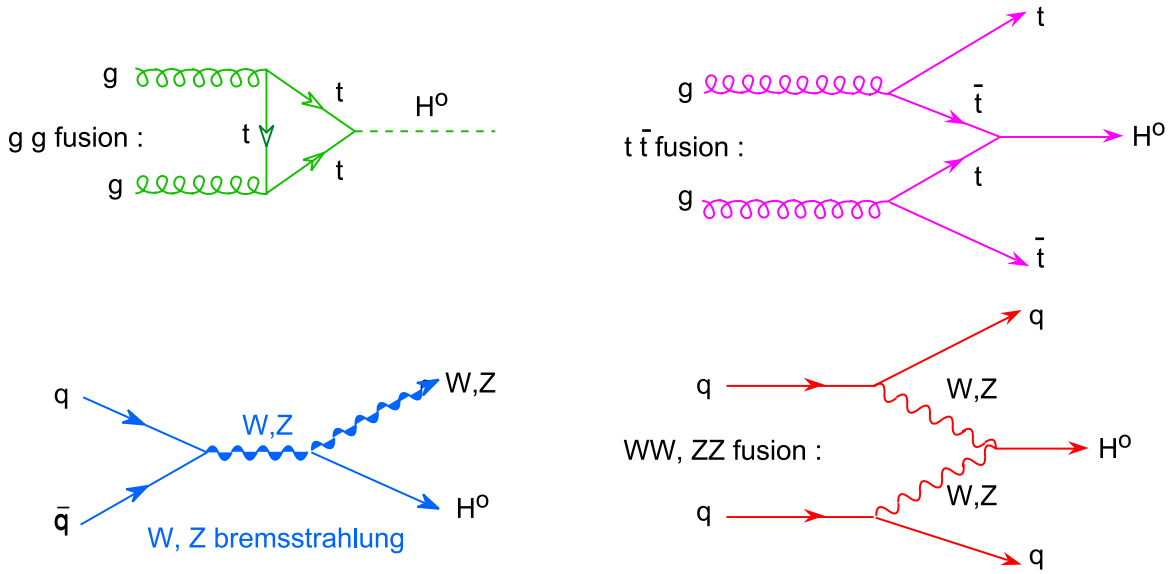
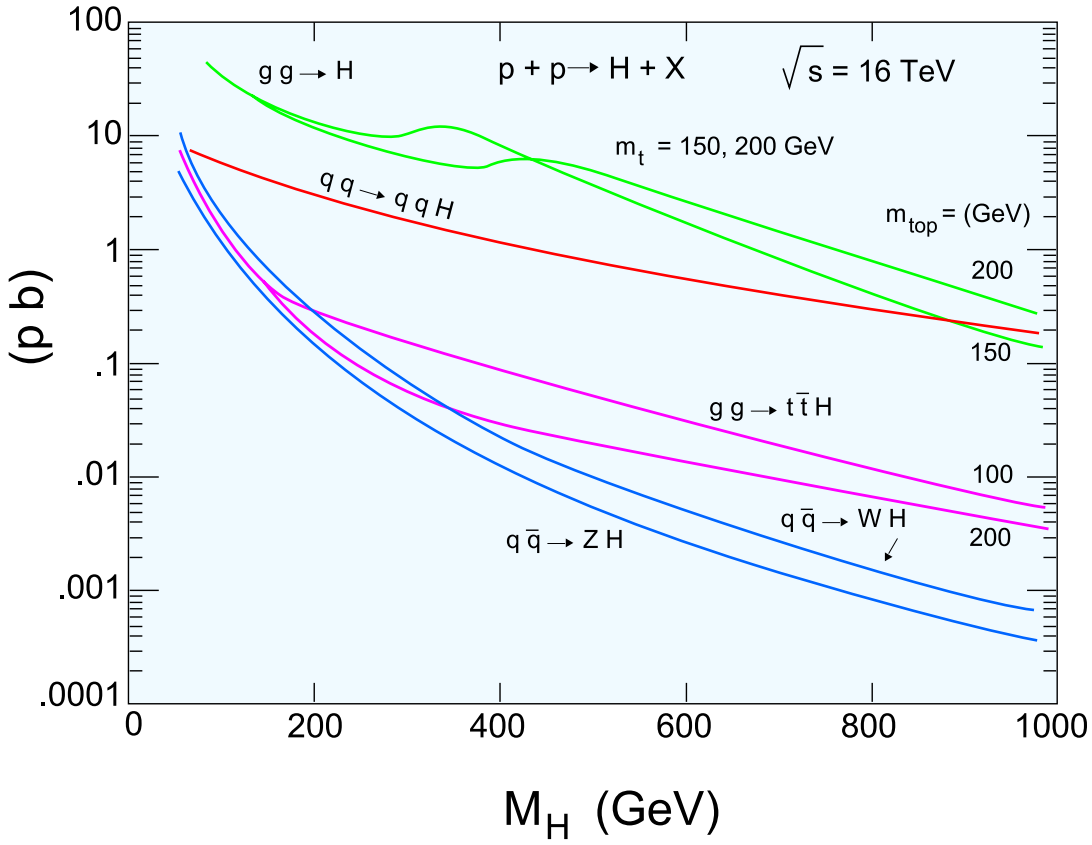
LHC SM Higgs Production



