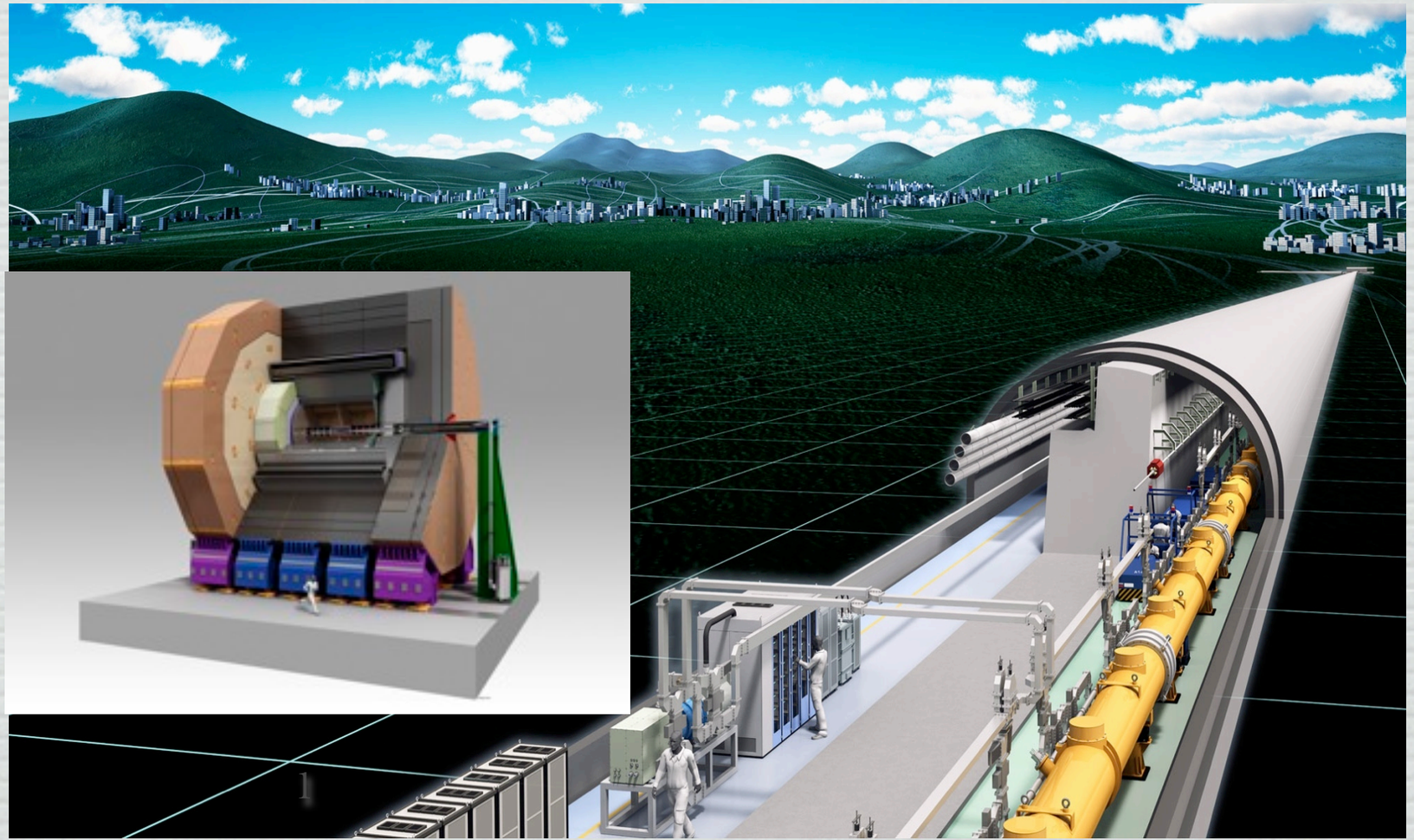
リニアコライダー計画 (ILC)- 物理学の挑戦 -

竹下徹（信州大学）

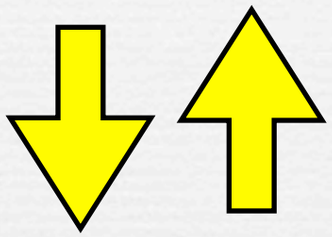
加速器学会 2013@名古屋大

Shinshu University



素粒子物理学の進展

- 加速器で新粒子を発見し精密測定



- 自然の理解＝理論の構築と進化
- AGS/SPEARで　Charm quark 1974
- Fermilab PSで　Bottom quark 1976
- Tevatron で　Top quark 1994
- LHC で　Higgs 2012
- 陽子加速器で発見し、詳細＝物理を電子加速器

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ILC

Higgs 革命

Standard Model

2010　2011　2012

軽いHiggs

Higgs ???

重いHiggs

複合Higgs

テクニカラー

Beyond SM理論

Standard Model like Higgs

DM

Higgsは1個?

SUSY, GUT...

Higgs 革命

Standard Model

2010　2011　2012

軽いHiggs

Higgs ???

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Standard Model like Higgs

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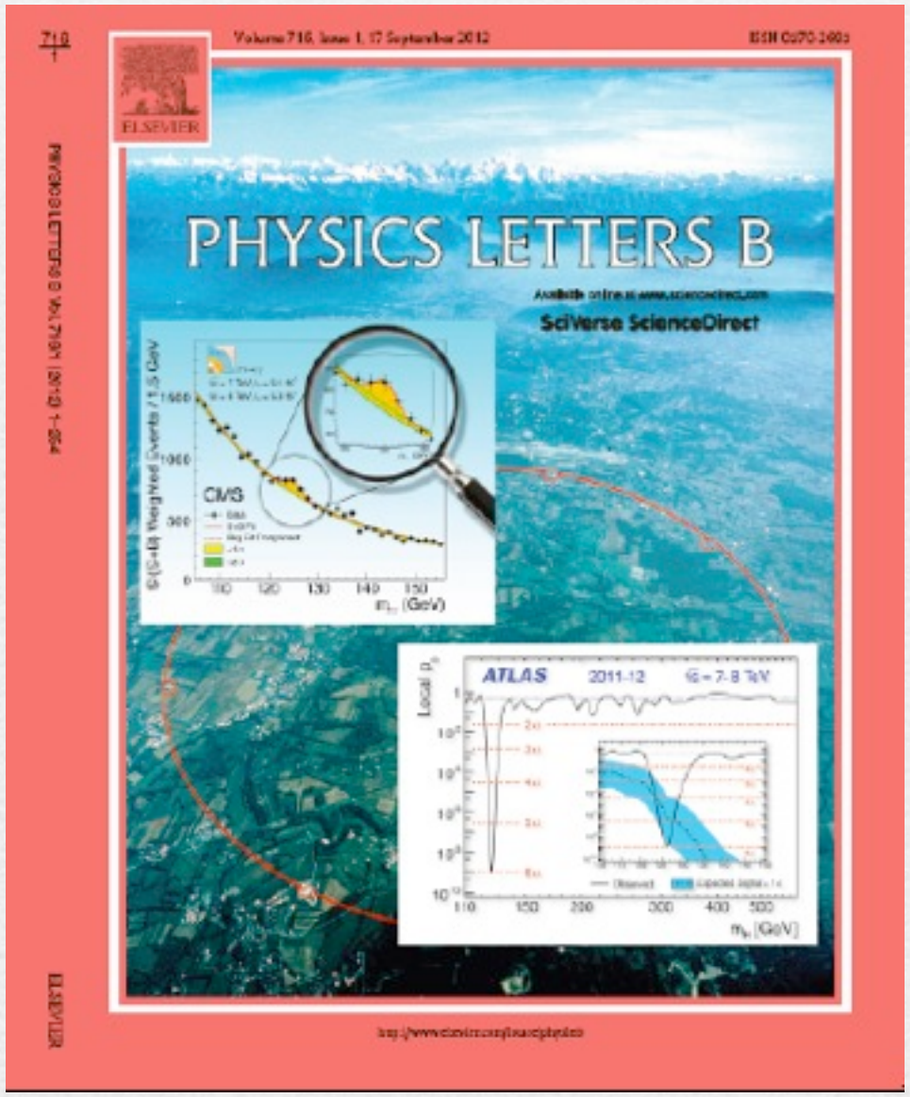
Higgsは1個?

SUSY, GUT...

Higgs 2012

July2012
Higgs(らしき)粒子発見

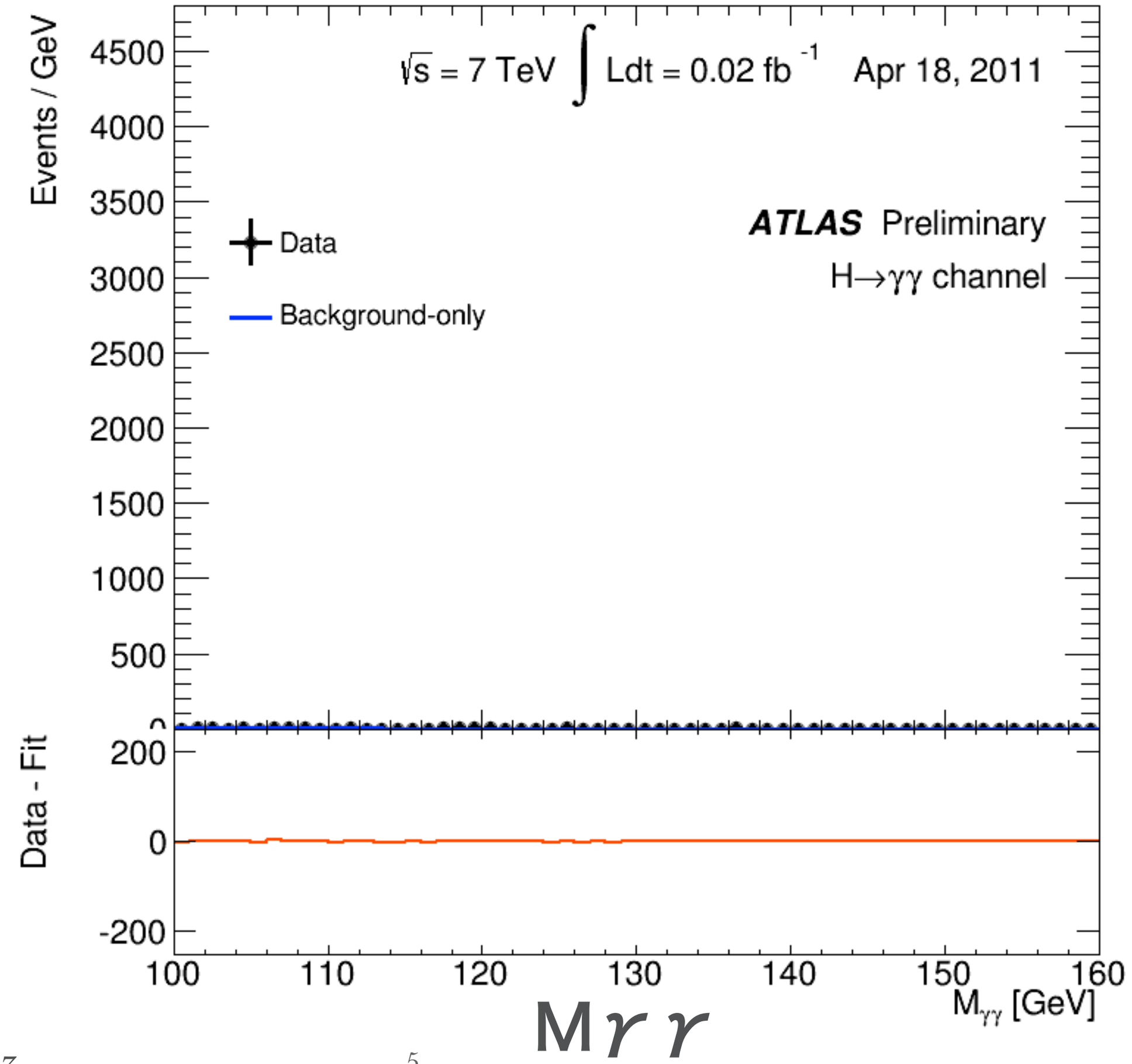


Phys.Lett.B 716 (2012) 1–29

Dec2012
A Particle Consistent with the Higgs Boson

Science **338**, 1576 (2012)

