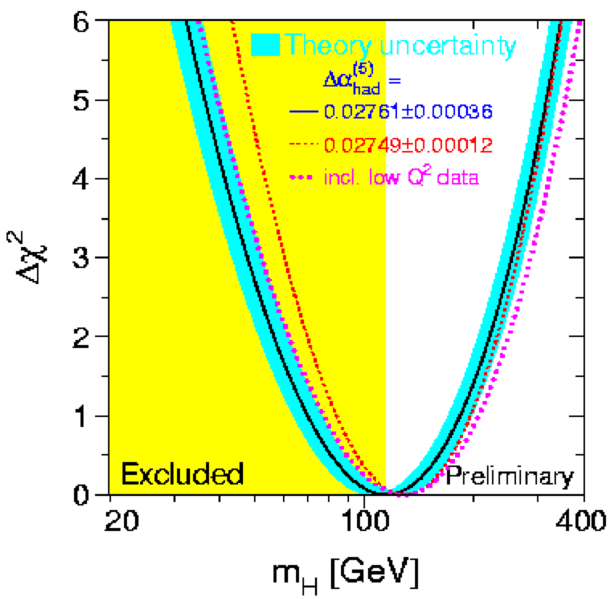
The elephant is still in the room.....



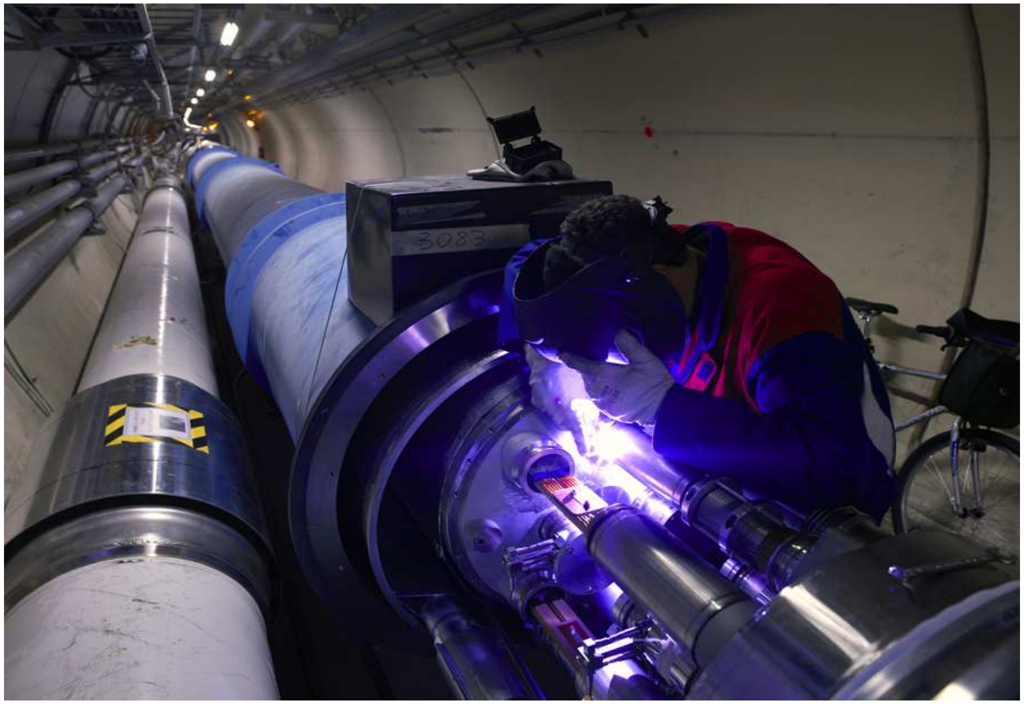
- Where does the mass come from?
- Does the d***d Higgs exist?
- What is really beyond Standard model ??
- Does it have anything to do with Dark Matter??

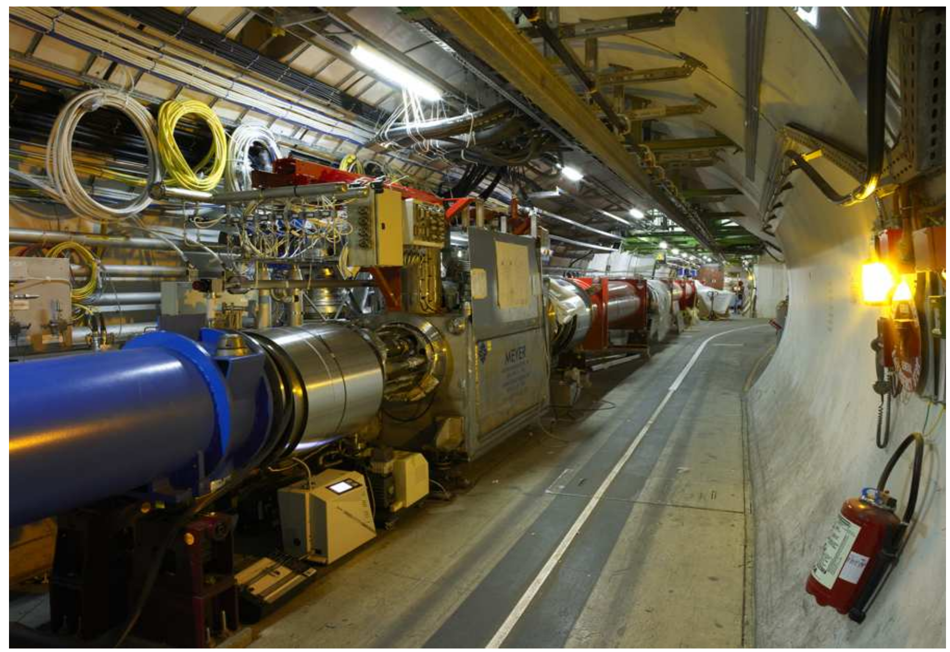
We looked for this Holy Grail...

- Not found at LEP
- Not found (yet) at Tevatron
- Tevatron could still find it???
- The end is in sight. SM dead if LHC doesn't get it



LHC status



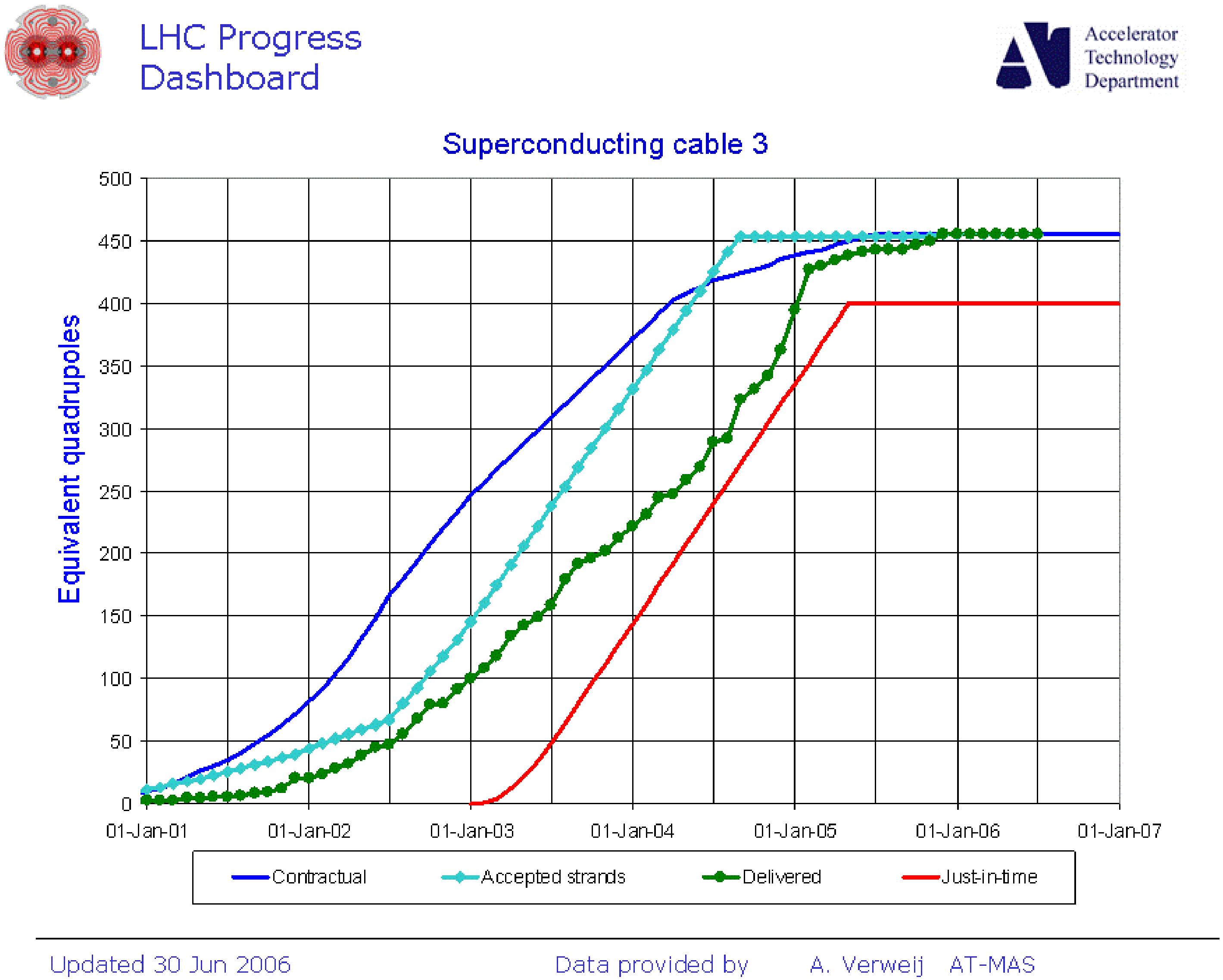


LHC status

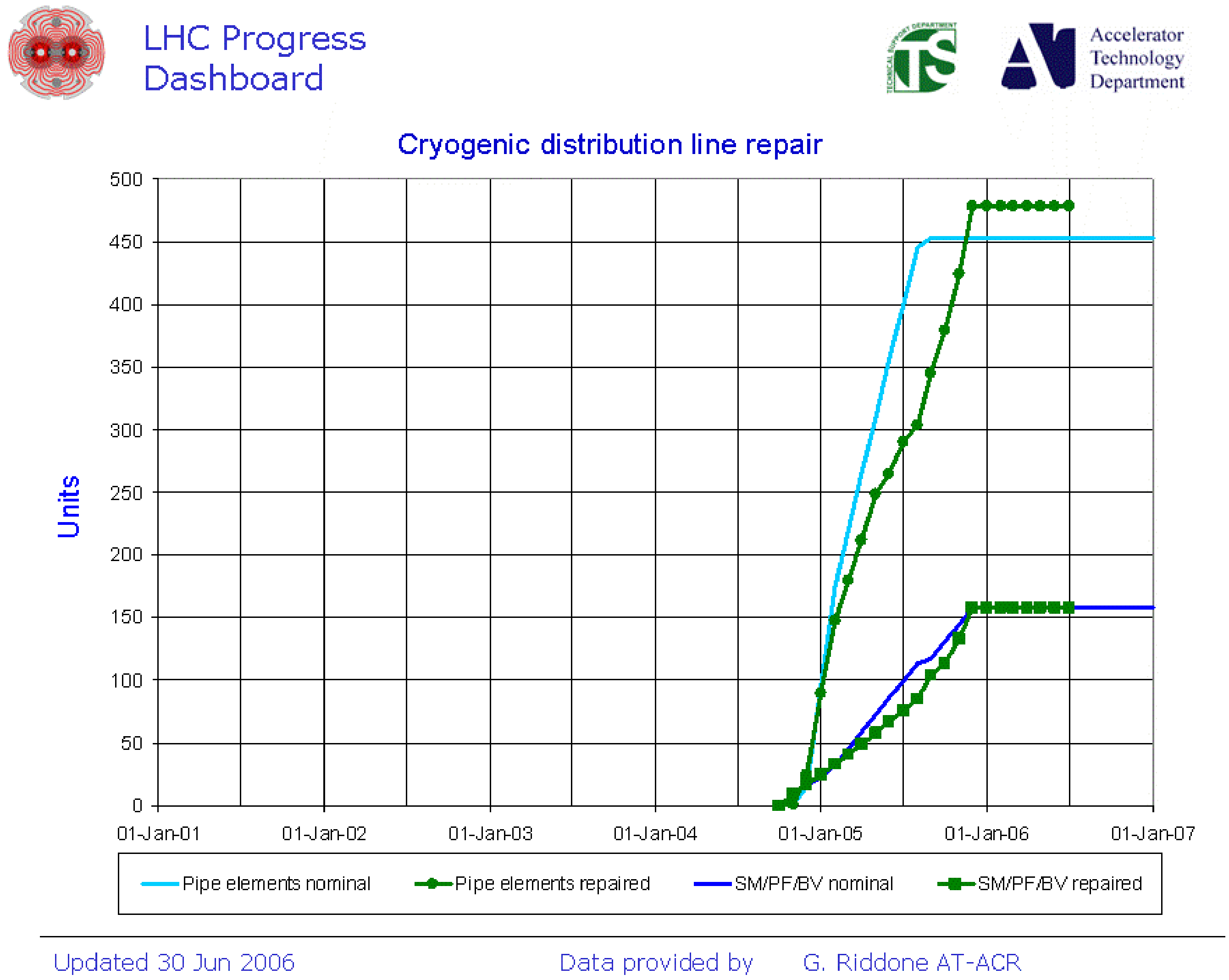
Underground

L.R. Evans

Dashboard (1)


LHC Progress
Dashboard
Accelerator
Technology
Department
Superconducting cable 3
Equivalent quadrupoles
500
450
400
350
300
250
200
150
100
50
0
01-Jan-01
01-Jan-02
01-Jan-03
01-Jan-04
01-Jan-05
01-Jan-06
01-Jan-07
Contractual
Accepted strands
Delivered
Just-in-time
Updated 30 Jun 2006
Data provided by A. Verweij AT-MAS

Dashboard (2)

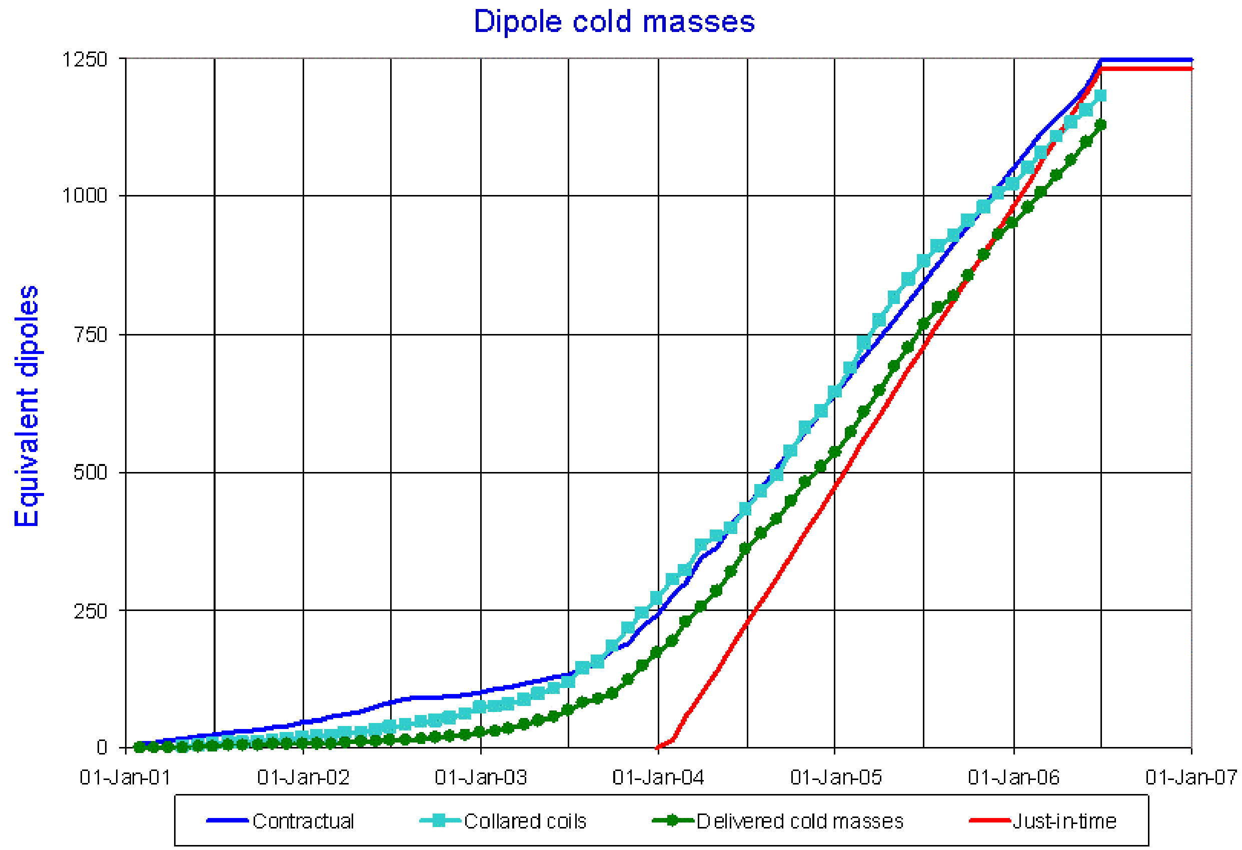


Last years panic!

