

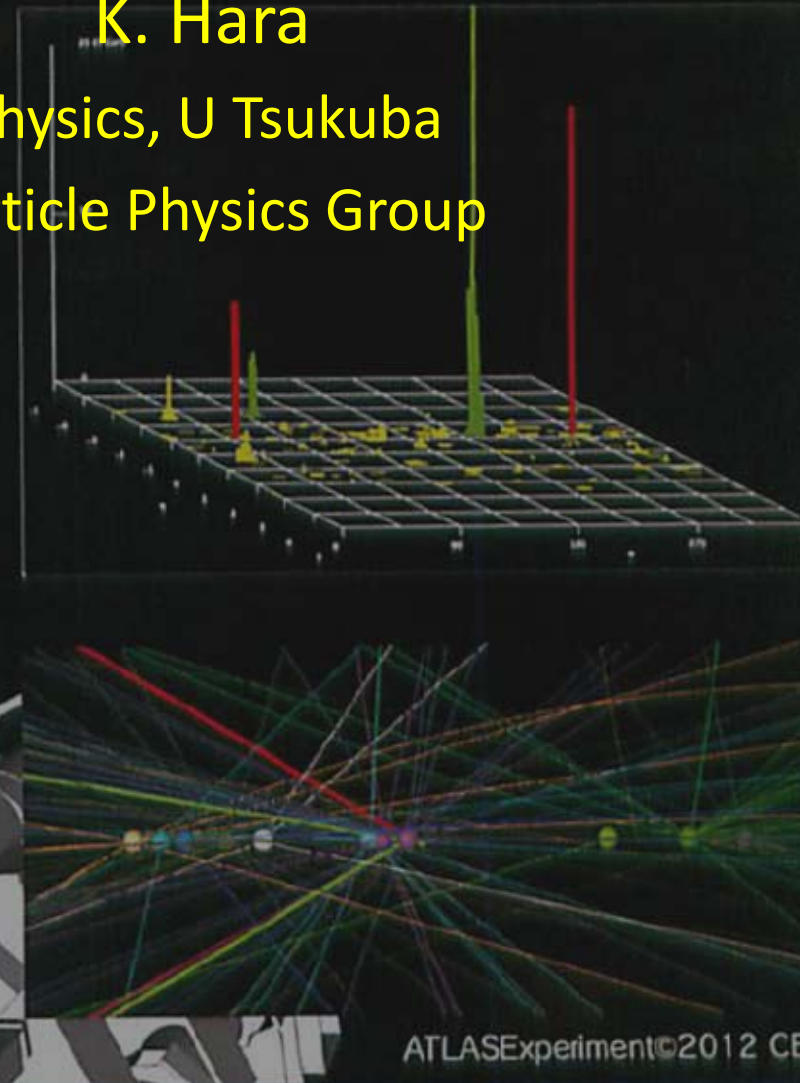
ATLAS Detector

ATLAS
EXPERIMENT
<http://atlas.cern.ch>
Run: 205113
Event: 12611816
Date: 2012-06-18
Time: 11:07:47 CEST

K. Hara

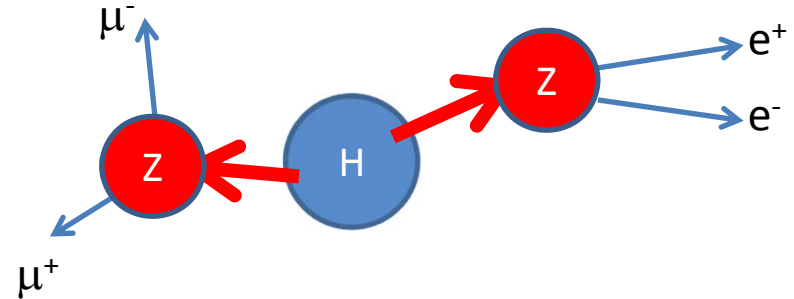
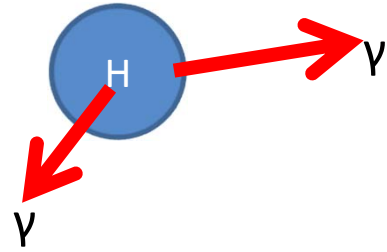
Physics, U Tsukuba
Particle Physics Group

CiRfSE Workshop 2015.3.12

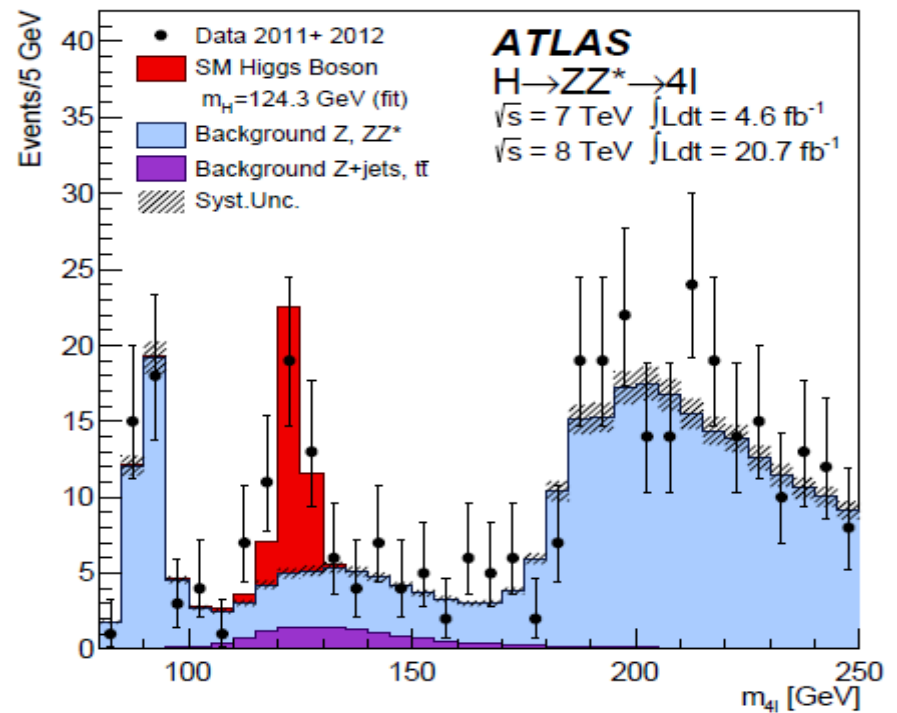
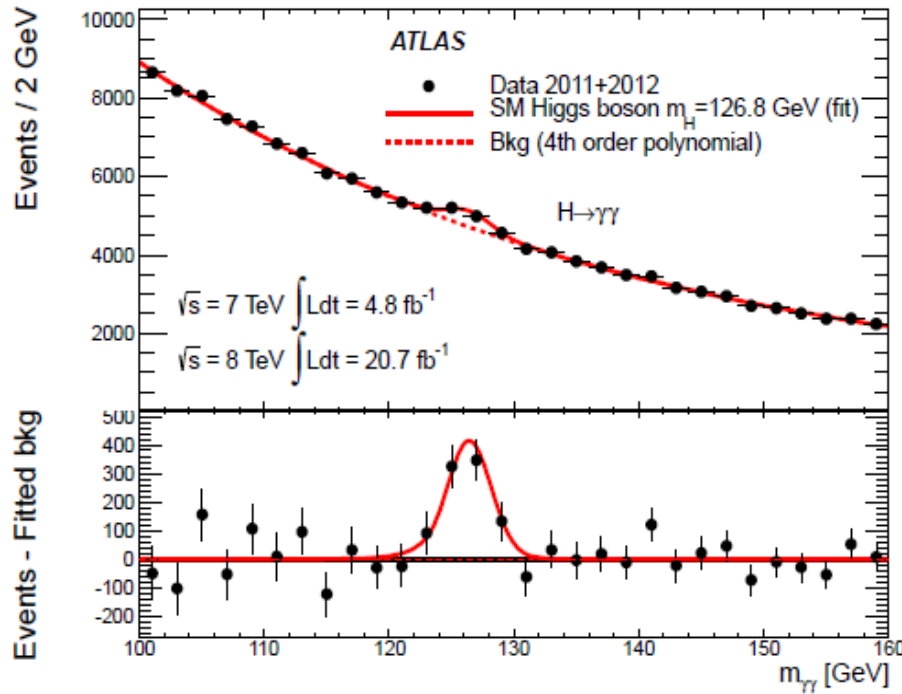


ATLASExperiment©2012 CERN

Higgs 粒子の発見 2013



事象数



Lorentz不変質量

Quarks ($s=1/2$)

u up	c charm	t top
d down	s strange	b bottom

Leptons ($s=1/2$)

ν_e e-neutrino	ν_μ μ -neutrino	ν_τ τ -neutrino
e electron	μ muon	τ tau

Force ($s=1$)

g
gluon

strong

W
W boson

Z
Z boson

electroweak

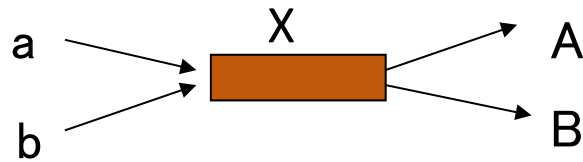
γ
photon

H
Higgs boson

Mass
($s=0$)

新粒子を発見する

新粒子の質量測定



$X \rightarrow A+B+C+\dots$ に崩壊するとき、
A, B, ...のエネルギーと運動量をすべて
測定すればXの質量が分かる

Einsteinの関係式

$$E = \sqrt{(m_0 c^2)^2 + (pc)^2}$$

エネルギー保存: $E = E_A + E_B + \dots$
運動量保存: $\vec{p} = \vec{p}_A + \vec{p}_B + \dots$

$$(m_0 c^2)^2 = E^2 - (\vec{p}c)^2 = (E_A + E_B + \dots)^2 - (\vec{p}_A c + \vec{p}_B c + \dots)^2$$

どんな運動系でも静止質量は計算できる

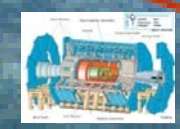
← 相対論的に不変な質量: 不変質量

「汎用素粒子検出器」

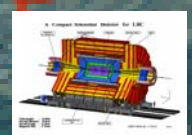
発生する粒子の種類、運動量、エネルギーを、
広い運動学領域($\sim 4\pi$)で精度よく測定する。



CERN
(Meyrin site)



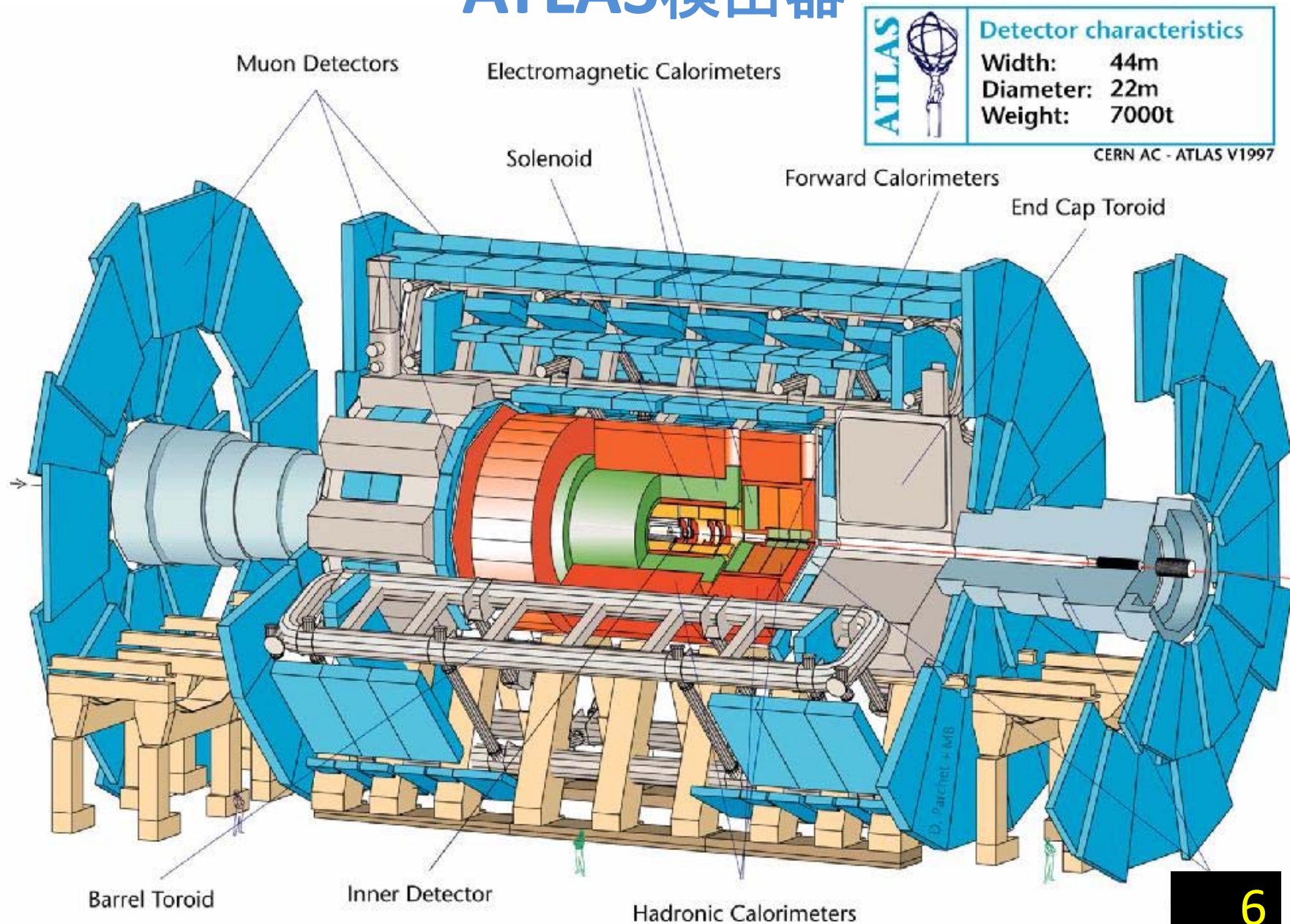
ATLAS



CMS

LHC加速器(ヒッグス研究)