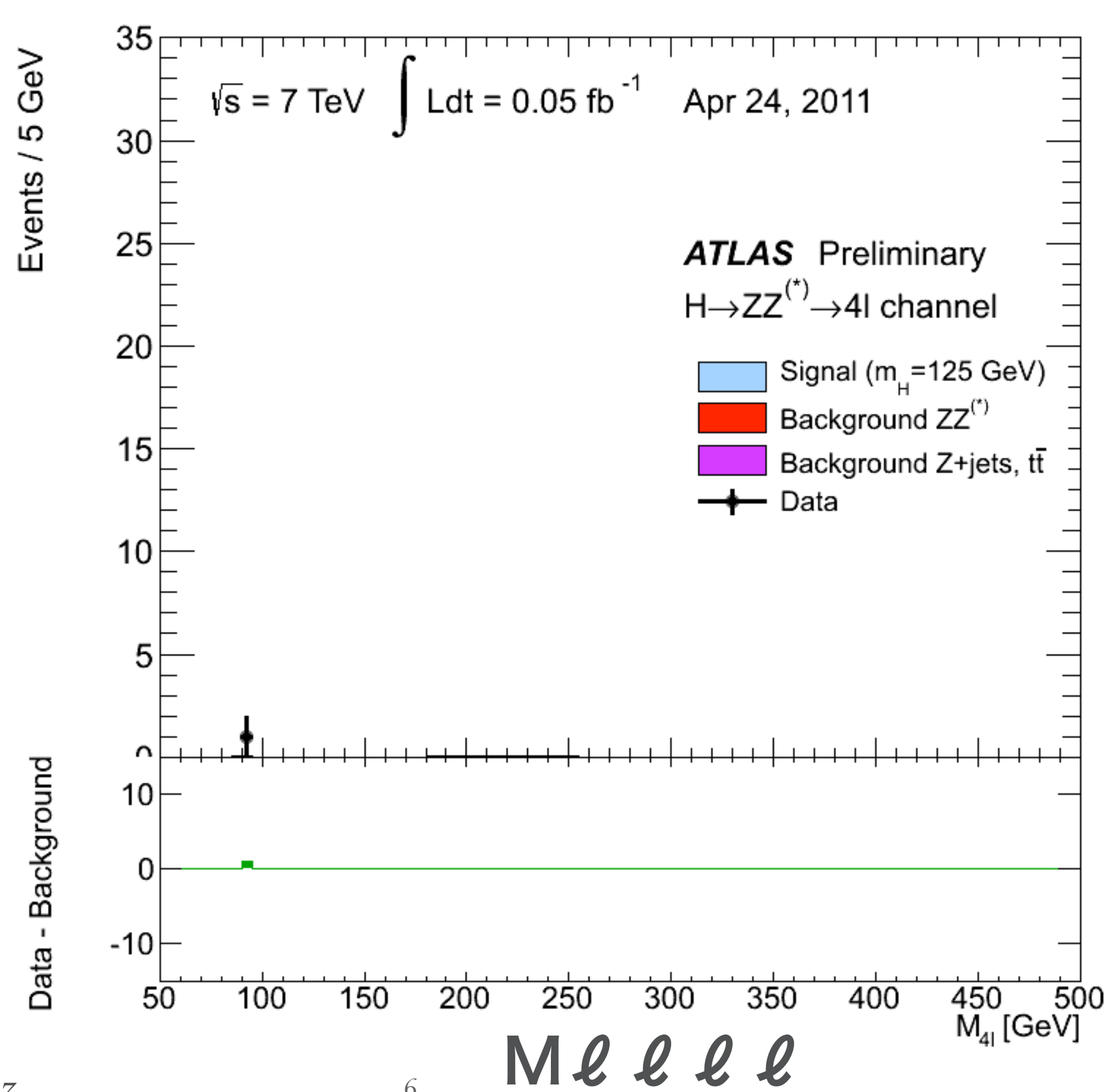
H> γγ



Mγγ

竹下：加速学会2013

H>ZZ>llll

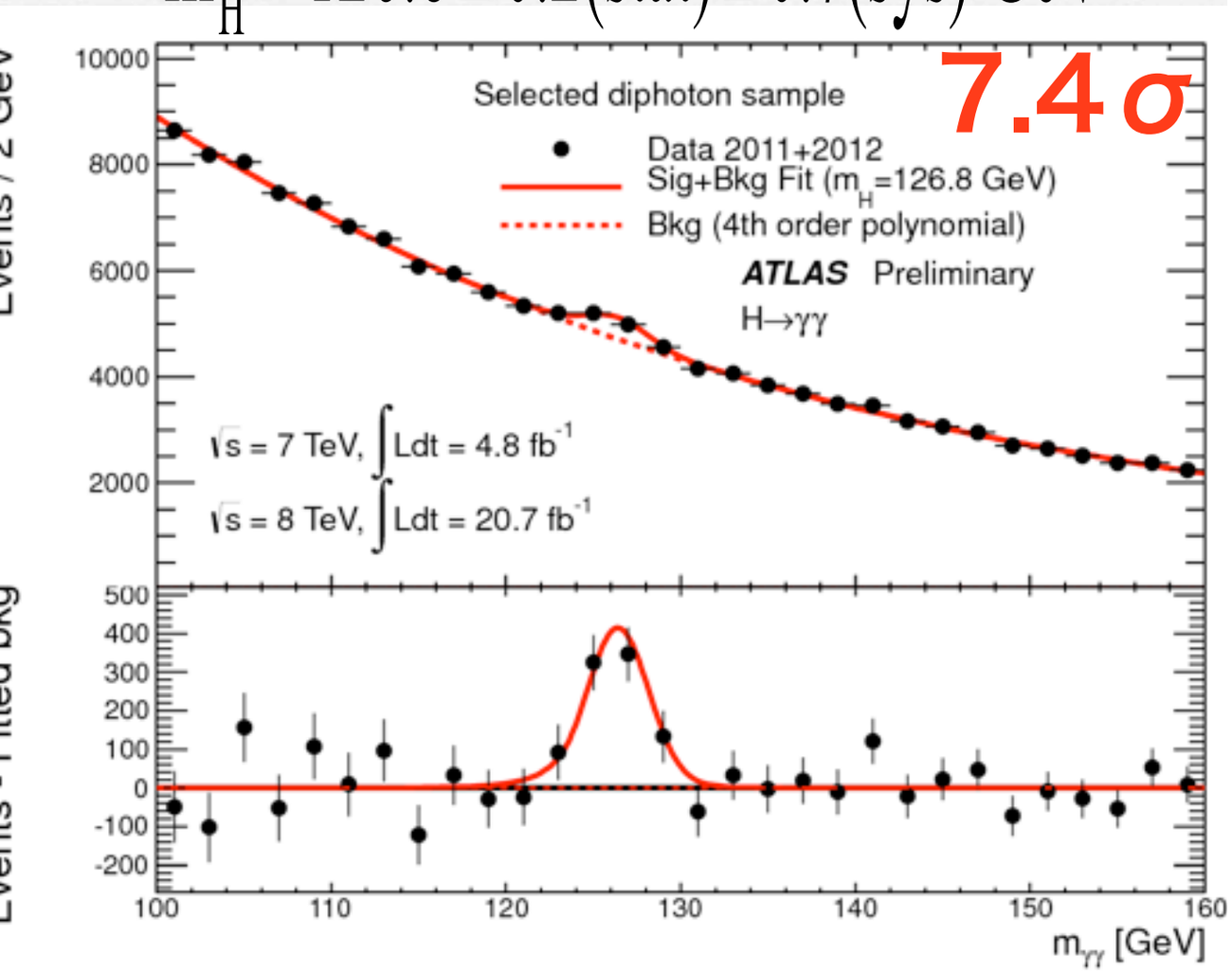

Events / 5 GeV
√s = 7 TeV ∫ Ldt = 0.05 fb-1 Apr 24, 2011
ATLAS Preliminary
H→ZZ(*)→4l channel
Signal (mH=125 GeV)
Background ZZ(*)
Background Z+jets, tt̄
Data
Data - Background
M4l [GeV]
Mllll

