９月１１日　日本物理学会2010年秋期大会　シンポジウム

エネルギーフロンティアの新たな地平
～LHC最初の２００日間～

ATLAS測定器のパフォーマンス

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Tau Lepton Physics Research Center

ATLAS Japan

Outline

データ収集状況

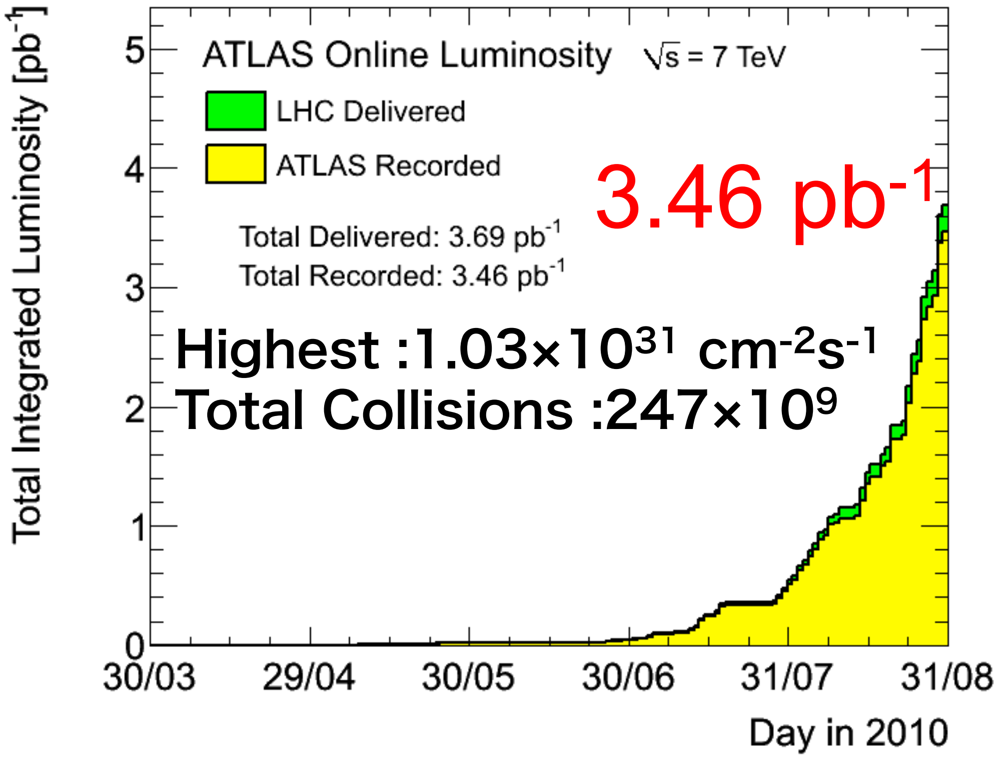
ATLAS測定器

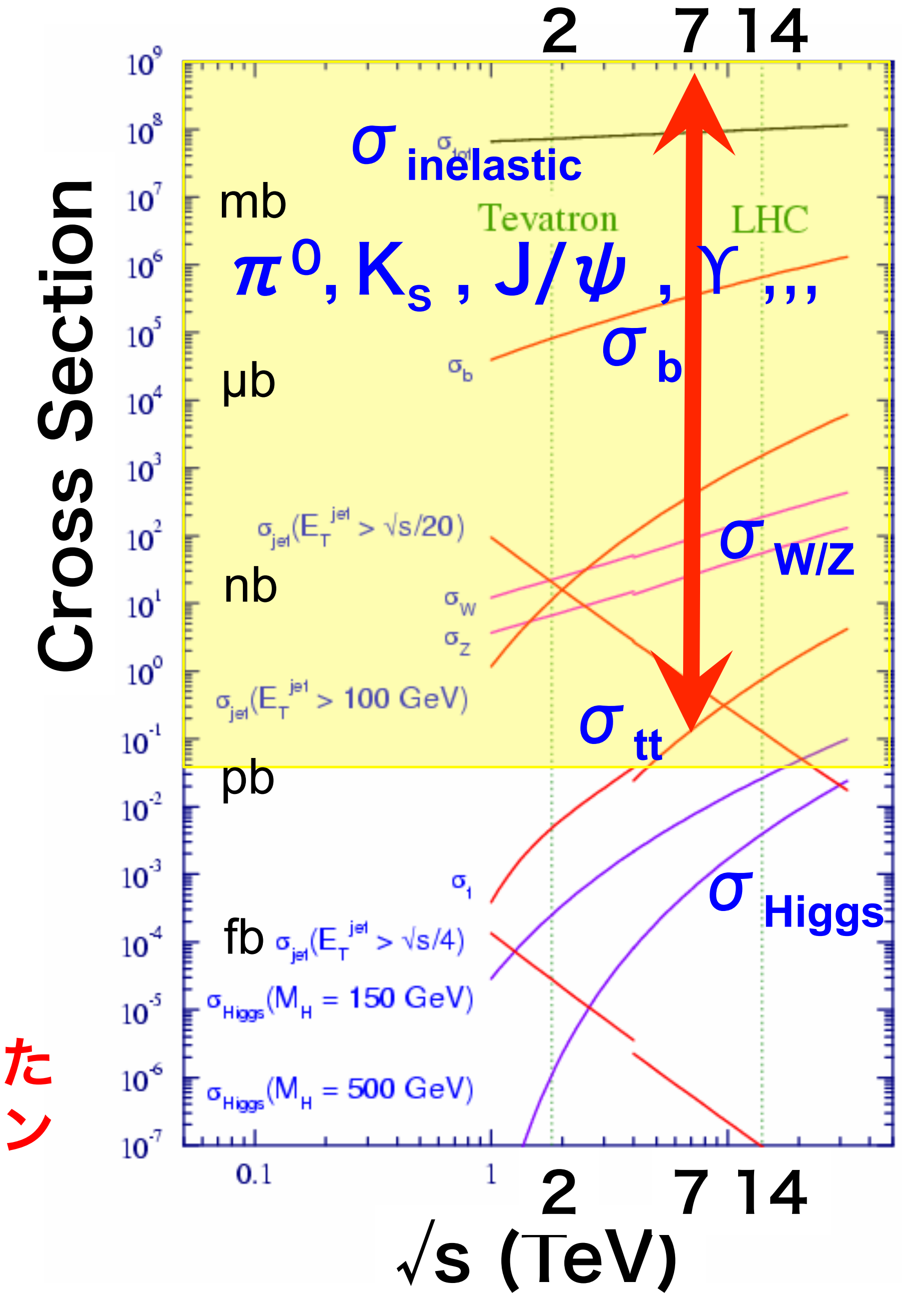
測定器パフォーマンス

まとめ

現在のATLAS

宇宙線→900GeV衝突を経て、
世界最高重心系エネルギー7TeV
3月30日〜8月31日（153日間）





○ 安定粒子、なじみ深い共鳴粒子を用いた測定器の性能評価とキャリブレーション
○ 標準模型素粒子の再発掘
○ 21世紀素粒子世界の発掘へ

A Toroidal LHC ApparatuS

Calorimeters:
LAr & Tile

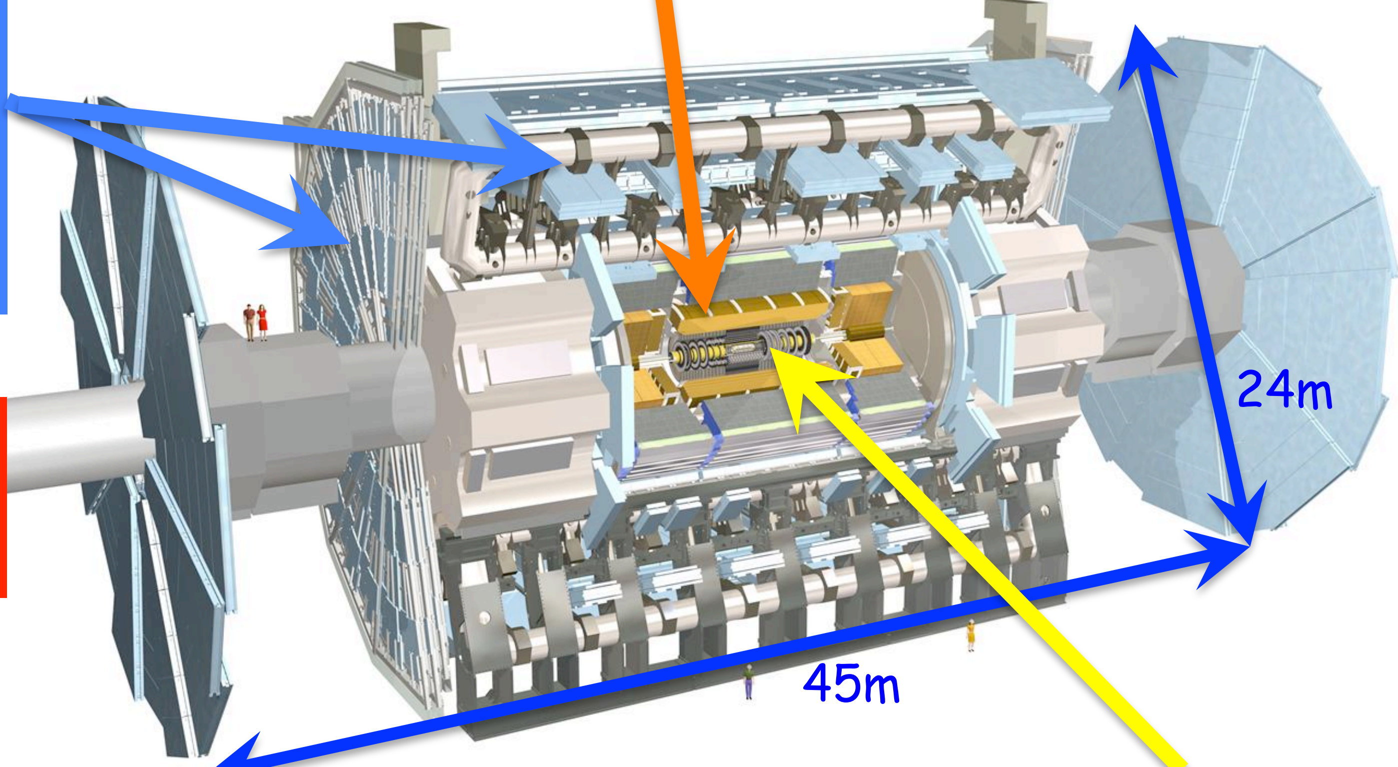
e/γ $\frac{\sigma(E)}{E} = \frac{10\%}{E} + 0.7\%$

Hadron $\frac{\sigma(E)}{E} = \frac{50\%}{E} + 3\%$ |η|<3, $\frac{\sigma(E)}{E} = \frac{100\%}{E} + 10\%$ |η|>3

Muons:

Trigger **TGC** **RPC**

Precision **CSC** **MDT**



大きさ：24m × 45m
重量：7000 トン
読み出し：1億6千万

Magnets:

Solenoid : 2テスラ

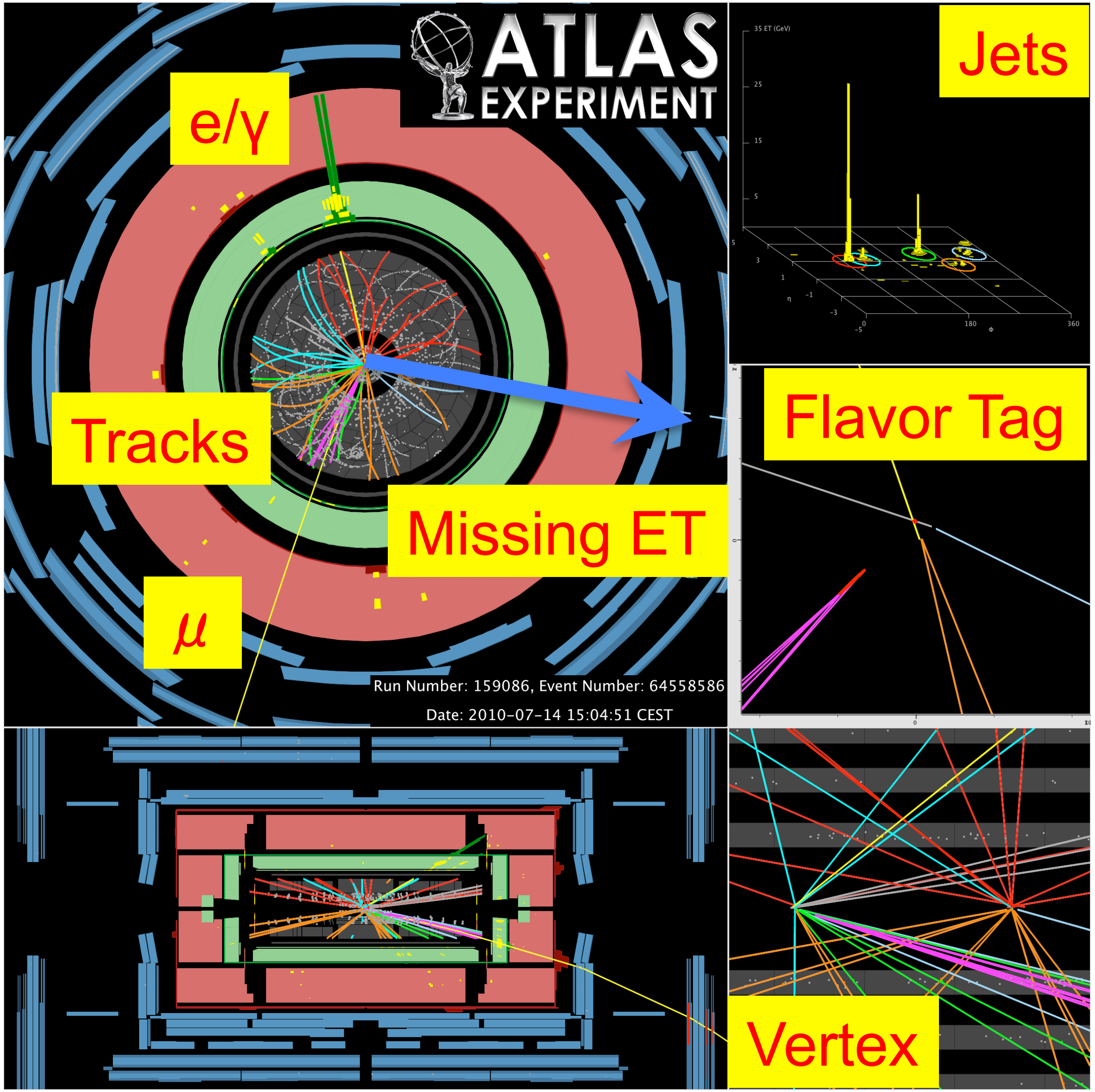
Toroidal :

$\int B \times d\ell$ = 2~6 (T×m)

Inner Tracker: $\frac{\sigma}{P_T} = 0.05\% \times P_T + 1\%$ (2% @ 20GeV)

Pixel:	**SCT:**	**TRT:**
50×400μm²	80μm × 6cm	4mmφ straw tube
80M channels	7M channels	350k channels

測定器に何が求められるか？

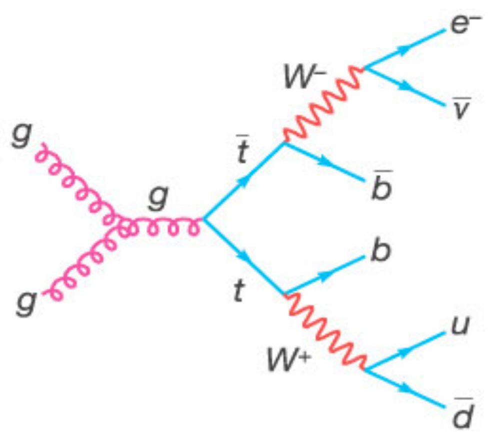


- 荷電粒子運動量
- 衝突点

- エネルギー
  e, γ, quark, gluon
- 欠損エネルギー
  ν, SUSY(?)

