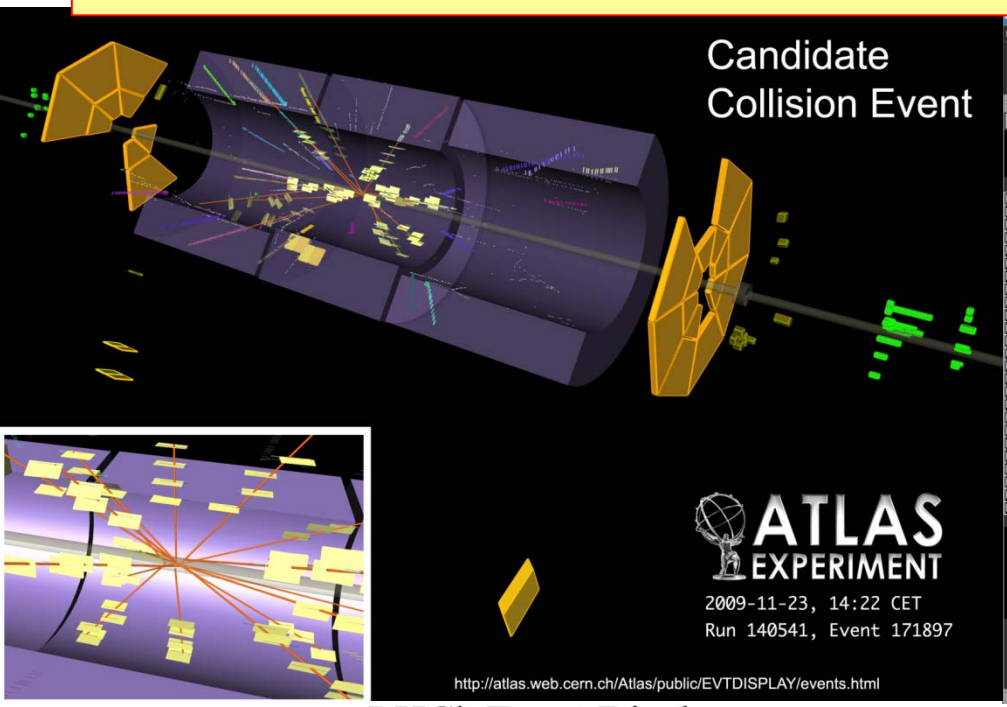
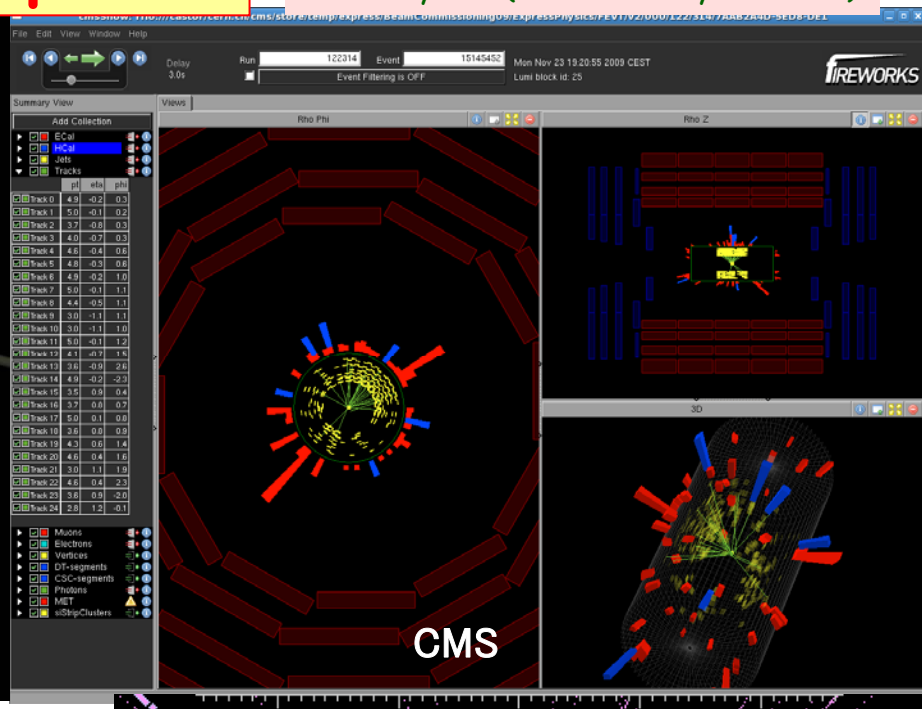
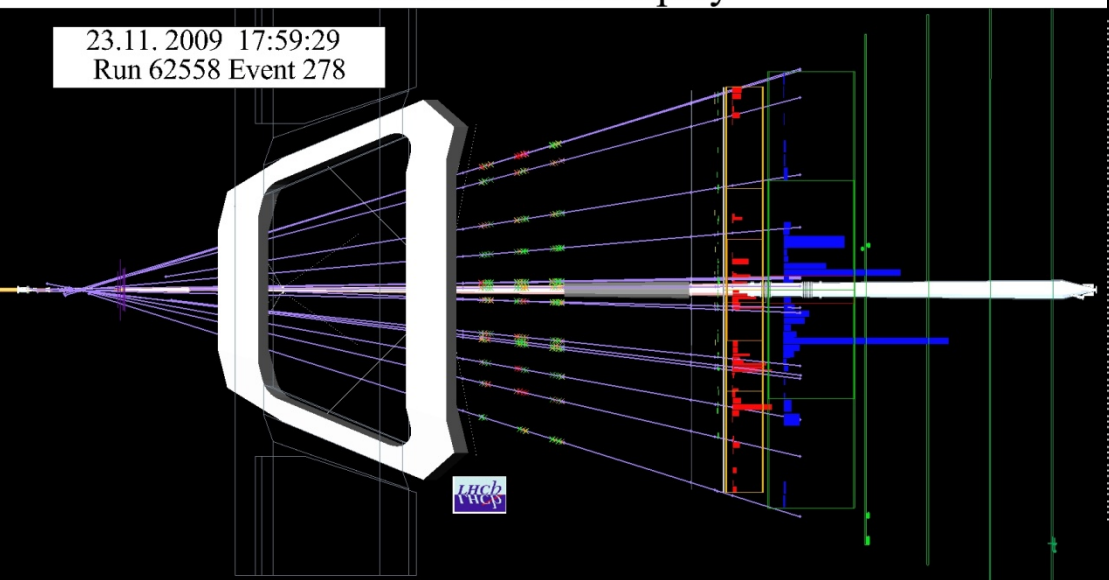
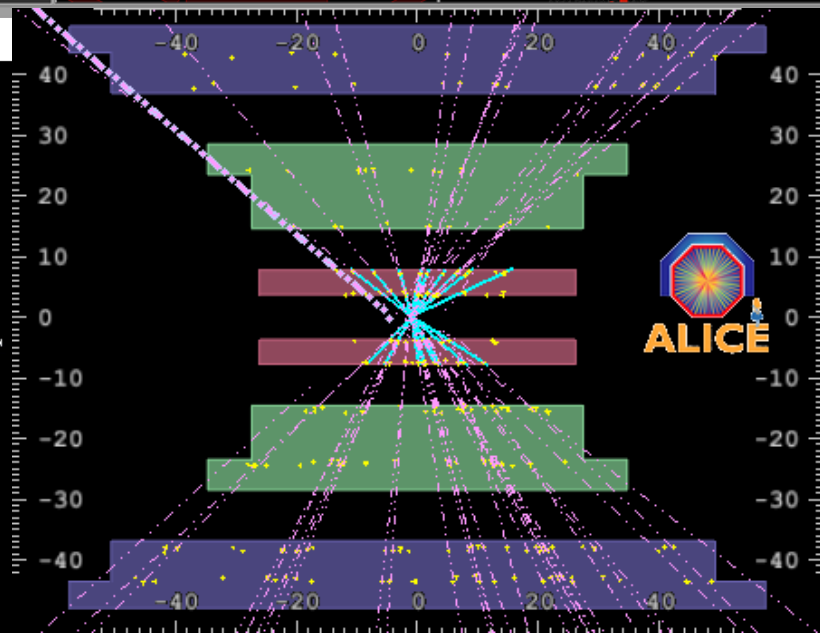
LHC Status and Prospect

2. Dec. 2009
ILC Detector Workshop
T. Kobayashi (Univ. of Tokyo /ICEPP)



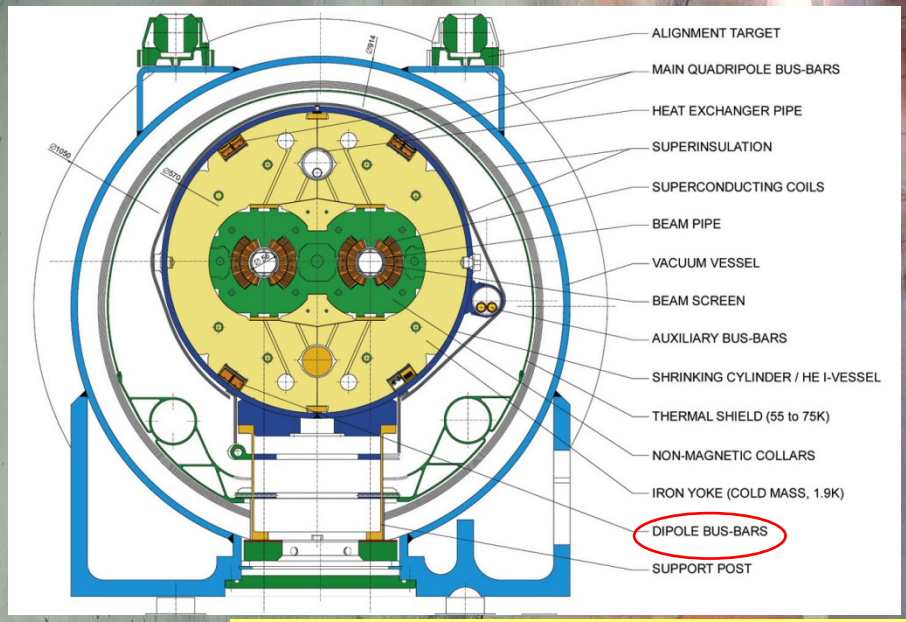






Large Hadron Collider (LHC) at CERN

- 14 TeV pp collider
- using LEP tunnel
- 14 years of construction period
- total cost ~5BCHF
- successfully started the beam circulation on 10.Sep.2008, but ···

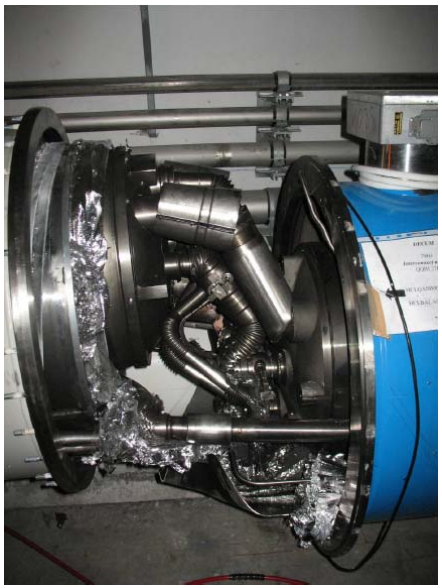


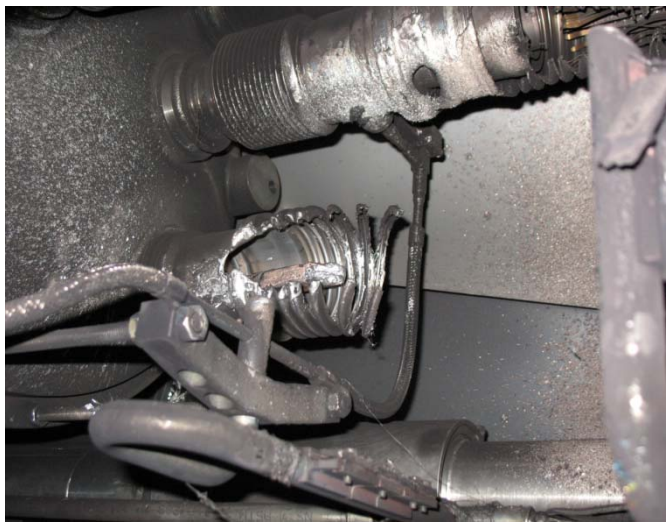
2-in-1 sc dipole magnet : 8.3T, 1.9K, 14.3m, 1232pcs

26th November 2009
Steve Myers

LHC is back!