ATLAS検出器

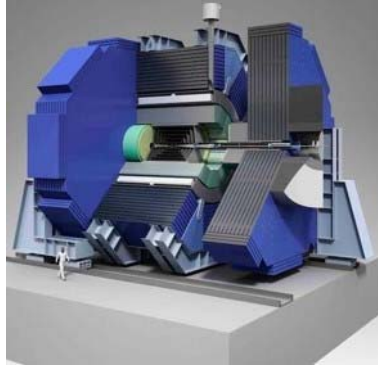


衝突型検出器のいくつか

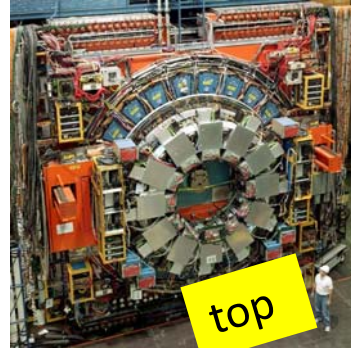
ILD: 14mDx13m



SiD: 12mDx12m



CDF: 12mHx16m



UA1: 6mHx10m



UA2: 4mHx6m

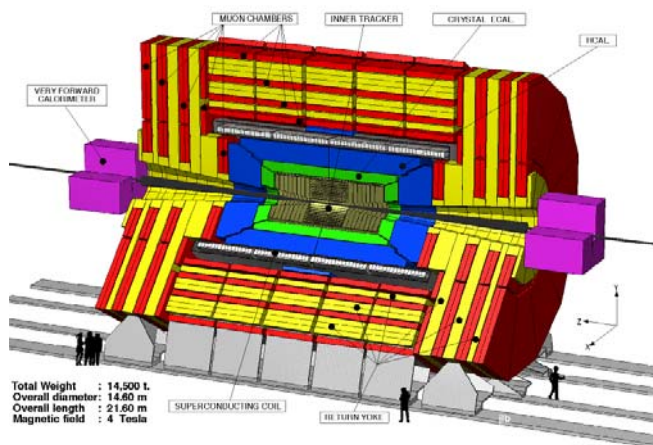


W/Z

Detector characteristics	
Width:	44m
Diameter:	22m
Weight:	7000t

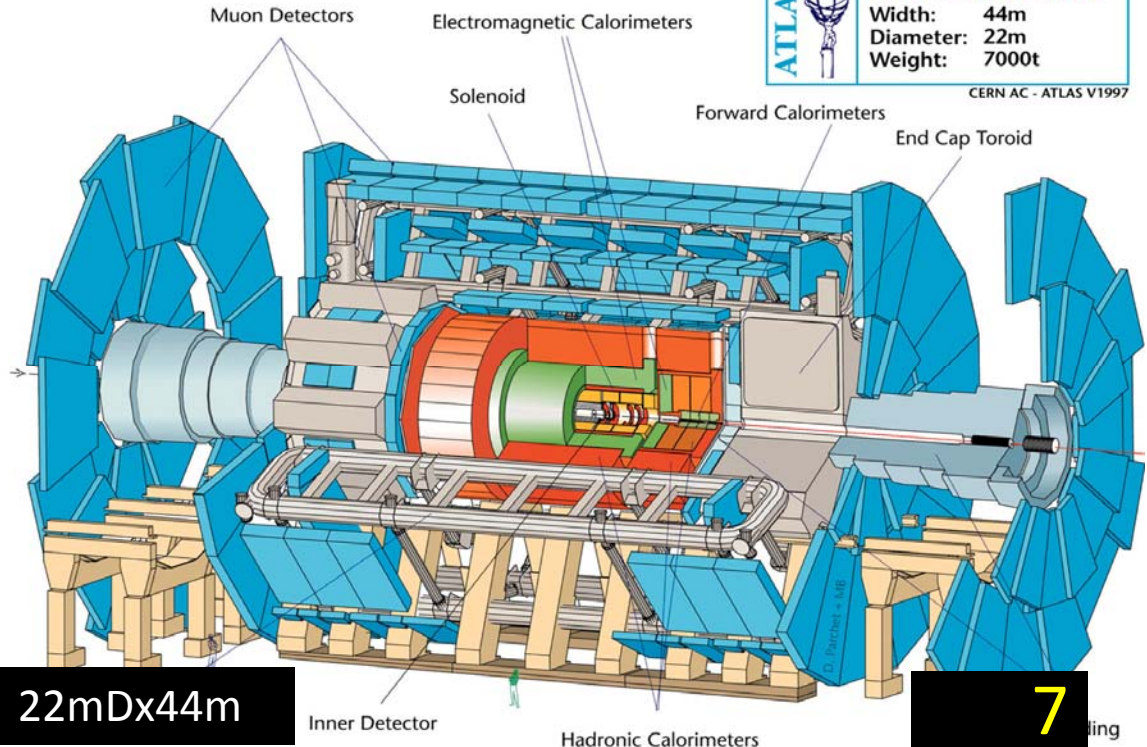
CERN AC - ATLAS V1997

Higgs



Total Weight : 14,500 t
Overall diameter: 14.80 m
Overall length : 21.50 m
Magnetic field : 4 Tesla

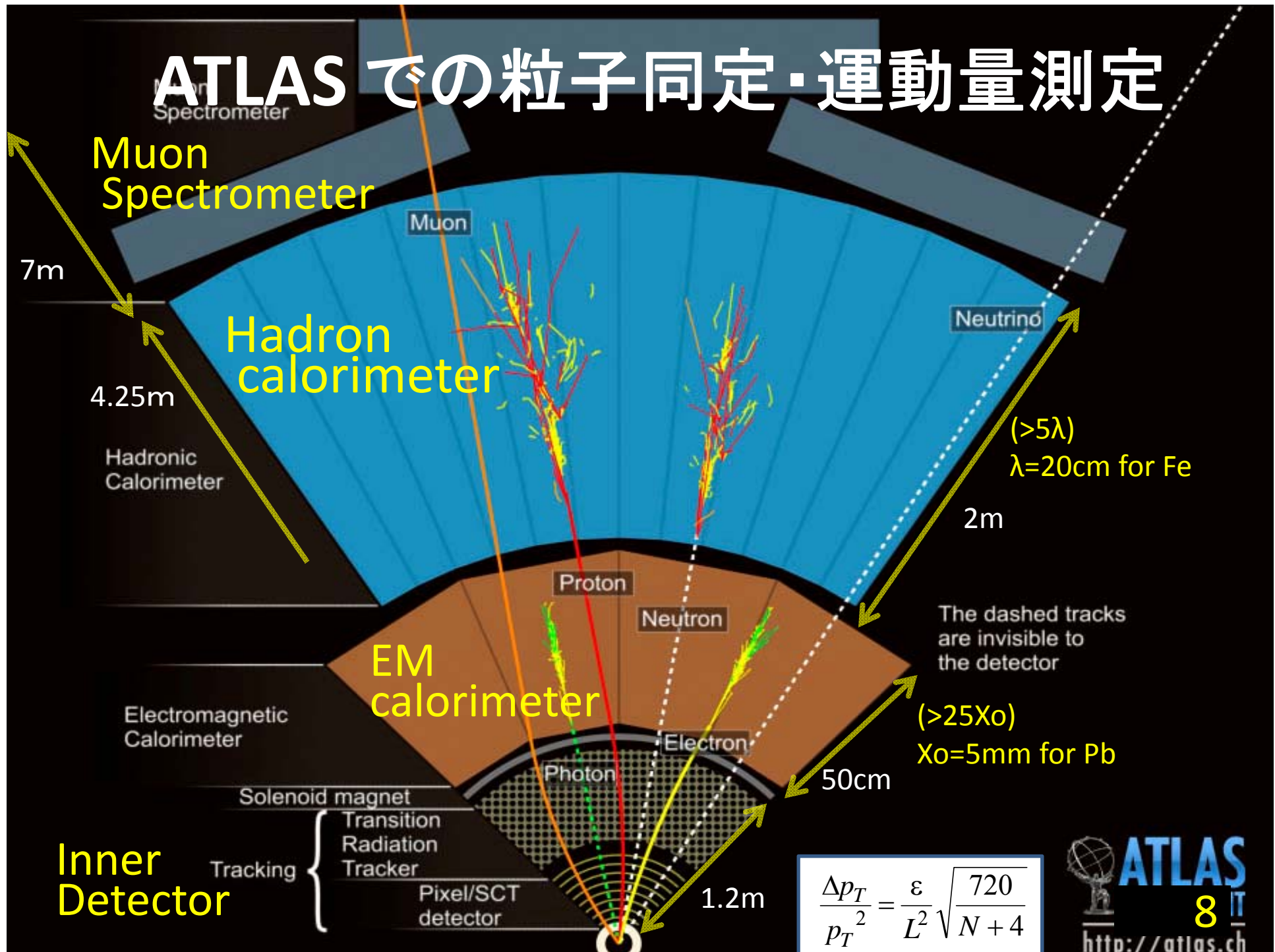
CMS: 15mDx30m



22mDx44m

7

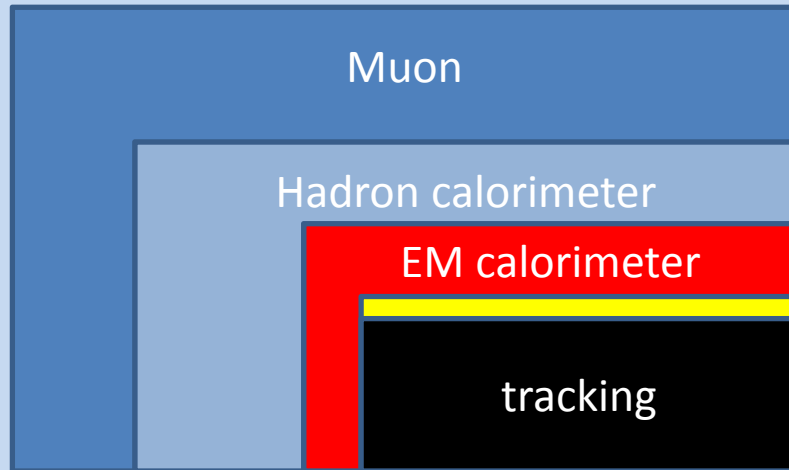
ATLAS での粒子同定・運動量測定



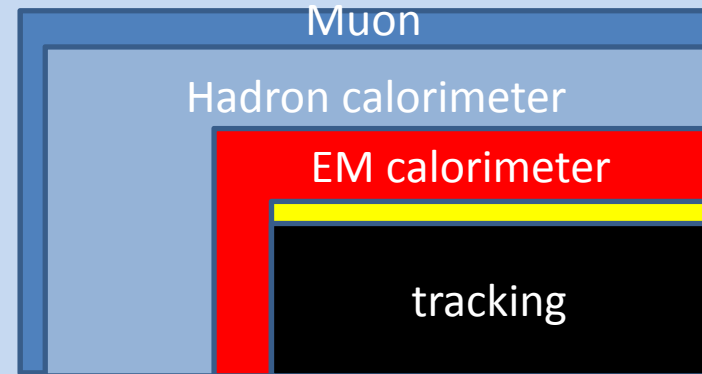
$$\frac{\Delta p_T}{p_T^2} = \frac{\epsilon}{L^2} \sqrt{\frac{720}{N+4}}$$

汎用衝突型検出器構成の分類

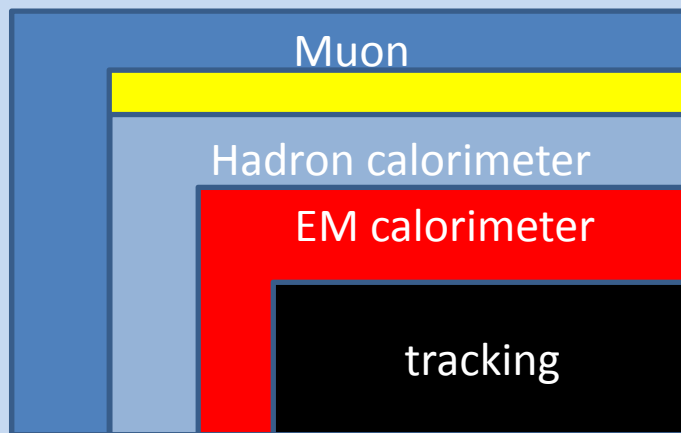
差異~検出器のtechnology, solenoid の位置



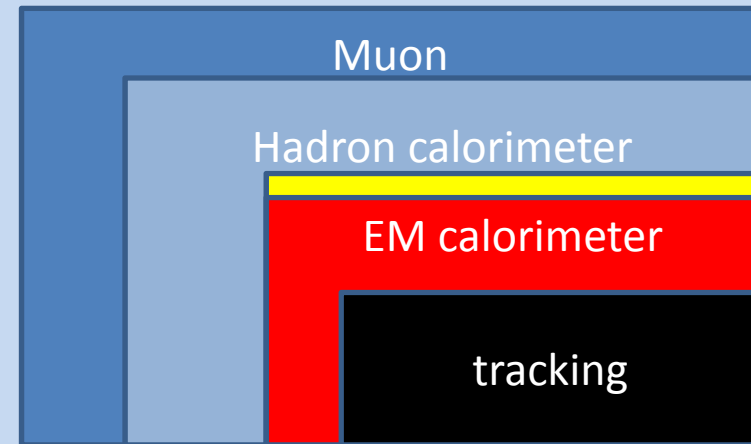
ATLAS, D0: thin solenoid ($\sim 2\text{T}$)
+muon spectrometer