-μ粒子識別

-Flavor(b, τ)の識別

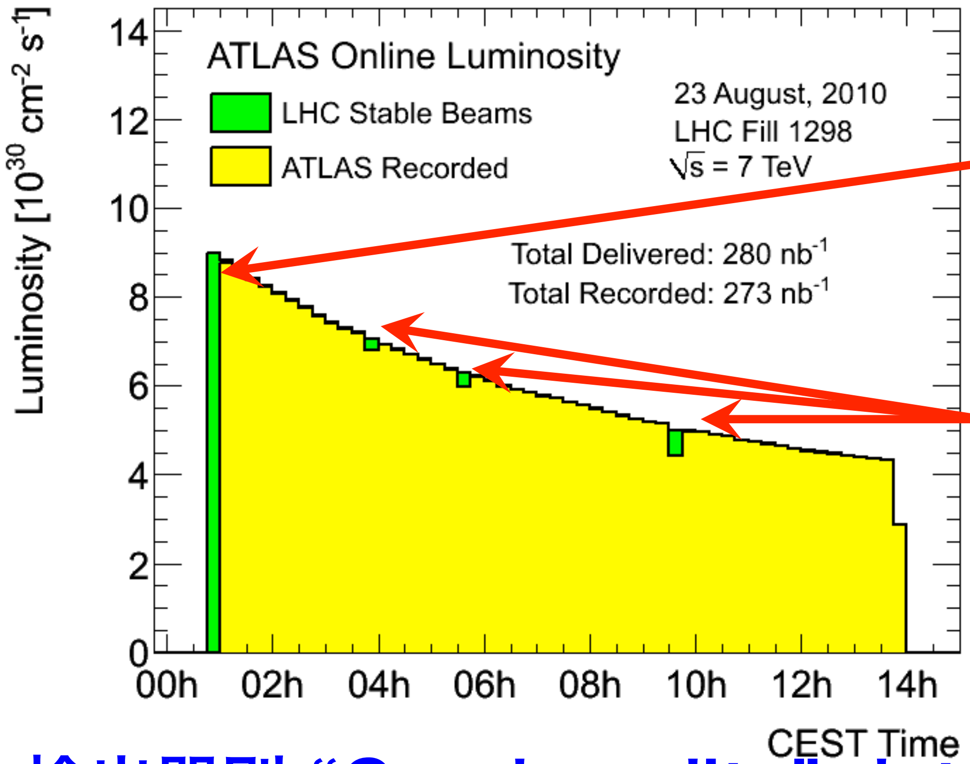


高い検出器稼働率

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.4%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.6%

> 97%の稼働率

典型的なデータ収集



Stable beam flagで
測定器Warm Start
(Standby → Readyへ)

BUSY→ Auto-recovery

94%のデータ収集効率

検出器別 "Good quality" data収集率

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
97.7	96.4	100	94.4	98.7	99.3	99.2	98.5	98.3	98.6	98.3

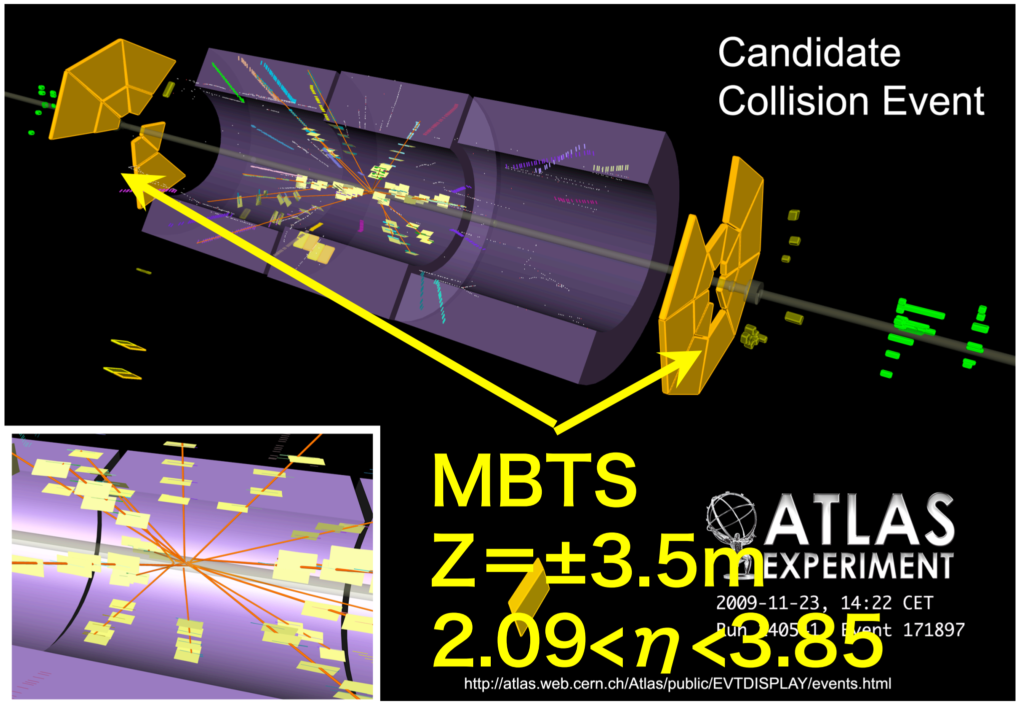
Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at √s=7 TeV between March 30th and August 14th (in %)

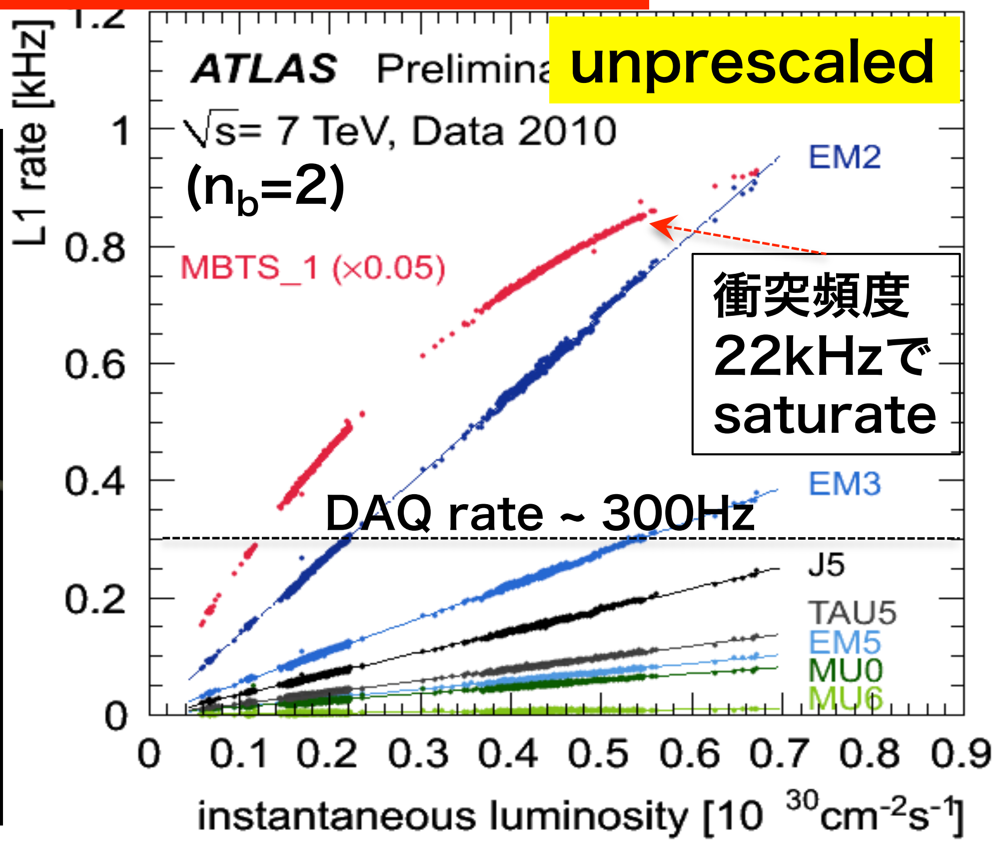
Trigger

$10^{27} cm^{-2}s^{-1}$

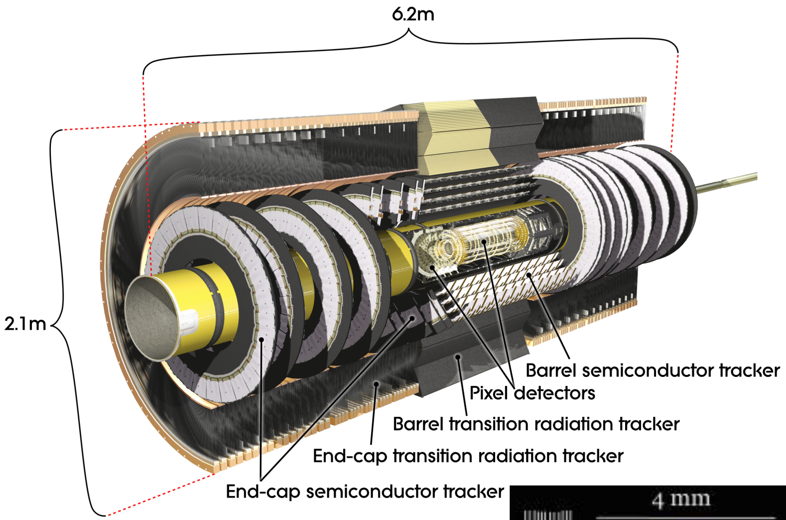
- Minimum Bias Scintillator Trigger
- Minimum Bias Scintillator Trigger prescaled
- L1 Trigger (e/γ, Jet, μ, τ, missing E_T) activate
- High Level Trigger monitoring mode
- High Level Trigger activate
- L1 Trigger with low threshold pre-scaled

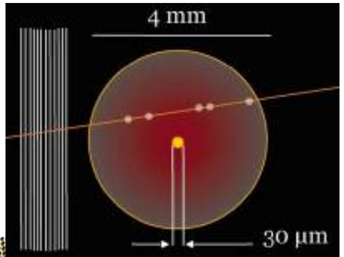
$10^{31} cm^{-2}s^{-1}$

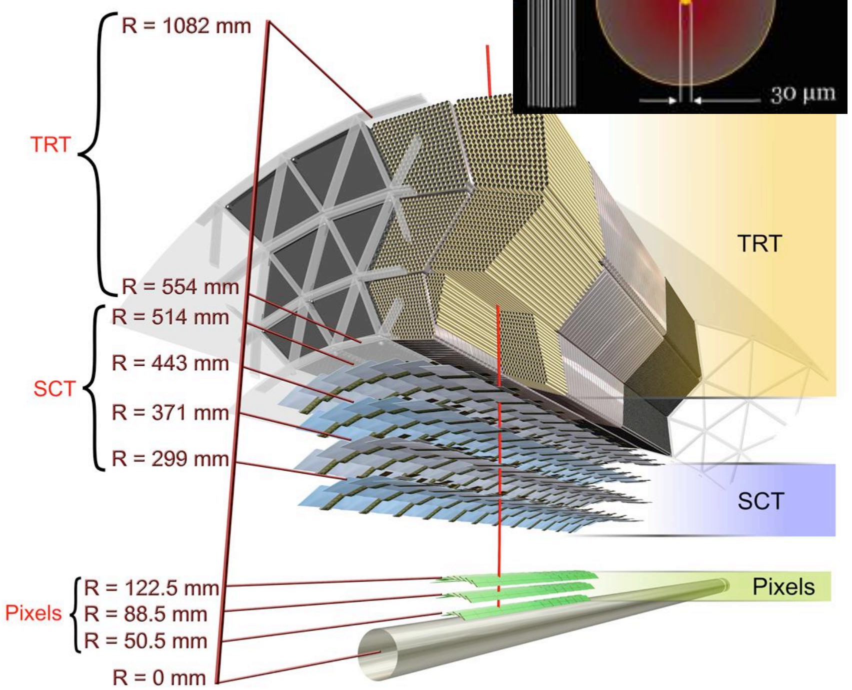




ATLAS Inner Detector (ID)







2テスラのソレノイド磁場中で運転

Pixel detector

3 barrel layers (r = 5, 9, 12 cm)
2x3 Forward disks
1744 modules, 80M channels
Resolution : 10μm(rϕ) x 115μm (z)

Semiconductor Tracker (SCT)

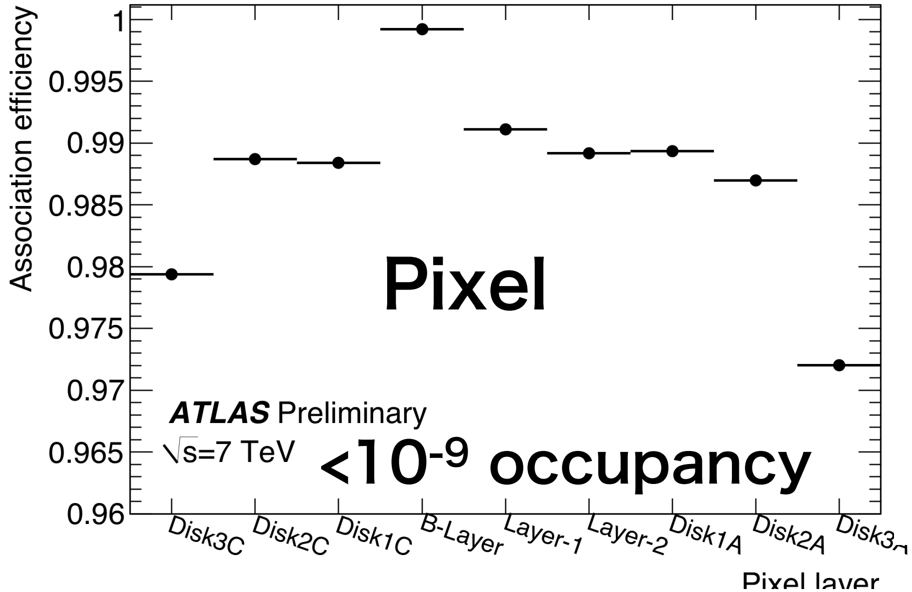
4 barrel layers (r = 30, 37, 44, 51 cm)
2x9 forward disks,
4088 modules with 80μm strips
6M channels
Resolution : 17μm(rϕ) x 580μm (z)

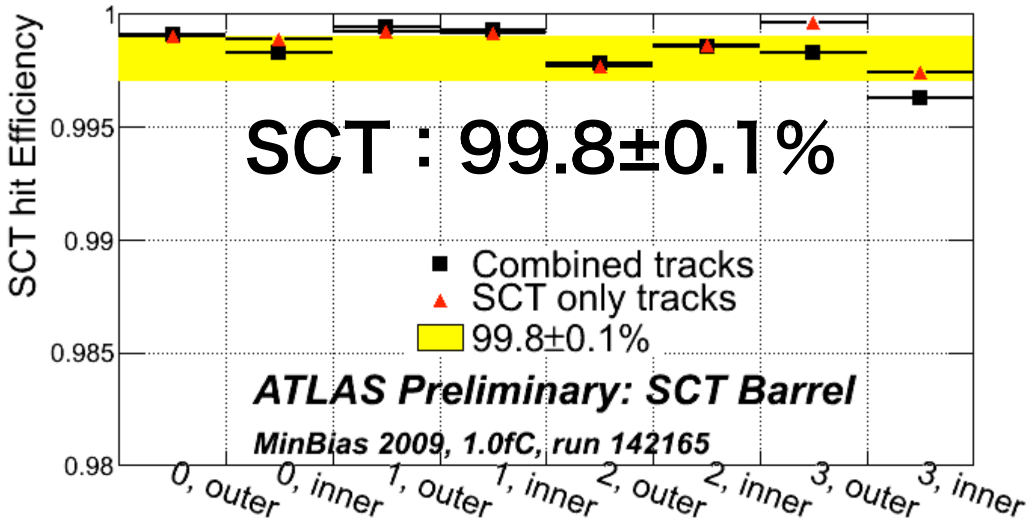
Transition Radiation Tracker (TRT)

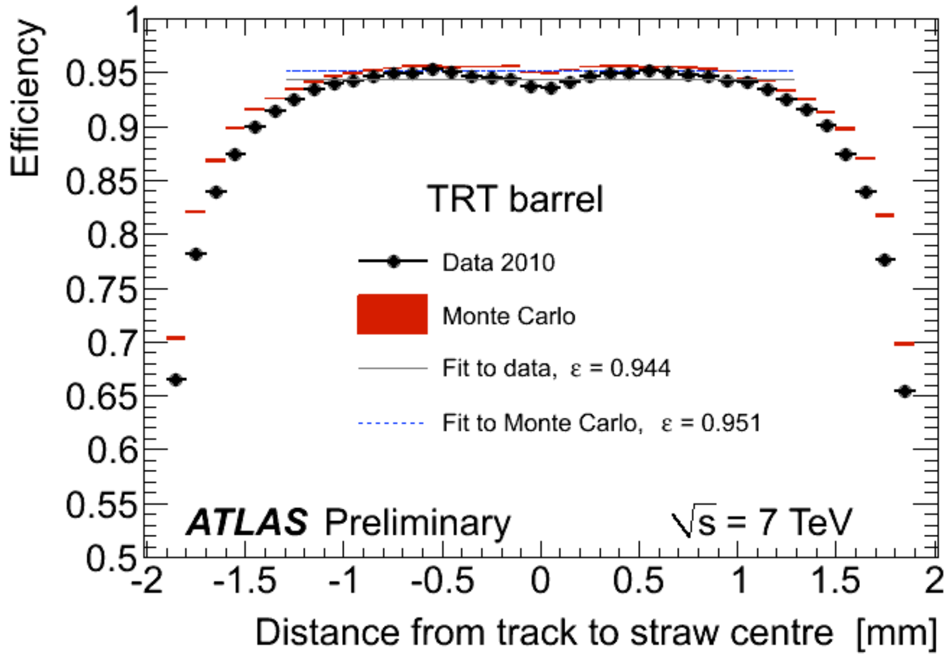
4mm straw tubes, 35μm anode wires
Gas … Xe(70%) : CO_2 (27%): O_2 (3%)
73 barrel layers
2 x 160 radial straws in forward
351K channels
Resolution : 130μm(rϕ)
Polypropylene radiator for e ID

