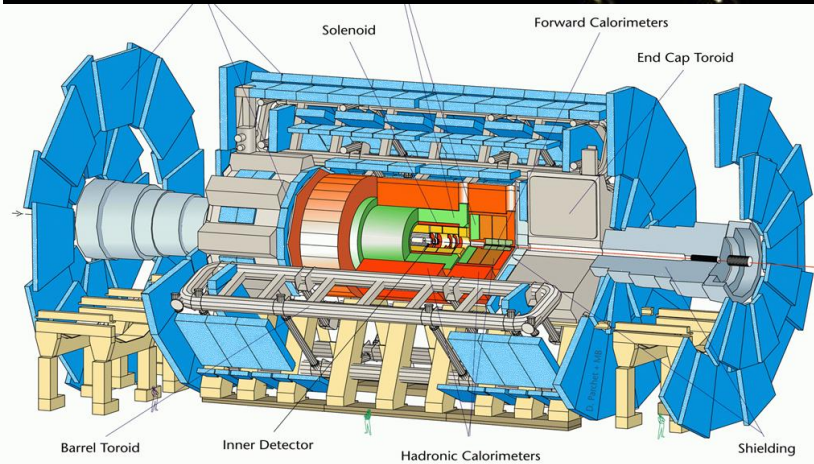
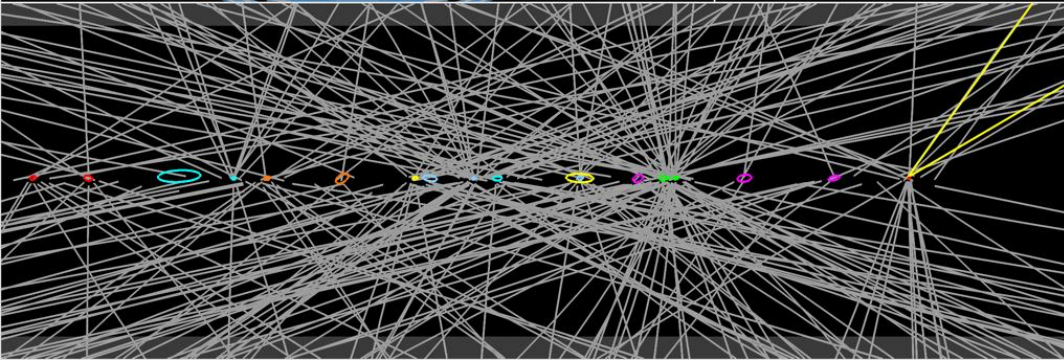
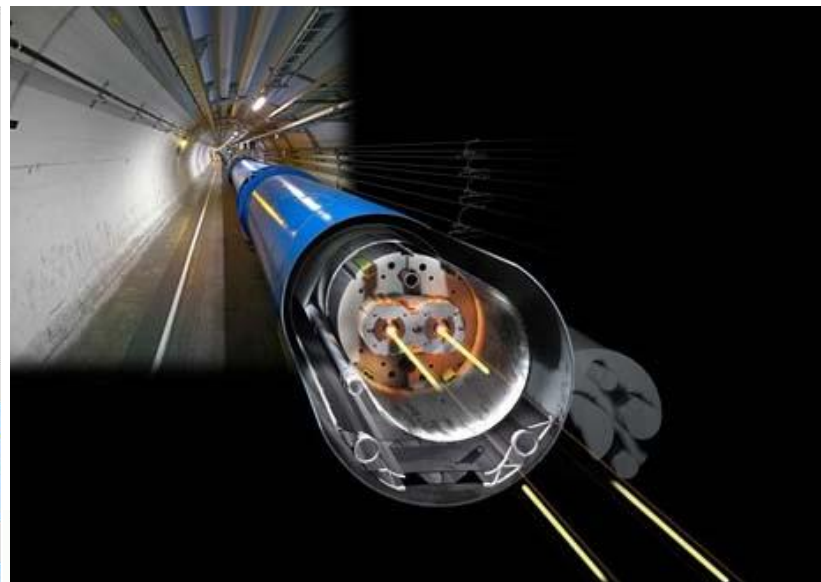
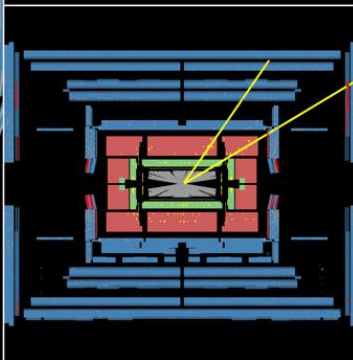
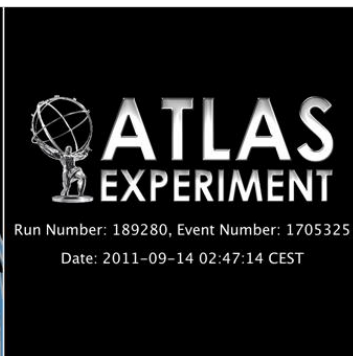
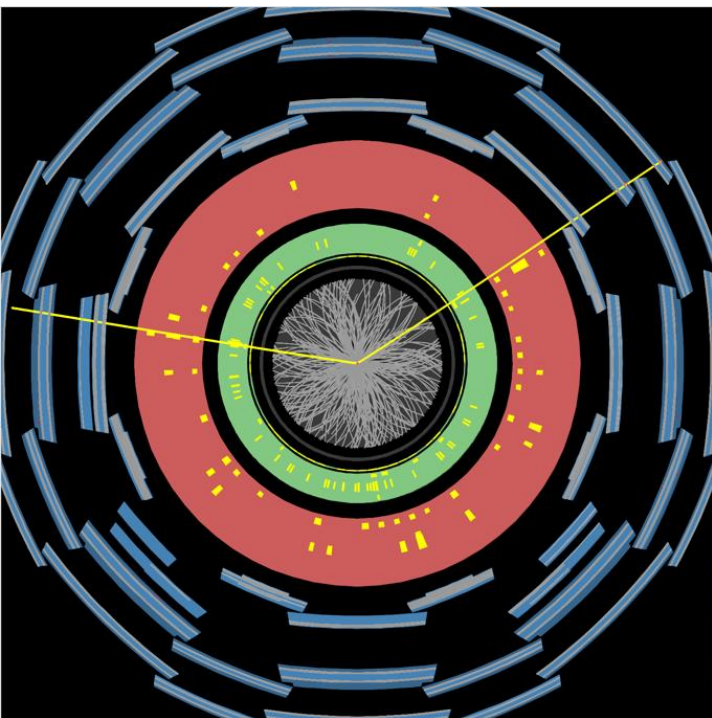


# LHC最初の二年

## ～実験結果と将来展望～

2012年5月18日  
高エネルギー 春の学校  
ラフォーレ琵琶湖

小林富雄  
(東大素粒子センター)

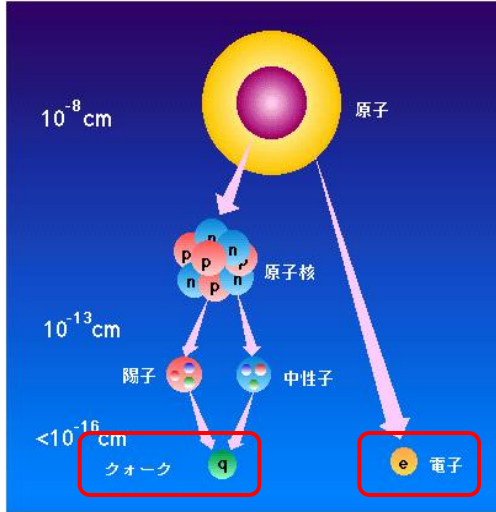


# 今日の話の内容:

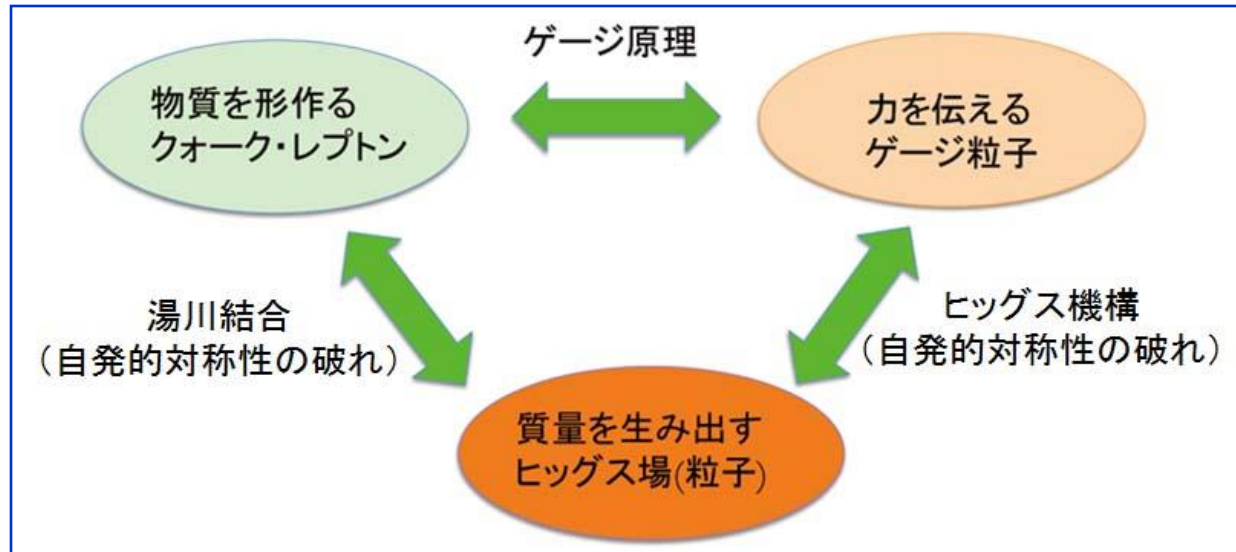
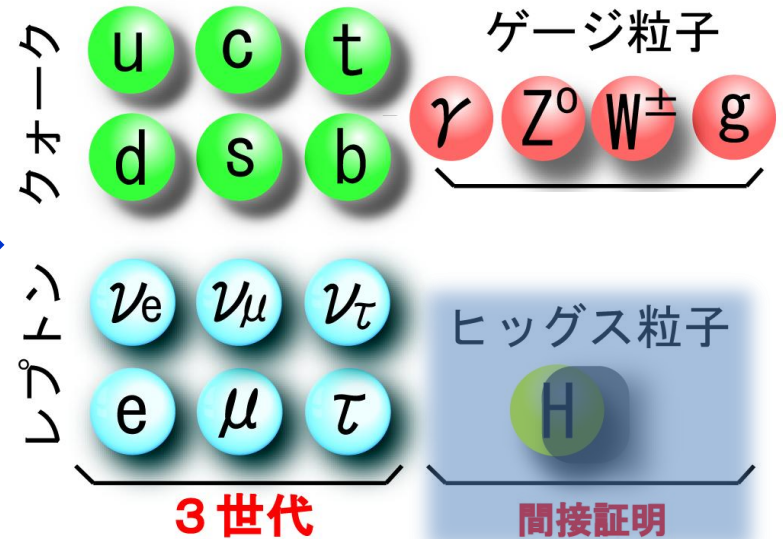
LHC/ATLAS実験の目的、  
実験装置

LHC最新結果（話題の  
ヒッグス粒子の話など）

# LHC開始以前の素粒子物理

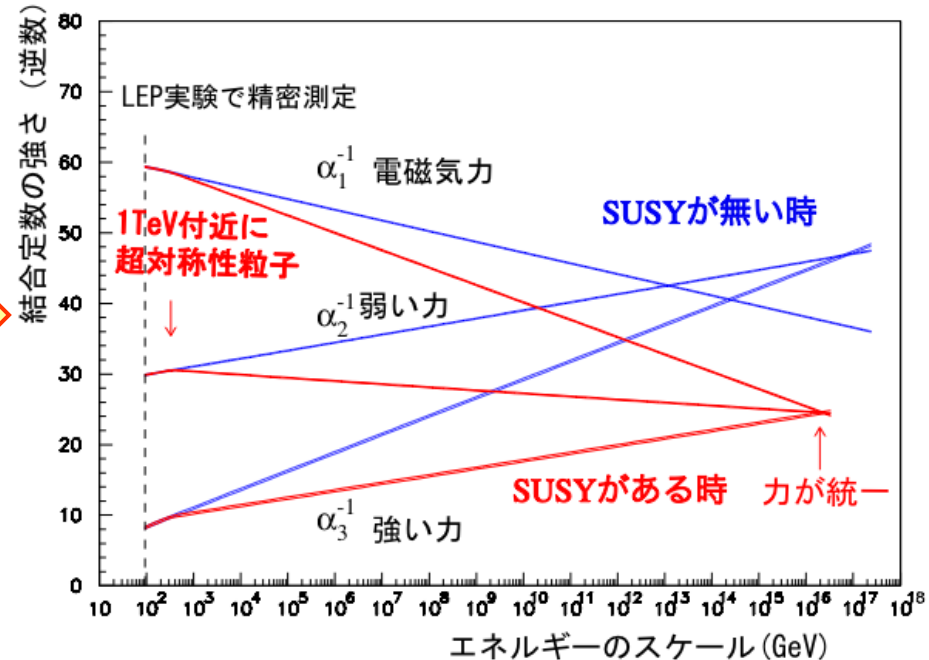
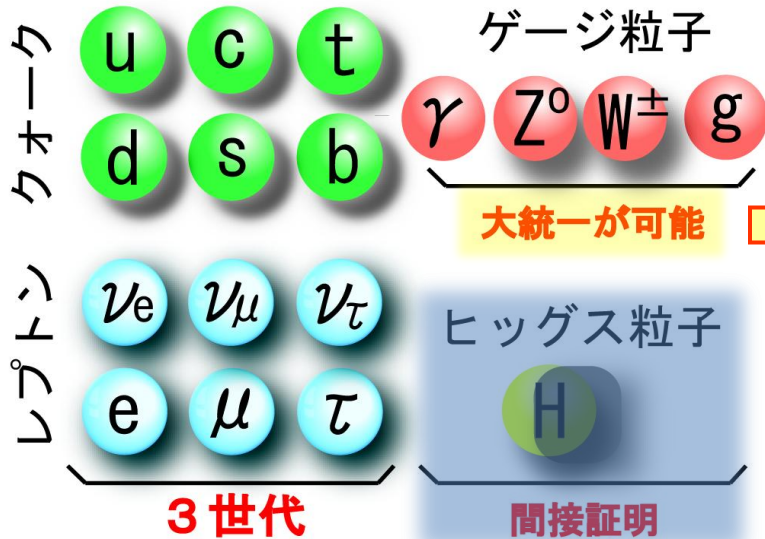


## 素粒子の標準モデル



# LHC開始以前の素粒子物理

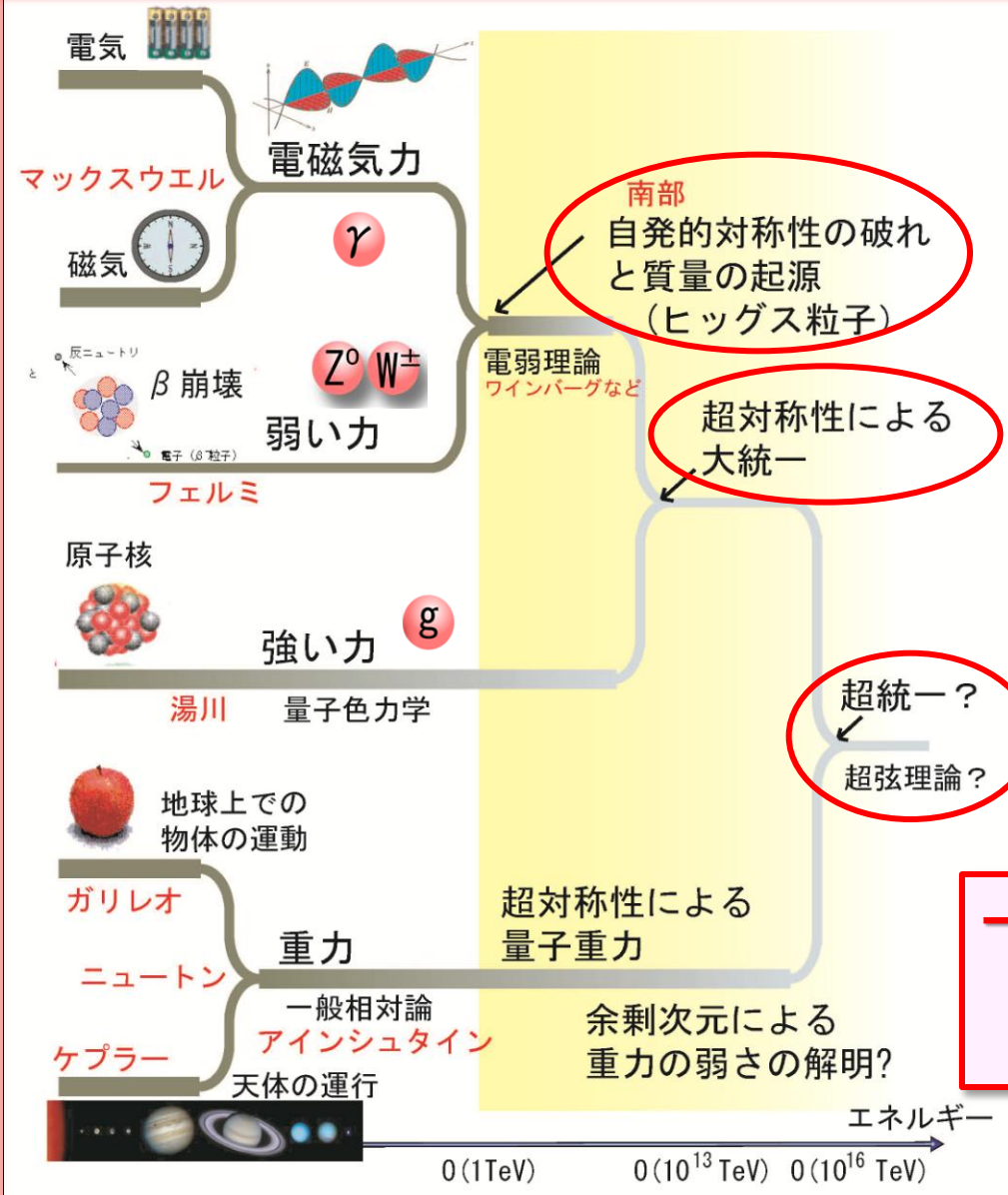
## 素粒子の標準モデル



## ゲージ理論

- 量子電磁力学 ...  $\gamma$  U(1) 対称性
- 電弱統一理論 ... Z, W,  $\gamma$  SU(2) × U(1)
- 量子色力学 ... gluon SU(3)
- 大統一理論 (?) ... SU(5) ?

# 物理学の発展と力の統一



標準理論

3つの力の統一

重力を含むすべての力の統一

→ 素粒子自体の研究のみでなく、真空や時空構造も研究対象に

# 第1部

# LHC加速器と 実験装置

# LHC加速器

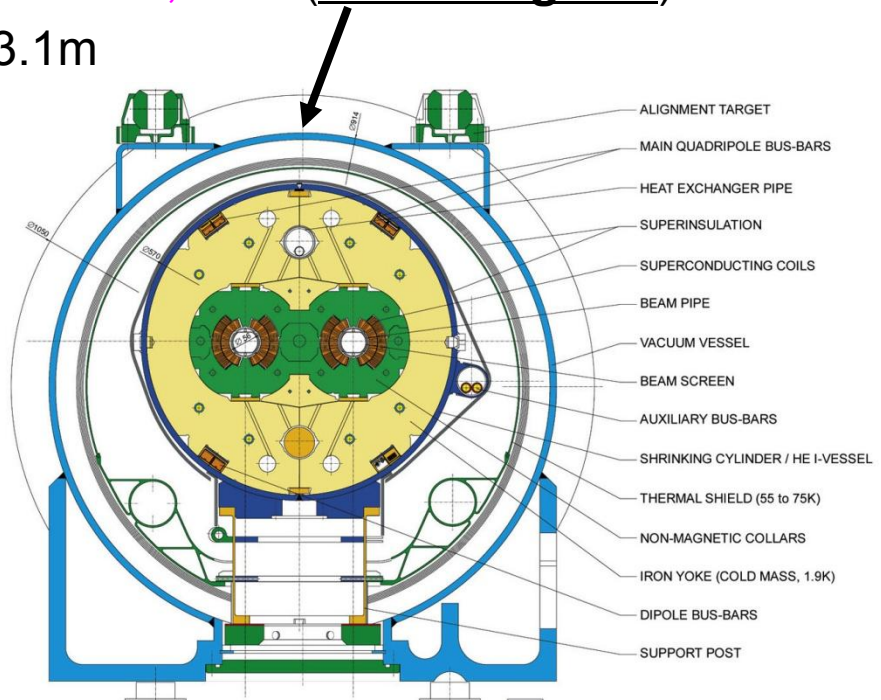
## Large Hadron Collider

- LHCはCERNで建設された**14TeV** の陽子・陽子衝突型加速器(周長27km)
- 超伝導磁石(8.3T dipole)を使用
- 建設に14年
- **2008年9月10日、陽子ビーム周回に成功**
- 同年9月19日、大量ヘリウム流出事故
- **2009年11月10日、運転再開**

# LHC Machine Parameters

## Proton-Proton Collider

Circumference:	26.7 km	(using LEP tunnel)
Beam Energy:	<b>7 TeV</b>	(Injection E: 450 GeV, PS→SPS→LHC)
1232 MR dipoles	<b>B=8.33 Tesla, L=14.3m, 1.9K</b>	<b>(2-in-1 magnets)</b>
368 MR quads	B'=223 T/m, L=3.1m	
No. of Bunches:	2808	
Bunch spacing:	<b>24.95 ns</b>	
Bunch size at IP:	16 $\mu\text{m}$	
Bunch length at IP:	77 mm	
Half crossing angle:	160 $\mu\text{rad}$	
Luminosity:	<b><math>10^{34}\text{ cm}^{-2}\text{s}^{-1}</math></b>	



## Heavy Ion Collider

Pb-Pb $E_{\text{cm}}$ :	1148 TeV
Pb-Pb Luminosity:	$10^{27}\text{ cm}^{-2}\text{s}^{-1}$

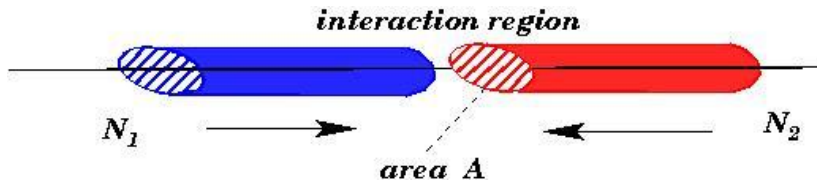
**~23 pp collisions/crossing**



# Luminosity について

The event rate  $N$  for a physics process with cross-section  $\sigma$  is proportional to the collider Luminosity  $L$ :

$$N = L\sigma$$



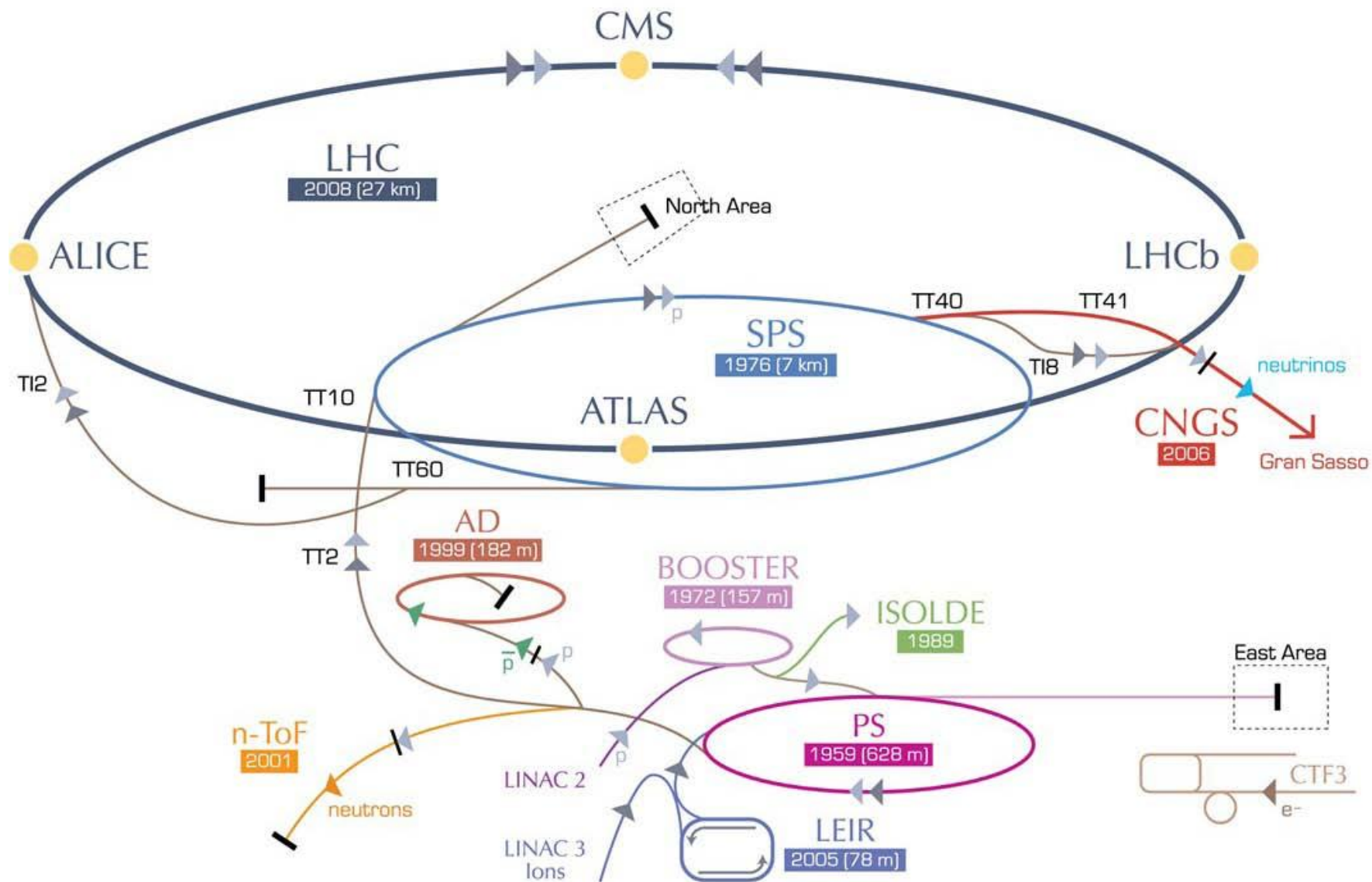
$$L = \frac{kN^2 f}{4\pi\sigma_x^* \sigma_y^*} = \frac{kN^2 f \gamma}{4\pi\beta^* \varepsilon}$$

## To maximize L:

- Many bunches ( $k$ )
- Many protons per bunch ( $N$ )
- Small beam sizes  $\sigma_{x,y}^* = (\beta^* \varepsilon)^{1/2}$

$\beta^*$  : beam envelope (optics)

$\varepsilon$  : beam emittance (phase space volume occupied by the beam)





YES! 3.5 TeV COLLISIONS!  
30-3-10 12:57

2010年3月30日  
3.5 TeV + 3.5 TeV  
での連続運転開始



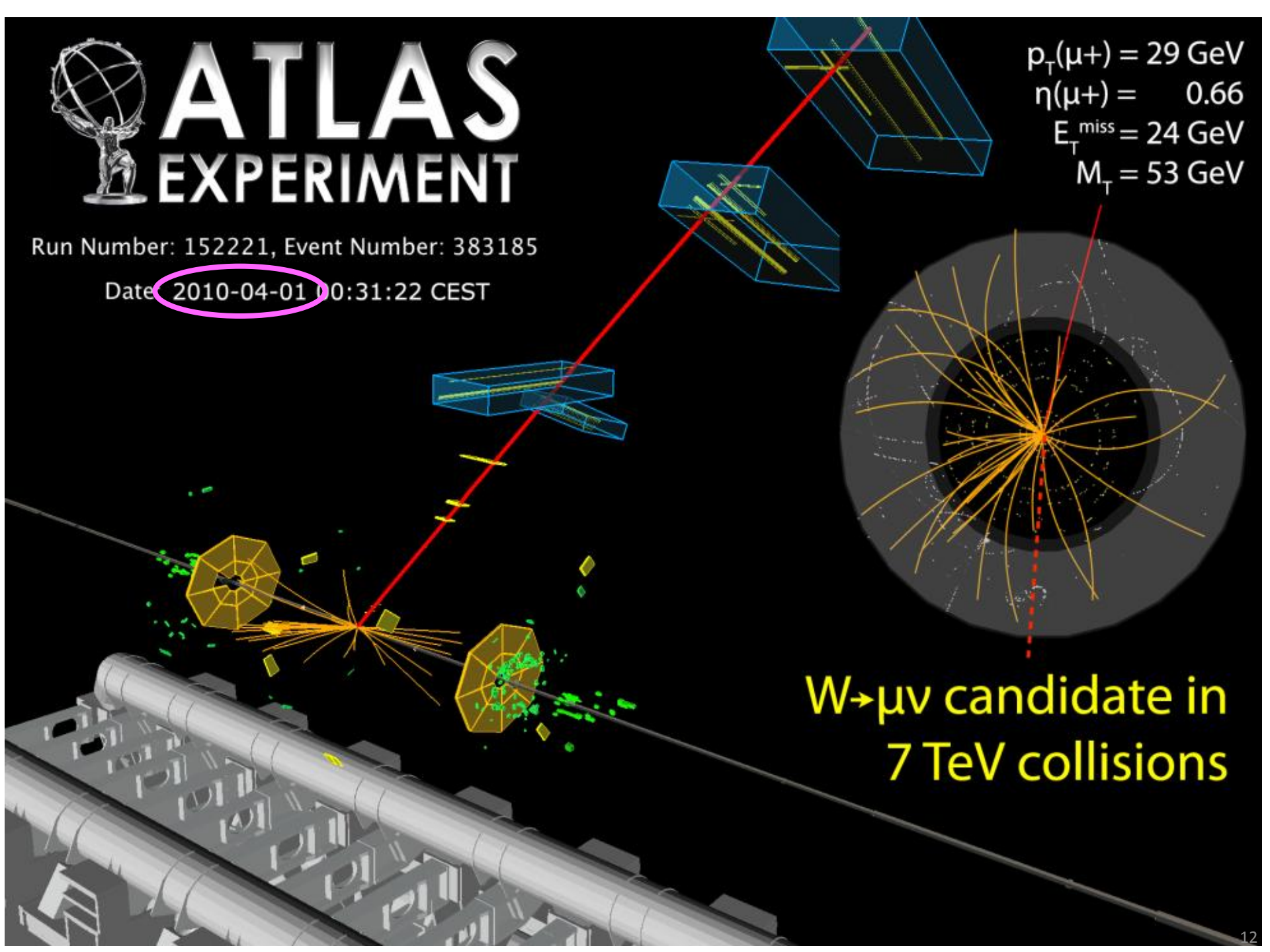


# ATLAS EXPERIMENT

Run Number: 152221, Event Number: 383185

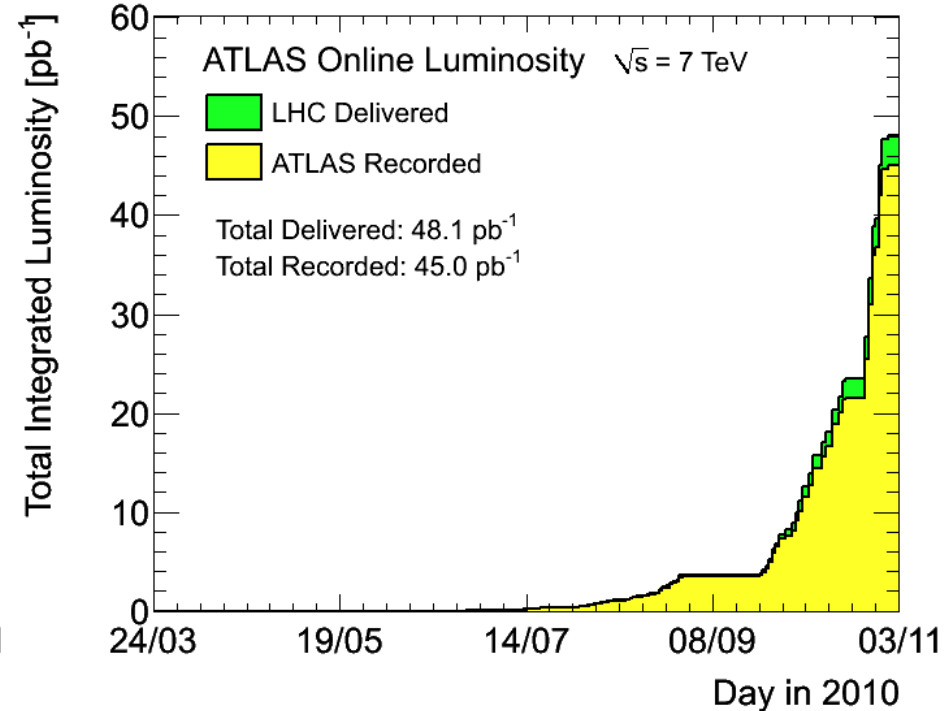
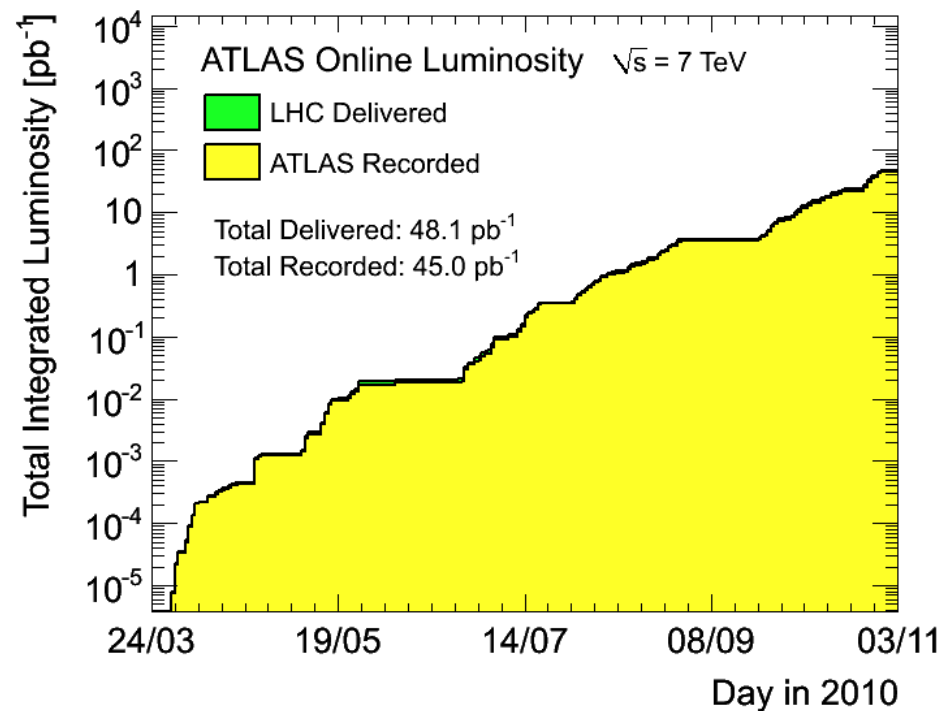
Date: 2010-04-01 00:31:22 CEST