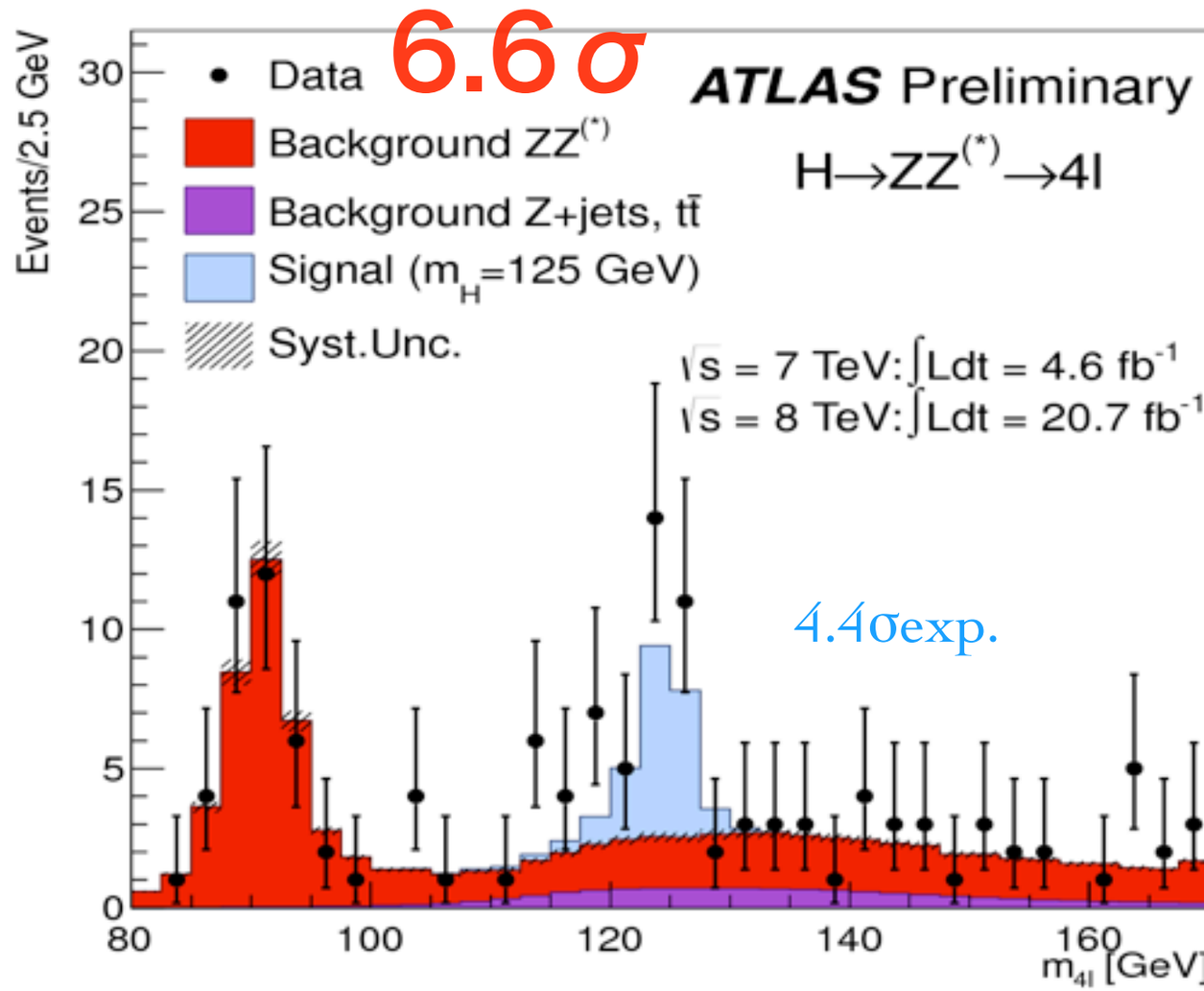
H>γγ & ZZ>4lepton

ATLAS: $m_H = 125.5 \pm 0.2(\text{stat})^{+0.5}_{-0.6}(\text{sys})$ GeV

$m_H = 126.8 \pm 0.2(\text{stat}) \pm 0.7(\text{sys})$ GeV

$m_H = 124.3^{+0.6}_{-0.5}(\text{stat})^{+0.5}_{-0.3}(\text{sys})$ GeV





CMS: combined: 125.8± 0.4± 0.4 GeV arXiv:1307.1427

γγ:125.4,7 4l: 125.8

竹下：加速学会2013

Spin,Parity

H>γγ mode : 0⁺/2⁺

ATLAS : 95% CLで $J^P = 2^+$ (75%ggF) を棄却

H>WW mode : 0⁺/2⁺

ATLAS: 95% CLで $J^P = 2^+$ (100%ggF) を棄却

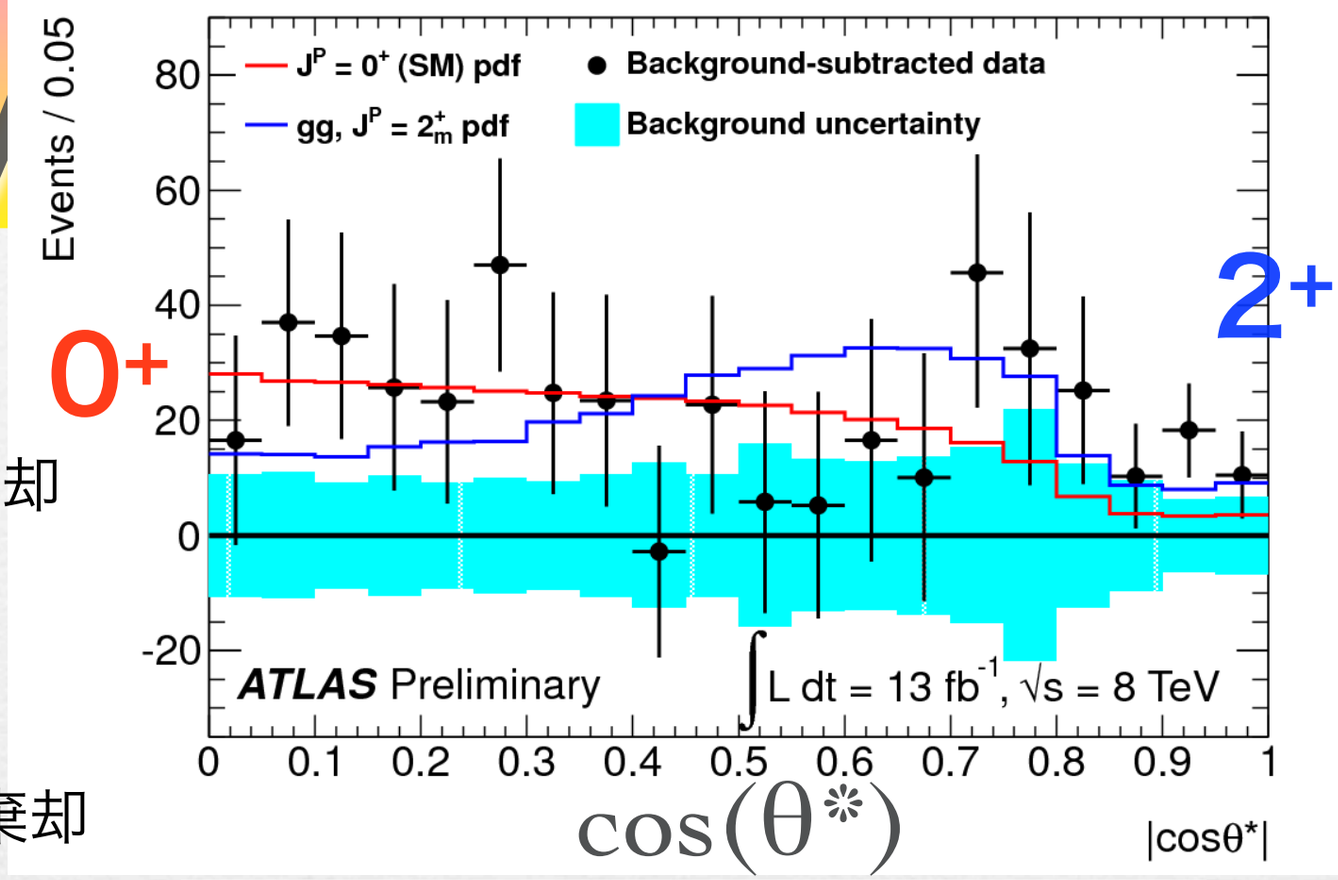
CMS: 88% CLで $J^P = 2^+$ (100%ggF) を棄却

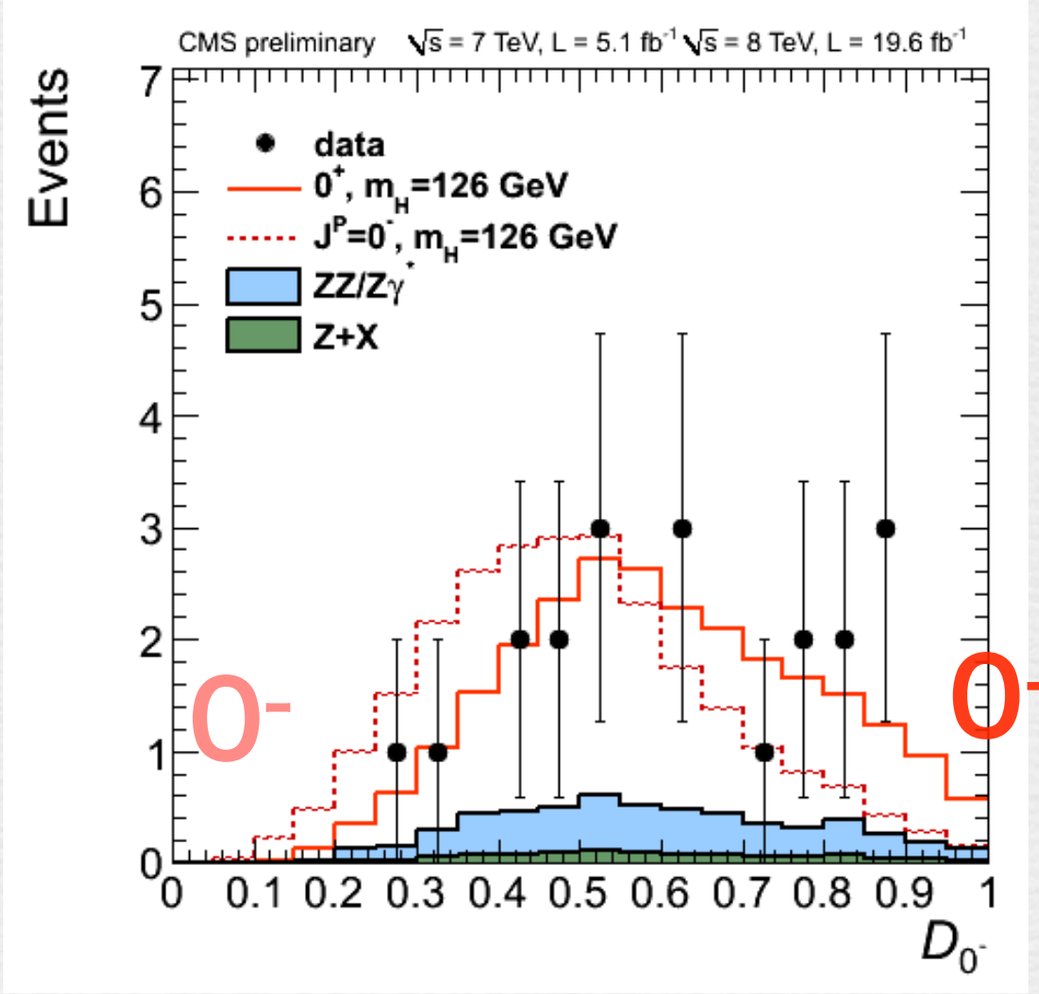
H>ZZ>4l : 0⁺/0⁻

CMS: 99.8% CLで $J^P = 0^-$ を棄却

ATLAS: 97.8% CLで $J^P = 0^-$ を棄却

SM Higgs 0^+ を支持





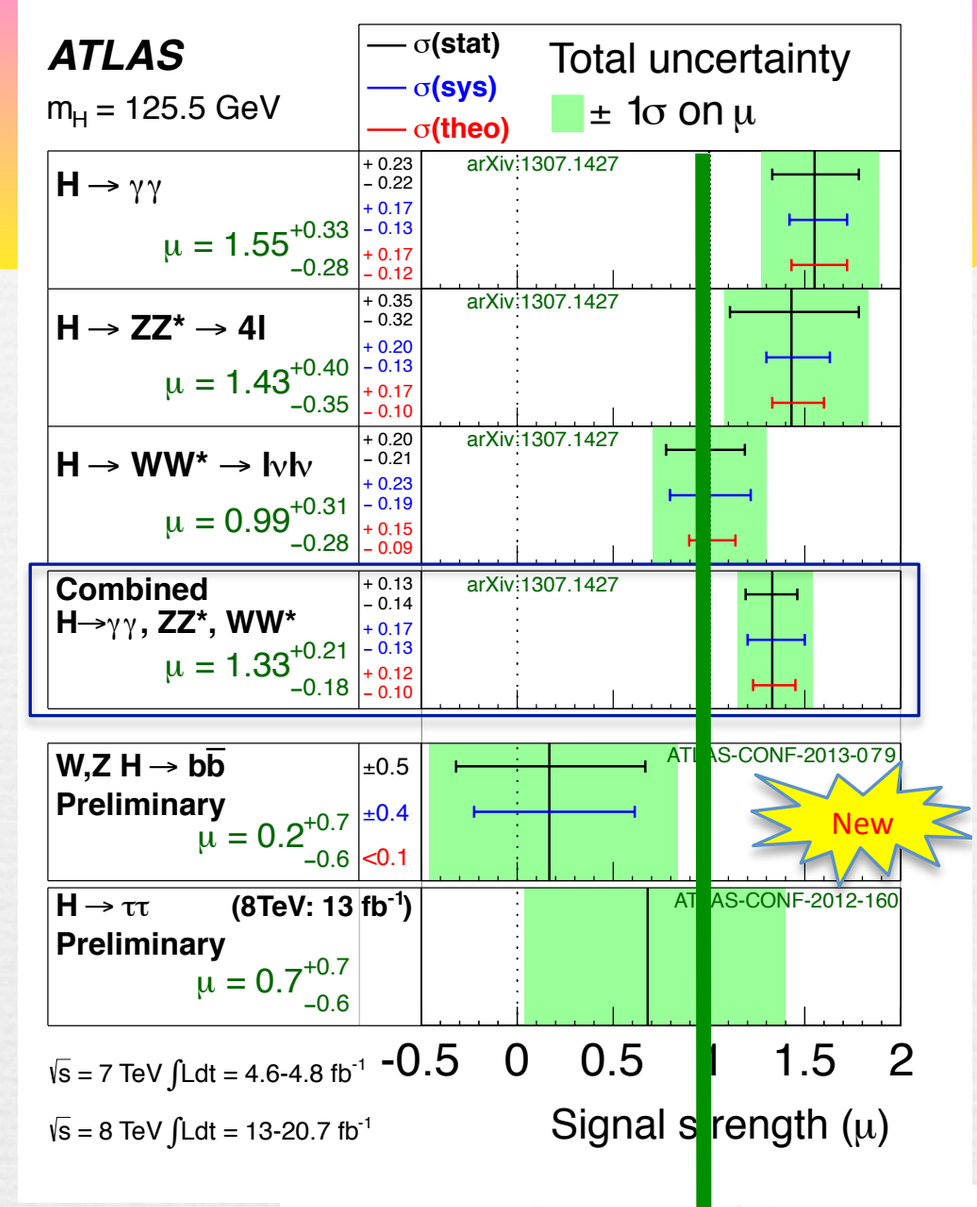
SM-Higgs ?

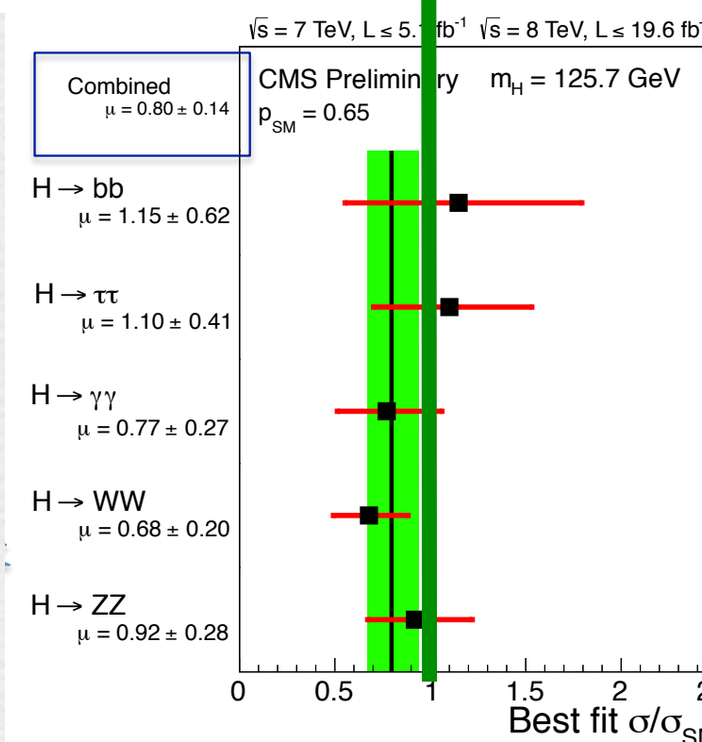
- if Higgs $m_i = v g_i$
- signal strength μ:
  - ~Meas./SM
  - if μ=1: SM

SM Higgsに近い

もっとデータを！

$20fb^{-1}/y > 300/y >$
$Int:3000fb^{-1}$





SM-Higgs ?

- if Higgs $m_i = v g_i$

compatible with a Standard Model Higgs boson

- signal strength μ:
  - ~Meas./SM
  - if μ=1: SM

SM Higgsに近い

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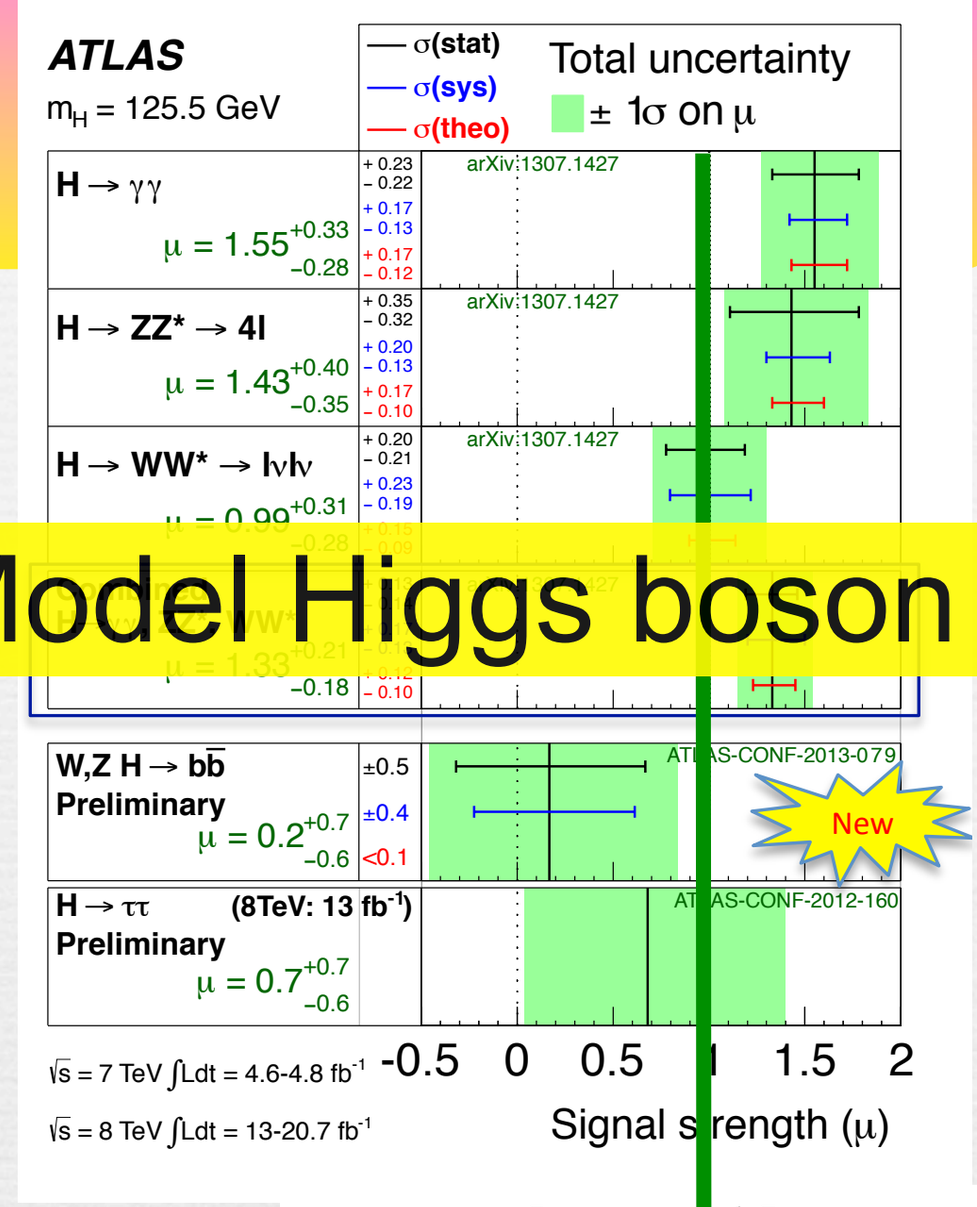
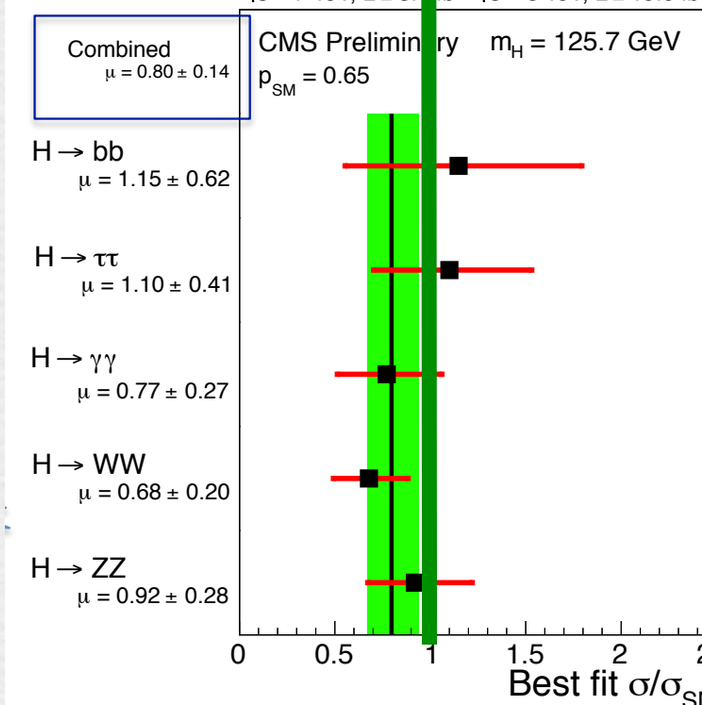
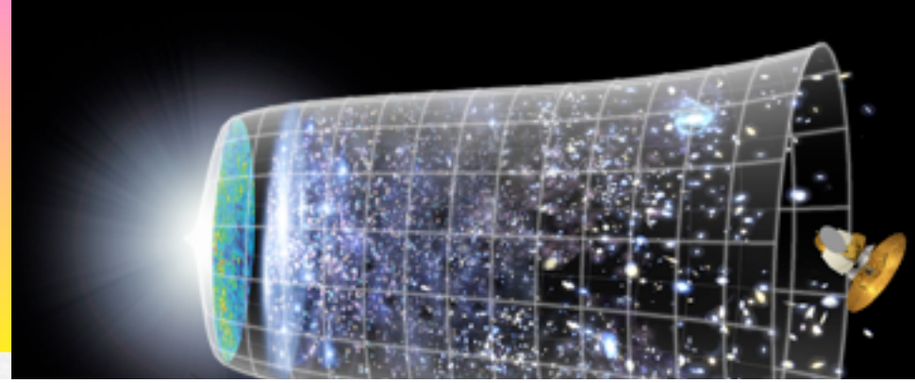
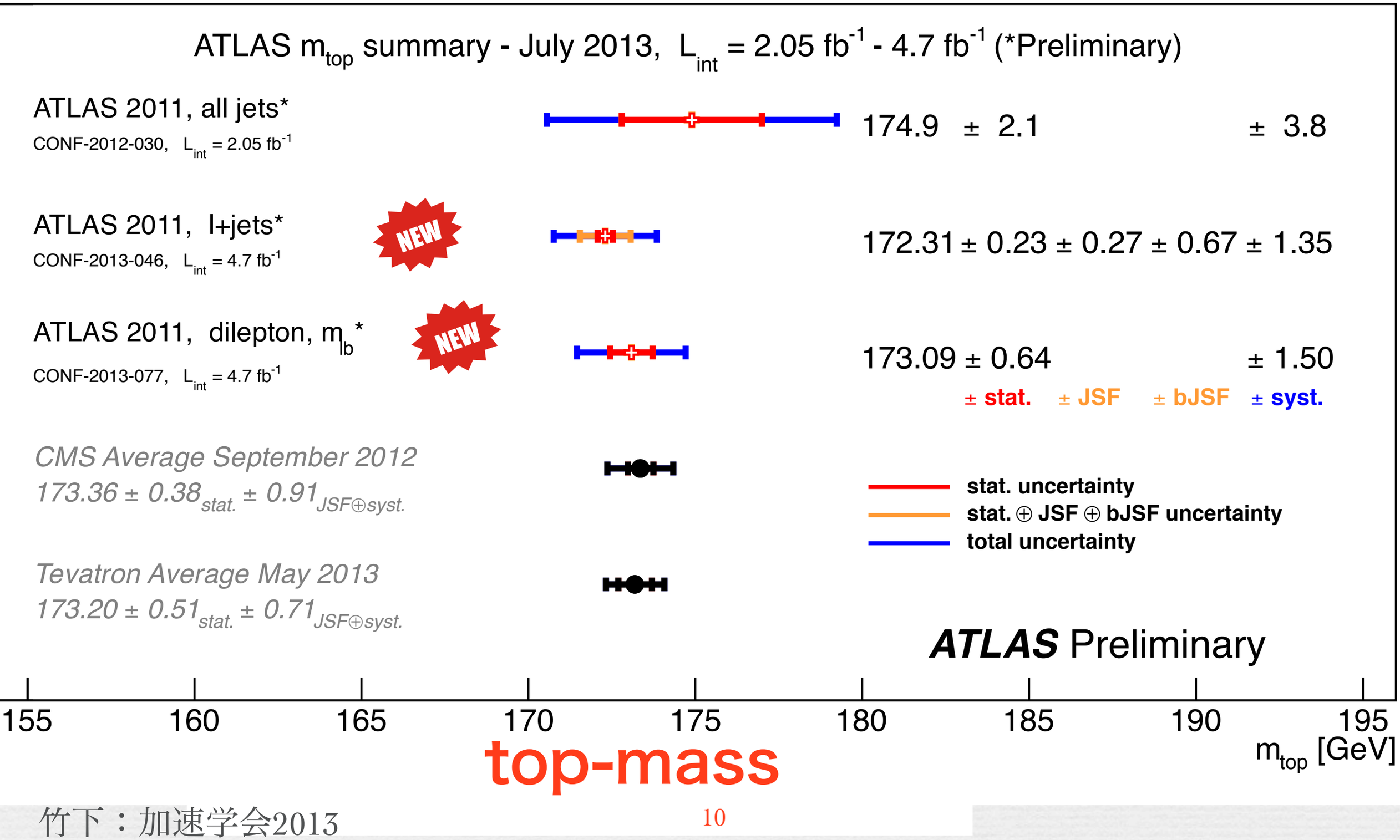