ID Hit 効率

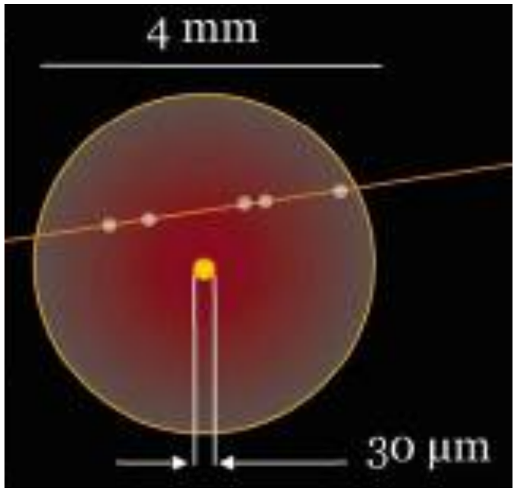
Layer毎の効率





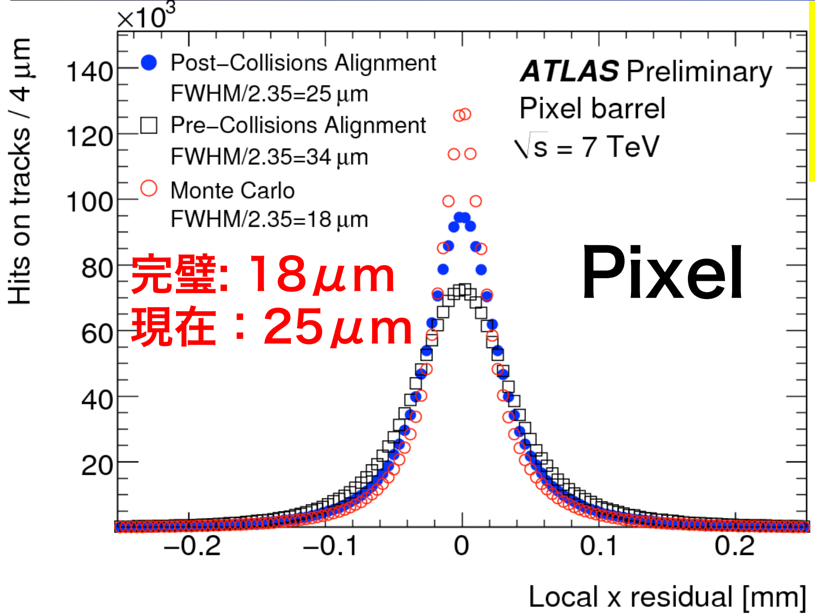


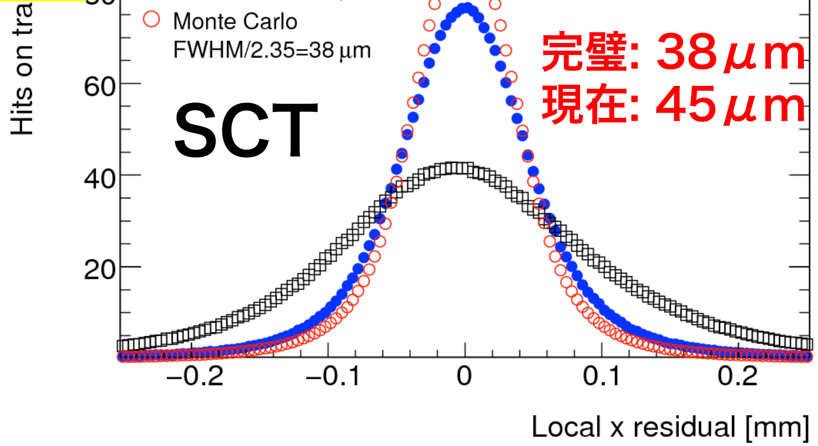
Straw中心から距離



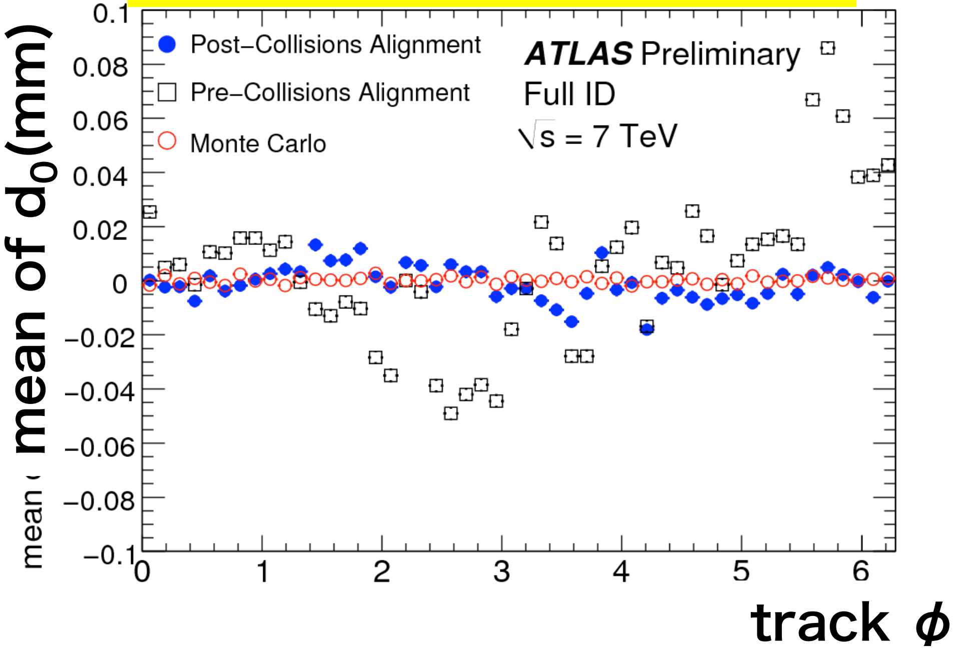
ID Alignment

Track-Hit Residual





Impact Parameterのφ依存

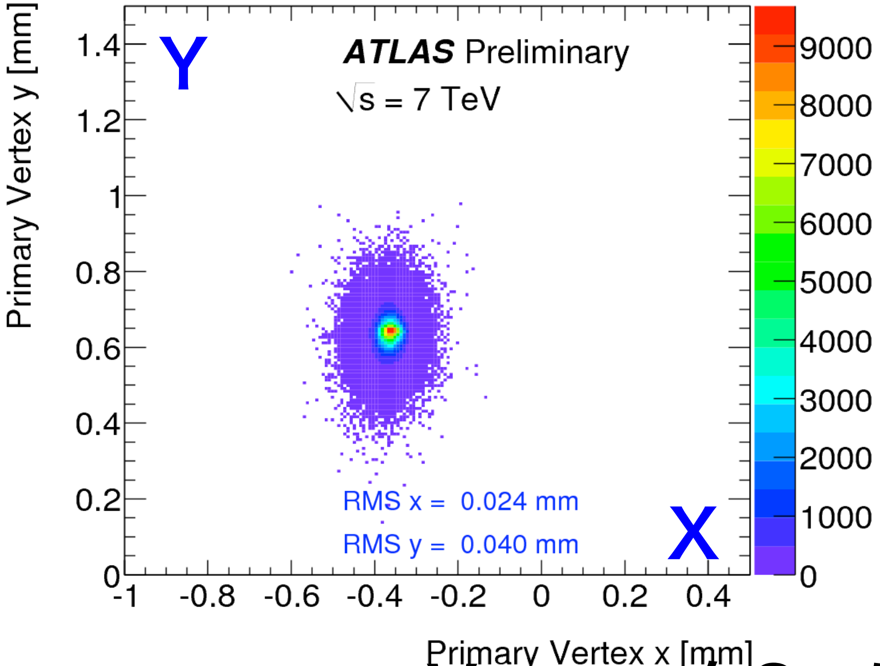


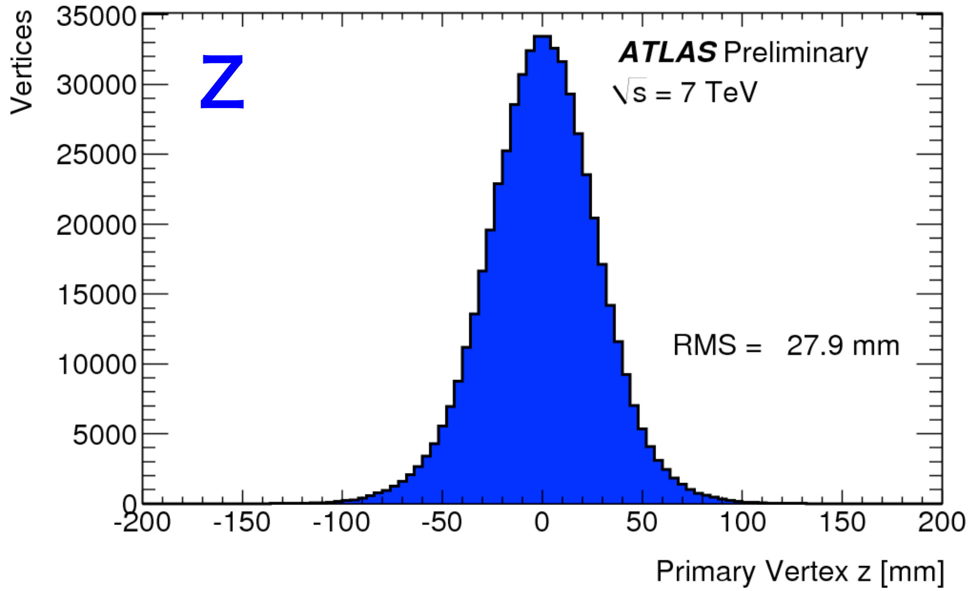
Post collision で明らかな改善
既にidealに近い

それぞれのモジュール
(Pixel:1744, SCT:4088)
に6つの自由度(移動３+回転３)

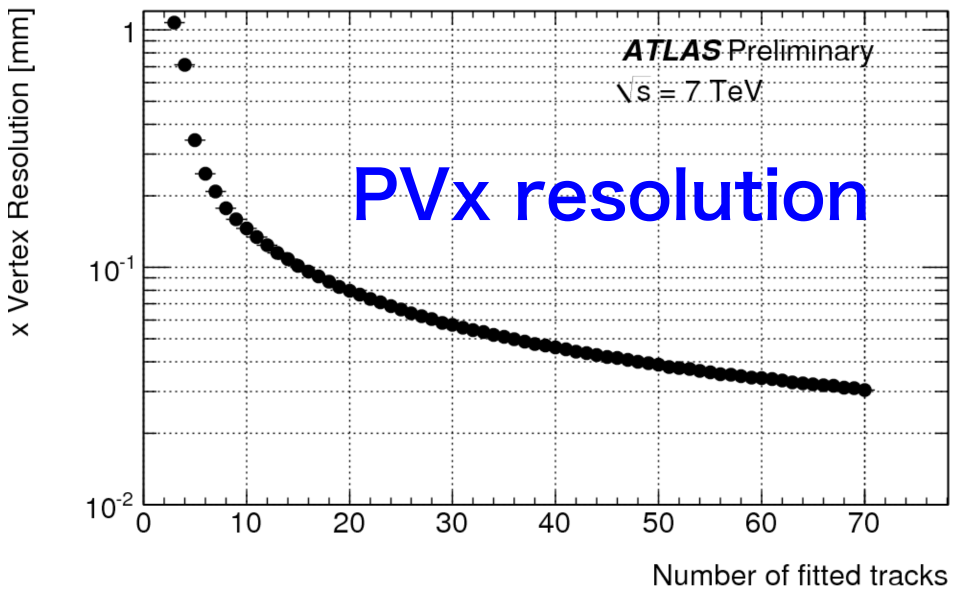
→ 完璧に向け大量の飛跡が必要

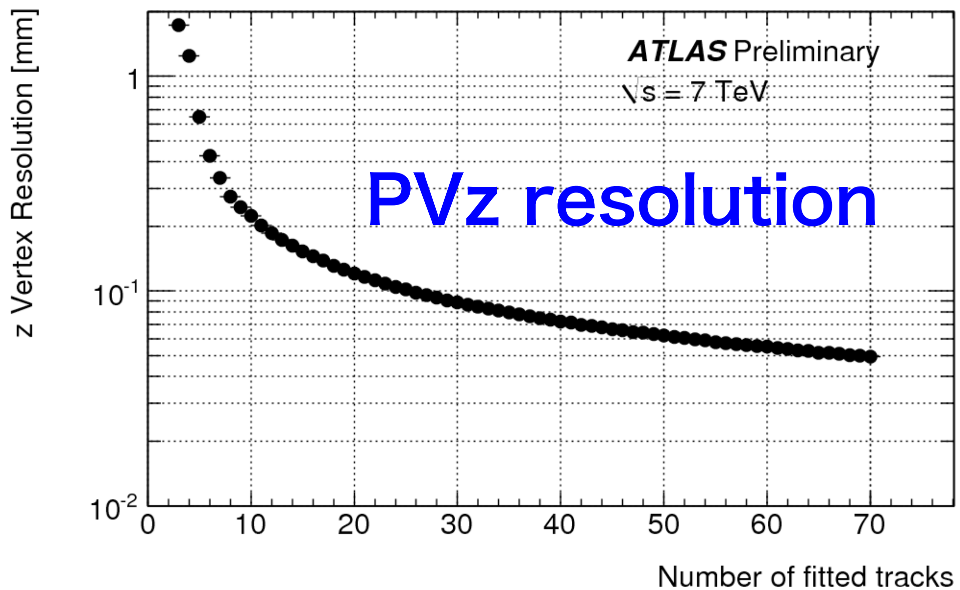
Primary Vertex





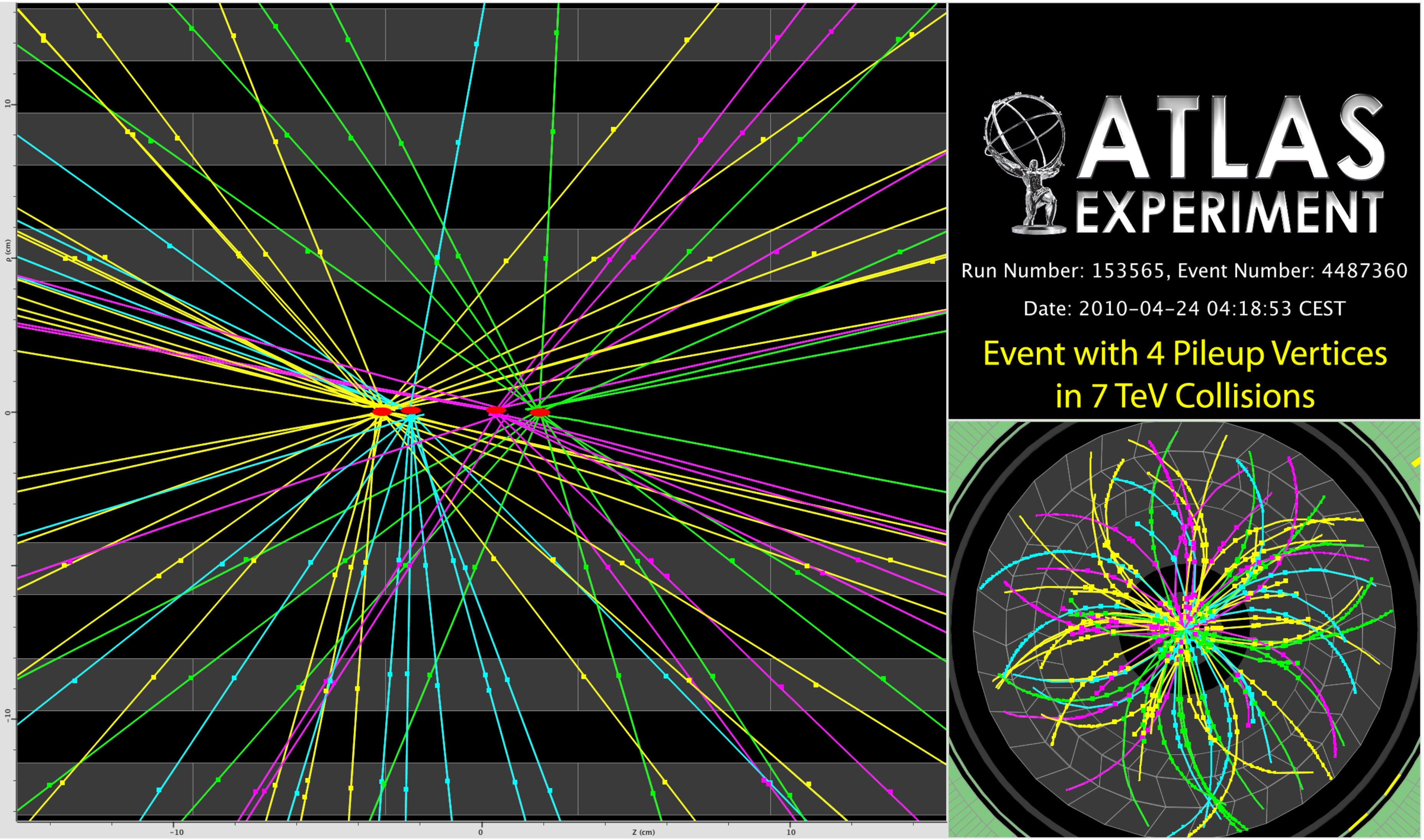
Vertex を2つに分けてresolutionを評価





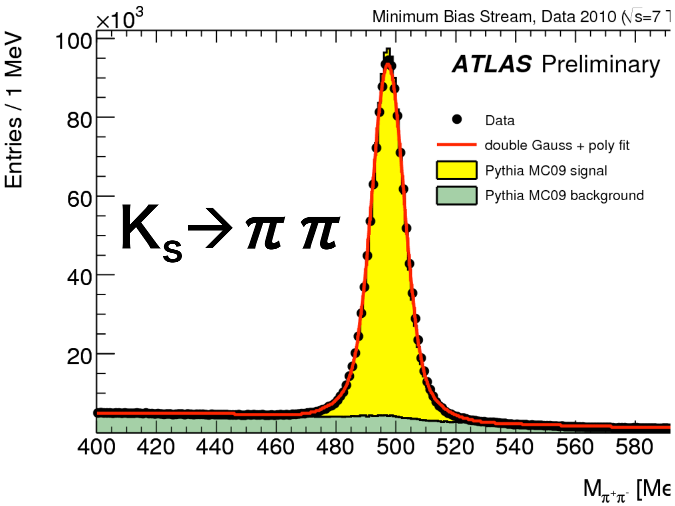
Event with 4 Pileup Vertices

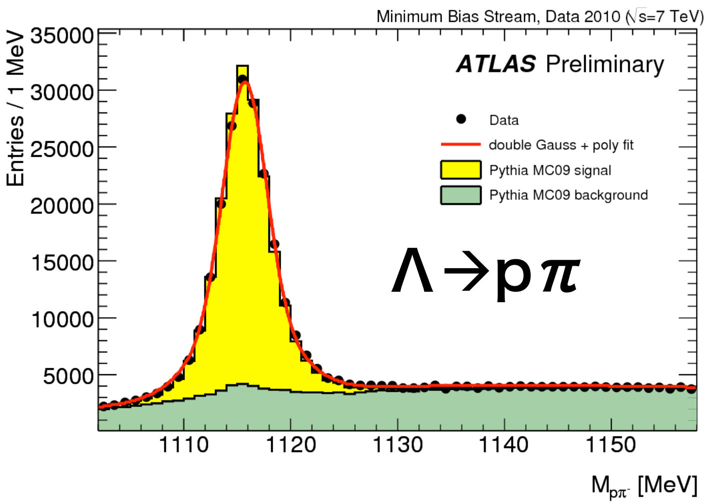
~10 - 45 tracks with p_T >150 MeV per vertex (σ_{zvtx} < ~200 μm)
Vertex z-positions : –3.2, –2.3, 0.5, 1.9 cm