CDF, UA1,ZEUS,OPAL:
compact, thin solenoid



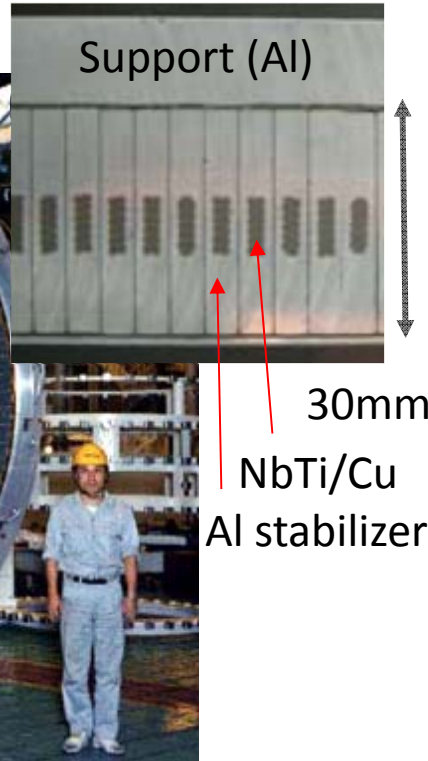
CMS, ILD,SID,H1:
good E-meas、large solenoid($\sim 5\text{T}$)



ALEPH, DELPHI:
compact, \sim thin solenoid

ATLASソレノイド電磁石

2.4mDx5.3mL (2T)



ちなみに,,,

3.0mDx5.0mL (1.5T)

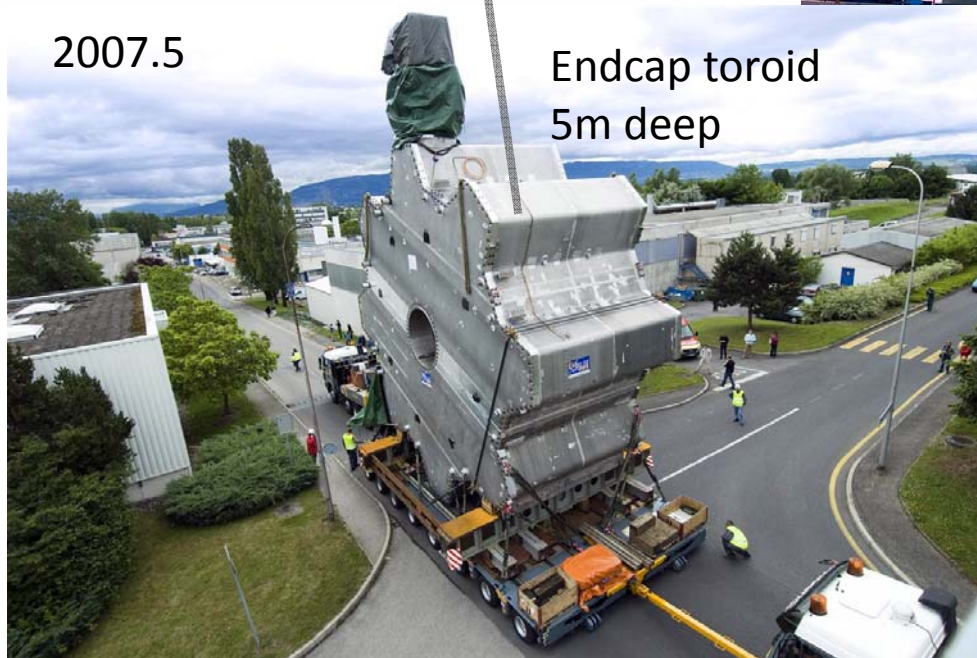
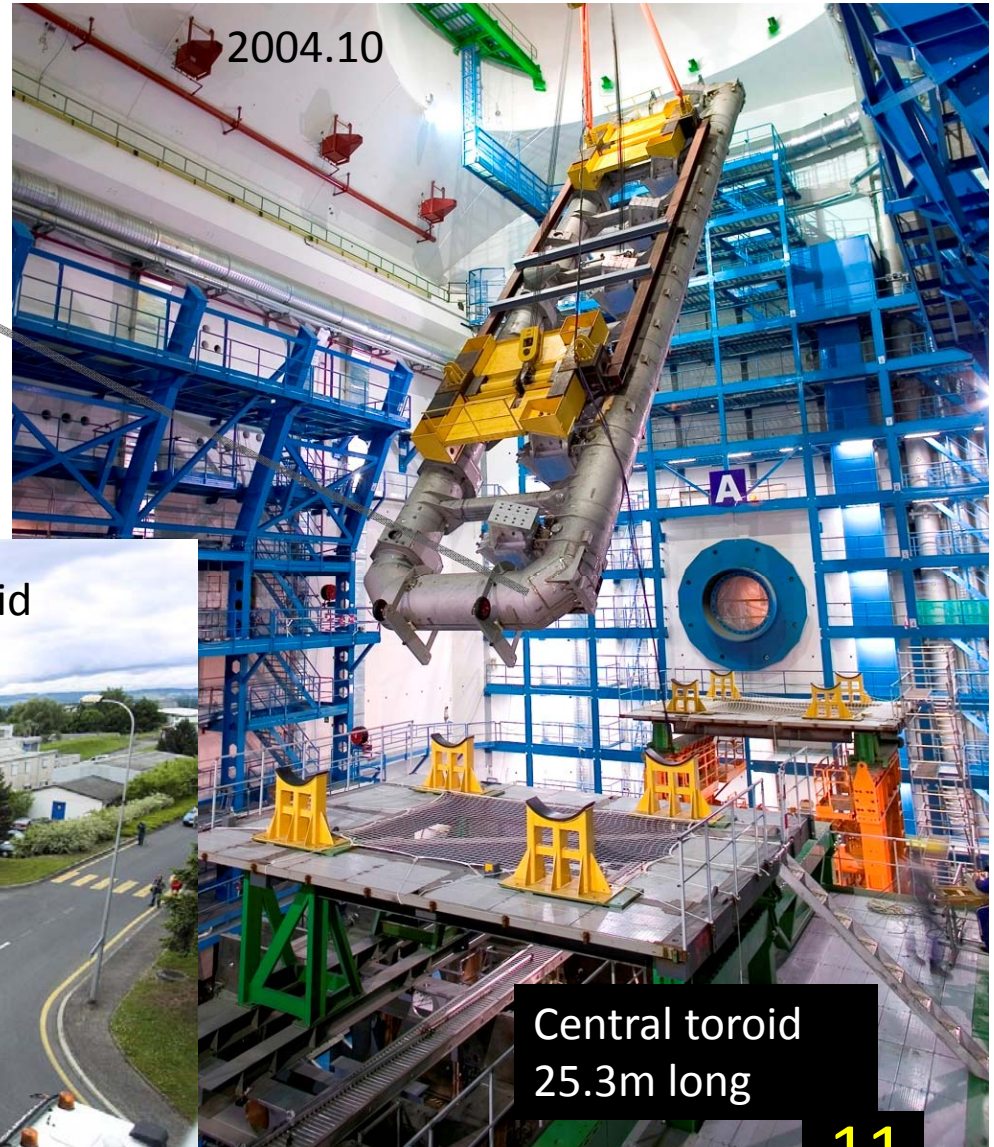
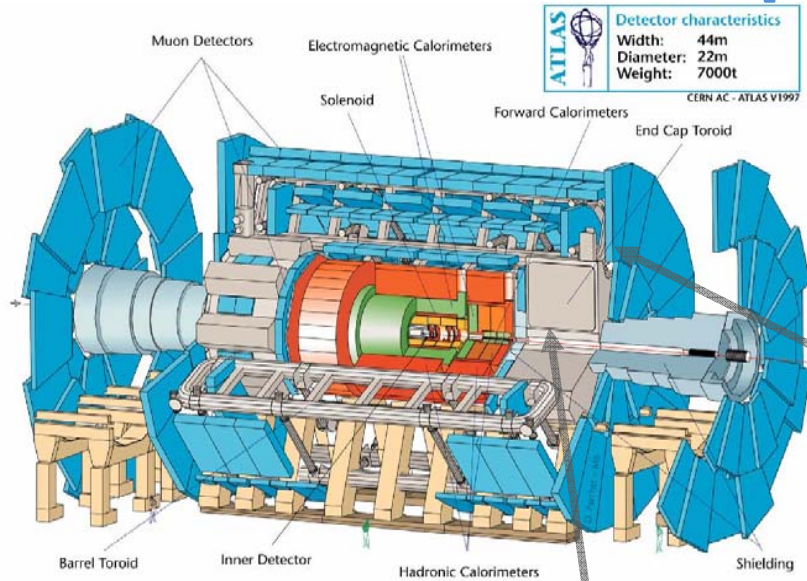


1984
CDF: Hitachi-Tsukuba
0.84X₀ (90deg)
NbTi/Cu-Al conductor

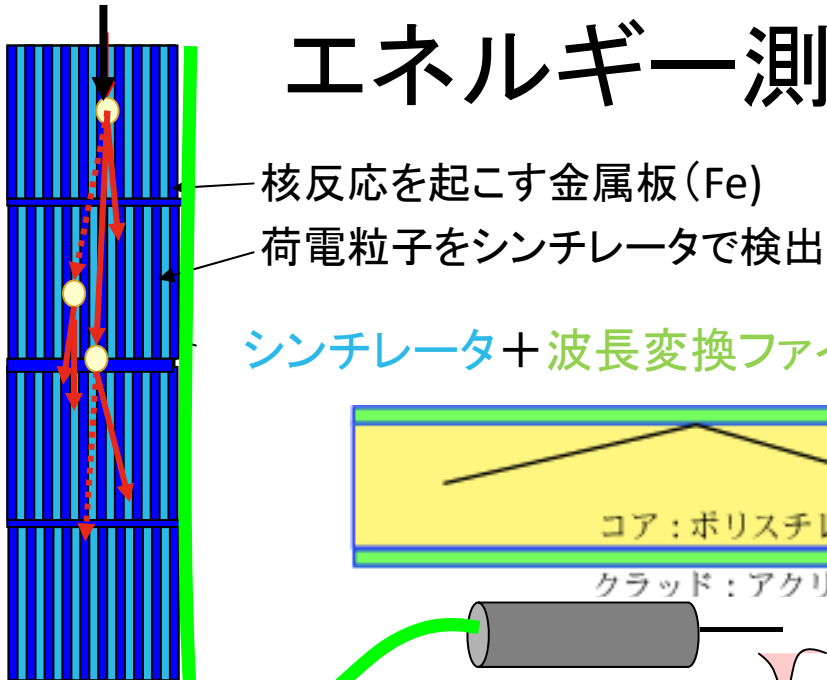
大強度磁場の生成 = 超伝導
(⇒発熱量小⇒冷却・電線の質量小): 薄型超伝導

1961: Nb₃Snによる高磁場超伝導の発見
(1か月後) LBLでバブルチェンバーの超伝導化の検討
1969: Argonne Bubble chamberの超伝導化 (NbTi)