$p_T(\mu^+) = 29 \text{ GeV}$   
 $\eta(\mu^+) = 0.66$   
 $E_T^{\text{miss}} = 24 \text{ GeV}$   
 $M_T = 53 \text{ GeV}$



$W \rightarrow \mu\nu$  candidate in  
7 TeV collisions

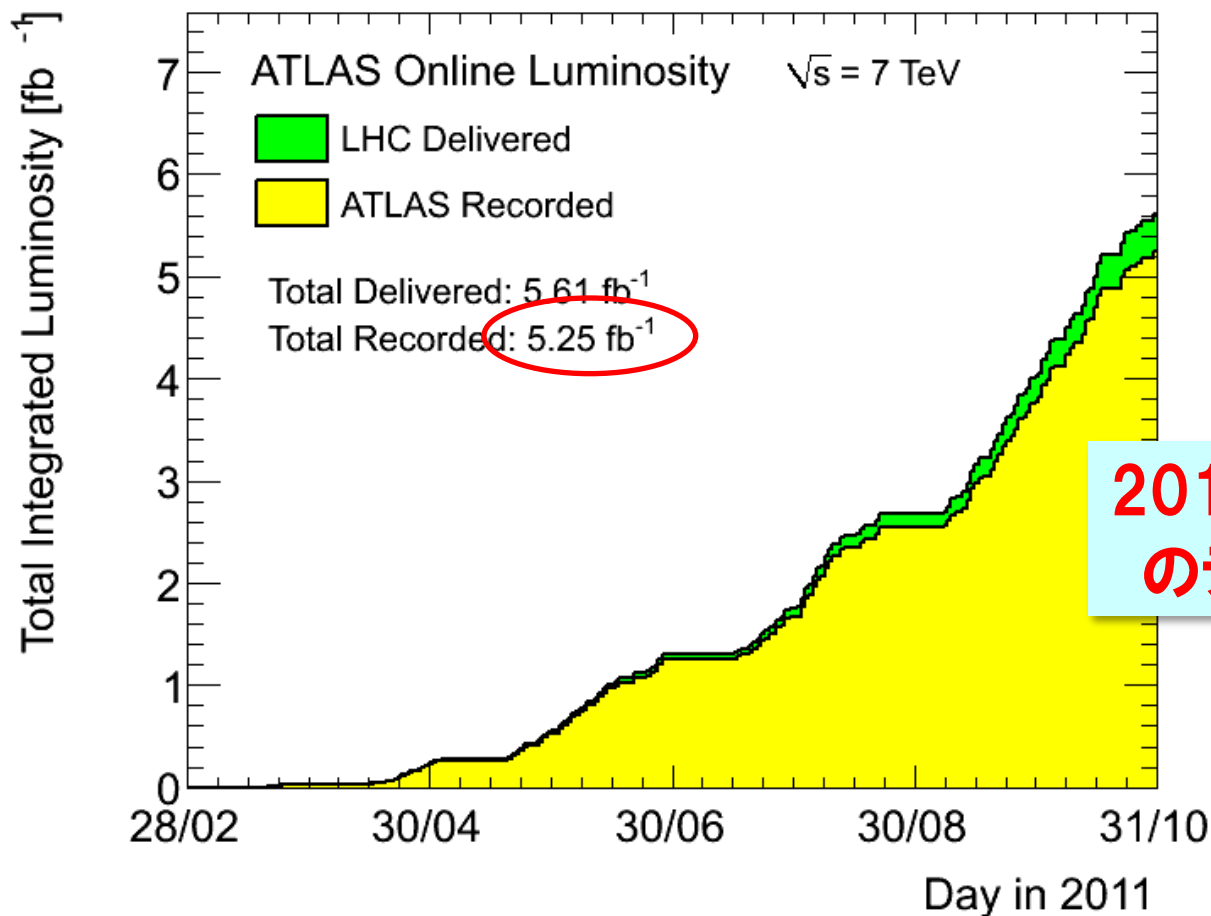
# LHC 積分luminosity (2010年)



Peak luminosity:  $2.1 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$   
ATLAS int. luminosity: 45 pb<sup>-1</sup>

Design luminosity  
=  $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

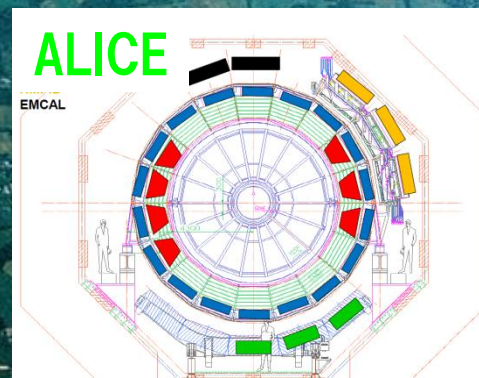
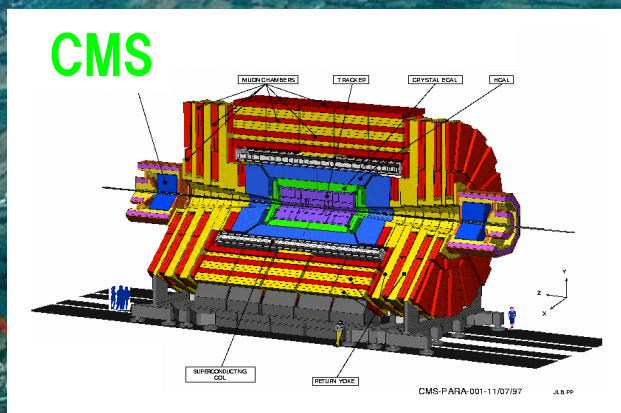
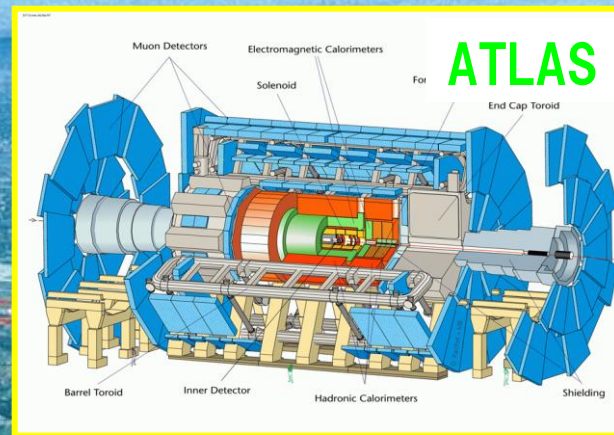
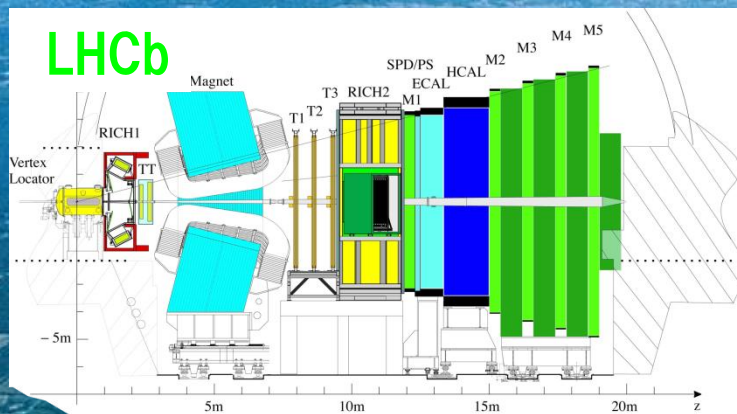
# LHC 積分luminosity (2011年)



2010年の~50倍  
のデータを取得

Peak luminosity seen by ATLAS:  $\sim 3.6 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

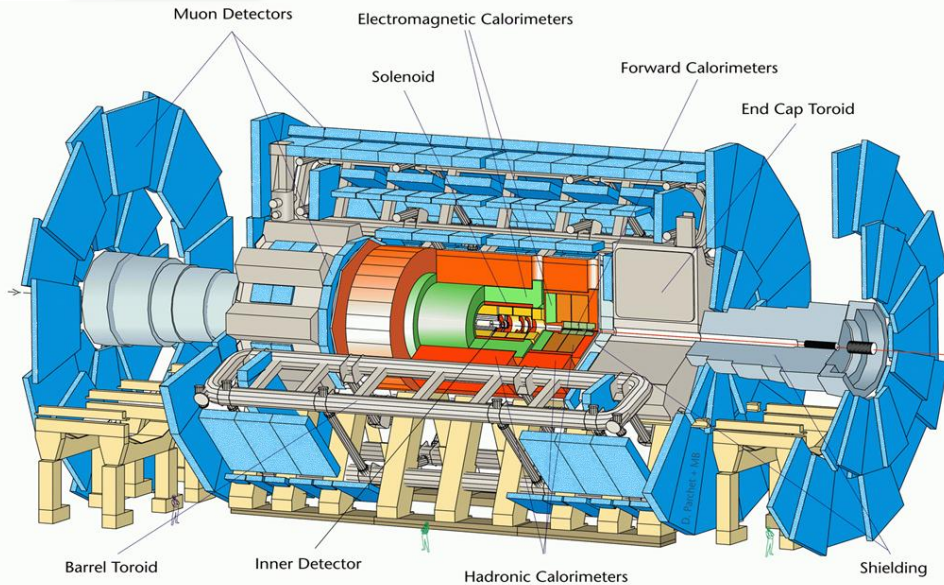
# 4つのLHC実験



LHC 加速器

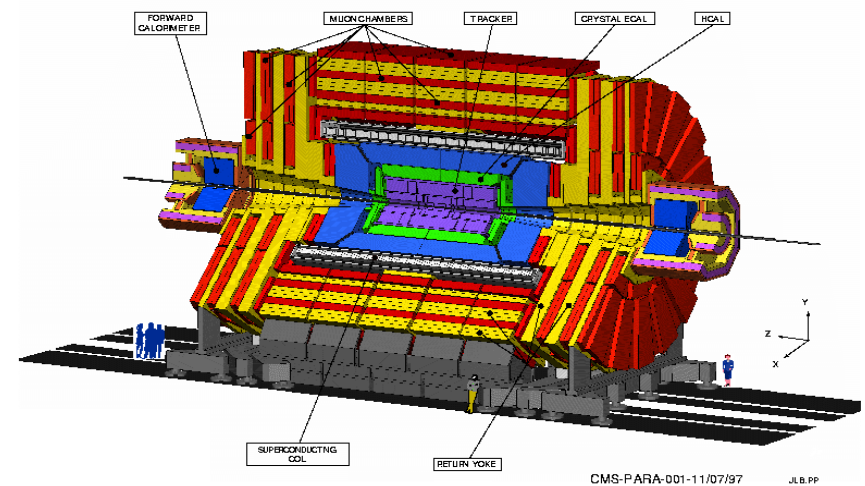
# General purpose detectors for pp collisions

## ATLAS



Length : ~45 m  
Diameter : ~24 m  
Weight : ~ 7,000 tons  
Solenoid : 2 T  
Air-core toroids  
日本グループが参加

## CMS

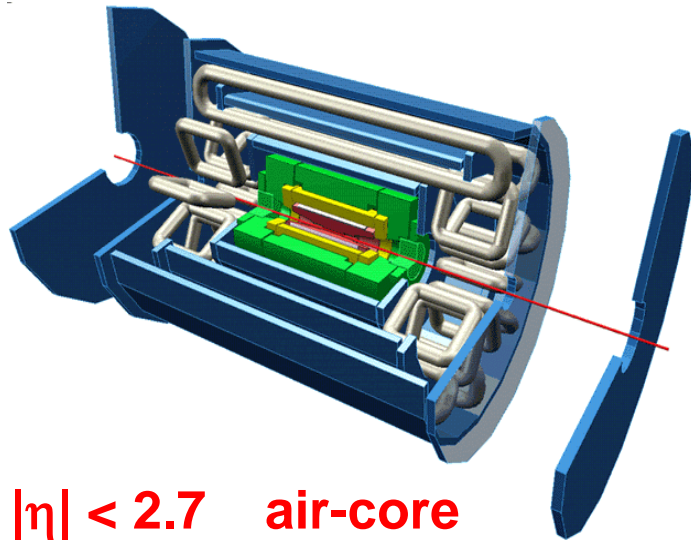


Length : ~22 m  
Diameter : ~14 m  
Weight : ~ 12,500 tons  
Solenoid : 4 T  
Fe yoke  
Compact and modular

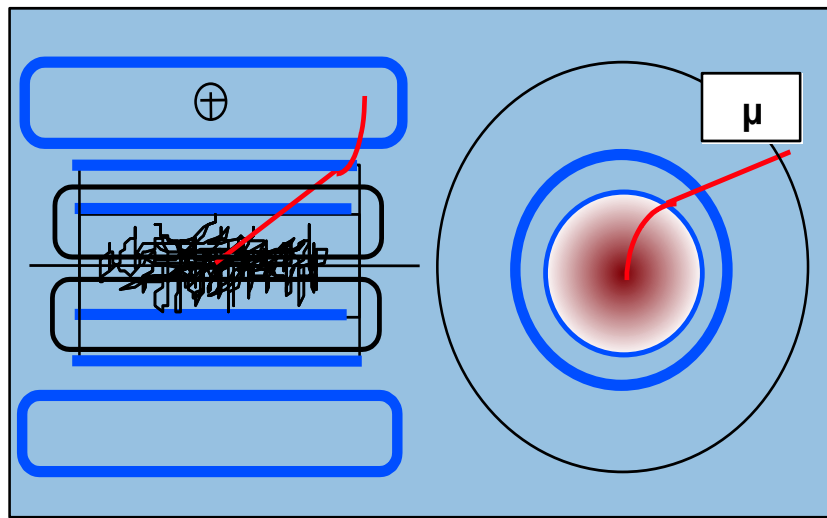


# Muon Detection and Magnet System

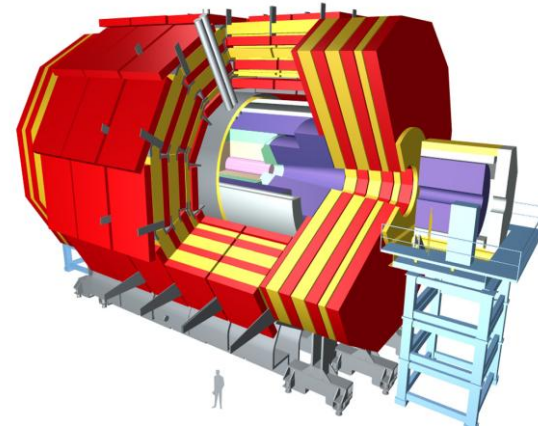
**ATLAS** A Toroidal LHC ApparatuS



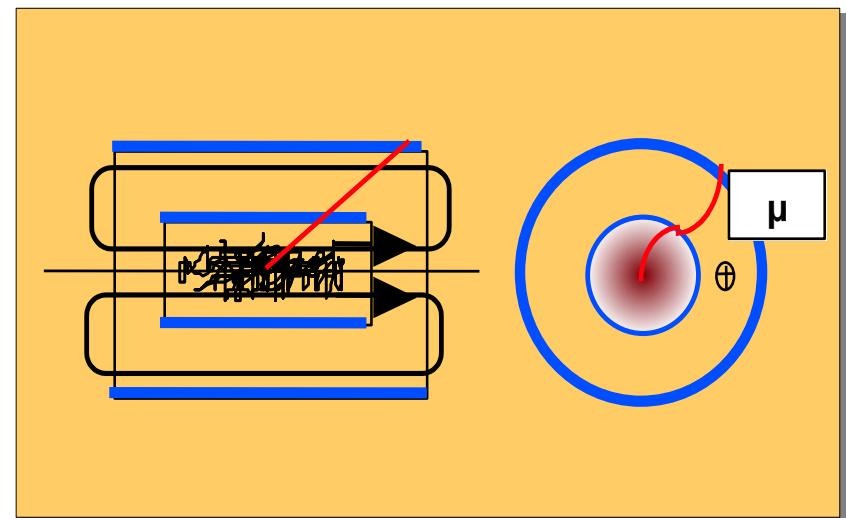
$|\eta| < 2.7$  air-core

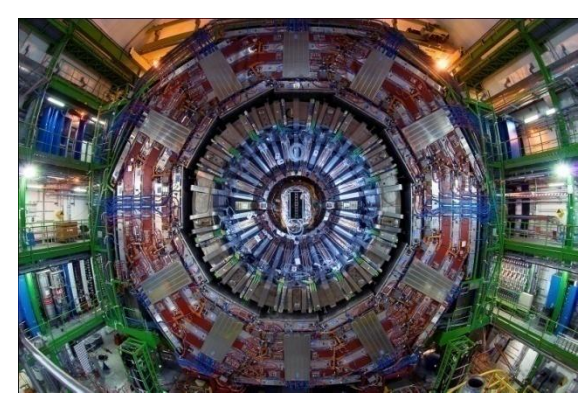
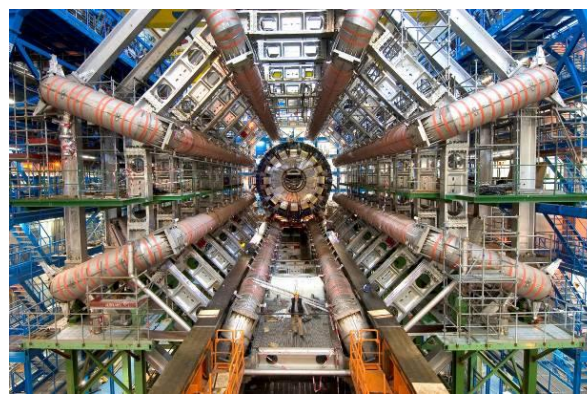


**CMS** Compact Muon Solenoid



$|\eta| < 2.4$  Fe



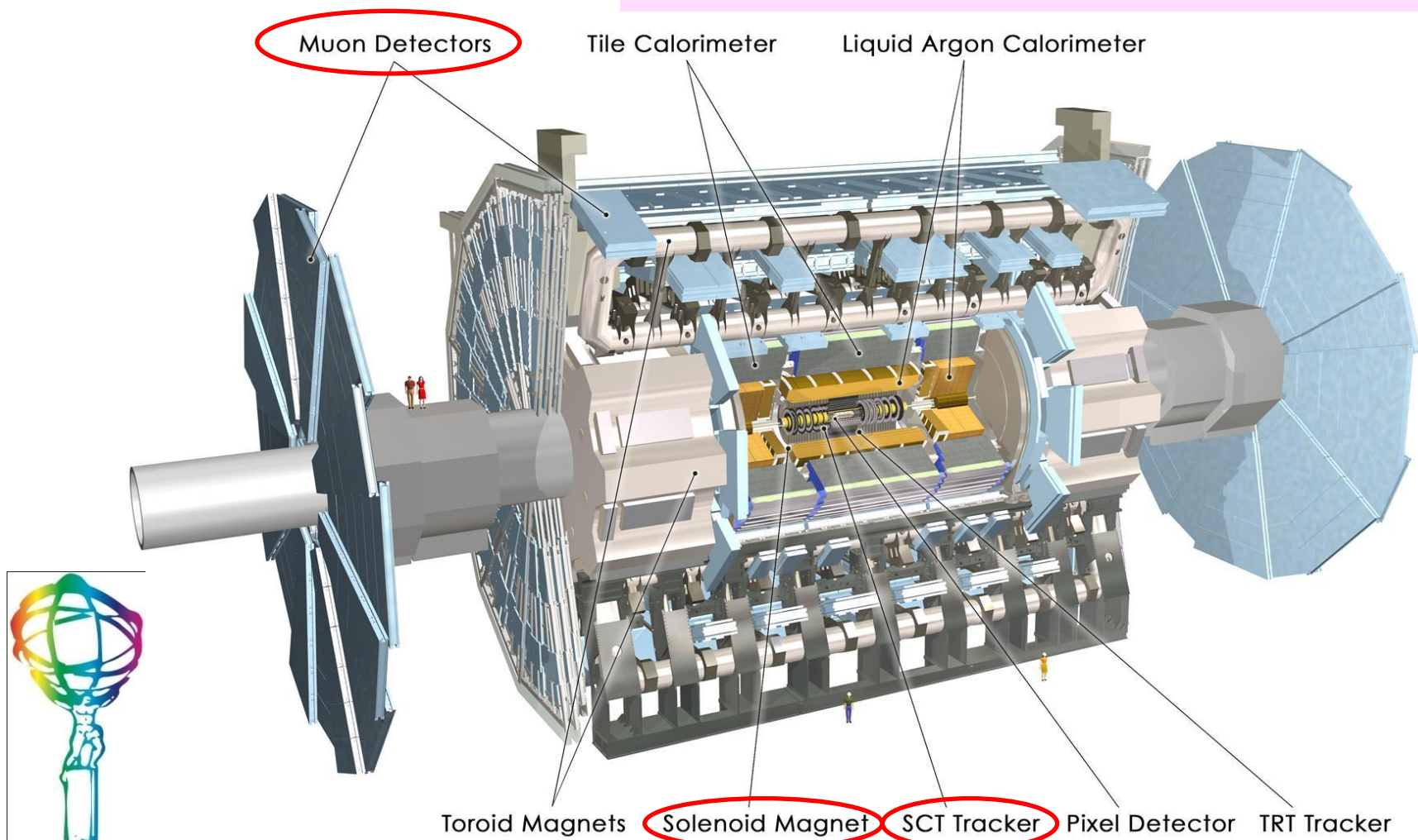


	ATLAS	CMS
TRACKER	<p>Si pixels + strips</p> <p>TRT → particle identification</p> <p><math>\sigma/p_T \sim 4 \times 10^{-4} p_T \oplus 0.01</math></p>	<p>Si pixels + strips</p> <p>No particle identification</p> <p><math>\sigma/p_T \sim 1.5 \times 10^{-4} p_T \oplus 0.005</math></p>
EM CALO	<p>Pb-liquid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

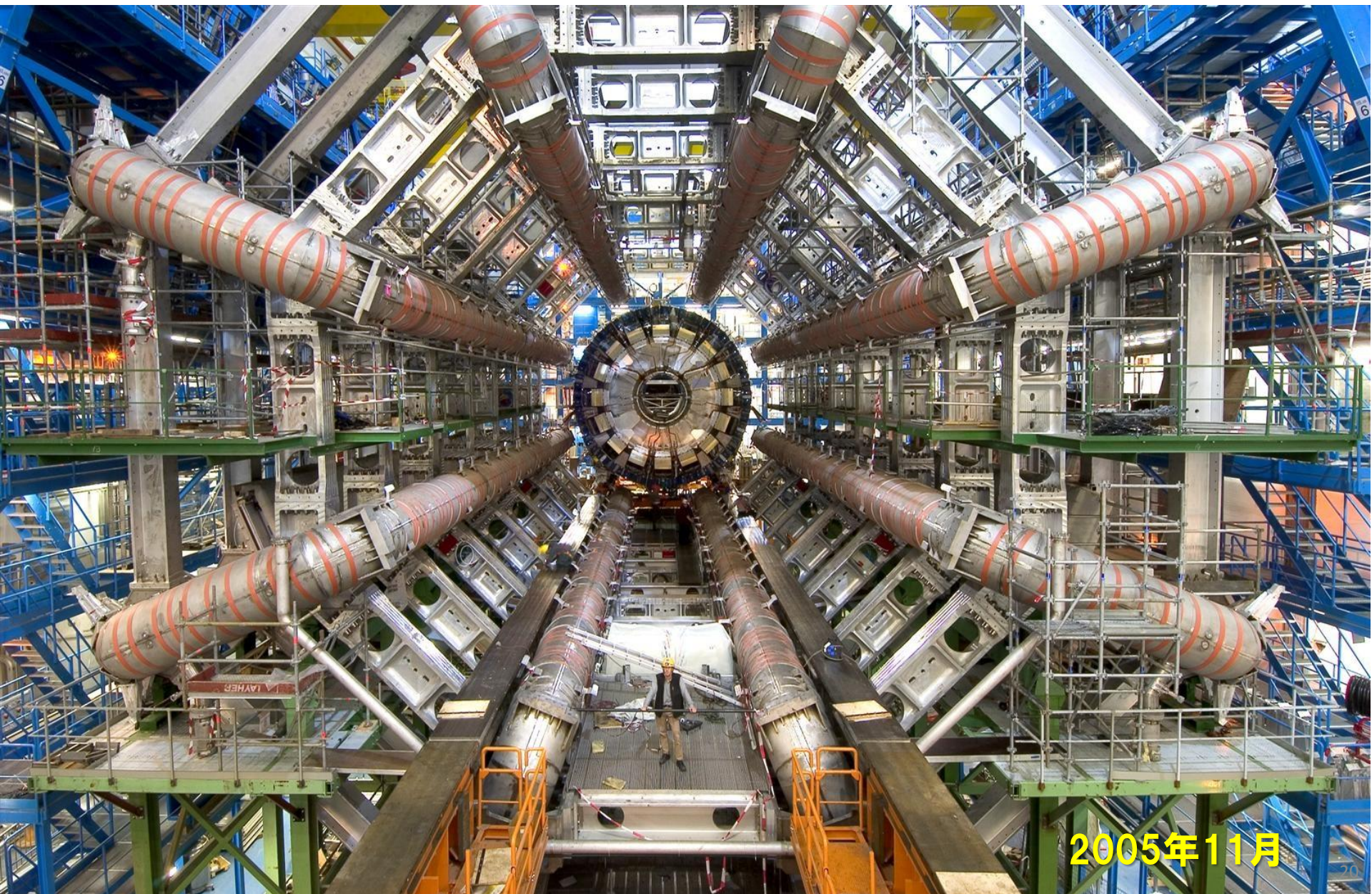
# ATLAS実験

(A Toroidal LHC Apparatus)

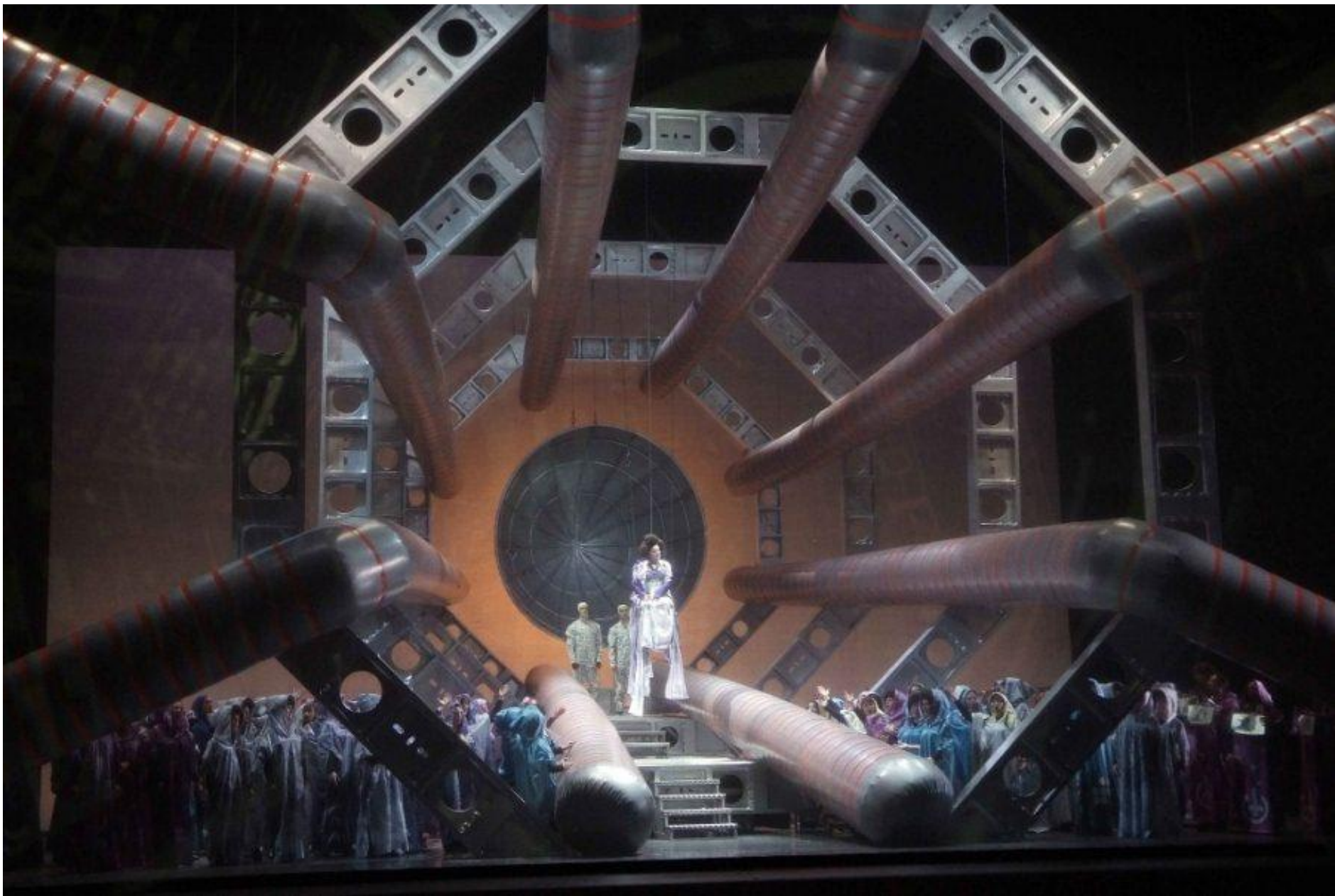
- 直径 22m、長さ 44m、重さ 7000t
- 世界最大の超伝導トロイド磁石
- 粒子検出器のセンサー数は全部で約1億チャンネル
- 38ヵ国からの約3000名の研究者による国際共同実験
- 日本グループ(16の大学・研究所、110名)は**ミュオントリガー検出器、内部飛跡検出器、ソレノイド超伝導磁石**などに貢献