Dashboard (3)

LHC Progress Dashboard

Accelerator Technology Department



Updated 30 Jun 2006 Data provided by F. Savary AT-MAS

Reporting - Installed magnets in LHC

	R					L					Total				
	Cryo-magnets			DFB + others	Total	Cryo-magnets			DFB + others	Total	Cryo-magnets			DFB + others	Total
	Dipoles	SSS	LSS			Dipoles	SSS	LSS			Dipoles	SSS	LSS		
Secteur 1-2					**0**					**0**	0	0	0	0	**0**
Secteur 2-3					**0**					**0**	0	0	0	0	**0**
Secteur 3-4	16	10			**26**	76	11			**87**	92	21	0	0	**113**
Secteur 4-5	76	21			**97**	75	24			**99**	151	45	0	0	**196**
Secteur 5-6					**0**	4	3			**7**	4	3	0	0	**7**
Secteur 6-7					**0**					**0**	0	0	0	0	**0**
Secteur 7-8	77	24		1	**102**	77	27	8	4	**116**	154	51	8	5	**218**
Secteur 8-1	77	26	6	3	**112**	77	23	4	1	**105**	154	49	10	4	**217**
LHC											555	169	18	9	**751**
Cryo-magnets													**742**		

Prepared by Pascal Ponsot TS-IC 14/06/2006 11:52

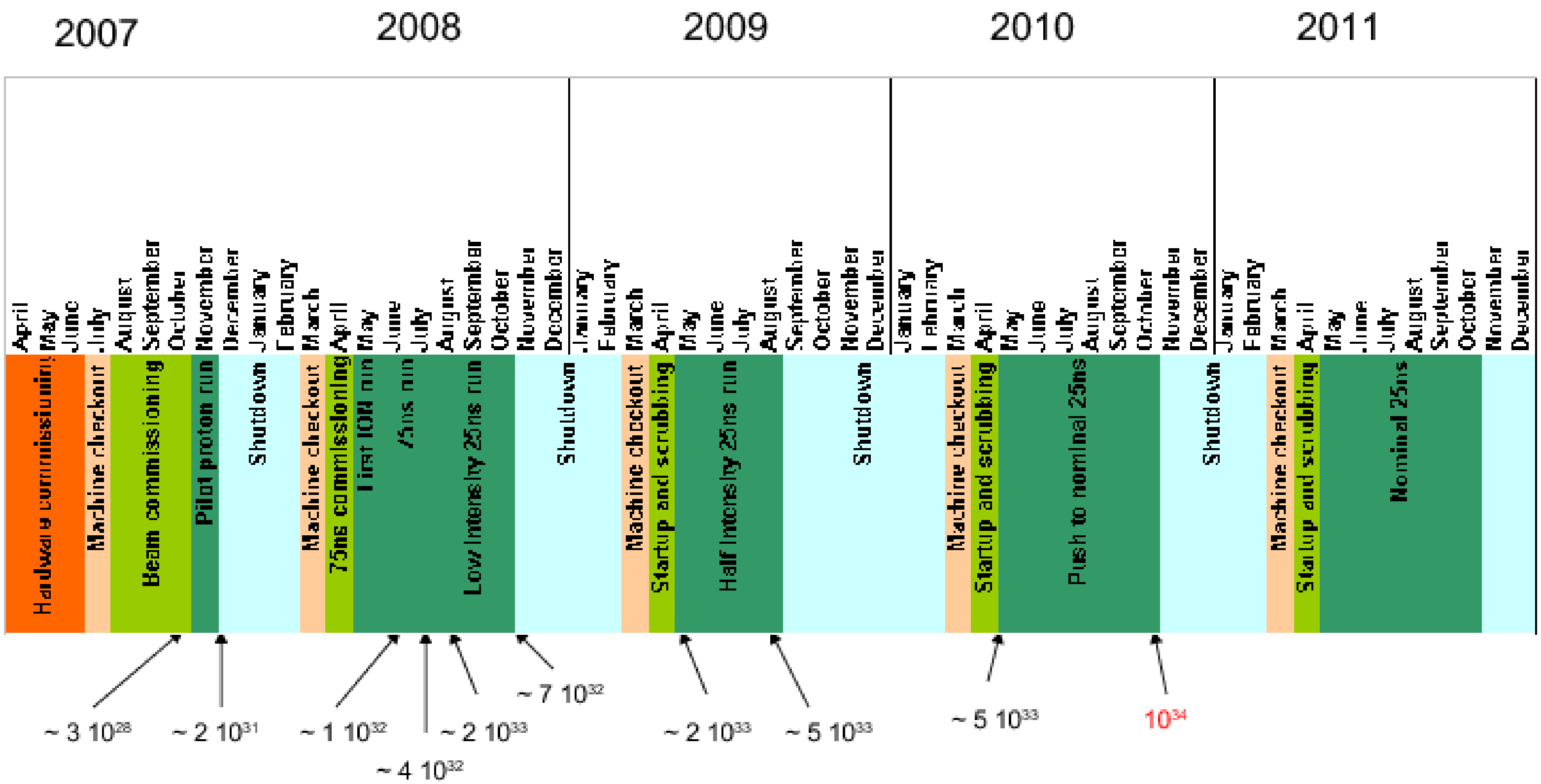
Schedule

- Sectors 7-8 and 8-1 will be fully commissioned up to 7 TeV in 2006-2007. If we continue to commission the other sectors up to 7 TeV, we will not get circulating beam in 2007.
- The other sectors will be commissioned up to the field needed for de-Gaussing.
- Initial operation will be at 900 GeV (CM) with a static machine (no ramp, no squeeze) to debug machine and detectors.
- Full commissioning up to7 TeV will be done in the winter 2008 shutdown

From J Engelen, CERN

Translation ?

- Low luminosity at 900 GeV at end 2007: Start debugging detectors
- Some months at beginning of 2008 to commission remaining LHC components
- 14 TeV Physics run in 2008. Significant luminosity is expected
- "Low luminosity" achieved (2 10**33)
- Operation in this mode
- Ramp up to full luminosity in 2010?
- A straw man run plan is shown on next page



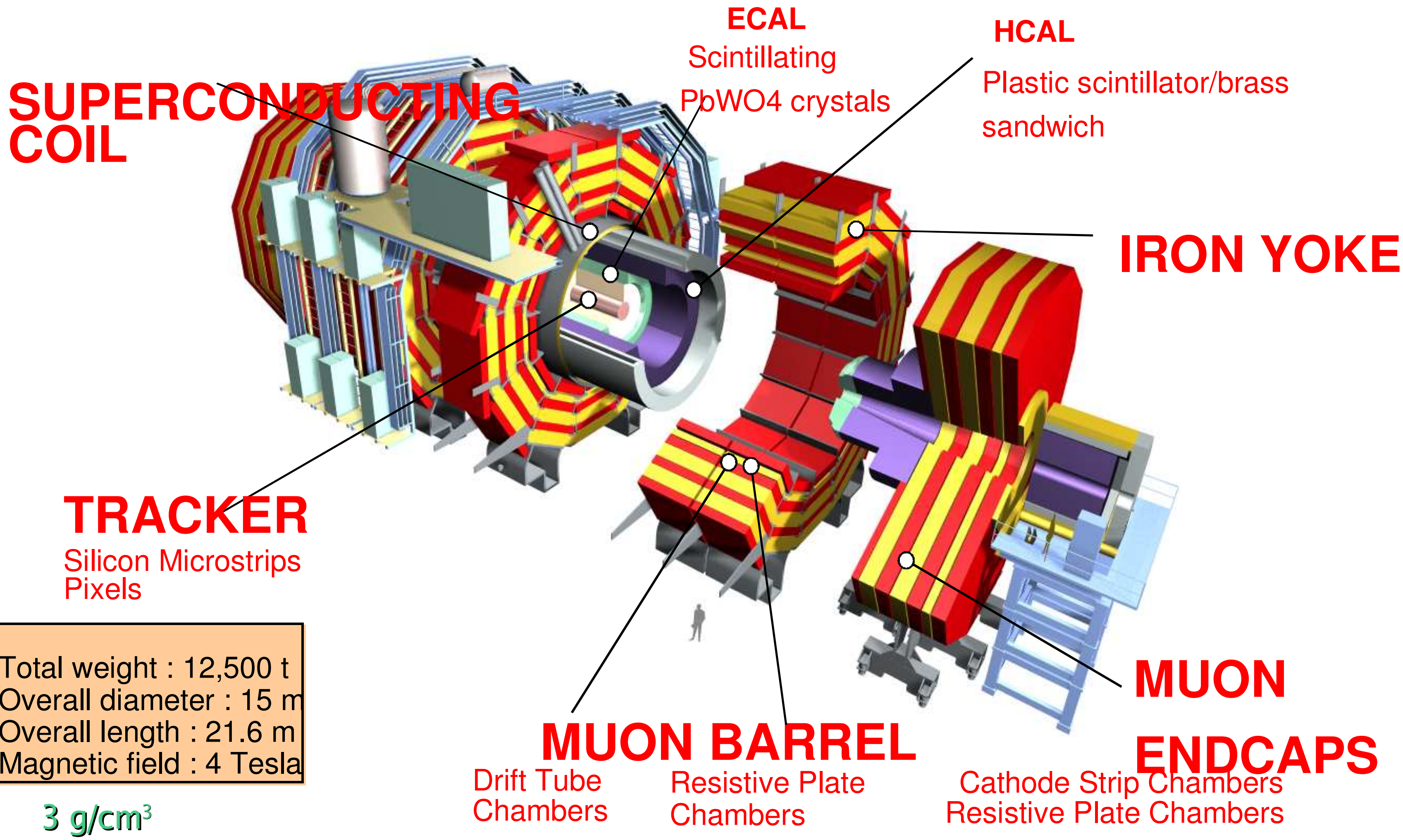
From R Bailey, predates recent delay

We need the detectors to do physics

-
- CMS and Atlas for High Pt (mainly)
- LHCb for B-physics
- ALICE for heavy Ions

See status talks from Crakow LHC meeting. Some highlights follow

CMS



Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

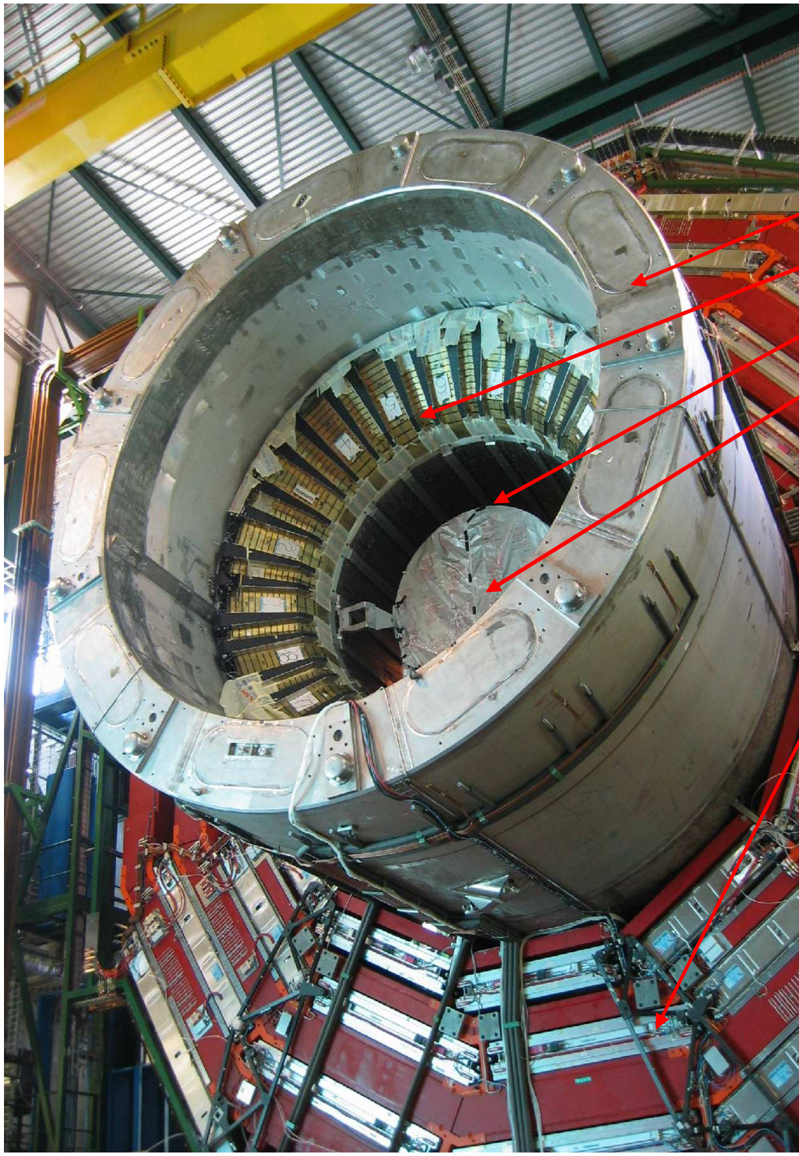
3 g/cm^3

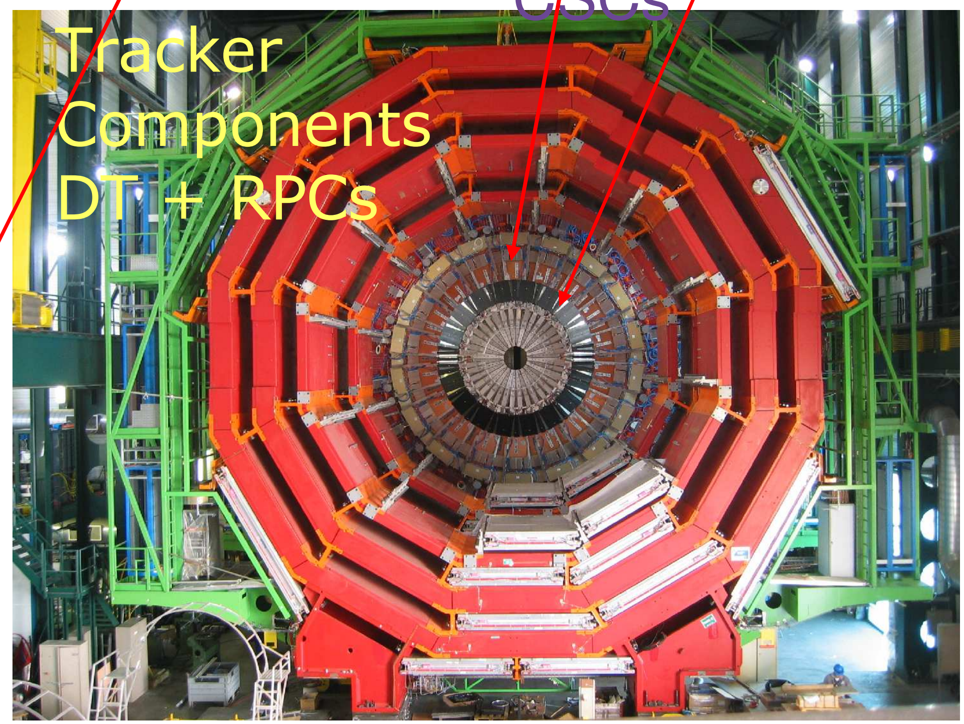
CMS Assembly at Point 5 for Slice Test

Magnet Test and Detector Test - Jul-Aug06

Solenoid is cold
HB inserted in coil
2 ECAL SM
Tracker Components
DT + RPCs

HCAL Endcap CSCs





CMS status

The 4 Tesla s.c. coil is now cold, at liquid He temperature 4.5K.

Tracker assembly progressing well. All parts (~220 m^2 of Si sensors) expected to be installed in Support Tube (by end06) for final commissioning and then transport to Point 5. TIB/TID+ Delivered to CERN on 14 June

83% of barrel crystals delivered. 27/36 bare Supermodules (1700 xtals) assembled. First half barrel integrated with electronics. Instal 30 SM into HB before lowering. Endcap ECAL will be installed for 2008 physics run.

Over 3 out of 5 wheels worth of DT/RPC packages installed. > 90% of CSCs installed on endcap disks. Half of endcap RPCs installed.

Commissioning with cosmics of large sub-parts (systems tests) has started.

Cosmics have been recorded for all sub-detectors: TK, ECAL, HCAL and Muon system. Test a full slice of CMS in July-Sep 06.

Start lowering disks and wheels in Oct06.

Engelen, Dobrzynski

Beam pipe in place by 31 Aug 2007 and ready to close for pilot physics run.