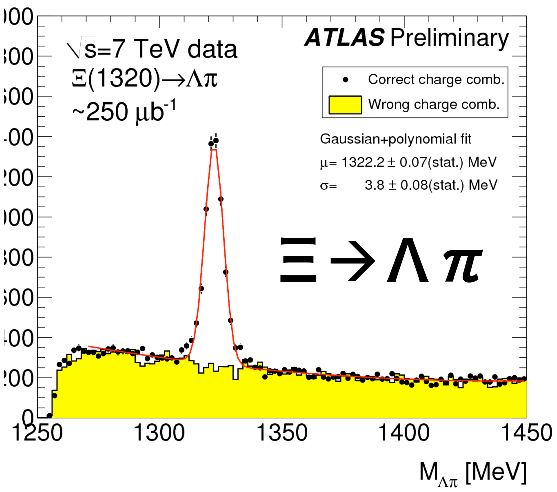


どんどん物理解析が複雑に。。。

Resonances







497.427±0.006 MeV

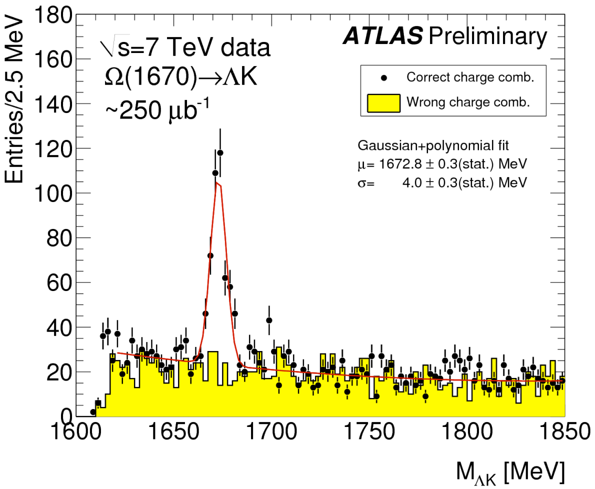
1115.73±0.01 MeV

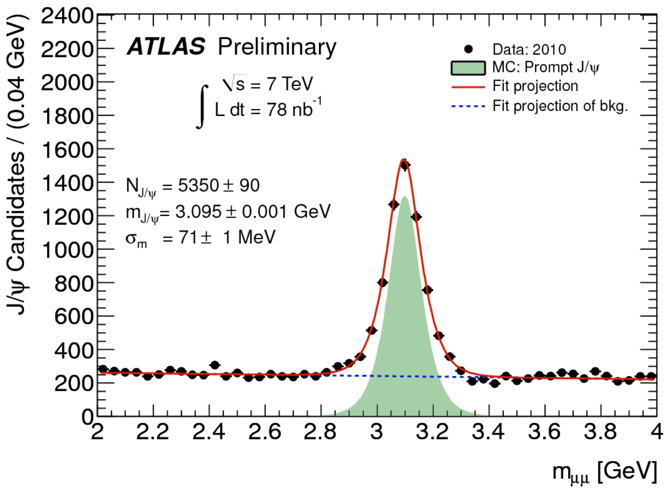
1322.7220.07 MeV

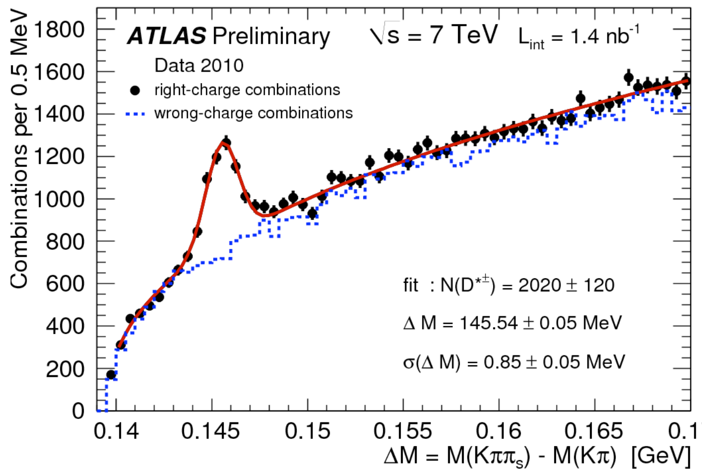
Ω→ΛK

J/ψ→μμ

D*:M(Kππ)-M(Kπ)

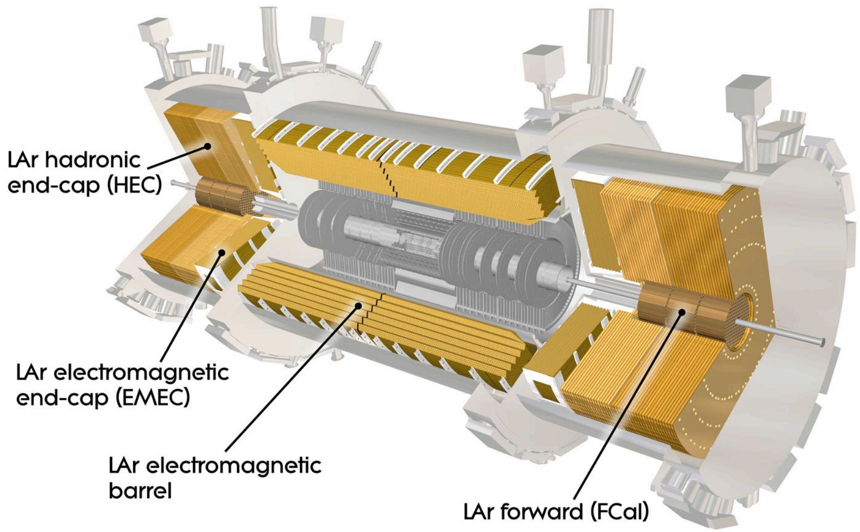


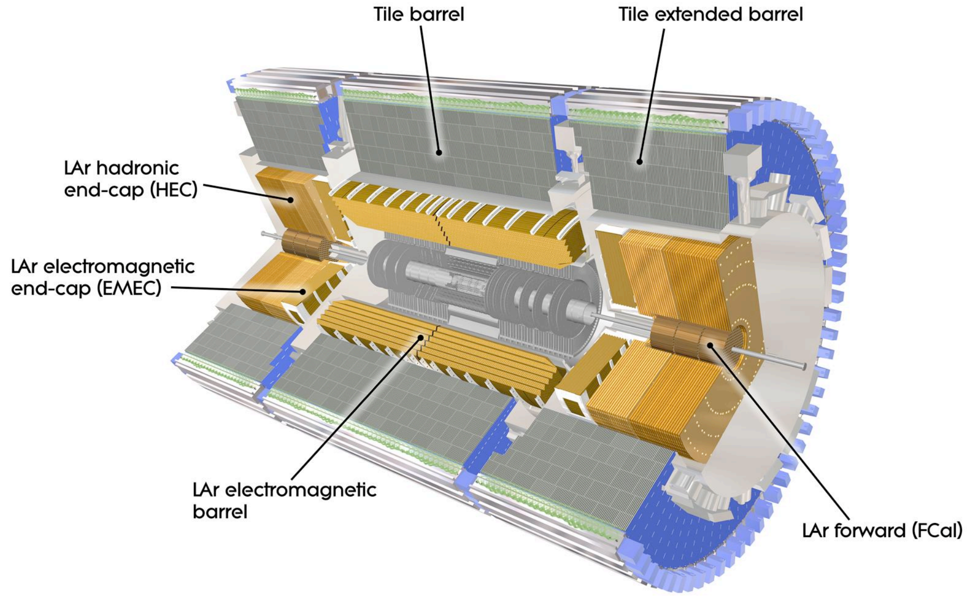




1672.78±0.33 MeV

Calorimeter





Complete azimuthally symmetry, coverage $\eta < 4.9$

Electromagnetic Calorimeter

Pb-LAr accordion geometry
3 longitudinal samples
Preshower detector $\eta < 1.8$
173K channels

$$\frac{\sigma(E)}{E} = \frac{10\%}{E} + 0.7\% \quad \eta < 2.5$$

Hadron Calorimeter

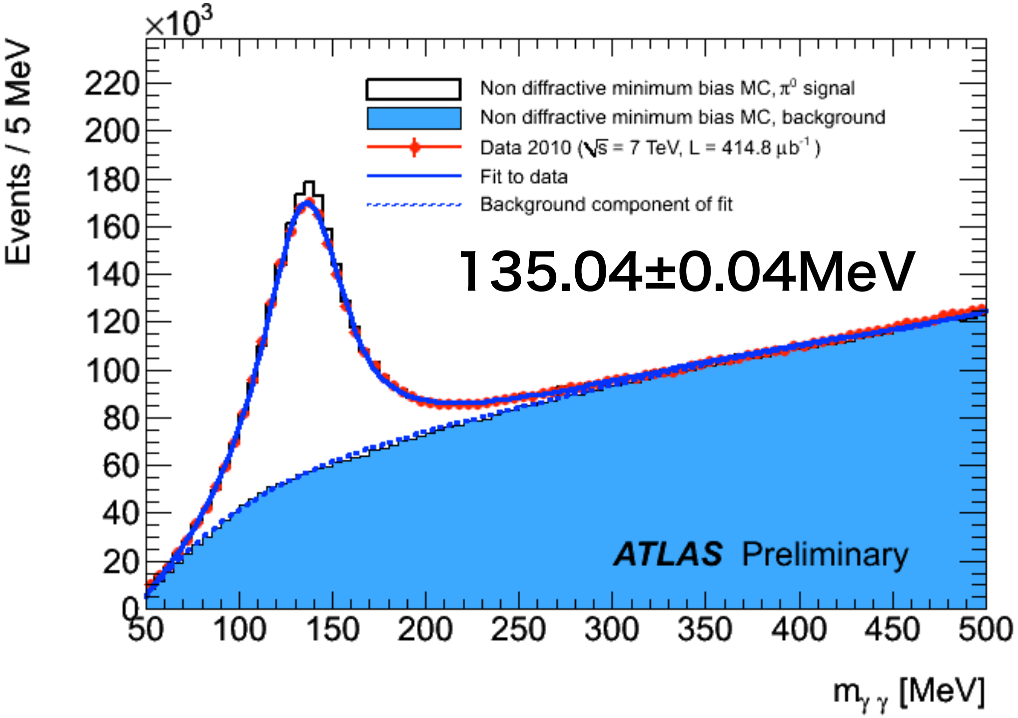
Barrel : Iron scintillator tiles
3 longitudinal samples
Endcap/Forward : Cu/W-LAr
4/3 longitudinal samples
20K samples

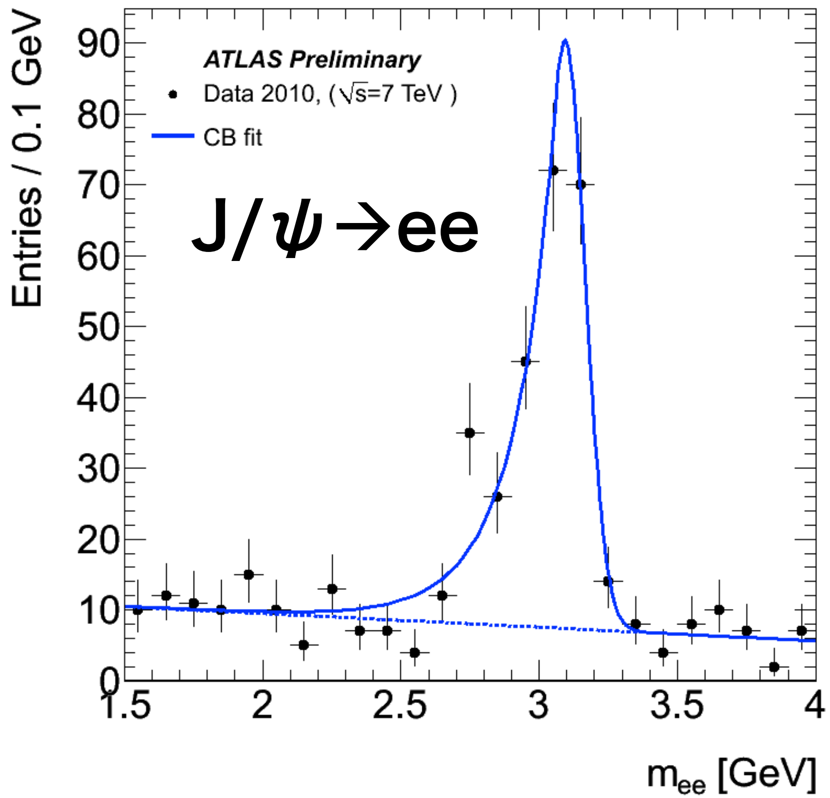
$$\frac{\sigma(E)}{E} = \frac{50\%}{E} + 3\% \quad \eta < 3.2$$

$$\frac{\sigma(E)}{E} = \frac{100\%}{E} + 10\% \quad \eta > 3.2$$

EM Calorimetry

$\pi^0 \rightarrow \gamma\gamma$



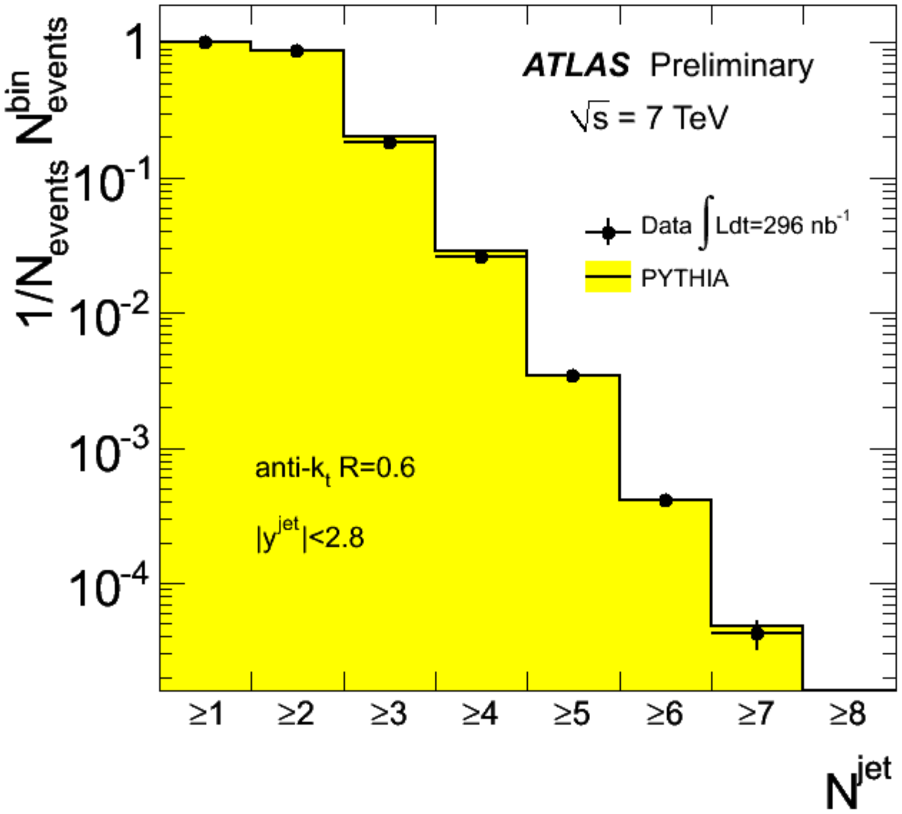


EM response uniformity
~2% in η, <0.7 % in ϕ

222±11 signals
28±2 backgrounds
3.09±0.01GeV
0.07GeV ±0.01 GeV

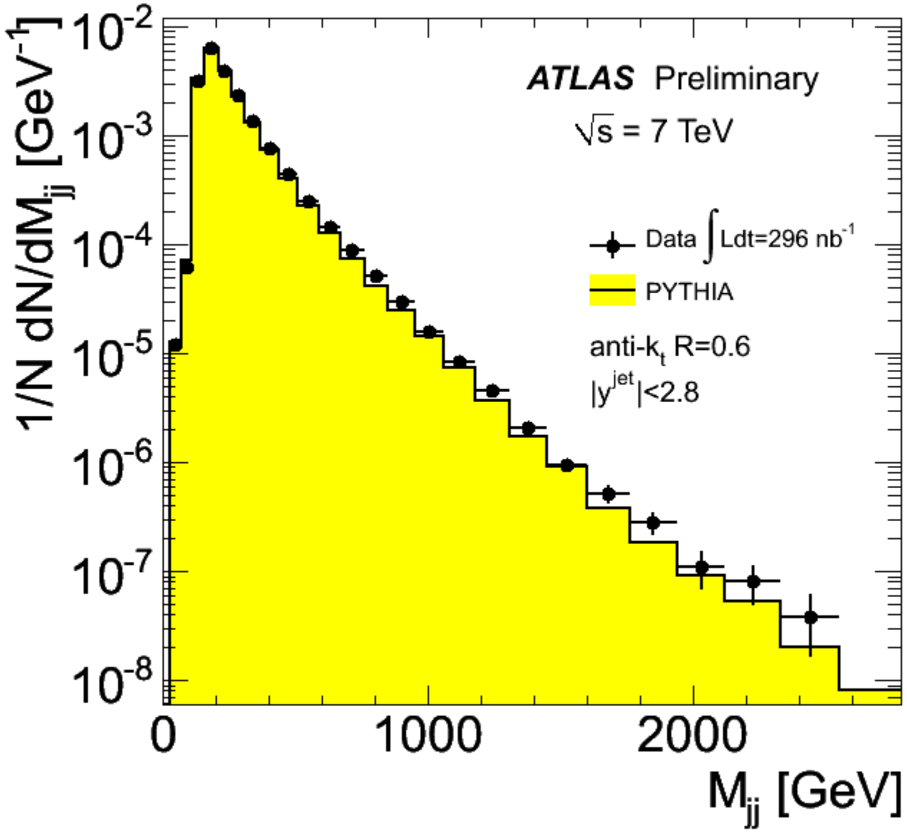
Jet

Inclusive Jet multiplicity



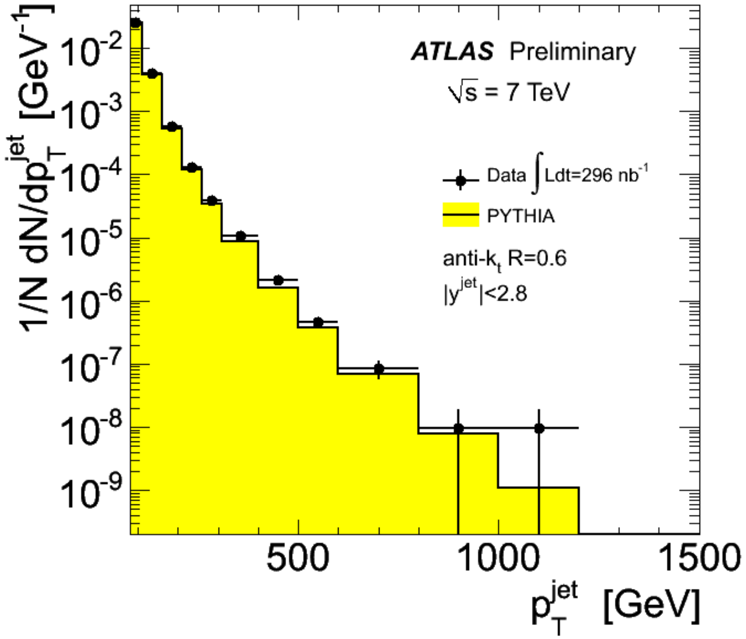
Leading jet pT>80GeV
Other jets pT>40GeV