LHC: the Large Higgs Creator (P.Sphicas)

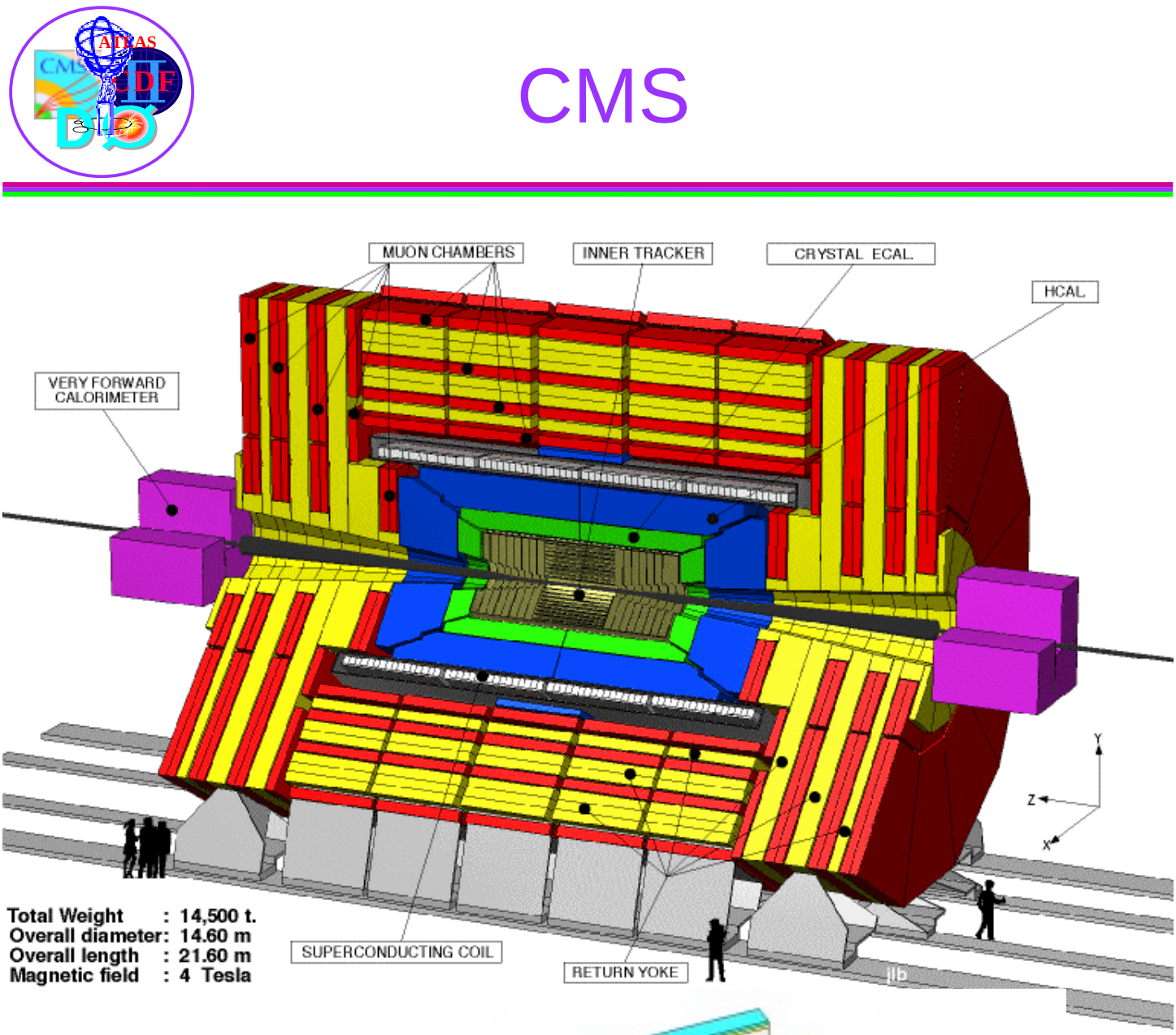


LHC SM & MSSM Higgs

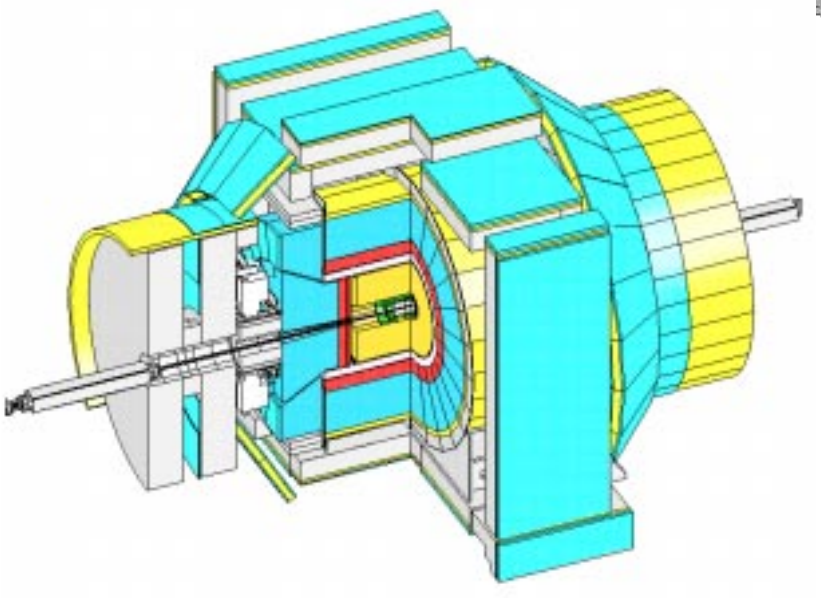
- SM Higgs Search strategies
  - $H \to bb$ $90 \le m_H \le 120$ GeV/c^2
  - $H \to \gamma\gamma$ $100 \le m_H \le 140$ GeV/c^2
  - $H \to ZZ^* \to 4l^{\pm}$ $130 \le m_H \le 200$ GeV/c^2
  - $H \to WW \to l\nu l\nu$ $140 \le m_H \le 200$ GeV/c^2
  - $H \to ZZ \to 4l^{\pm}$ $200 \le m_H \le 750$ GeV/c^2
  - $H \to ZZ \to 2l^{\pm} + 2\nu$ $0.5 \le m_H \le 1.0$ TeV/c^2