# ATLAS実験の超伝導トロイド磁石



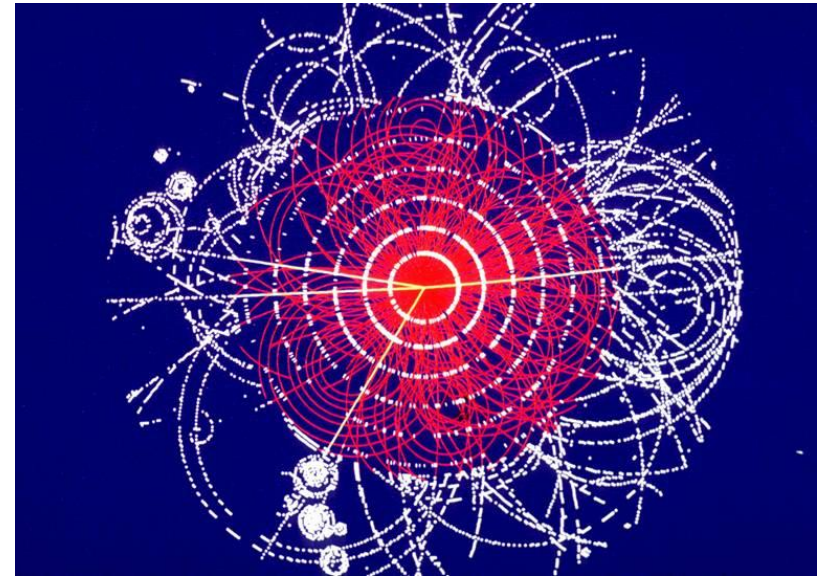
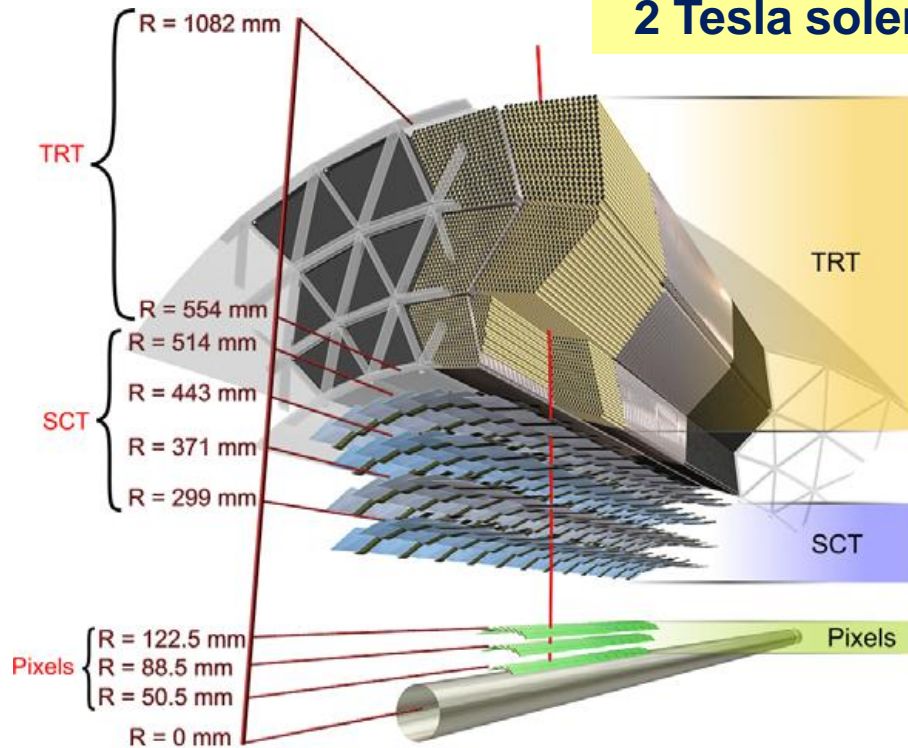
2005年11月



**ベルリオーズのオペラ(トロイア人たち)、2009年、バレンシアにて上演**

# ATLAS Tracking Detectors

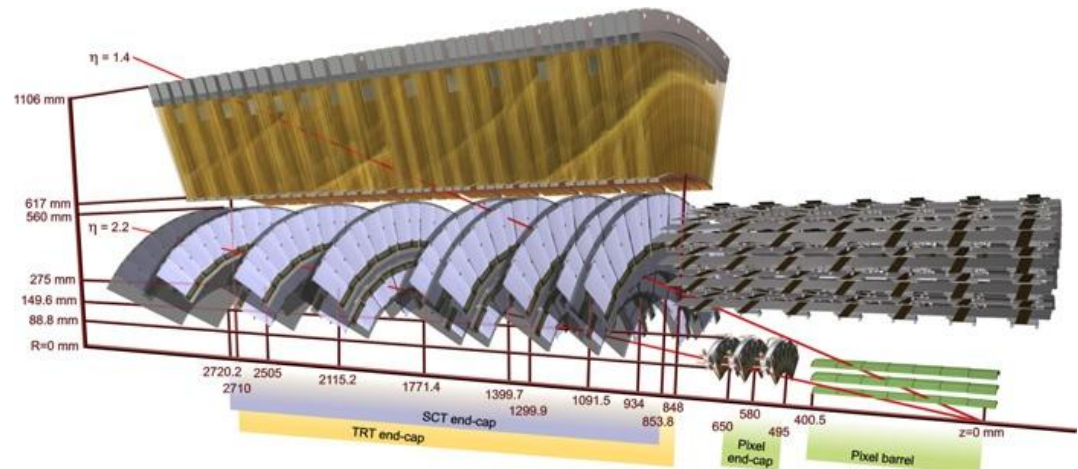
2 Tesla solenoid  $\sigma/p_T \sim 5 \times 10^{-4} p_T \oplus 0.01$



Transition Radiation Tracker (TRT)  
( $4 \times 10^5$  channels) with  $e/\pi$   
separation

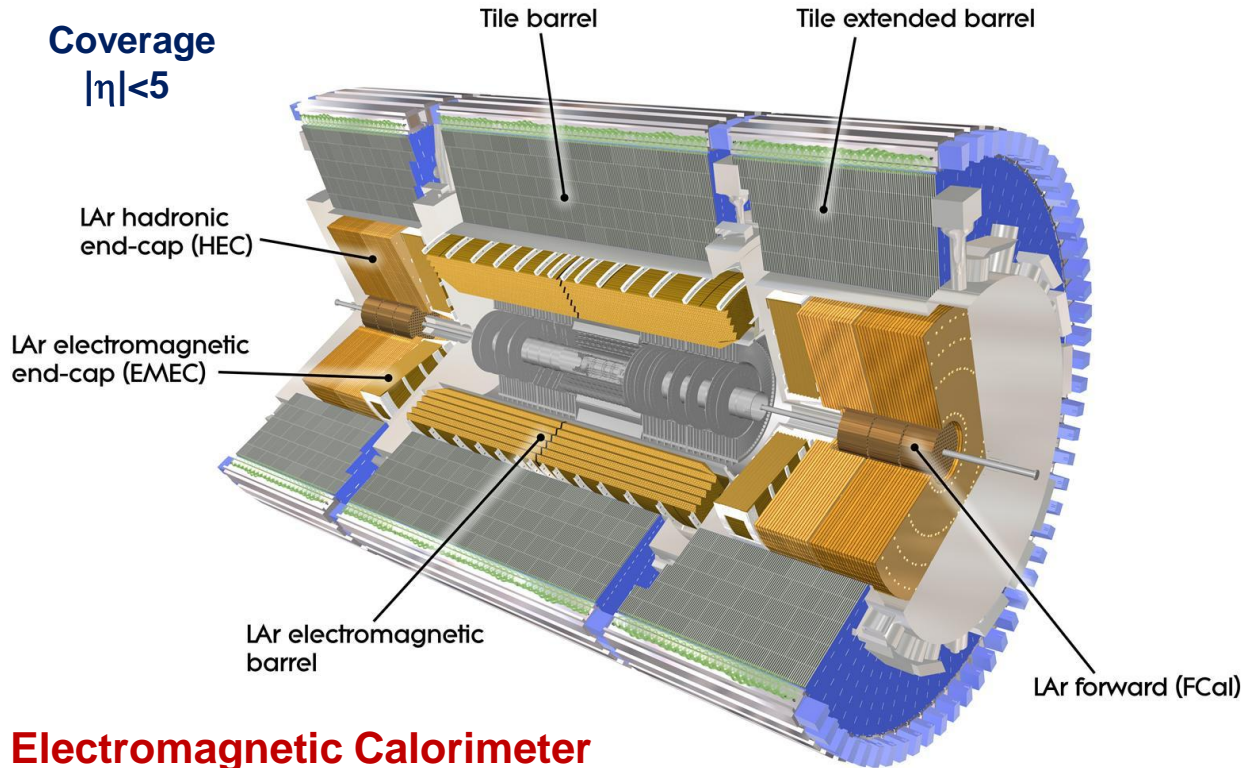
Si Strips Tracker (SCT)  
( $6 \times 10^6$  channels)

Pixels  
( $0.8 \times 10^8$  channels)



# Calorimetry

Coverage  
 $|\eta| < 5$



## Electromagnetic Calorimeter

barrel, end-cap: Pb-LAr

$\sim 10\%/\sqrt{E}$  energy resolution  $e/\gamma$

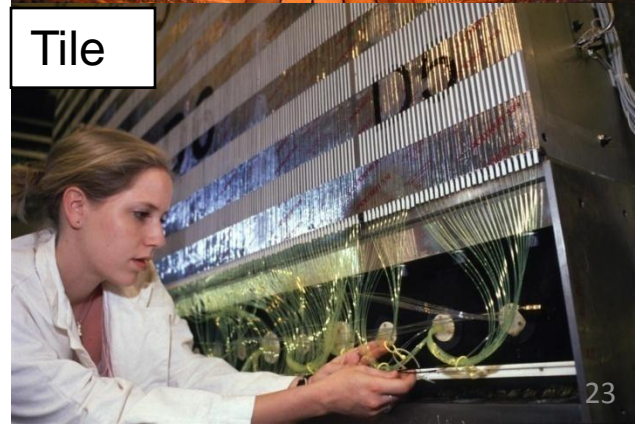
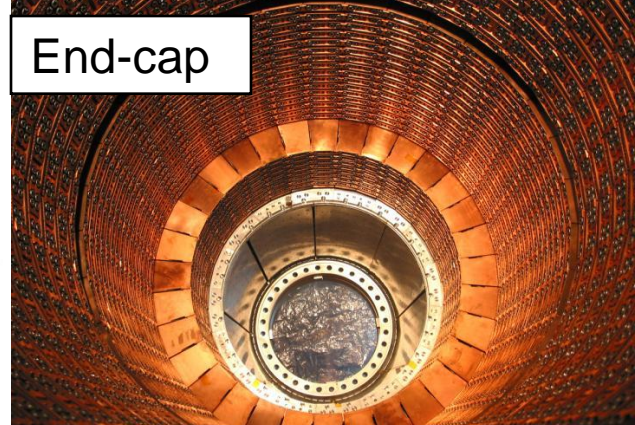
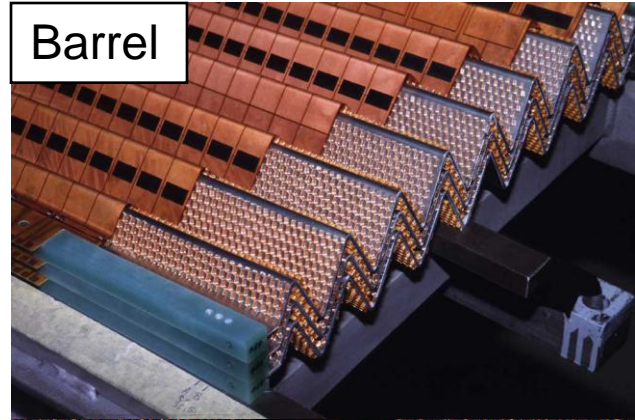
180'000 channels: longitudinal segmentation

## Hadron Calorimeter

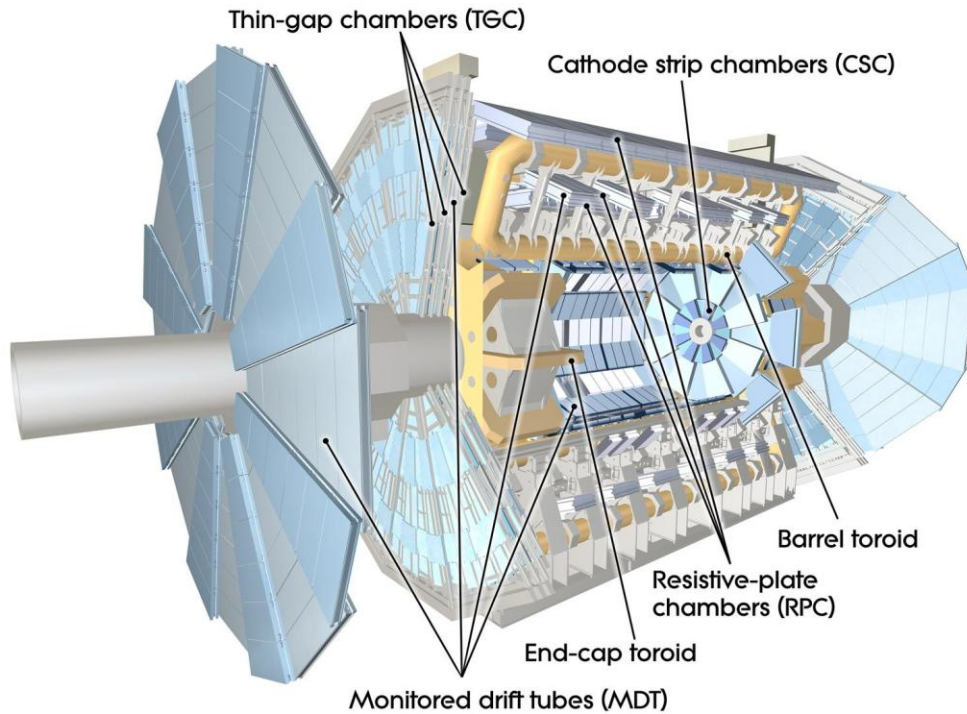
barrel Iron-Tile, EC/Fwd Cu/W-LAr ( $\sim 20000$  channels)

$\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$  pion ( $10 \lambda$ )

**Trigger for  $e/\gamma$ , jets, missing  $E_T$**



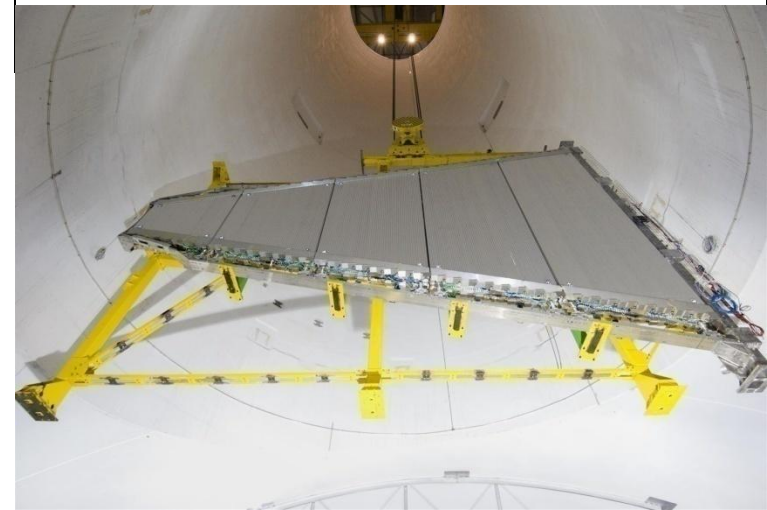
# Muon System



Stand-alone momentum resolution  
 $\Delta p_T/p_T < 10\%$  up to 1 TeV

2-6 Tm  $|\eta| < 1.3$  4-8 Tm  $1.6 < |\eta| < 2.7$

~1200 MDT precision chambers for track



~600 RPC and ~3600 TGC trigger chambers





# ATLAS実験：日本の貢献



ミュオントリガー検出器



内部飛跡検出器



超伝導ソレノイド磁石

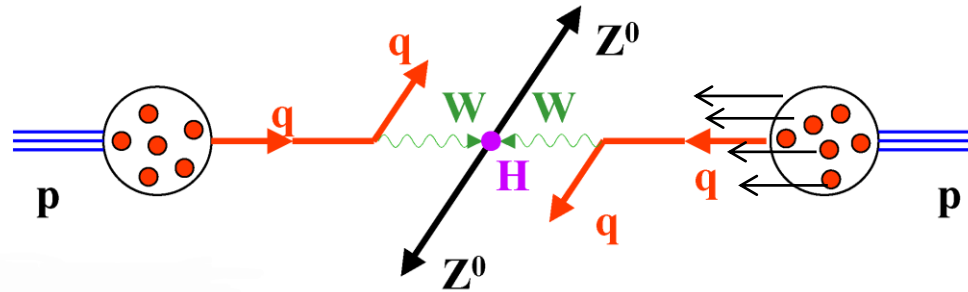


LHC Computing Grid  
地域解析センター



ビーム最終収束  
超伝導四極磁石

# Hadron Collider Basics



Rapidity:  $y = \frac{1}{2} \ln \left( \frac{E + p_z}{E - p_z} \right)$   $\rightarrow \Delta y$  : Lorentz inv. in  $z$ -direction

Pseudorapidity:  $\eta \equiv -\ln \tan \frac{\theta}{2}$

( $y \rightarrow \eta$ , as  $m \rightarrow 0$ )

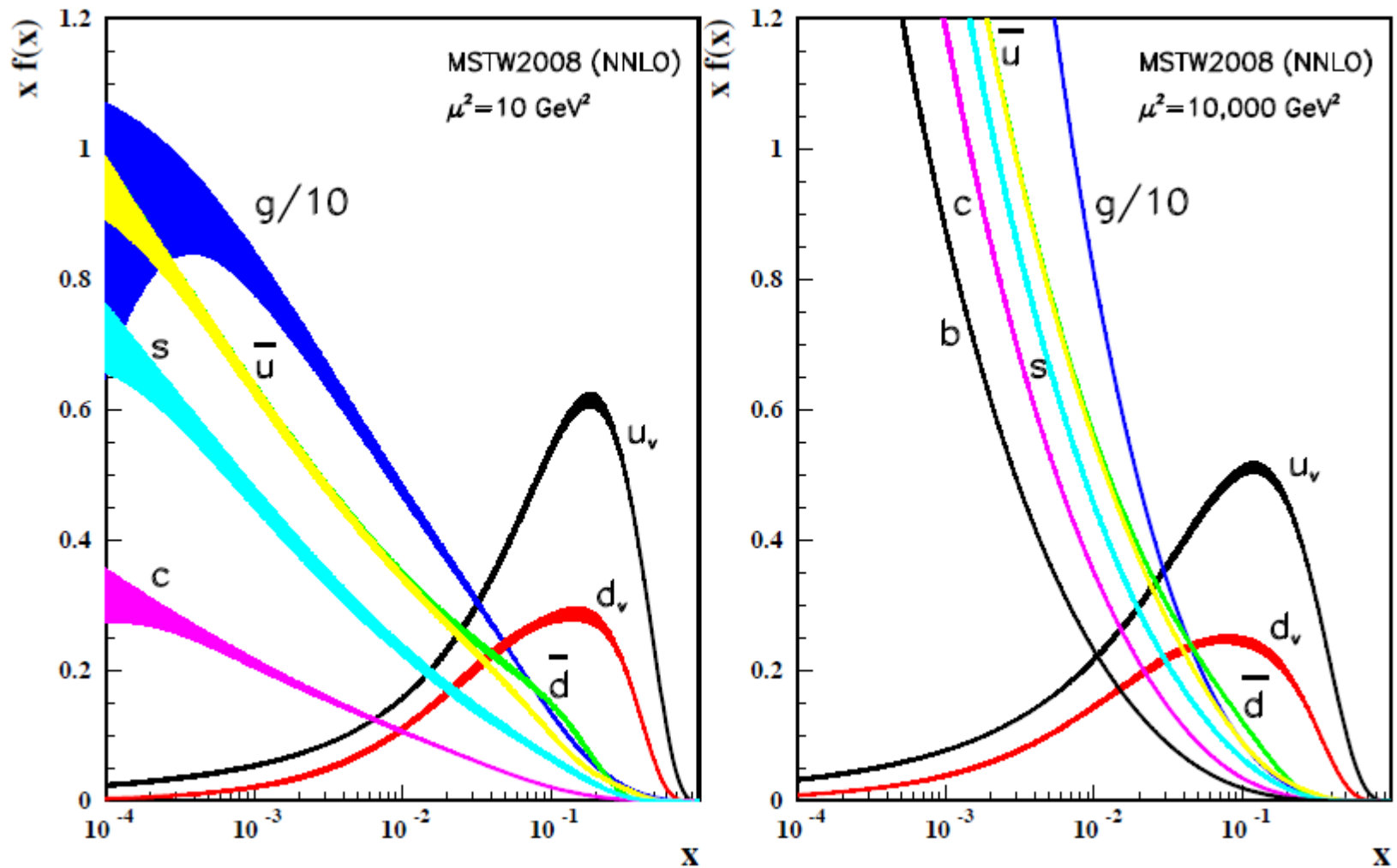
$$\cos \theta = p_z/p$$

$\eta = 0$	$\leftrightarrow$	$\theta = 90^\circ$
1	$\leftrightarrow$	$40.4^\circ$
2	$\leftrightarrow$	$15.4^\circ$
3	$\leftrightarrow$	$5.7^\circ$
4	$\leftrightarrow$	$2.1^\circ$
5	$\leftrightarrow$	$0.77^\circ$

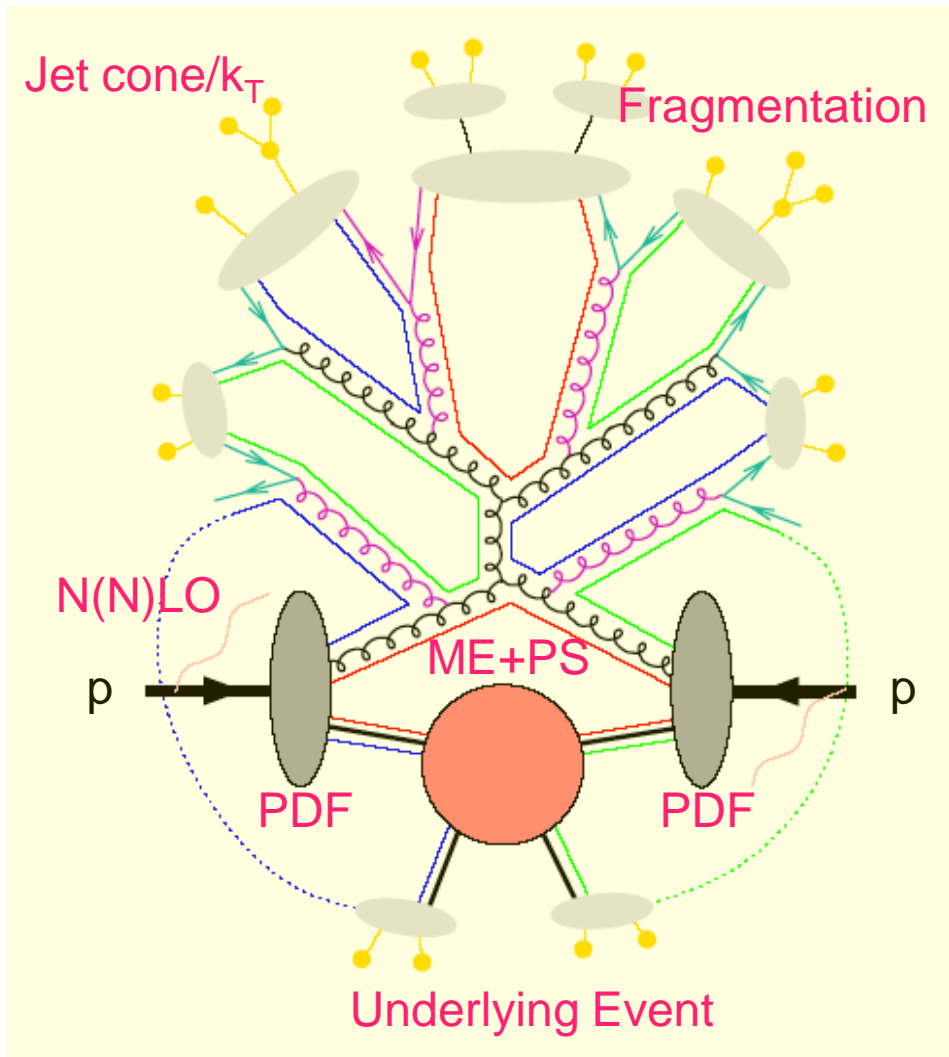
“Transverse mass”:  
(Transverse energy)

$$m_T^2 = m^2 + p_x^2 + p_y^2$$

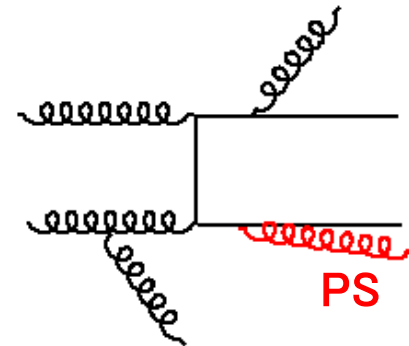
# Parton Distribution Functions



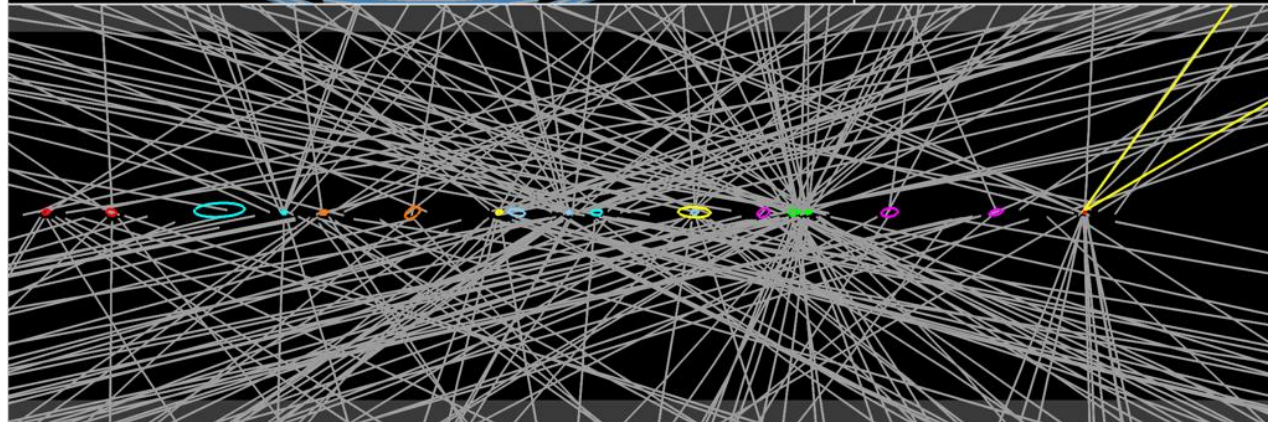
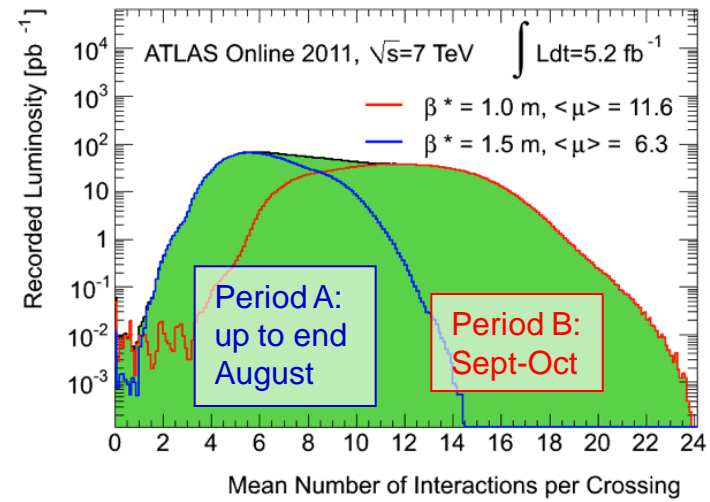
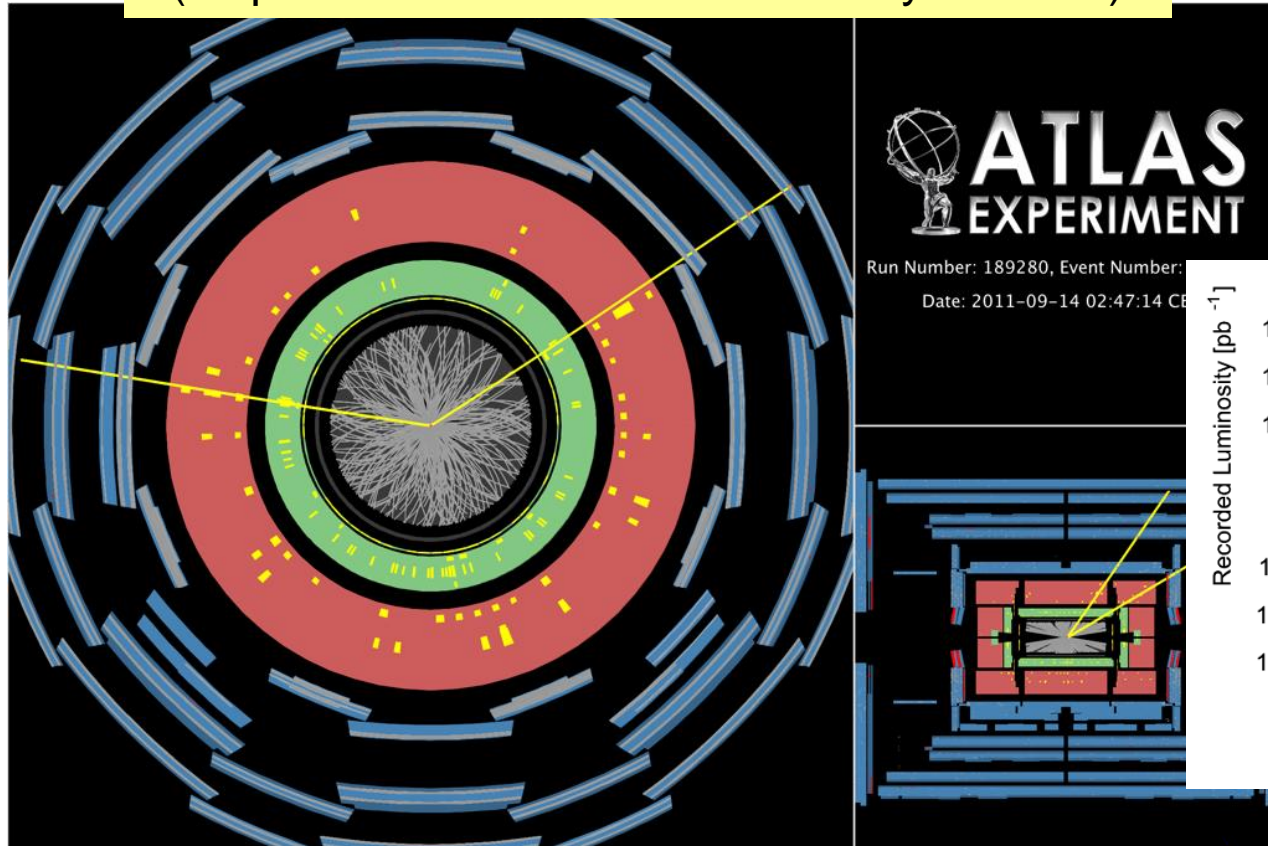
# QCD Processes and Experimental Complications



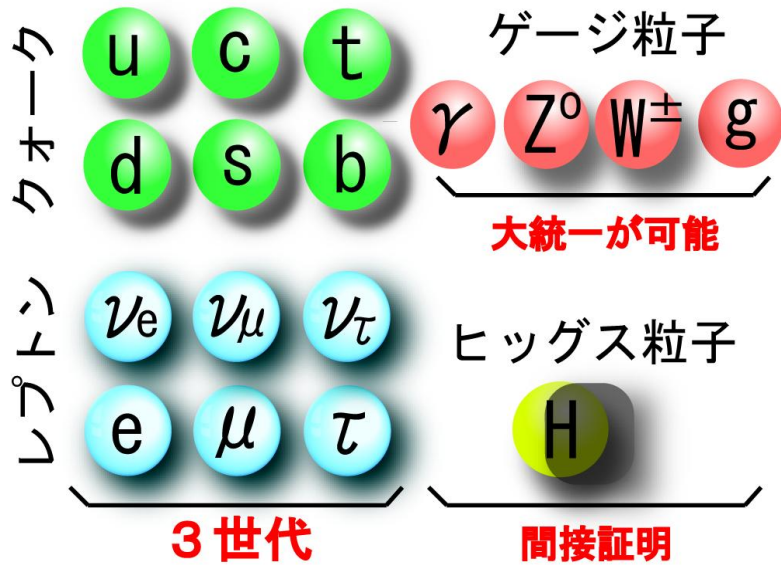
- Parton distribution function (PDF)
- Underlying events
- Matrix element (pQCD calculation)
- Parton shower (ME+PS matching)
- Fragmentation (Hadronization)
- Jet finding algorithm
- Jet energy scale calibration
- Pile-up events