From the dark days after September 19, 2008 to the bright days of late November 2009



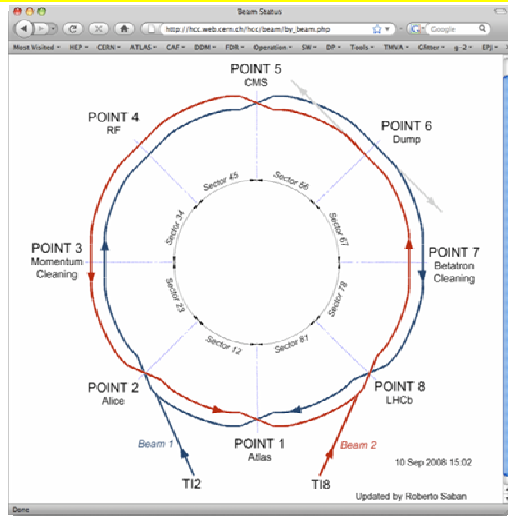


Friday November 20

18:30 Beam 1

- 19.00 beam through CMS (23, 34, 45)
  - beam1 through to IP6 19.55 Starting again injection of Beam1
  - corrected beam to IP6, 7, 8, 1
- 20.40 Beam 1 makes 2 turns
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .1)
- 20.50 Beam 1 on beam dump at point 6
- 21.50 Beam 1 captured

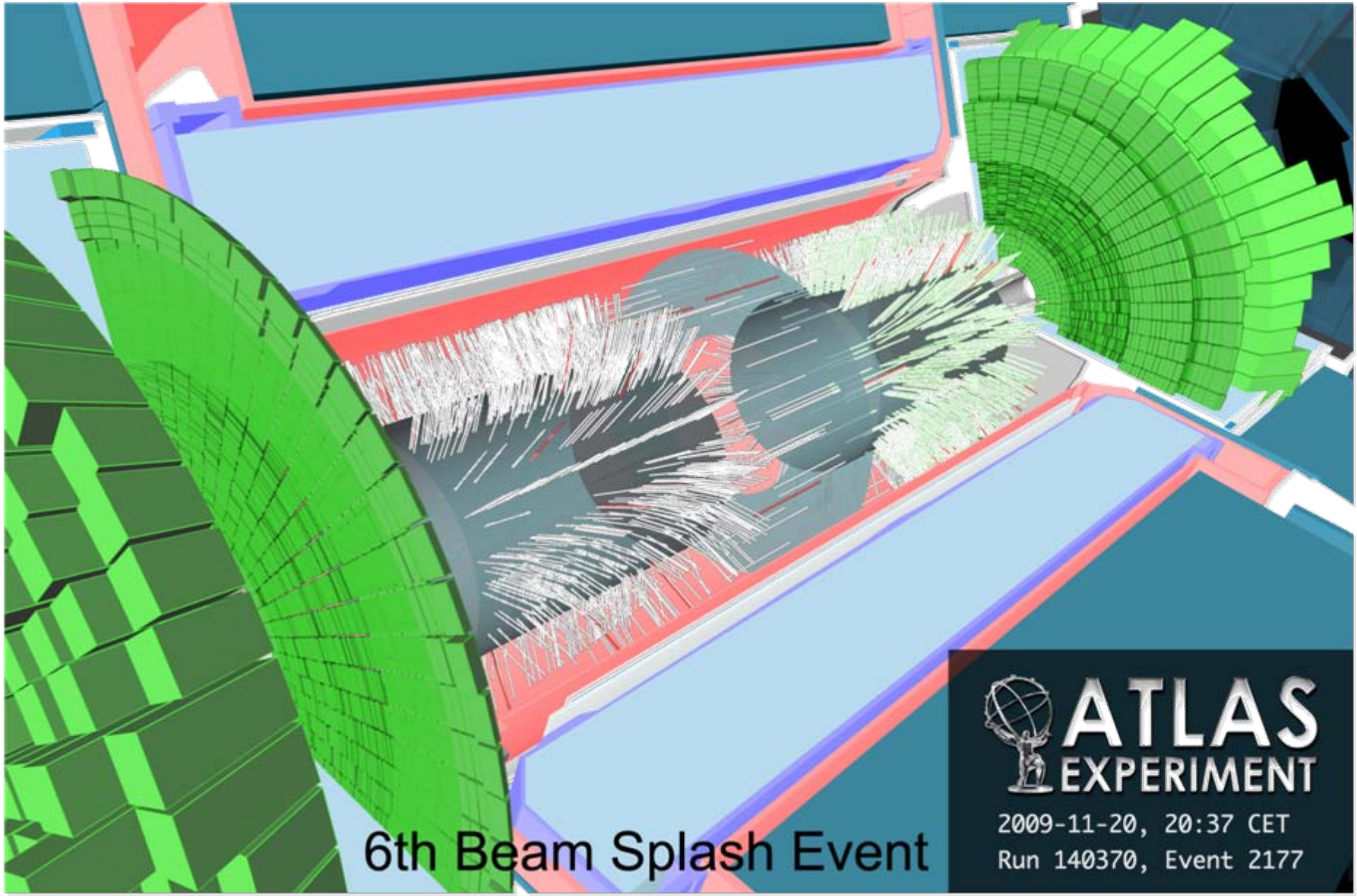
2h10 for 27km: 12.5km/h average speed



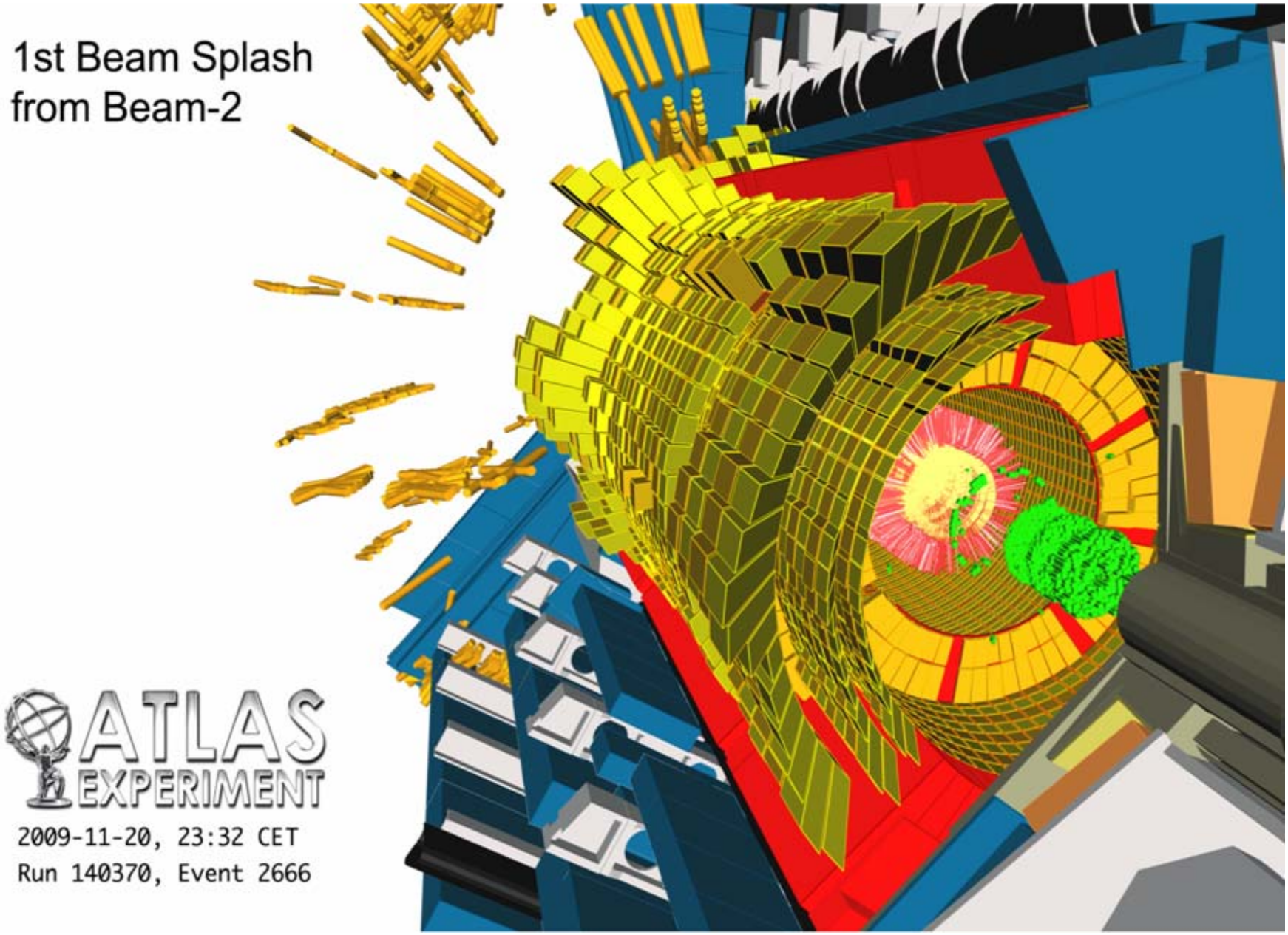
22:15 Beam2

- 23.10 Start threading Beam2
  - Round to 7 6 5 2 1
- 23.40 First Turn Beam2
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .05)
- 24.10 Beam 2 captured

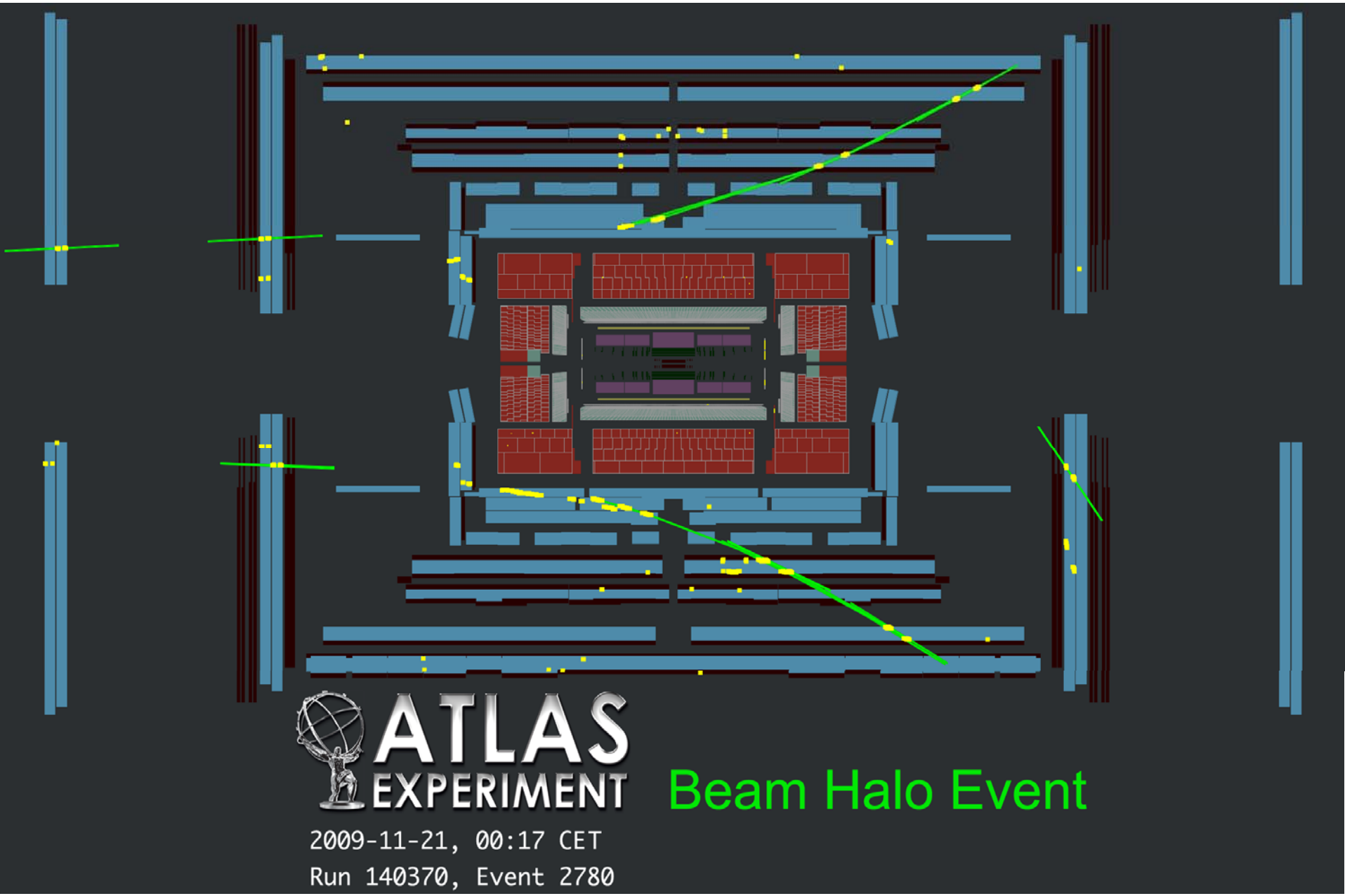
1h25 for 27km: a bit faster


6th Beam Splash Event
ATLAS
EXPERIMENT
2009-11-20, 20:37 CET
Run 140370, Event 2177