  - $H \to WW \to l\nu jj$ $m_H \sim 1.0$ TeV/c^2

- MSSM Higgs Search Channels
  - $h,H \to bb,\gamma\gamma$, and in association with W/Z
  - $tth \to l^{\pm}\gamma\gamma$
  - $hH \to ZZ^*$ or $ZZ \to 4l^{\pm}$
  - $h,H,A \to \tau\tau \to l^{\pm} + \pi^{\pm} + \not{E}_T$
    $\to e + \mu + \not{E}_T$
    $\to \pi^+ + \pi^- + \not{E}_T$
  - $h,H,A \to \mu\mu$
  - $H^{\pm} \to \tau\nu$ from $t\bar{t}$

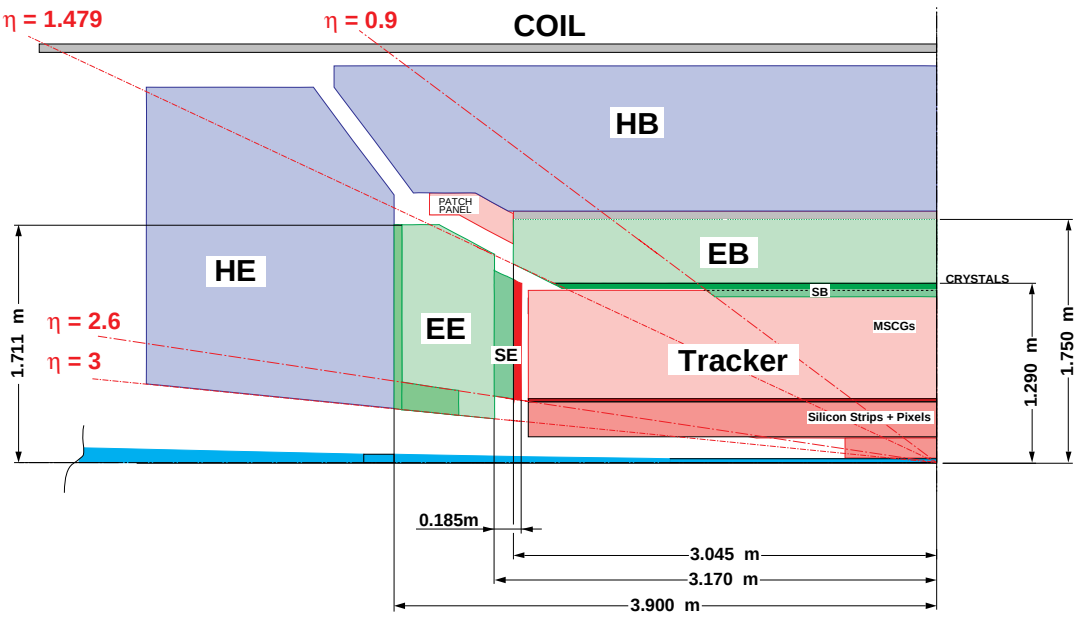
  $\Rightarrow$ **regions of sensitivity in (m_A, tanβ)**