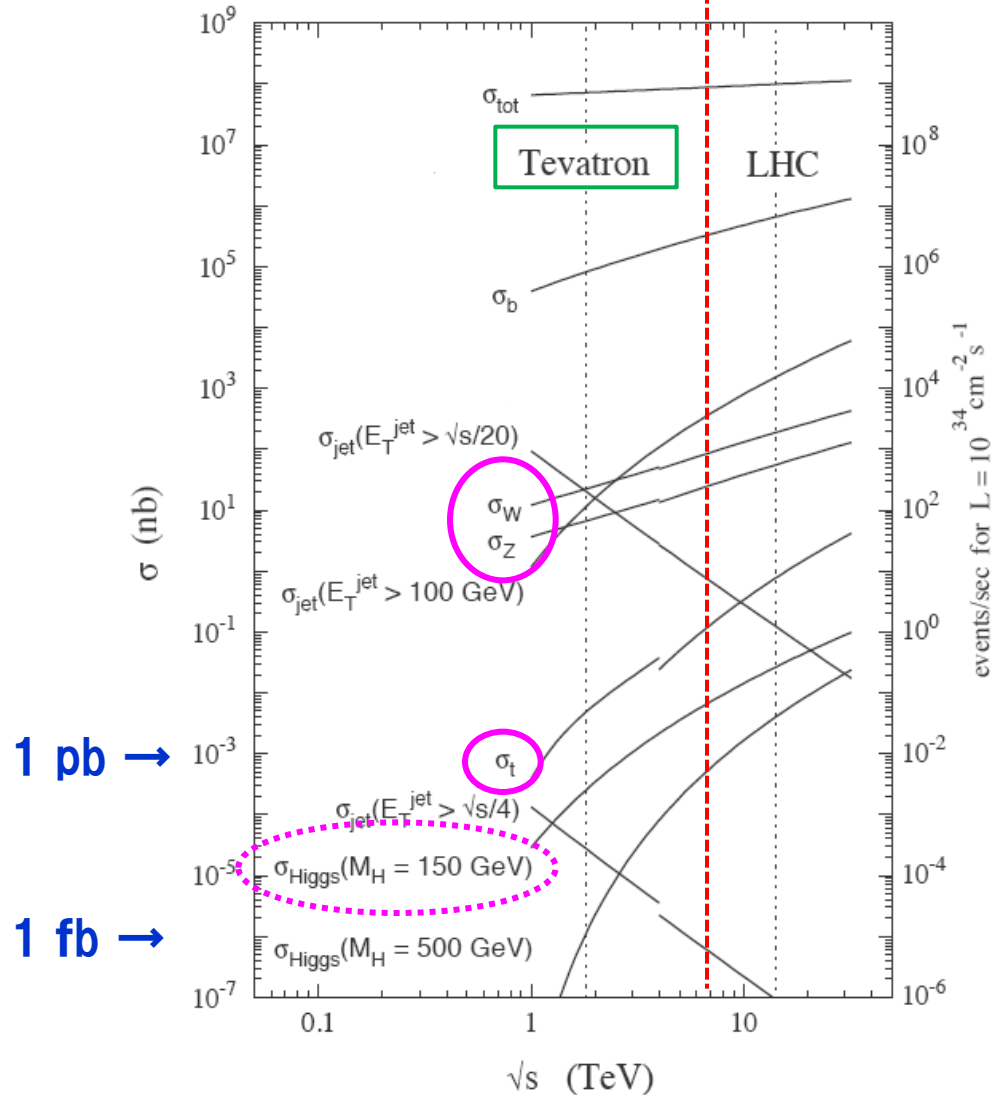
$Z \rightarrow \mu\mu$  event with 20 reconstructed vertices  
(Ellipses have  $20 \sigma$  size for visibility reasons)



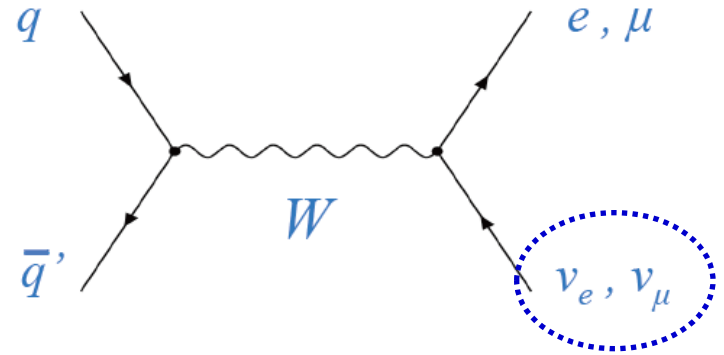
# SM粒子の再発見



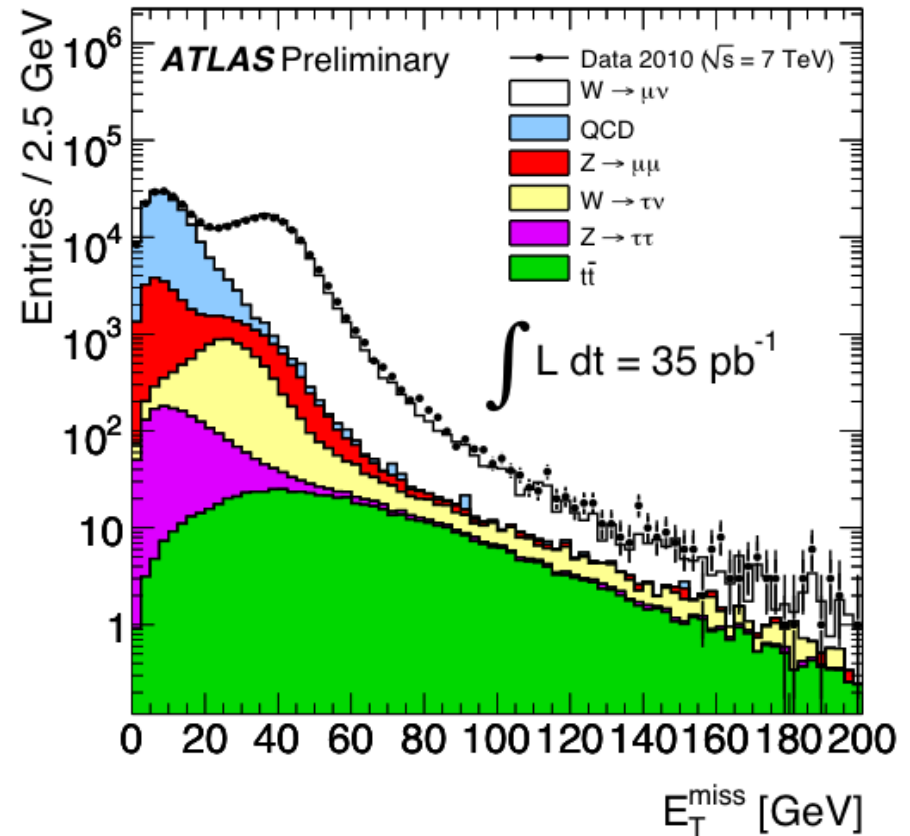
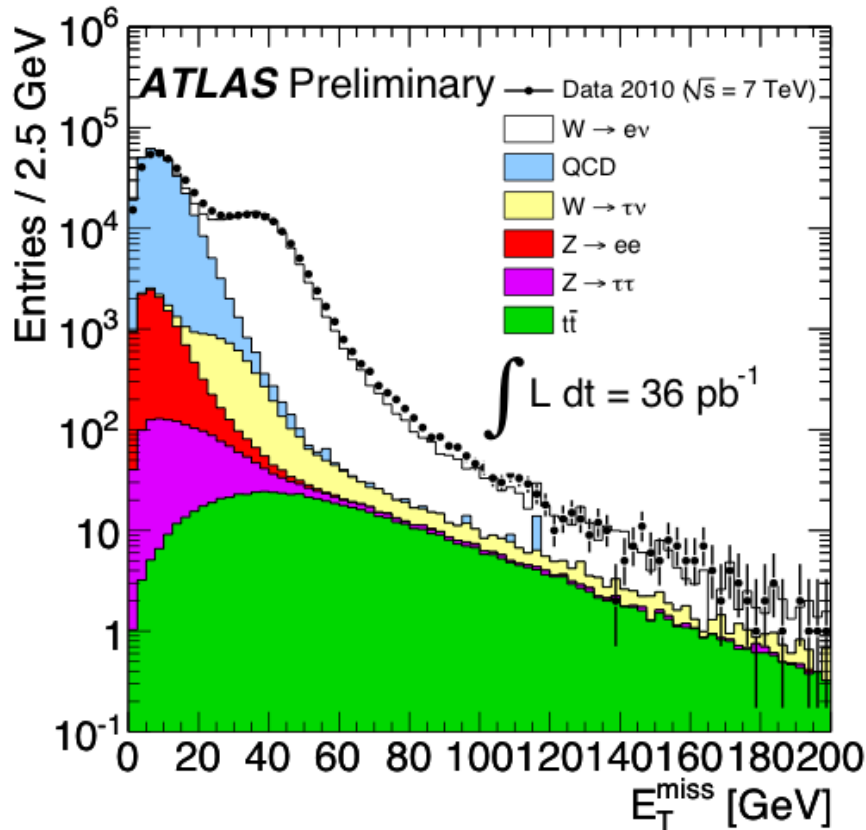
LHC  
(7TeV)



# W boson 生成

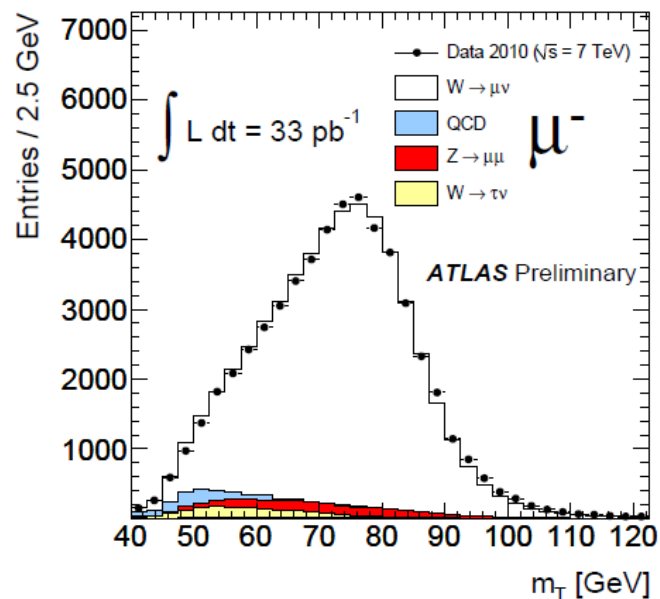
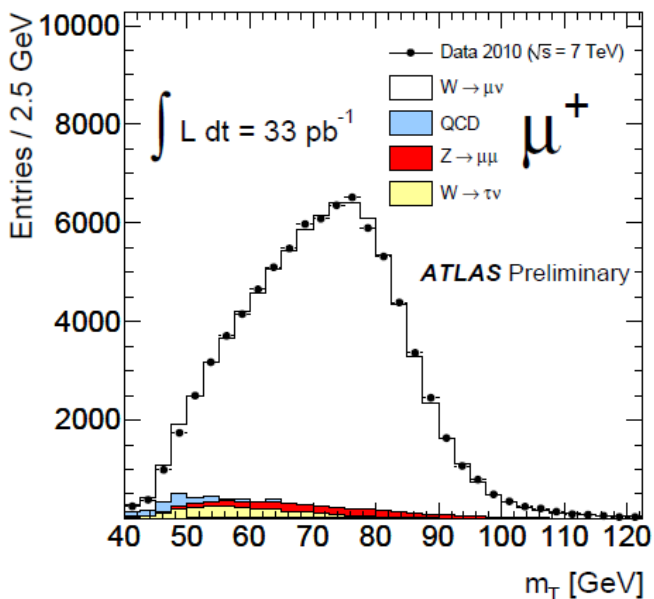
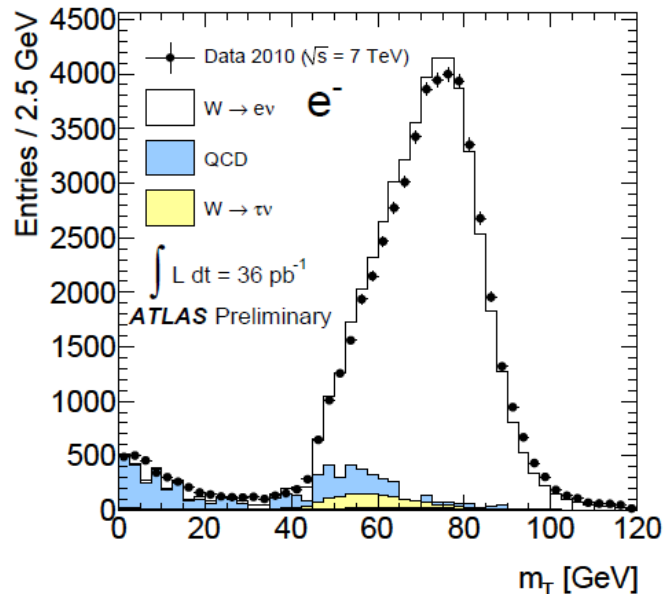
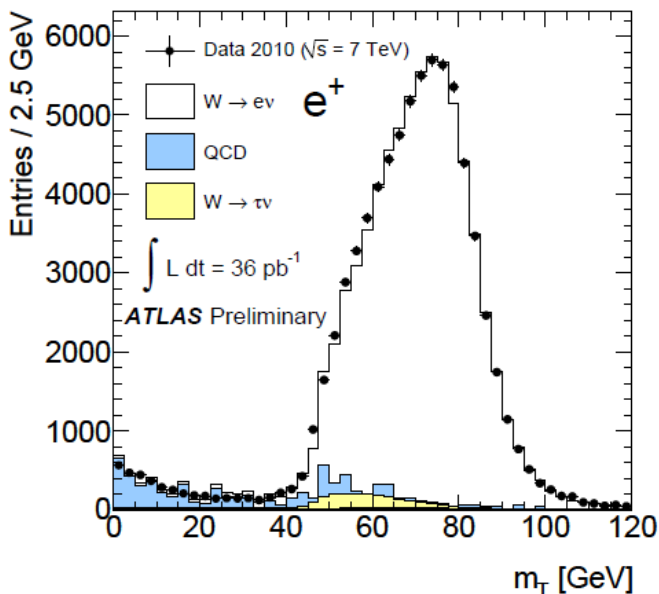


$E_T^{\text{miss}}$  distribution for events with e or  $\mu$  with  $p_T > 20$  GeV

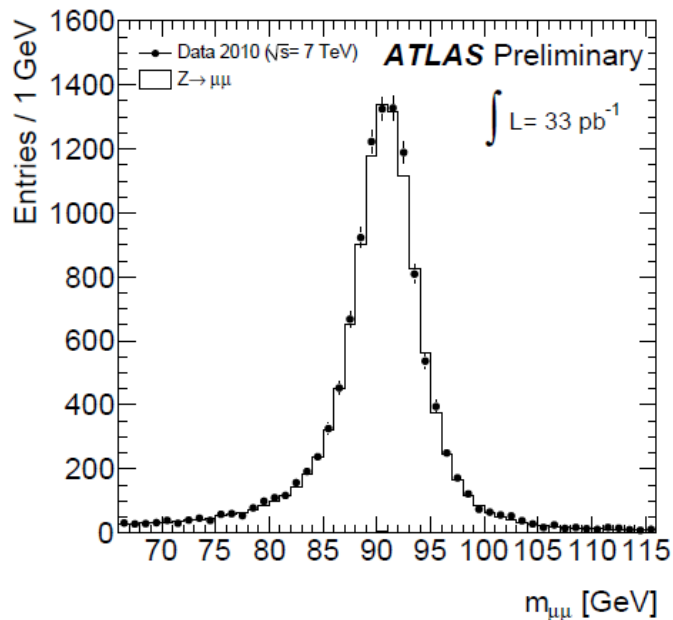
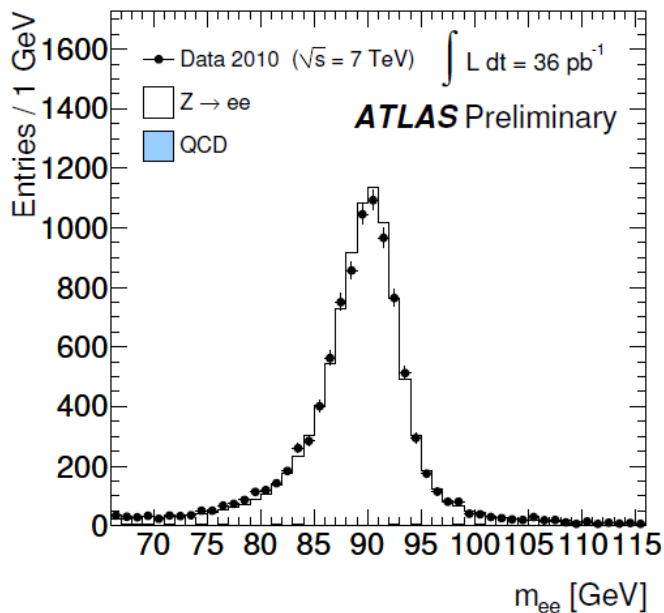


# W transverse mass 分布

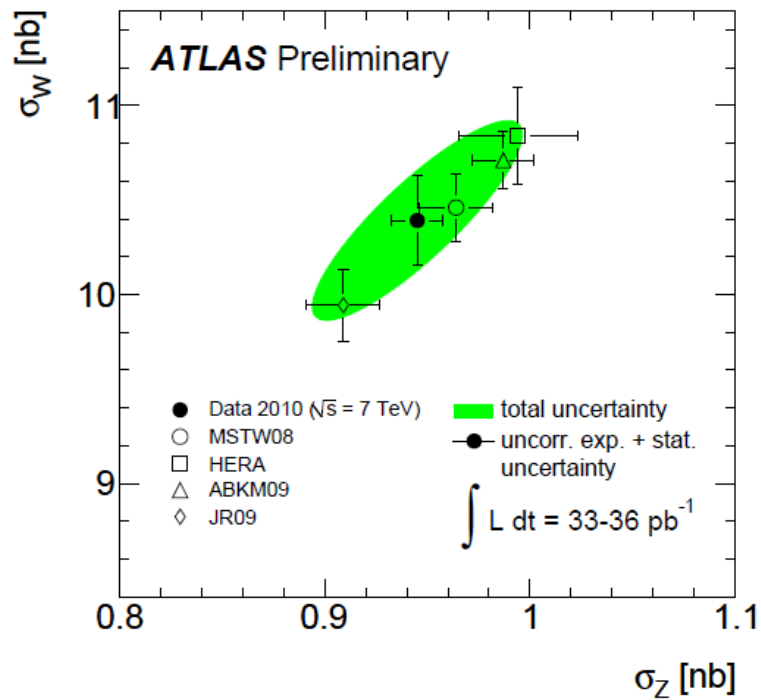
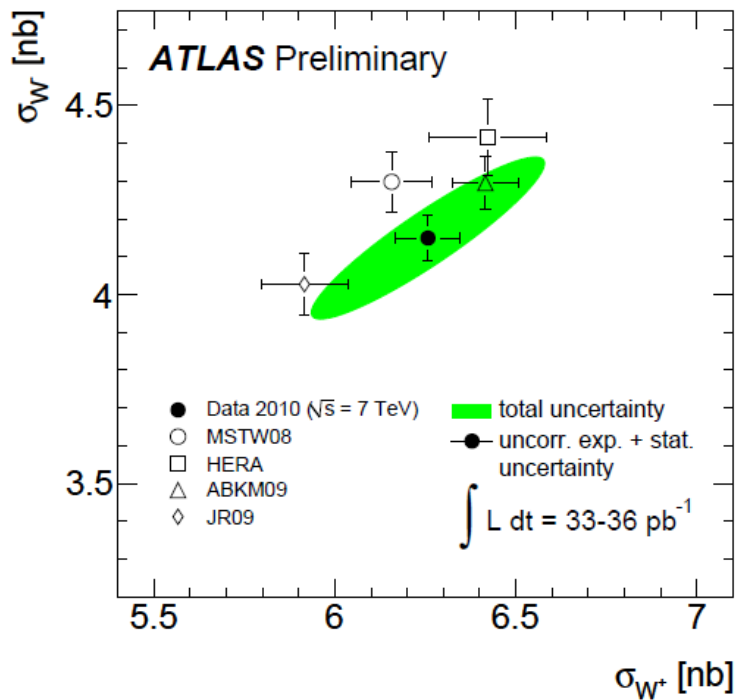
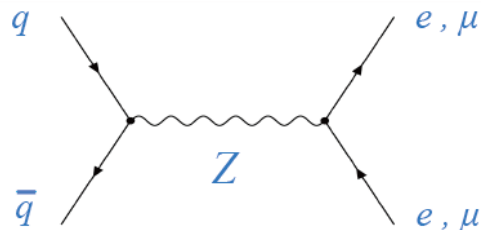
$$m_T = \sqrt{2p_T^\ell p_T^\nu (1 - \cos(\phi^\ell - \phi^\nu))}$$







# Z boson 生成

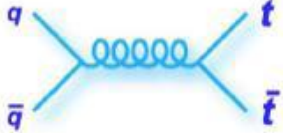


# Top quark pair production at hadron colliders

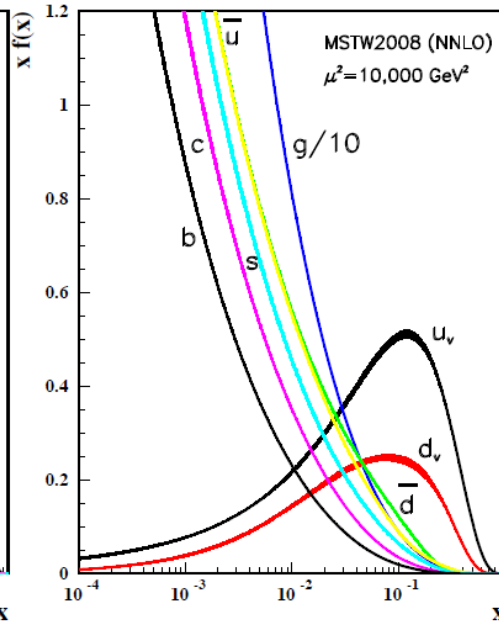
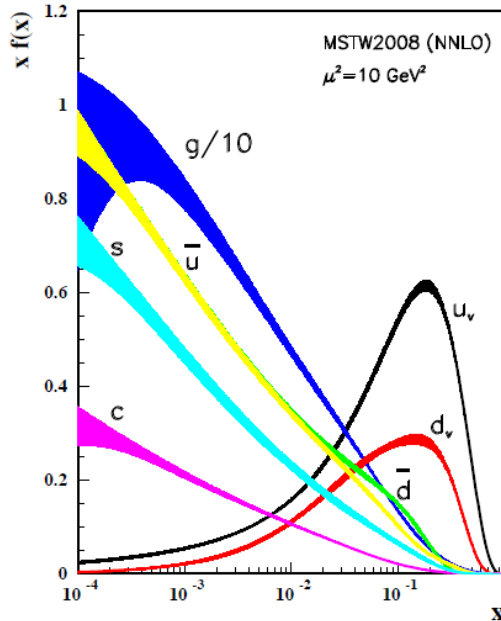
- Gluon fusion (dominant at LHC)



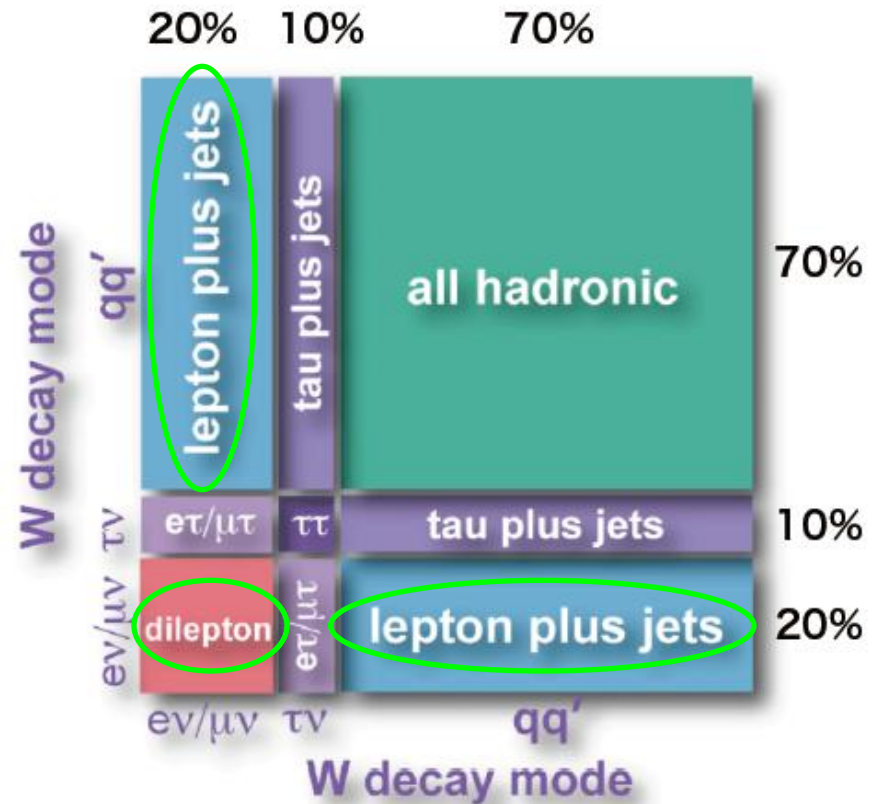
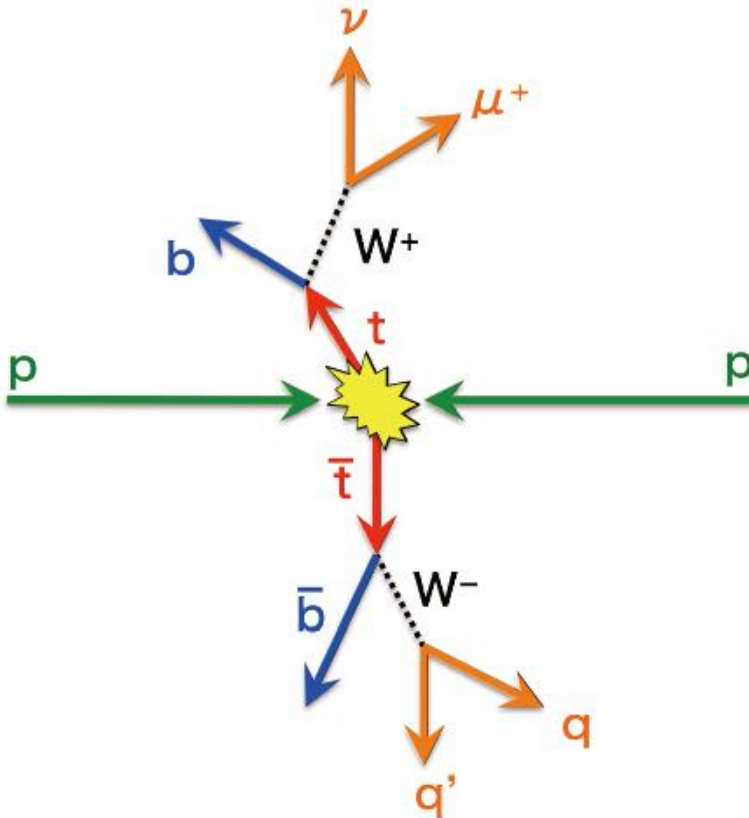
- Quark-antiquark annihilation



	Tevatron	LHC(7TeV)	LHC(14TeV)
Gluon fusion	15%	85%	90%
Quark-antiquark annihilation	85%	15%	10%
$\sigma \sim$	7pb	165pb	885pb

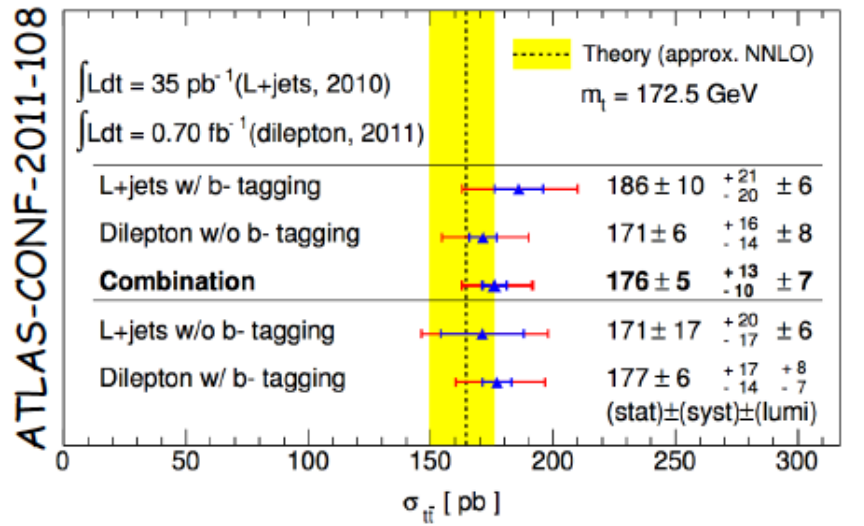


# Top quark decay



# Top quark pair production

## ATLAS

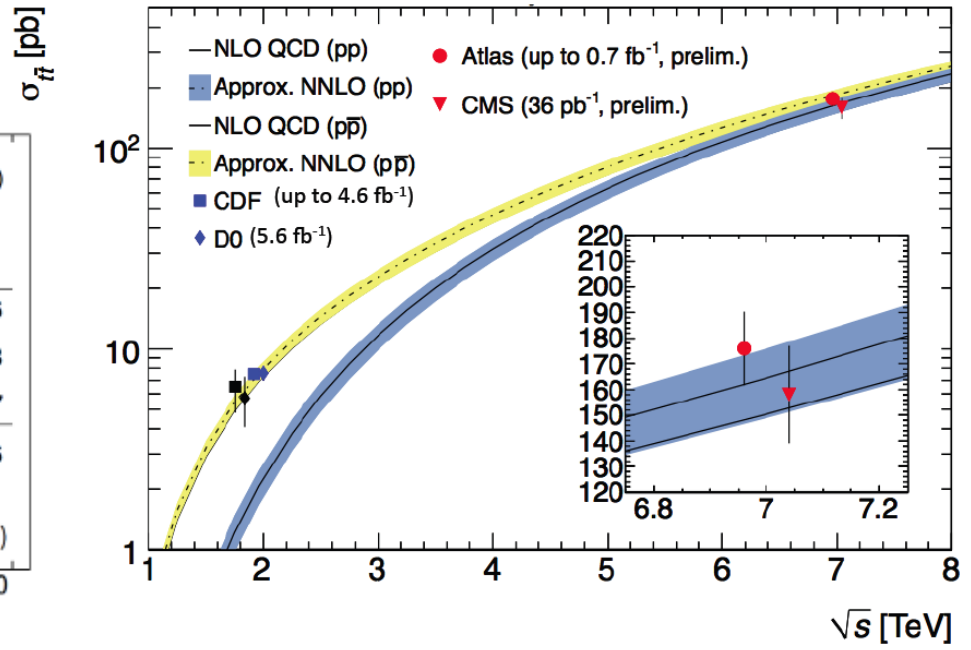


$$\sigma_{t\bar{t}} = 176 \pm 5 \text{ (stat.)} \pm \frac{13}{10} \text{ (syst.)} \pm 7 \text{ (lumi.) pb.}$$