真空の安定性

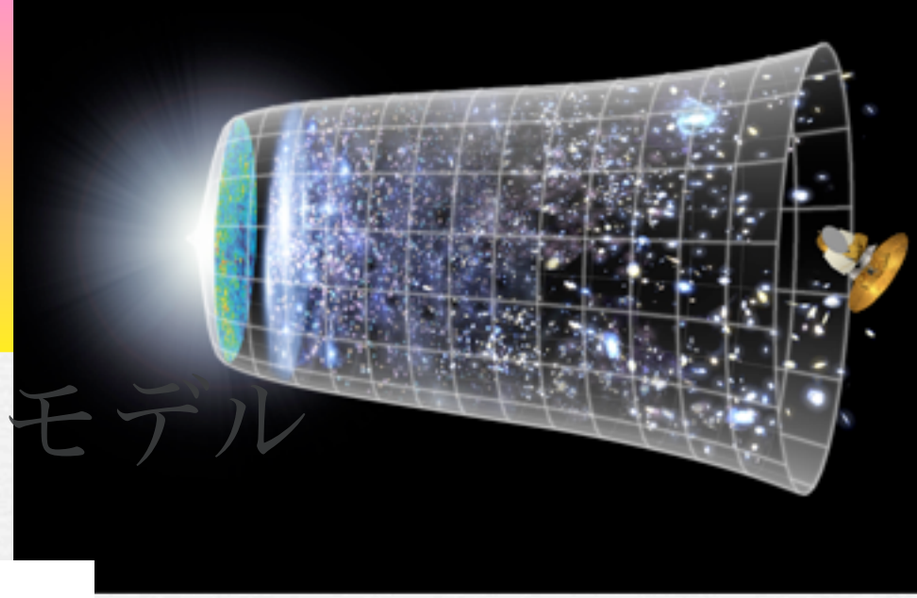




top-mass

真空の安定性

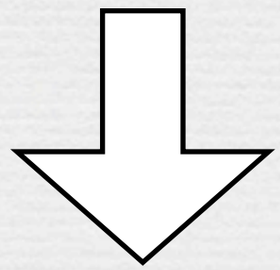
宇宙の初まりのインフレーションモデル



MH=126GeVは

MSSMでは

ほぼ最小値



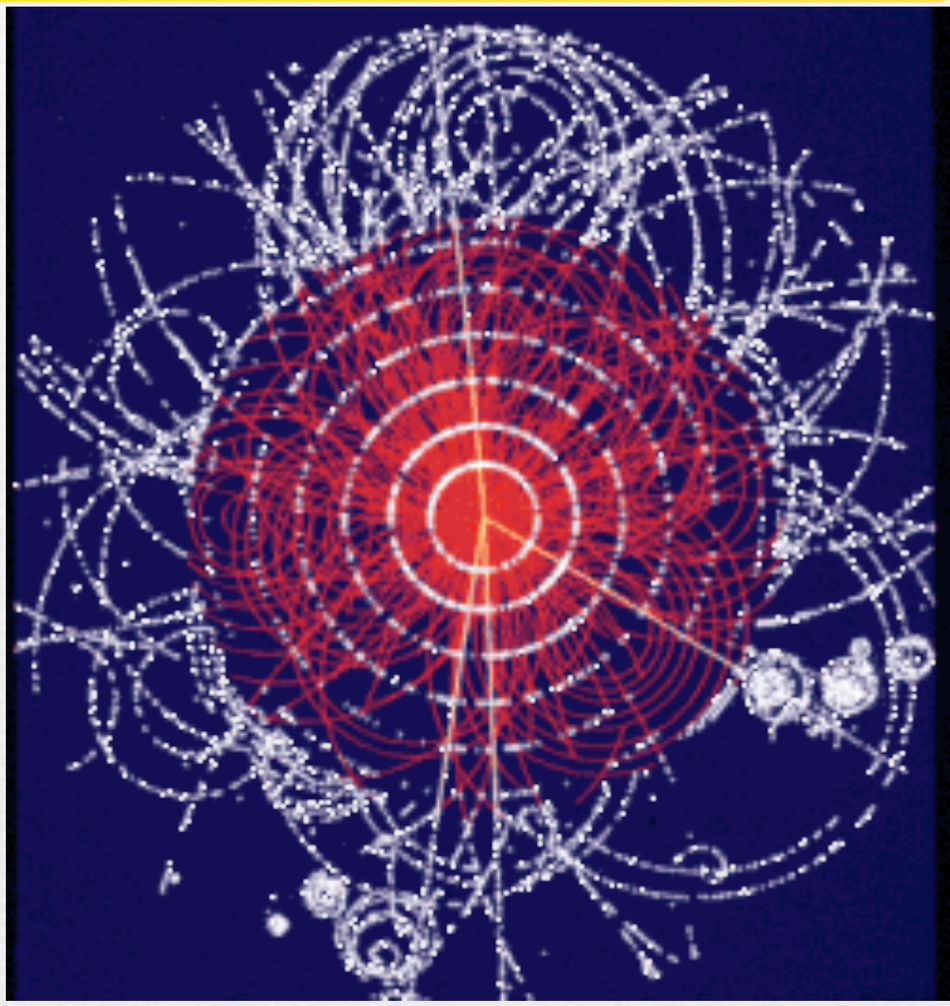
meta stable

真空の安定性

arXiv:1205.6497

ILCの物理と計画

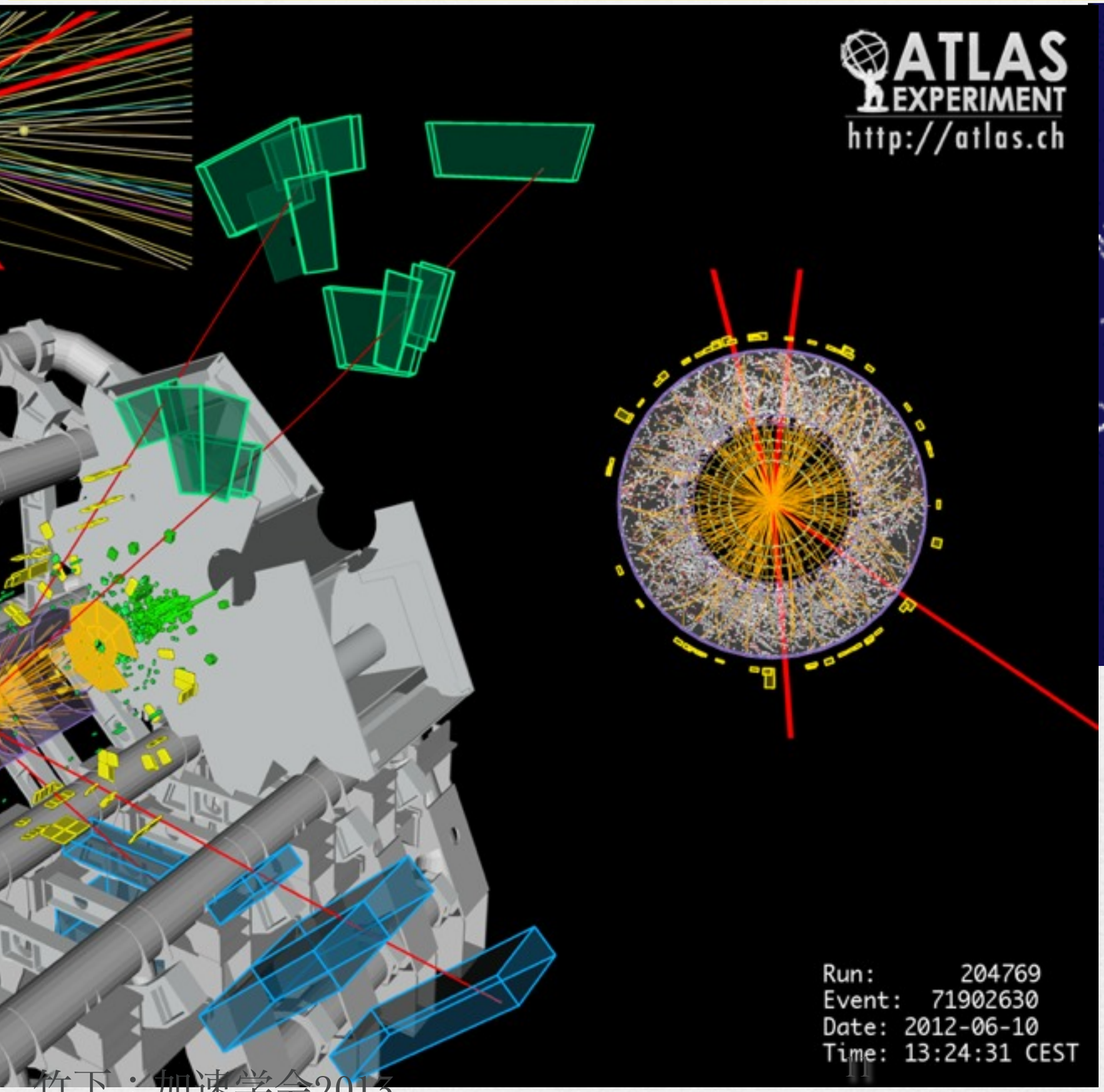
LHC to ILC

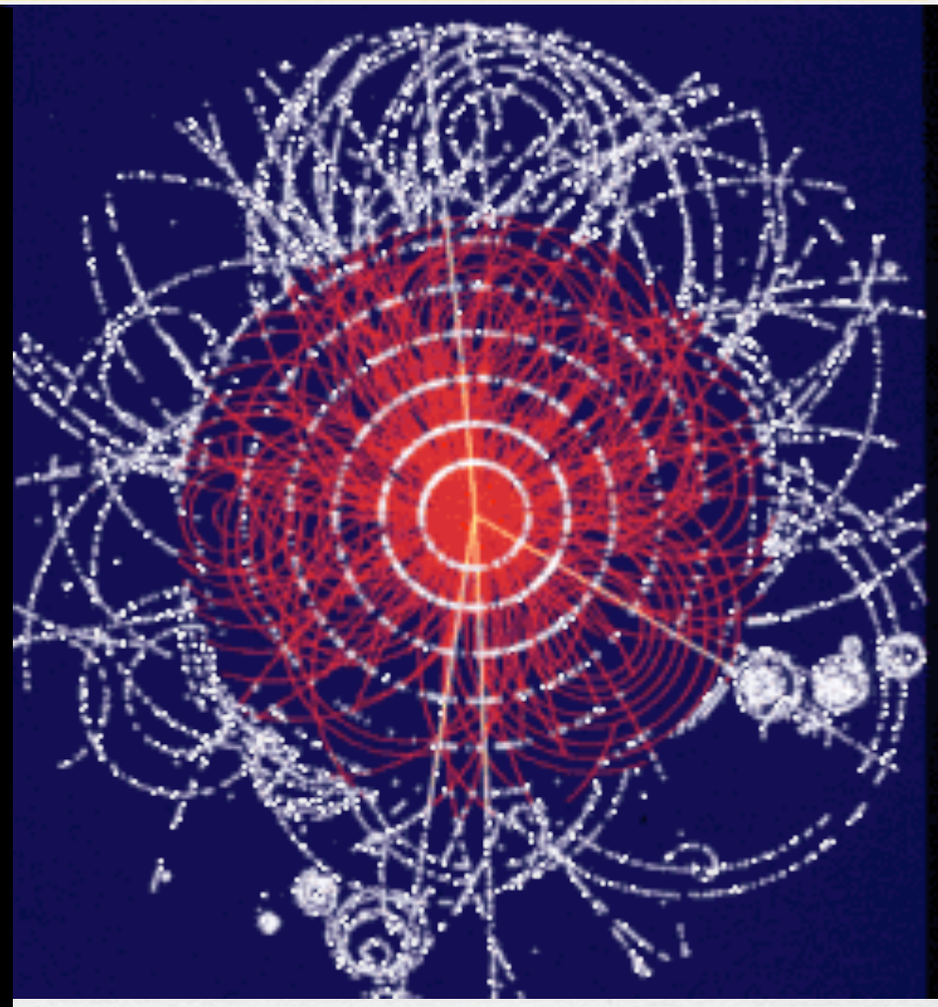


ATLAS-simulation

ILCの物理と計画

LHC to ILC





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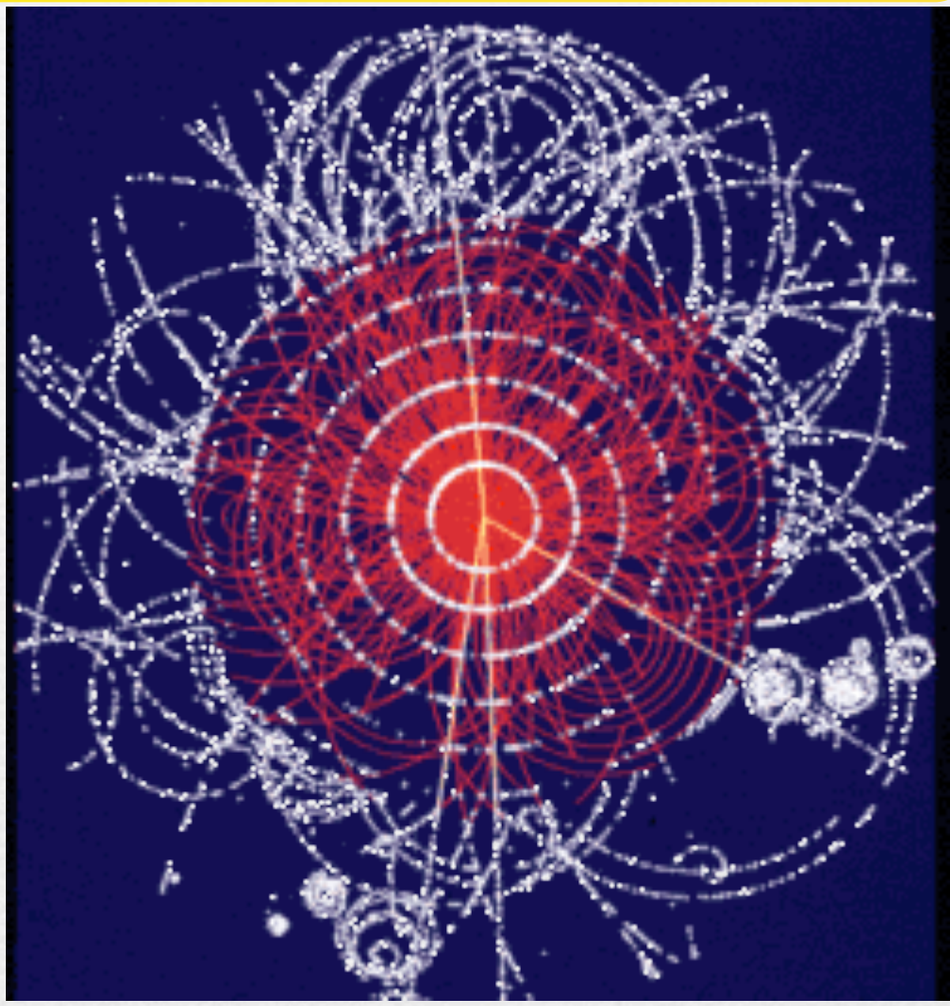