MUON CHAMBERS
INNER TRACKER
CRYSTAL ECAL
HCAL
VERY FORWARD CALORIMETER
SUPERCONDUCTING COIL
RETURN YOKE
Total Weight : 14,500 t.
Overall diameter: 14.60 m
Overall length : 21.60 m
Magnetic field : 4 Tesla
Y
Z
X

CMS

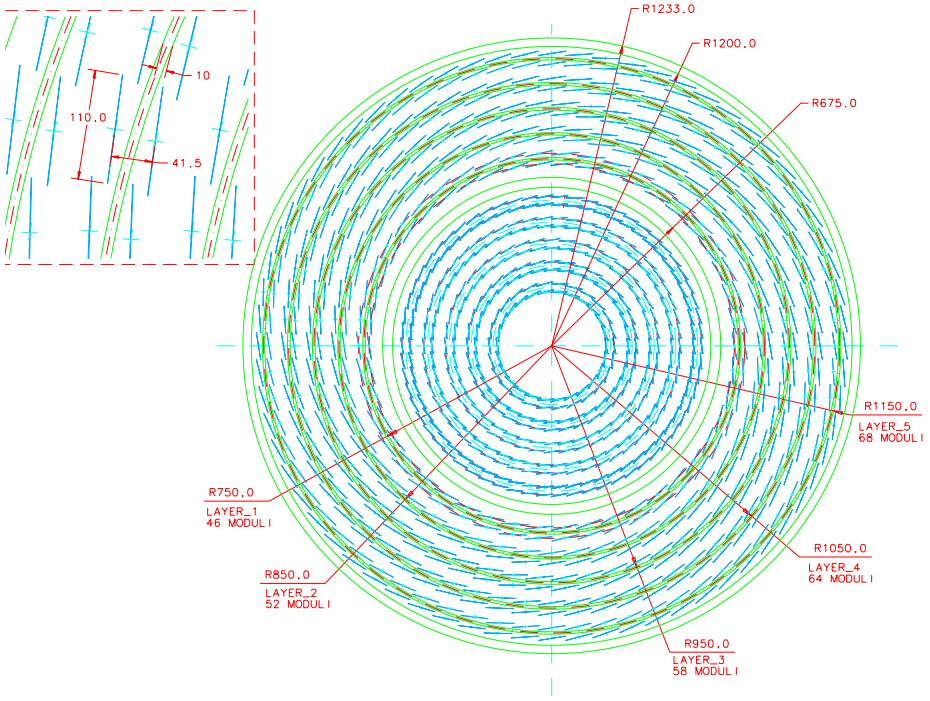


CMS Inner Detector



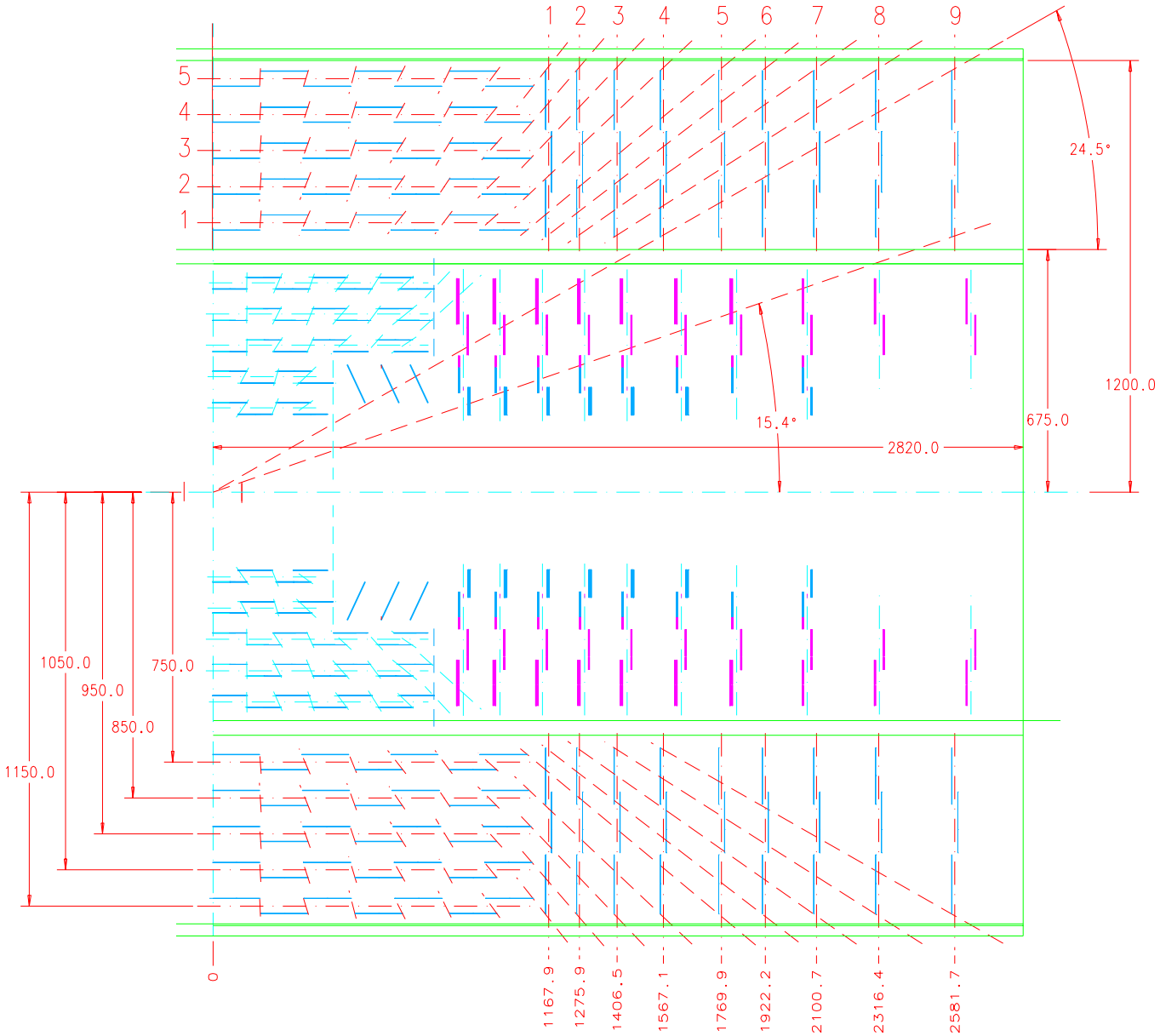
- Inside of the 4T Solenoid Field
  - Pixels: 2 Layers everywhere
  - Inner Si Strips: 5 Layers and 10 disks/end
  - ~~MSGCs: 6 Layers and 11 disks/end~~
  - Outer Si Strips: 5 Layers and 9 disks/end
  - EM Calorimeter: $PbWO_4$ crystals w/Si APD's
  - Had Calorimeter: Cu+Scintillator Tiles