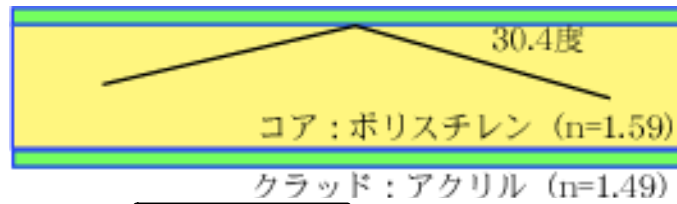
ATLAS トロイド電磁石



エネルギー測定：ハドロンカロリメータ

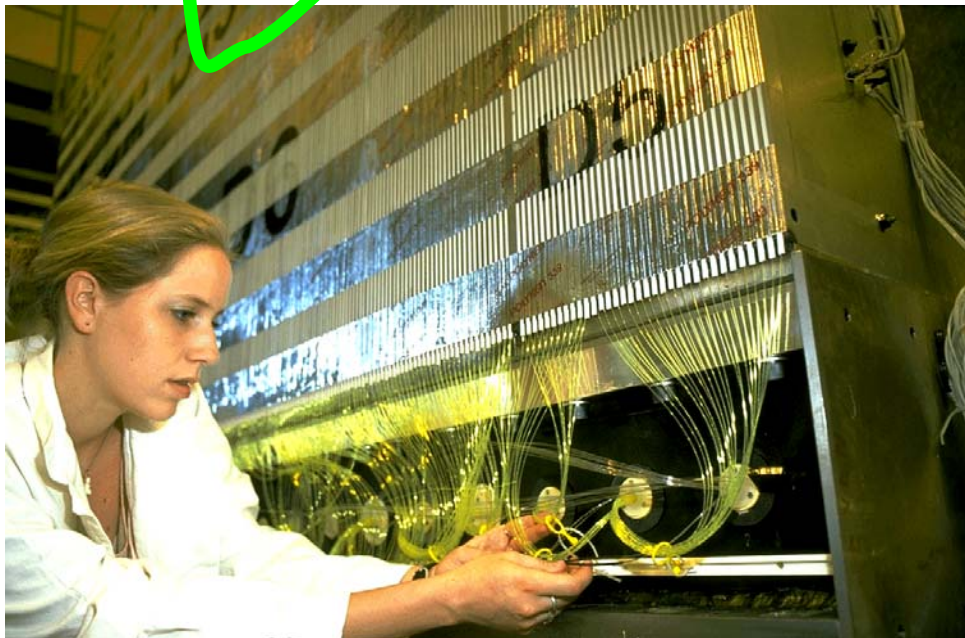


入ってきた粒子のエネルギーに比例した電流が光検出器から得られる

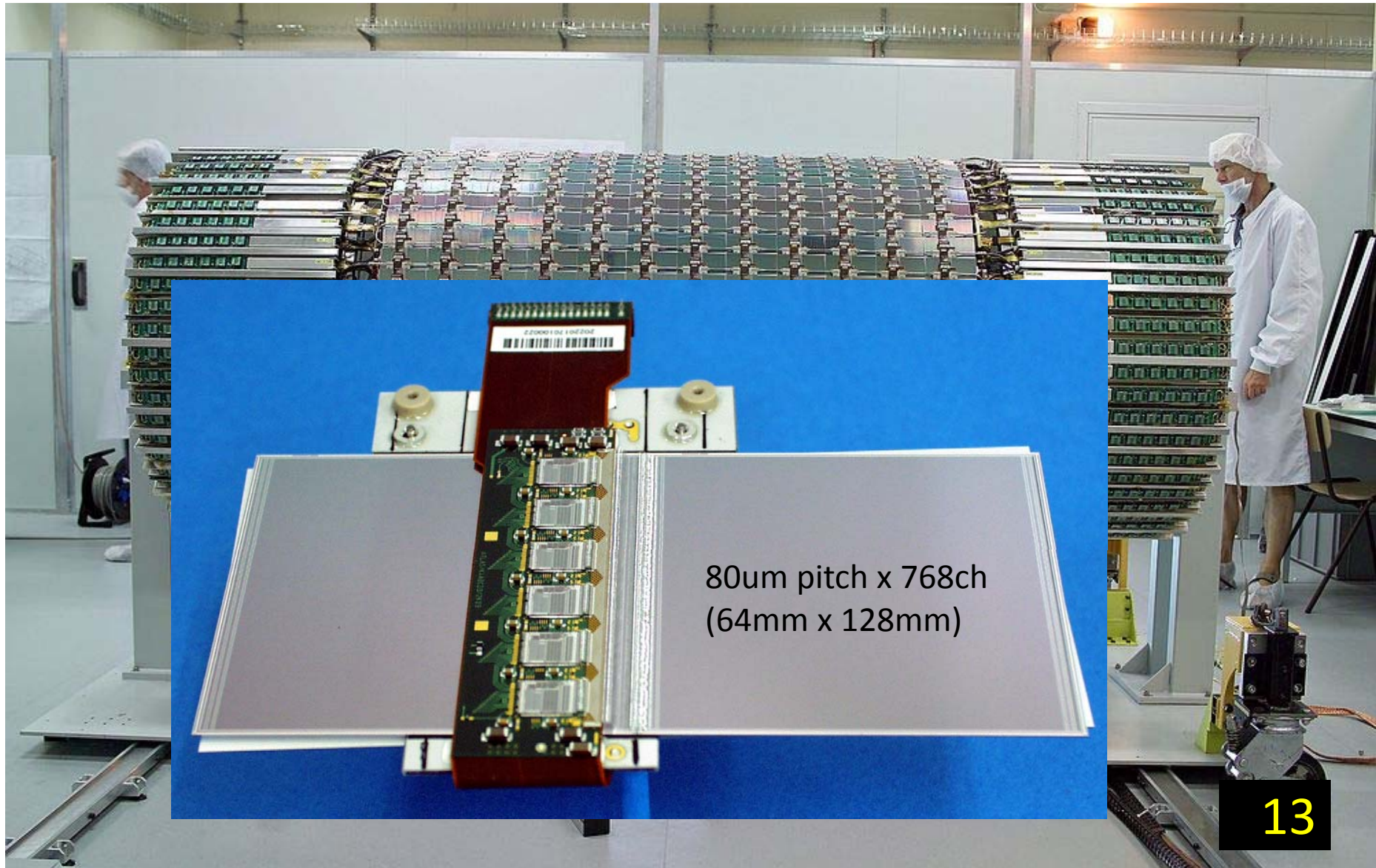


シンチレータの“縦置き”

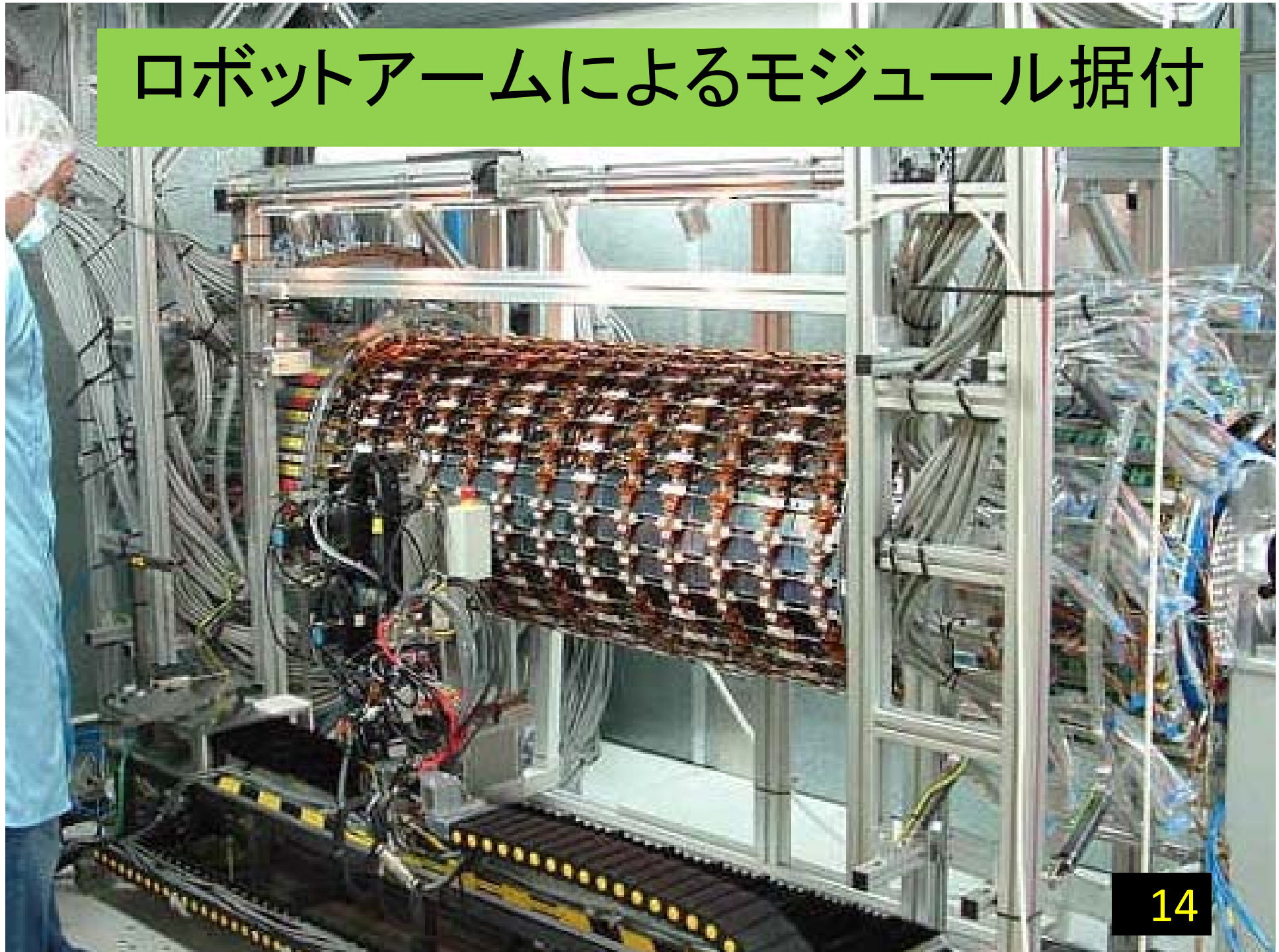
- シンチサイズが11 種類
- WLSファイバーを接合しやすい
- 奥行き分割(=3)しやすい