## CMS

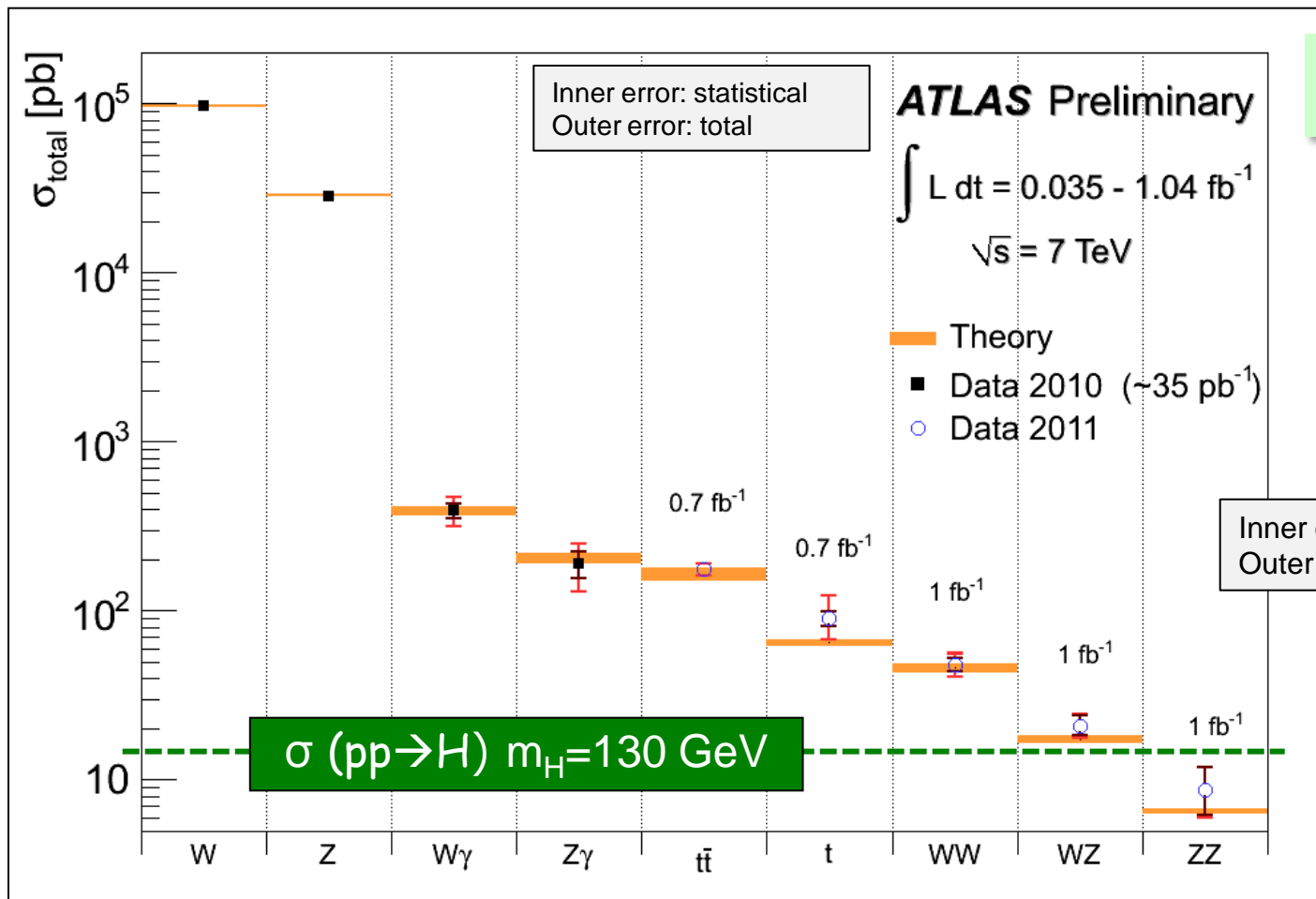
Measurement	Cross section [pb]	Weight
CMS l+jets+tag	$150 \pm 9(\text{stat}) \pm 17(\text{syst}) \pm 6(\text{lumi})$	58%
CMS dilepton	$168 \pm 18(\text{stat}) \pm 14(\text{syst}) \pm 7(\text{lumi})$	42%

$$\sigma_{t\bar{t}} = 158 \pm 10(\text{unc.}) \pm 15(\text{cor.}) \pm 6(\text{lumi}) \text{ pb}$$



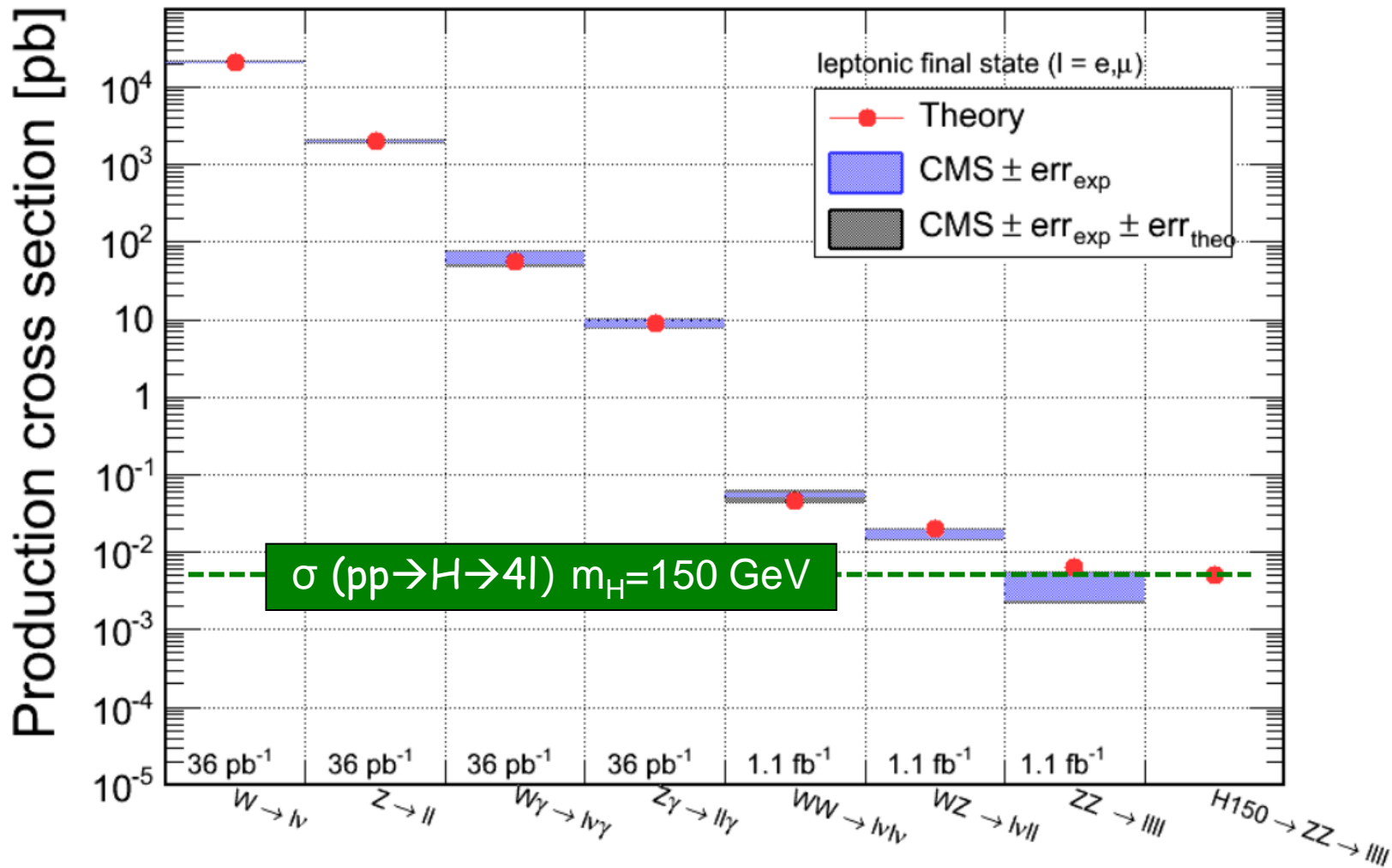
**9% の精度で  
生成断面積測定**

# Summary of main electroweak and top cross-section measurements



**ATLAS**

→ SM予想値とよいい一致



# 第2部

## LHC最新結果

(話題のヒッグス粒子の話など)

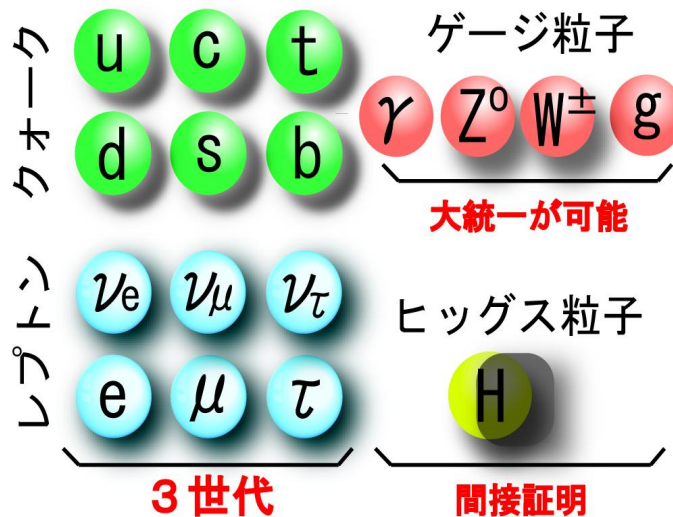
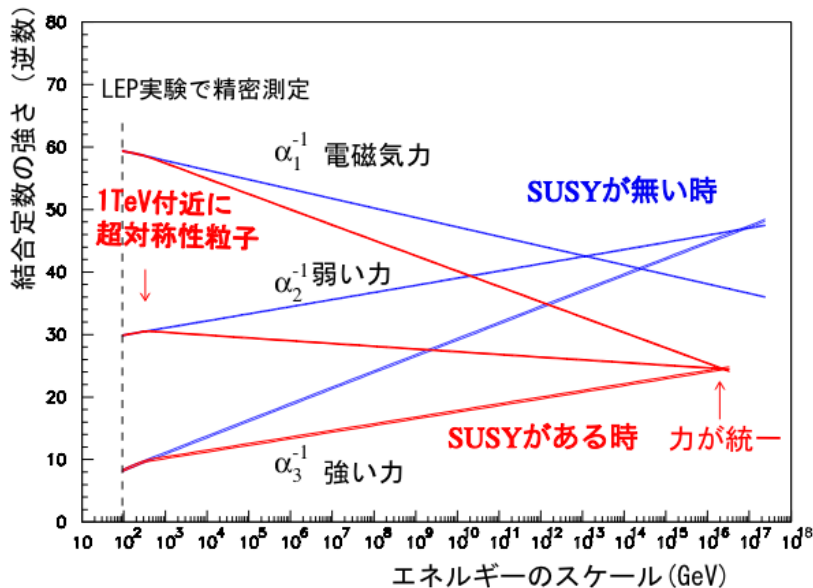
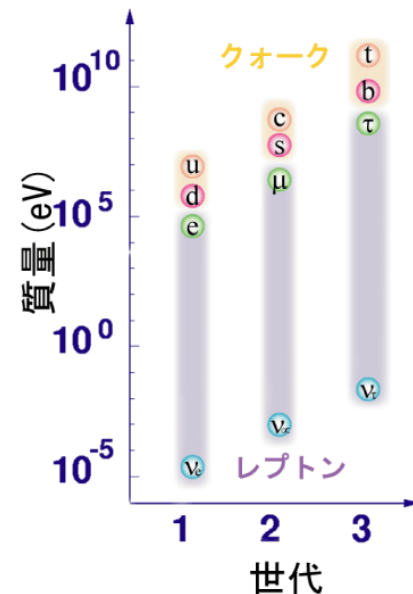
# LHC実験の主な目的

## • 当面の課題:

**ヒッグス粒子の探索** → 質量の起源  
EW sym. breaking

## • 標準理論を超える現象の探索:

**標準理論の大きな問題点 … 階層性問題**

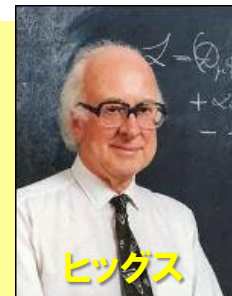






南部先生

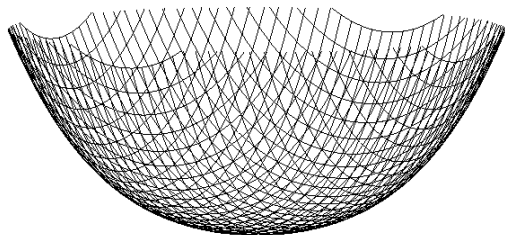
# 自発的対称性の破れと ヒッグス機構



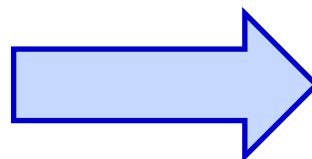
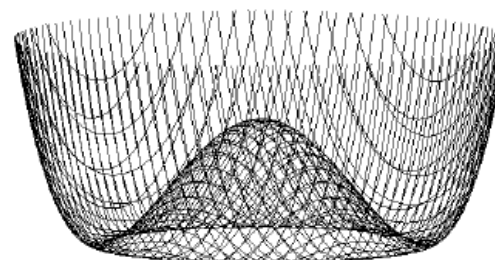
ヒッグス

“質量0のNGボソンが存在”

“NGボソンが  
素粒子の質量に”



ヒッグス場の  
ポテンシャル



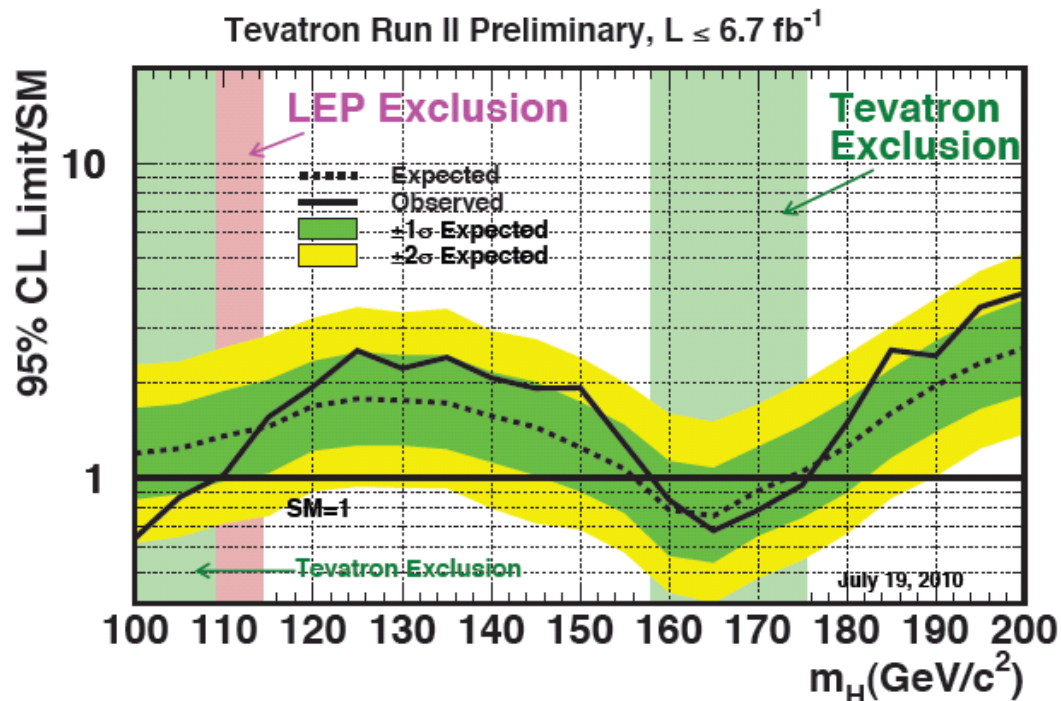
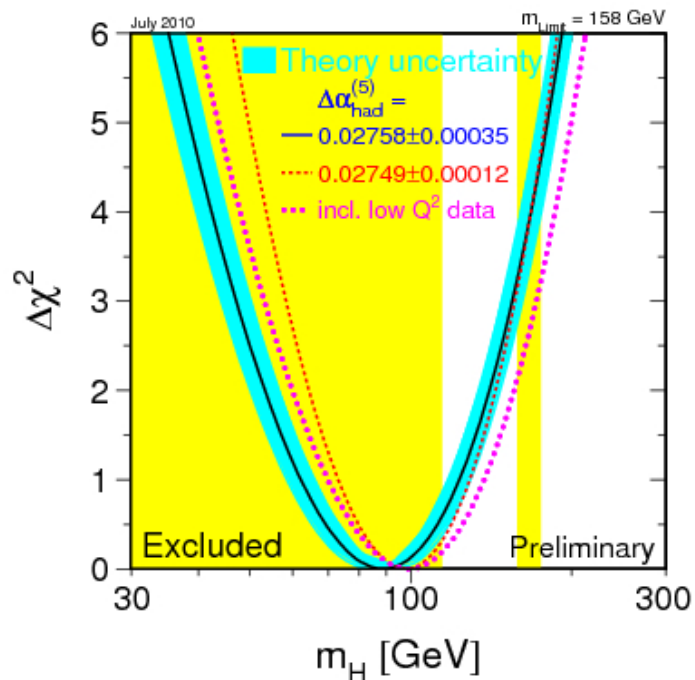
真空の  
相転移

→ そのおかげで  
宇宙に物質  
が誕生

ビッグバン直後の真空

ビッグバンの $10^{-10}$ 秒後の真空

# ヒッグス粒子 (SM) : LHC開始前の状況



## 直接探索(LEP)

$M_H > 114.4 \text{ GeV}$  (95% C.L.)

## EW精密測定

$M_H = 89 \text{ GeV} + 35 - 26 \text{ GeV}$

$M_H < 158 \text{ GeV}$  (95% C.L.)

## 直接探索(Tevatron)

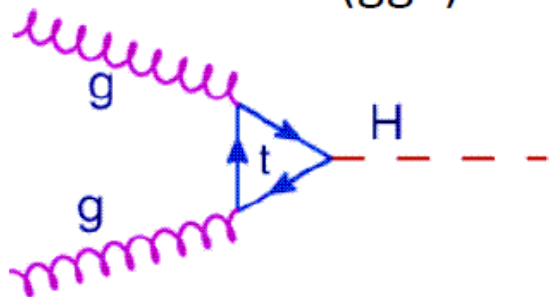
$158 \text{ GeV} < M_H < 175 \text{ GeV}$  (95% C.L.)

→ Excluded

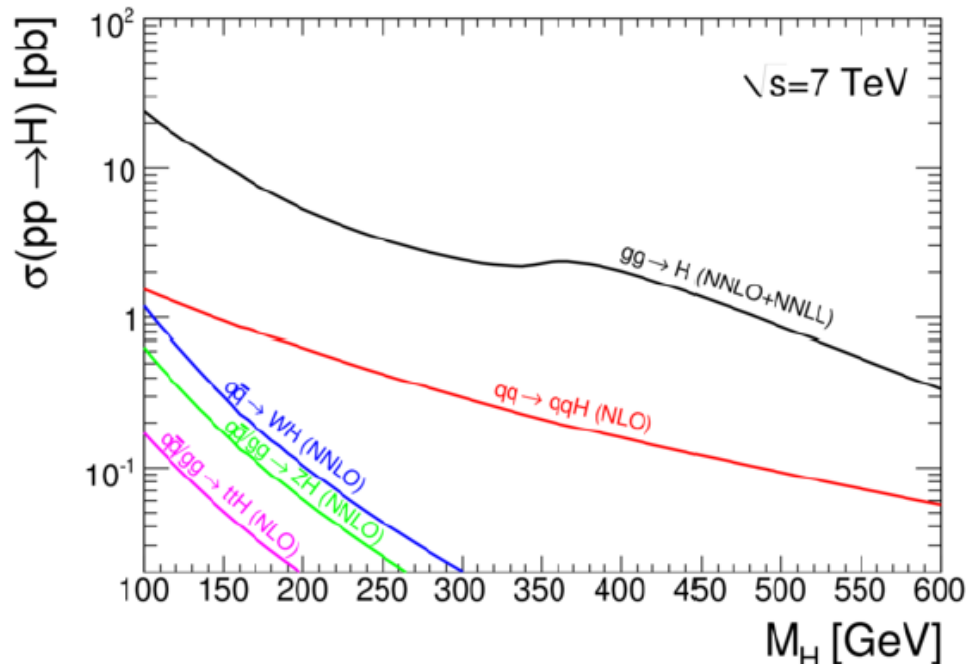
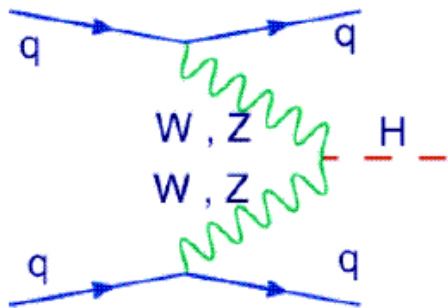
⇒  **$114 \text{ GeV} < M_H < 158 \text{ GeV}$**

# 生成過程

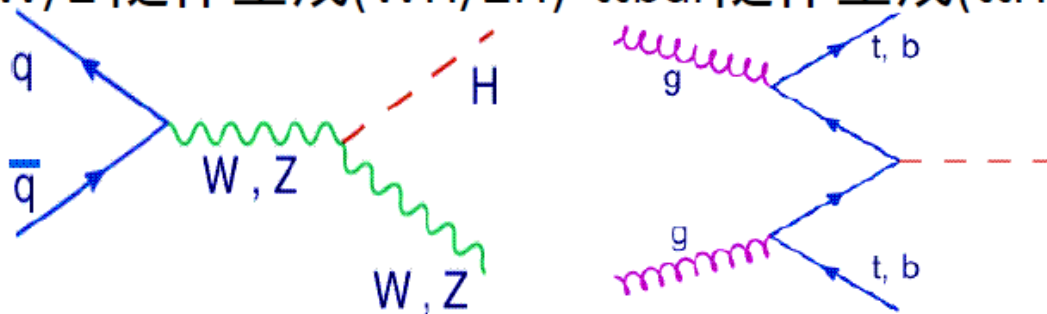
Gluon Fusion(ggF)



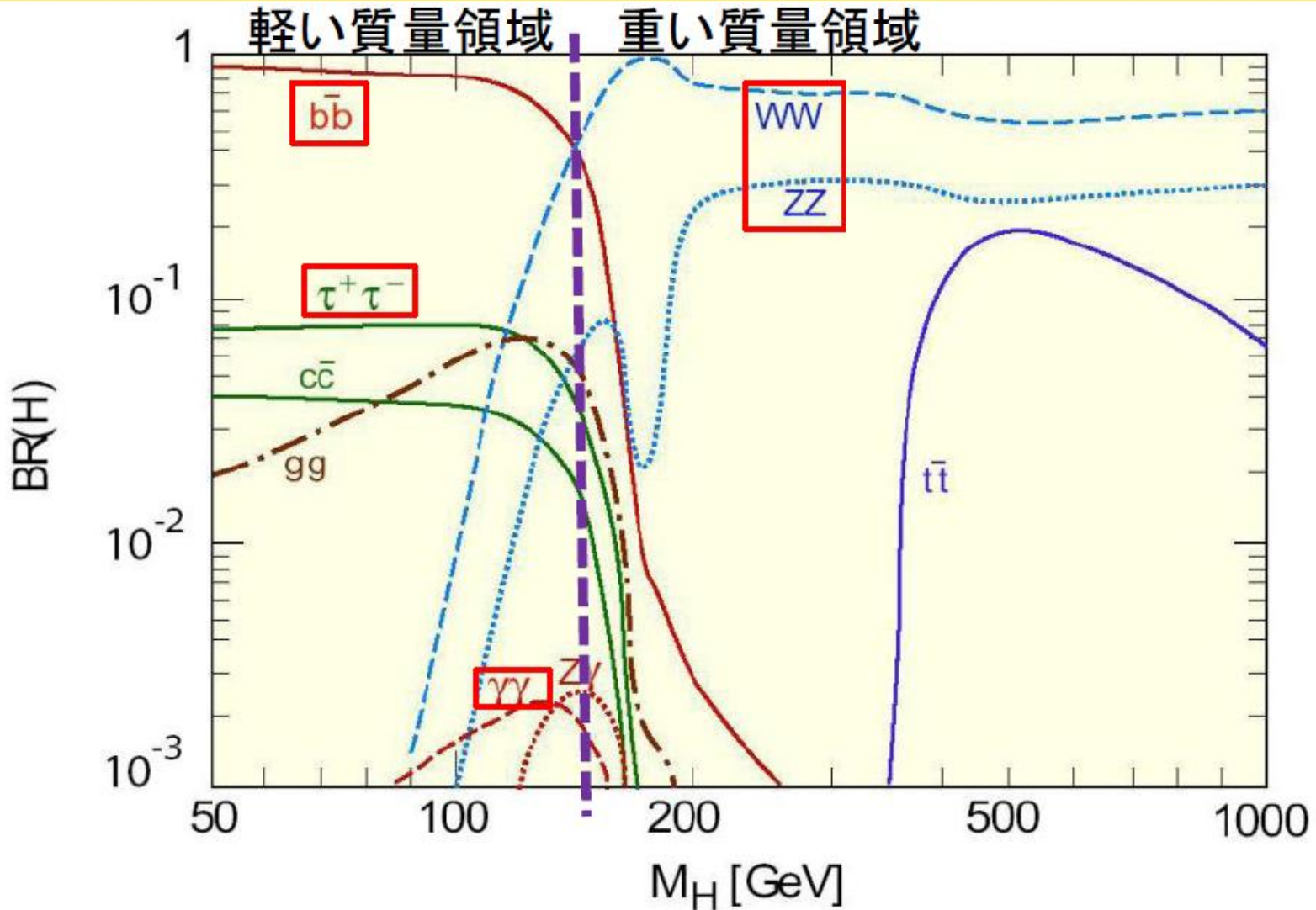
Vector Boson Fusion(VBF)



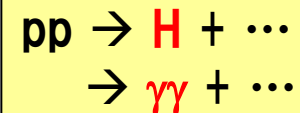
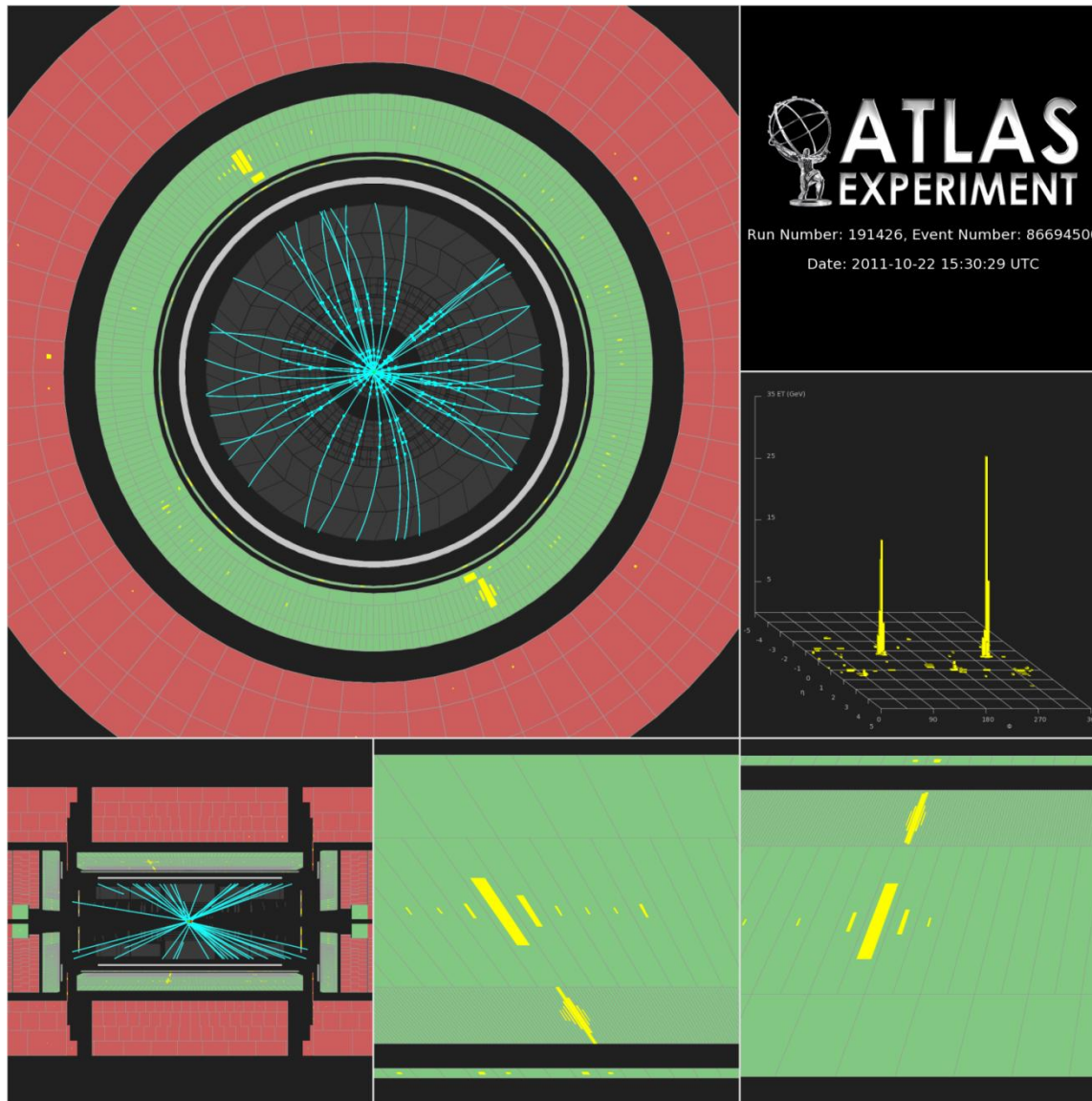
W/Z 隨伴生成(WH/ZH)  $tt\bar{t}$  隨伴生成(ttH)