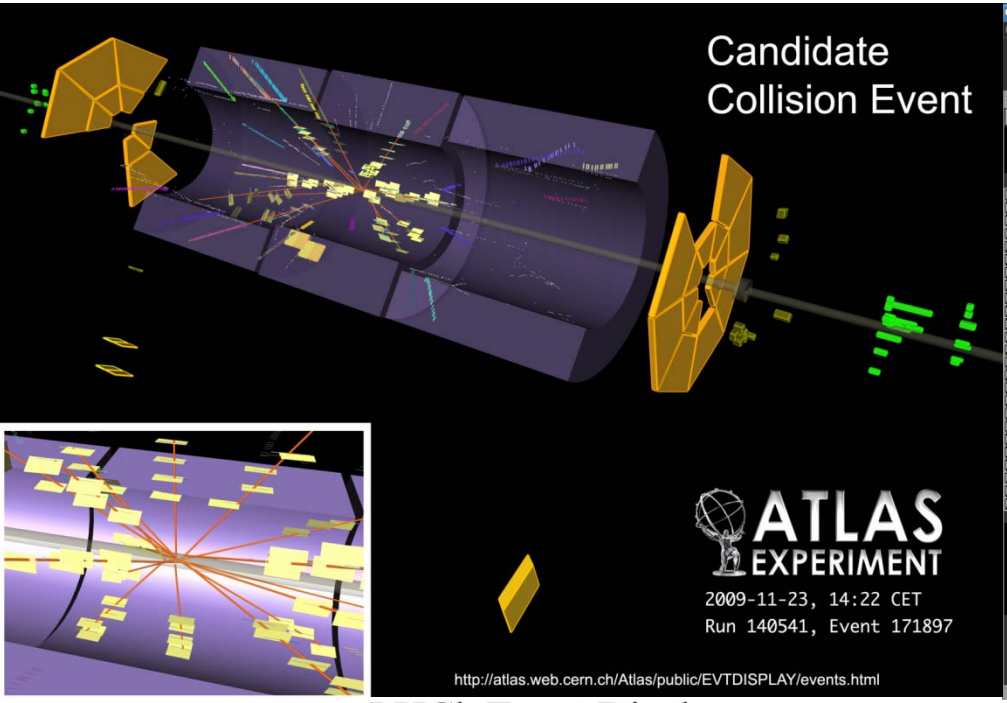
1st Beam Splash from Beam-2

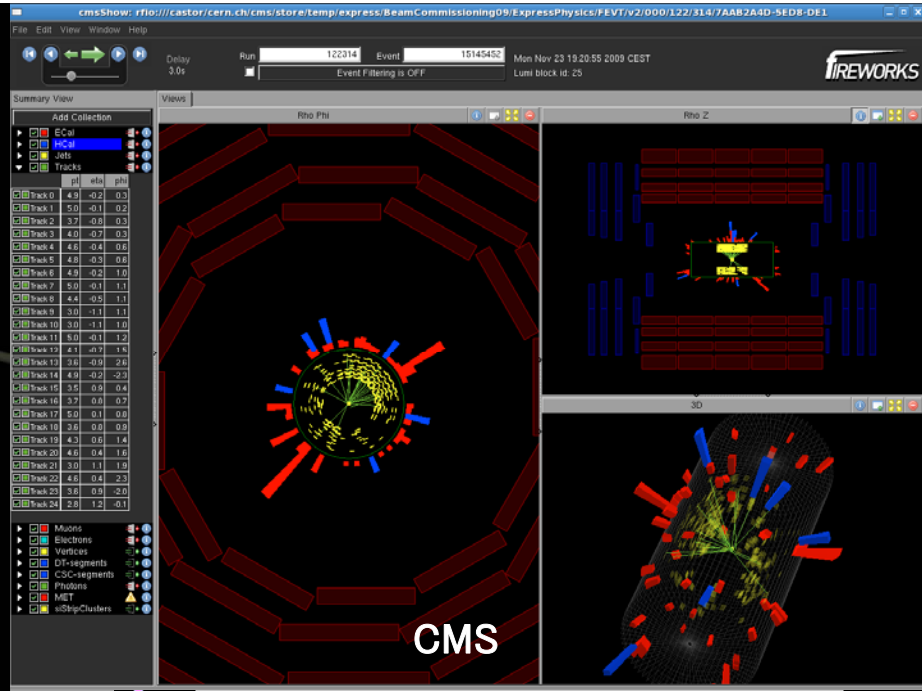


2009-11-20, 23:32 CET
Run 140370, Event 2666

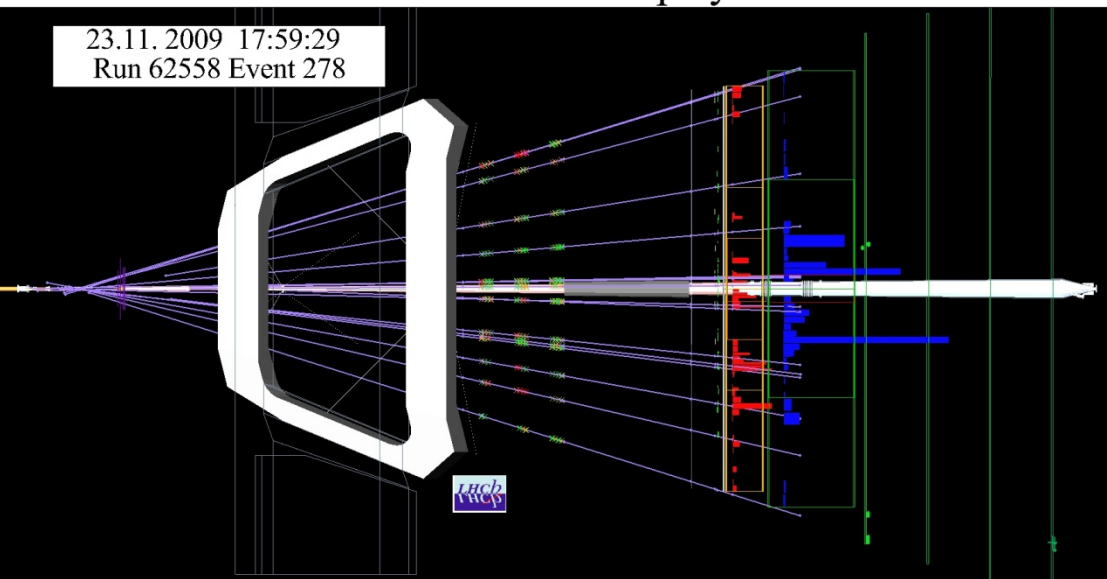

ATLAS
EXPERIMENT
Beam Halo Event
2009-11-21, 00:17 CET
Run 140370, Event 2780

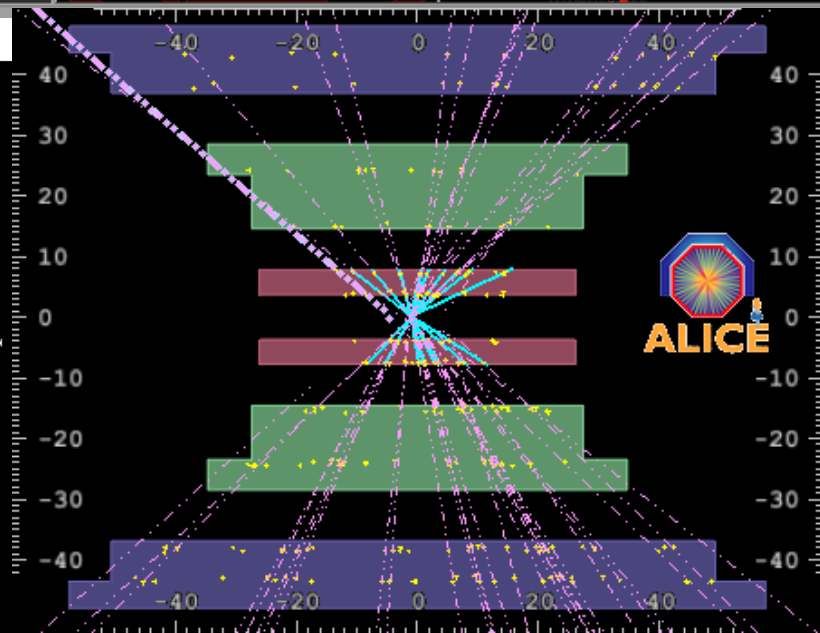
First collision events seen on Nov.23 (at 450GeV+450GeV)



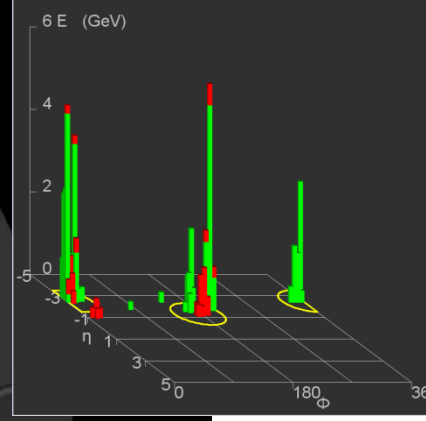


LHCb Event Display





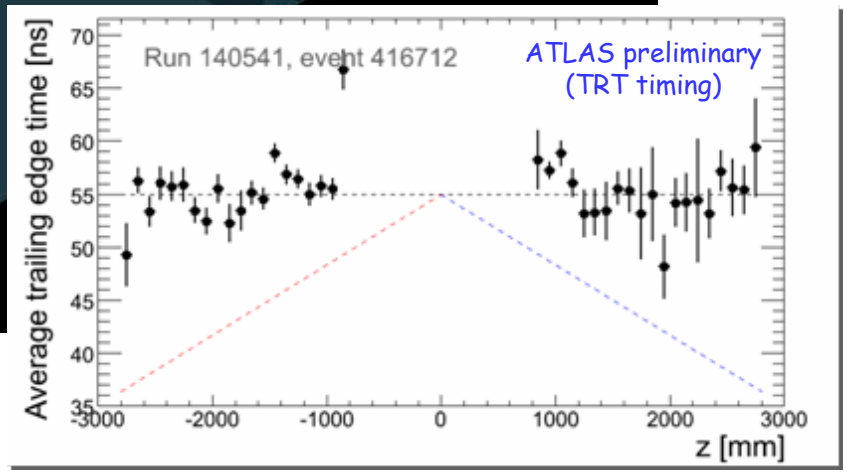
A di-jet candidate



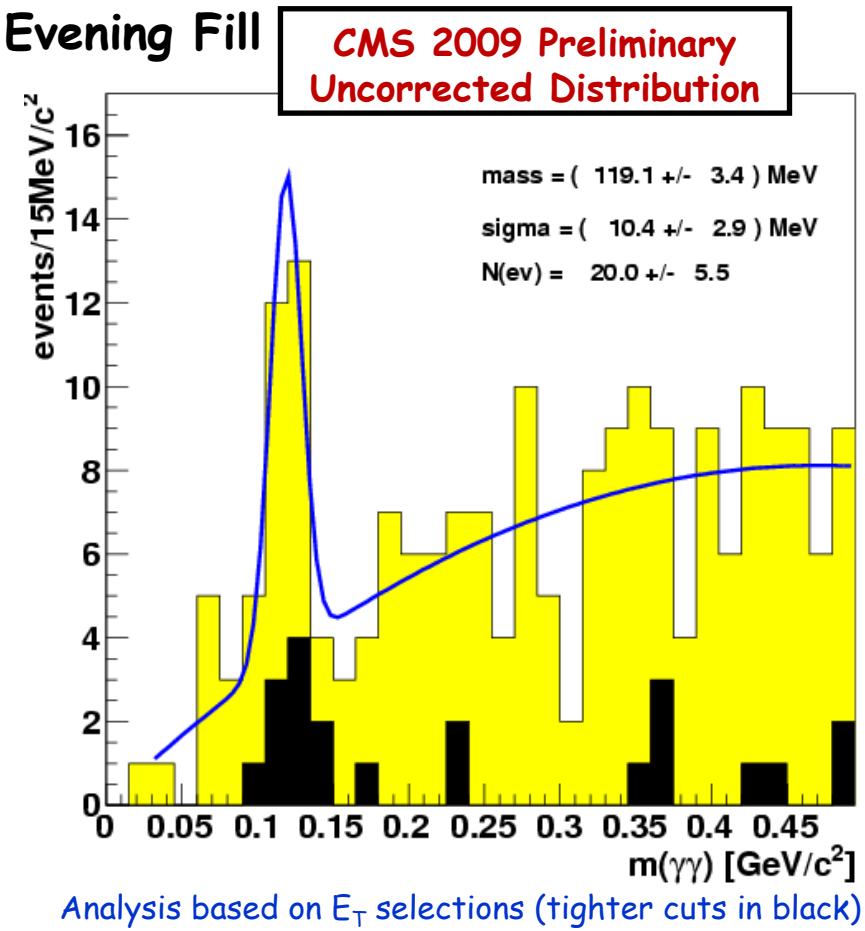
Run 140541
Event 416712

Two jets back-to-back in ϕ, both with (uncalibrated) E_T ~ 10 GeV,
η of –1.3 and –2.5,
~ no missing E_T

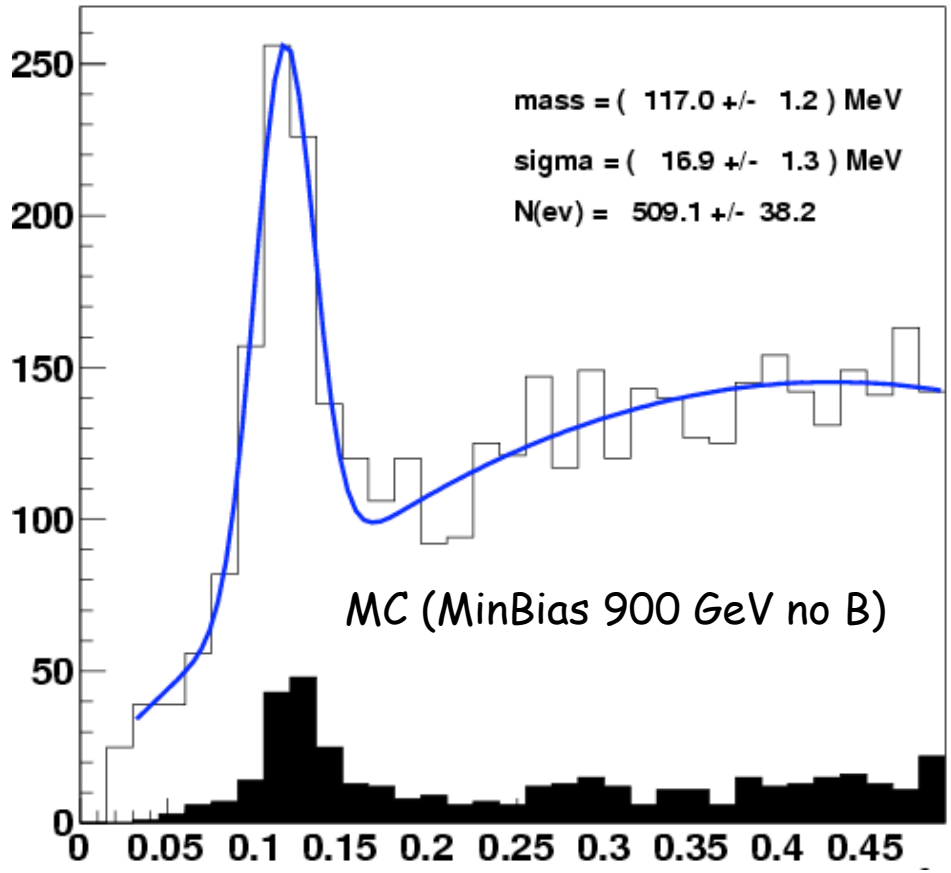
Triggered by MBTS A/B in time, several hits
Also triggered by L1Calo EM3