位置測定：SCT半導体飛跡検出器



ロボットアームによるモジュール据付

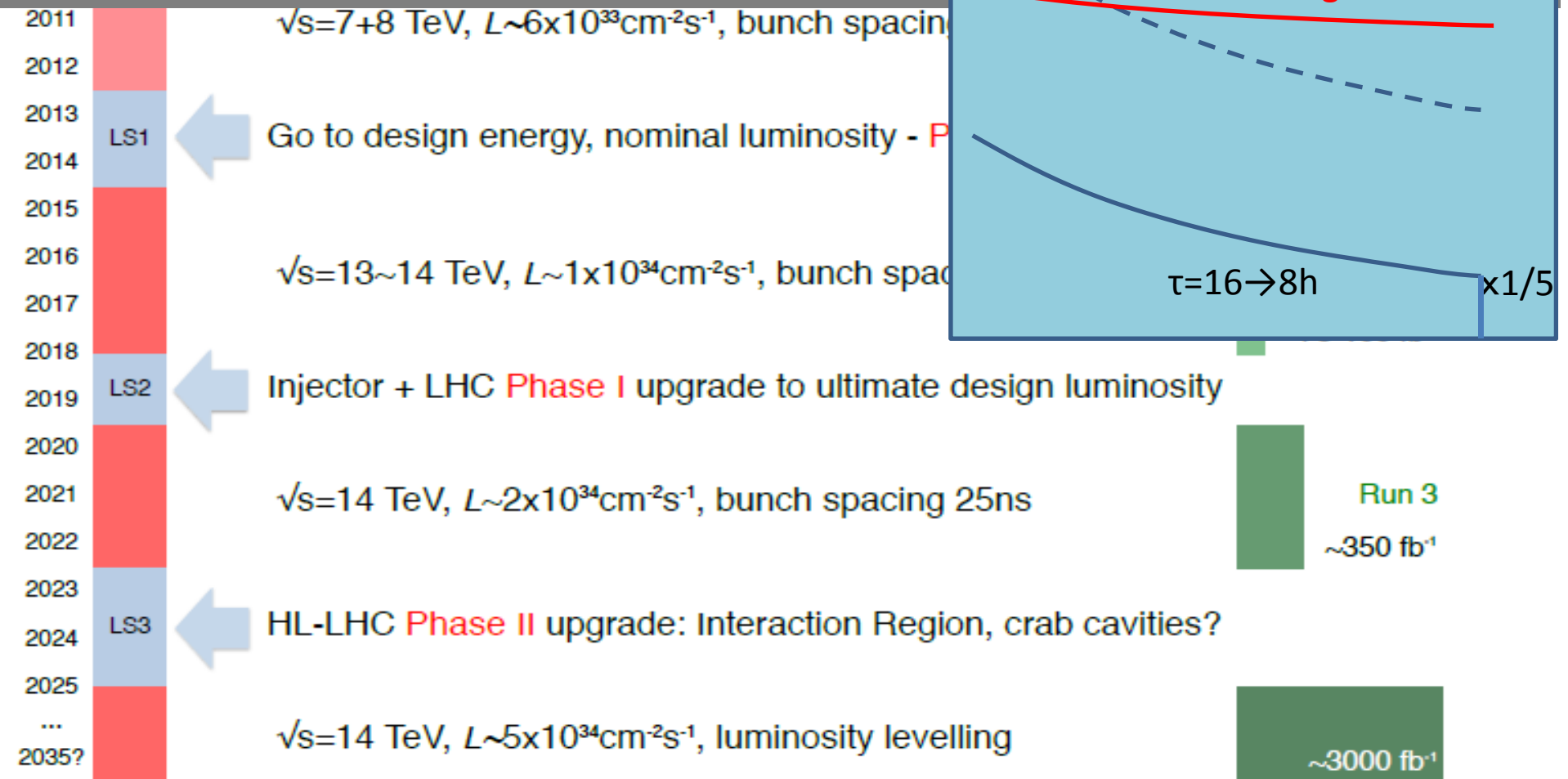


LHC roadmap

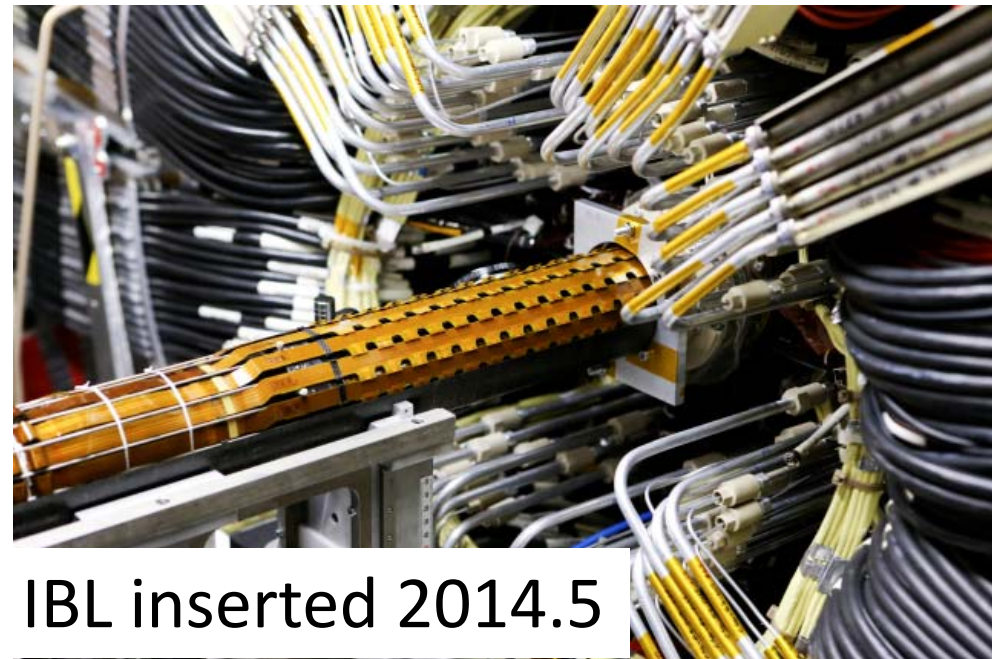
PHASE-0 (2015) IBL

PHASE-I (2018) FTK – designed LHC $1 \times 10^{34} / \text{cm}^2 / \text{s}$

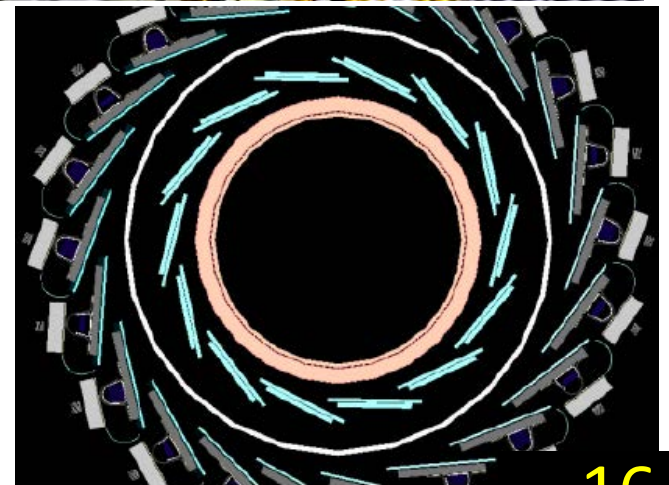
PHASE-II (2023) all silicon tracker ITK– high luminosity



IBL (Insertable B-layer) from 2015



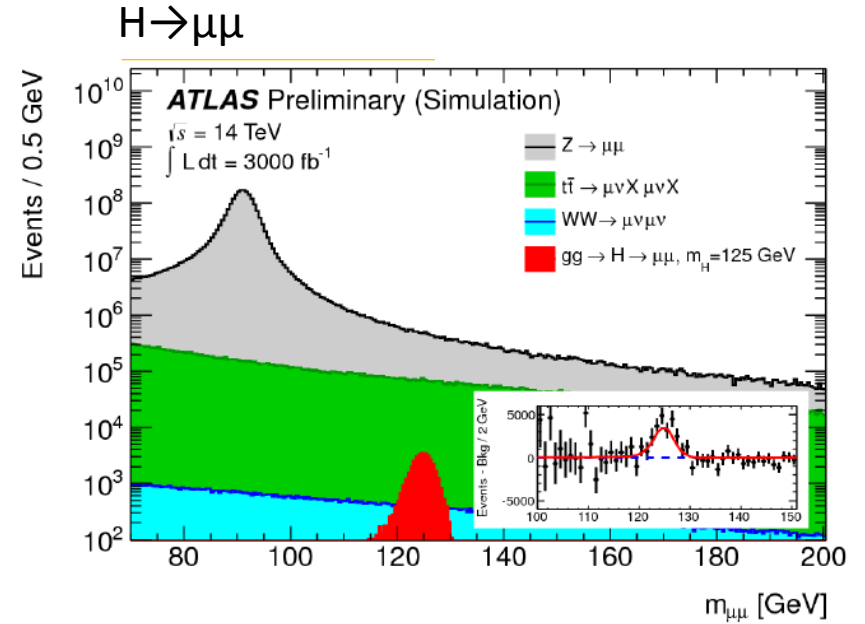
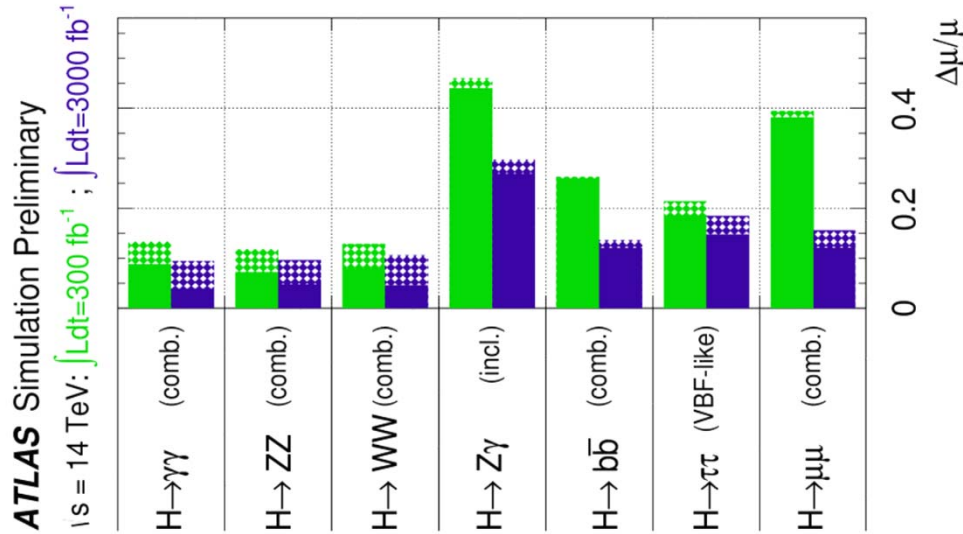
3→4 pixel layers
Closest measurement 3.3cm from IP
Significantly improves light-jet rejection
50x250um n-on-n & 3D



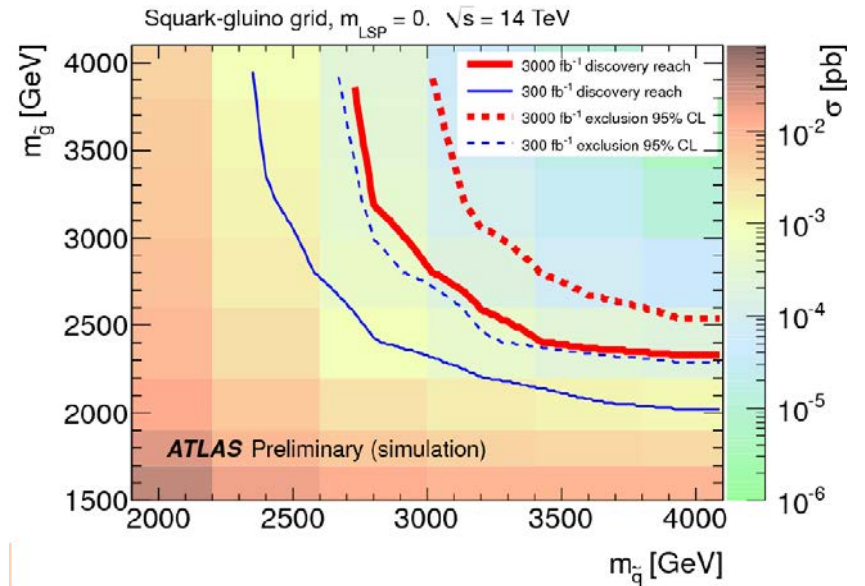
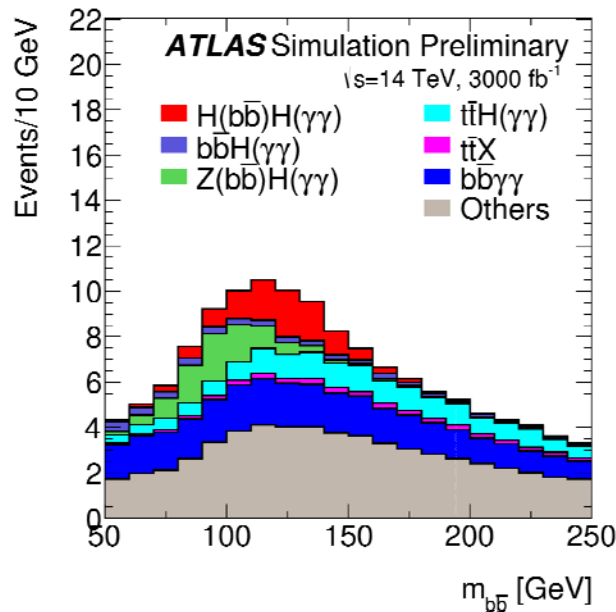
Why HL-LHC?

- ILCが完成するまでEnergy Frontier実験
(ILCが完成しても物理は相補的)
- Higgs分岐比の精密測定、Higgs自己結合
- HL-LHCのための技術開発は将来の高エネルギー加速器(HE-LHC, VLHC,,,)実験の礎

HL-LHC Physics Reach



$pp \rightarrow HH (\rightarrow bb\gamma\gamma)$:
 #signals=14 if $\lambda_{HHH}=0$
 #signals=8 if $\lambda_{HHH}=1$
 #bkgr=47
 $\sim 1.3\sigma / 3000\text{fb}^{-1}$

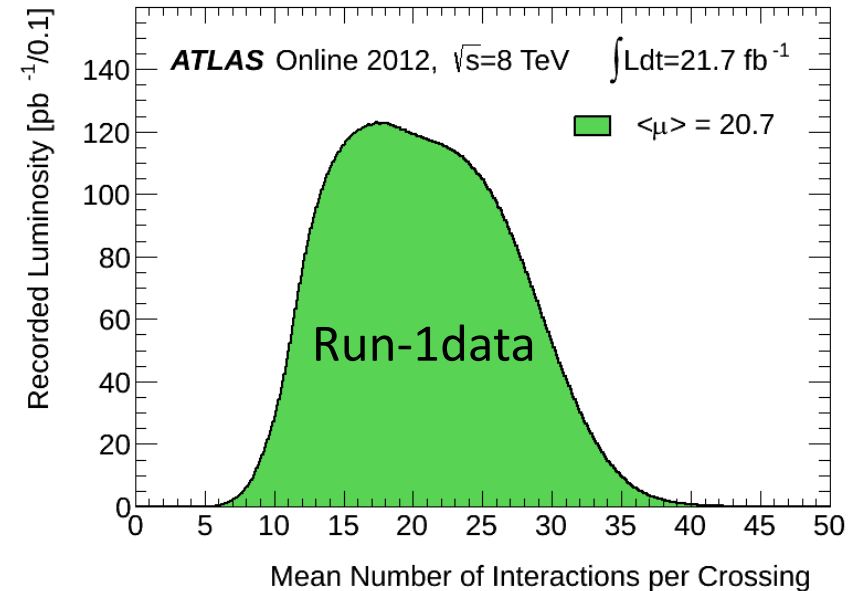
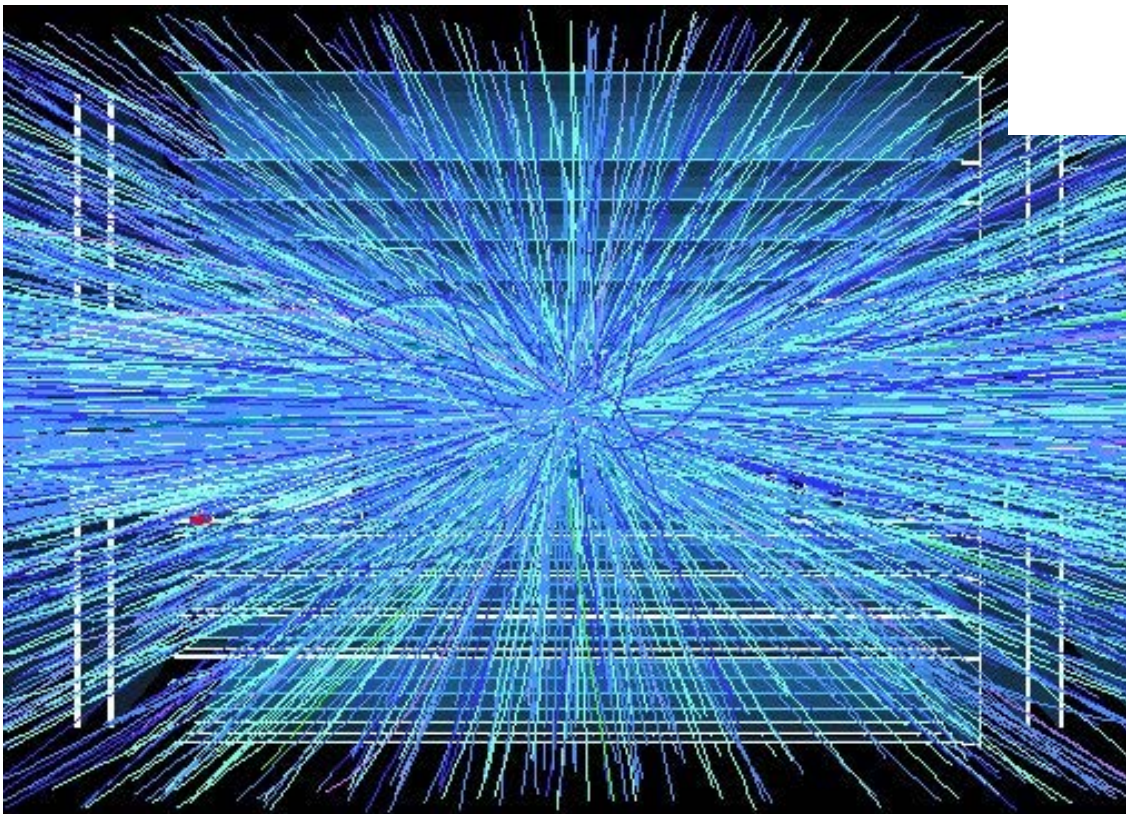