# 崩壊過程



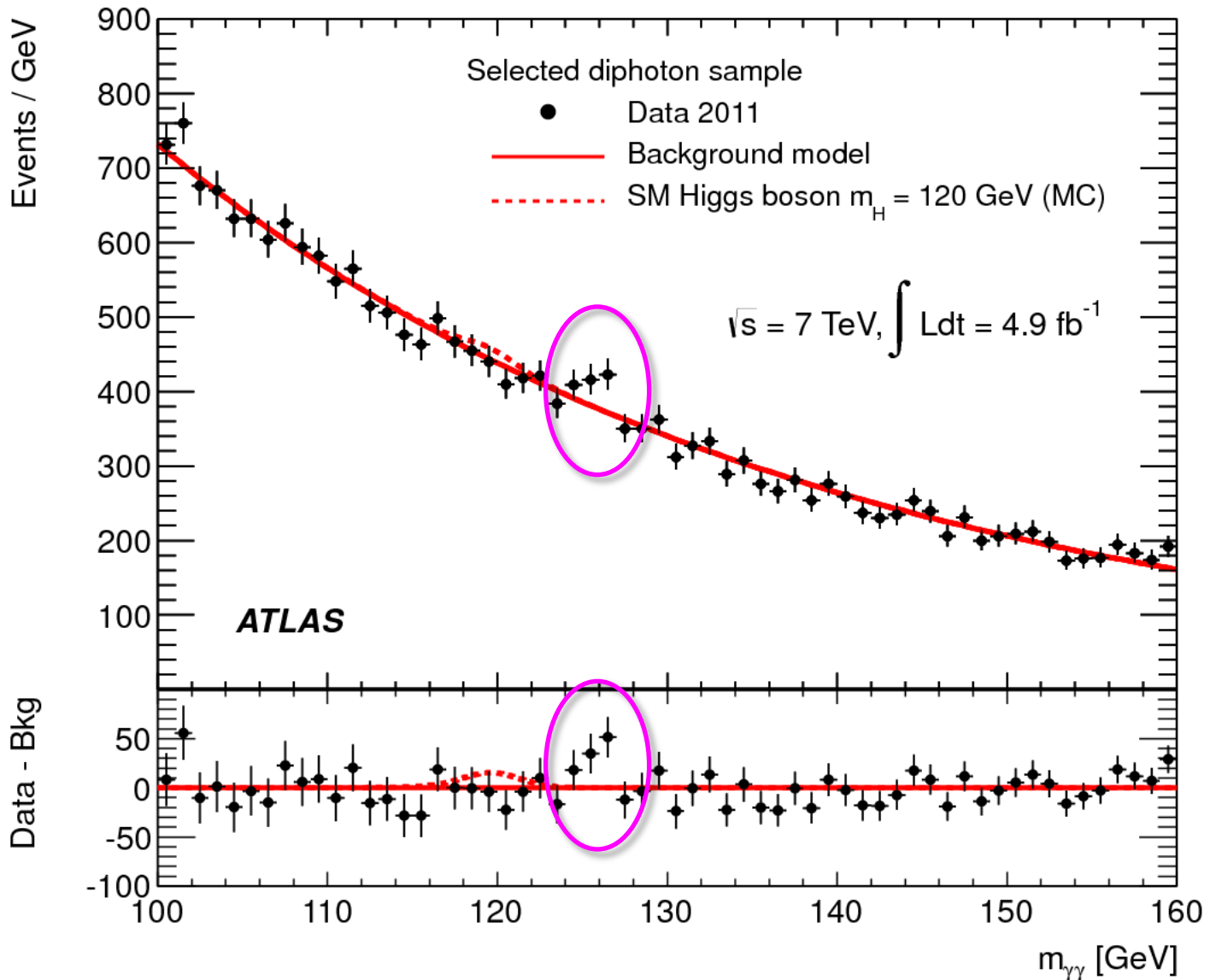
# 標準モデルヒッグス粒子探索



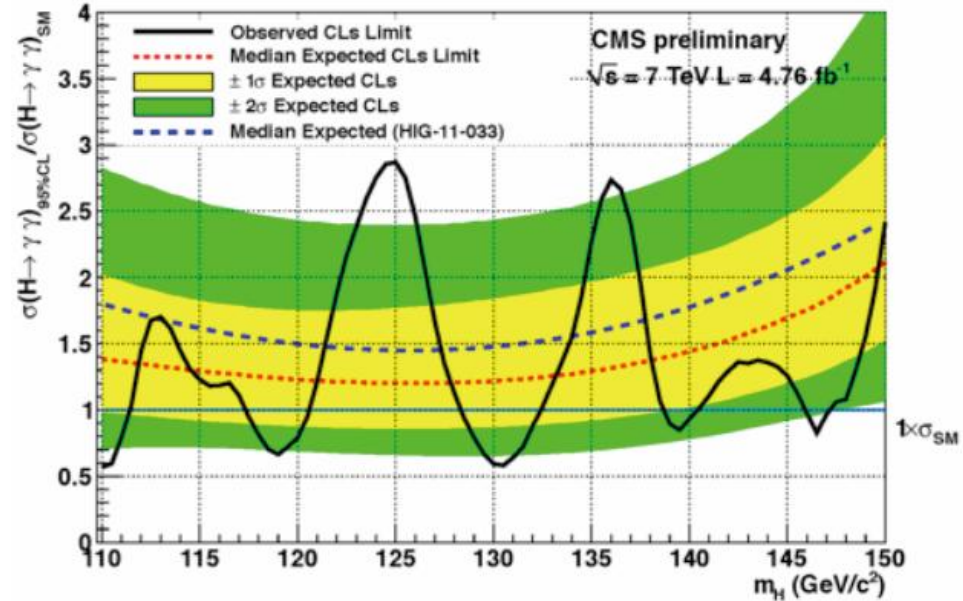
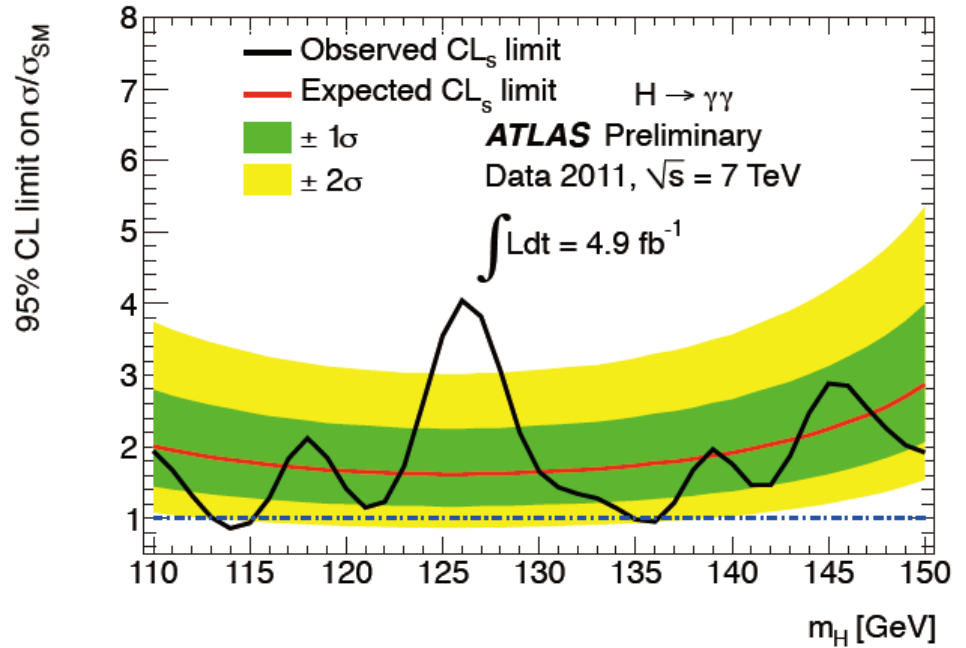
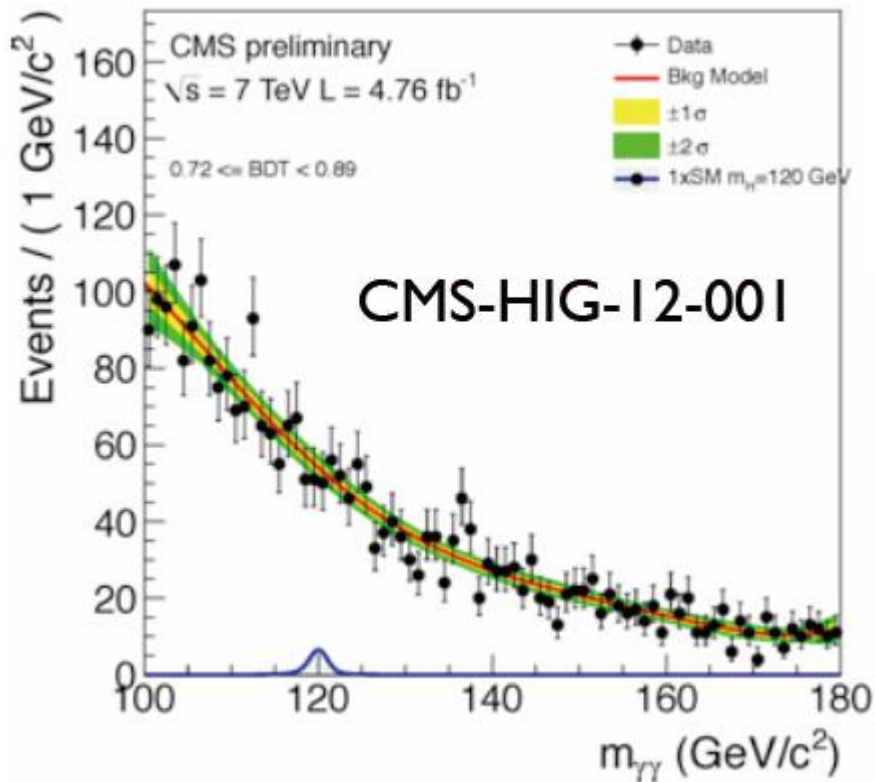
LHCの陽子陽子衝突でヒッグス粒子が生成され2光子(ガンマ線)に崩壊する事象の候補。

バックグラウンド事象も多い。

# 2光子の不変質量分布

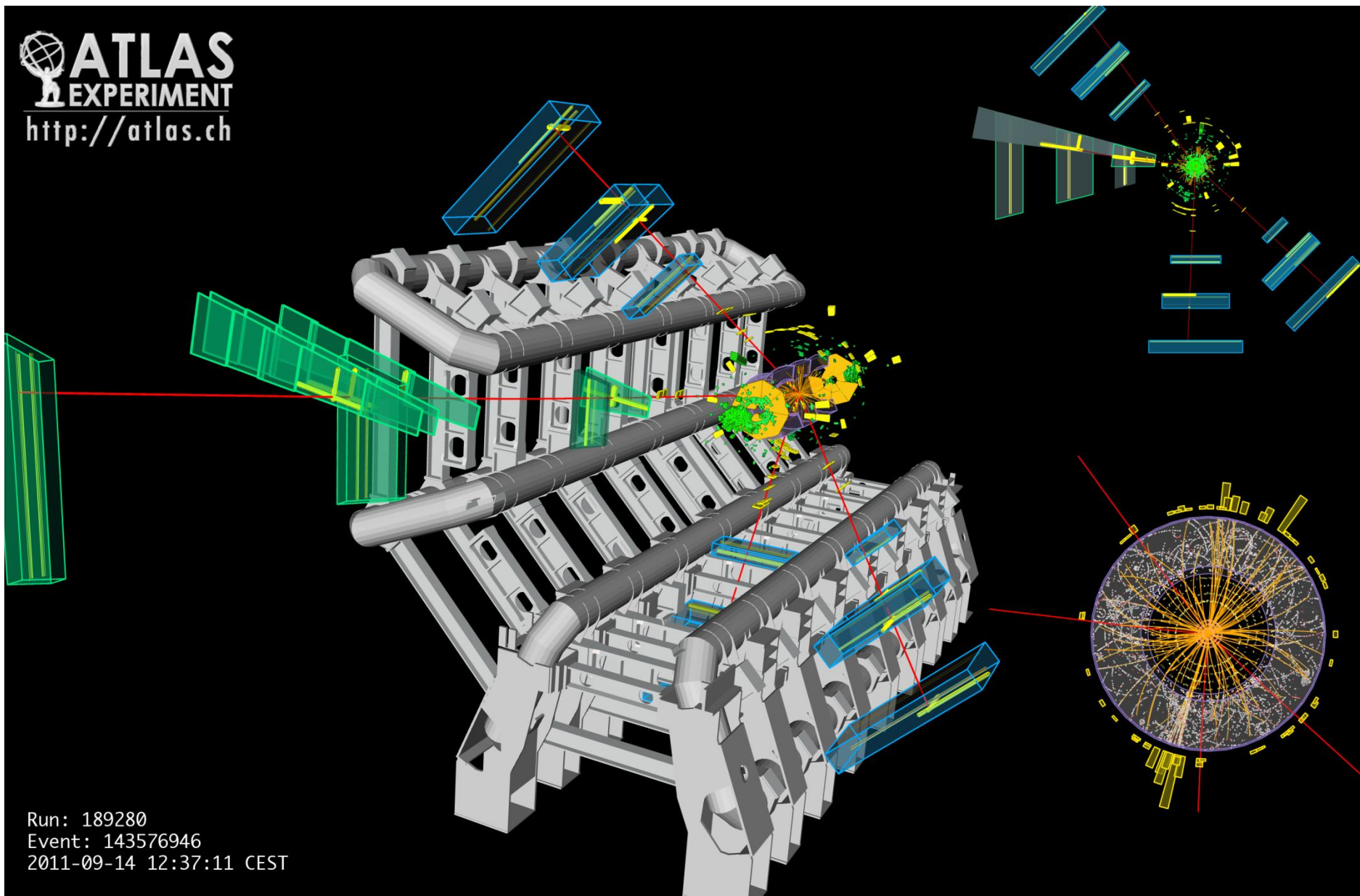


# Exclusion Limit



$H \rightarrow ZZ^{(*)} \rightarrow 4\mu$  候補事象、 $m_{4\mu} = 124.6 \text{ GeV}$

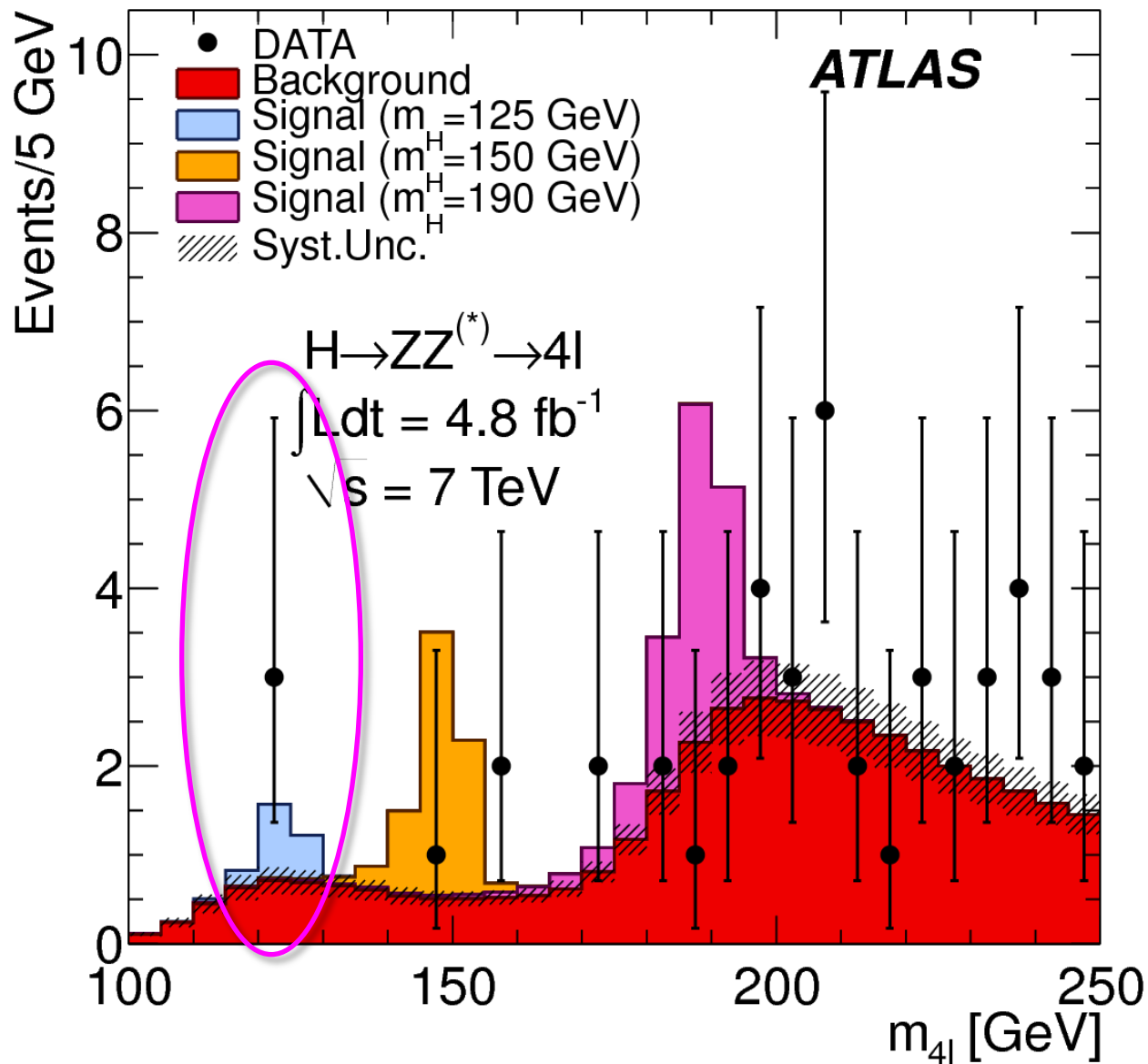
 **ATLAS**  
EXPERIMENT  
<http://atlas.ch>

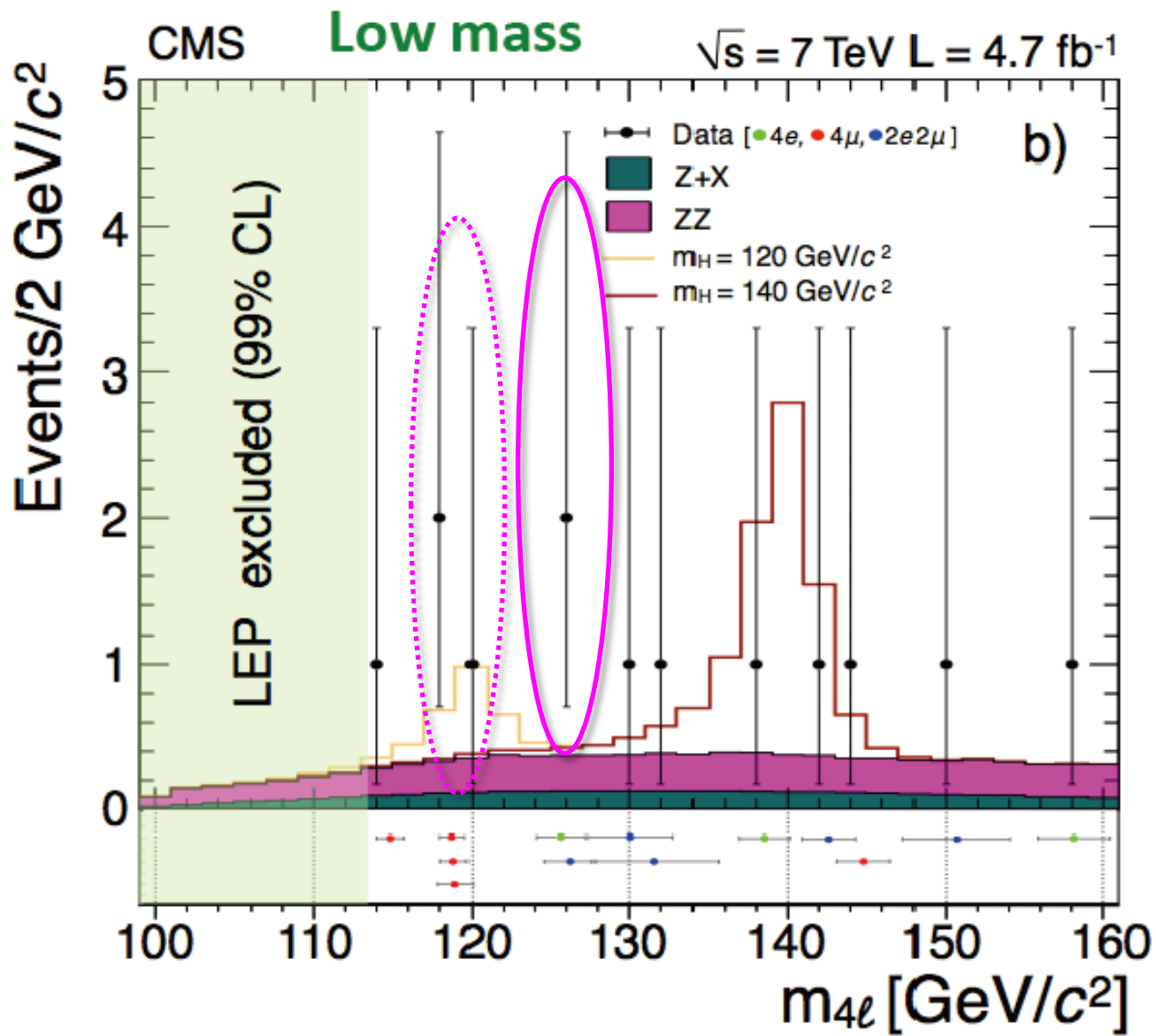


Run: 189280  
Event: 143576946  
2011-09-14 12:37:11 CEST

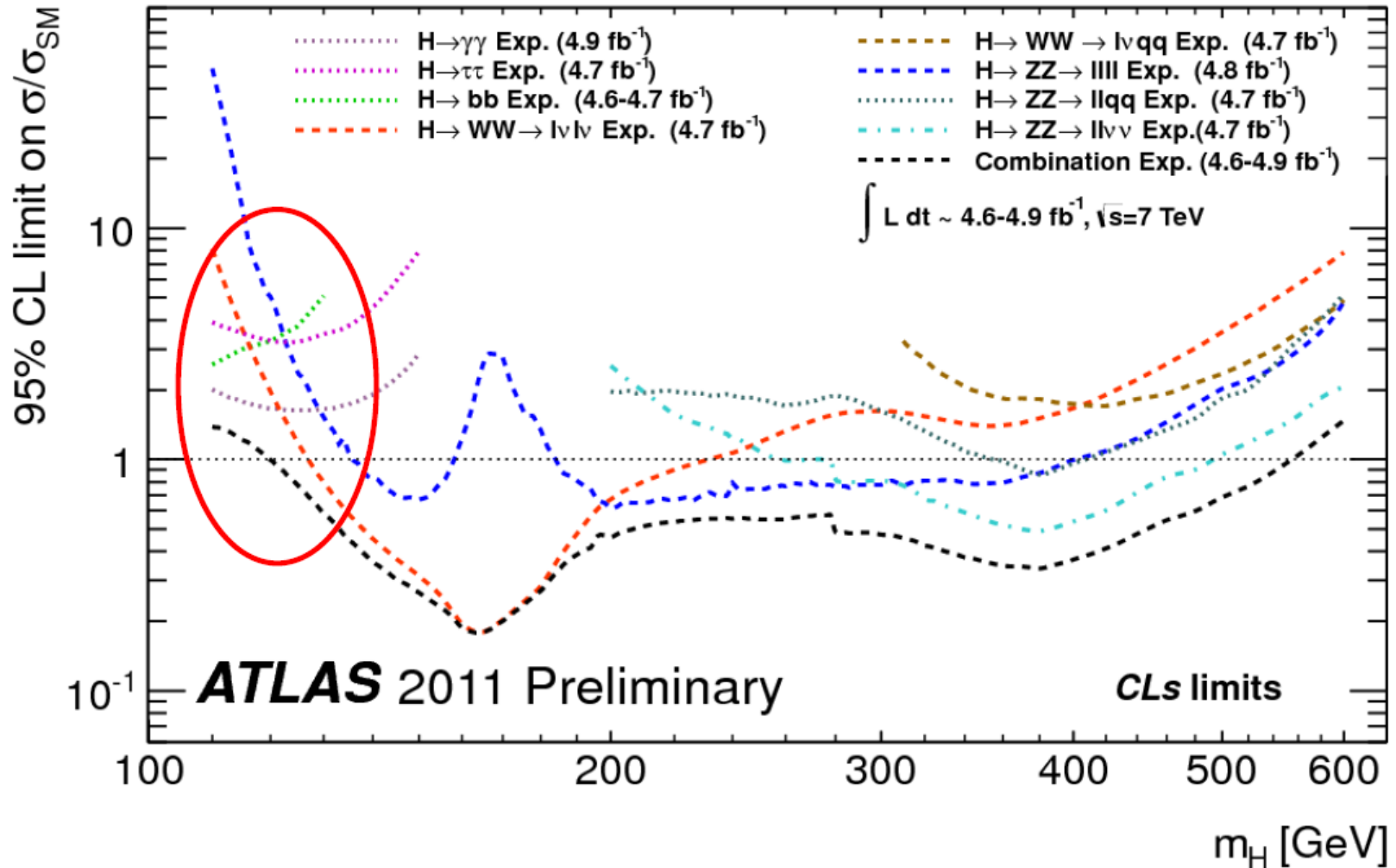


# 4レプトンの不変質量分布

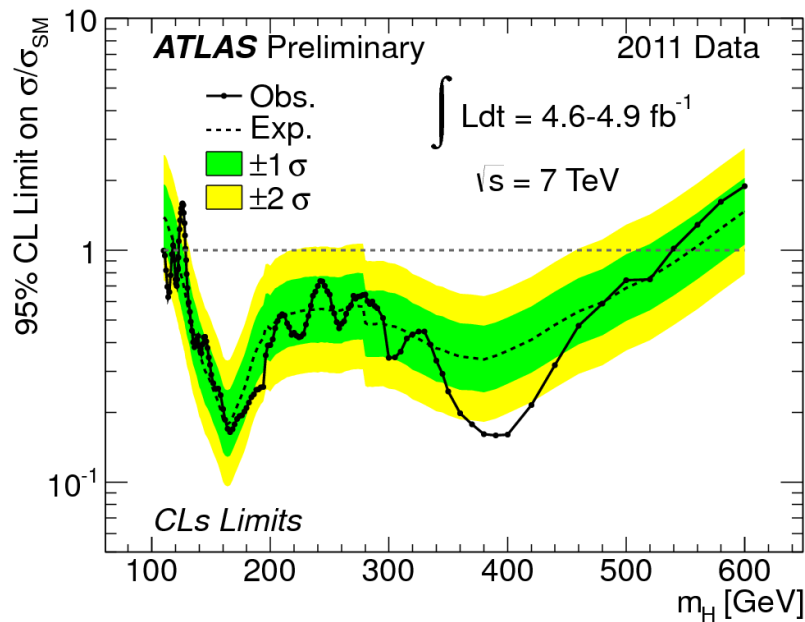




# Combination: Sensitivities



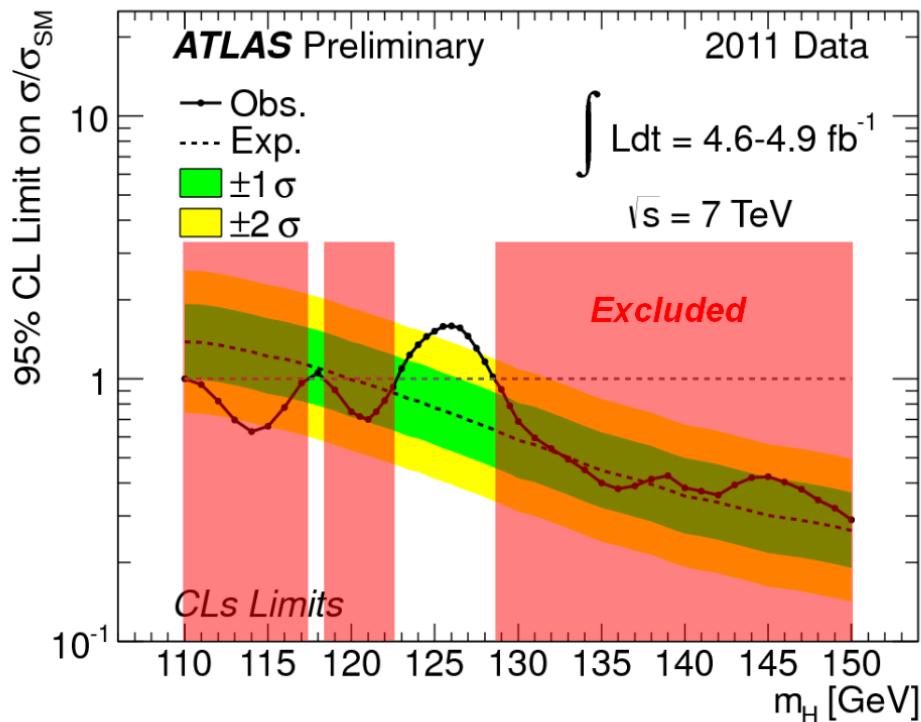
Every channel contributes,  $H \rightarrow WW \rightarrow l\nu l\nu$   
 has the best sensitivity between 125 GeV and  $\sim 200$  GeV



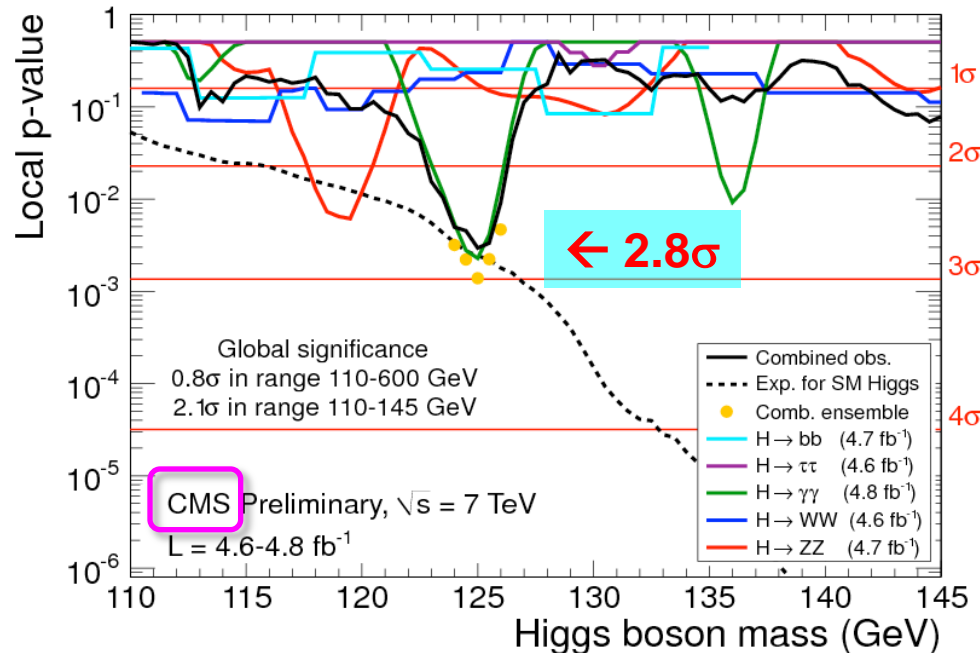
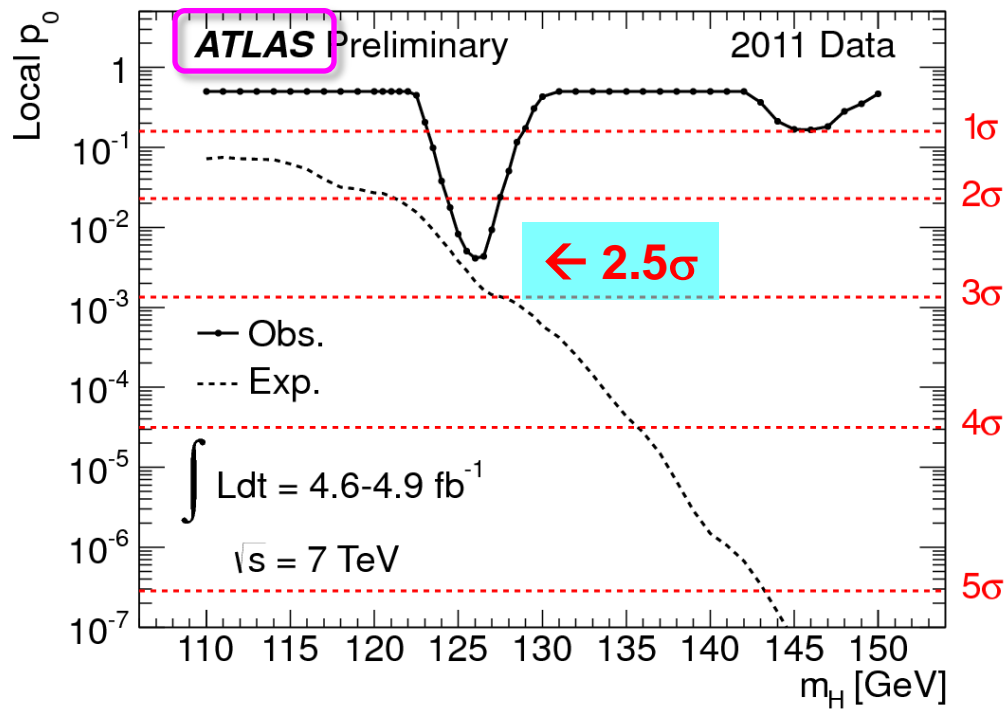
# Combination: Exclusion

Moriond Conf. での発表結果  
(7.Mar.2012)

**129 < m<sub>H</sub> < 539 GeV を棄却 (95% CL)**

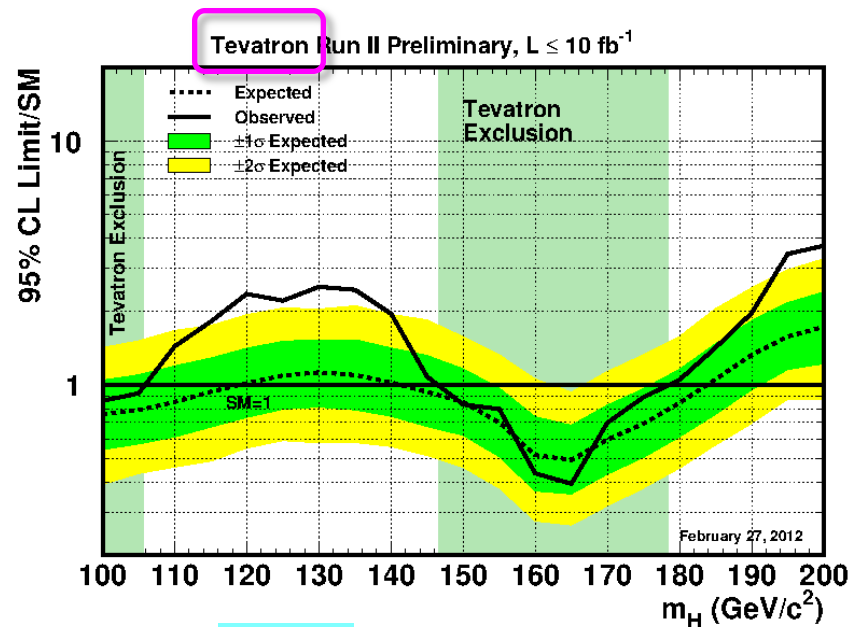


**110 < m<sub>H</sub> < 117.5 GeV**  
**118.5 < m<sub>H</sub> < 122.5 GeV**  
**も棄却 (95% CL)**



# Observed Excess

Moriond Conf. での発表結果  
(7.Mar.2012)