First Di-photon Distribution in CMS



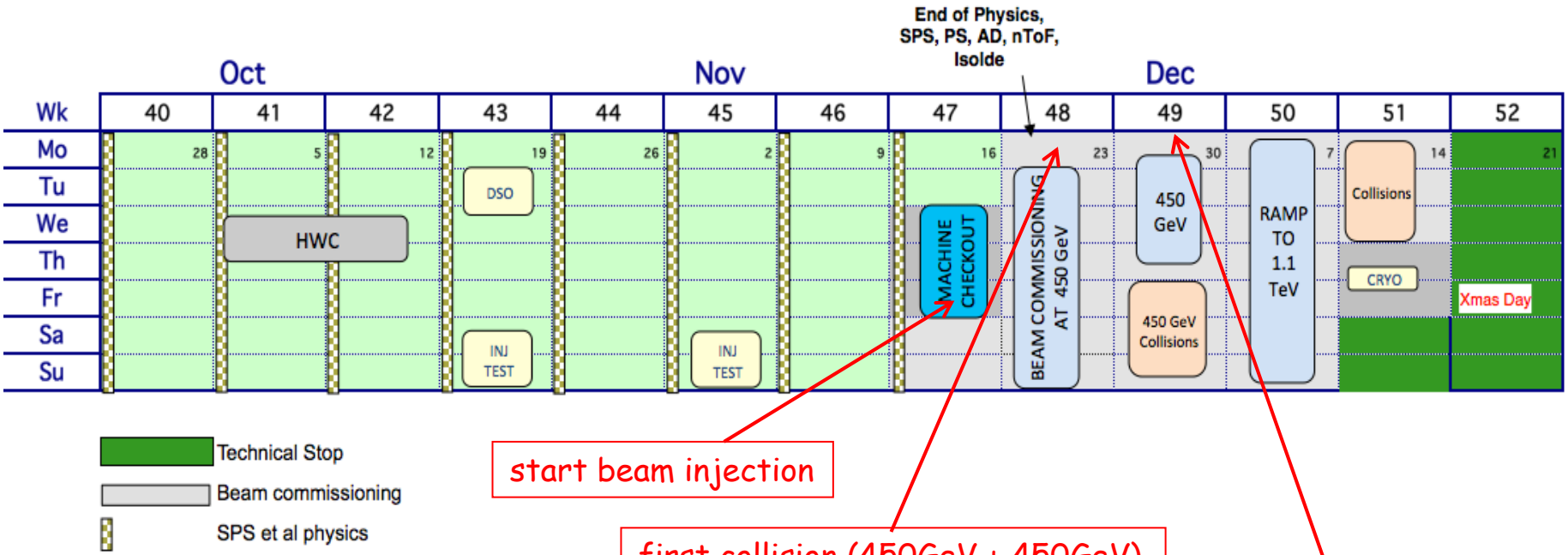
Analysis based on E_T selections (tighter cuts in black)



- M(π^0) is lower in both data and MC
- Mostly due to the readout threshold (100 MeV/Crystal).
- Conversions: part of the energy is deposited upstream of ECAL.
- Event timing is consistent

LHC Schedule 2009

23.Oct.2009
17.Nov.2009



start beam injection

first collision (450GeV + 450GeV)

beam accelerated to 1.18TeV

Press Release (30.11.2009)
"LHC sets new world record"

How much luminosity did we collect? Naïve estimate

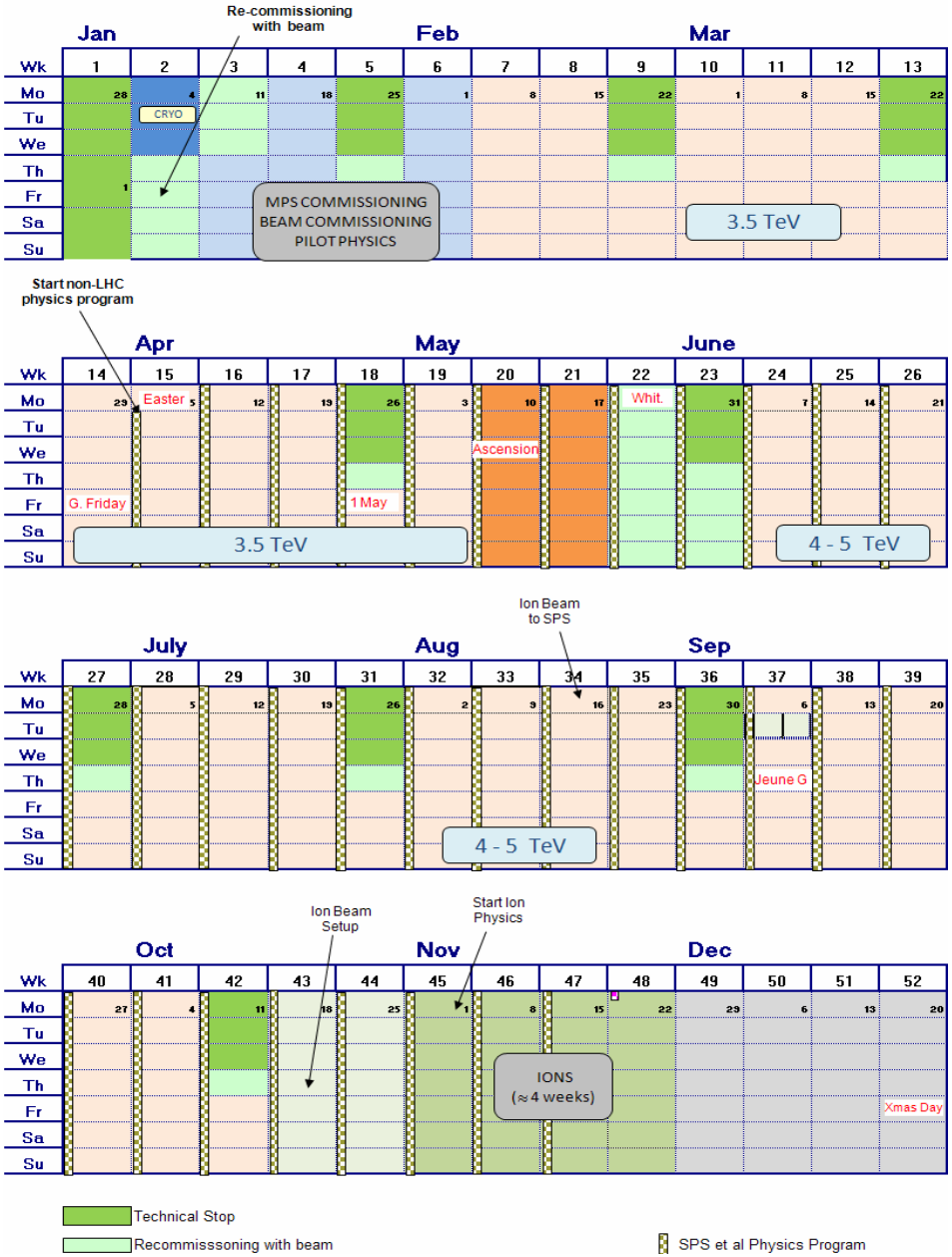
- With a tight calorimeter-based timing selection, cross-checked by the MBTS and TRT ToF measurements, we have identified 197 golden collision candidates from run 140541 of Nov 23
- We separate this sample into 2 parts (afternoon=A, evening=B) of different beam conditions
- From Monte Carlo (solenoid field on) we find that the selection efficiency, including trigger, for inelastic and diffractive minimum bias events is about 70%
- Using as total minimum bias cross section of 58 mb (40 mb inelastic, 12/6 mb SD/DD):

Sample	Number of events	DAQ duration	Average rate	Average inst. luminosity	Integrated luminosity
A	61	54 mins	0.03 Hz	0.5×10^{24} cm^{-2} s^{-1}	1.5 mb^{-1}
B	136	46 mins	0.07 Hz	1.2×10^{24} cm^{-2} s^{-1}	3.4 mb^{-1}

Cross checks:
- Assuming that ε=0% for SD and DD → increases luminosity by 10%
- change inelastic cross section to 34 mb → increases luminosity by 15%

LHC 2010 – very draft

26.Oct. 2009
Steve Myers



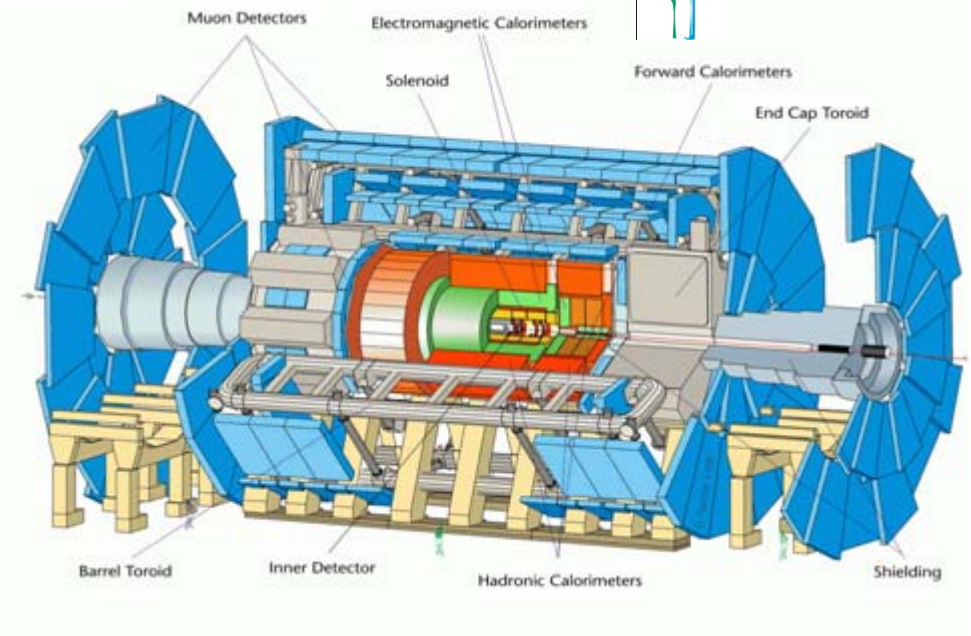
- **2009**:
  - 1 month commissioning
- **2010**:
  - 1 month pilot & commissioning
  - 3 month 3.5 TeV
  - 1 month step-up
  - 5 month 4 - 5 TeV
  - 1 month ions

Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal
1	Beam commissioning						
2	Pilot physics combined with commissioning	43	3×10^{10}	4	8.6×10^{29}	~200 nb^{-1}	
3		43	5×10^{10}	4	2.4×10^{30}	~1 pb^{-1}	
4		156	5×10^{10}	2	1.7×10^{31}	~9 pb^{-1}	2.5
5a	No crossing angle	156	7×10^{10}	2	3.4×10^{31}	~18 pb^{-1}	3.4
5b	No crossing angle – pushing bunch intensity	156	1×10^{11}	2	6.9×10^{31}	~36 pb^{-1}	4.8
6	Shift to higher energy: approx 4 weeks	Would aim for physics without crossing angle in the first instance with a gentle ramp back up in intensity					
7	4 – 5 TeV (5 TeV luminosity numbers quoted)	156	7×10^{10}	2	4.9×10^{31}	~26 pb^{-1}	3.4
8	50 ns – nominal Xing angle	144	7×10^{10}	2	4.4×10^{31}	~23 pb^{-1}	3.1
9	50 ns	288	7×10^{10}	2	8.8×10^{31}	~46 pb^{-1}	6.2
10	50 ns	432	7×10^{10}	2	1.3×10^{32}	~69 pb^{-1}	9.4
11	50 ns	432	9×10^{10}	2	2.1×10^{32}	~110 pb^{-1}	12

General purpose detectors for pp collisions

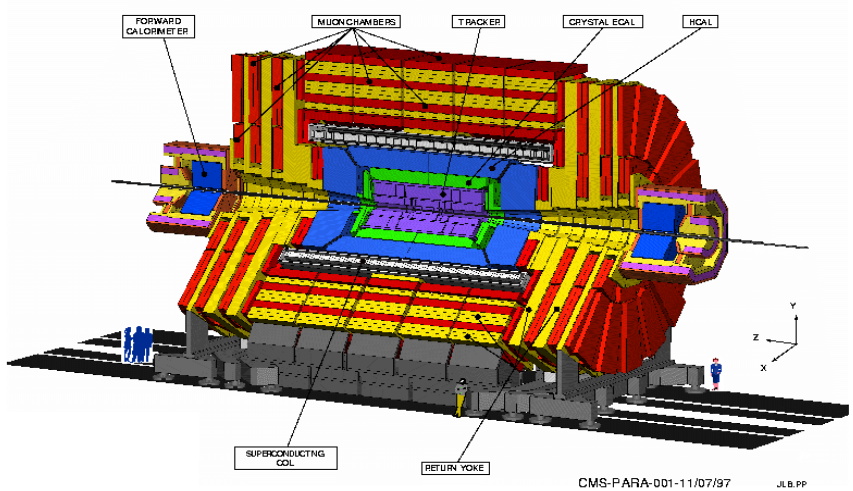
+ LHCb, ALICE, TOTEM, LHCf

ATLAS

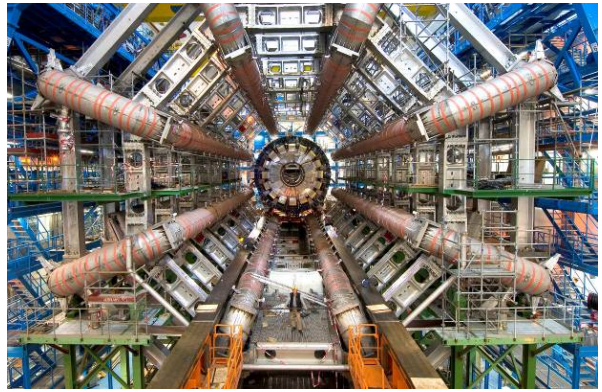


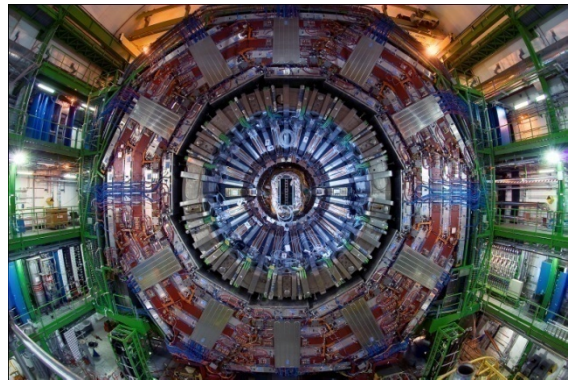
Length : ~45 m
Diameter : ~24 m
Weight : ~ 7,000 tons
Electronic channels : ~ 10^8
Solenoid : 2 T
Air-core toroids

CMS



Length : ~22 m
Diameter : ~14 m
Weight : ~ 12,500 tons
Solenoid : 4 T
Fe yoke
Compact and modular