ビーム交差あたりの反応数 $\langle \mu \rangle$

For luminosity: $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$

$$\langle \mu \rangle = \frac{L \times \sigma(pp)}{f} = \frac{5 \times 10^{34} \times 100 \times 10^{-27}}{40 \times 10^6} = 125$$

200 pp collisions/crossing simulation



New Inner Tracker (ITK)

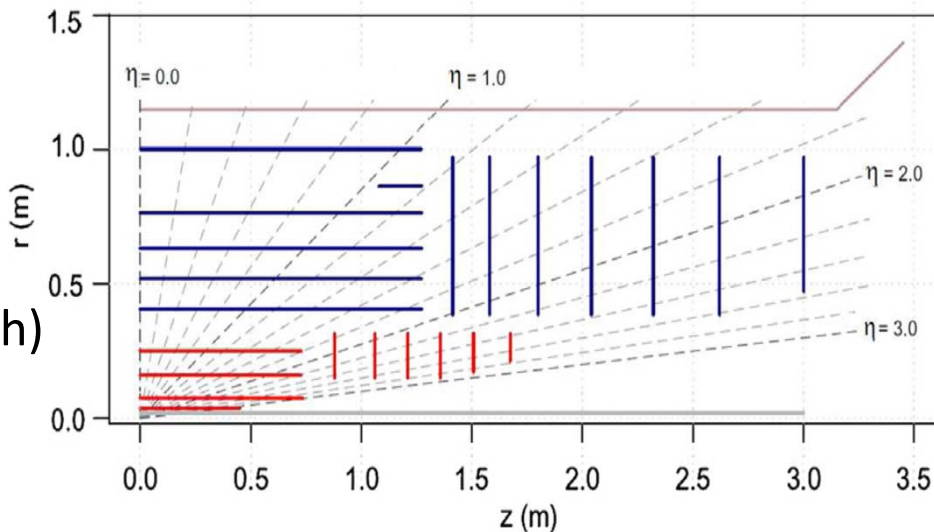
- Fast response \Rightarrow all Si
- Occupancy/ch $< 1\% \Rightarrow$ smaller ch
- Radiation hard (x10)
-

(tracking performance better than present ID)

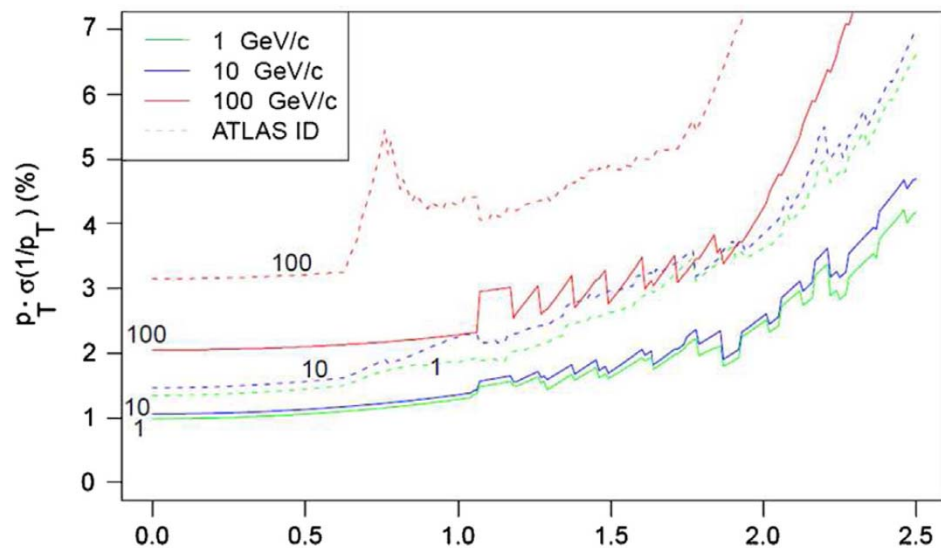
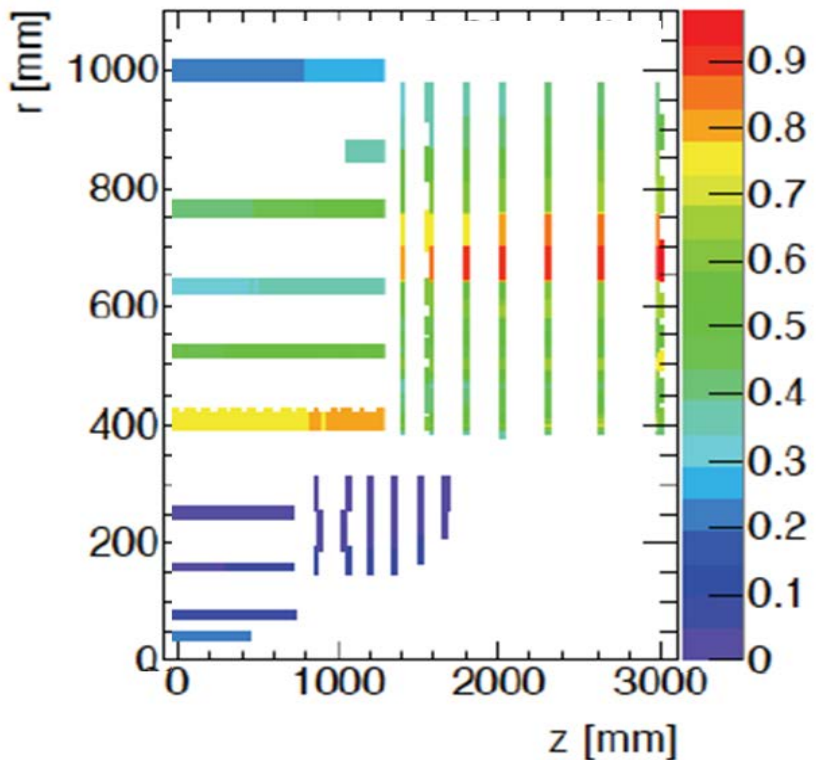
UPGRADE Baseline (LoI 2012) Design

Present: pixel(50x600um)
strip (80umx12.4 cm)

2+1 Long strip layers (74umx4.8cm)
3 Short strip layers (74umx2.4cm) :74Mch
4 pixel layers (25x150um,50x250um:638Mch)



Occupancy (%) for $\mu=200$

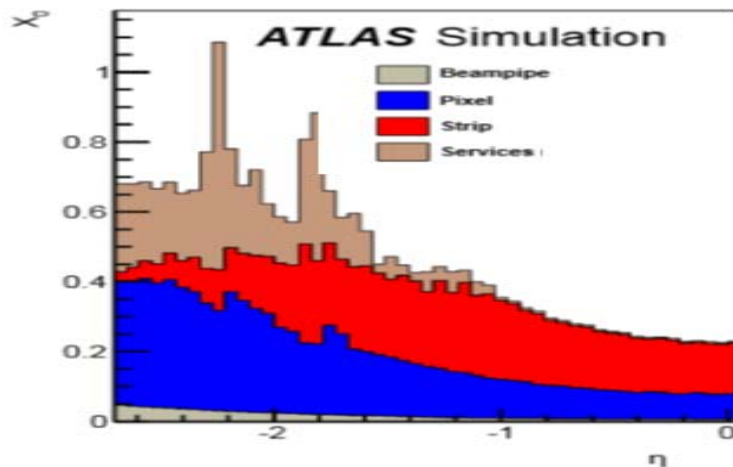


Pseudo-Rapidity η
 $\eta = -\ln \tan(\theta / 2)$

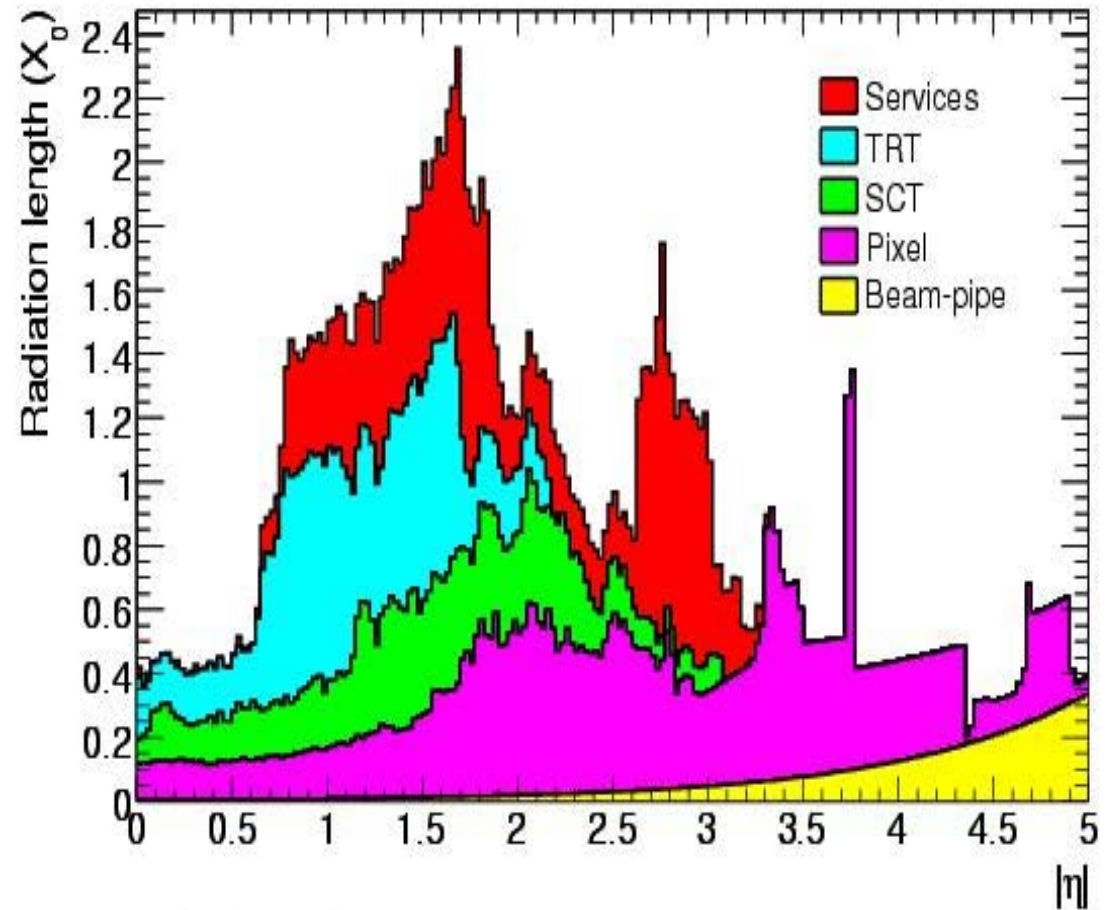
Material

Least material is important for

- ✓ Better energy measurement by Calorimeters
- ✓ Minimize Coulomb scattering
- ✓ Minimize secondary interaction