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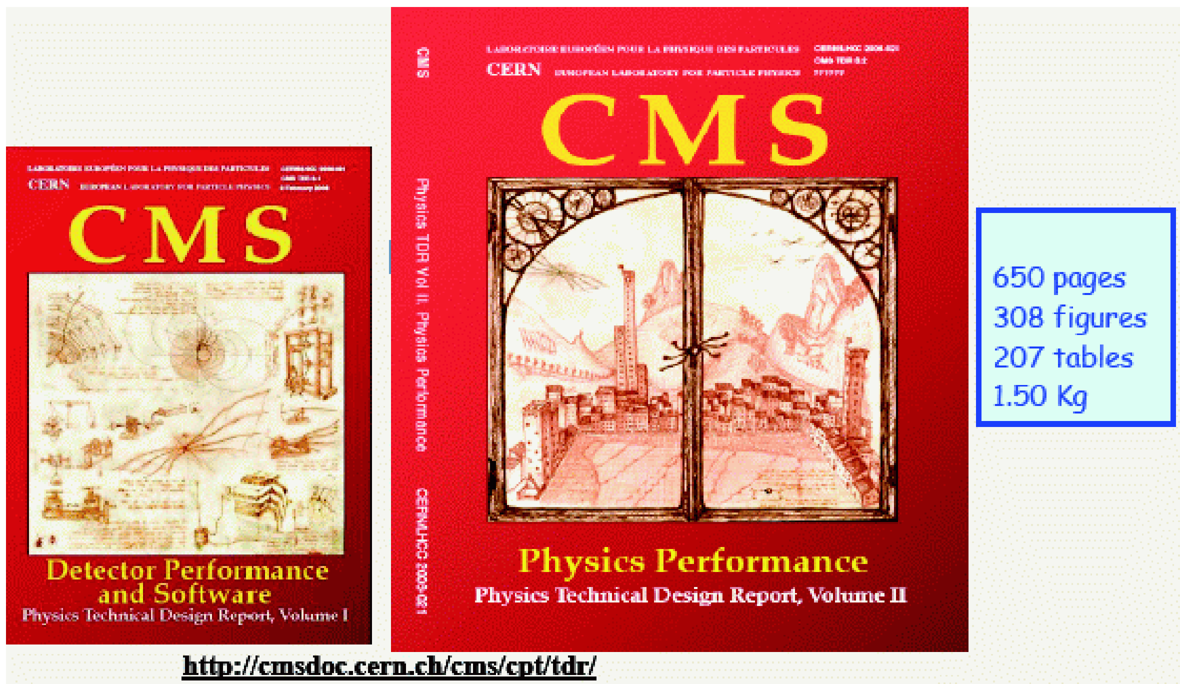
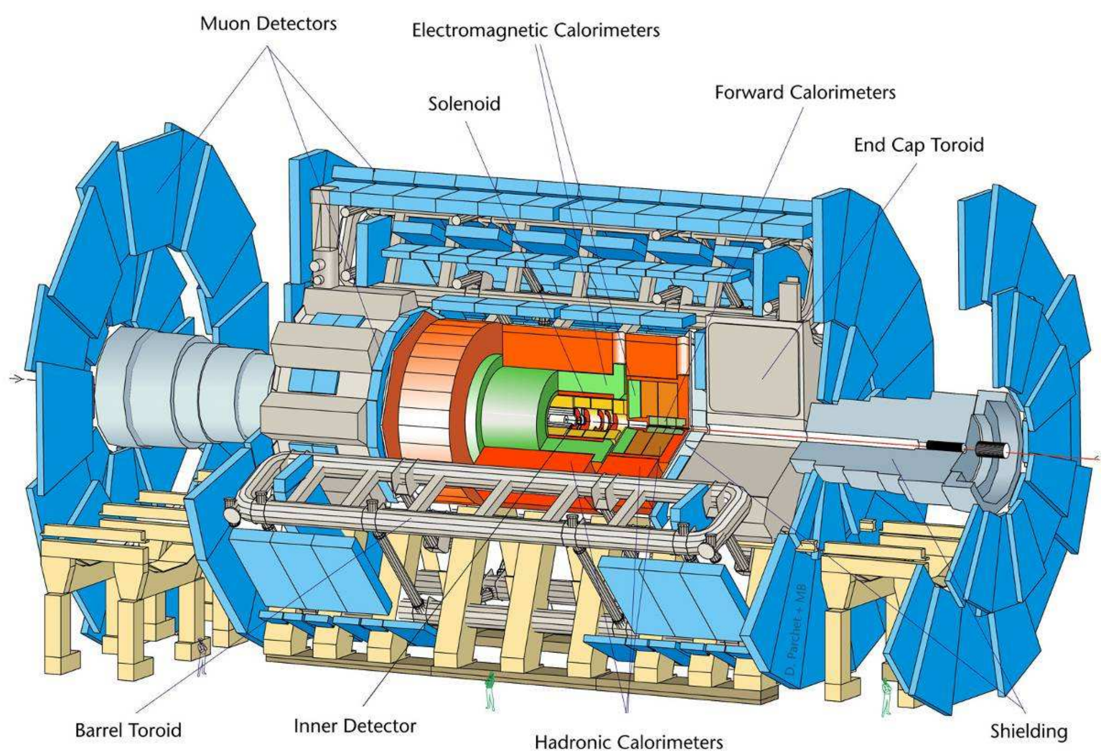
CMS status (3)

- Physics TDR available now. Ideal summer vacation reading!

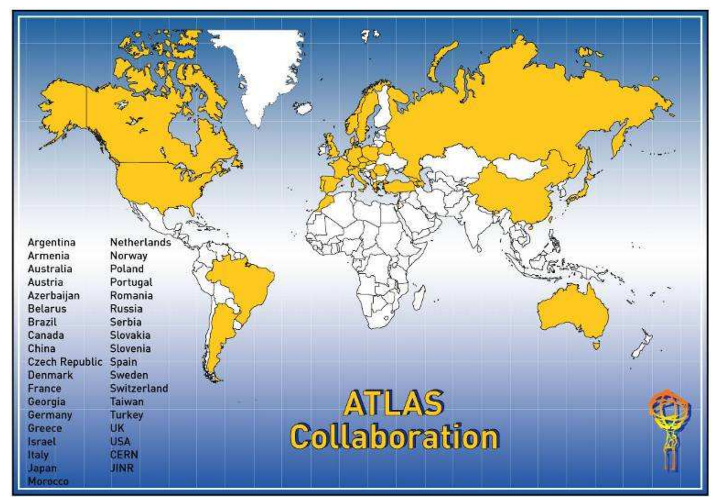
http://cmsdoc.cern.ch/cms/cpt/tdr/

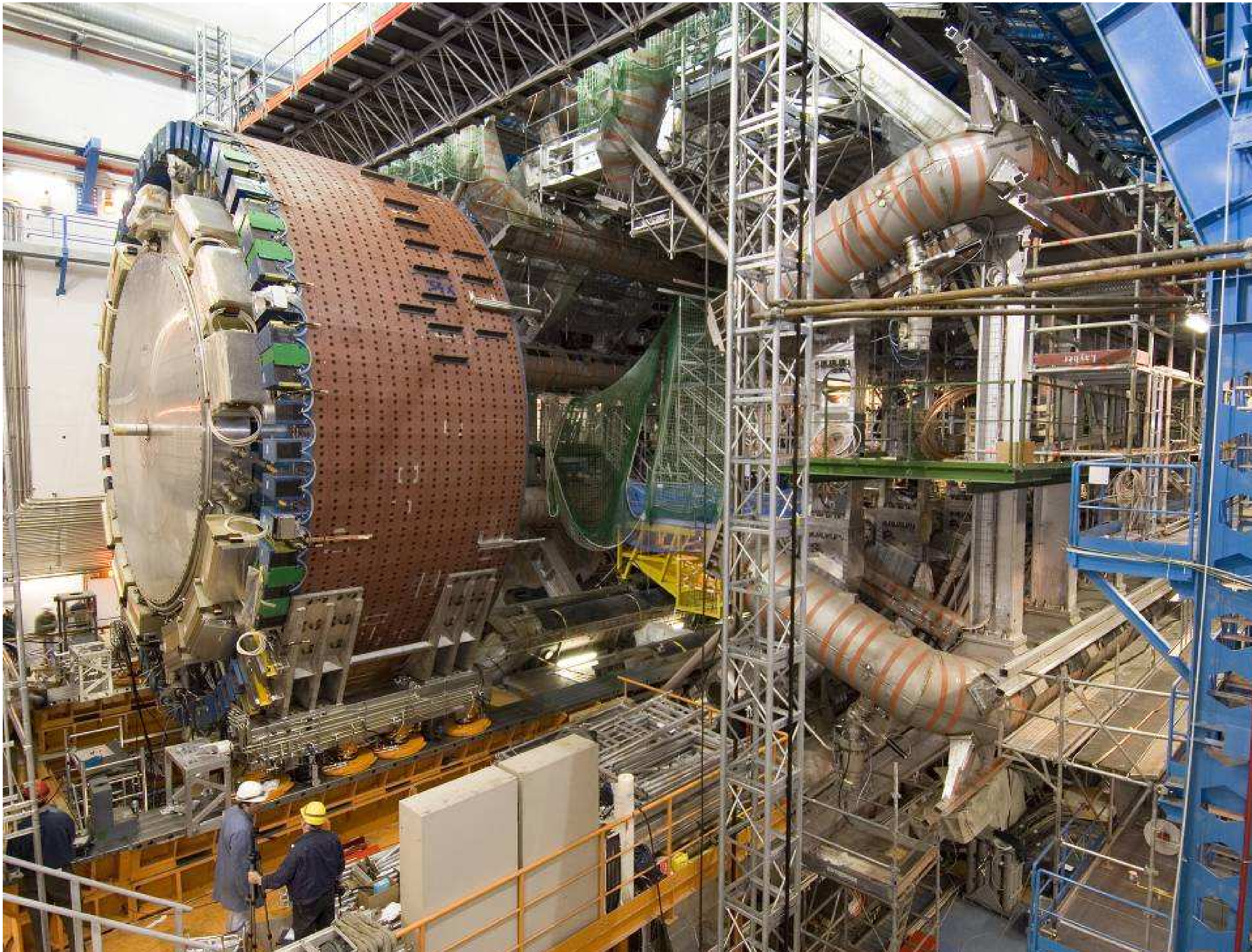


ATLAS

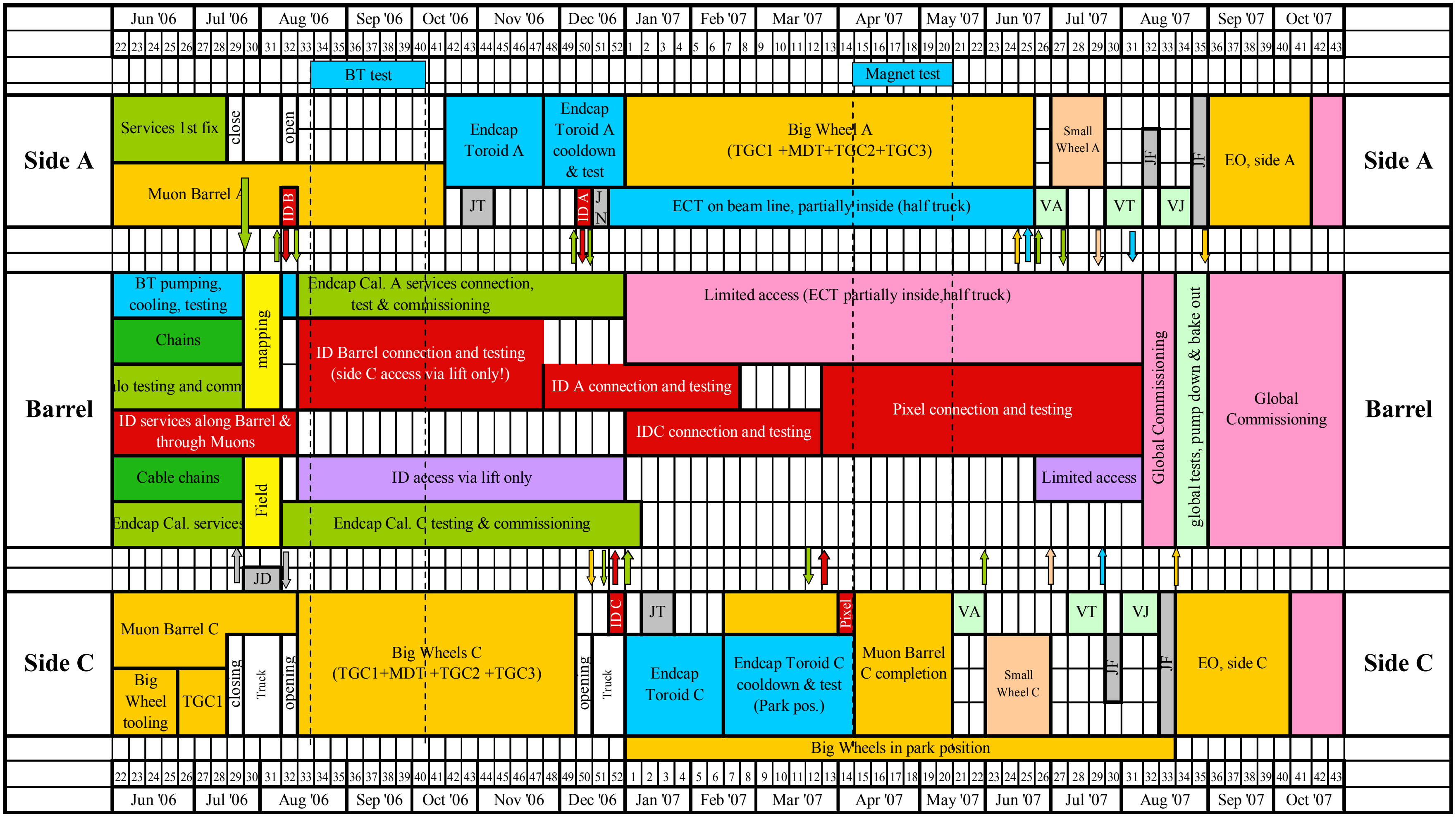


“”Closed ready for beam in August 2007”-- P Jenni

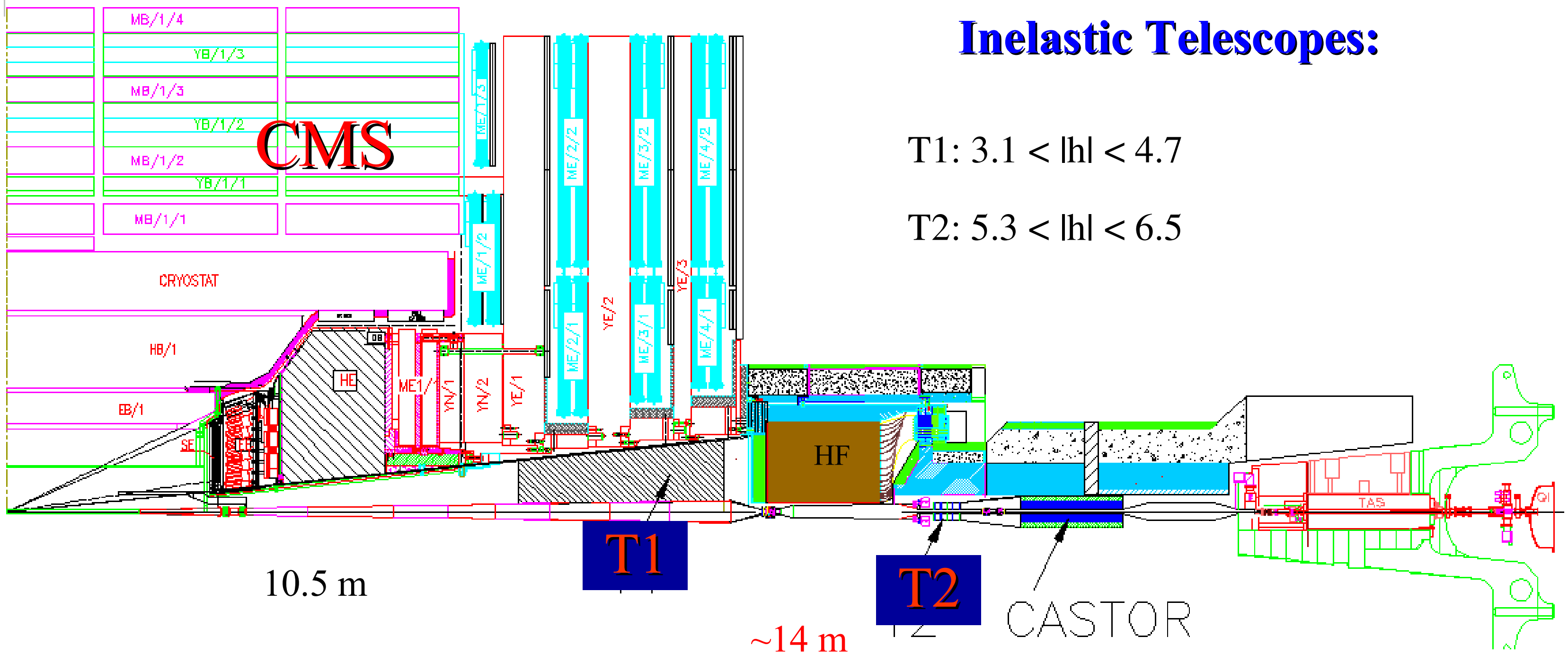




ATLAS schedule



Don't forget TOTEM

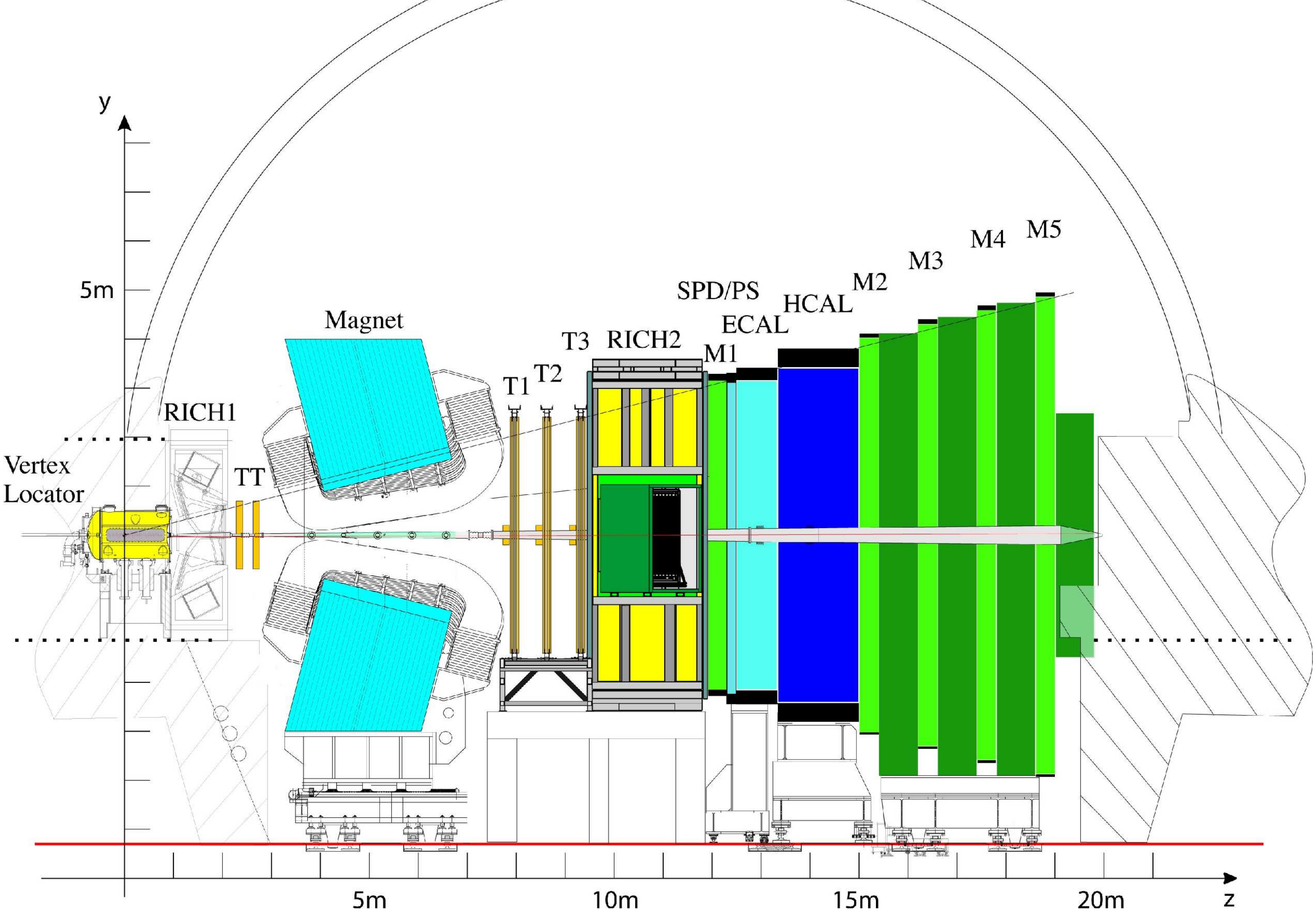


Inelastic Telescopes:

T1: $3.1 < |\eta| < 4.7$

T2: $5.3 < |\eta| < 6.5$

LHCb



y
5m
Magnet
RICH1
Vertex
Locator
TT
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
5m
10m
15m
20m
z

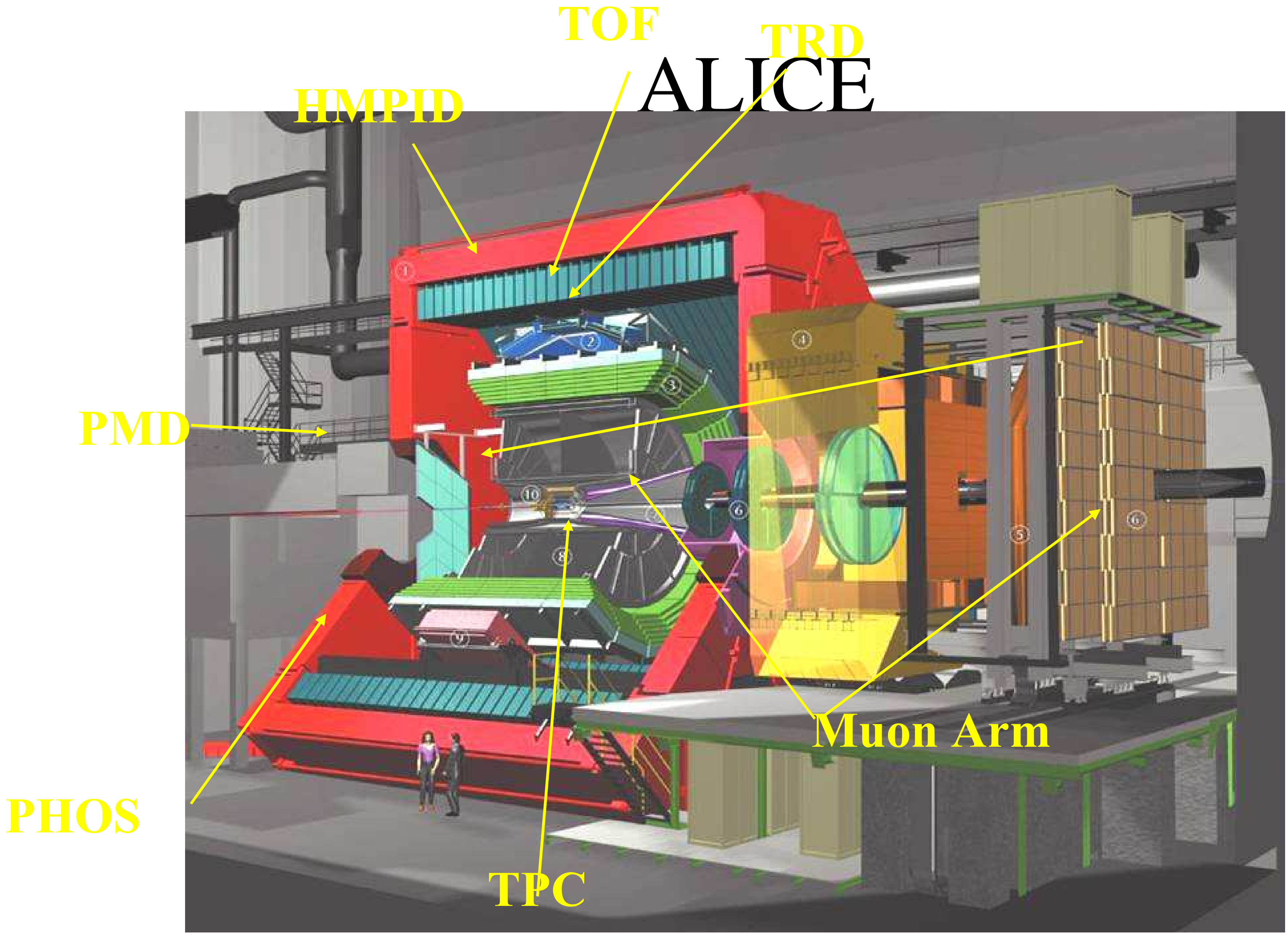
LHCb

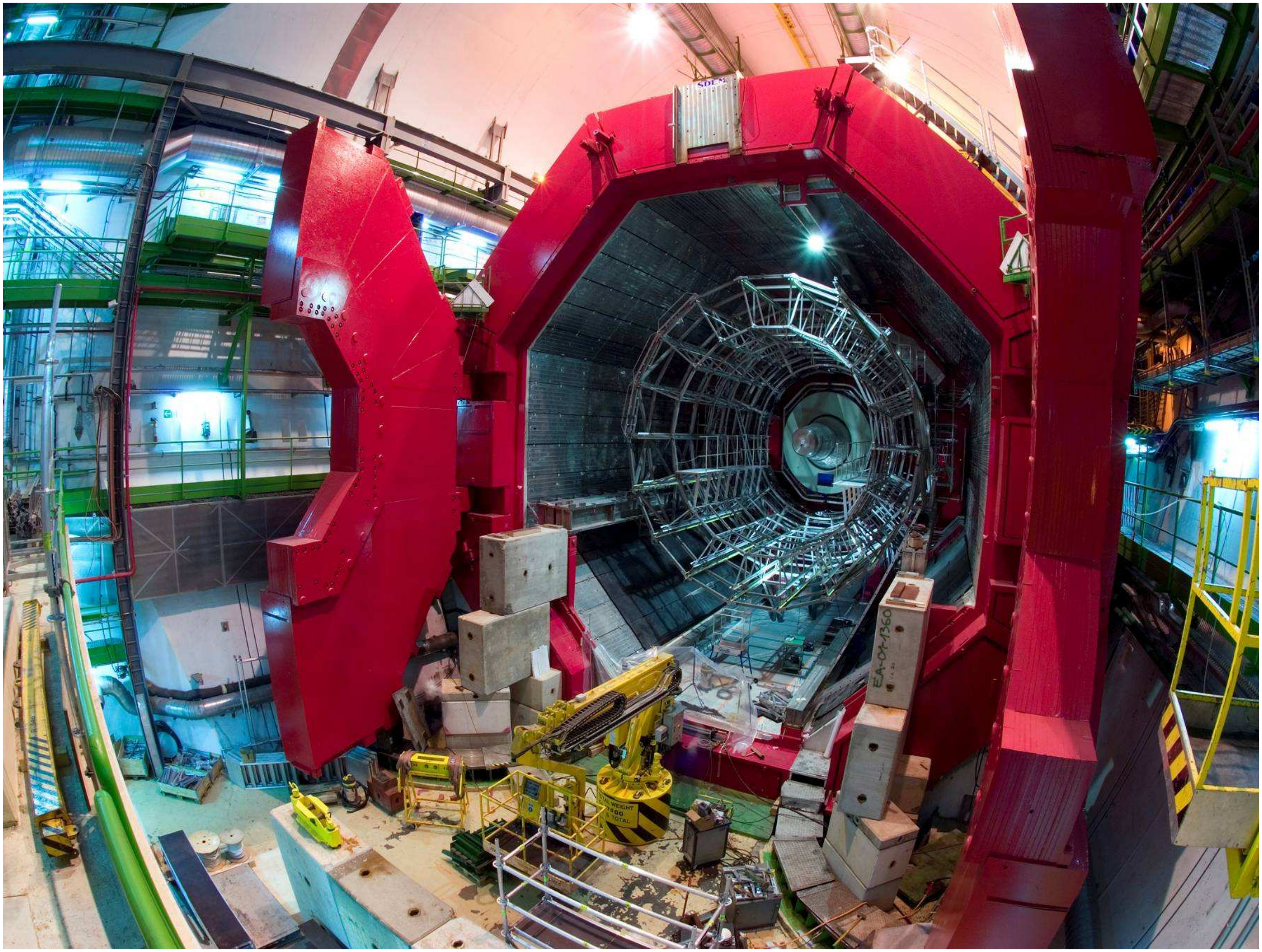
Magnet: commissioned, B field measurement completed
VELO: Vertex Locator
vacuum tank installed, sensor module production started
Outer Tracker:
module construction completed, support structure being installed
Silicon Tracker: Inner Tracker and Trigger Tracker
Si ladder production and support structure construction in progress
RICH: RICH2 mechanics installed, RICH1 shielding box installed
Calorimeters:
Ecal and Hcal modules installed, Preshower ready for installation
Muon:
chamber production progressing, infrastructure in preparation
Trigger:
Level-0 electronics production about to start

Plan to be ready for the first beam collisions

LHCb installation

ALICE





S

ALICE

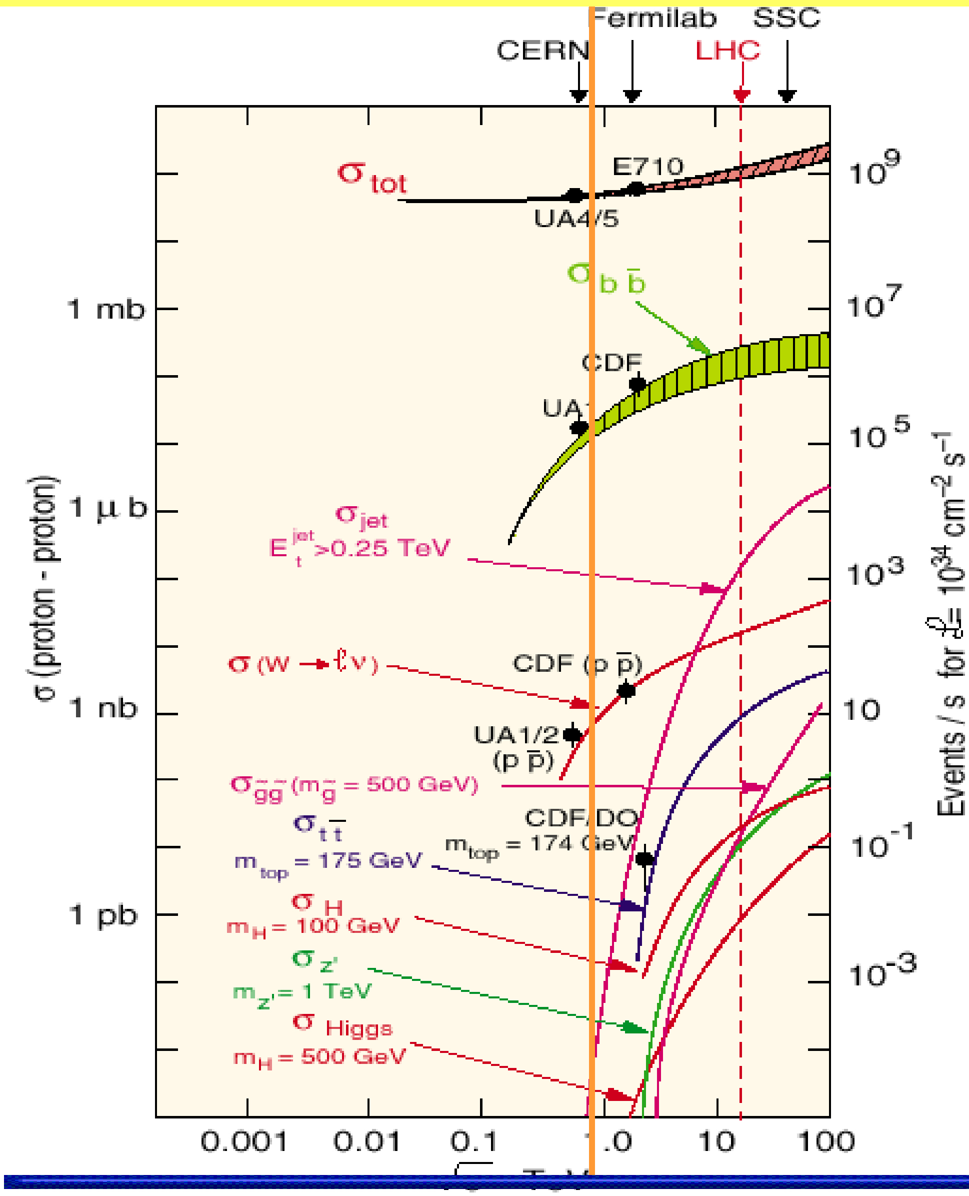
- Infrastructure (large structures, μ-absorbers, magnets,..)
  - installed and commissioned

- Detector Construction
  - **completed:** TPC, HMPID, PHOS, ZDC, Muon trigger, cosmic trigger array
  - **nearing completion:** Muon tracking, TOF, TRD, ITS, forward (V0, T0, PMD, FMD)
    - **critical path: Silicon Vertex Detector (ITS)**

- Detector Installation
  - **precomissioning** of all detectors **on surface,** started
  - **Installation:**
    - **Muon Spectrometer:** June 06 to March 07
    - **Central Barrel:** Sept. 06 to April 07
  - **Installation after summer 2007**: parts of TRD, TOF, PHOS

S

PP Physics Program

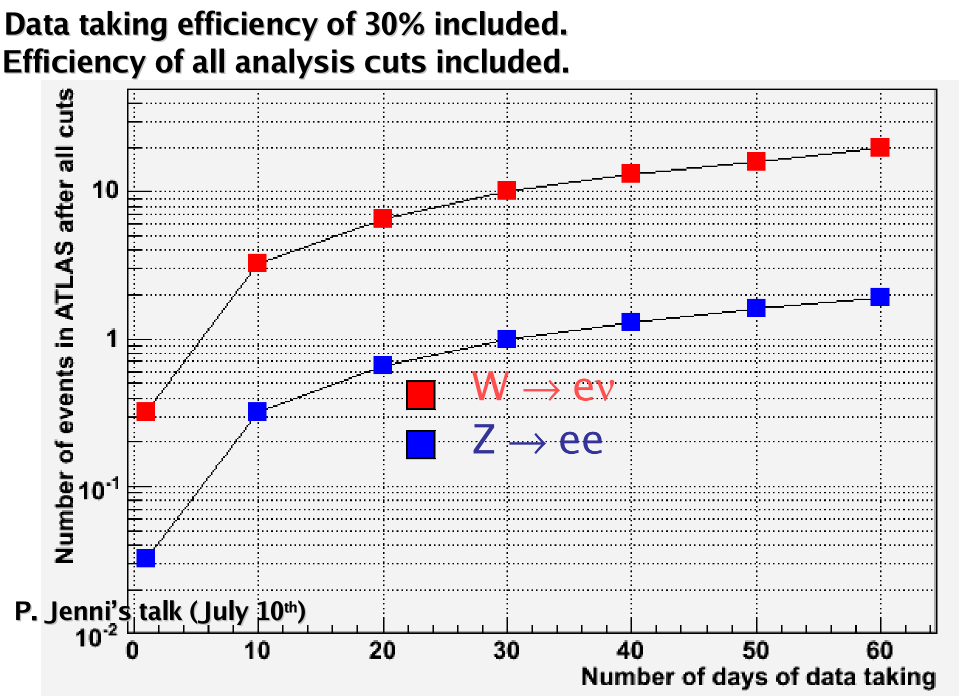


Process	σ(nb)	Ns^{-1}	$L=10pb^{-1}$	$L=10fb^{-1}$
Minimum bias	10^8	10^7	10^{12}	$\sim10^{15}$
	100	100	10^6	$\sim10^9$
Inclusive jets – p_T>200GeV	15	15	10^5	$\sim10^8$
W → eν	1.5	1.5	10^4	$\sim10^7$
Z → e^+e^-	0.2	10^{-3}	10	10^4

Physics Program

- Start by “rediscovering standard model” in new energy regime and new detectors
- Some QCD needed for “engineering” of Monte Carlo: e.g. Min bias and underlying events
- Top and W/Z production are well understood theoretically, start with inclusive and move to exclusive states that are harder for theory
- Some important results will come as soon as detectors are understood sufficiently
- Theorists should pay attention during this phase: which predictions are poor and why? If you wait for “new physics” you may be too late
- Don't believe new “pink elephant” discovery if SM is not understood

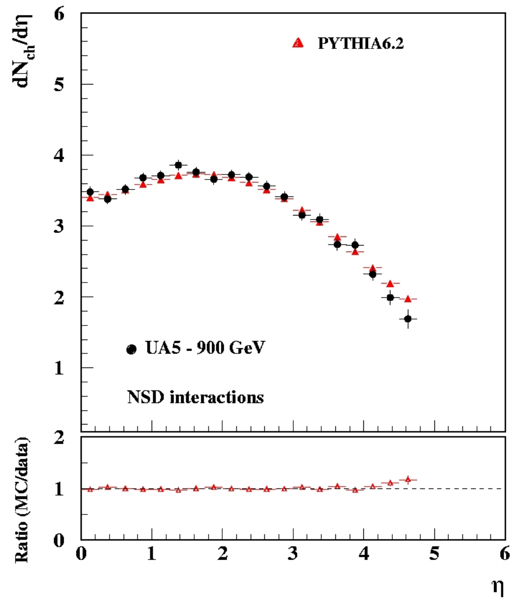
2007? What to do at 900 GeV?