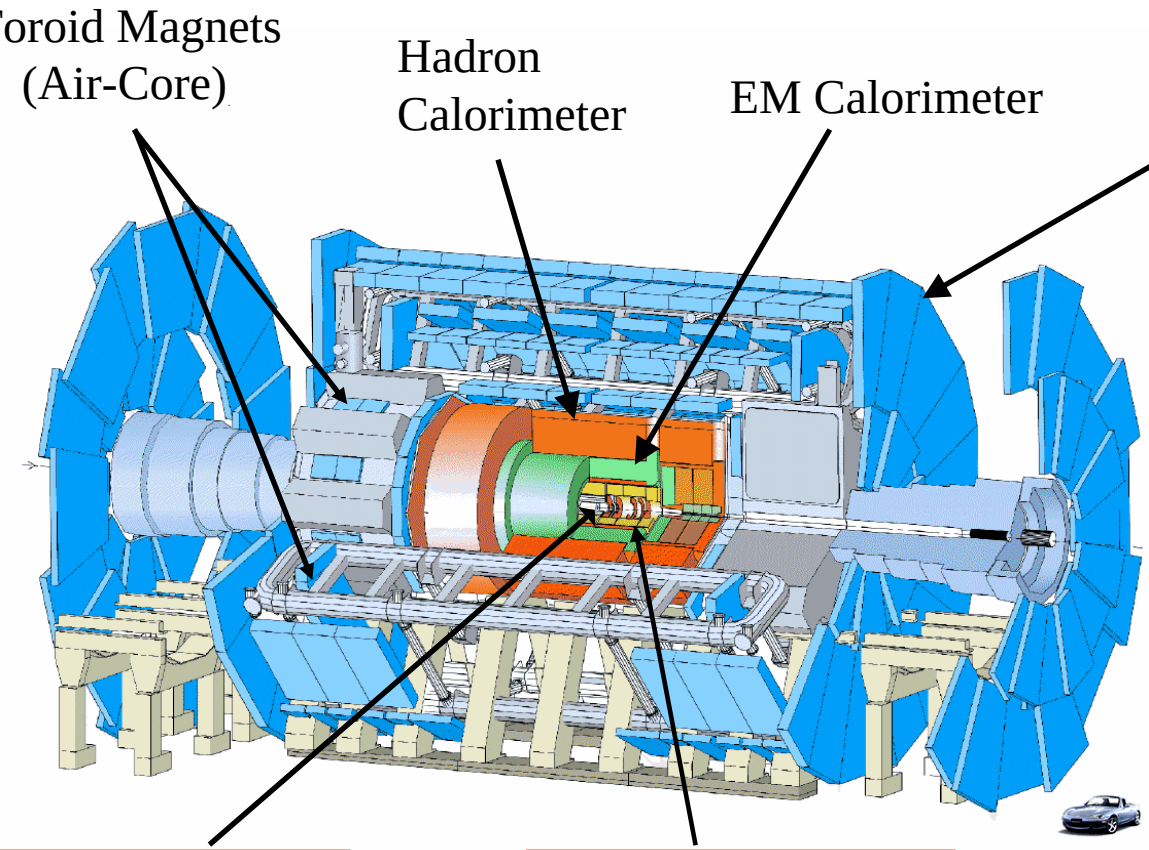




	ATLAS	CMS
TRACKER	Si pixels + strips TRT → particle identification $\sigma/p_T \sim 4\times10^{-4}\ p_T \oplus 0.01$	Si pixels + strips No particle identification $\sigma/p_T \sim 1.5\times10^{-4}\ p_T \oplus 0.005$
EM CALO	Pb-liquid argon $\sigma/E \sim 10\%/\sqrt{E}$ uniform longitudinal segmentation	$PbWO_4$ crystals $\sigma/E \sim 2\text{-}5\%/\sqrt{E}$ no longitudinal segmentation
HAD CALO	Fe-scint. + Cu-liquid argon ($\geq 10\ \lambda$) $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$	Brass-scint. ($\geq 5.8\ \lambda$ + catcher) $\sigma/E \sim 100\%/\sqrt{E} \oplus 0.05$
MUON	MDT, CSC, RPC, TGC $\sigma/p_T \sim 7\ \%$ at 1 TeV standalone	DT, CSC, RPC $\sigma/p_T \sim 5\%$ at 1 TeV combining with tracker

Activities of ATLAS-Japan Group

15 Institutes (KEK, Tsukuba, UT/ICEPP, TMU, Shinshu, Nagoya, Ritsumeikan, Kyoto, KUE, Osaka, Kobe, Okayama, Hiroshima, HIT, NIAS)
~100 Participants (staff + students)
Funded through KEK (detector budget) and ICEPP (data analysis budget)



+ DAQ
+ Software
+ Regional Center

Contributions from Japan


TGC (KEK, ICEPP, Kobe, Nagoya, --)


SCT (KEK, Tsukuba, --)


Solenoid (KEK)


Tier-2 (ICEPP)

and
TDAQ, Geant4

Detector hardware status summary in one page

Sub-detector	Number of channels	Operational fraction (%)
Pixels	80 M	98.0
SCT Silicon Strips	6.3 M	99.3
TRT Transition Radiation Tracker	350 k	98.2
LAr EM Calorimeter	170 k	98.8
Tile Calorimeter	9.8 k	99.5
Hadronic Endcap LAr Calorimeter	5.6 k	99.9
Forward LAr Calorimeter	3.5 k	100
MDT Muon Drift Tubes	350 k	99.7
CSC Cathode Strip Chambers	31 k	98.4
RPC Barrel Muon Trigger Chambers	370 k	97.0
TGC Endcap Muon Trigger Chambers	320 k	99.8

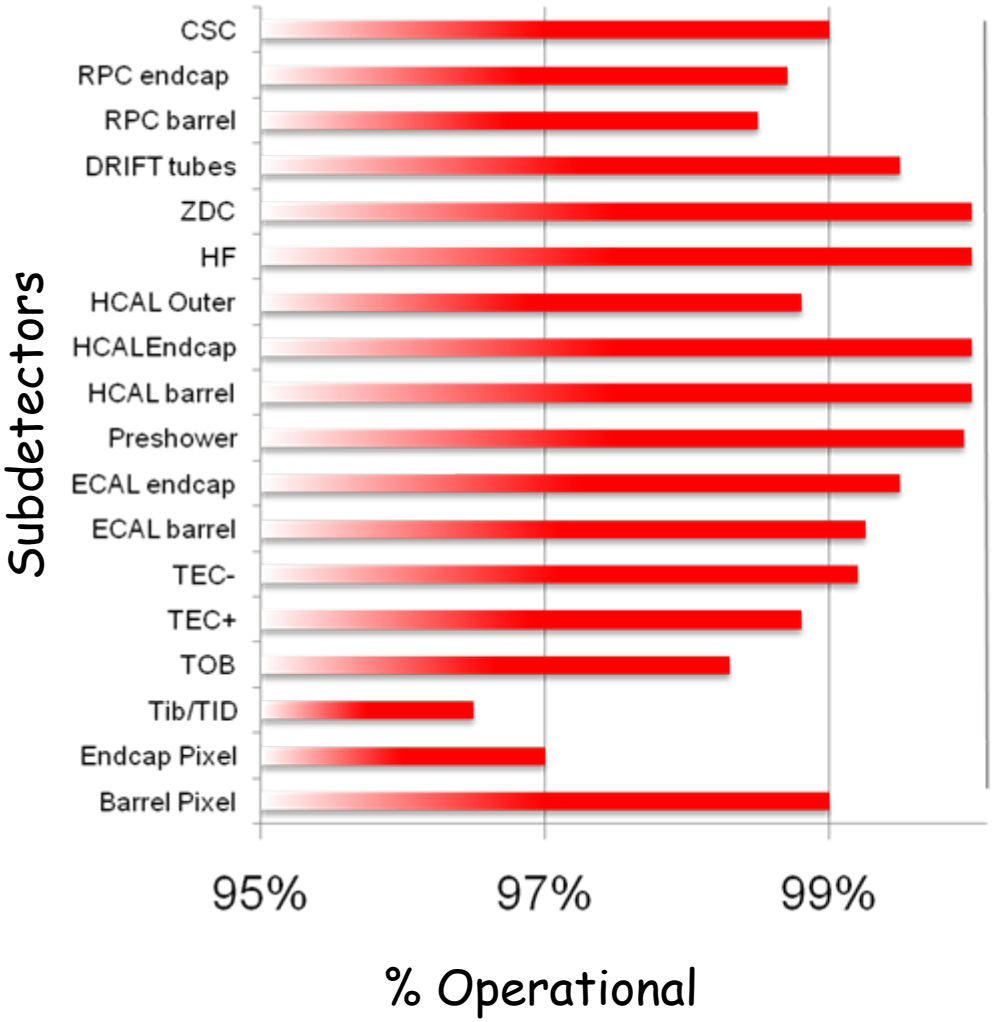
Trigger and DAQ: routinely taking long runs of cosmic data with all detector integrated at >300 MB/s

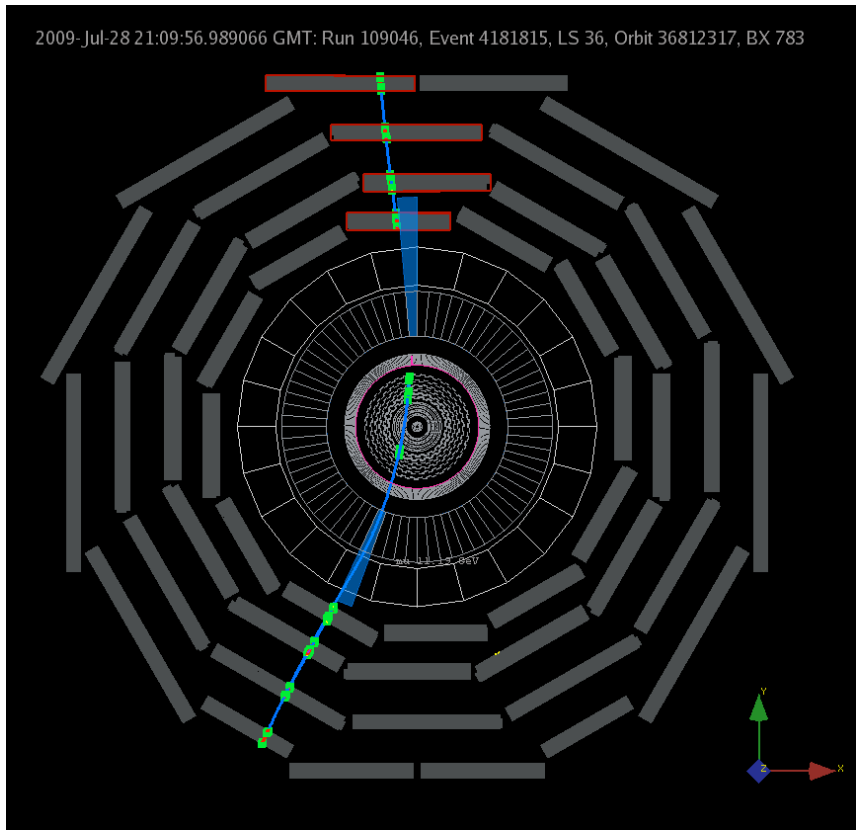
X. Wu, HCP2009, Evian, 17/11/09

W.Smith (U.Wisconsin)
HCP, Nov.6, 2009

CRAFT09 Performance

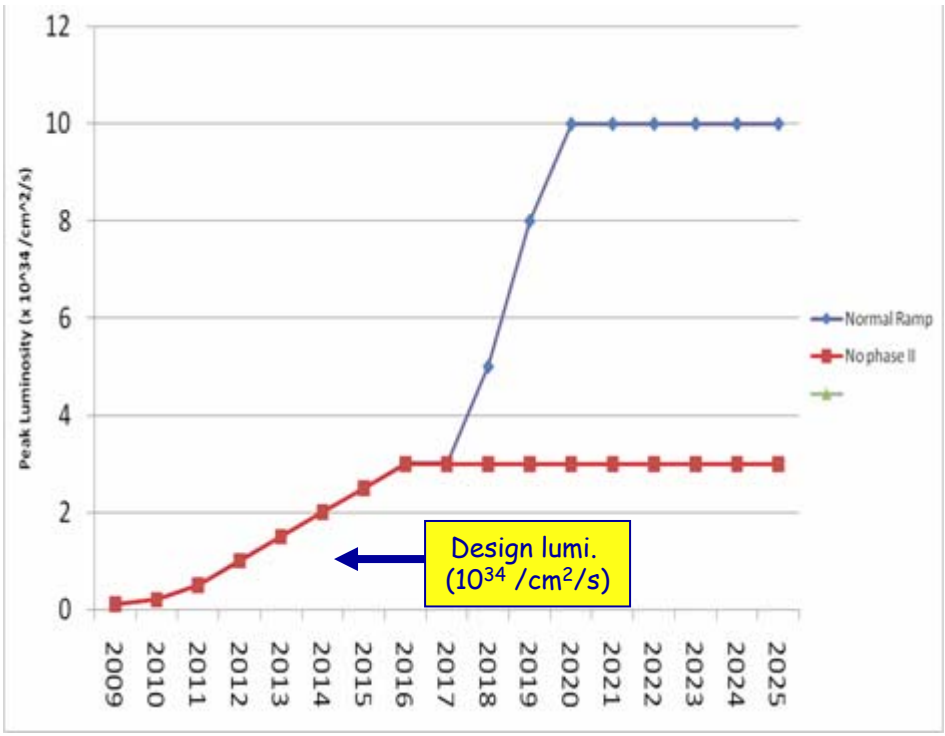
Cosmics Run at 4T* (operating at 3.8T)