dijet mass



Leading jet pT>80GeV
2nd leading jet pT>40GeV

Hardest Jet

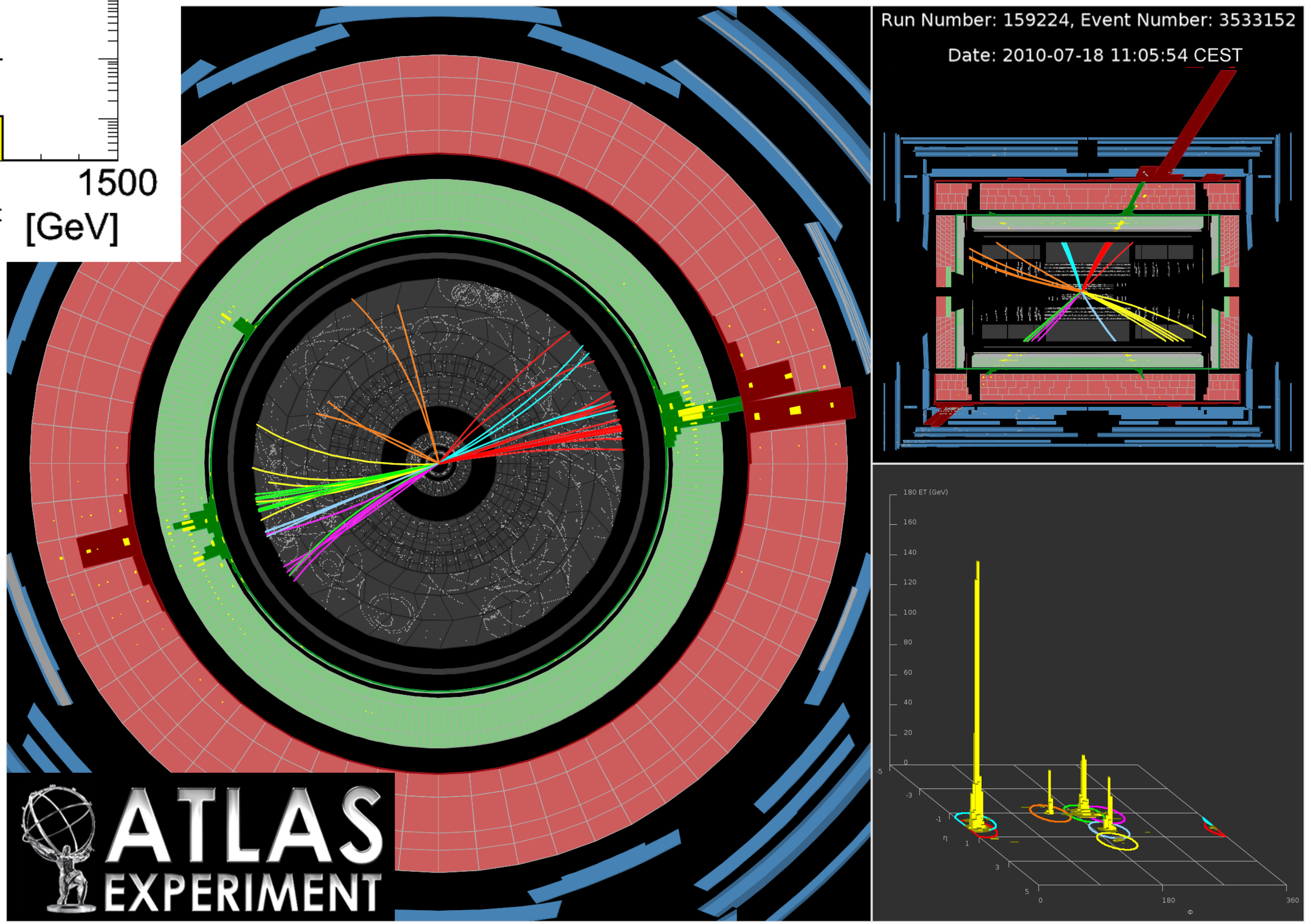


p_T (j_1)= 1120 GeV

p_T (j_2)= 480 GeV

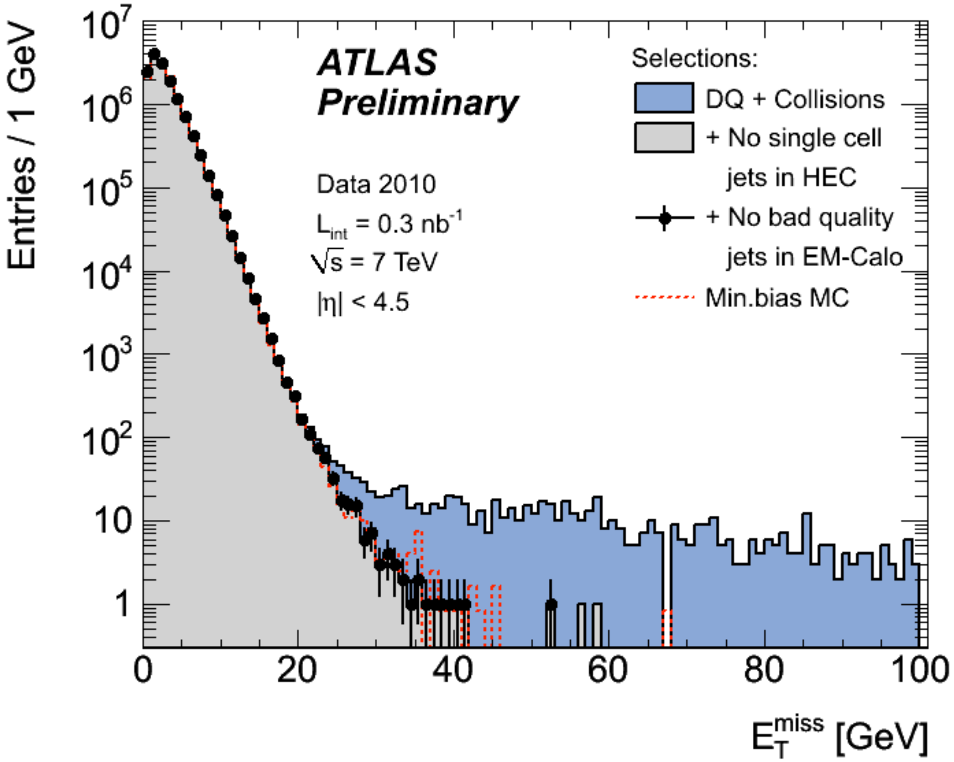
p_T (j_3)= 155 GeV

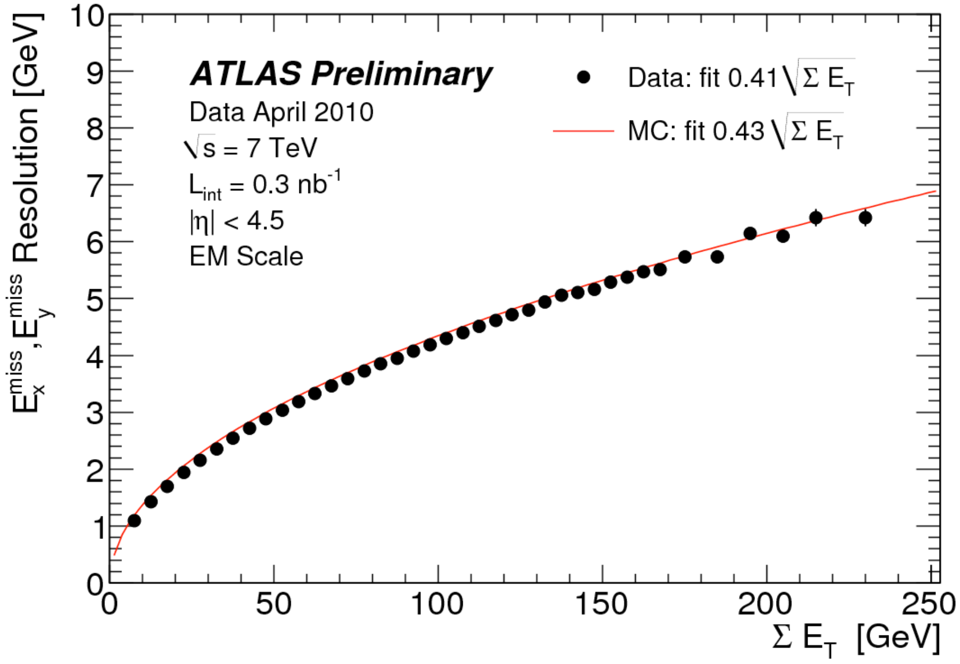
p_T (j_4)= 95 GeV



欠損エネルギー

minimum bias events ：
小さいはずの欠損エネルギーが正しく小さくでているか？



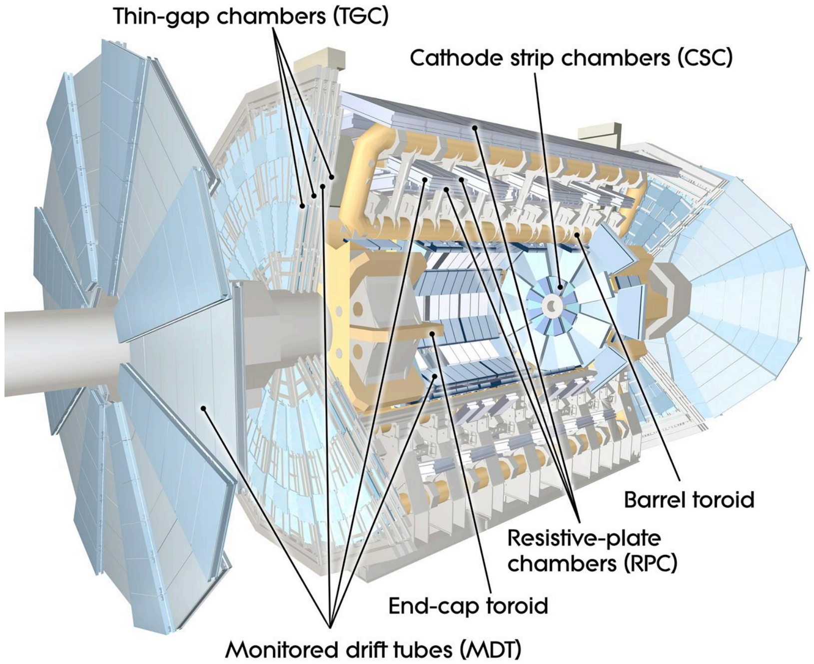


解析によってDark Matter(?)を作らないために重要

Muon system

Stand-alone P_T resolution : σ(pT)/pT~10% (up to 1 TeV)
Air-core toroidal magnet : 1.5~5.5 T*m (η<1.4), 1~7.5 T*m (1.6<η<2.7)

Coverage : η < 2.5 (trigger η < 2.4)



Dedicated fast trigger

2-dimensional readout
< 10 ns time resolution
Spatial resolution : 5-10 mm

Resistive Plate Chambers (RPC)

544 chambers with 359 K channels
70% of chamber operational
(To be increased to 95.5% in 2009)

Thin Gap Chambers (TGC)

3588 chambers with 318 K channels

High Precision tracking chamber

Spatial resolution : 35μm – 40μm
Optical alignment system : 12,232 sensors

Monitored Drift Tube (MDT)

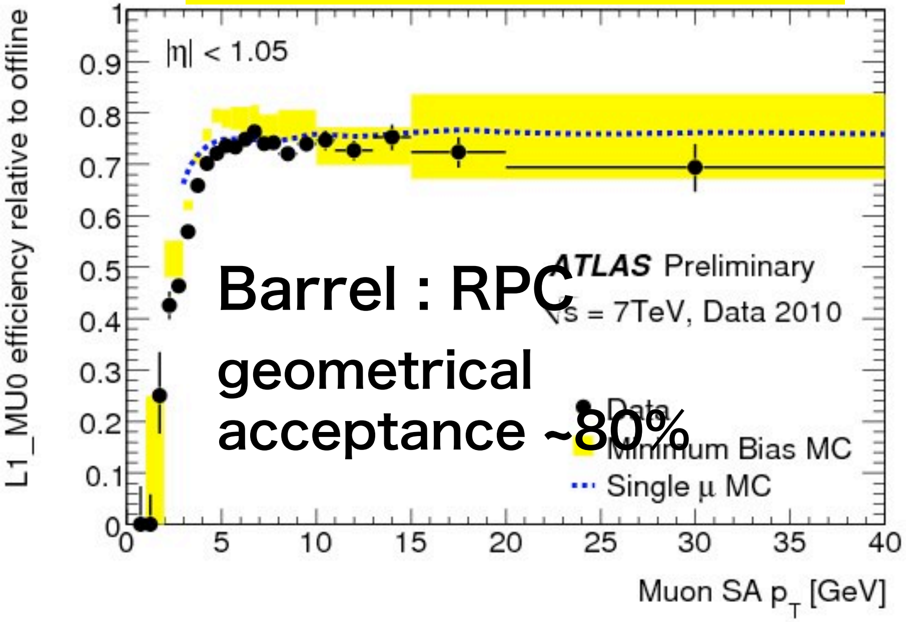
1088 chambers with 339 K channels

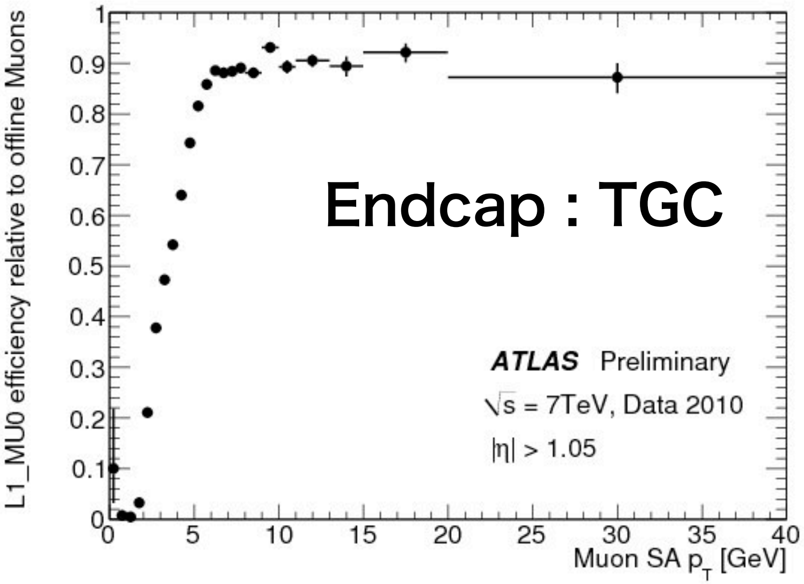
Cathode Strip Chamber (CSC)