CMS Tracking



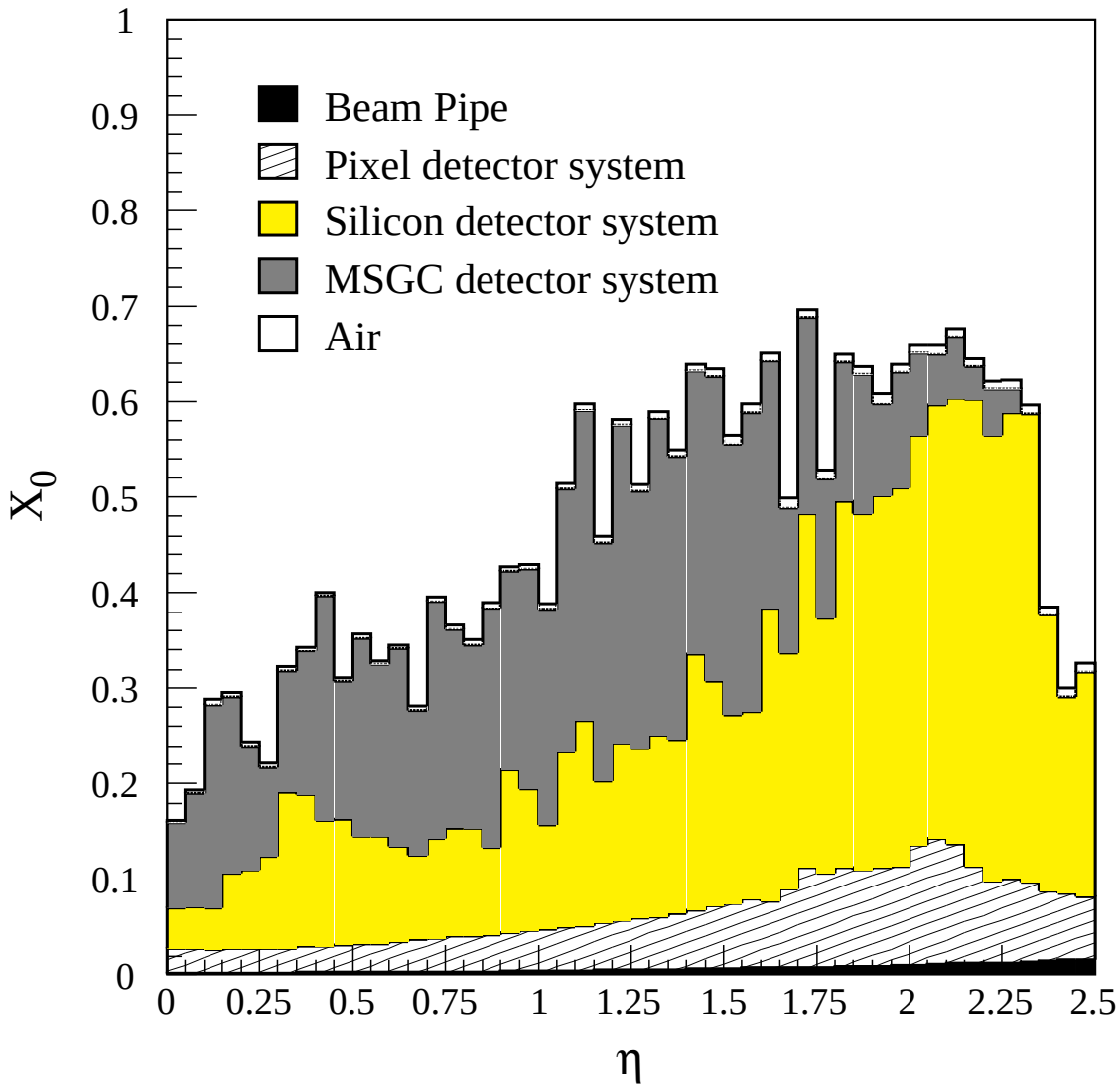
System	Description	Area [m^2]	Resolution (μm)		Channels (10^6)	η coverage (approximate)
			σ(rφ)	σ(rz)		
Si Pixels n-in-n analog	2 Barrel layers 4,7 → 7,11 cm	0.15,0.25, and 0.38	10-15	10-15	36	±1.5
	2 disks/end	0.07/disk	15-20	15-20	12	1.5-2.5
Si Strips Inner	5 barrel layers L1,L2,L5 DS	~38	12-20	20-60	2.7	±1.4
	3 mini-disks/end	~2	12-15	20-30	1.2	1.4-1.8
	10 disks/end EC1,EC10 DS	~38	12-20	20-60	2.7	1.4-2.5
Si Strips Outer	5 Barrel layers L6 DS	~97.3	40	60	3.4	±1.0
	9 disks/end L1,L9 DS	~67	40	60	2.3	1.0-2.1