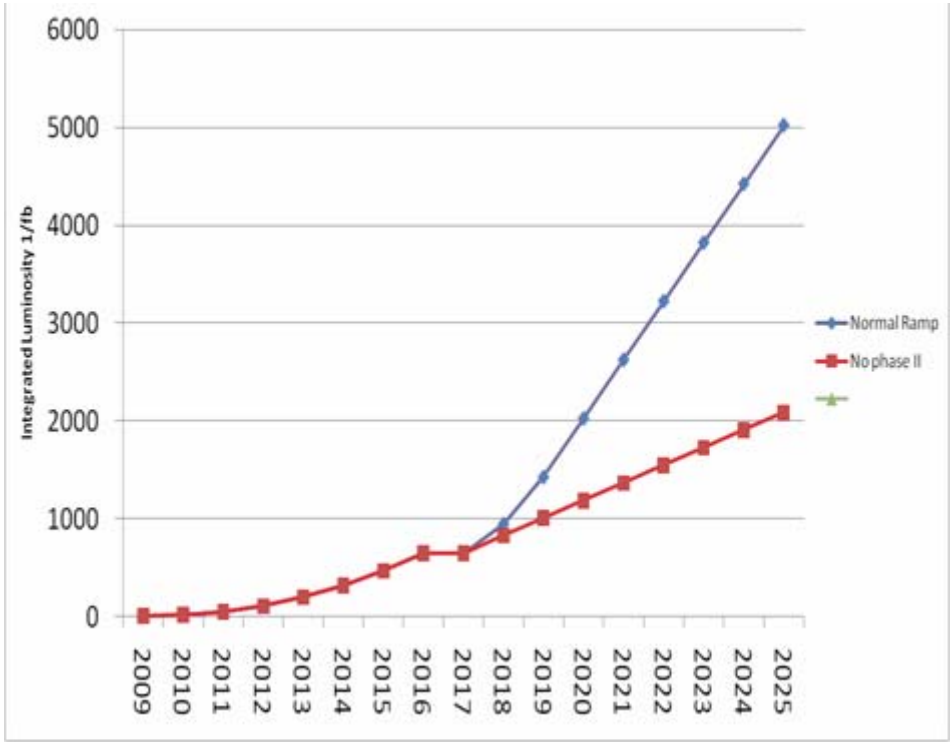


What was expected in Summer 2008

Peak Luminosity



Int. Luminosity (fb^{-1})



+1(2?) more year(s)

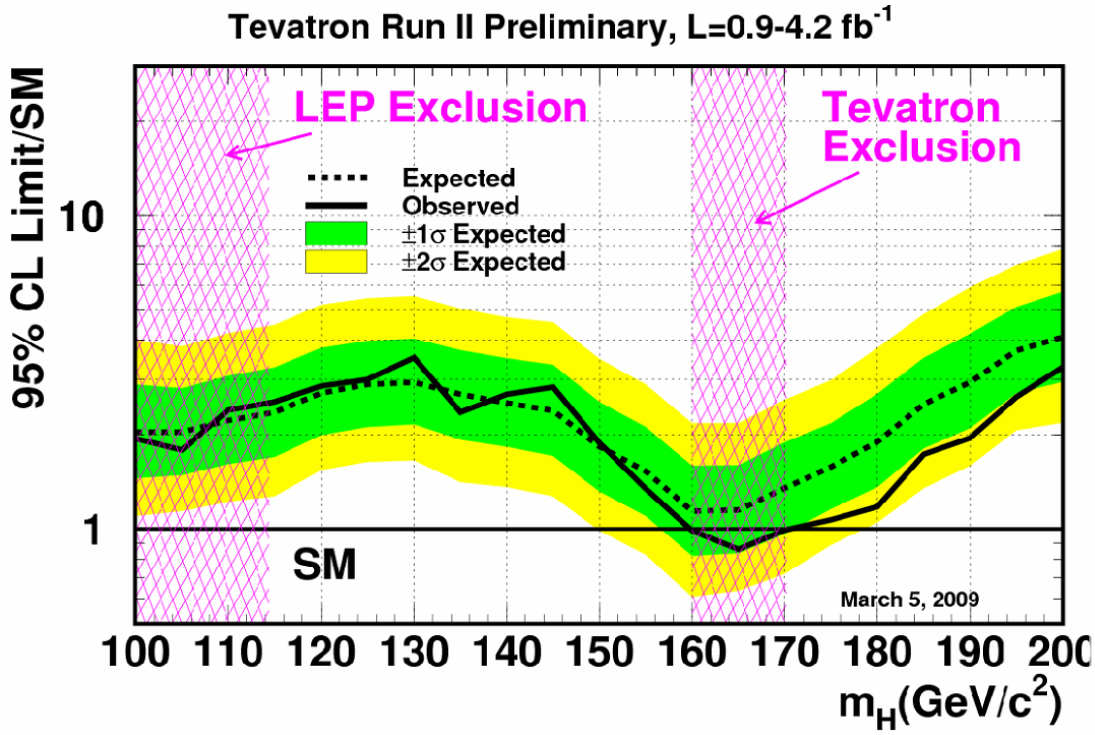
2011年: O(1) fb^{-1} at 14TeV(?)
2012年: O(10) fb^{-1} (?)

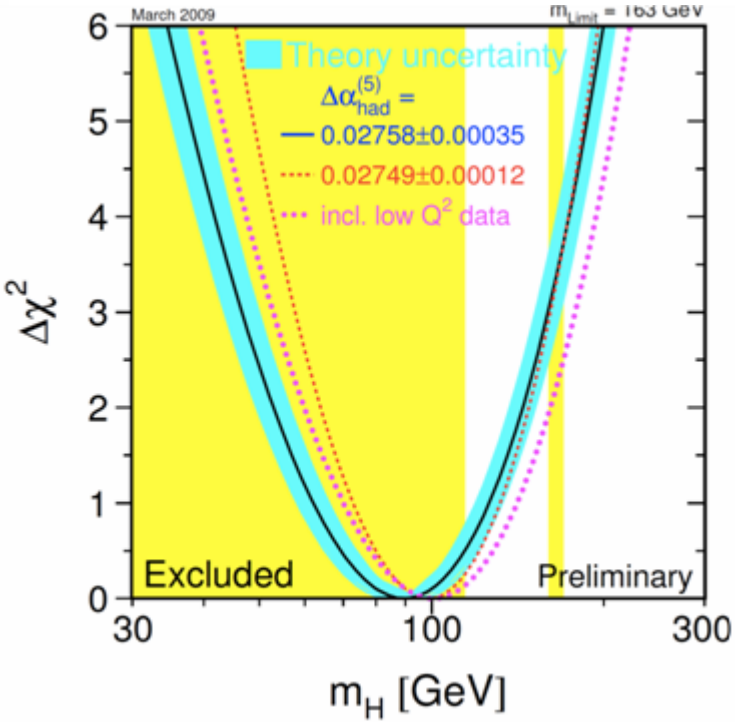
ATLAS upgrade schedule

IBL: TDR, iMoU next year
LoI for Phase-II: ~April next year
TP: 2012
TDR: end 2013 (ID TDR), ---

Current Experimental Limit on SM Higgs Mass

Moriond Conf. (Mar.2009)



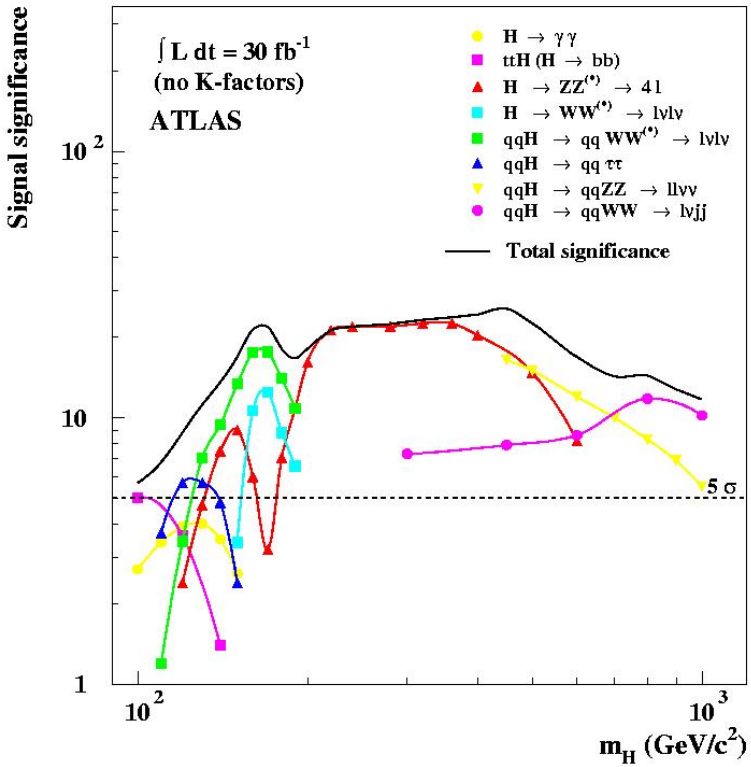


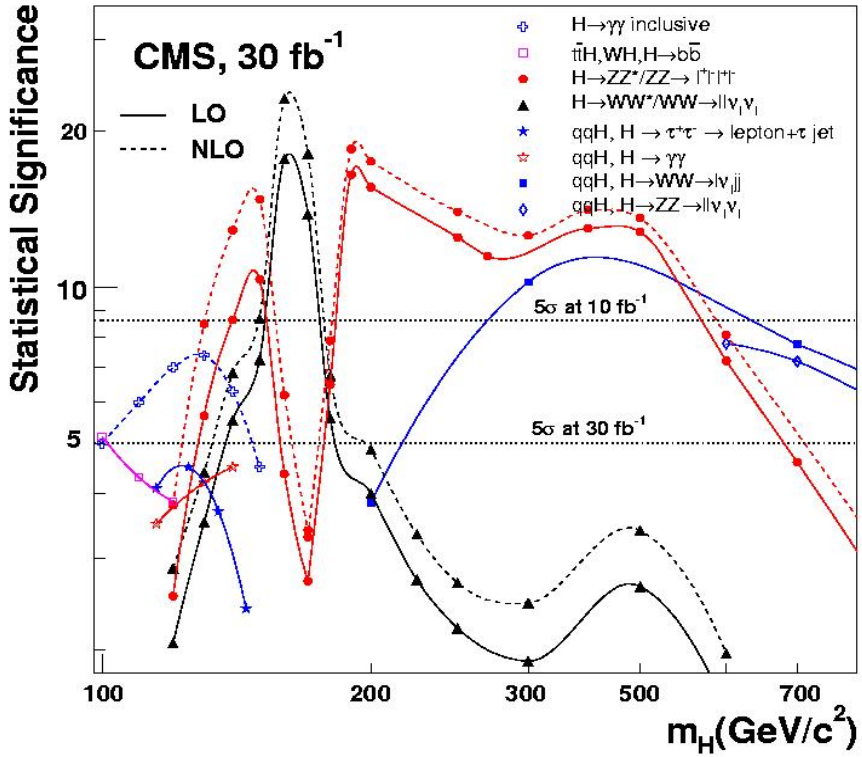
SM Higgs excluded in the mass range 160-170 @ 95% c.l.

Global E&W fit with latest averages of M_t and M_W

$\Rightarrow$ $114.4 < M_H < 160$ (GeV)

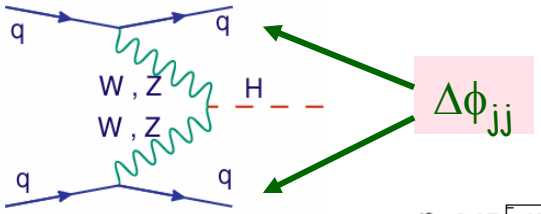
SM Higgs boson discovery would be made in early years of LHC run (until 2012~2013)

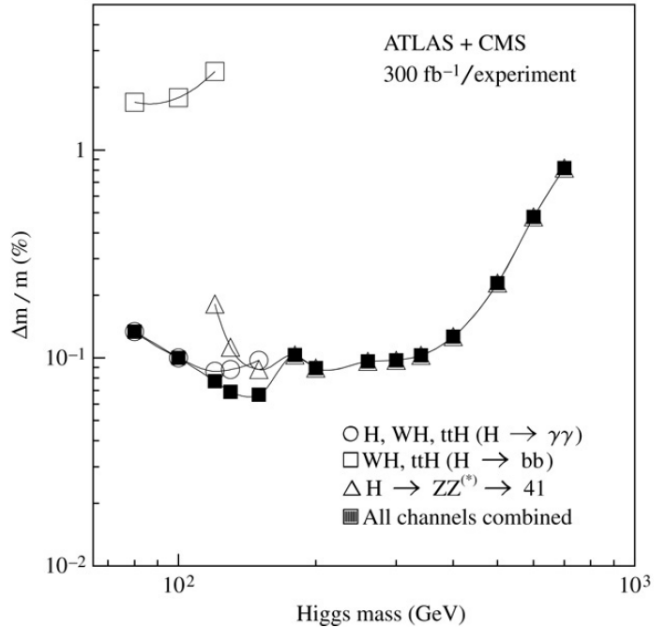


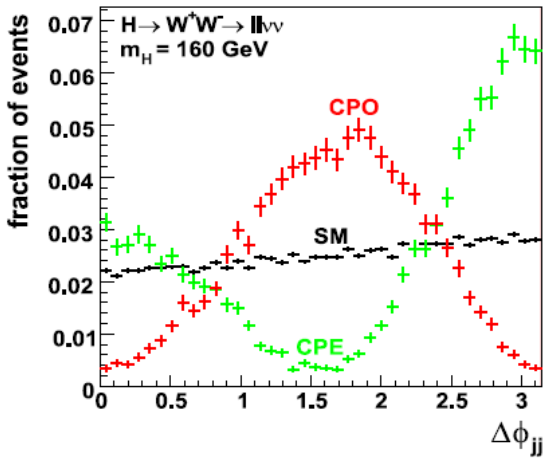


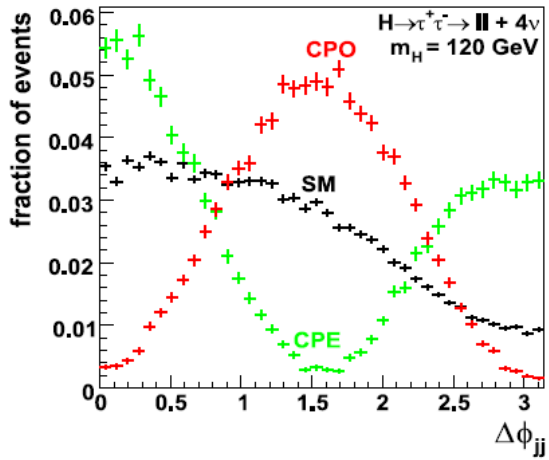
After Higgs(-like) Particle is found ---