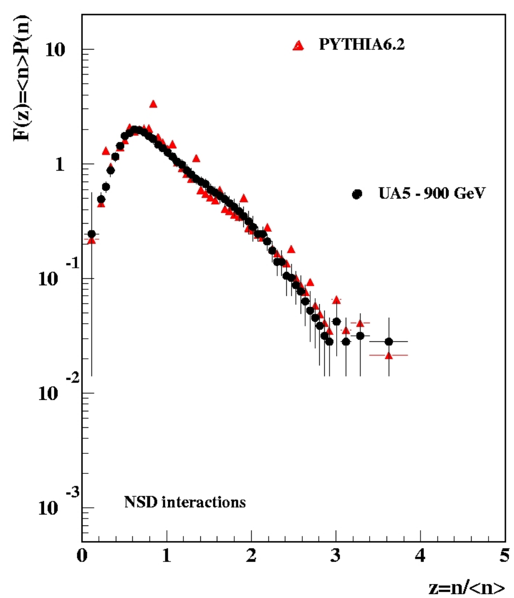


- Very low luminosity
- Only a handful of leptonic W's
- Must look to QCD, and B physics. Min bias approx 10kHz. Still need a trigger!
- Low pt dijets 13μb for pt>17 GeV
- J/psi to ee/mumu 1.8μb
- Start to understand detector

Minbias at 900 GeV

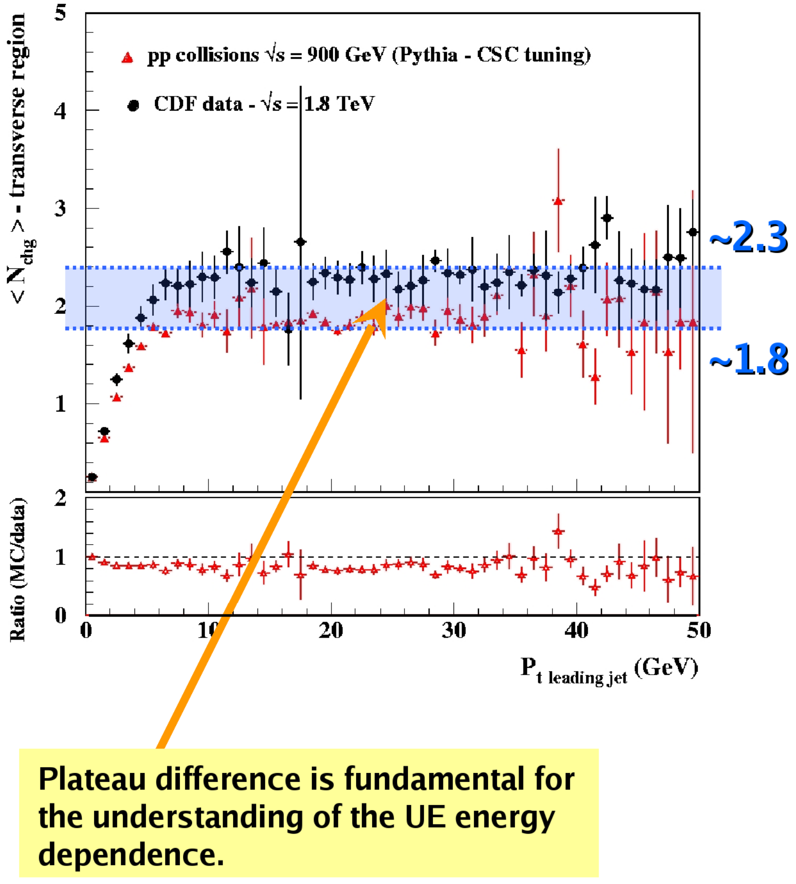
- This is new physics as there are only ppbar results at this energy
- Measure pt and rapidity
- **Debug tracking**





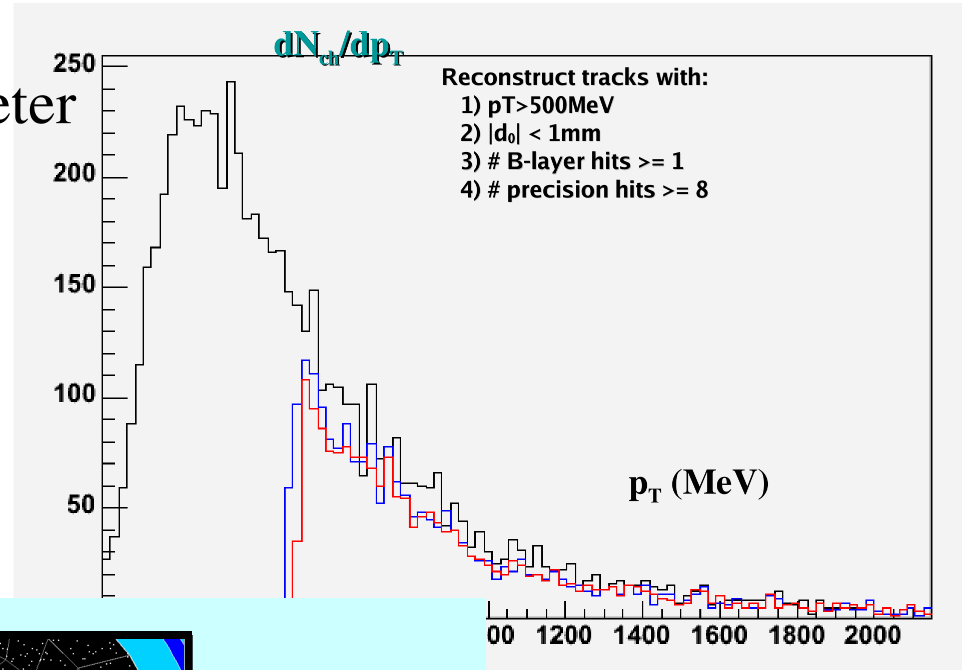
Underlying event at 900 GeV

- Jet underlying event
- Least understood parts of Monte Carlo

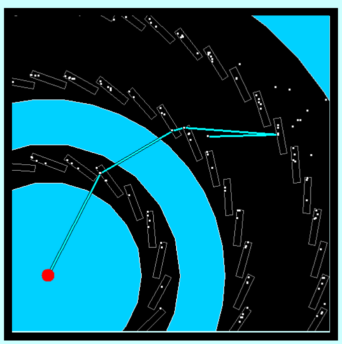


Standard model min bias

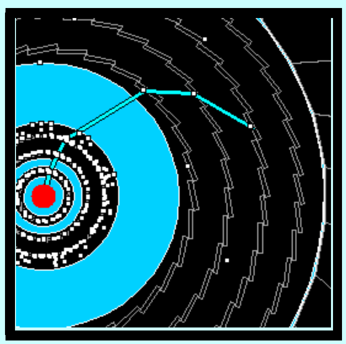
Soft Tracks do not make it to calorimeter



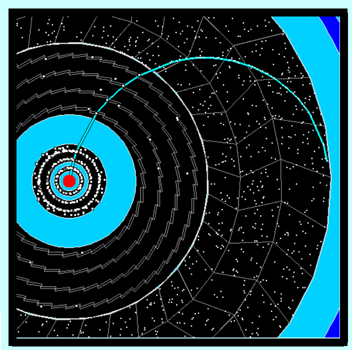
ATLAS



50 MeV tracks:
reach all Pixel layers



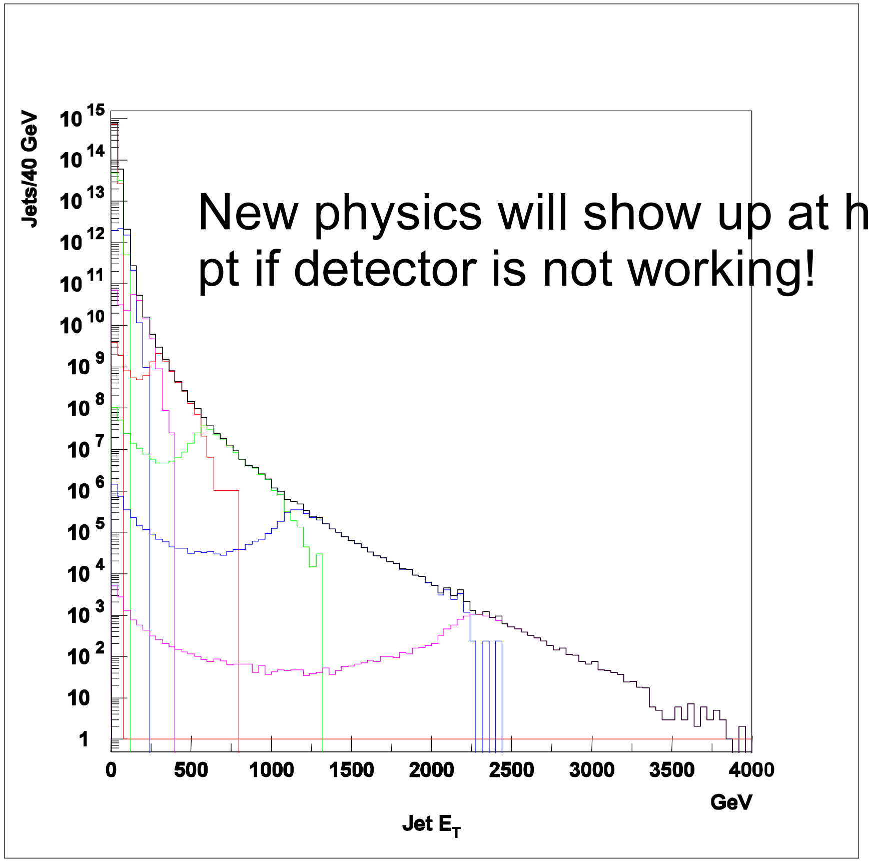
150 MeV tracks:
reach last SCT layer



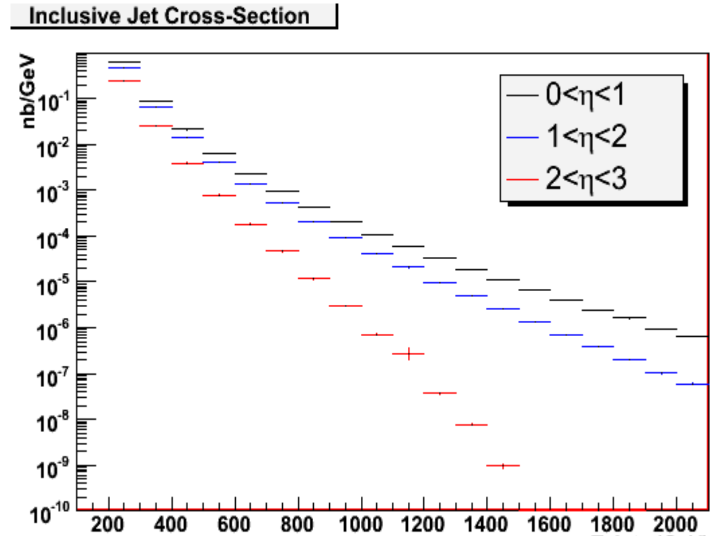
400 MeV tracks:
reach end of TRT

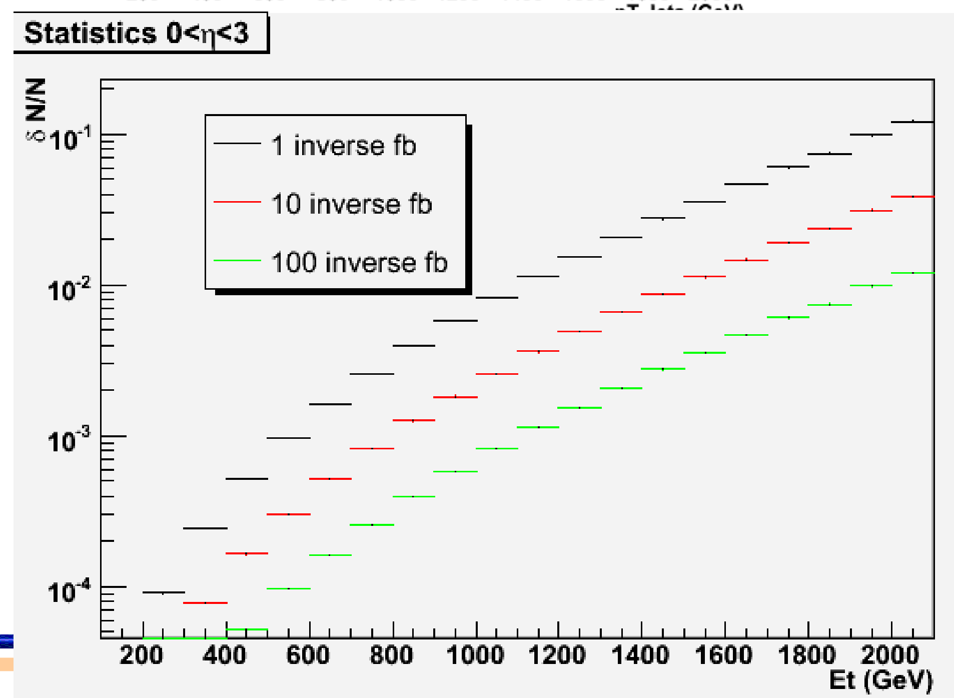
CMS has smaller radius, higher field

Jets



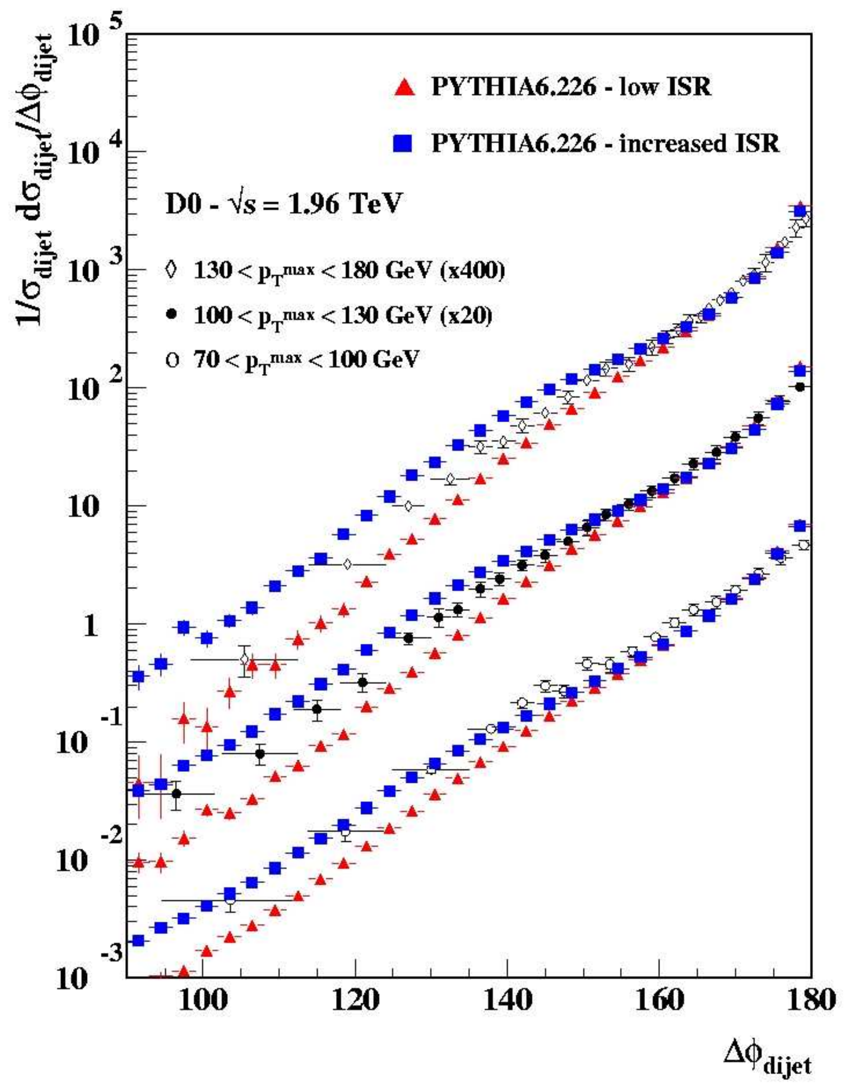
New physics will show up at high pt if detector is not working!