Silicon Tracker*



*Pixels not shown

Material



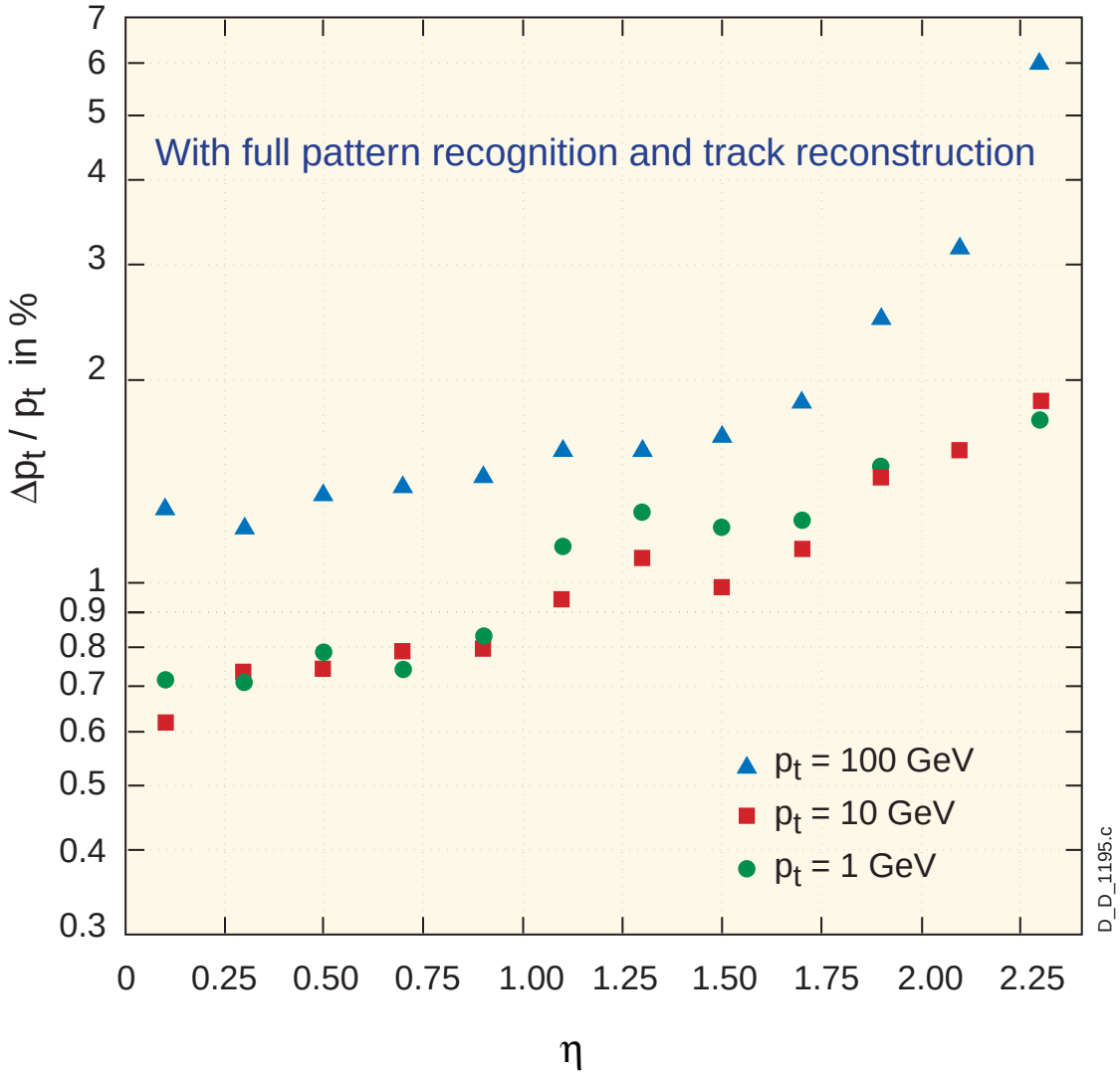
$\sigma/p_T \sim (15 \bullet p_T \oplus 0.5)\ \%$ $\quad |\eta| \leq 1.6$

$\rightarrow 4.5 \bullet \sqrt{p}\ \%$ when combined w/μ detectors