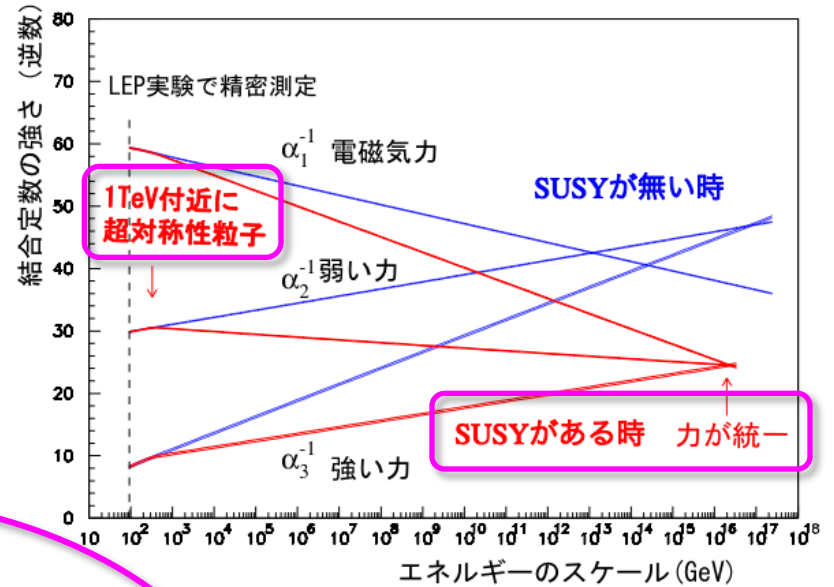
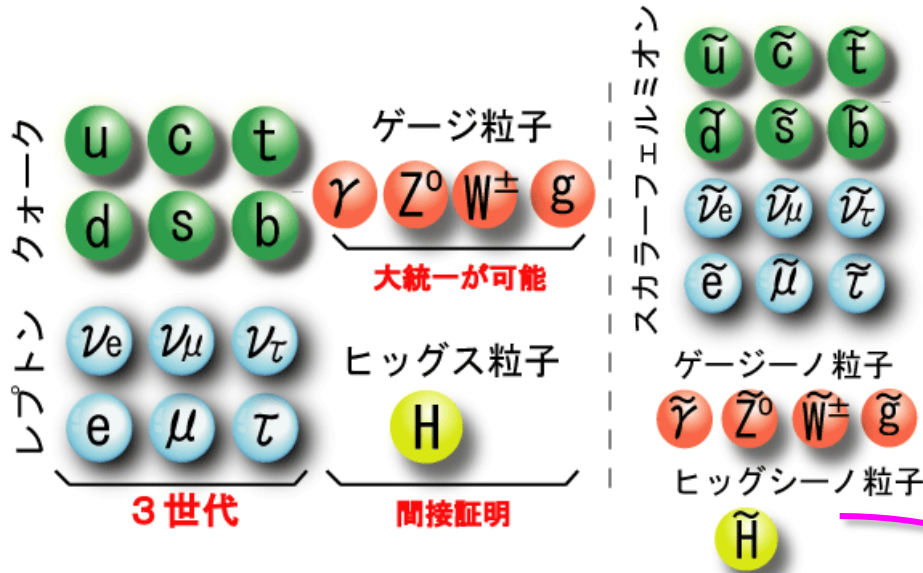


$2.2\sigma$

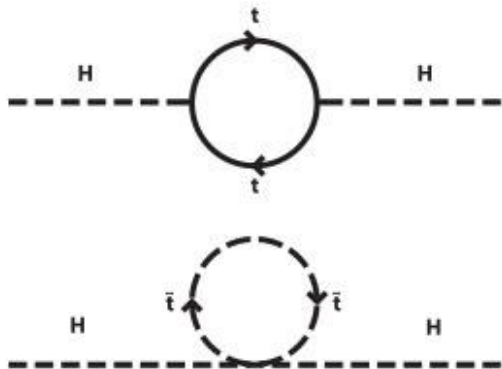
**→ 今年中に決着**

# 超対称性 (SUSY)

超弦理論



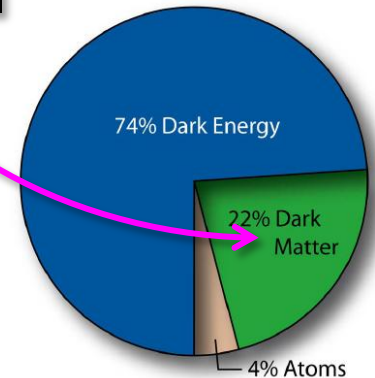
## ヒッグス粒子の質量の量子補正:



$$\Delta m_H^2 = -\frac{|\lambda_f|^2}{8\pi^2} [\Lambda_{UV}^2 + \dots]$$

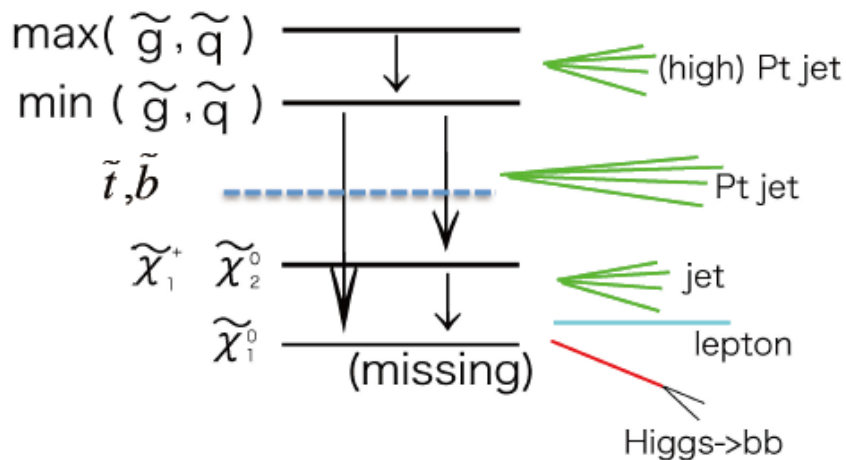
→ 2次発散をcancel  
(階層性問題の解決)

## 暗黒物質



# SUSY signals at LHC

## (1) $mE_T$ が特徴 (conventional)



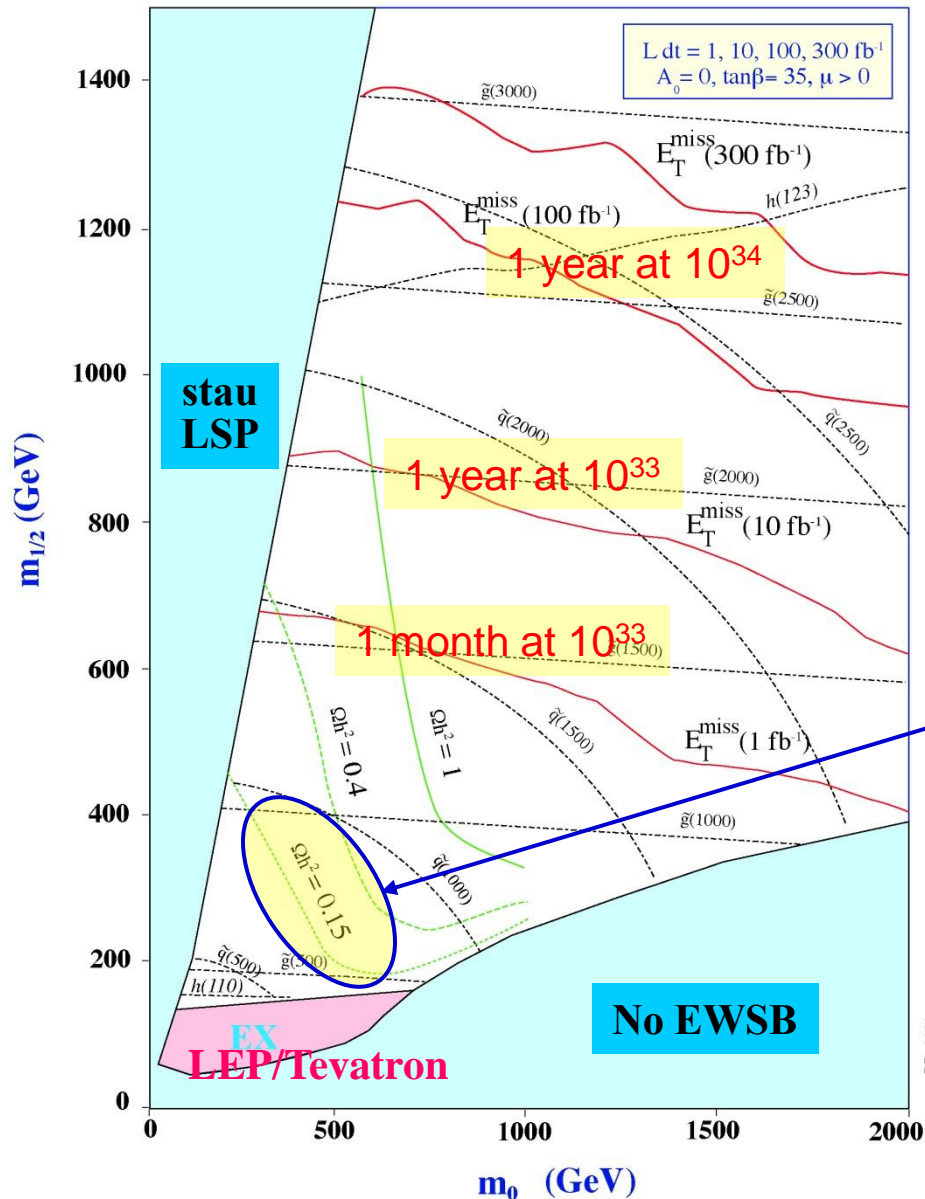
multi  $E_T$  + High  $P_T$  jets + b-jets  
leptons  
T-jets .....

## (2) 長寿命粒子が特徴 (ちょっとexotic)

GMSB stau, AMSB wino,  
Split SUSY model Gluino など

- (1) Missingがあるものもあり  
exclusiveな関係ではなく、一般には  
これらも普通に $mE_T$ が見えることが多い。
- (2) DMはMSSMと別のものが必要になる。
- (3) 検出器に近い要素が多くて実験的に  
面白い

# Discovery Potential of SUSY (mSUGRA)



$m_{1/2}$ : universal gaugino mass at GUT scale  
 $m_0$ : universal scalar mass at GUT scale  
 $\tan\beta$ : vev ratio for 2 Higgs doublets  
 $\text{sign}(\mu)$ : sign of Higgs mixing parameter  
 $A_0$ : trilinear coupling

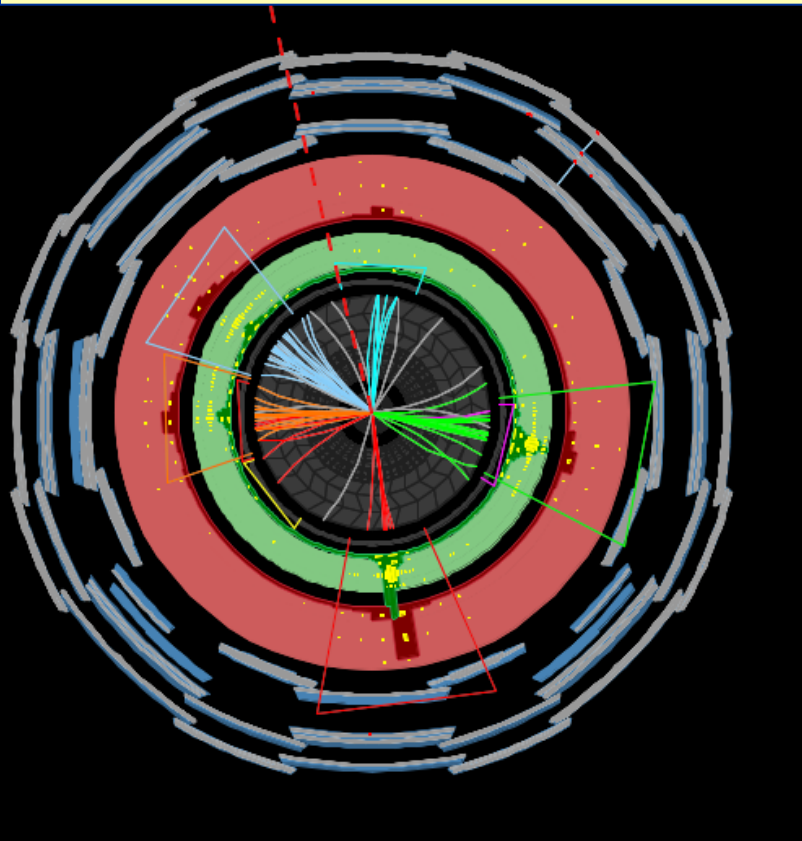
- If low energy Supersymmetry exists, LHC will almost certainly observe it
- Squarks and Gluinos detectable up to 2.5-3 TeV mass with  $300 \text{ fb}^{-1}$

Need only a short time to cover the interesting region for Cold DM

…とか、LHC実験開始前には言っていたのですが、…



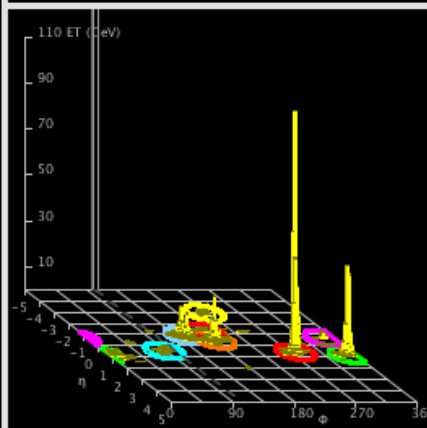
# 超対称性粒子生成とも考えられる事象



**ATLAS**  
EXPERIMENT

Run Number: 183021, Event Number: 66383304

Date: 2011-06-03 11:01:56 CEST



Run=183021 #66383304

$M_{\text{eff}}(4j) = 1810 \text{ GeV}$

MET = 460 GeV  $\phi = 1.8$

Jets

$p_T = 528 \text{ GeV}$   $\eta = 0.58$   $\phi = -1.45$

$p_T = 418 \text{ GeV}$   $\eta = 0.83$   $\phi = -0.19$

$p_T = 233 \text{ GeV}$   $\eta = -0.91$   $\phi = 2.54$

$p_T = 171 \text{ GeV}$   $\eta = -0.47$   $\phi = -3.11$

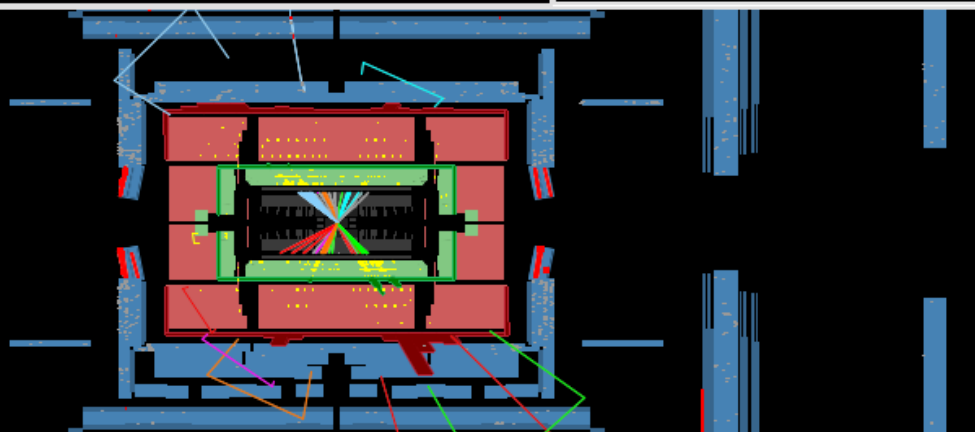
$p_T = 42 \text{ GeV}$   $\eta = 0.47$   $\phi = 1.52$

Nvtx = 1 with 94 tracks

Muon

$p_T = 5.4 \text{ GeV}$   $\eta = -0.25$   $\phi = 1.0$

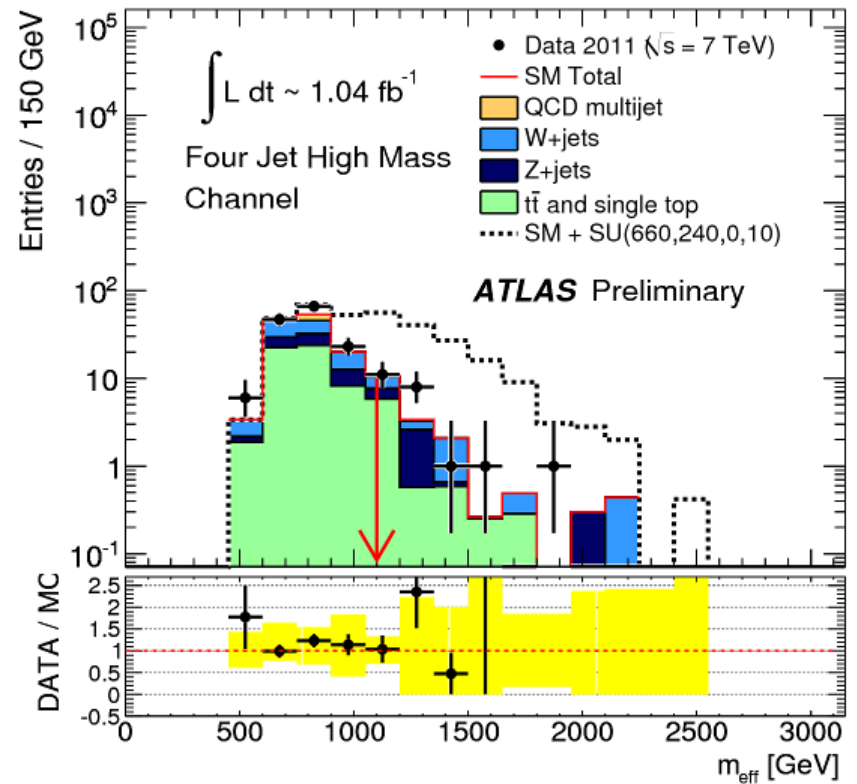
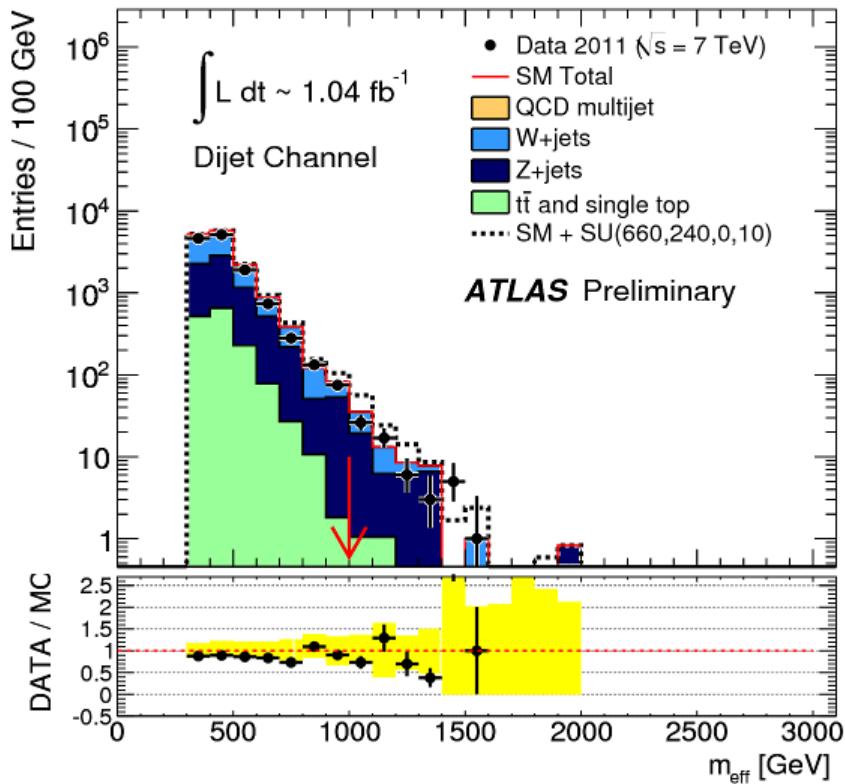
MT=40GeV



# SUSY in 0-lepton channel

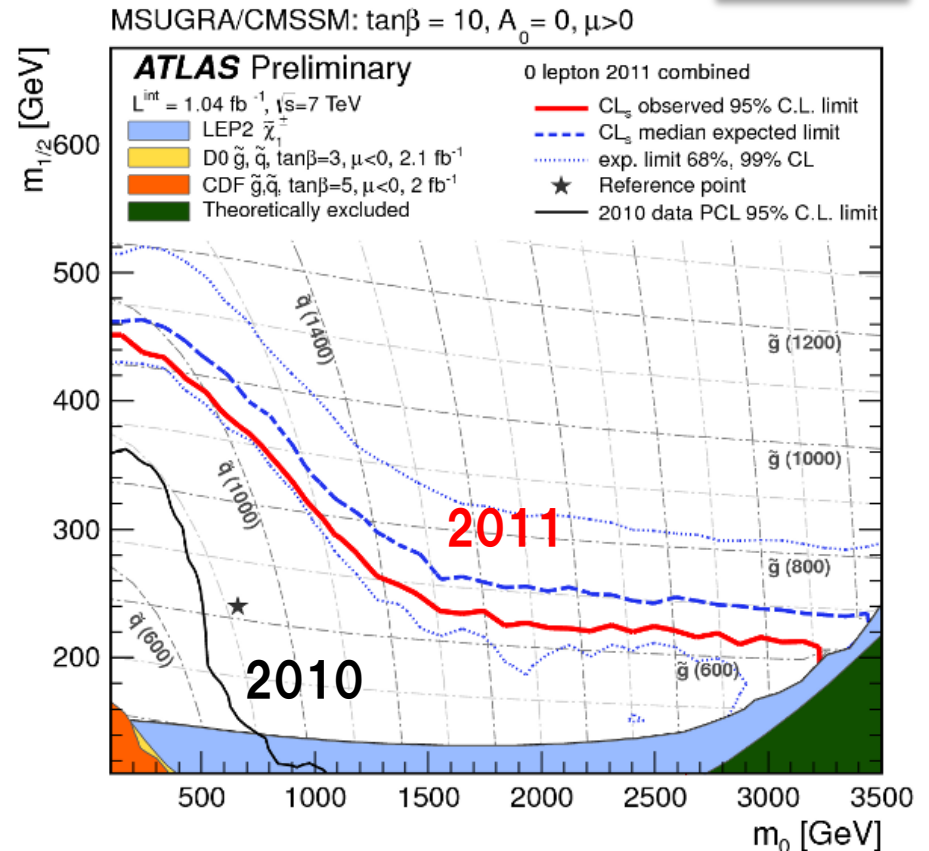
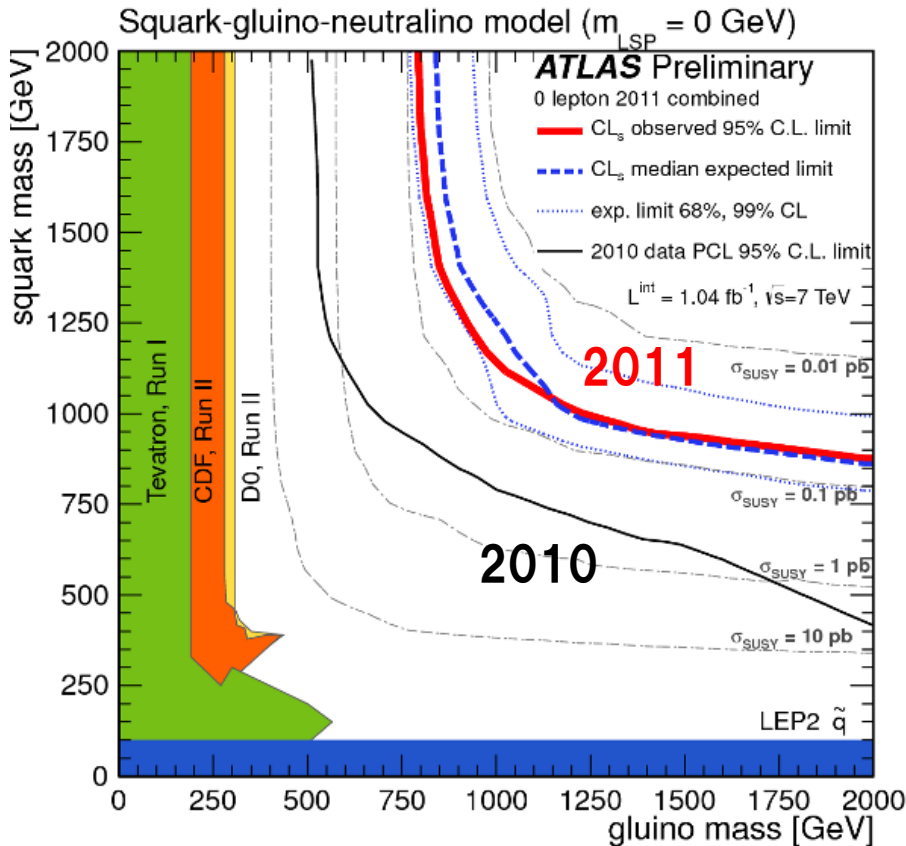
$$m_{eff} = E_T^{miss} + \sum_1^n p_T^{jet}$$

ATLAS



# SUSY in 0-lepton channel

ATLAS

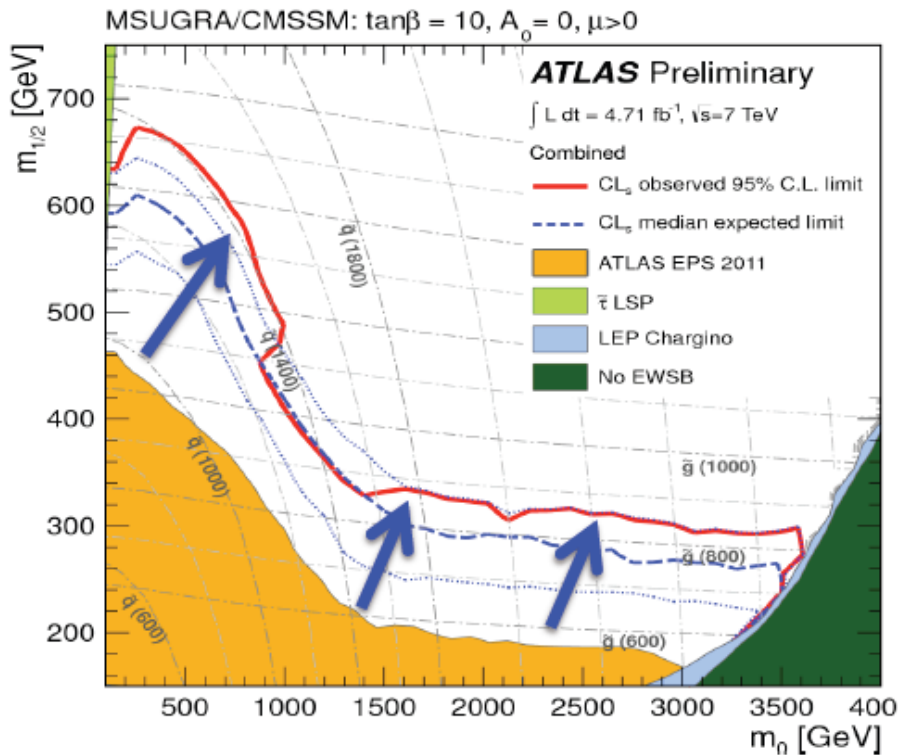


Simplified model with two  $\tilde{q}$  generations,  $m(\tilde{\chi}_1^0) \sim 0$   
 $m_{\tilde{g}} > 800 \text{ GeV}$      $m_{\tilde{q}} > 850 \text{ GeV}$   
 Equal mass case:  $m_{\tilde{g}} = m_{\tilde{q}} > 1.075 \text{ TeV}$

MSUGRA/CMSSM:  $\tan\beta=10, A_0=0, \mu > 0$   
 Equal mass case:  $m_{\tilde{q}} = m_{\tilde{g}} > 980 \text{ GeV}$

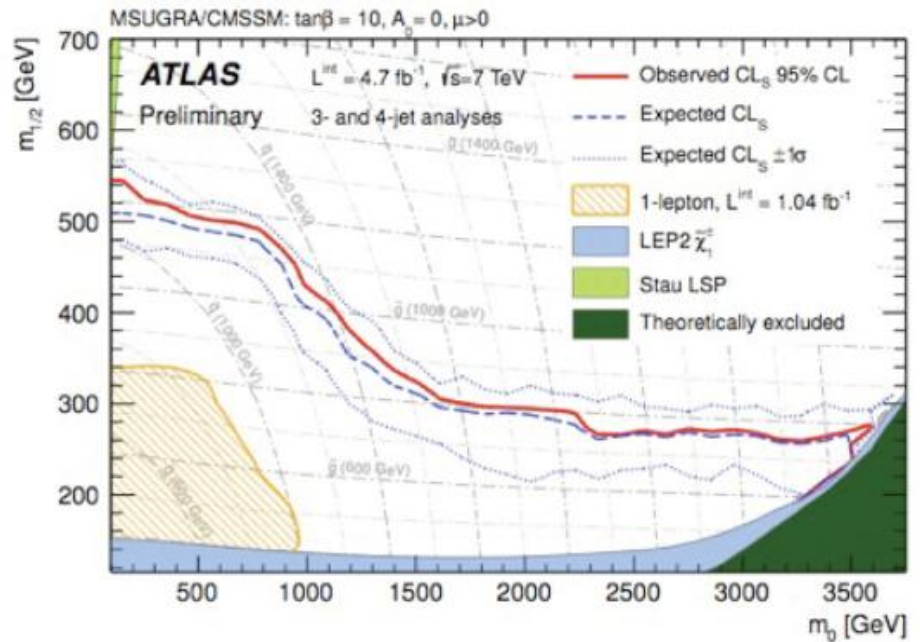
# ATLAS最新結果 (Mar.2012)

## 0-lepton channel

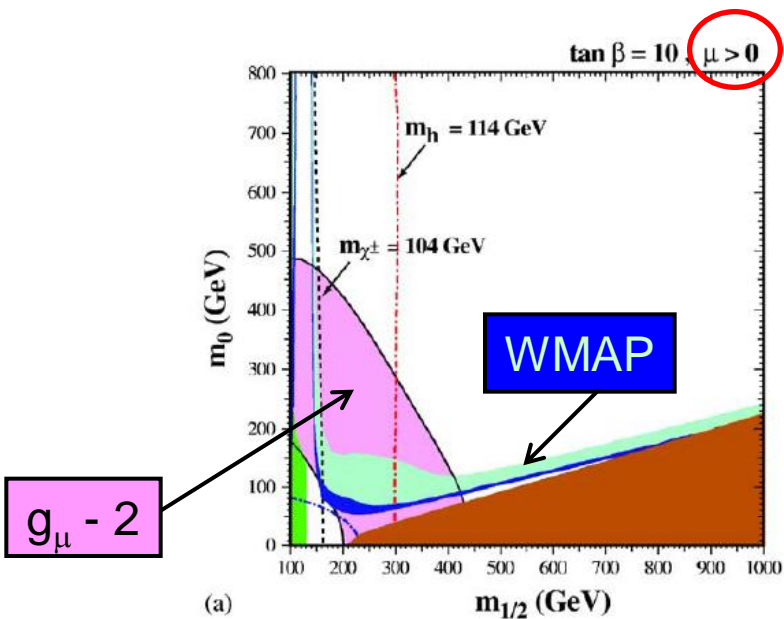


$m_q = m_g = 1.4 \text{ TeV}$  is excluded

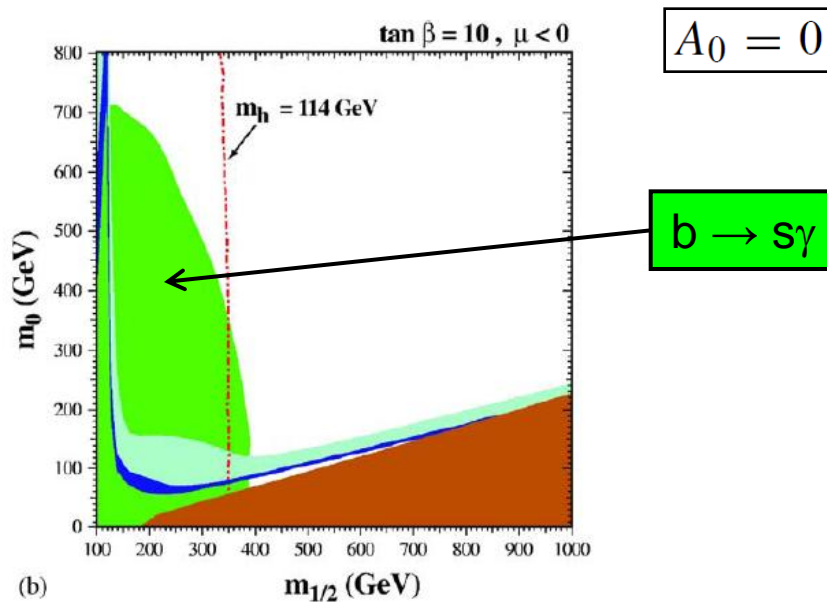
## 1-lepton channel



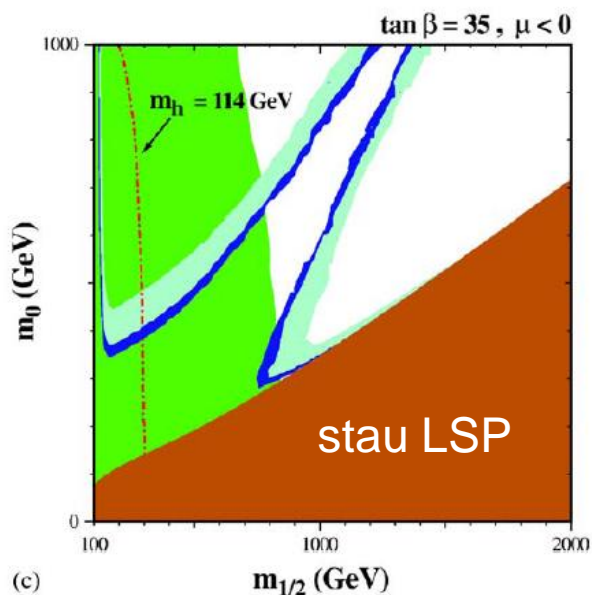
# Where is Dark Matter (in mSUGRA/cMSSM) ?