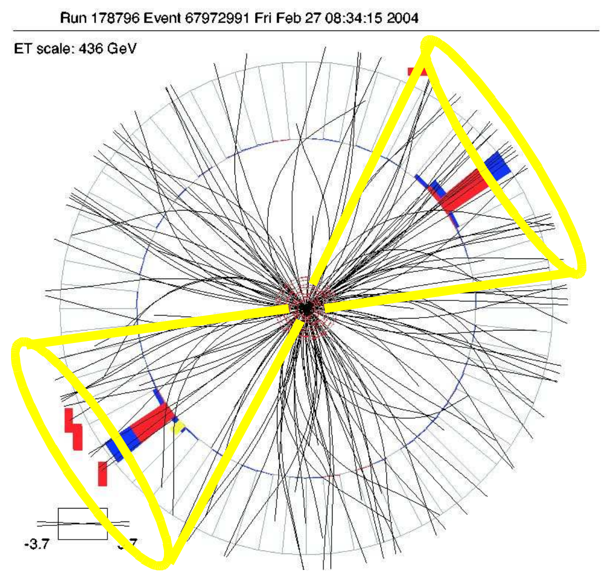




This program starts on Day 1 and never ends

Dijet phi correlations



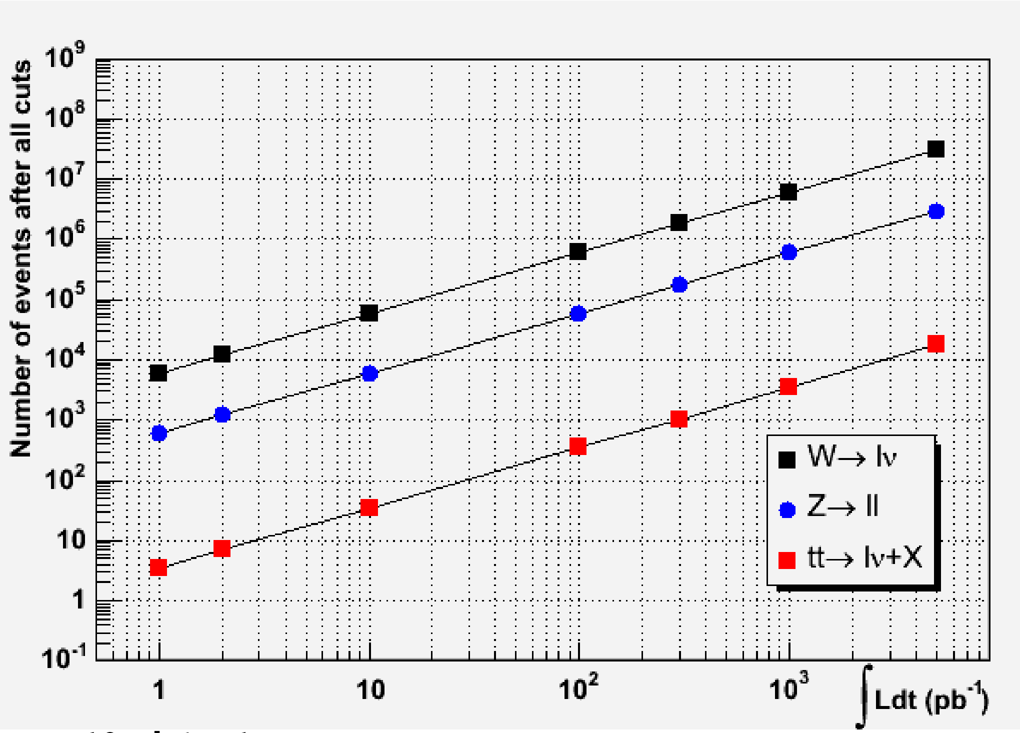


Data from D0 compared to MC decorrelation should increase at large rapidity separation

This should be early LHC result

Standard model W/Z

- Large W/Z rates
- Clean samples of e and mu
- Calibrate e/m calorimeter, muons tracking
- Understand electron fakes



~10 pb^{-1} ≡ 1 month at 10^{30} and < 2 weeks at 10^{31}, ε=50%

100 pb^{-1} ≡ few days at 10^{32}, ε=50%

Measuring Z rates

Need to trigger on either e or mu

Use mass constraint to calibrate both

Measure track effic by starting with good e and e-m energy

Measure trigger effic by comparing to offline

Very rapidly reach systematic limit on cross-section

$$\varepsilon^{trig} = f(N_1^z, N_2^z)$$

$$R = \sigma \cdot L \cdot (2\varepsilon - \varepsilon^2) \cdot A_Z \cdot \varepsilon_Z$$

σ_{Zee} = 1.87nb ⇒ L =$10^{31}cm^{-2}s^{-1}$

A_Z x ε_Z ≈ 12% (acceptance X reconst. eff.)

ε ≈ 87% (HLT single electron efficiency)

R ≈ 2.2 mHz

Statistical uncertainty	Time ε≈87%	Time ε≈60%
20%	20 min	2 hours
10%	72 min	8.3 hours
5%	5 hours	33 hours
2%	30 hours	8.6 days
1%	5 days	34 days

S. Jézéquel, SM meeting – March 2006

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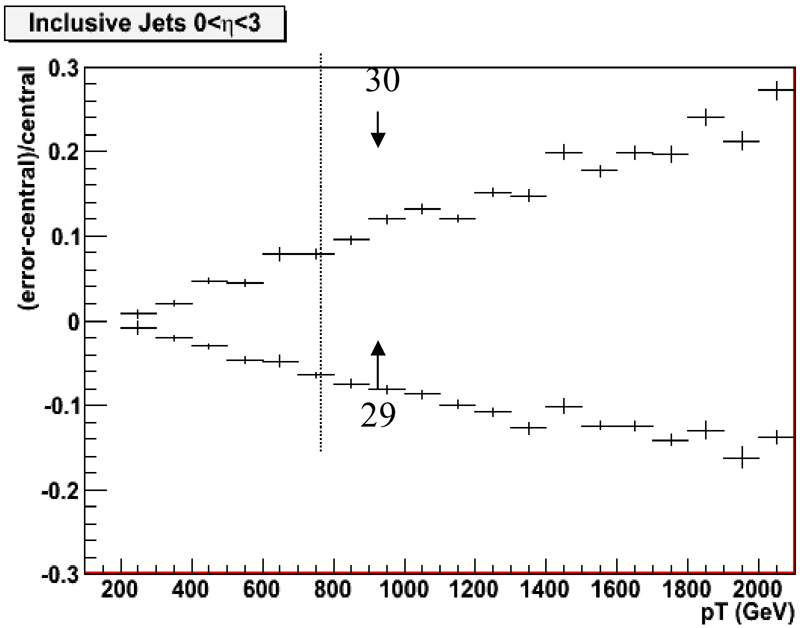
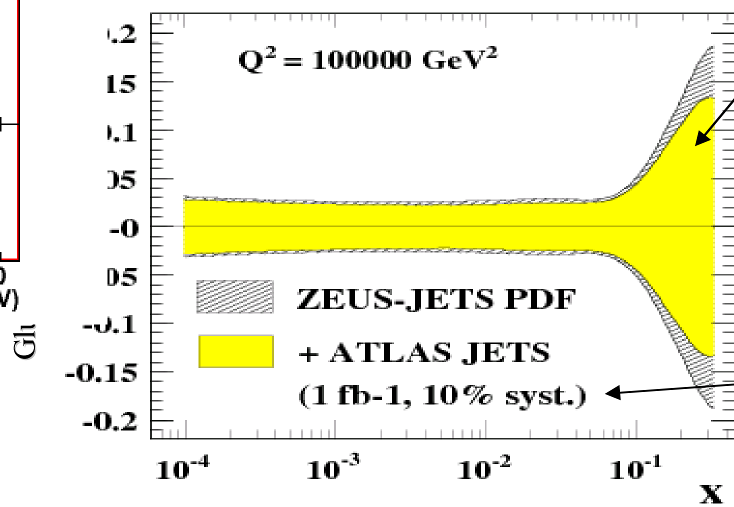
PDF's are constrained by data

- Grids were generated for the inclusive jet cross-section at ATLAS in the pseudorapidity ranges $0<\eta<1$, $1<\eta<2$, and $2<\eta<3$ up to p_T=3TeV (NLOJET).
- In addition pseudo-data for the same process was generated sing JETRAD.

  The pseudo-data was then used in a global (ZEUS) fit to ssess the impact of ATLAS data on constraining PDFs:





Preliminary indications suggest that ATLAS data can constrain the high x-gluon.

Systematic errors are uncorrelated, $10fb^{-1}$=1 year of nominal data-taking

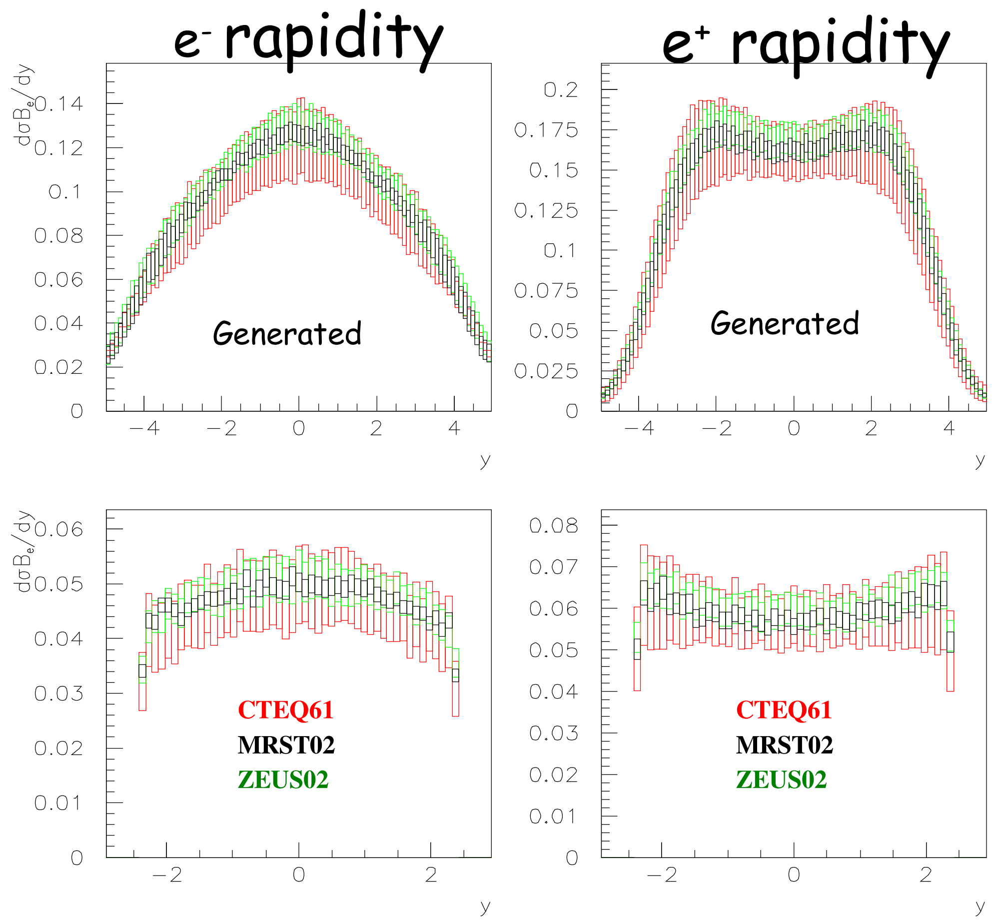
PDF uncertainties

$$u\bar{d} \rightarrow W^{+} \rightarrow e^{+}\nu$$

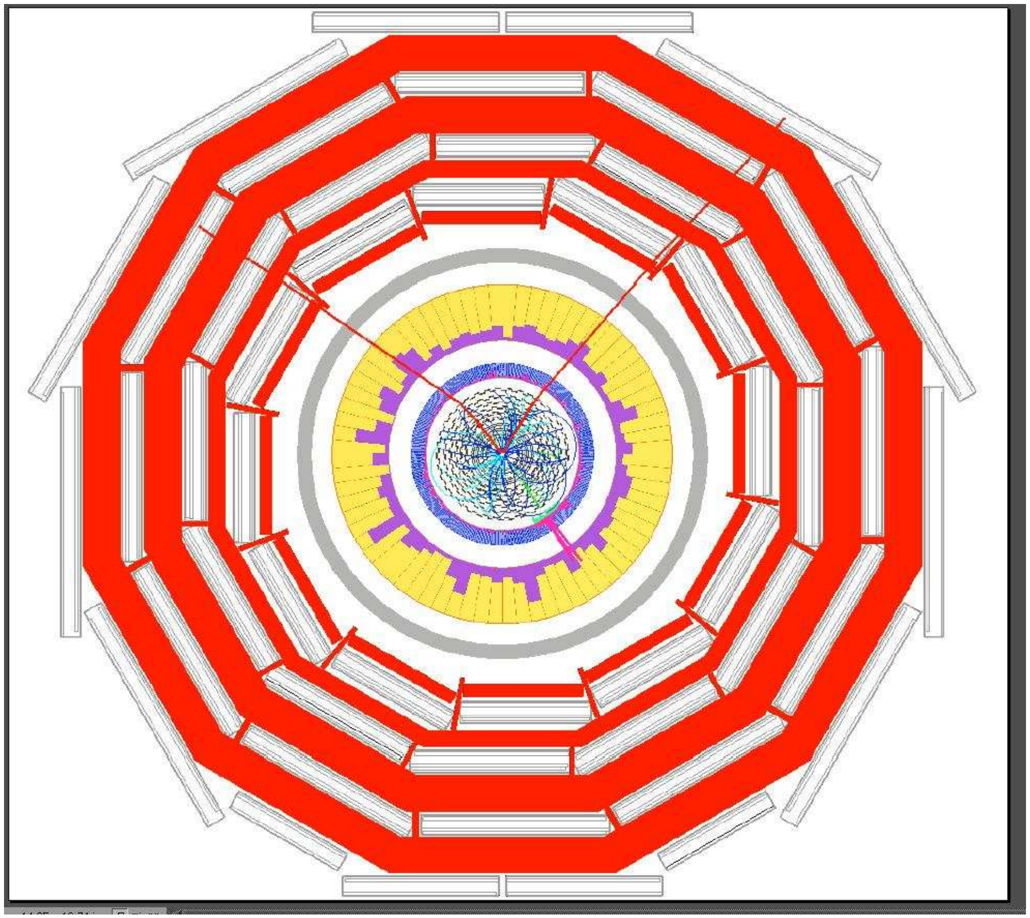
$$d\bar{u} \rightarrow W^{-} \rightarrow e^{-}\bar{\nu}$$

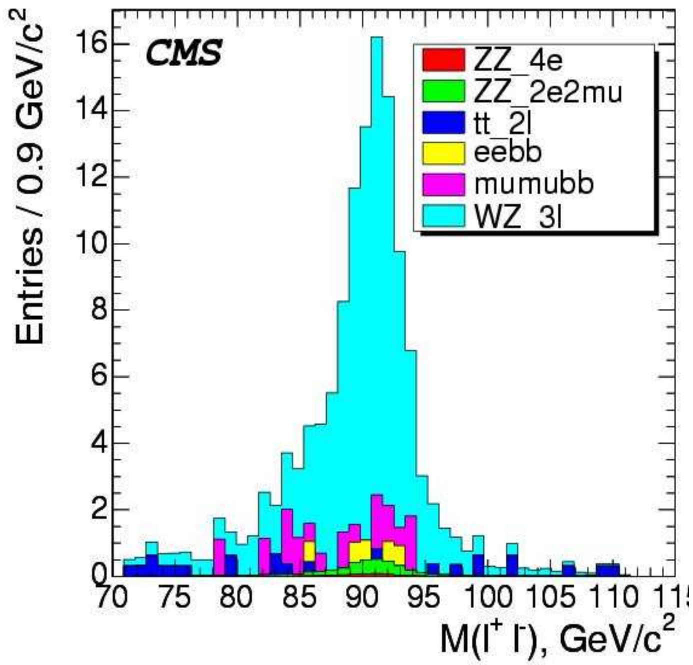
Large rapidity is sensitive to quarks at large x.