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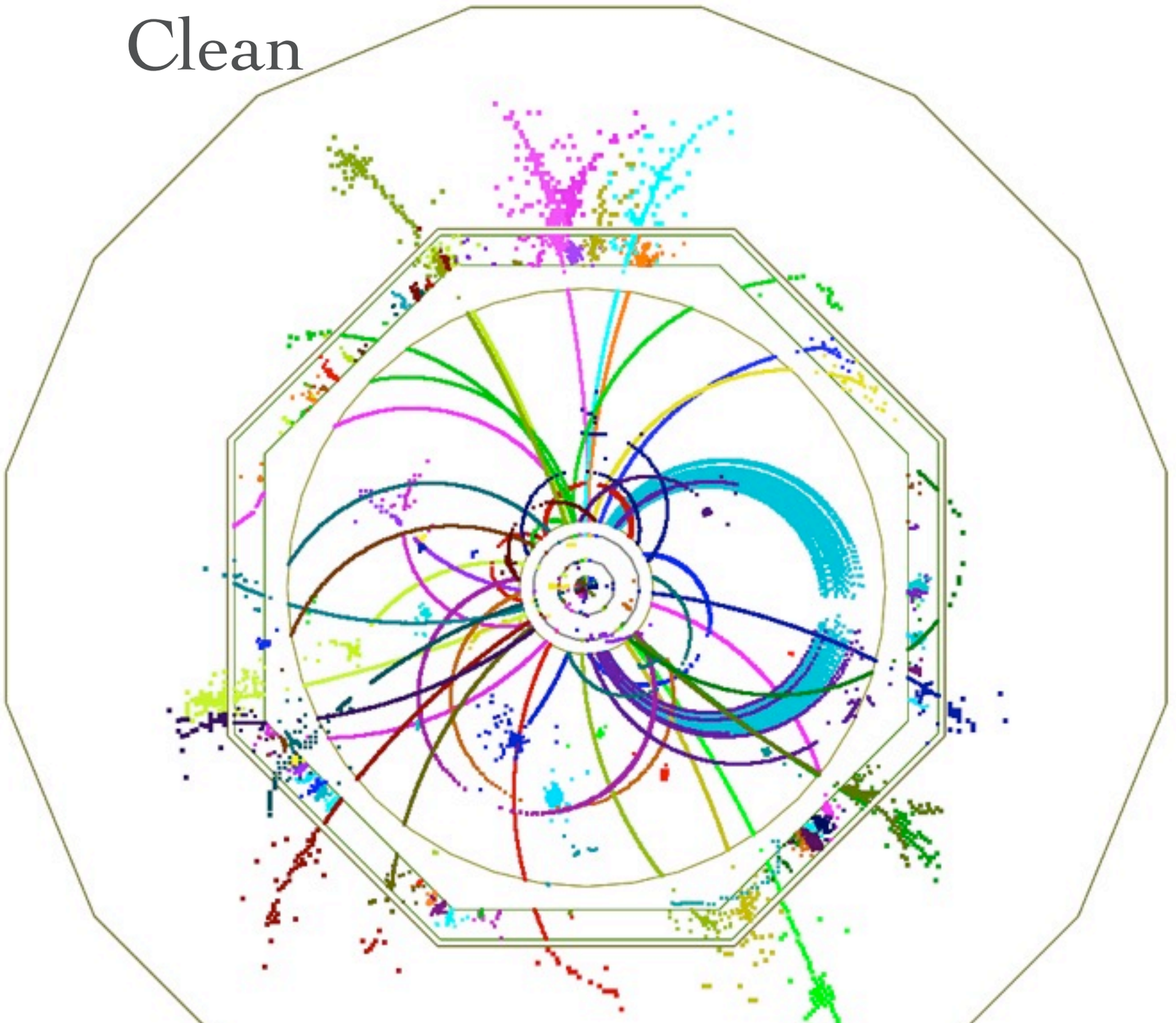
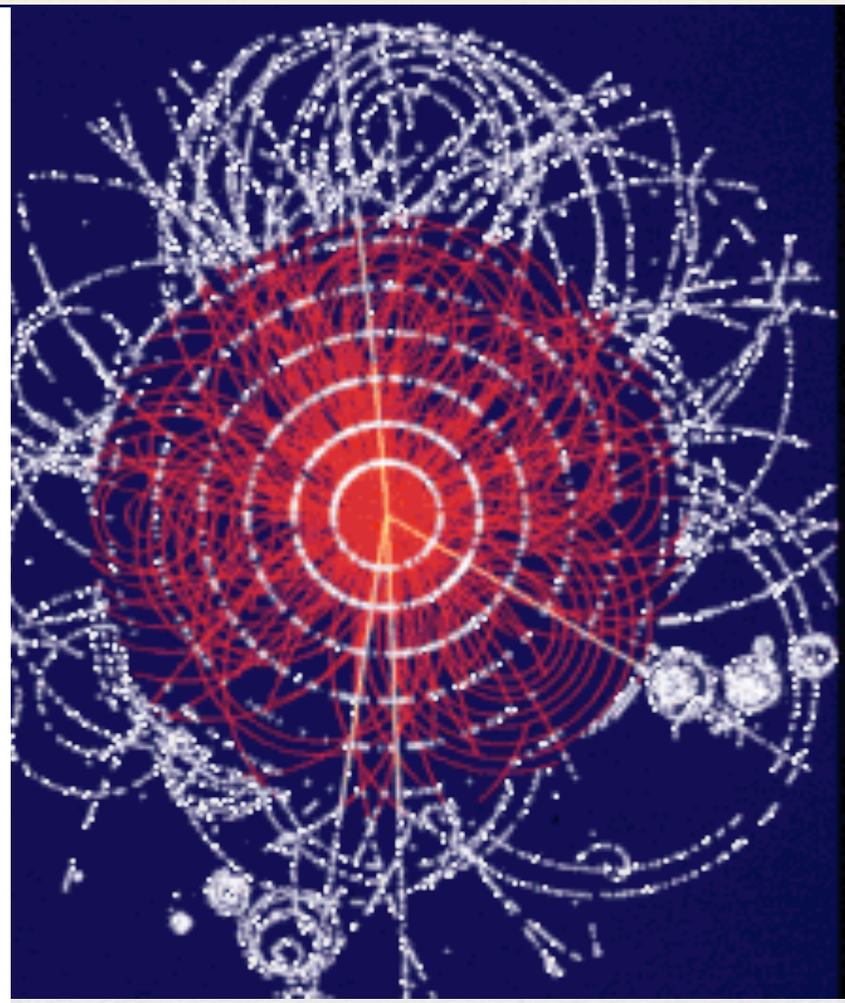


ILC: ee>ZH>qqbb sim.



ATLAS-simulation

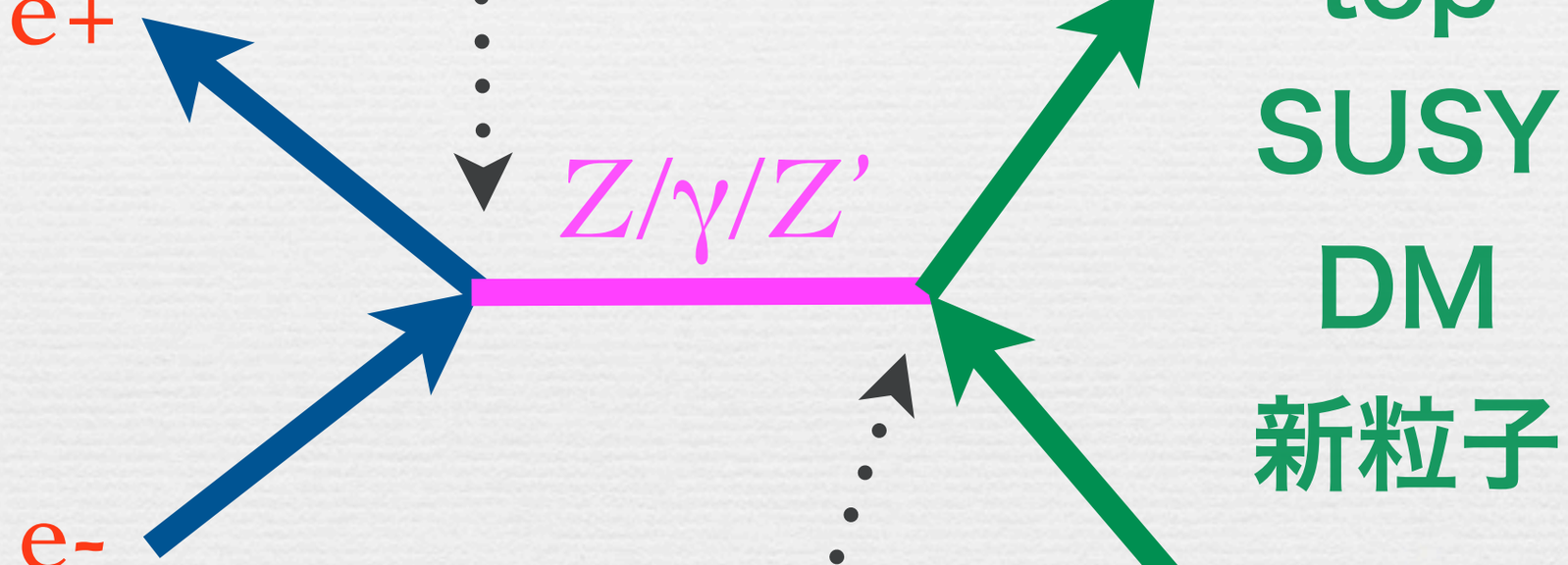
ILC実験

低BG:Clean

e+e- collider

初期状態素粒子 well known

偏極電子



Higgs

top

SUSY

DM

新粒子

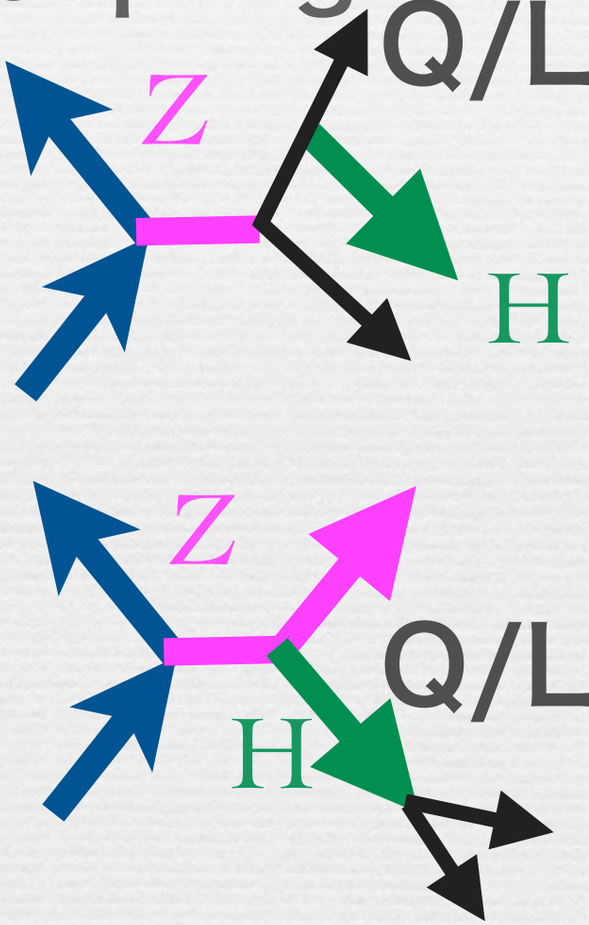
...

質量、スピン、結合定数の決定

SMを超えるより基本原理の発見

ILC : Higgs粒子

- W/Z/γに質量を与える：Higgs 機構: HWW/HZZ
- Fermionに質量：Yukawa 結合：Hff coupling
- 自己結合：HHH :triple Higgs