- Measurement of mass and decay width
- Measurement of spin/CP
- Measurement of its couplings
  to fermions/VB (See next page)
- Higgs self coupling
  (→ looks difficult at LHC)







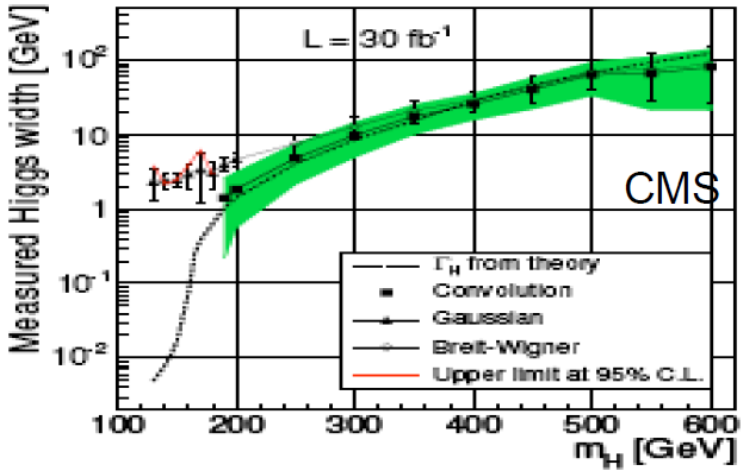


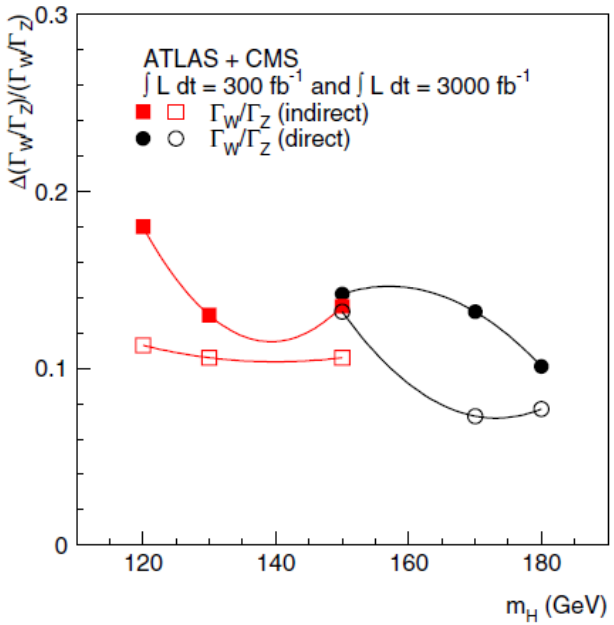
Anomalous couplings can be excluded at 5σ (2σ) for m_H = 160 (120) GeV with 10 (30) fb^{-1}

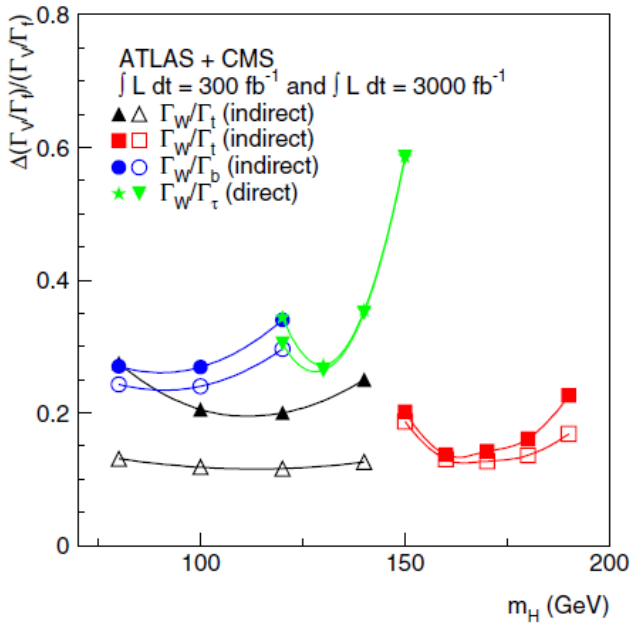
Higgs couplings to fermions and bosons

$$\sigma_{yy \to H} \cdot BR(H \to xx) \sim \Gamma_y \cdot \Gamma_x / \Gamma_H$$

Precise measurement of Γ_H is difficult for $m_H < 200$GeV



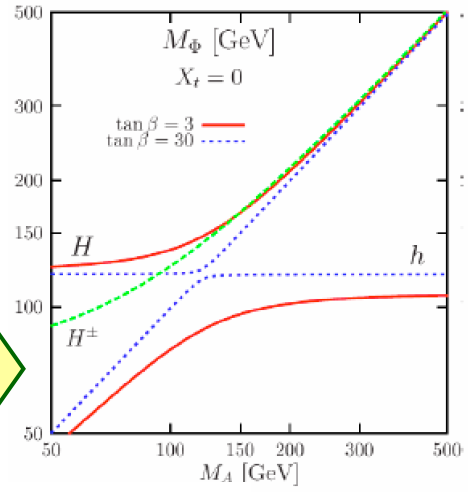


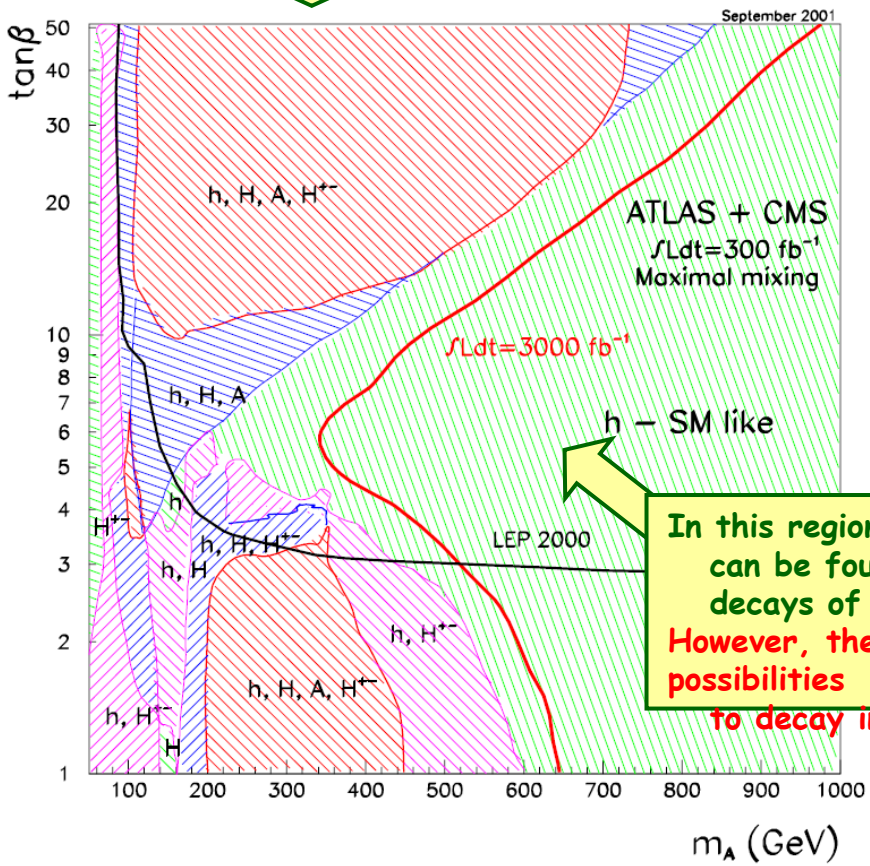


Ratio of the couplings can be measured at ~10% accuracies

Is there only one type of Higgs bosons?

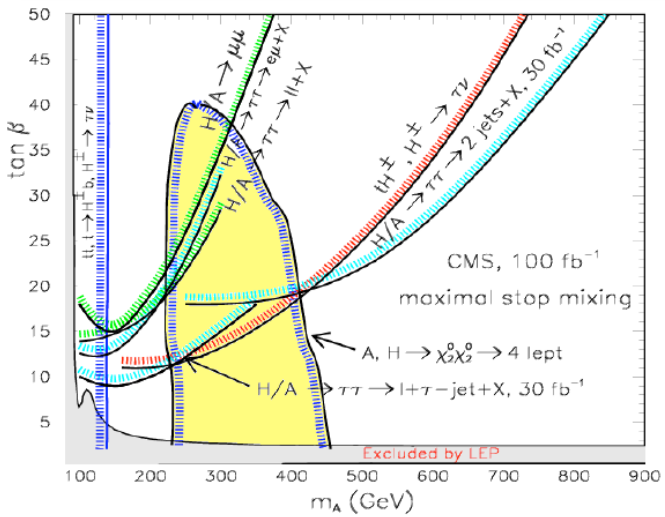
In case of MSSM model



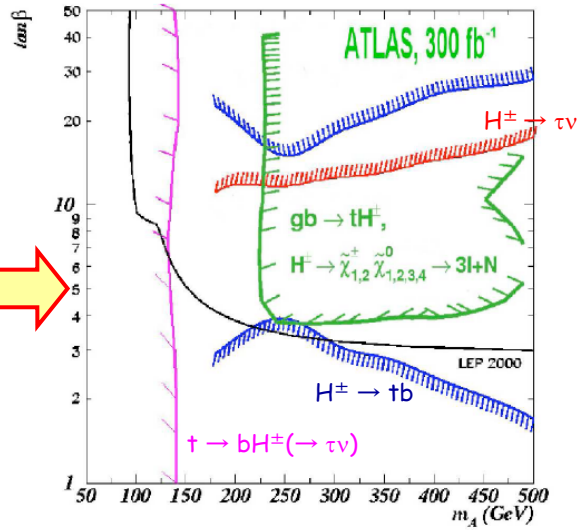


In this region only one type can be found (in the decays of SM particles)
However, there are possibilities to decay into SUSY particles

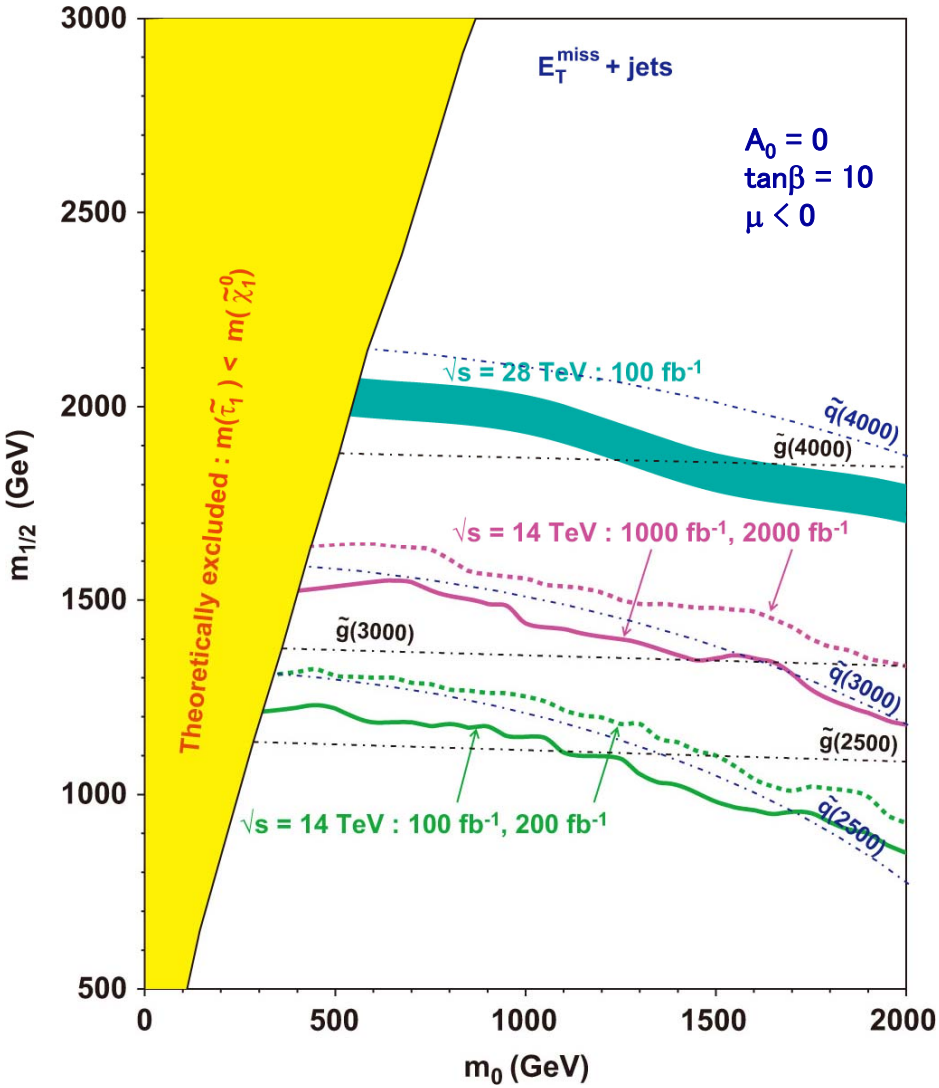
$H/A \rightarrow \chi^0_2\chi^0_2 \rightarrow \ell\ell\chi^0_1\ \ell\ell\chi^0_1$

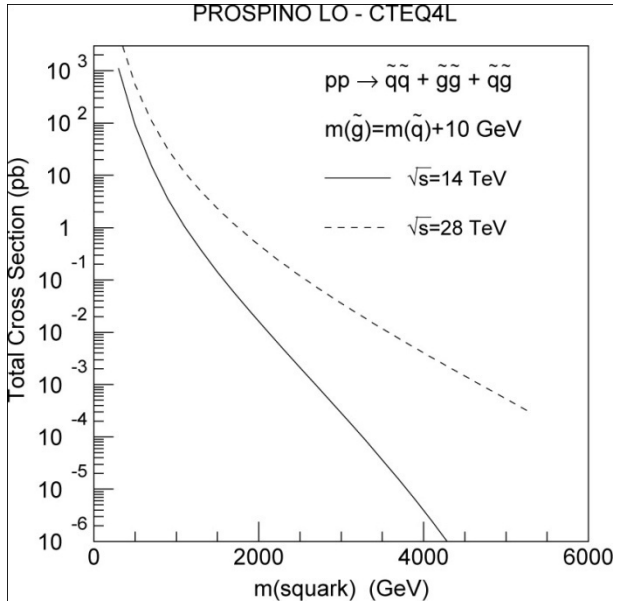


$gb \rightarrow tH^+,\ H^\pm \rightarrow \chi_{2,3}^0\ \chi_{1,2}^\pm \rightarrow 3\ell + E_T^{miss}$