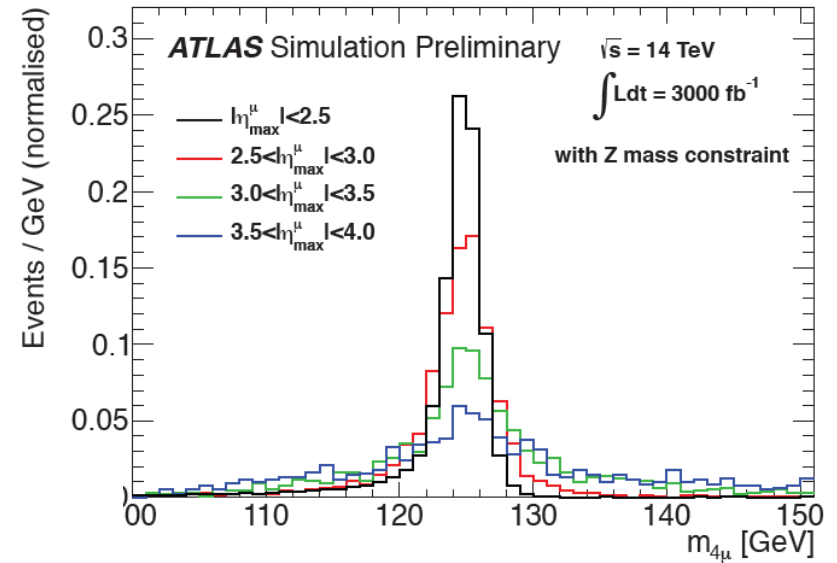
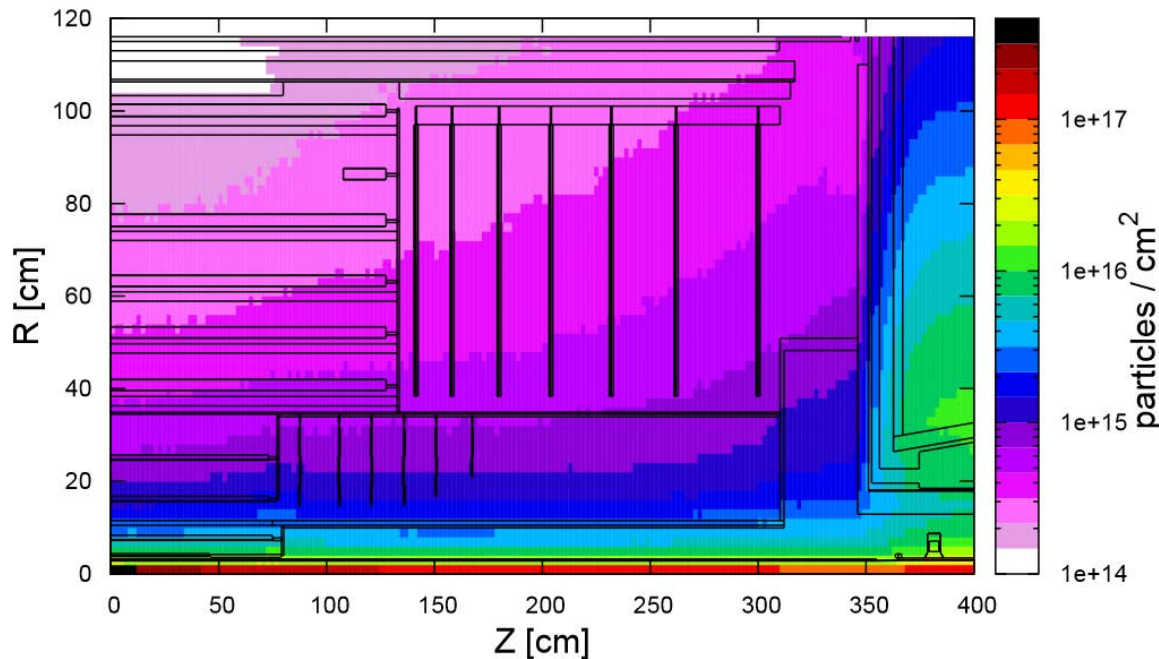
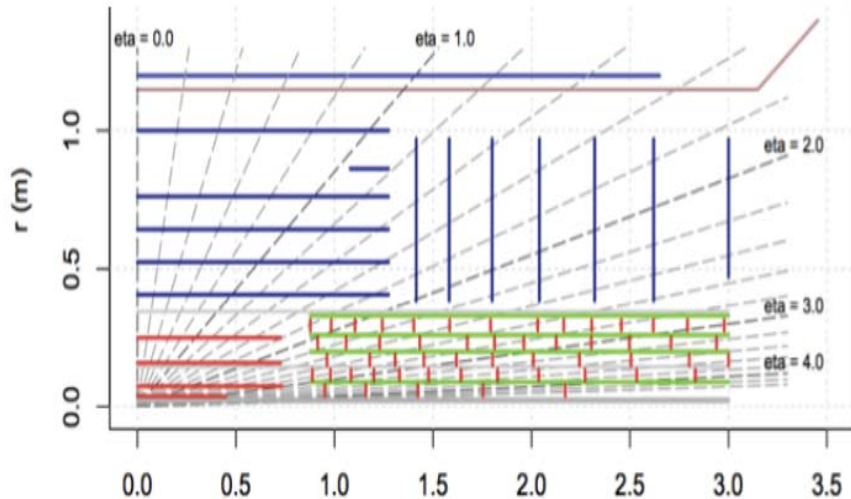
Baseline ITK



RUN-1 ID

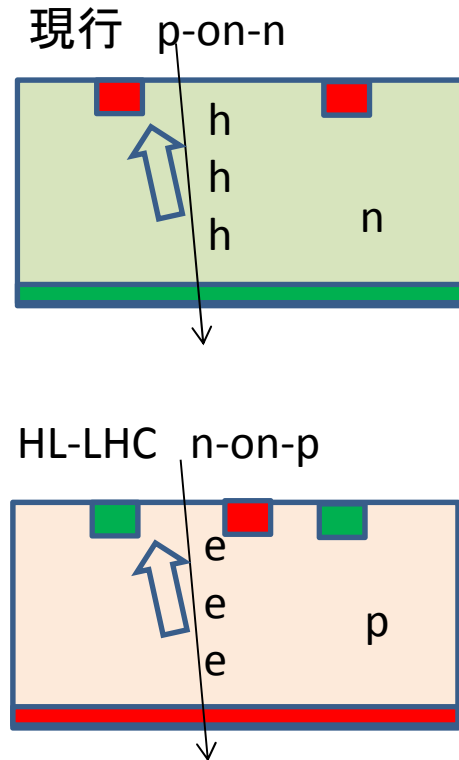
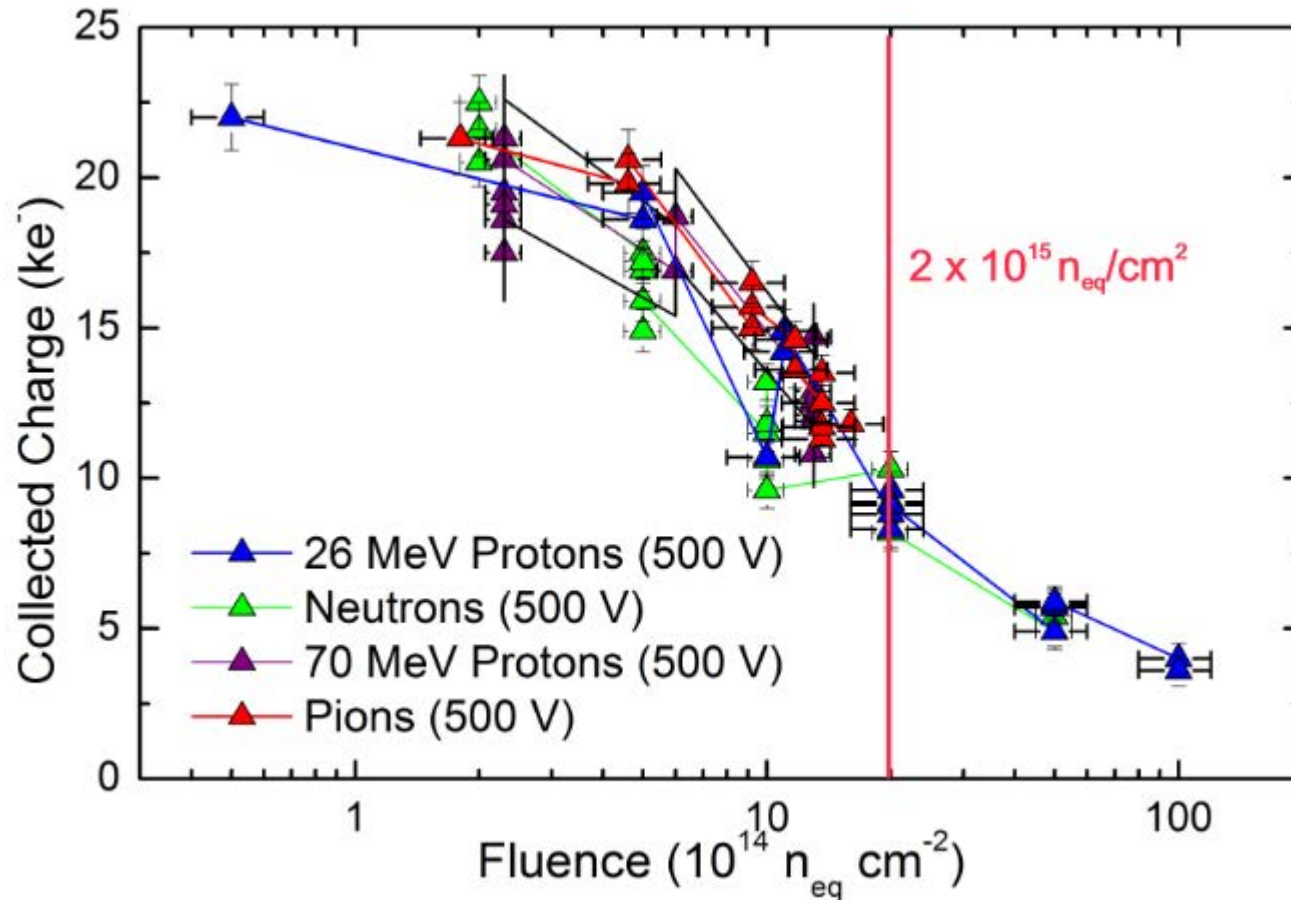
UPGRADE AGGRESSIVE DESIGN

Tracking down to $\eta=4.0$ ($\theta=2^\circ$): better coverage for multi-lepton events
(control SM background for HH production)



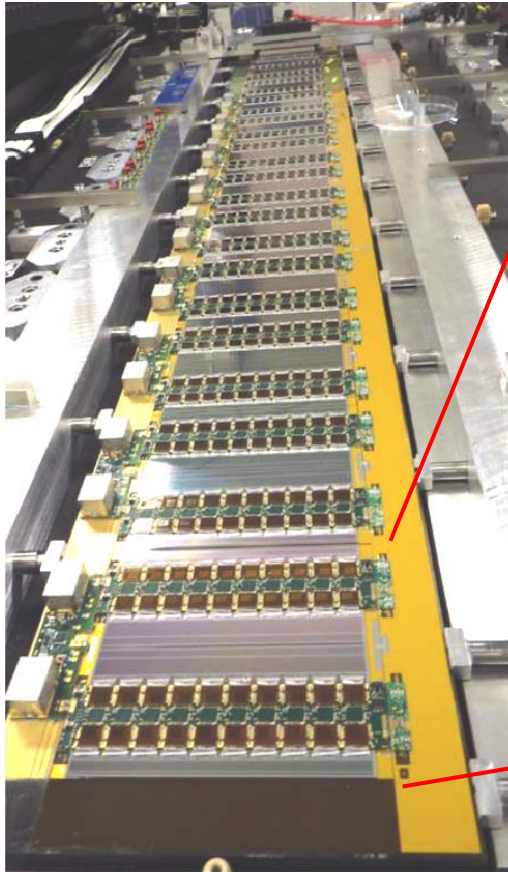
Pixel $< 1.3 \times 10^{16} / \text{cm}^2$, 11 MGy
Strip $< 6 \times 10^{14} / \text{cm}^2$, 3.5 MGy
(current Pixel $< 10^{15}$, Strip $< 10^{14}$)

Radiation Hardness

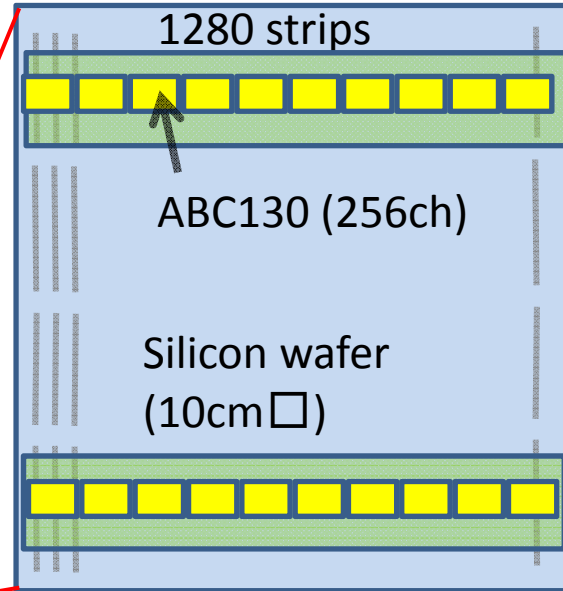


p型センサー(電子を収集)は従来のn型より、放射線耐性があり、HL-LHCでも十分な信号量が得られる S/N>20

Stave: baseline



New SCT – strip module



x13

present 0.8um DMILL

256ch-ABC130 CMOS 130nm
 Amp+shaper+comparator
 L0buffer (256/40MHz=6.3us)

L0A:calorimeter/muon in 6us

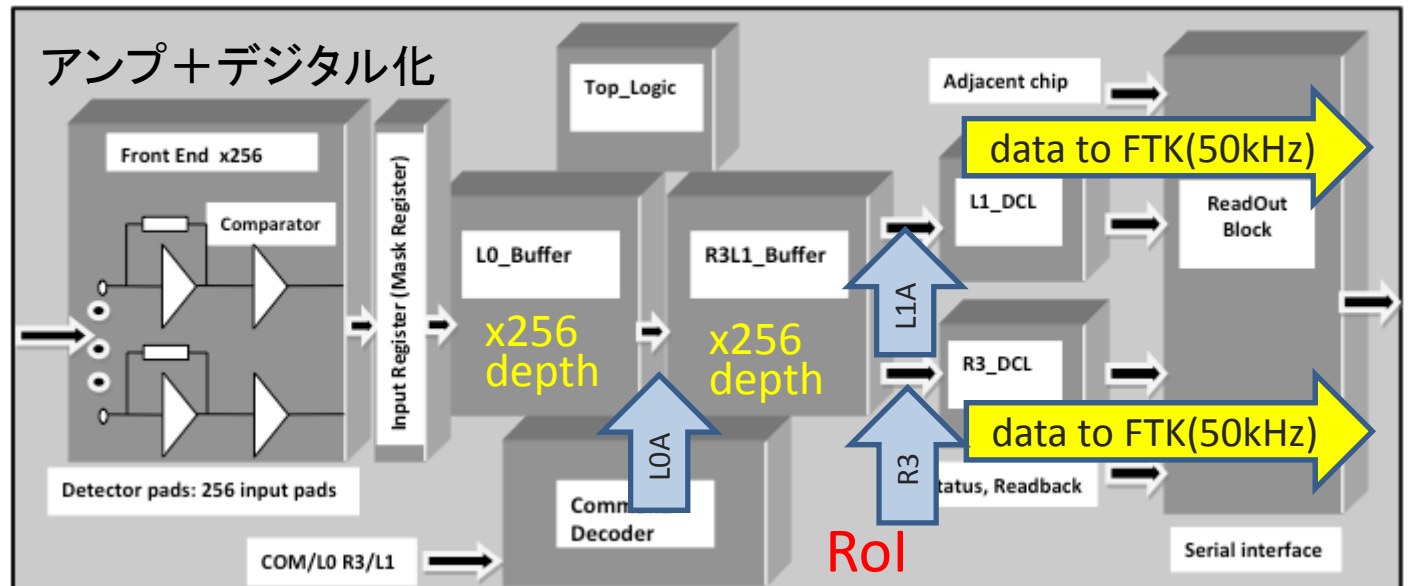
L1buffer (256/500kHz=512us)