32 chambers with 31 K channels

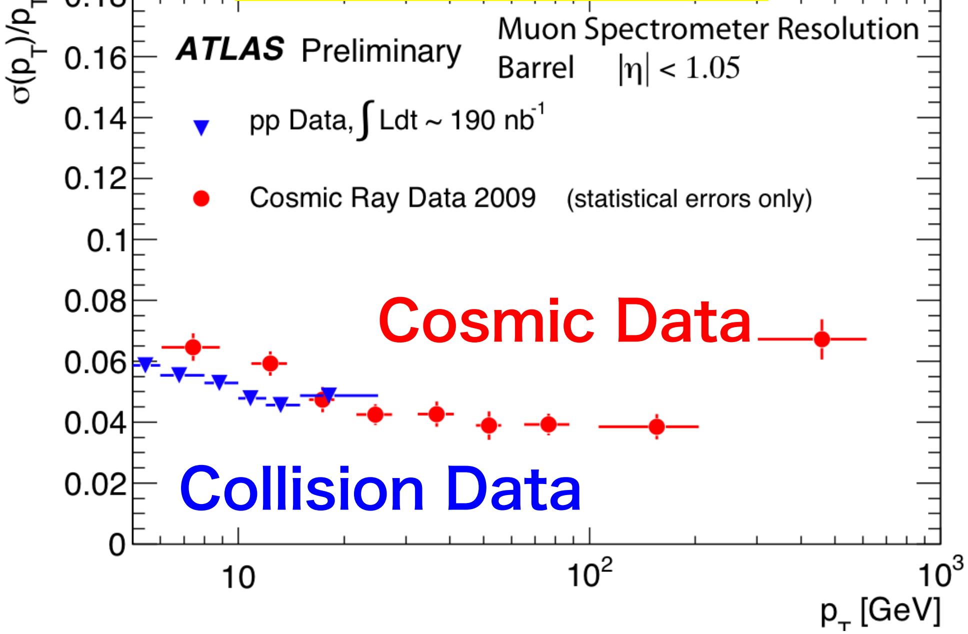
μ パフォーマンス

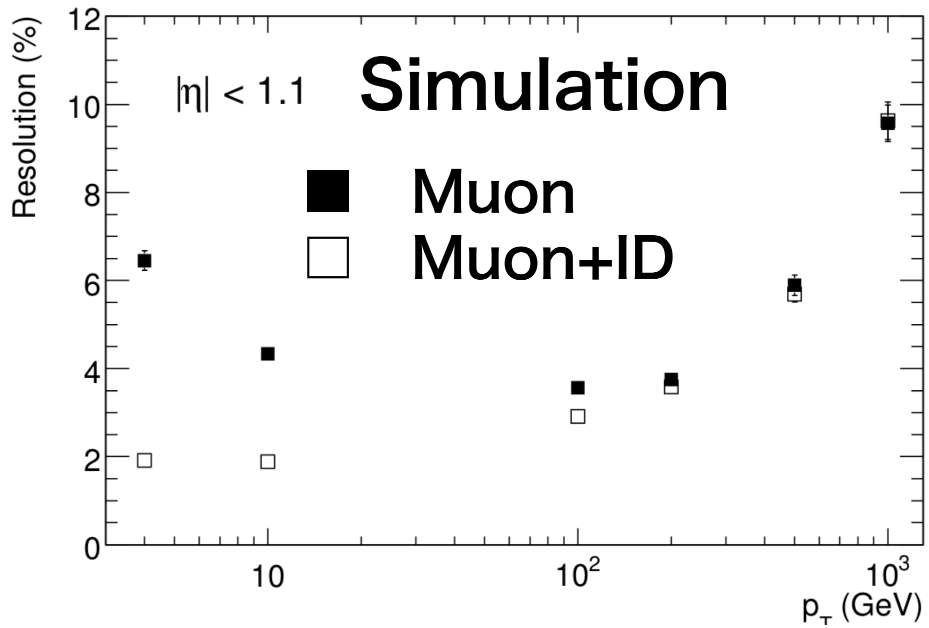
L1 Trigger efficiency



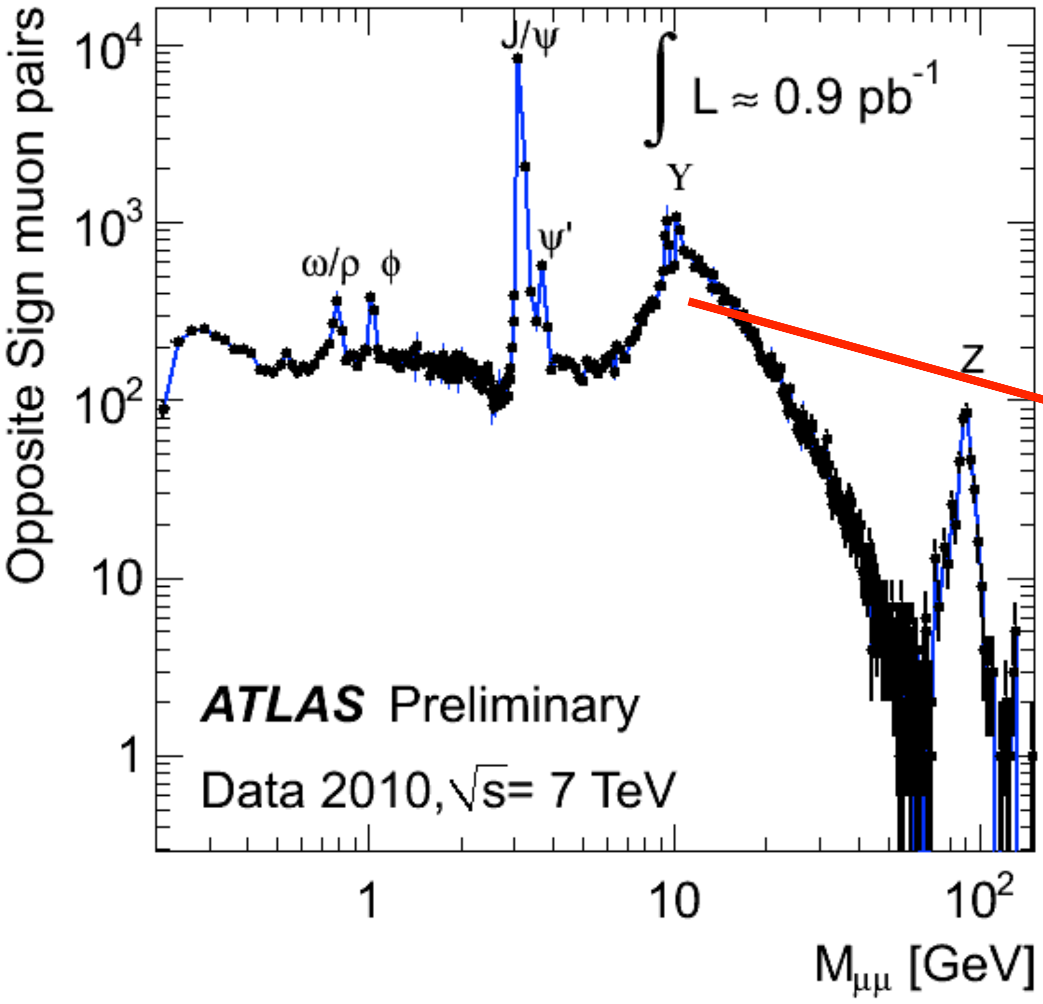


MDT 運動量分解能

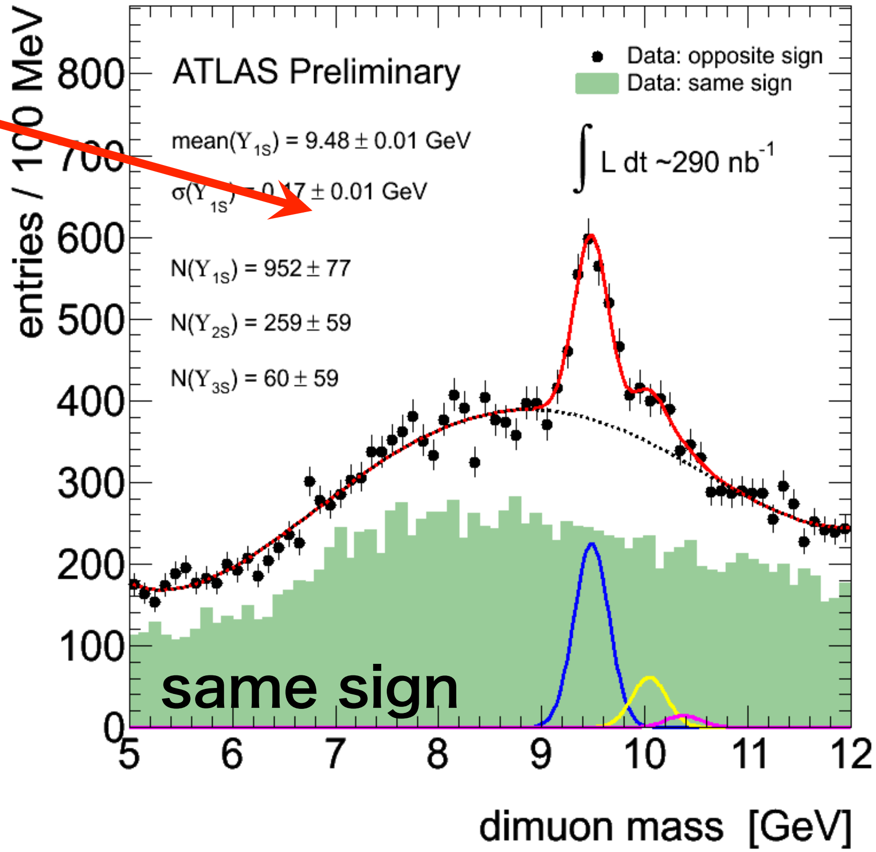




X→μμ



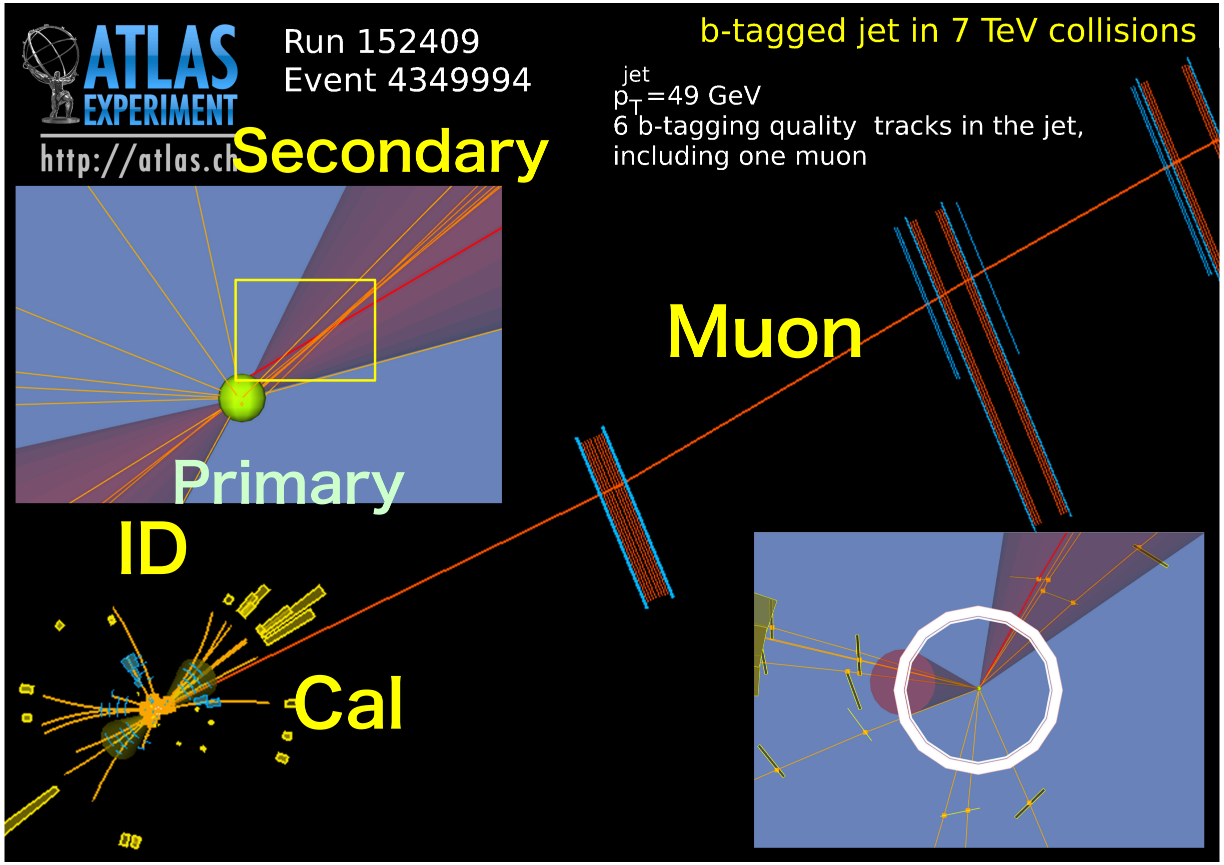
Opposite sign muon
ID+Muon combined
pT>6GeV

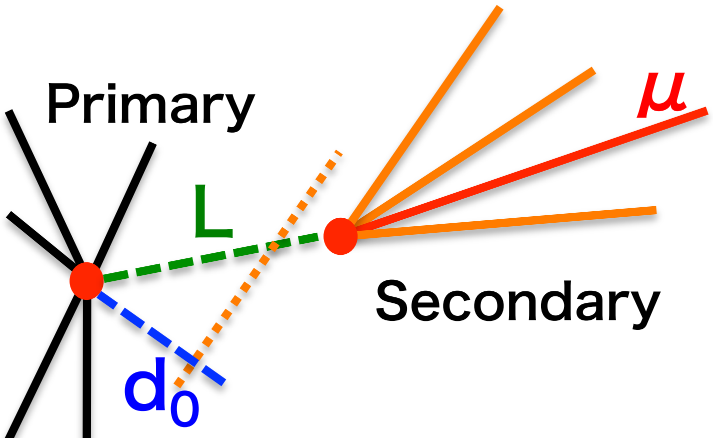


Distances between resonances
fixed to PDG values

Flavor tag (bジェット同定)

b hadoron：
- 長寿命(cτ~450μm)
- Hard fragmentation
- 重い(5GeV)
- e/μへの崩壊過程



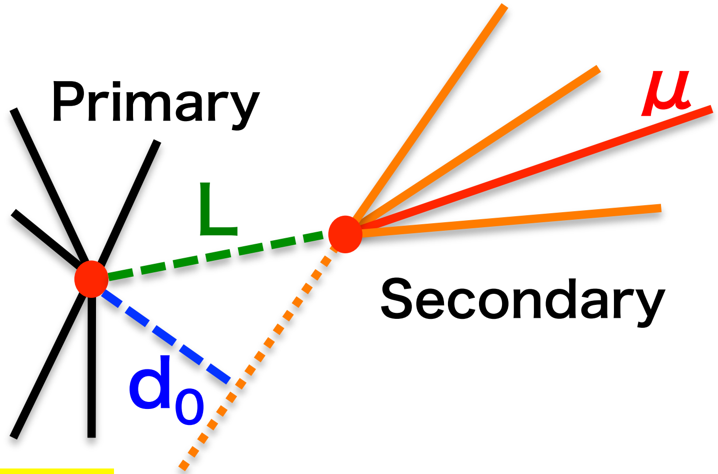


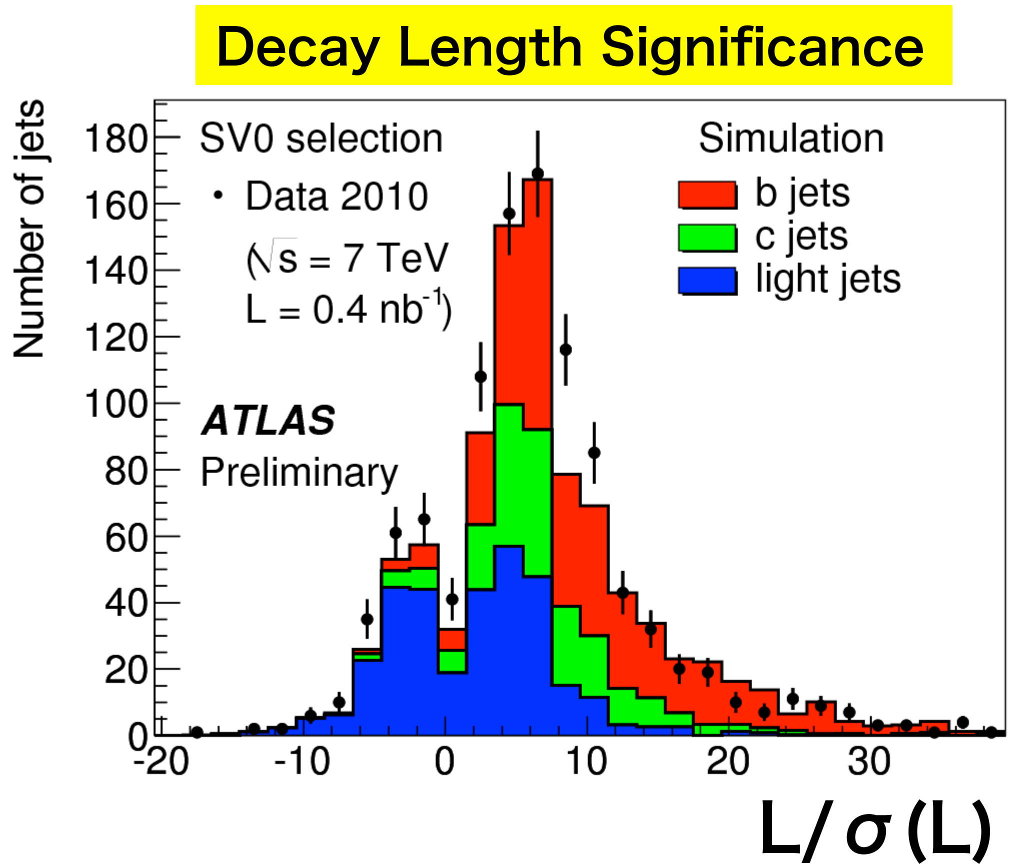
Decay Length significance (L/σ(L))
Impact Parameter significance (d_0/σ(d_0)) に特徴