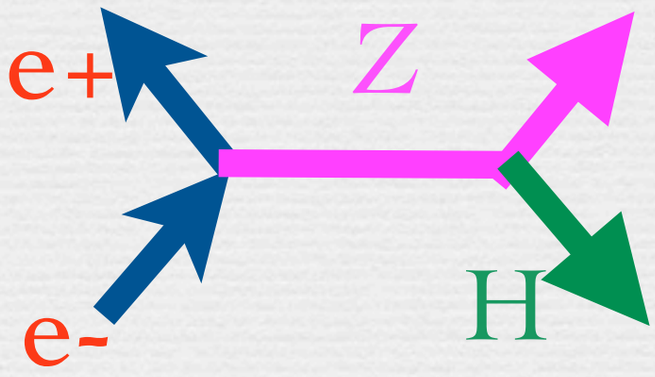


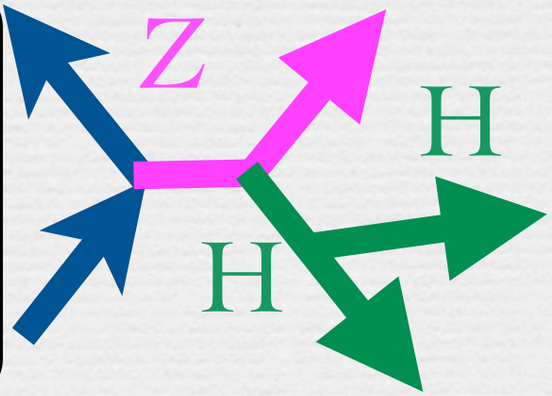
Higgs Mec.
W/Z質量

Yukawa
Q/L質量

ILCの独立測定

自己質量
真空

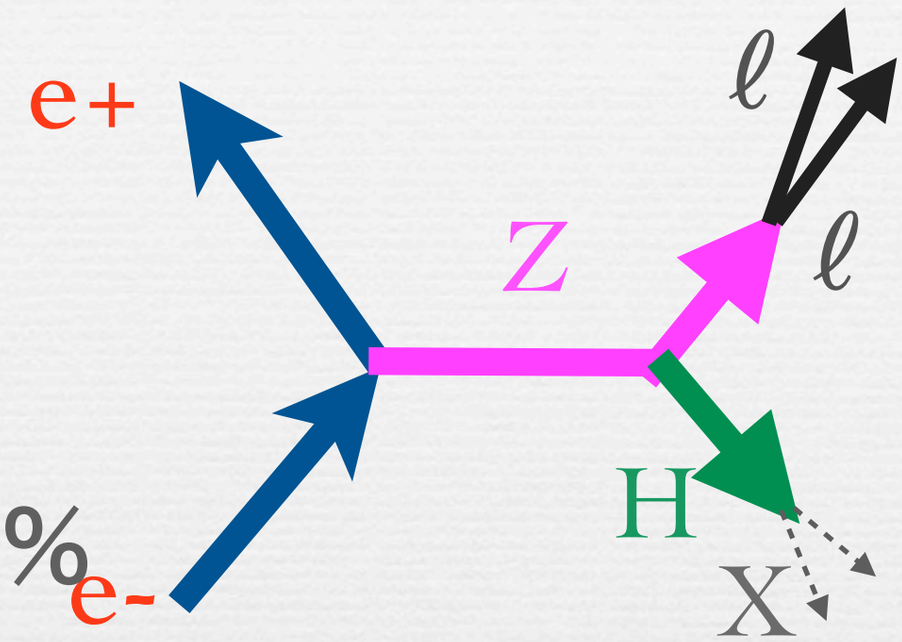




竹下：加速学会2013

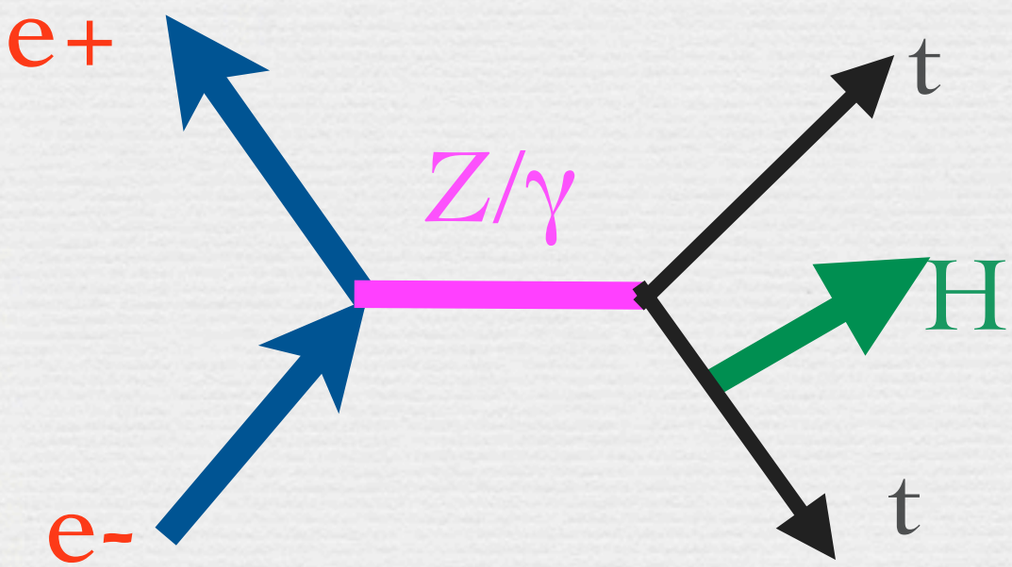
ILC: Higgs factory

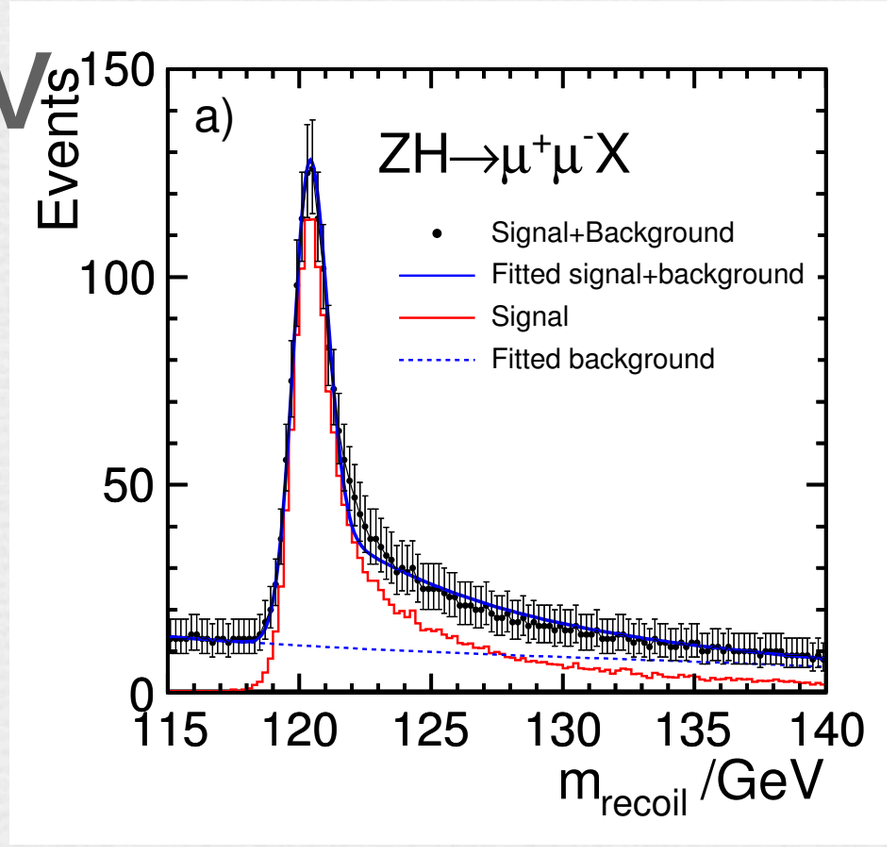
- e+e->ZH　ヒッグスの再発見を１日で達成
- モデルによらない測定
- 質量精度Δm_H~30MeV,$\Delta \sigma_H$~2.5%



- e+e->ttH: $\Delta g/g$~13% @500GeV

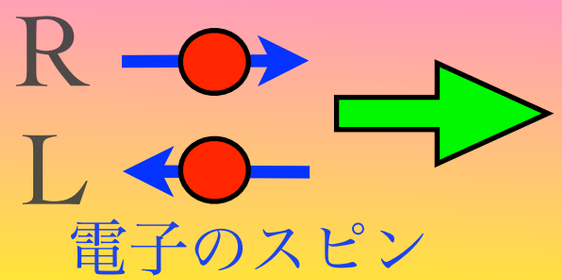
500 fb-1





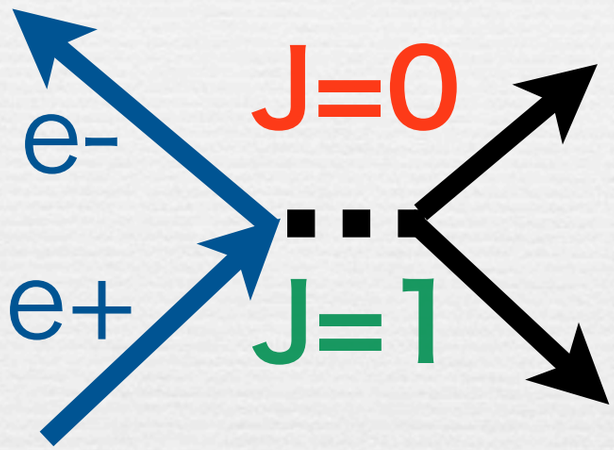
250GeV 250 fb-1

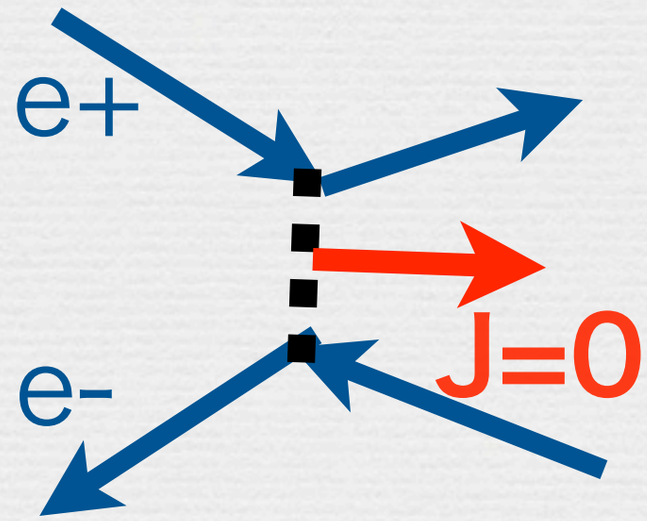
偏極実験



e+e-

- 生成粒子のスピンを制御
- $P(e^{\pm})<0$: L, $P(e^{\pm})>0$: R
- J=1: RL/LR : SM and NewParticle
- J=0: LL/RR: NewParticle!
- スピン偏極度 $P=(N_L-N_R)/(N_L+N_R)$
- $P(e^-)\sim 80\%$, $P(e^+)\sim 30\%$



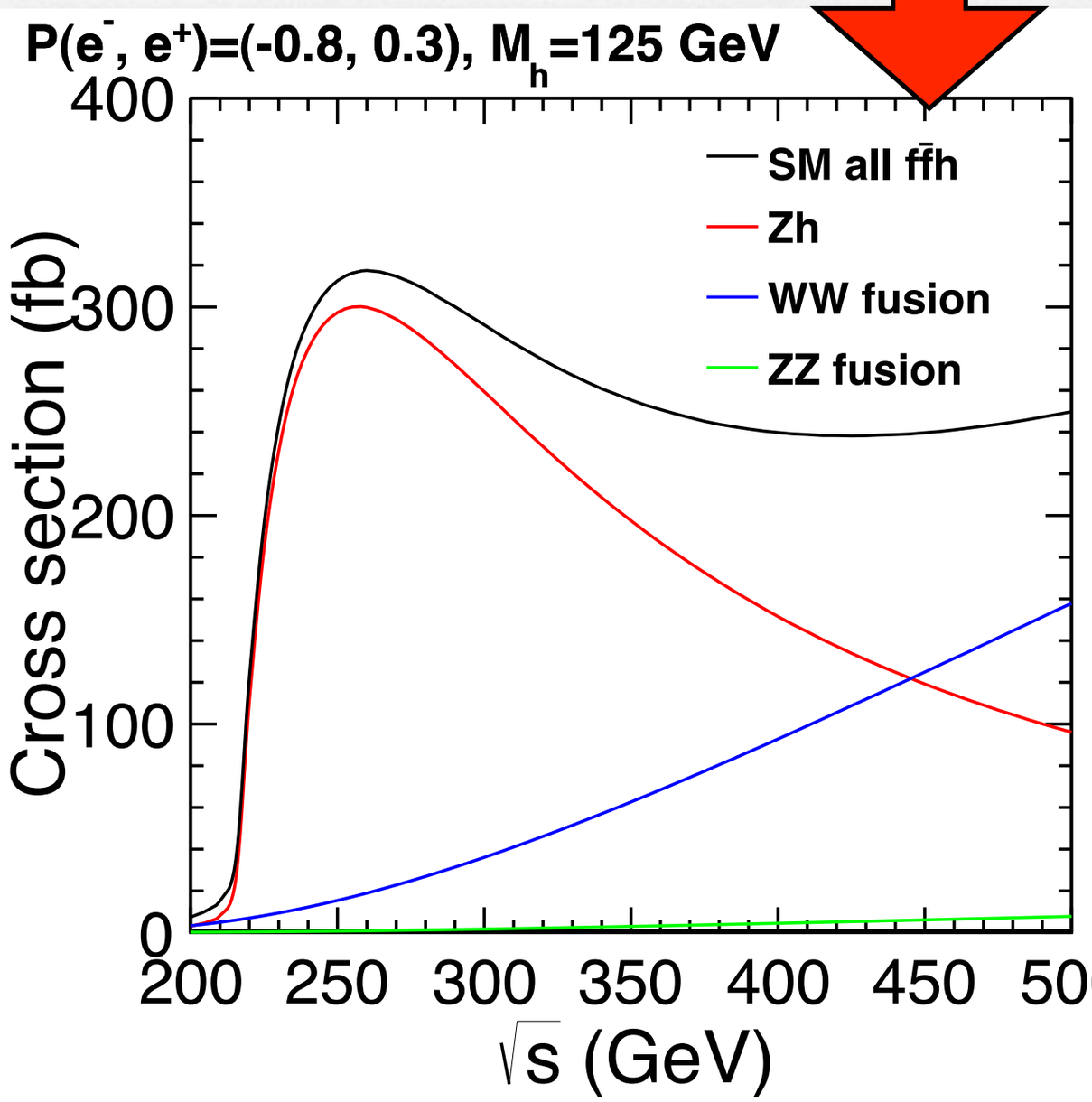


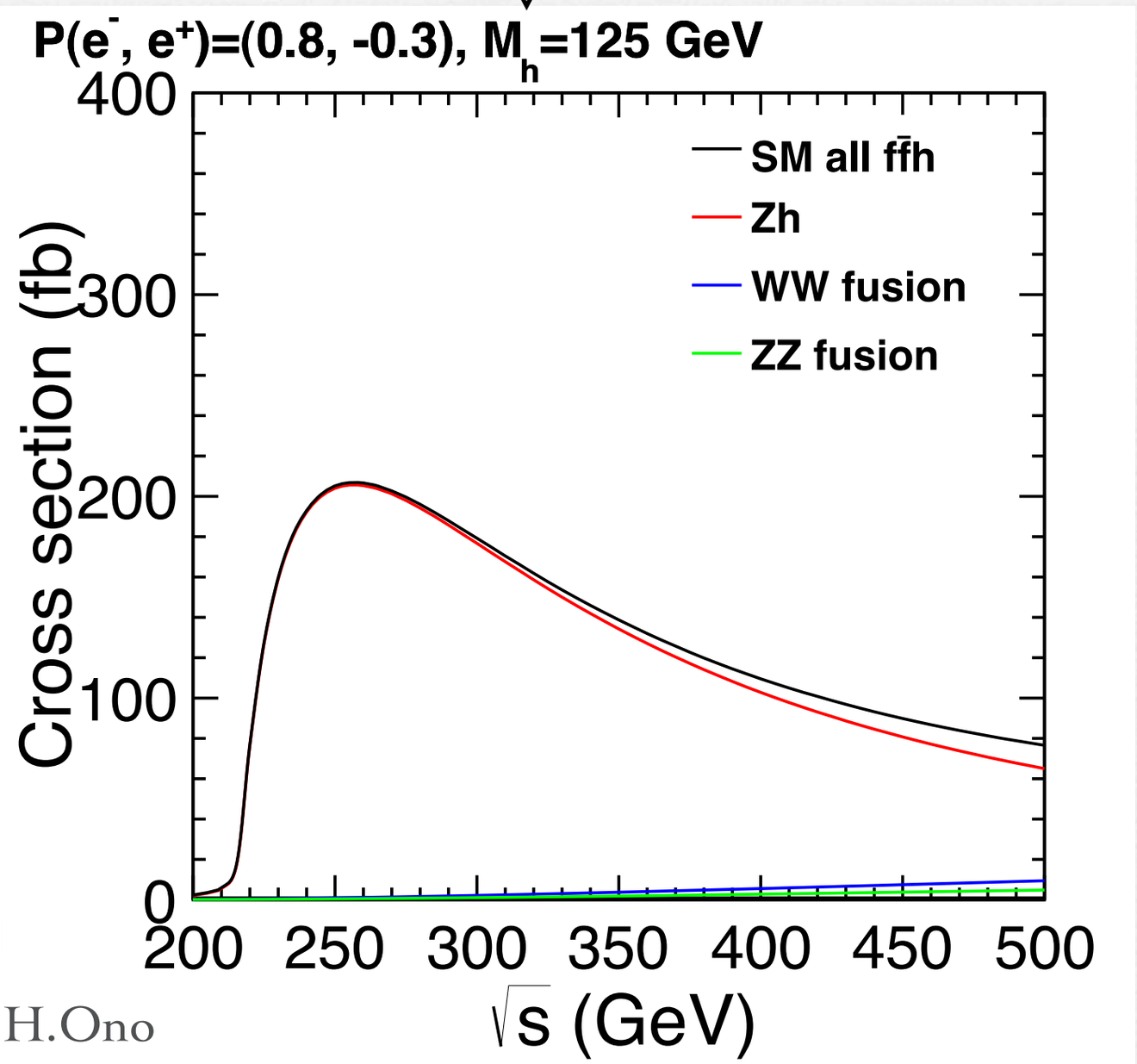
偏極の効果

- ee>ZH の断面積：P(e-,e+)