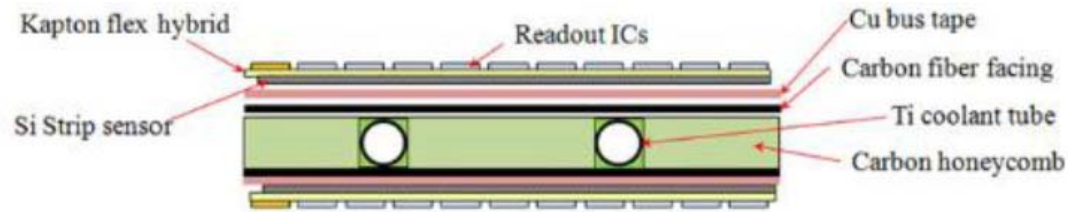
L1A:calo/muon/FTK in ~30us

L1buffer ← 3time slots



L1bufferでは直ちに clusteringをし、RoIに指定されたdataはFTK processorに転送



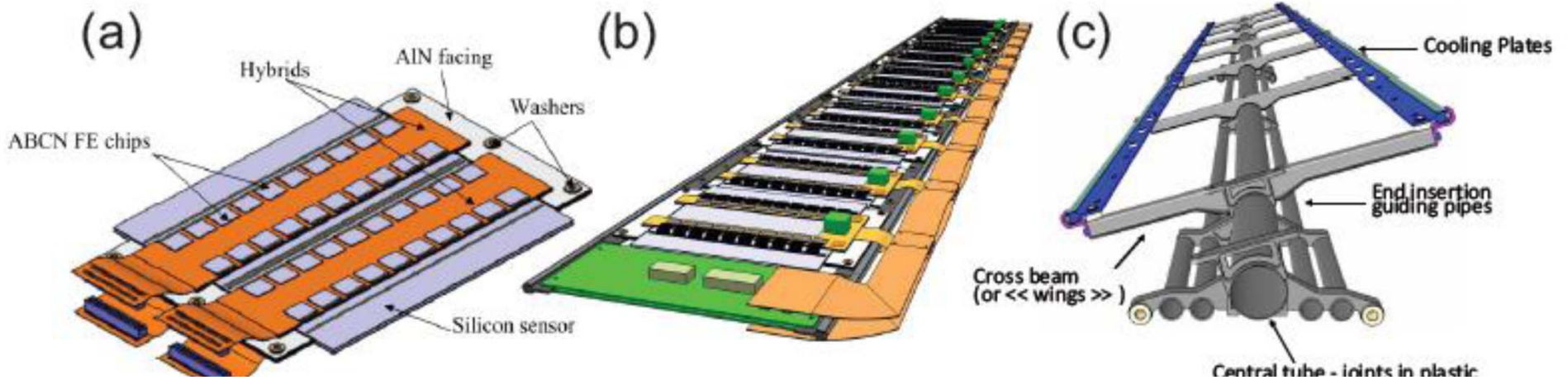


Stave - baseline



No major difference in performance
 Baseline : same concept also for endcap

Barrel SCT - backup



New PIXELs – 放射線耐性, cost,....

- Standard Planer Pixel

- 150um high resistive silicon [n-on-n (inner) and n-on-p(outer)]

- 3D Sensor

- Used in IBL

- Diamond

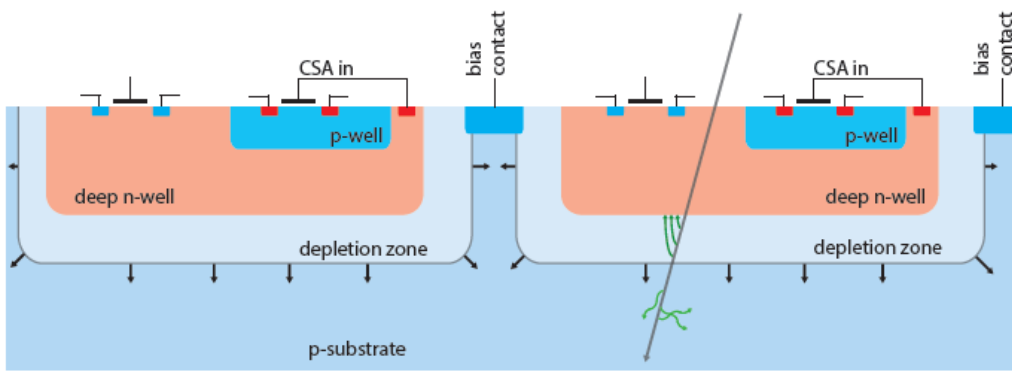
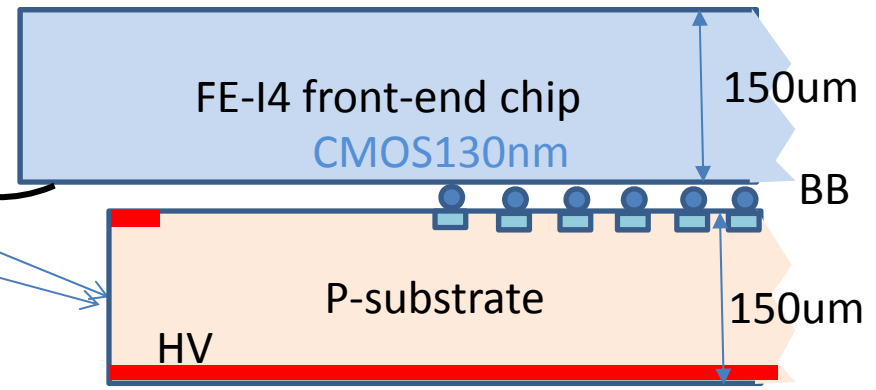
- Used in BCM

- CMOS

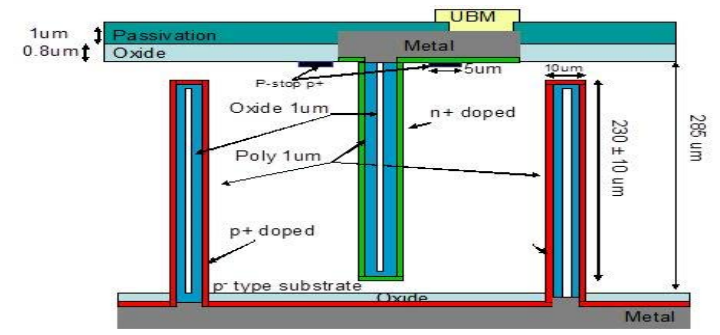
- New, cheap

Replace with 3D

Replace with diamond



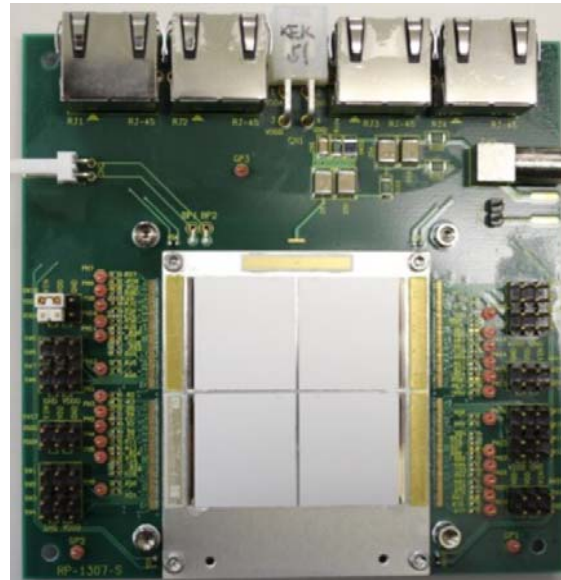
CMOS



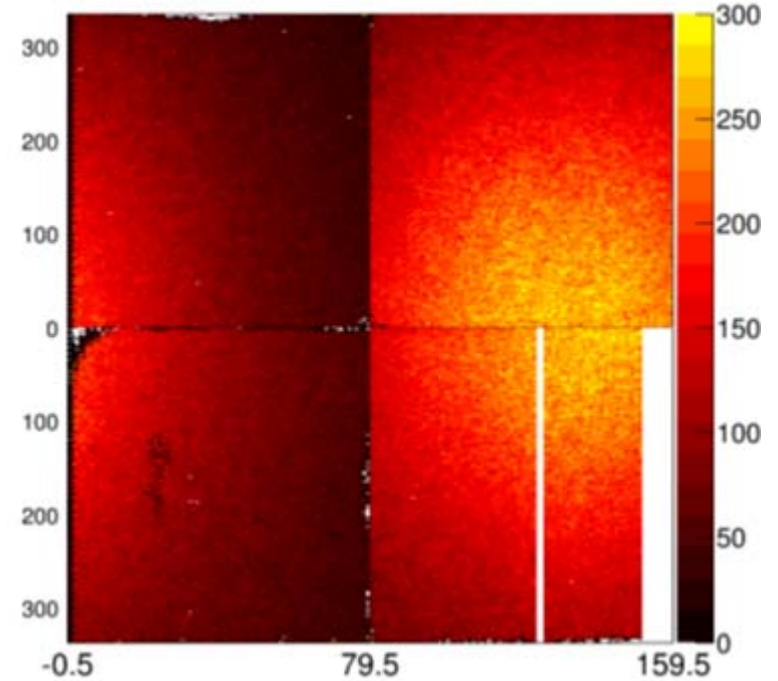
3D

Planar p-bulk pixel

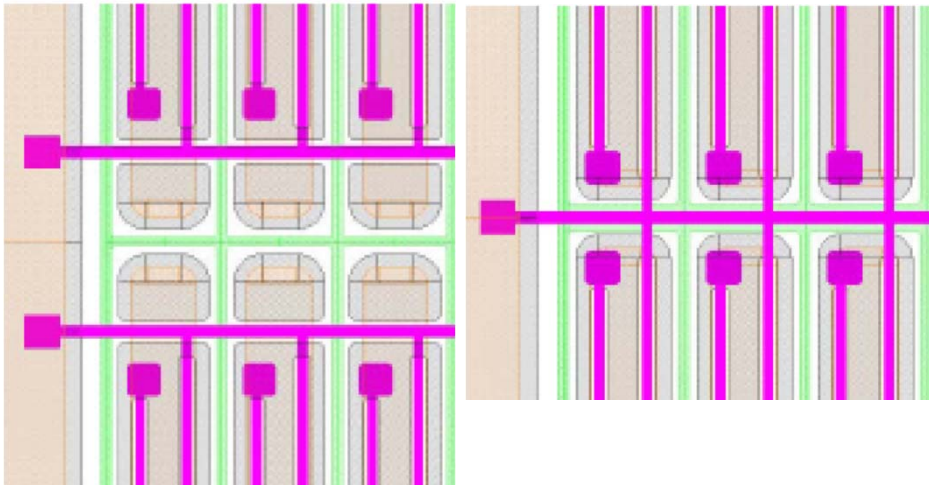
4-chip test module
(chip=2x2cm)



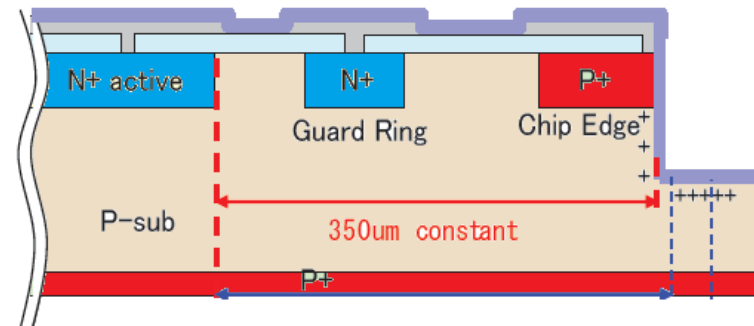
1. Bump bonding (SnAg)
Noise distribution



2. optimize bias routing



3. Edge protection



0. radiation tolerance

まとめ

- ATLAS検出器は予定通りに稼動し、Higgs粒子を発見した。精度の高い測定を継続するために、加速器および検出器のUPGRADEが行われる。
- 2023年以降のHL-LHCでは、すべてシリコン検出器で構成されるITK
 - PIXEL検出器(candidates – cost, rad-hardnessでchoice)
 - STRIP検出器(sensor selectionはほぼ決定)
- PHASE2 upgrade技術設計書2016年
- 建設開始2017年