SUSY(mSUGRA) 5σ Discovery Reach





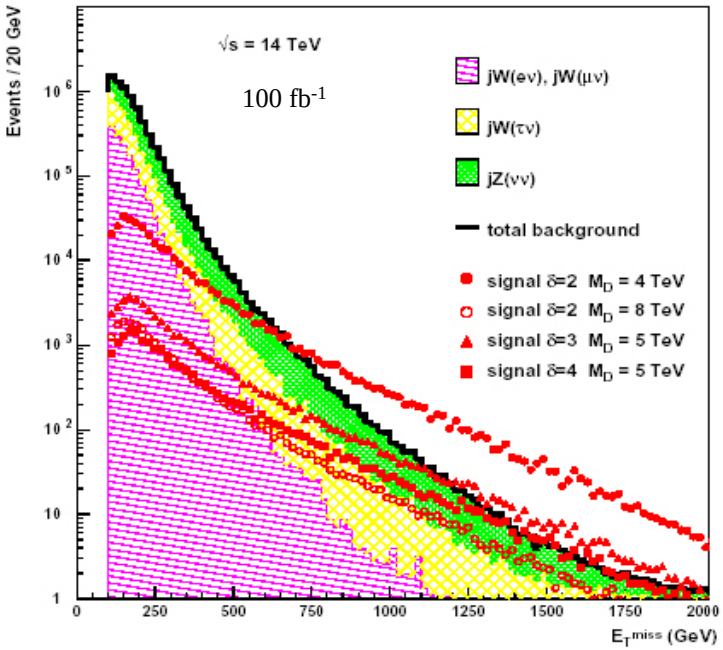
The reach for squarks and gluinos:

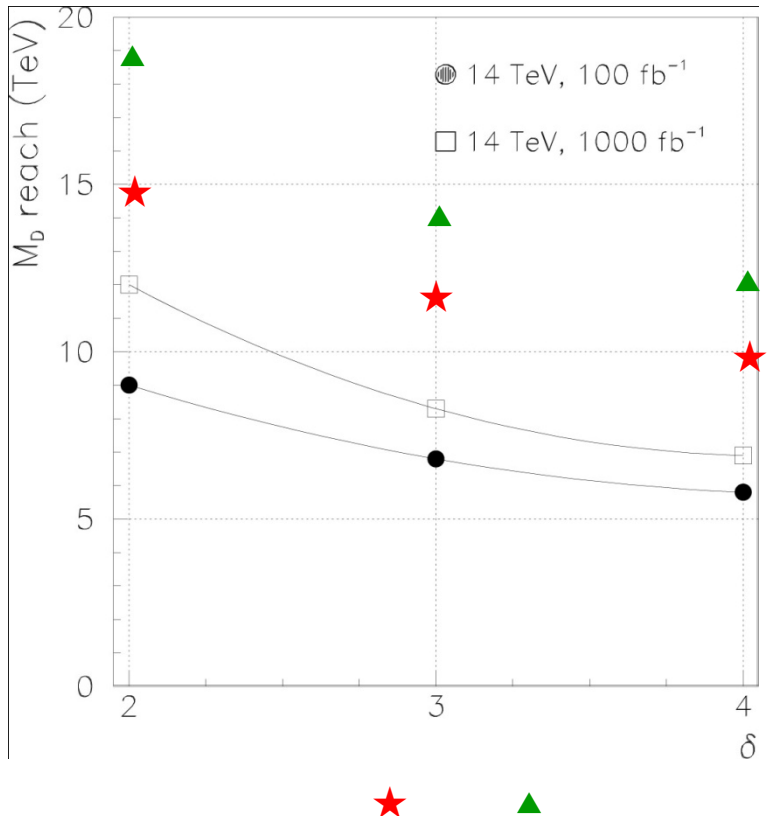
~2.5TeV (LHC)
~3TeV (SLHC)
~4TeV (DLHC)

Extra-Dimension(ADD Models) 5σ Discovery Reach

Signal: q/g + KK graviton (jet + missing-E_T)

E_T(jet) > 1 TeV





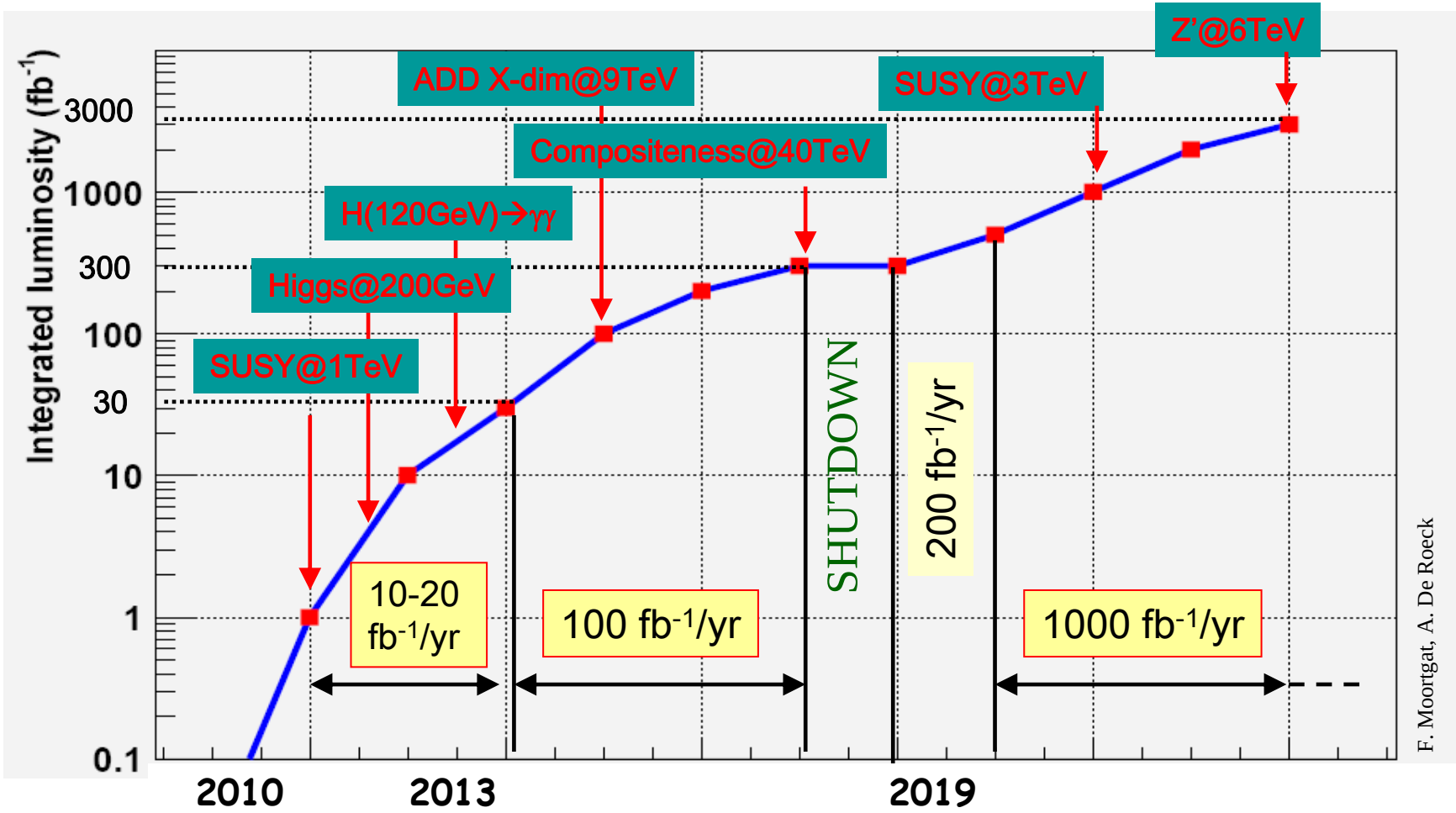
δ	14 TeV 100 fb^{-1}	14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}	28 TeV 1000 fb^{-1}
2	9	12	15	19
3	6.8	8.3	11.5	14
4	5.8	6.9	10	12

Table 6: 5 σ discovery limits that can be achieved on M_D, in TeV, as a function of the number of extra dimensions (δ) for various values of energy and integrated luminosity.

Summary of LHC New Physics Reach

SM Higgs	100 GeV ~ 1 TeV
MSSM Higgs	covers full (m_A, tanβ)
SUSY (squark, gluino)	2.5 - 3 TeV (300 fb^{-1})
New gauge bosons (Z')	< 4.5 TeV (100 fb^{-1})
Quark substructure (Λ_C)	< 25/40 TeV (30/300 fb^{-1})
q*, l*	< 6.5/3.4 TeV (100 fb^{-1})
Large ED (M_D for n=2,4)	< 9/5.8 TeV (100 fb^{-1})
Small ED (M_C)	< 5.8 TeV (100 fb^{-1})
Black holes	< 6 ~ 10 TeV
M(top quark)	σ_M ~ 1 GeV (~ 0.5 %)
M_W	σ_M ~ 15 MeV
CP-violation in B-decay	σ(sin2β) ~ 0.016 (30 fb^{-1})
Rare B-decay ($B_S \rightarrow \mu\mu$)	~ 5σ (130 fb^{-1})

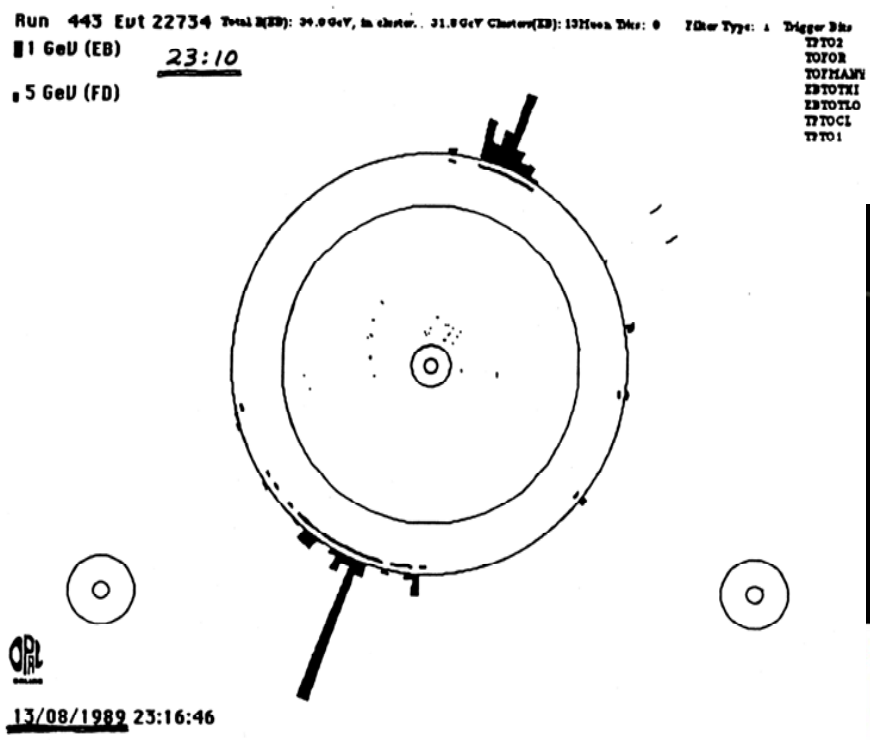
Discovery/Luminosity Roadmap?



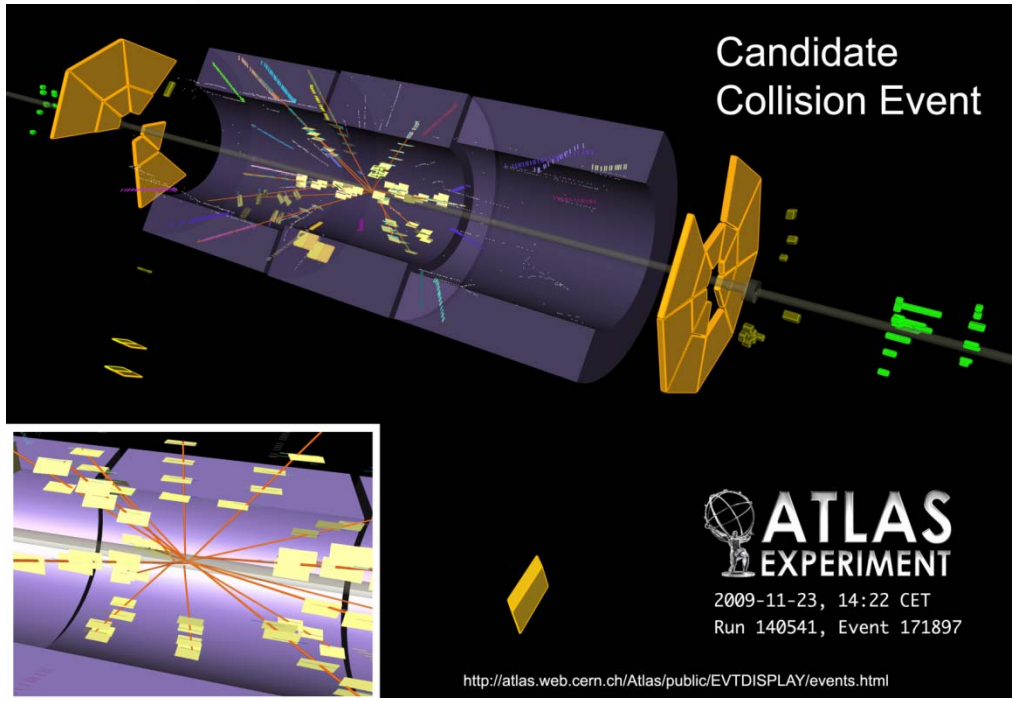
2010 : 7~10 TeV, O(200 pb^{-1})
2012~2013 : Higgs, SUSY(?)

2019~2020 : super-LHC will start

20 years ago



Now



Hoping that the next excitement would come well before 2029