Less well measured now



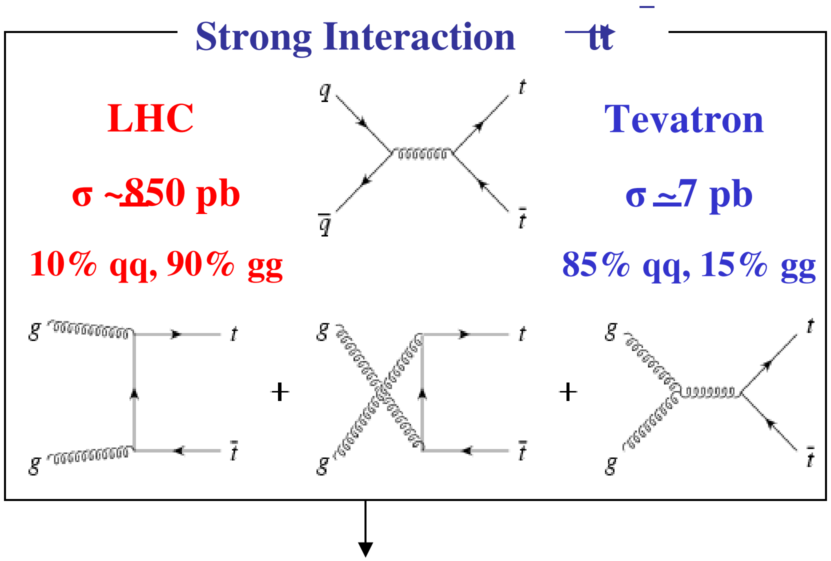
W/Z pairs





CMS 1 inverse fb

Top

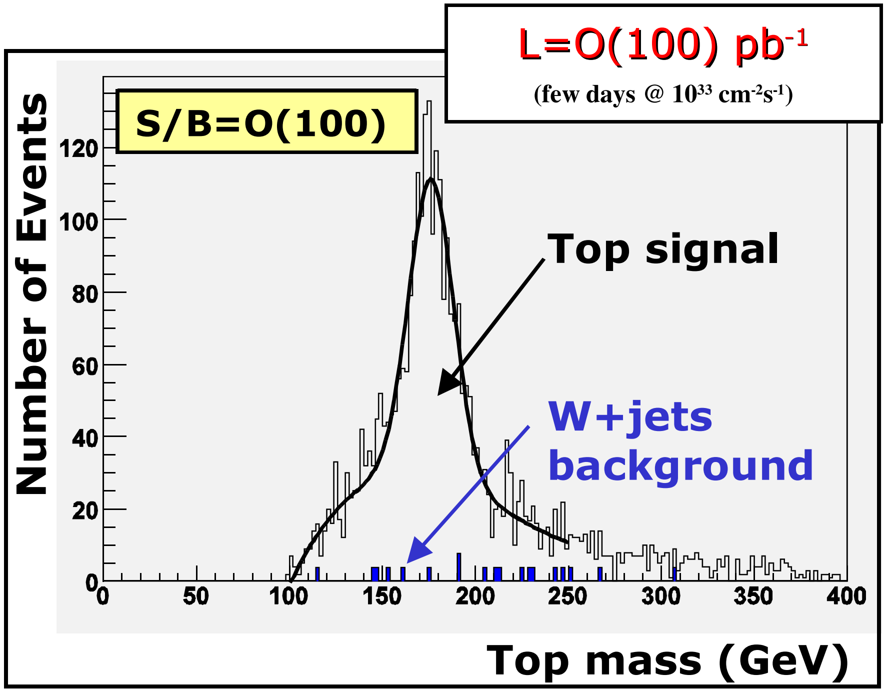


1.8 Hz at low luminosity

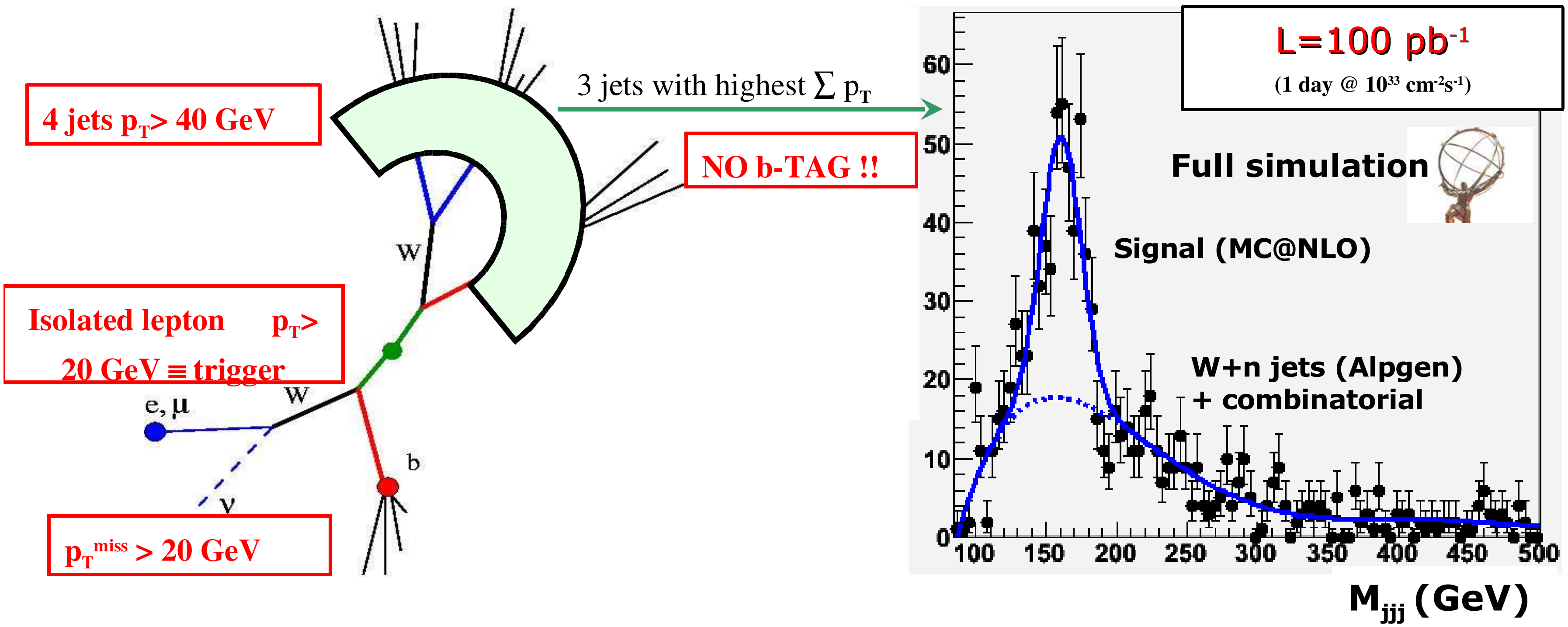
- Production fully described by QCD
- Mass known
- Ideal benchmark for detector calibrations

Top

- Very low background with everything working
- 1 lepton, missing Et, two identified b-jets



Top w/o btag



Now we have sample of bjets without using tracker

Use these to calibrate the b-tagging

Bottom and Charm

	14 TeV	900 GeV
Total LHC bb cross section	500 μb	25 μb
Total LHC inelastic σ	70 mb	40 mb
bb → μ6(5) X	4000 nb	60 nb
bb → μ6(5) μ3 X	200 nb	2 nb
bb → J/ψ (μ6(5) μ3) X	7 nb	0.1 nb
pp → J/ψ (μ6(5) μ3) X	28 nb	1 nb
pp → ϒ (μ6(5) μ3)	9 nb	1.7 nb

***) pT cuts for 14TeV are μ6 μ3 and for 900 GeV μ5μ3**

For both muons |η|<2.5

Bs to mu mu

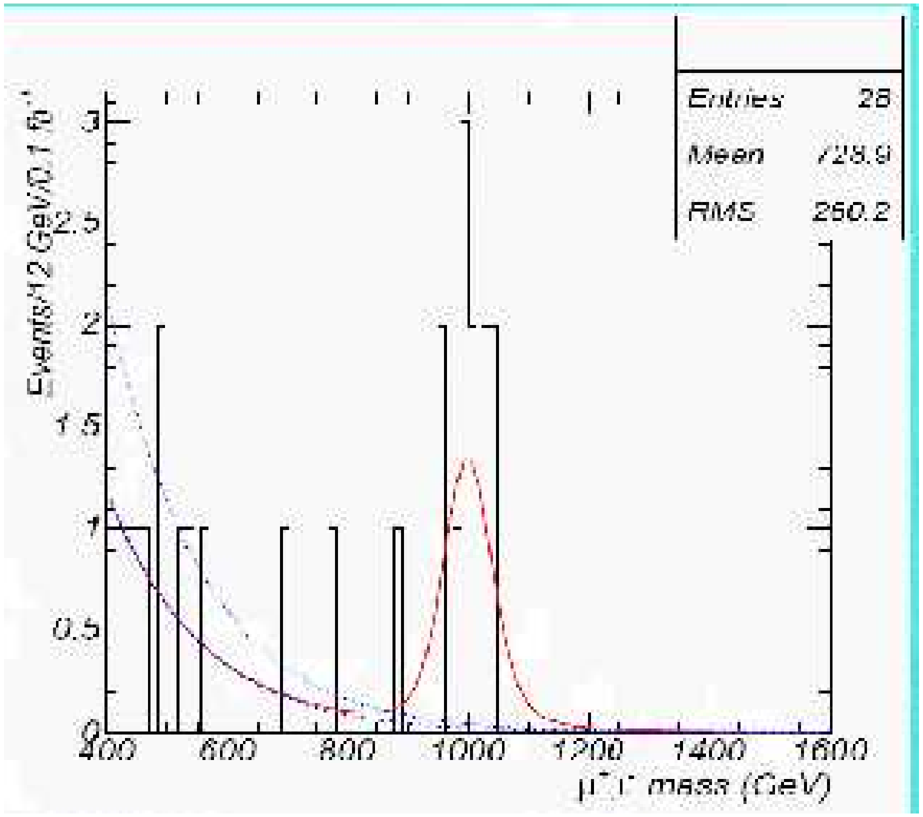
Less advantage over Tevatron because cross section rises slowly

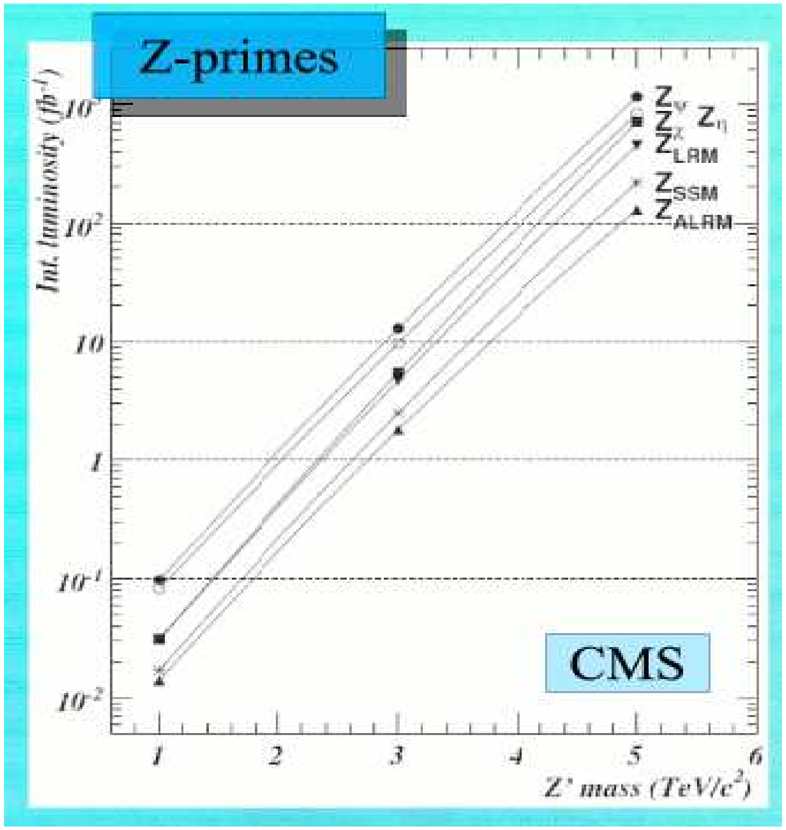
Integral LHC Luminosity	Signal ev. after cuts	BG ev. after cuts	ATLAS upper limit at 90%	CDF&D0 upper limit at 90% CL
100 pb^{-1}	~ 0	~ 0.2	6.4×10^{-8}	8×10^{-8}
10 fb^{-1}	~ 7	~ 20	7.0×10^{-9}	
30 fb^{-1}	~ 21	~ 60	6.6×10^{-9}	

ATLAS

Easy new physics:Z primes

Follow the dilepton invarient mass from Z upwards



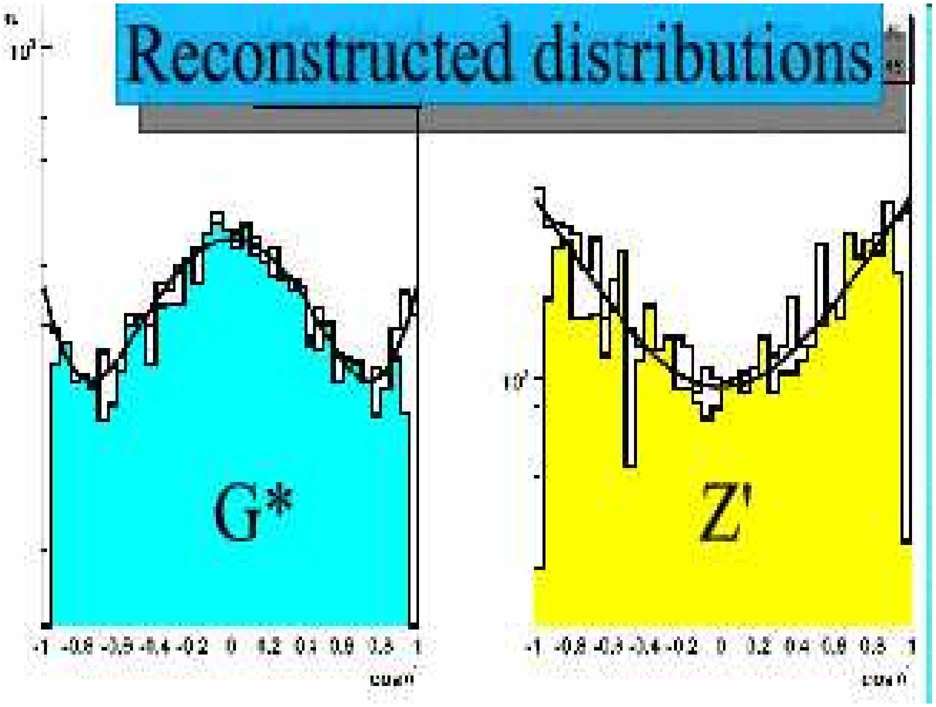


100 inverse picobarns

Easy new physics:Z primes

The CMATLAS experiment operating at LHC has observed 4 dimuon and two dielectron events where the invariant mass if the lepton pair is between 1.13 and 1.15 TeV. No other events withi invarient mass above 900 GeV have been seen. These events are consistent with the production and decay of a heavy particle of mass 1.14 TeV and an effective production cross section of aaa pb. Such an effect could be production of a Z', Kaluza Klein gravition.

Z prime; type

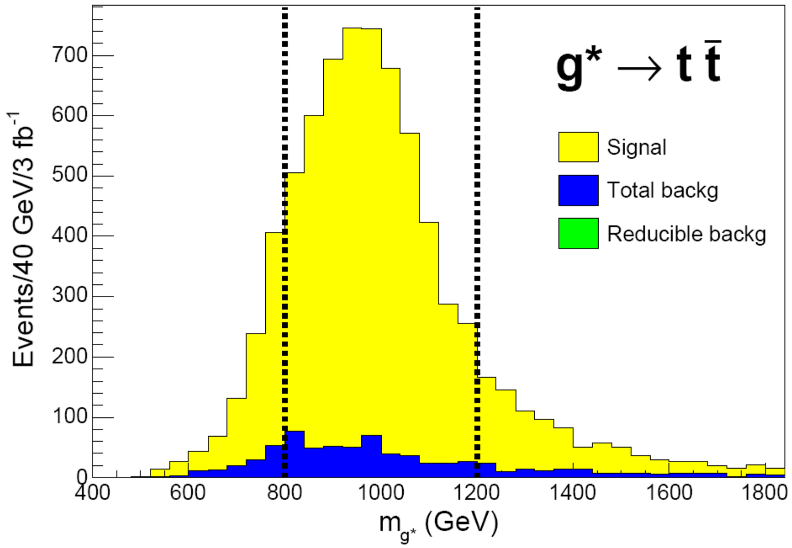


CMS

- Is it spin 1 or spin 2?
- Look at angular dist
- This comes later!

Extra dimension resonance

- Gluon excitation decaying to ttbar



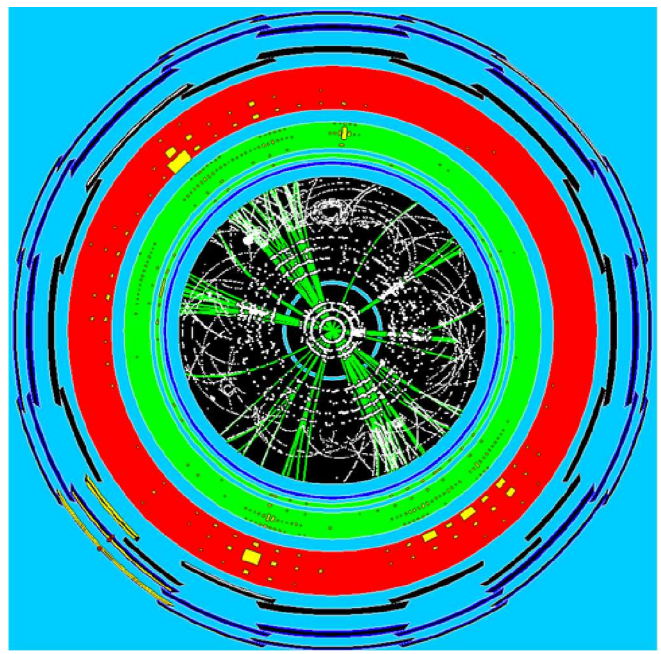
ATLAS

Black hole anyone?