P(-0.8,0.3) vs P(0.8,-0.3)

wwなし





竹下：加速学会2013

ILC: Higgs 結合

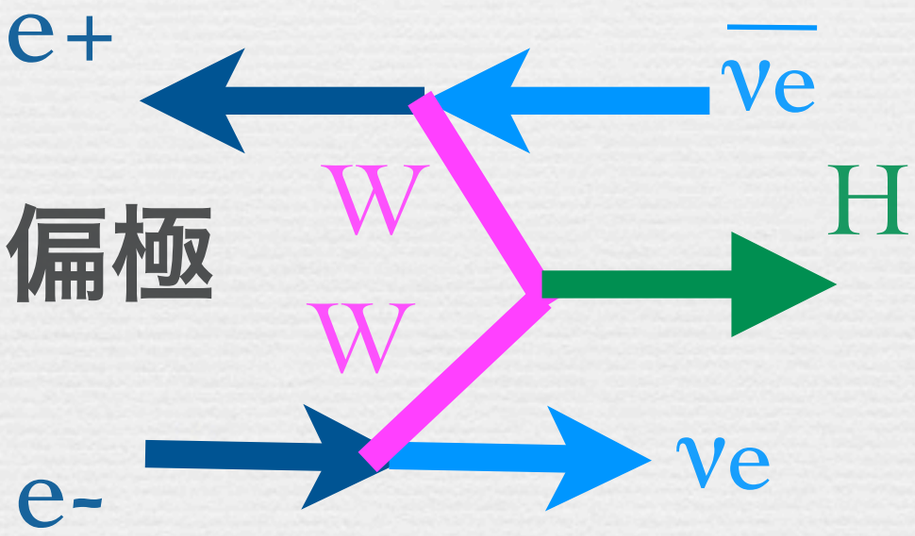
LHCで測り> Higgs factory LC>ILC

ILC250=HLC

ILC=ILC500

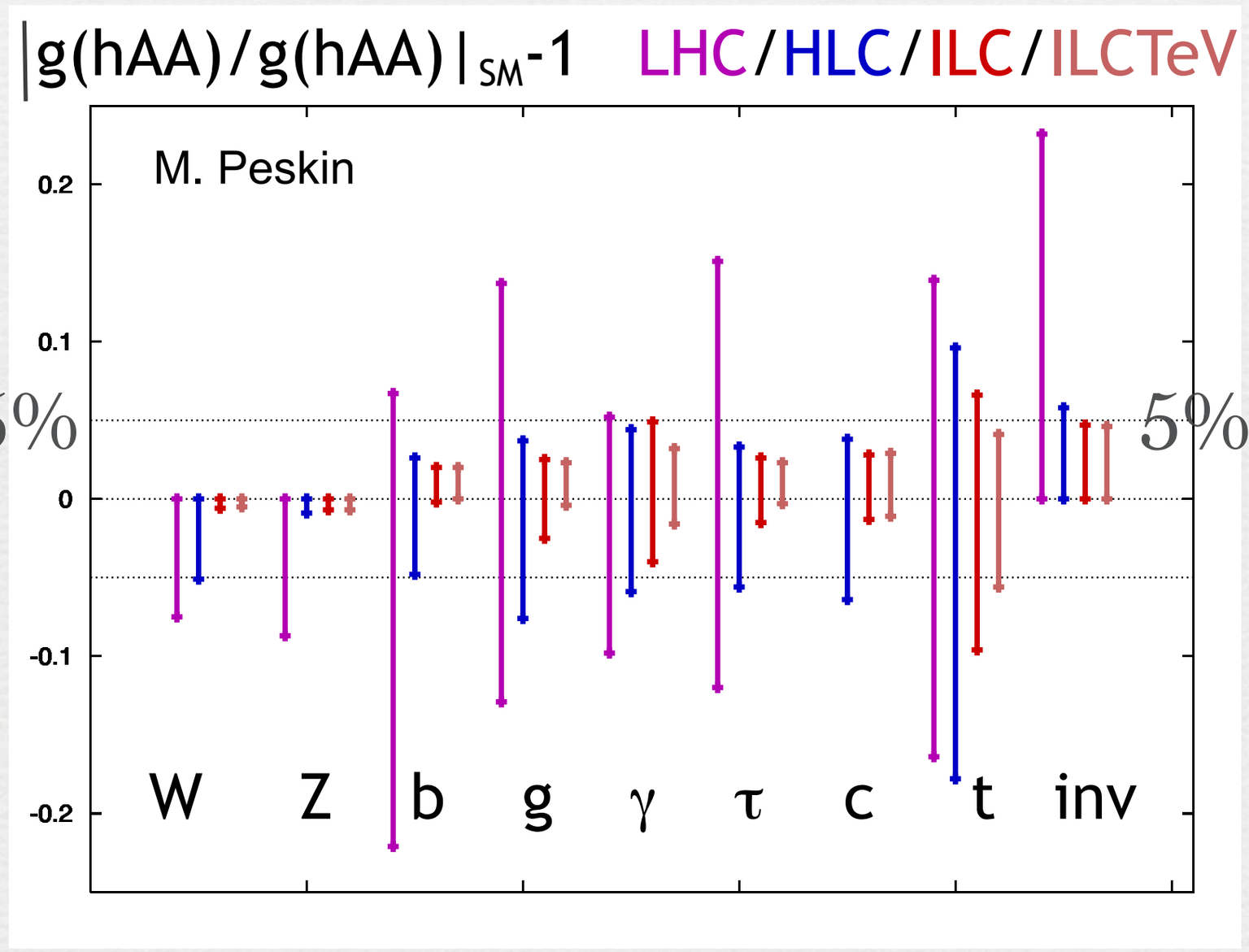
synergy

HWW結合測定過程



ttH: Δg/g~5%@1TeV

1 ab-1

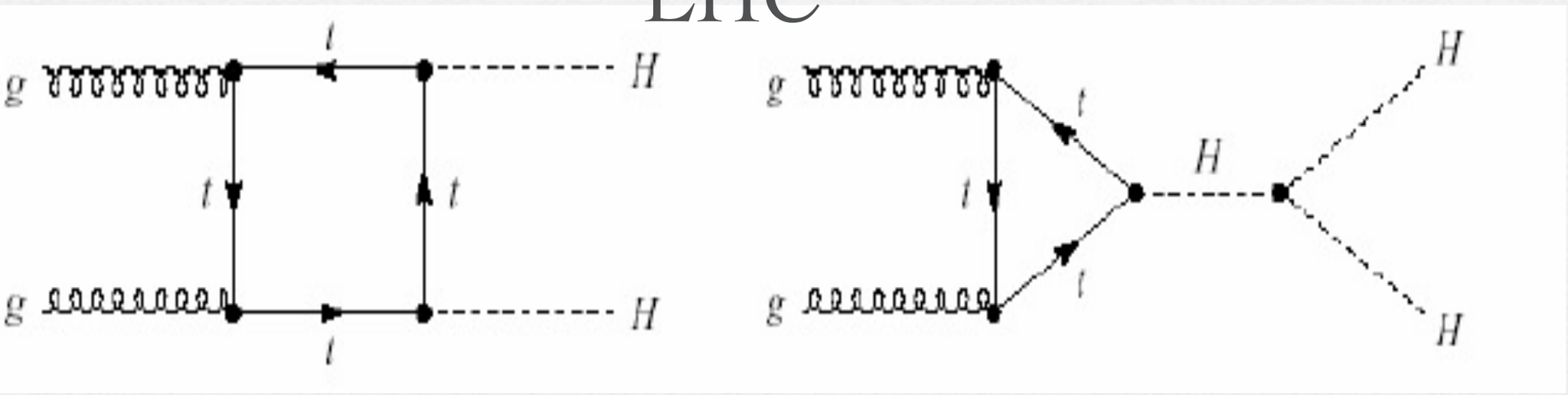


竹下：加速学会2013

LHC:300,HLC:250 ILC:500,ILCTeV:1000fb^{-1}

Higgs self-coupling

LHC



- LHC self coupling 測定

HH -> bb γγ

After cut, ~10 events passed by sim. at 3000fb^{-1} : 2030

LHC time line

2011 : 7TeV
2012 : 8TeV
2013~2014 : upgrade
2014~2016: 13~14TeV, 100fb^{-1}

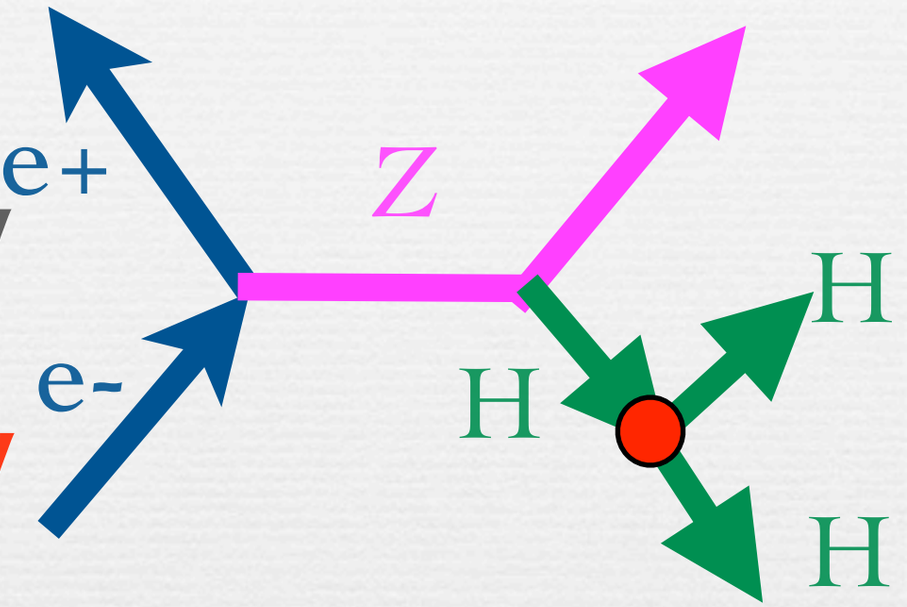
2016~2018 : upgrade
2018~2020 :14TeV, 300fb-1
> HL-LHC
(3000fb^{-1}:2030)

竹下：加速学会2013

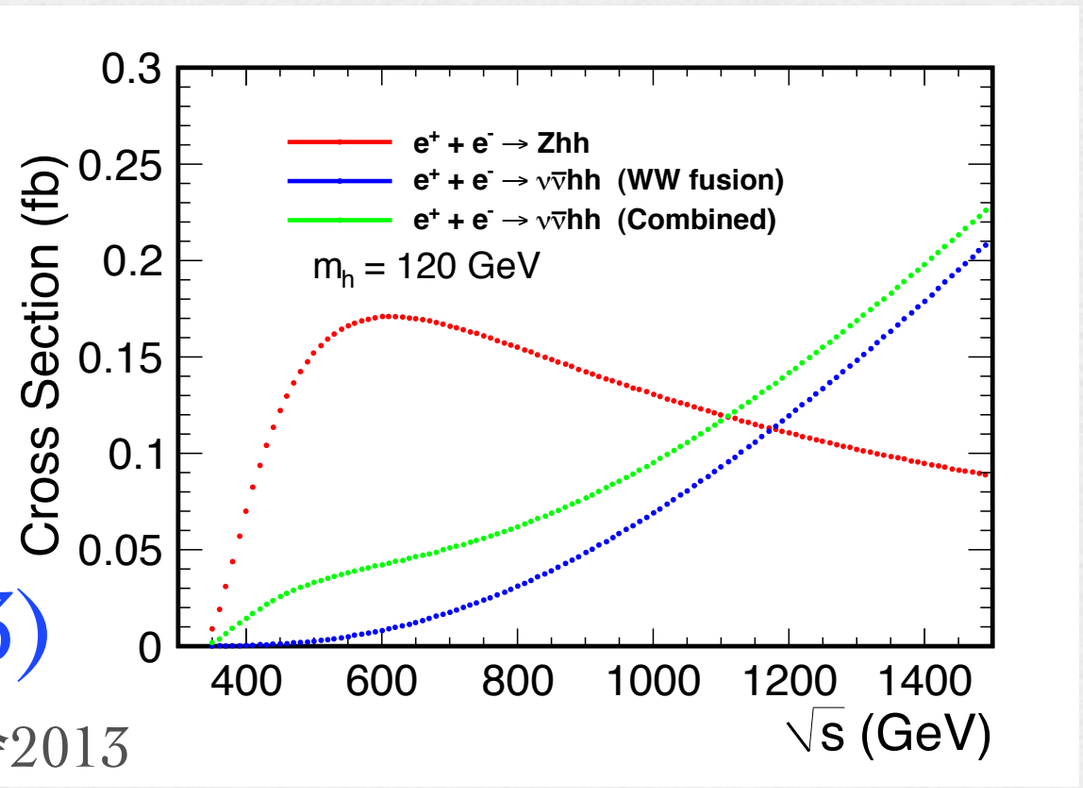
Higgs 自己結合

ILC

- Higgs ポテンシャルを決める
- ee>ZHH: Δg/g~53%@500GeV
  2 ab-1
- ee>ννHH: Δg/g~21% @1TeV
  2 ab-1

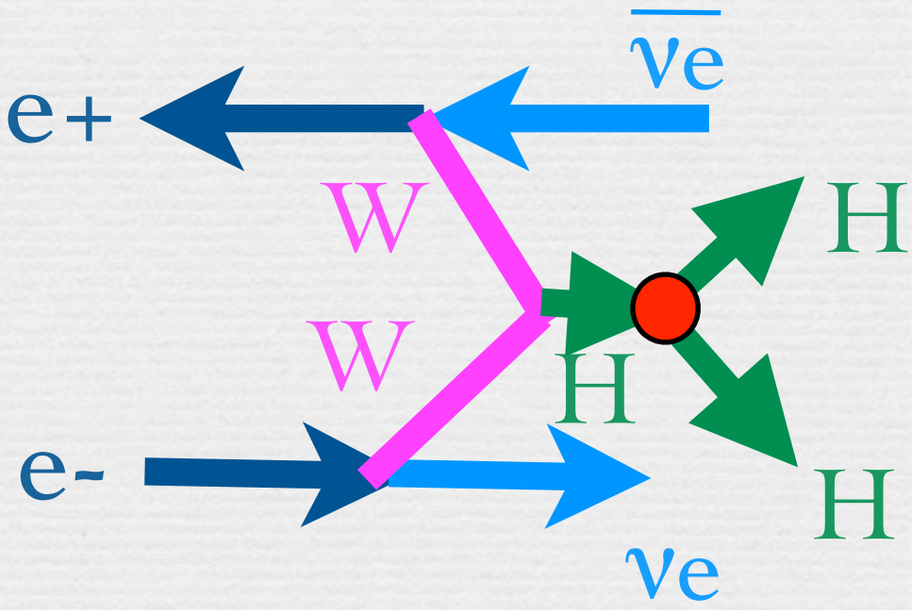


- BSM-モデル予言　10～100%



P(-0.8,0.3)