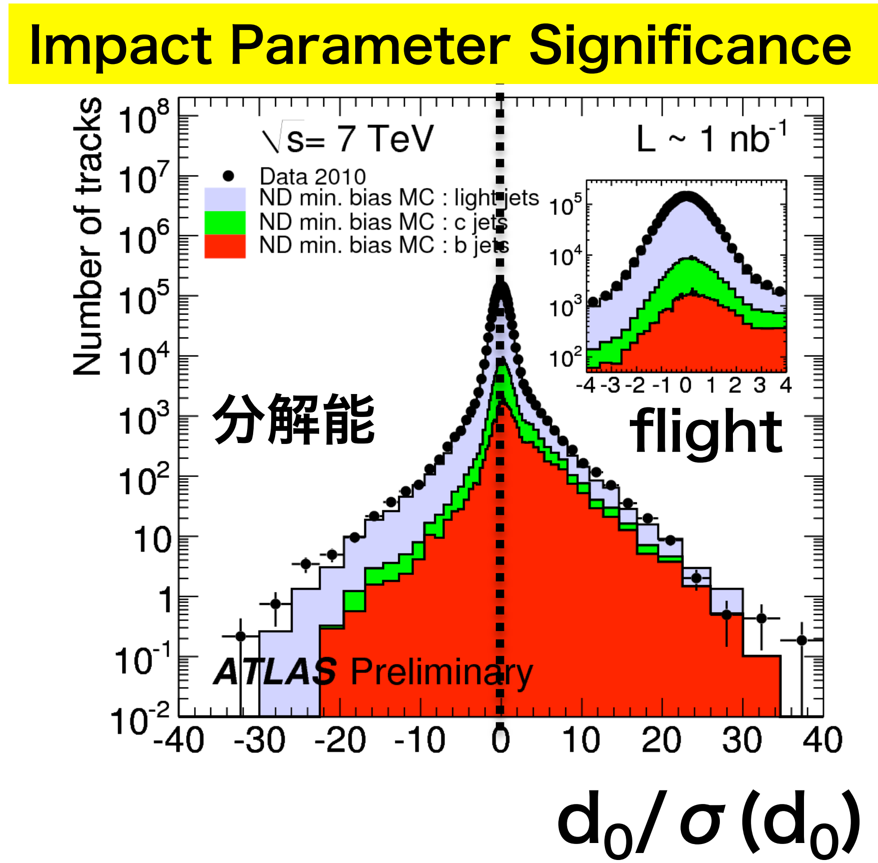
Higgs(湯川結合Y_b), SUSYなど特徴の理解に不可欠

Flavor tag (bジェット同定)

b hadoron：
- 長寿命(cτ~450μm)
- Hard fragmentation
- 重い(5GeV)
- e/μへの崩壊過程

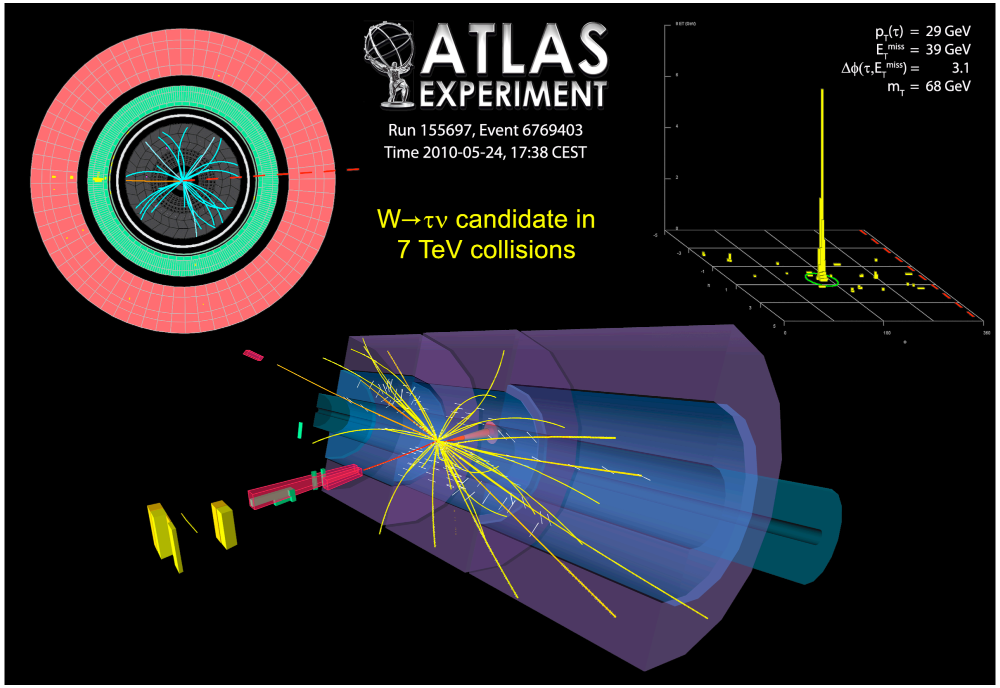




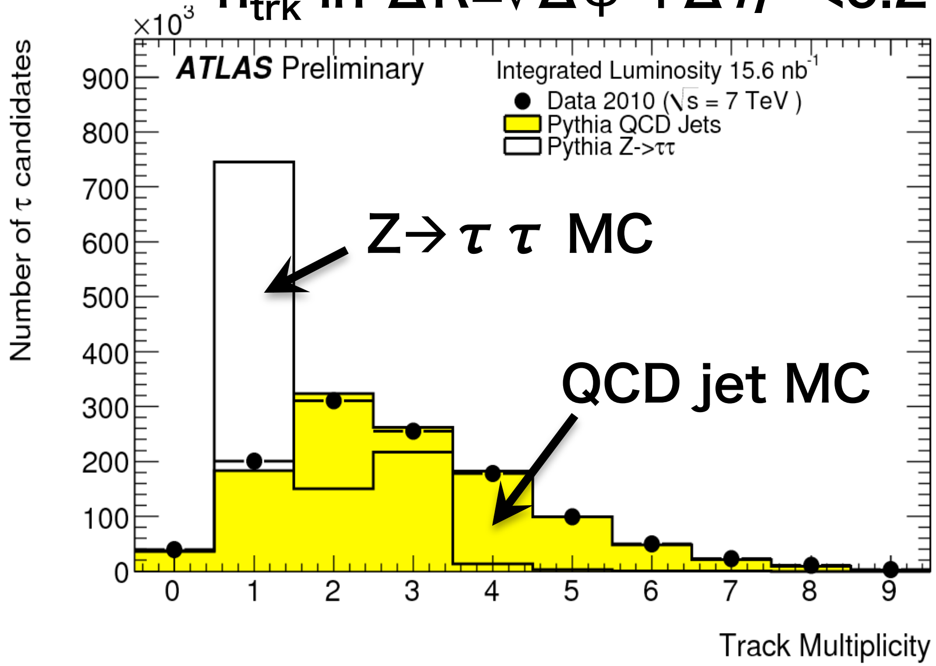


Flavor tag (τレプトン同定)

tau lepton jet (Hadronic tau decay)
奇数本の荷電粒子（特に１本、３本）
energyの広がりがjetより狭い



n_{trk} in $\Delta R=\sqrt{\Delta\phi^2+\Delta\eta^2}<0.2$



pT(τ) = 29 GeV
missing ET = 39 GeV
Δϕ(τ, missing ET) = 3.1
m_T = 68 GeV

Higgs, SUSYなどに不可欠

まとめ

LHC実験は、
2010年3月30日から√s=7TeVで本格始動

L＝3.46 pb^{-1}

ATLAS測定器は、
高い稼働率かつGood quality data収集率で
データ収集を続けている。

ミニマムバイアス、共鳴粒子などの実データ
により、測定器の高いパフォーマンスを立証

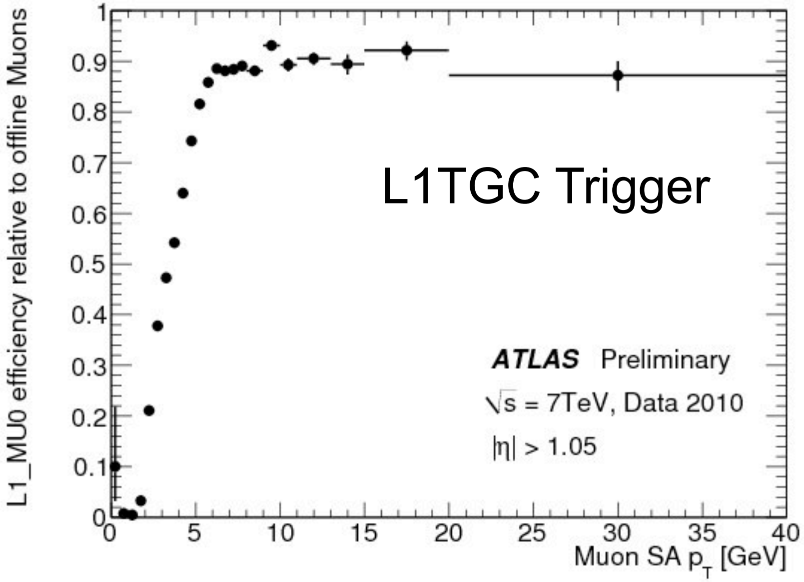
こうした測定器を用いた最初の物理結果は、

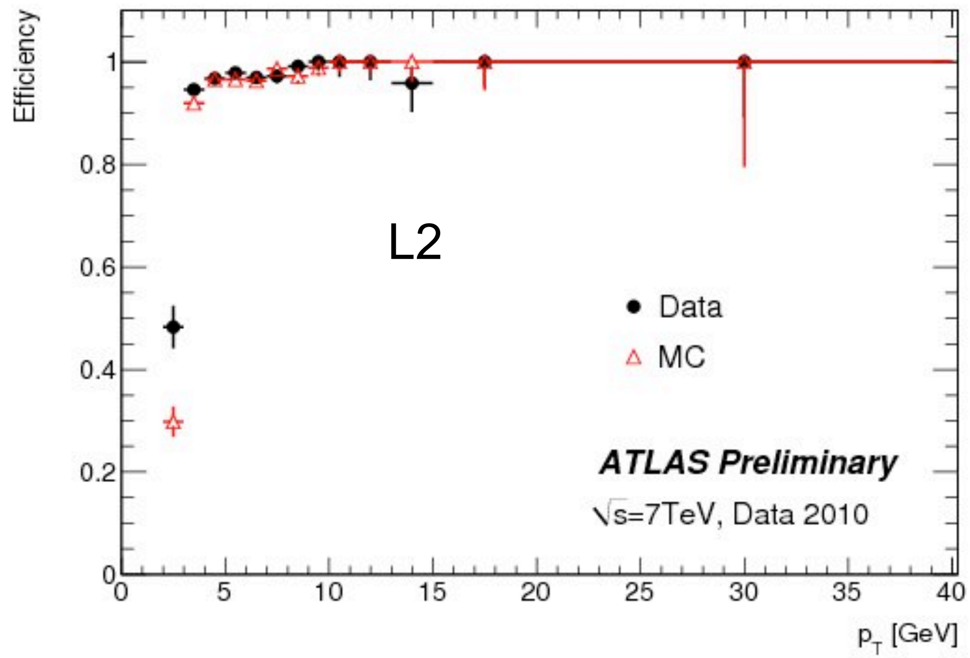
次のトーク

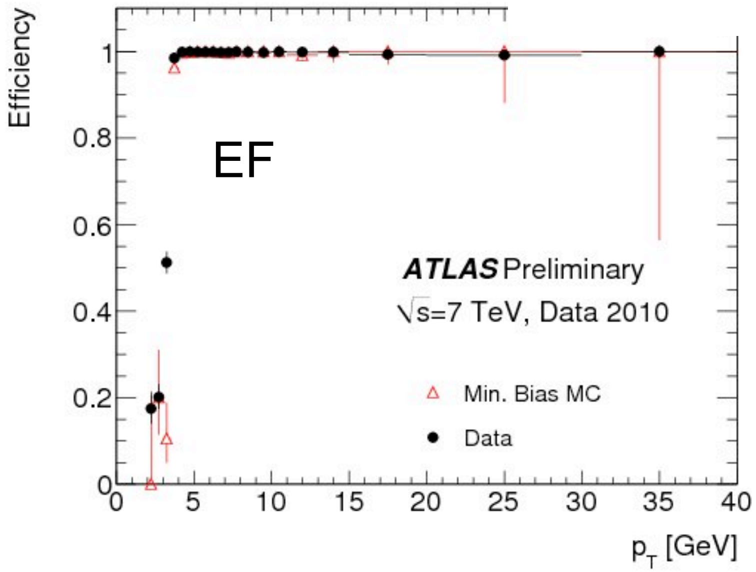
おしまい

バックアップ

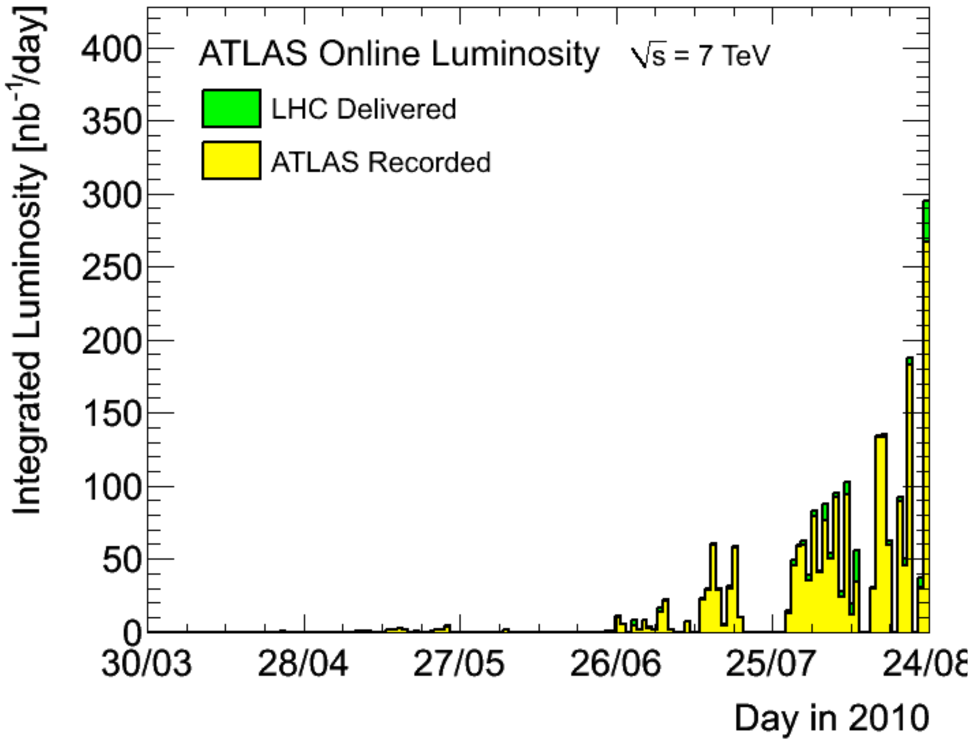
Trigger

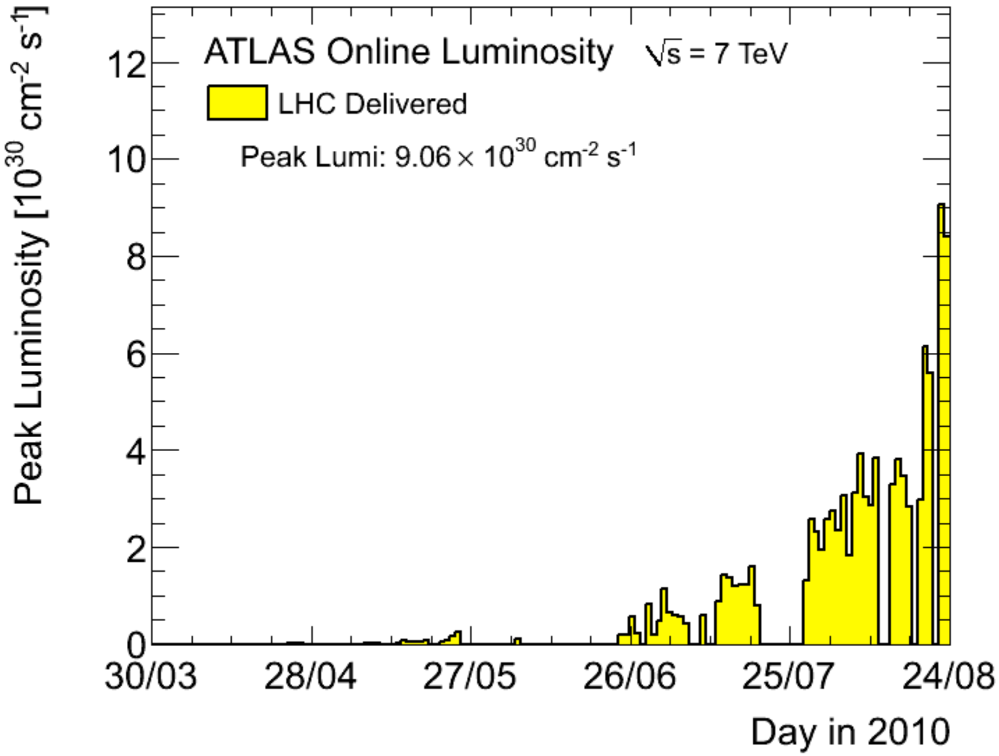

L1TGC Trigger
L1_MU0 efficiency relative to offline Muons
Muon SA p_T [GeV]
ATLAS Preliminary
$\sqrt{s}$ = 7TeV, Data 2010
$|\eta|$ > 1.05