Distinguishing features

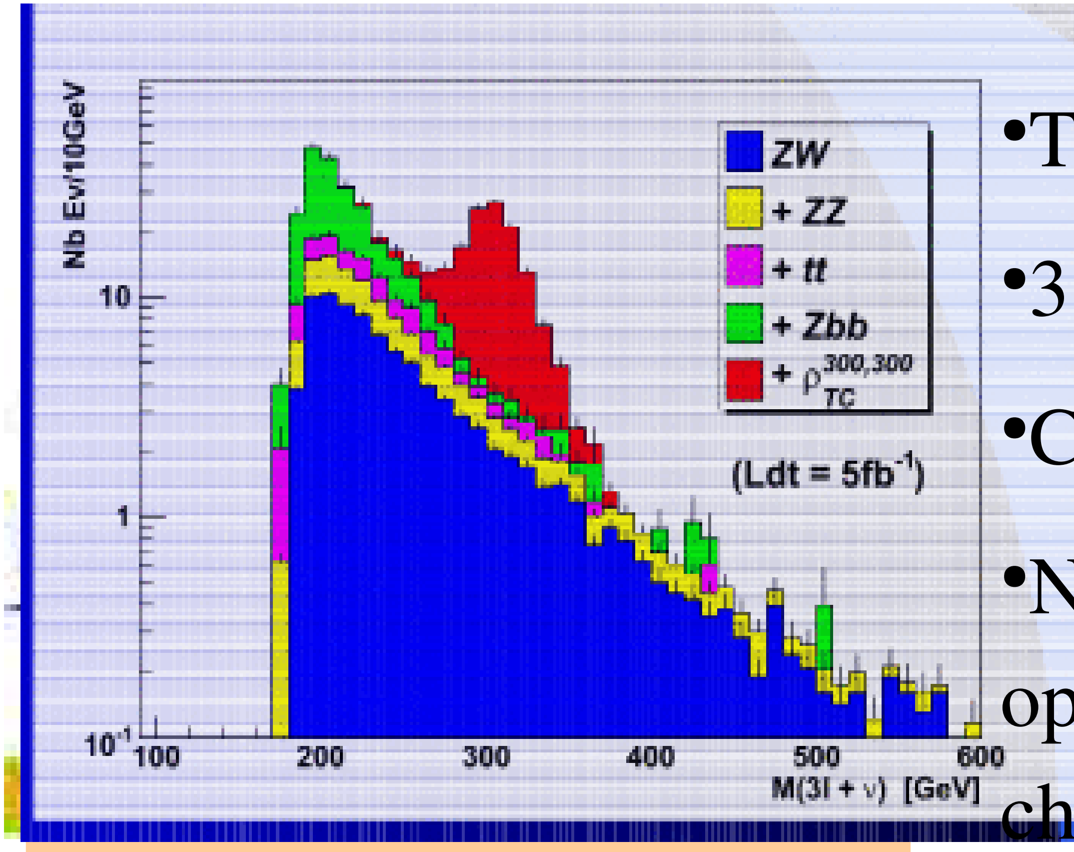
- High Multiplicity
- High ΣE_T
- High Sphericity
- High Missing P_T
- Democratic Decay

Sensitivity Dominated by Theoretical uncertainty



ATLAS

Techicolor ("rumors of my death are greatly exaggerated")

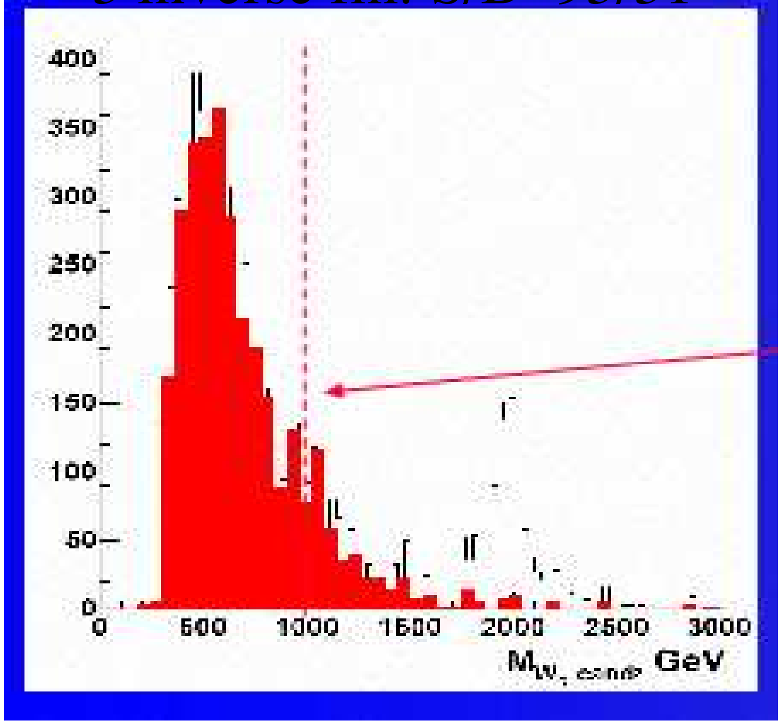


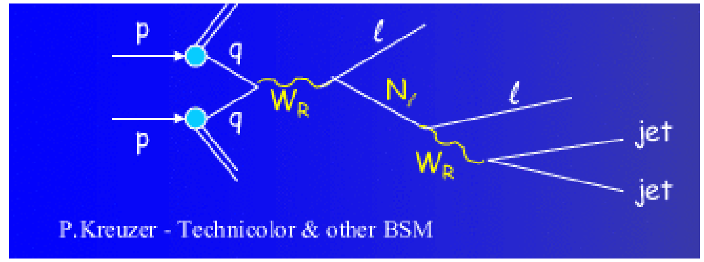
CMS

- TechiRho to WZ
- 3 lepton final state
- Clean
- Not very likely in my opinion (therefore a good chance to be seen??)

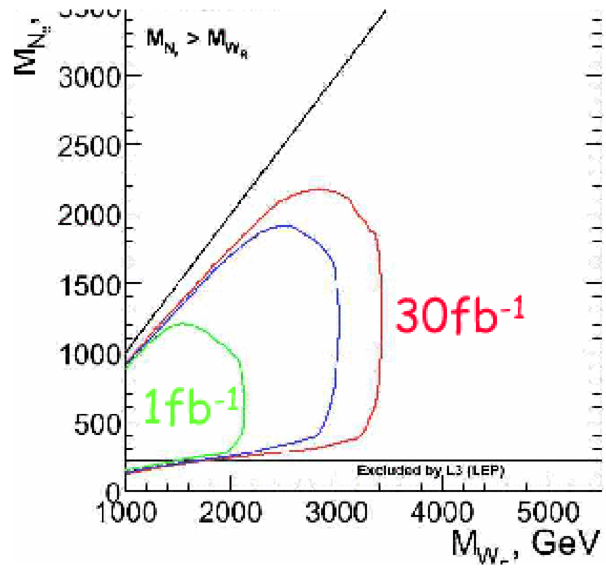
W'

3 inverse fm: S/B=93/31

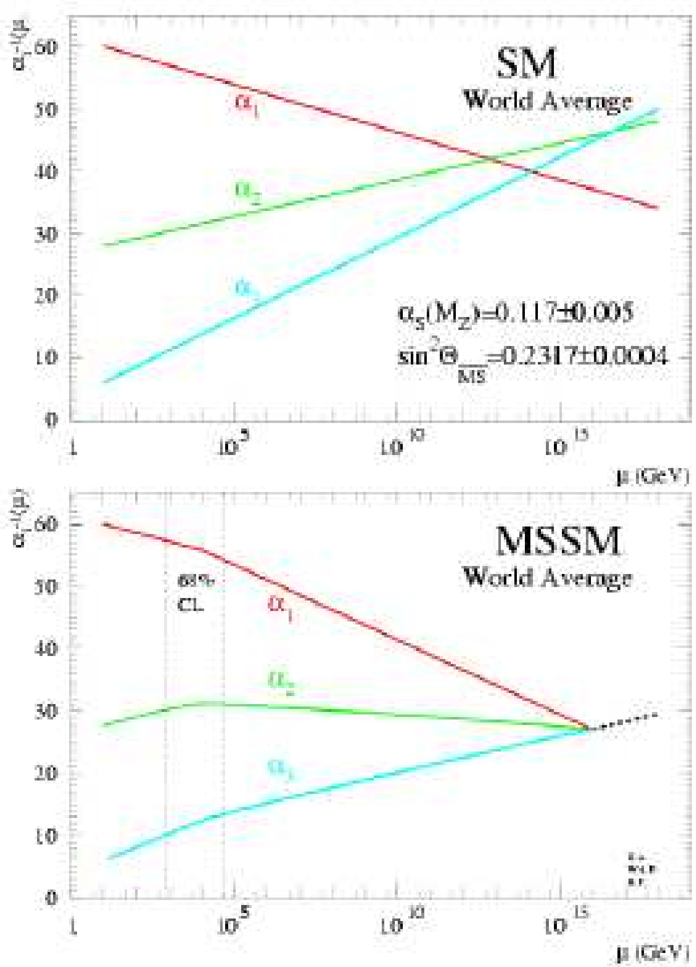


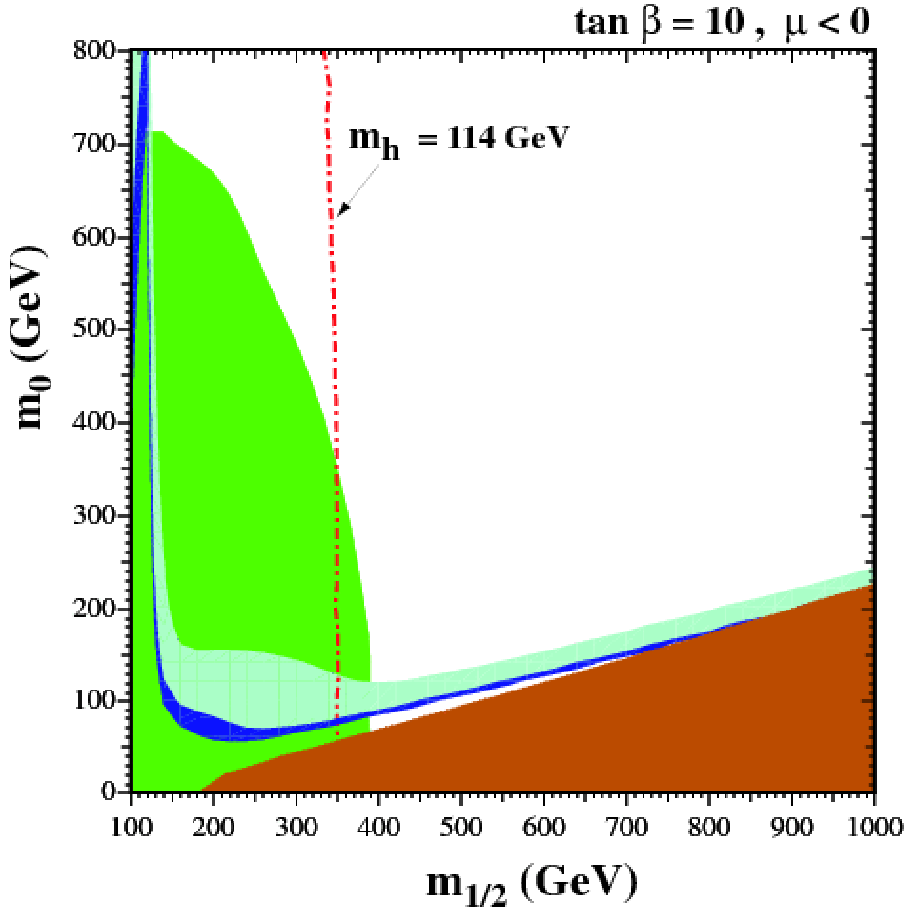


CMS (Kreuzer)



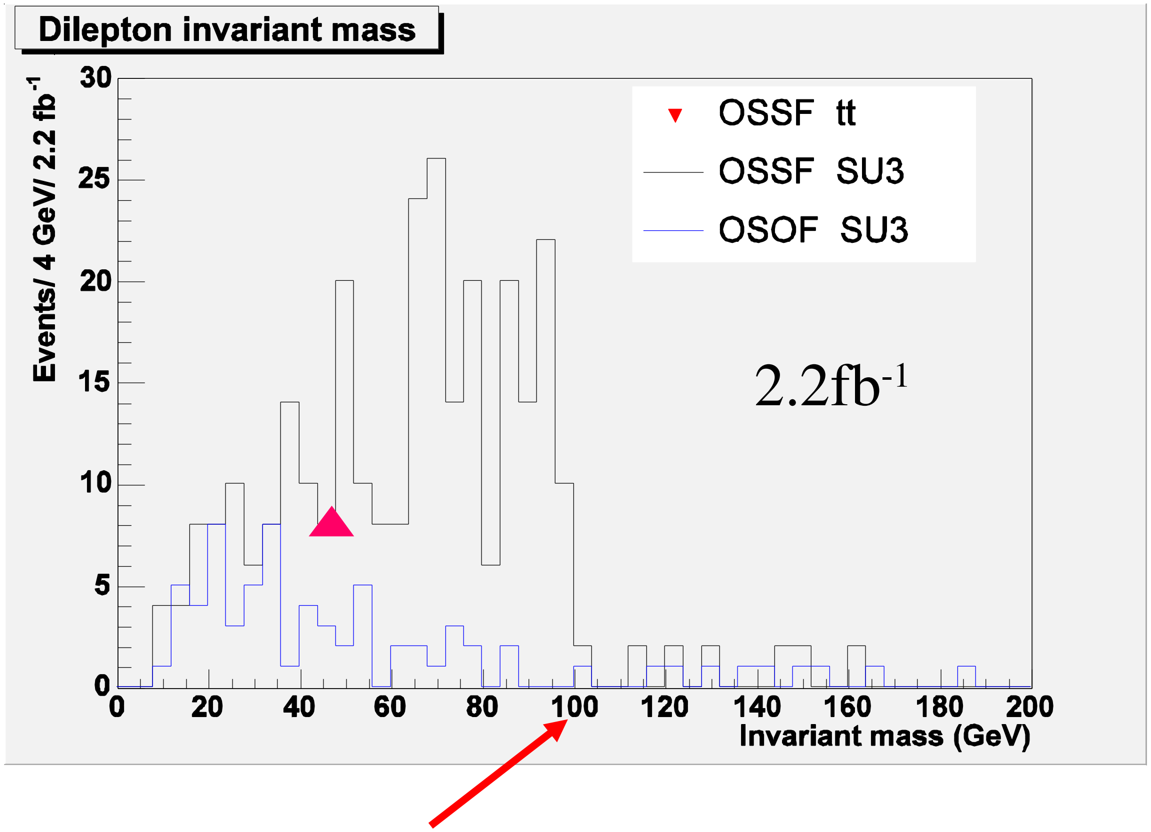
SUSY





This is not evidence.....

Susy



This would be much better but its still not SUSY....

New phyiscs

The CMATLAS experiment operating at LHC has observed an excess of 9 dimuon and 11 dielectron events in events selected to have 4 jets with pt>50 GeV. The invariant mass if the lepton pair is below 109 GeV and has no peak. These events are inconsistent with the standard model expecation of 2 events. They are consistent with the cascade decay of a two or more new particles. This signal could due for example, to SUSY or UED.

Susy vs UED?

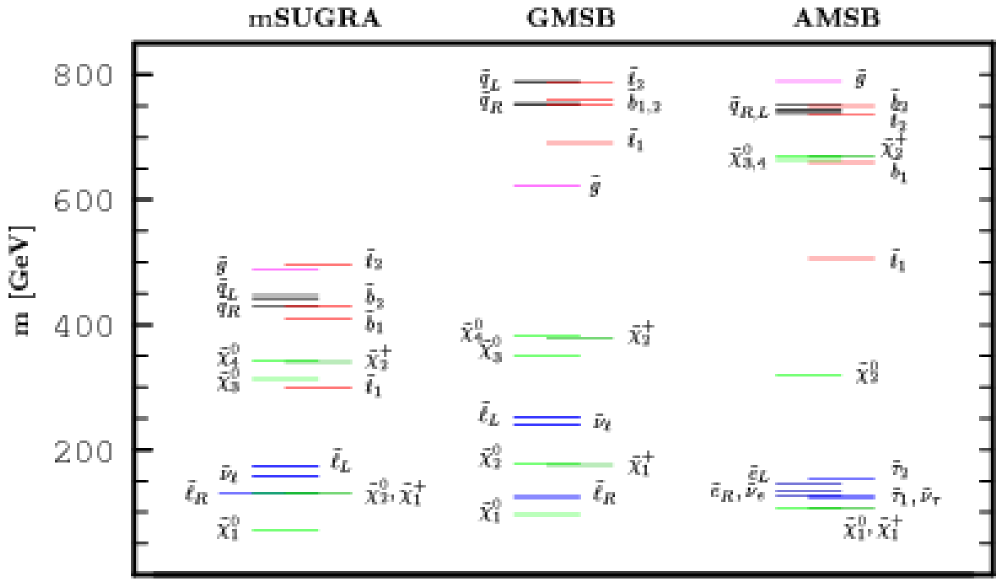
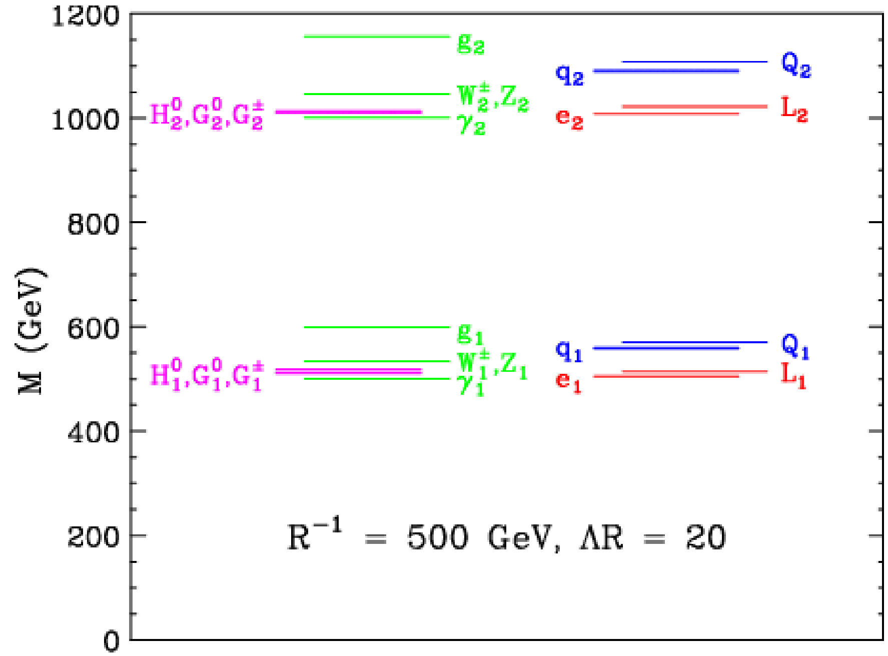


Figure 3.0.1: *Examples of mass spectra in mSUGRA, GMSB and AMSB models for* $\tan\beta = 3$, *sign* $\mu > 0$. *The other parameters are* $m_0 = 100\ eV$, $m_{1/2} = 200\,GeV$ *for mSUGRA;* $M_{mess} = 100\,TeV$, $N_{mess} = 1$, $\Lambda = 70\,TeV$ *for GMSB; and* $m_0 = 200\,GeV$, $m_{3/2} = 35\,TeV$ *for AMSB.*



Much theoretical angst over this problem

This is a problem that we need to keep us all busy!!

New physics for realists

- If Tevatron did not see it and it's inside their mass reach, apply strong health warning
- If it looks “totally crazy”, it probably is
- Beware of “counting experiments” until SM is calibrated or S/B is huge
- Beware 4σ peaks in expected places
- Beware “old men in a hurry”

How will experiments and theorists collaborate?

- Same way they always have!!
- We all expect/hope that LHC will revolutionize field.
- Recall J/Psi, charm, tau......
- I was in high school the last time we had a comparable leap in effective energy: DONT BLOW IT!

Perhaps we might find the Grail(Higgs)?

But we hope for something more revolutionary

Come back for the 2010/2011 school when one of you will be showing real LHC data