$\sigma/p_T \sim (60 \bullet p_T \oplus 0.5)\ \%$ $\quad |\eta| \sim 2.5$

p_T in [TeV/c]

CMS p_T Resolution



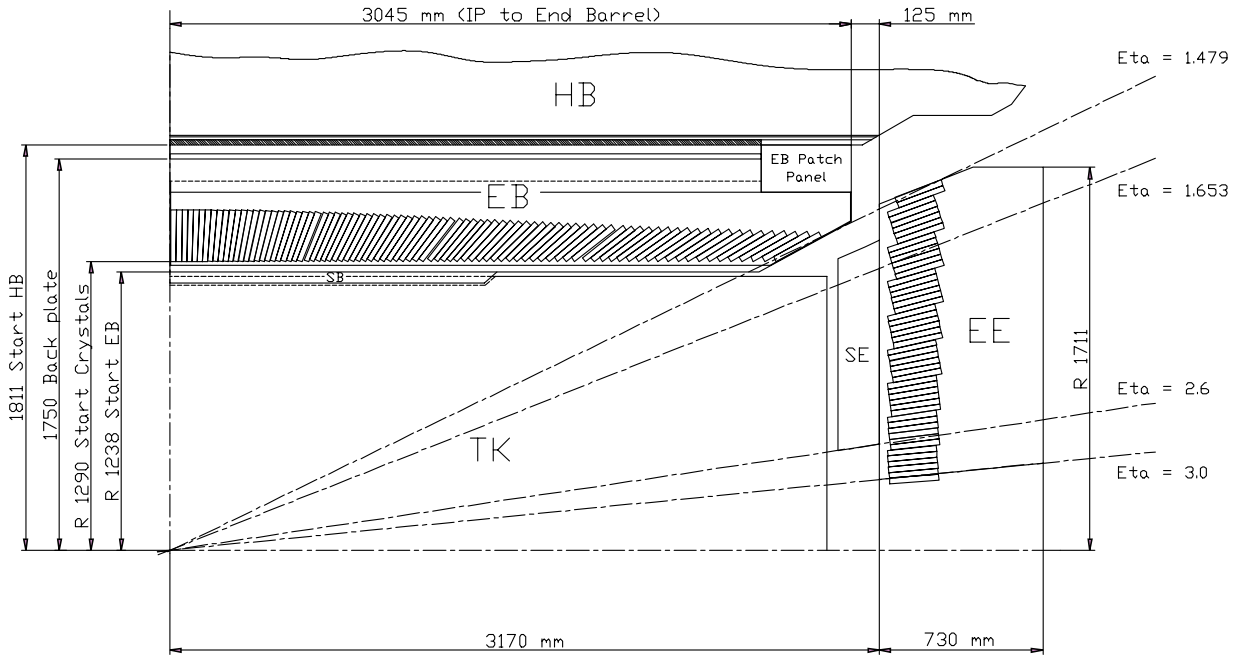
$\sigma/p_T \sim (15 \bullet p_T \oplus 0.5)\ \%$ $\quad |\eta| \leq 1.6$