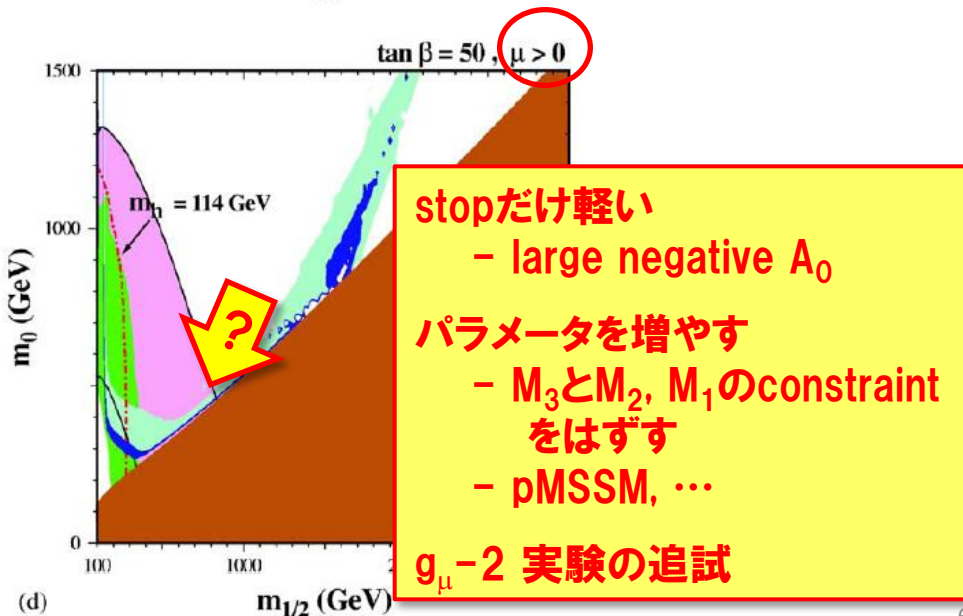
(a)



(b)

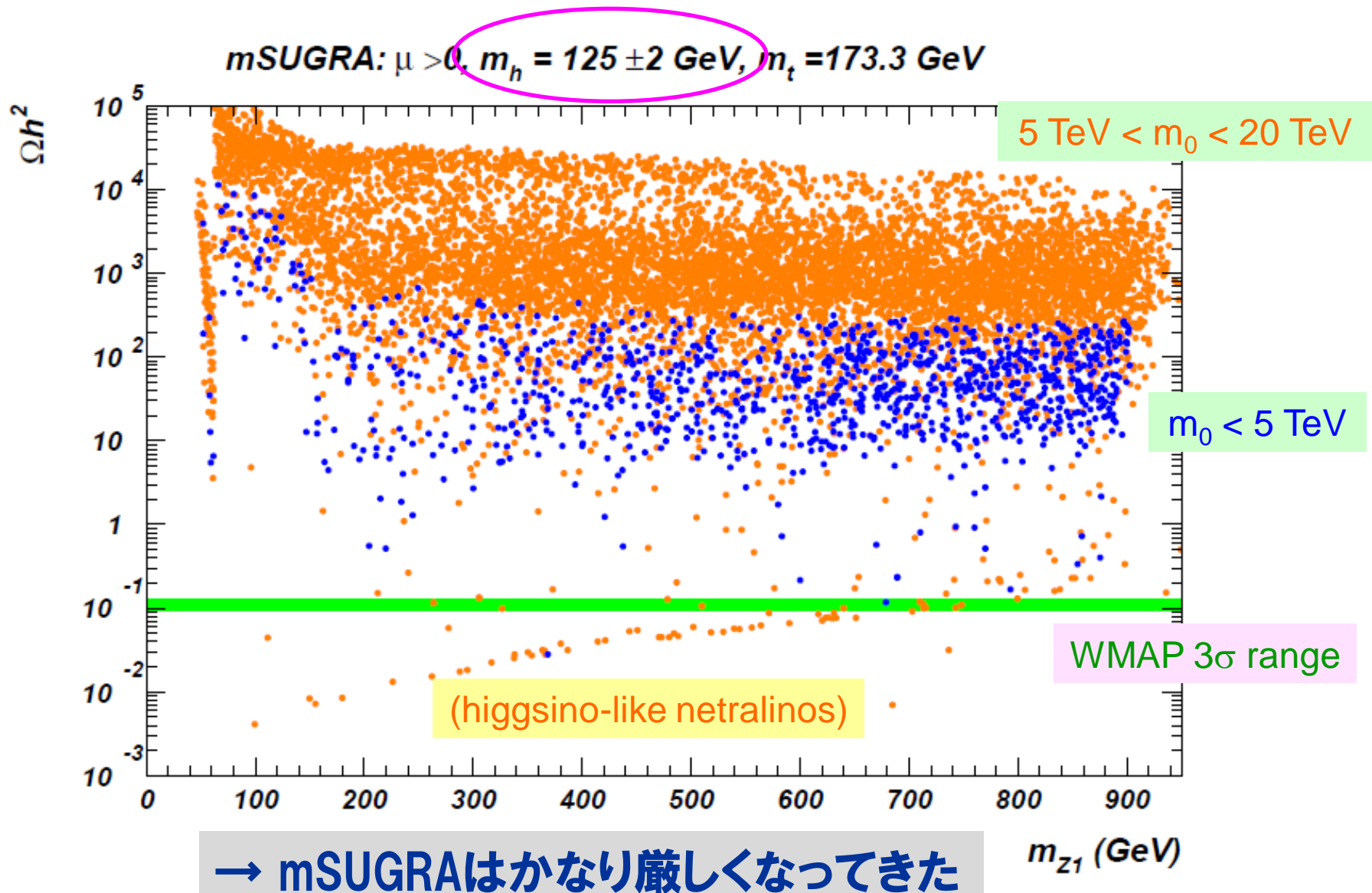


(c)



(d)

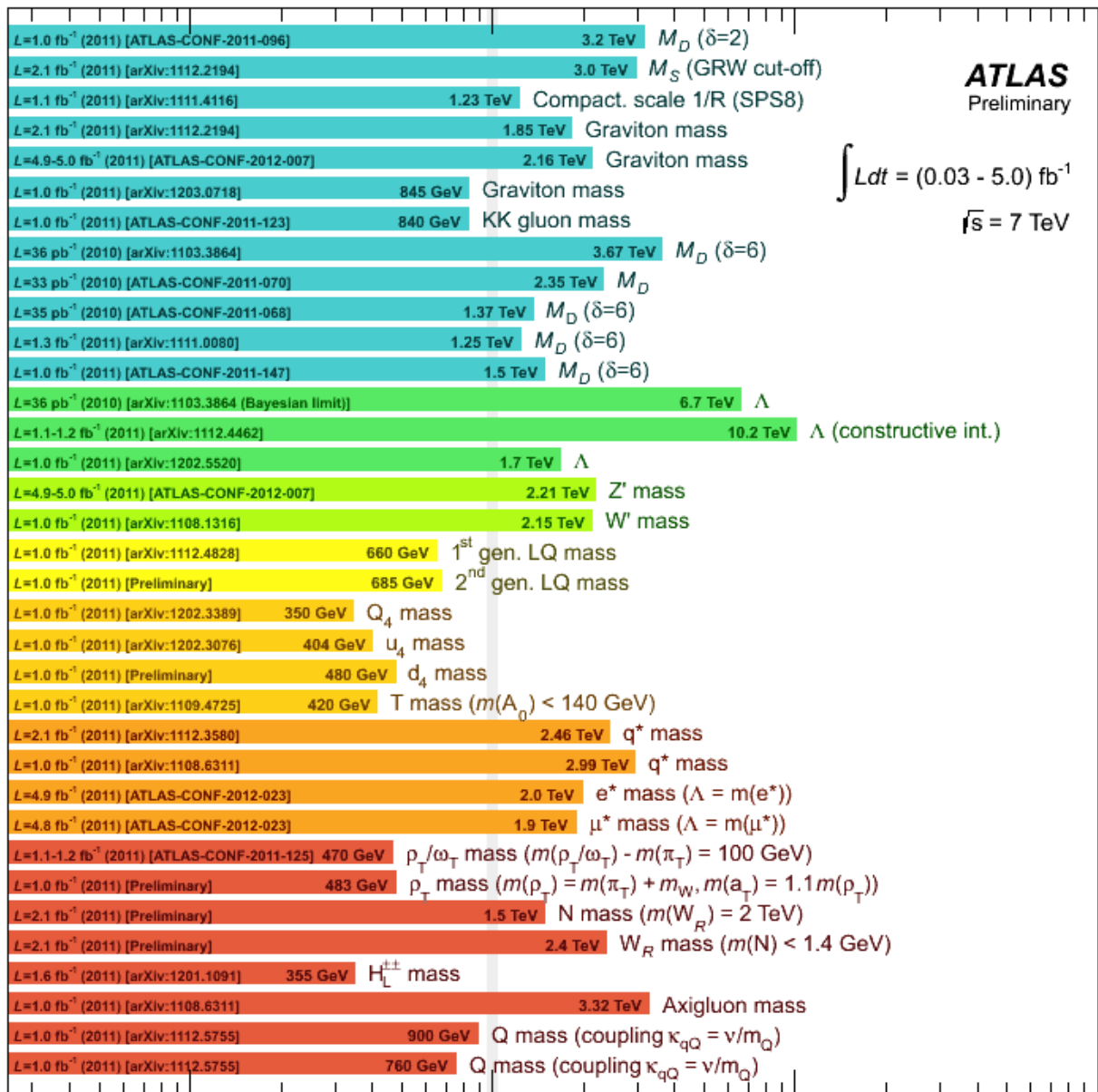
# Neutralino relic density vs. neutralino mass



# ATLAS Exotics Searches\* - 95% CL Lower Limits (Status: Moriond EW 2012)

Extra dimensions  
CI  
V  
LQ  
4-th gen  
Excit. ferm.  
Other

Large ED (ADD) : monojet  
Large ED (ADD) : diphoton  
UED :  $\gamma\gamma + E_{T,miss}$   
RS with  $k/M_{Pl} = 0.1$  : diphoton,  $m_{TT}$   
RS with  $k/M_{Pl} = 0.1$  : dilepton,  $m_{ll}$   
RS with  $g_{qqqKK}/g_s = -0.20$  :  $t\bar{t} \rightarrow ll+X, H_T + E_{T,miss}$   
Quantum black hole (QBH) :  $m_{dijet}, F(\chi)$   
QBH : High-mass  $\sigma_{t+X}$   
ADD BH ( $M_{TH}/M_D=3$ ) : multijet,  $\Sigma\rho_T, N_{jets}$   
ADD BH ( $M_{TH}/M_D=3$ ) : SS dimuon,  $N_{ch. part.}$   
ADD BH ( $M_{TH}/M_D=3$ ) : leptons + jets,  $\Sigma\rho_T$   
qqqq contact interaction :  $F_\chi(m_{dijet})$   
qqll CI :  $e\bar{e}, \mu\bar{\mu}$  combined,  $m_{ll}$   
uutt CI : SS dilepton + jets +  $E_{T,miss}$   
SSM  $Z'$  :  $m_{ee/\mu\mu}$   
SSM  $W'$  :  $m_{Te/\mu\mu}$   
Scalar LQ pairs ( $\beta=1$ ) : kin. vars. in  $e\bar{e}jj, e\nu jj$   
Scalar LQ pairs ( $\beta=1$ ) : kin. vars. in  $\mu\bar{\mu}jj, \mu\nu jj$   
4<sup>th</sup> generation :  $Q_4 \bar{Q}_4 \rightarrow WqWq$   
4<sup>th</sup> generation :  $u_4 \bar{u}_4 \rightarrow WbWb$   
4<sup>th</sup> generation :  $d_4 \bar{d}_4 \rightarrow WtWt$   
 $T\bar{T}_{exo. 4th gen.} \rightarrow t\bar{t} + A, A_0$  : 1-lep + jets +  $E_{T,miss}$   
Excited quarks :  $\gamma$ -jet resonance,  $m_{Tjet}$   
Excited quarks : dijet resonance,  $m_{dijet}$   
Excited electron : e- $\gamma$  resonance,  $m_{e\gamma}$   
Excited muon :  $\mu$ - $\gamma$  resonance,  $m_{\mu\gamma}$   
Techni-hadrons : dilepton,  $m_{ee/\mu\mu}$   
Techni-hadrons : WZ resonance ( $\nu ll$ ),  $m_{T,WZ}$   
Major. neutr. (LRSM, no mixing) : 2-lep + jets  
 $W_R$  (LRSM, no mixing) : 2-lep + jets  
 $H_L^{\pm\pm}$  (DY prod.,  $BR(H^{\pm\pm} \rightarrow \mu\mu)=1$ ) : SS dimuon,  $m_{\mu\mu}$   
Axigluons : dijet resonance,  $m_{dijet}$   
Vector-like quark : CC,  $m_{lvq}$   
Vector-like quark : NC,  $m_{llq}$

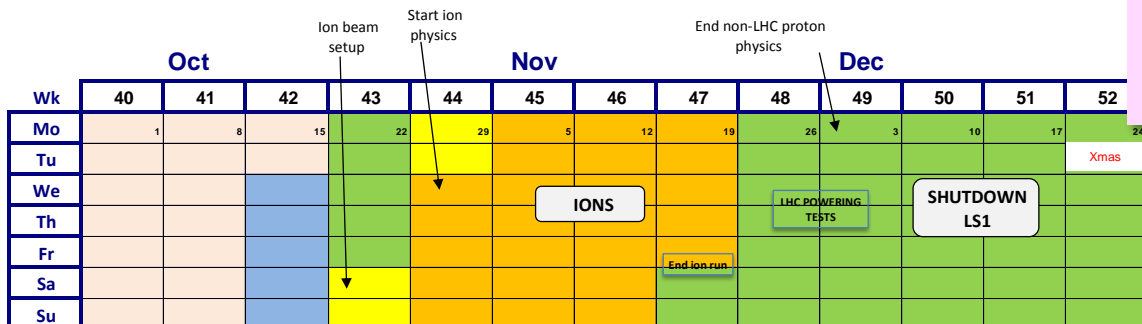
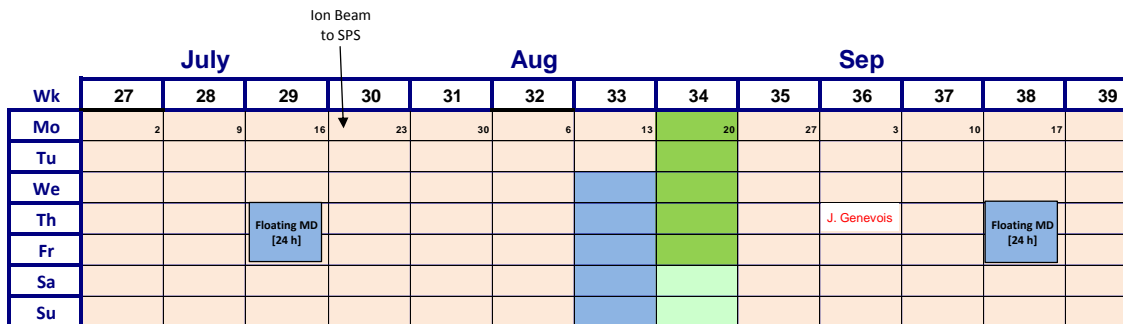
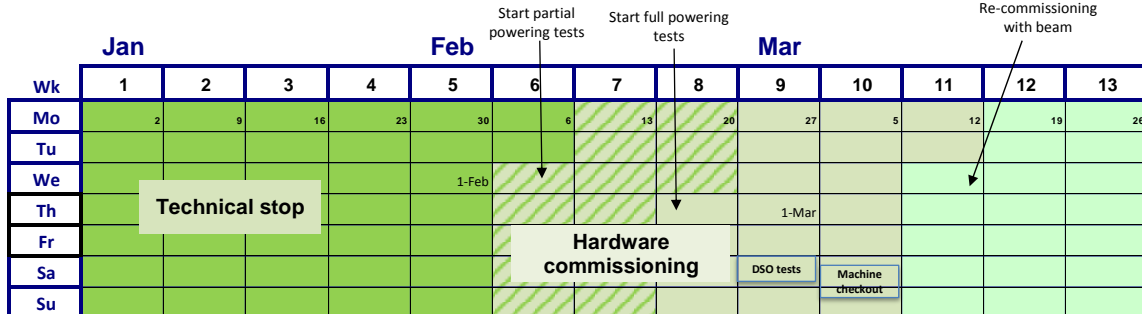


**ATLAS**  
Preliminary

$\int Ldt = (0.03 - 5.0) \text{ fb}^{-1}$   
 $\sqrt{s} = 7 \text{ TeV}$

10<sup>-1</sup> 1 10 10<sup>2</sup>  
Mass scale [TeV]

\*Only a selection of the available mass limits on new states or phenomena shown



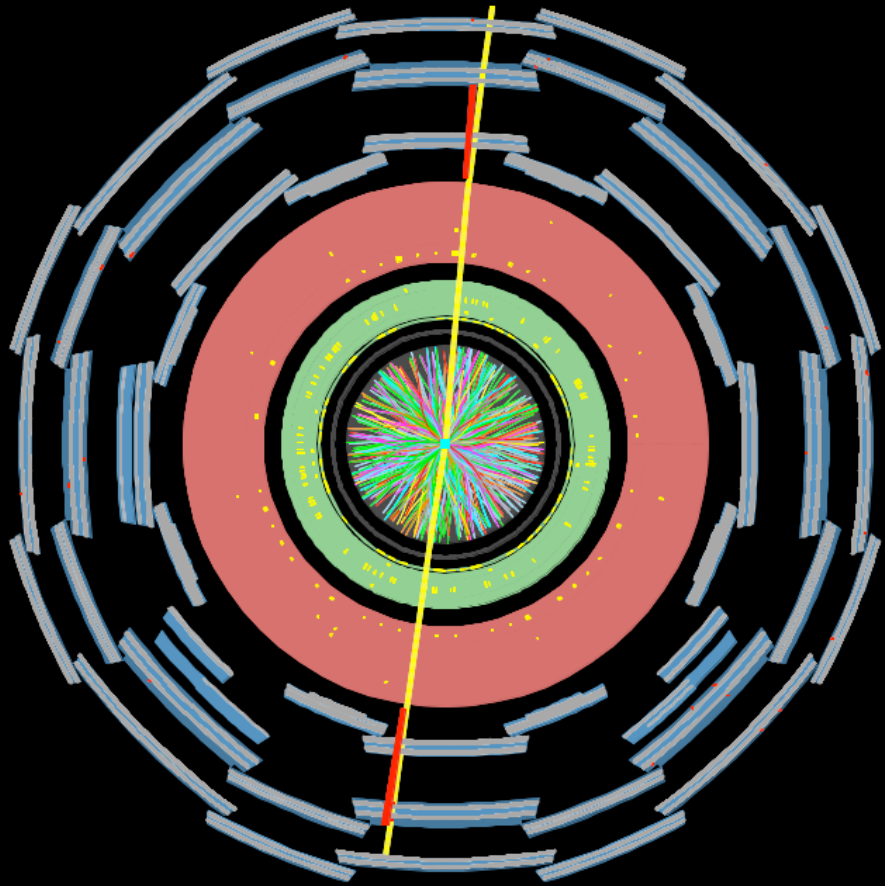
# LHC 今年の 運転予定

pp衝突: 4/7 ~ 10/16  
 ビームエネルギー = **4 TeV**  
 ピークルミノシティ  
 ~  $6.8 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$   
 積分ルミノシティ ~ **15 fb<sup>-1</sup>**

Pb-Pb衝突: 10/31 ~ 11/23

その後、長期シャットダウンに



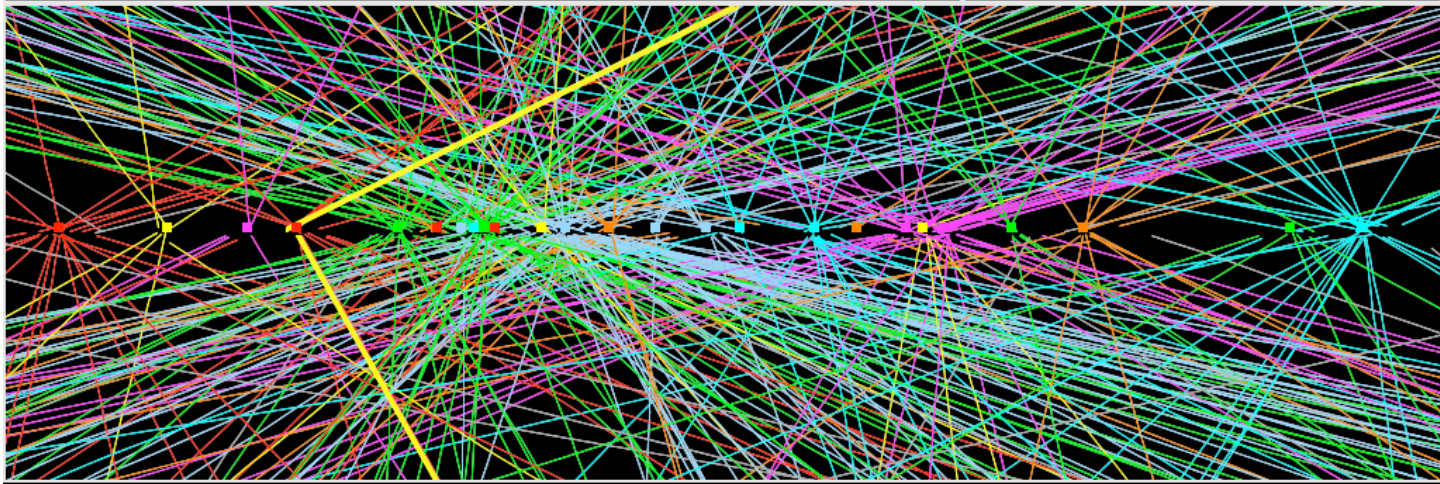
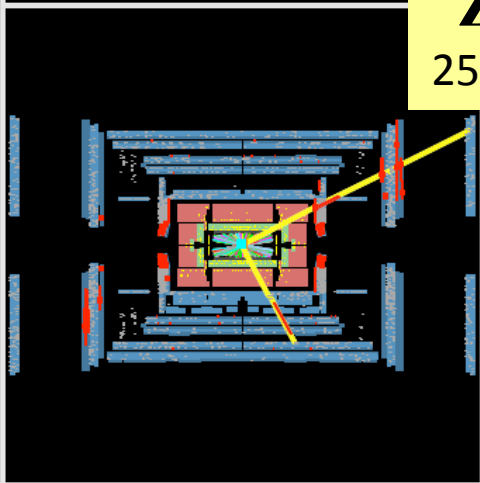


 **ATLAS**  
**EXPERIMENT**

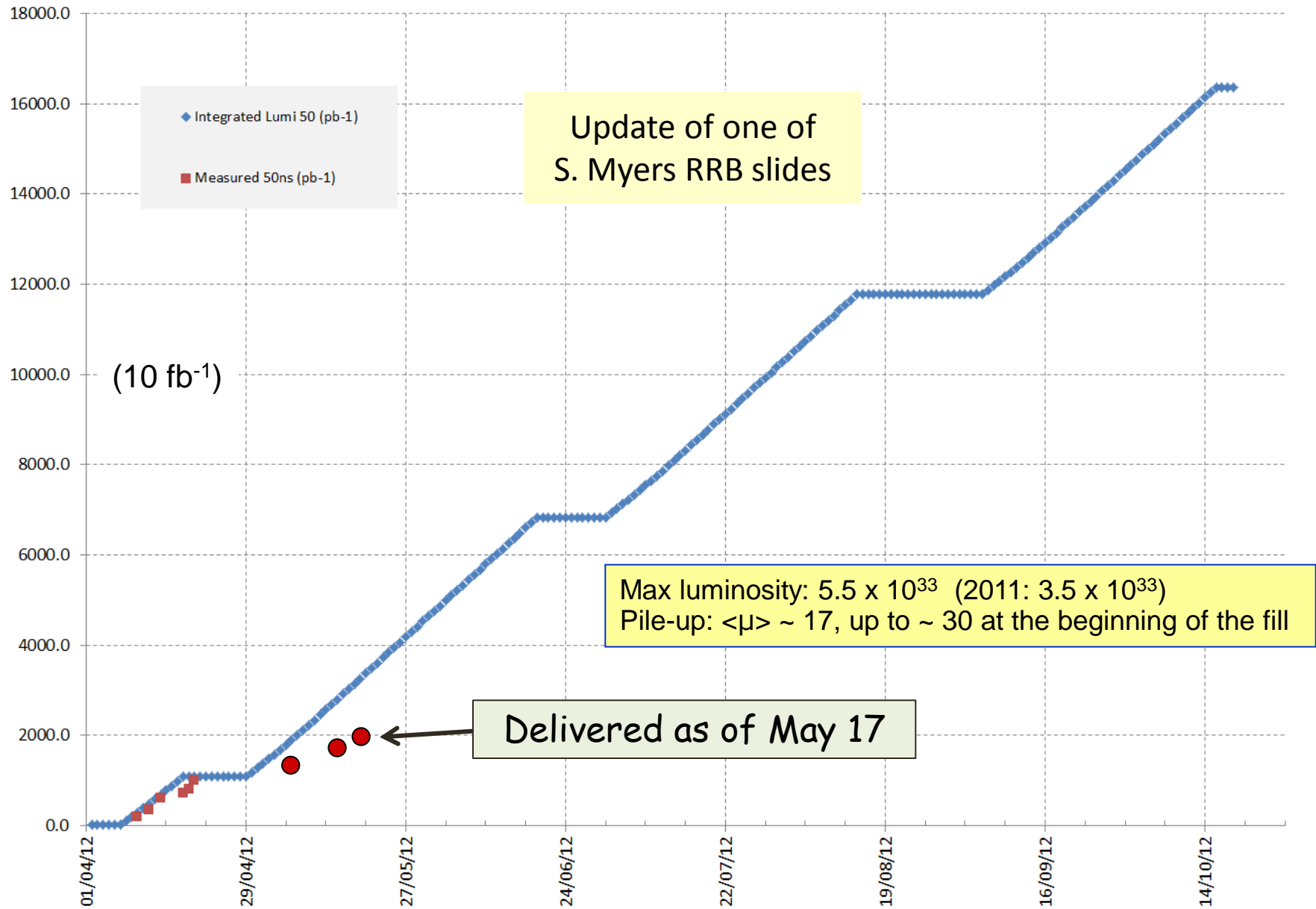
Run Number: 201289, Event Number: 24151616

Date: 2012-04-15 16:52:58 CEST

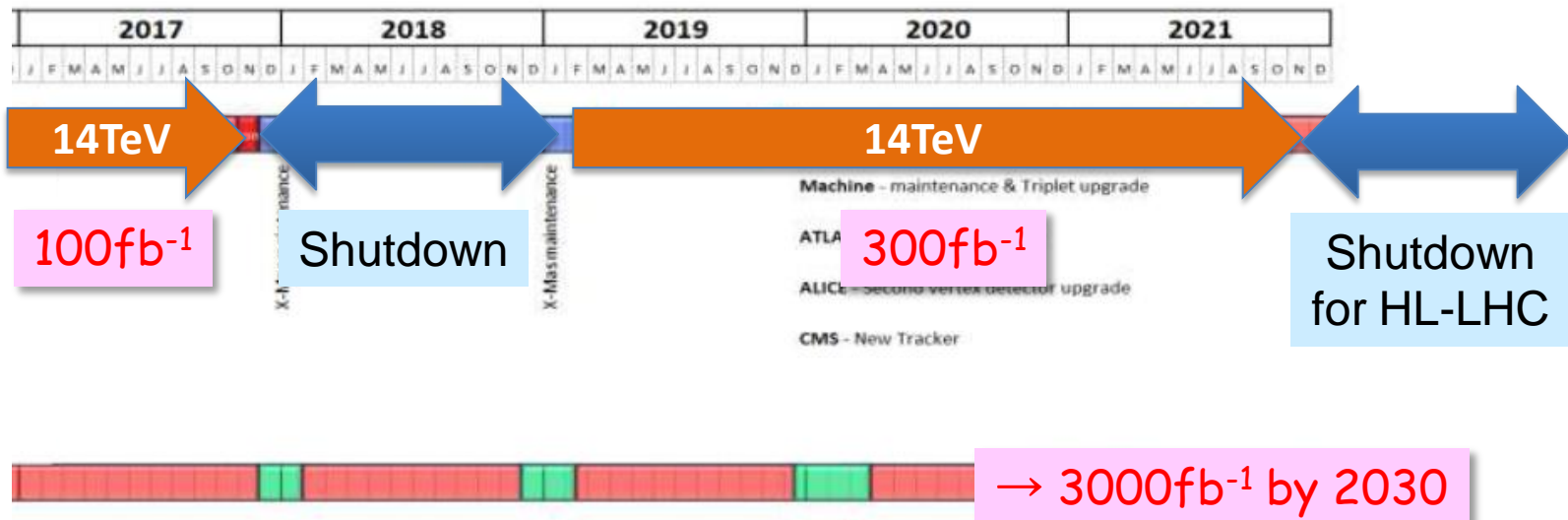
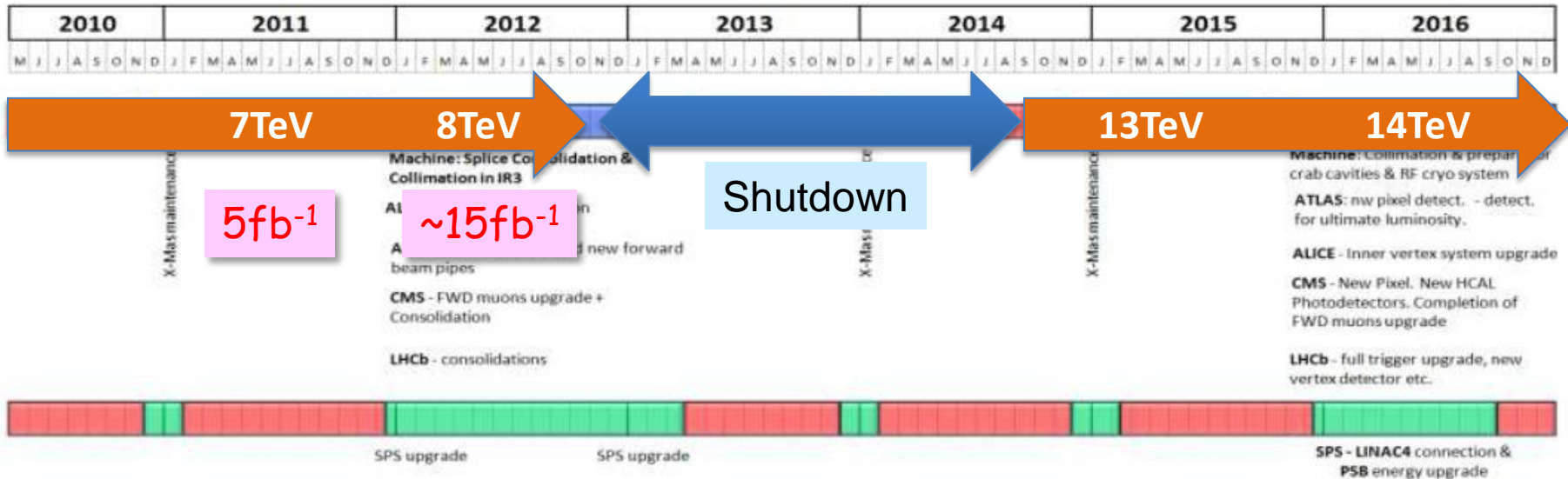
**8 TeV run**  
 $Z \rightarrow \mu\mu$  event with  
25 reconstructed vertices



# 2012 Measured vs Predicted Integrated Luminosity



# The 10 Year Technical Plan



# 今後の見通し

## Experimental Summary (Alain Blondel)

The near future is exciting!

- confirm existence of 125 GeV effect
- study its properties
- study/understand what should be the next step  
LHC only? Linear collider? Ring collider ( $e^+e^-$  or  $\mu^+ \mu^-$ ?)  
(much too soon to make decision)

## Theory Summary (Wilfried Buchmuller)

EWSB: hints for Higgs mass at 125 GeV very exciting;  
compositeness or extrapolation to GUT scale?

SUPERSYMMETRY: data suggest 'split spectrum';  
hope for states in LHC reach