L2
Efficiency
p_T [GeV]
Data
MC
ATLAS Preliminary
$\sqrt{s}$=7TeV, Data 2010

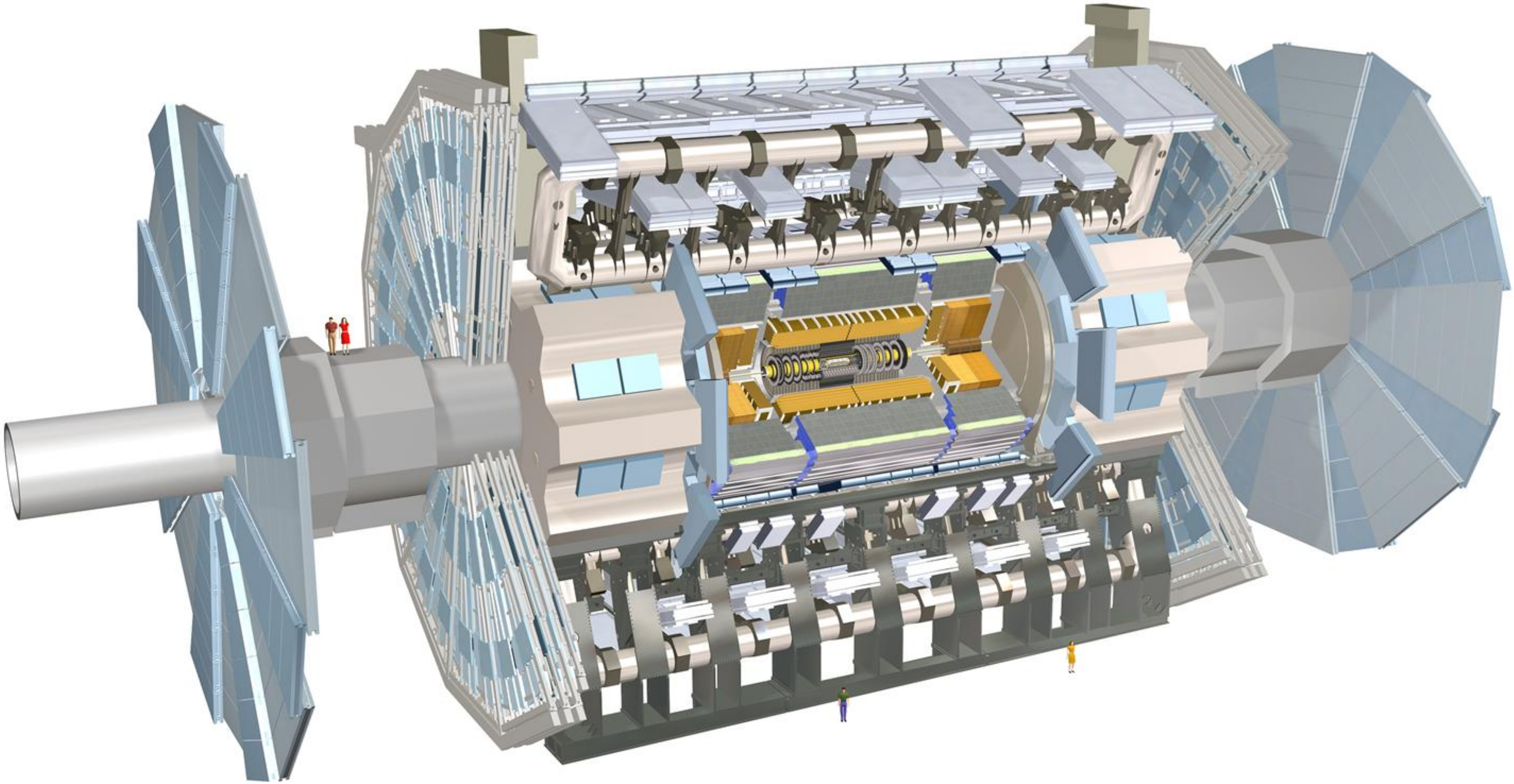

EF
Efficiency
p_T [GeV]
ATLAS Preliminary
$\sqrt{s}$=7 TeV, Data 2010
Min. Bias MC
Data

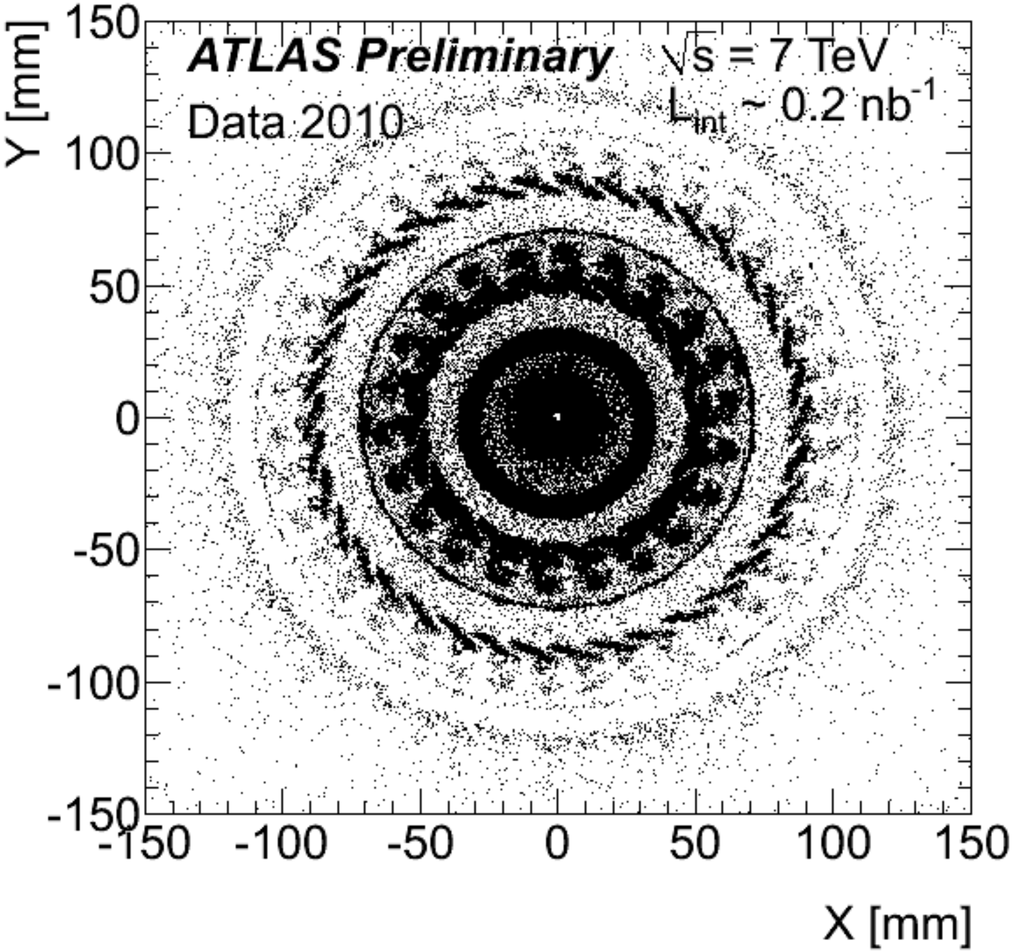
Luminosity

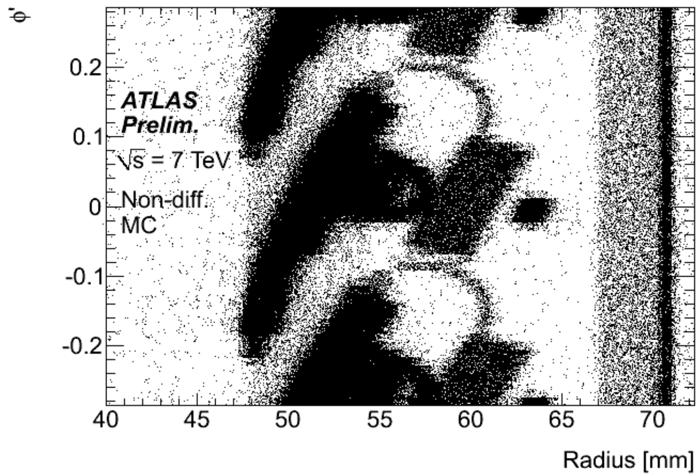

ATLAS Online Luminosity √s = 7 TeV
LHC Delivered
ATLAS Recorded
Integrated Luminosity [nb-1/day]
400
350
300
250
200
150
100
50
0
30/03
28/04
27/05
26/06
25/07
24/08
Day in 2010

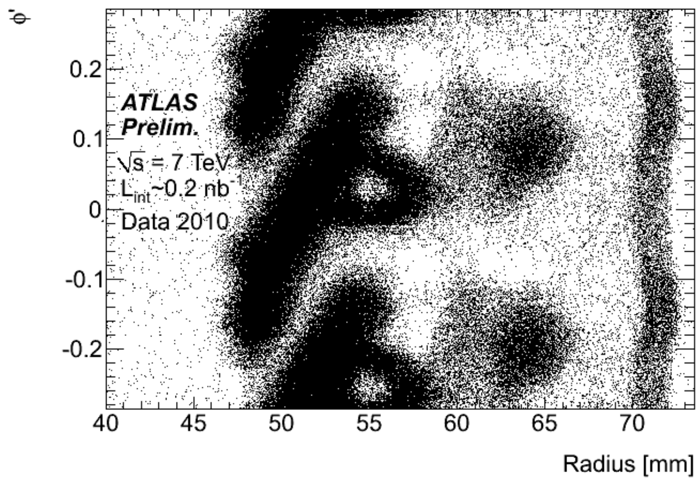

ATLAS Online Luminosity √s = 7 TeV
LHC Delivered
Peak Lumi: 9.06 × 10^30 cm^-2 s^-1
Peak Luminosity [10^30 cm^-2 s^-1]
12
10
8
6
4
2
0
30/03
28/04
27/05
26/06
25/07
24/08
Day in 2010

ATLAS Detector



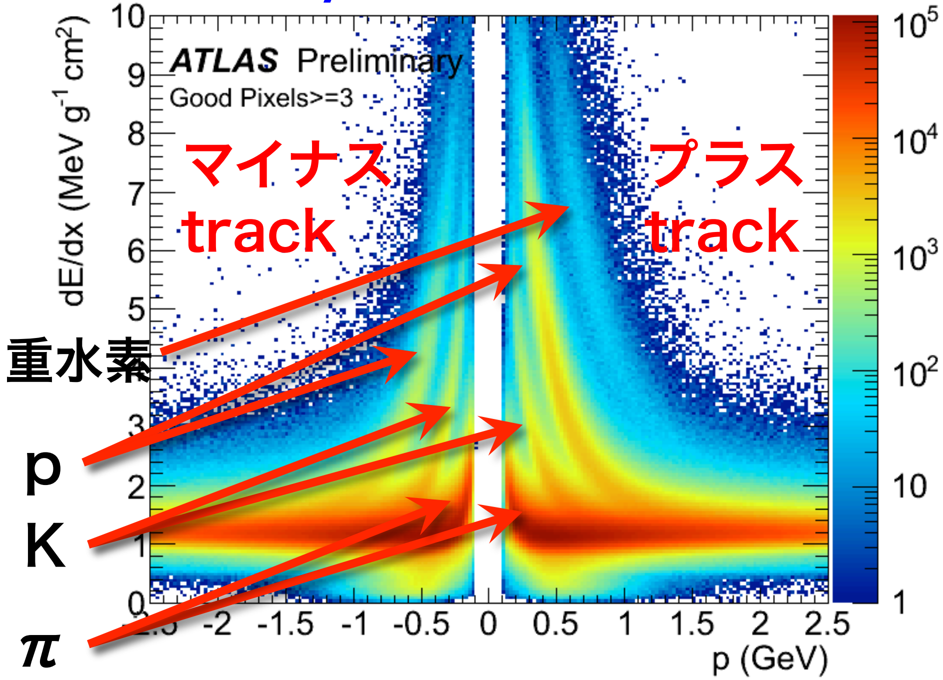

ATLAS Preliminary
√s = 7 TeV
L_int ~ 0.2 nb^-1
Data 2010
Y [mm]
X [mm]


ATLAS
Prelim.
√s = 7 TeV
Non-diff.
MC
φ'
Radius [mm]

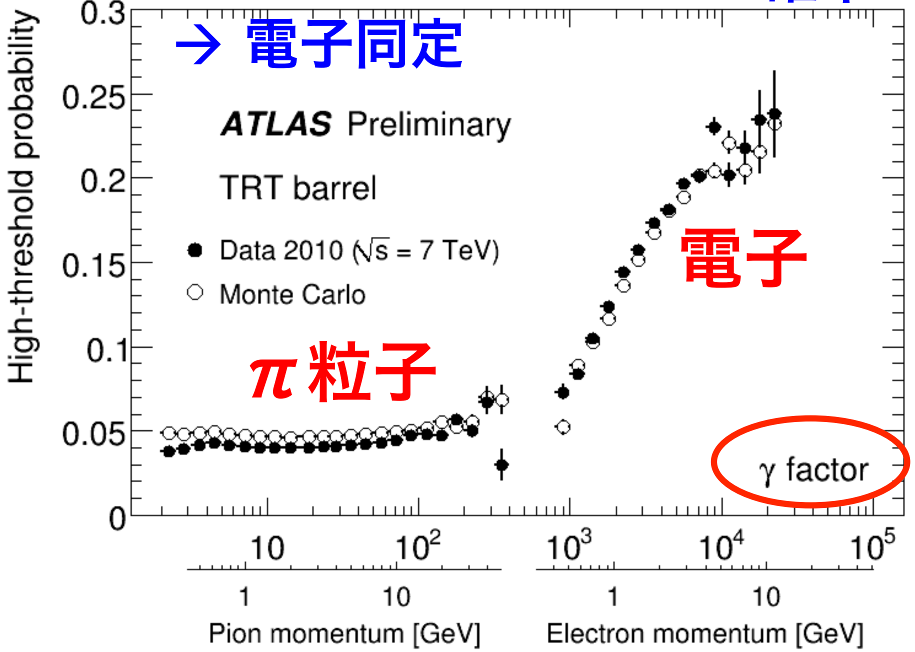

ATLAS
Prelim.
√s = 7 TeV
L_int~0.2 nb
Data 2010
φ'
Radius [mm]

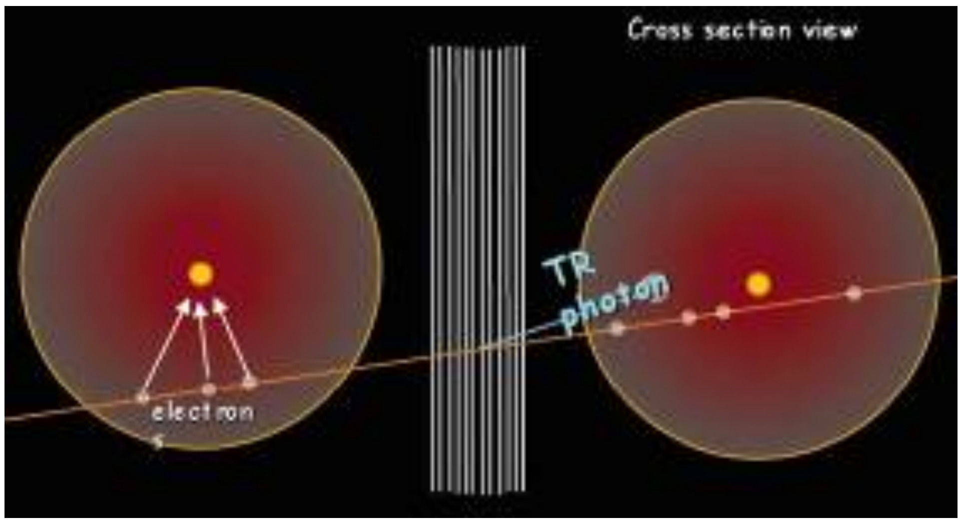
IDでParticle ID

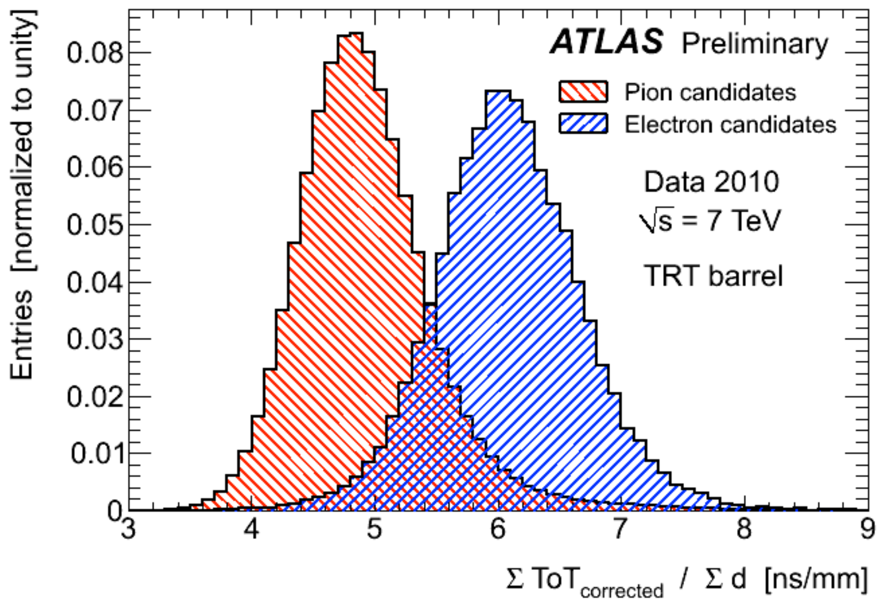
Pixel: dE/dx



Transition Radiation確率 → 電子同定







Anti-k_T Algorithm

1. Start with a list of preclusters.

2. For each precluster i, define

$$d_i = p_{T,i}^2$$

For each pair of preclusters,

$$d_{ij} = \min(p_{T,i}^{-2}, p_{T,j}^{-2}) \frac{\Delta R_{ij}^2}{D^2}$$

3. Find the minimum of all d_i and d_{ij}.

4. If d_{min} is a d_{ij}, merge preclusters i and j into a new precluster.

5. If d_{min} is a d_i, precluster i is a jet.

6. Repeat until no preclusters remain.

Parameters:

- minimum separation distance D

- precluster definition

- possible d_{cut}

➔stop algorithm when $d_{min} < d_{cut}$

➔used to separate final-state jets from beam jets

➔useful for defining *exclusive* jet cross sections, as in e^+e^- experiments

Anti-k_T in Practice

Like k_T, anti-k_T clusters nearby particles, but soft particles are combined with hard particles before combining with each other

Collinear particles are still recombined first, but now with more circular jets

No split/merge step necessary

Infrared and collinear safe!

Pairs containing a high-p_T jet will have a small d_{ij}