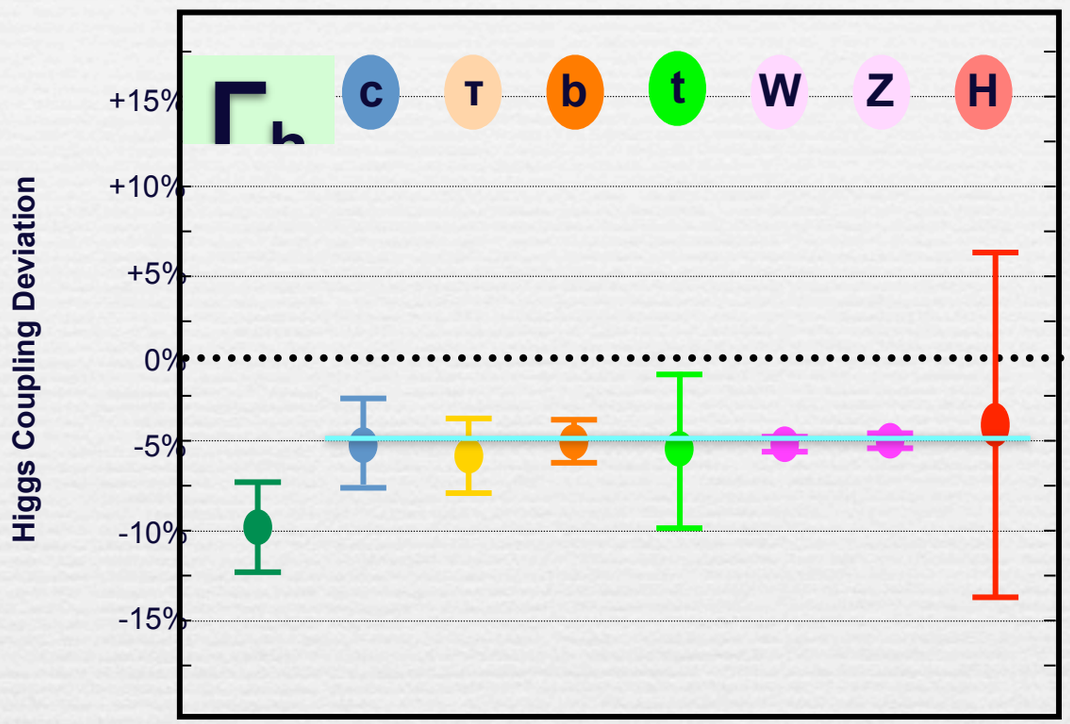
竹下：加速学会2013



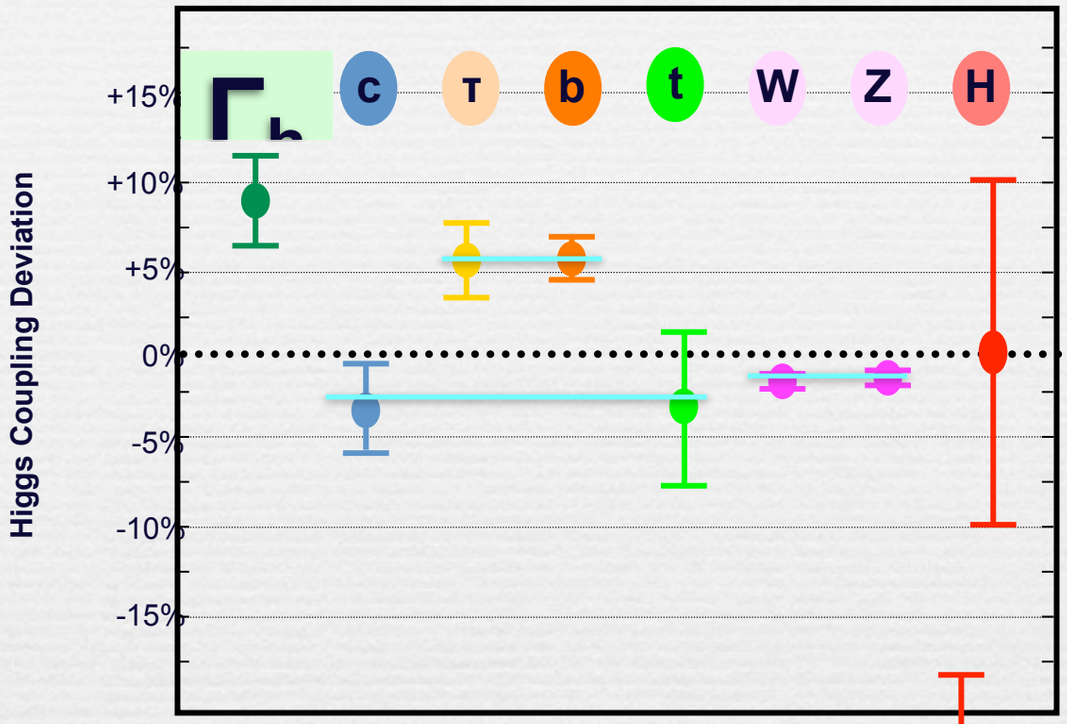
新物理はどう見えるか？

Higgs Coupling Precision with Full ILC Program (Model-Independent Analysis)

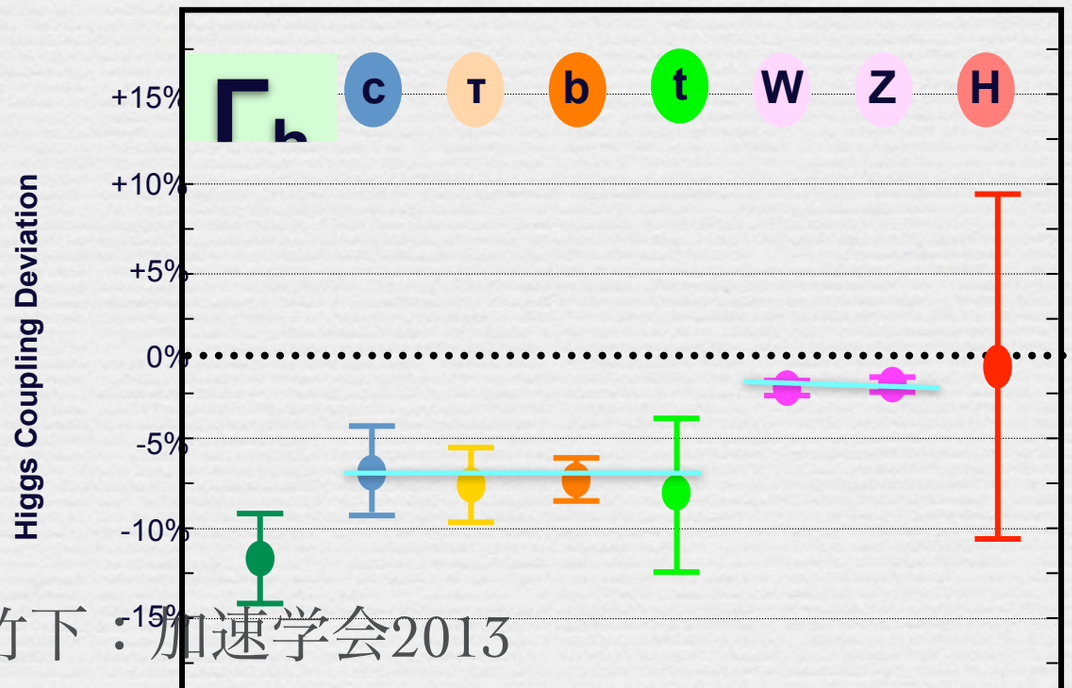
Singlet Mixing



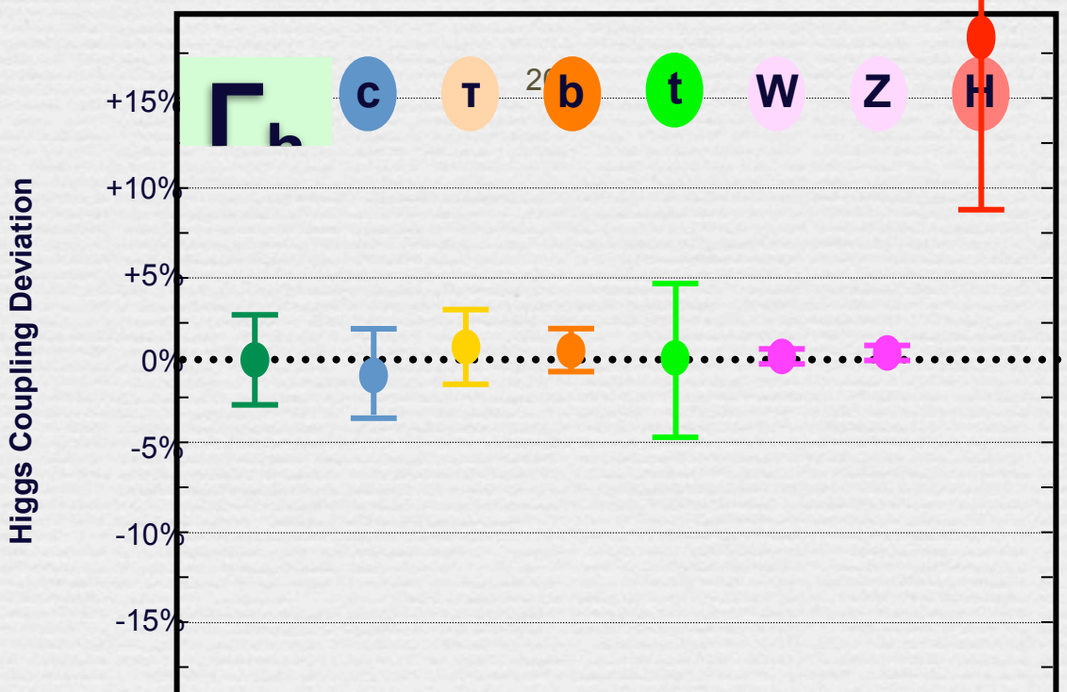
MSSM / Type II 2HDM



Composite Higgs



Electroweak Baryogenesis

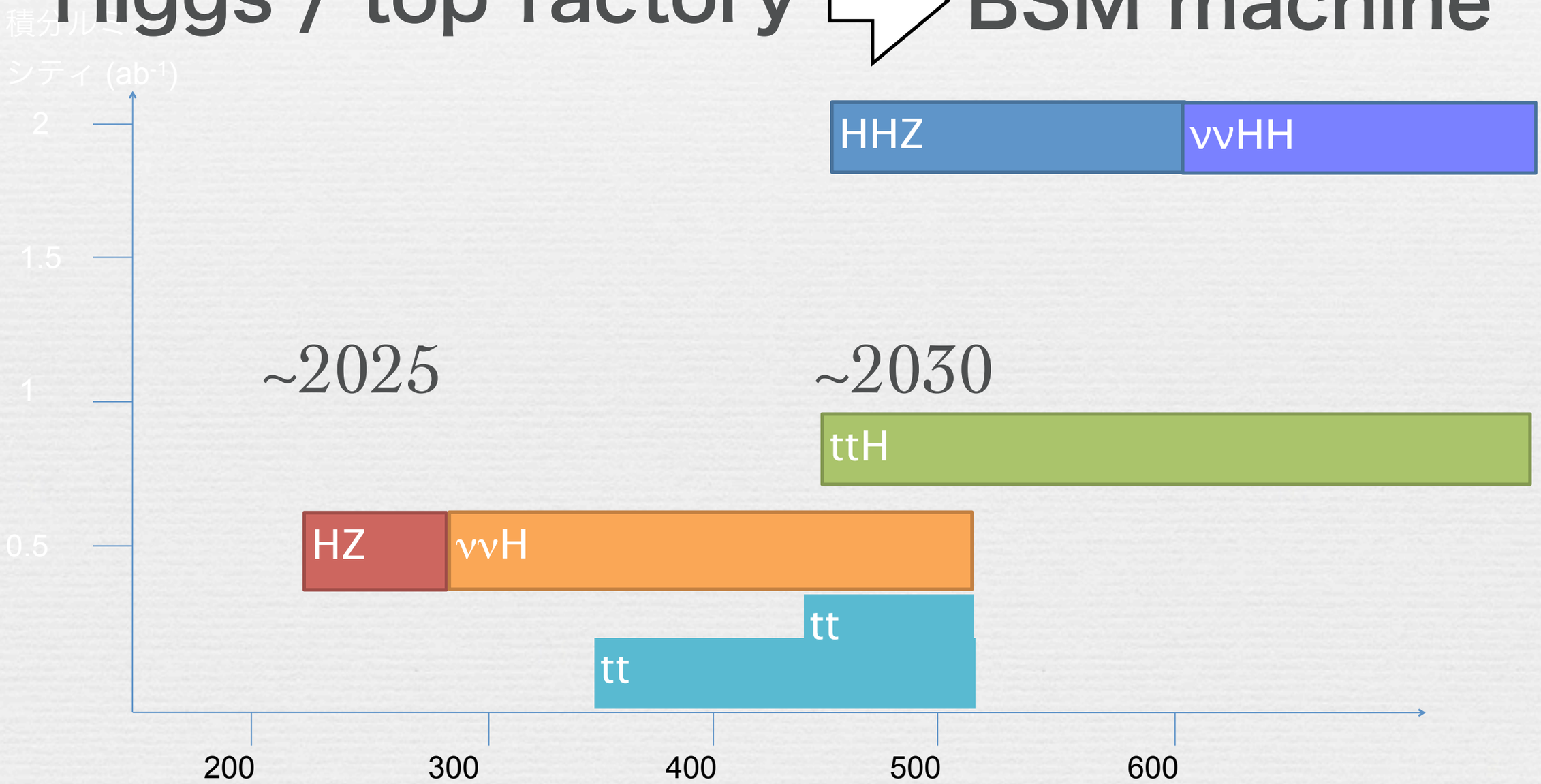


竹下：加速学会2013

ILCの物理計画

- Higgs物理と新物理探索

Higgs / top factory ⇨ BSM machine



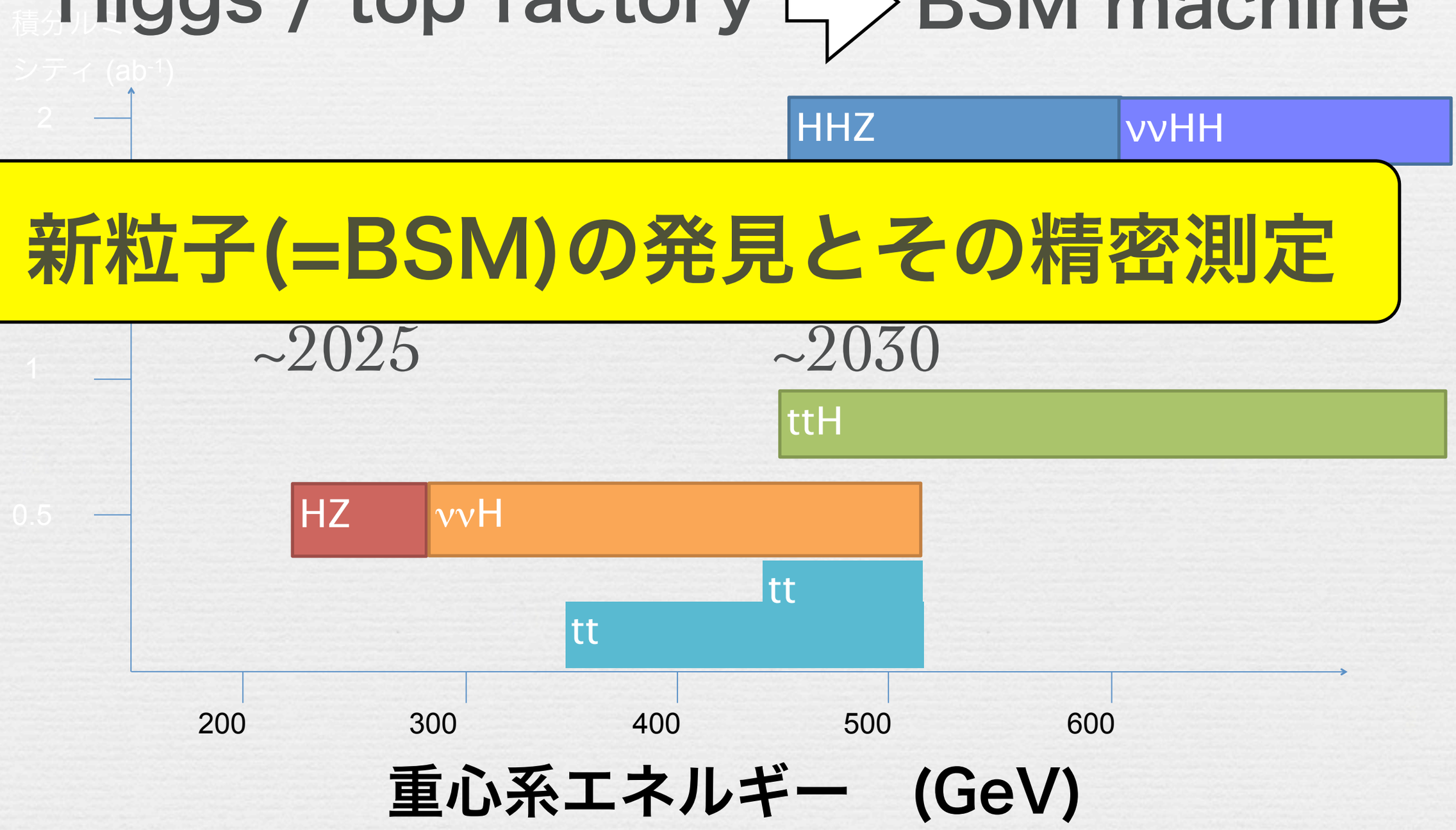
竹下：加速学会2013

ILCの物理計画

- Higgs物理と新物理探索

Higgs / top factory ⇒ BSM machine

新粒子(=BSM)の発見とその精密測定



竹下：加速学会2013

まとめ

- LHCはHiggs粒子を見つけた

新粒子探索

- 標準理論は完成したので次の理論への挑戦
- 挑戦はILCが行う
- ILCは準備万端である。
- 宇宙の創生に近づく！

	hadron	e+e-
charm	◎	◎
b	◎ →	
CP		◎
top	◎ →	ILC
Higgs	◎ →	ILC