$\rightarrow 4.5 \bullet \sqrt{p}\ \%$ when combined w/μ detectors

$\sigma/p_T \sim (60 \bullet p_T \oplus 0.5)\ \%$ $\quad |\eta| \sim 2.5$

p_T in [TeV/c]

CMS EM Calorimeter

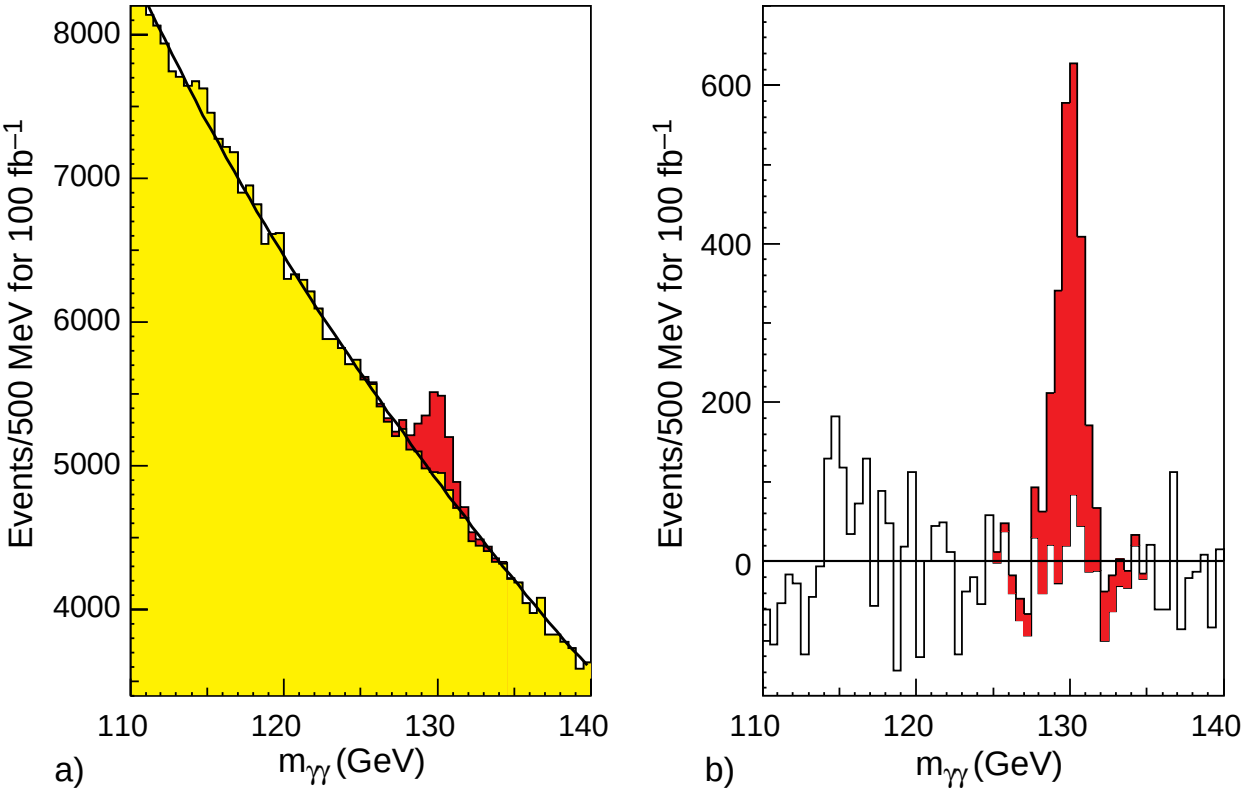


Parameter	Barrel	Endcaps
Pseudorapidity coverage	$\|\eta\| < 1.48$	$1.48 < \|\eta\| < 3.0$
ECAL envelope: r_{inner}, r_{outer} [mm]	1238, 1750	316, 1711
ECAL envelope: z_{inner} z_{outer} [mm]	0, ±3045	±3170, ±3900
Granularity: $\Delta\eta \times \Delta\phi$	0.0175×0.0175	0.0175×0.0175 to 0.05×0.05
Crystal dimension [mm^3]	typical: $21.8 \times 21.8 \times 230$	$24.7 \times 24.7 \times 220$
Depth in X_0	25.8	24.7
No. of crystals	61 200	21 528
Total crystal volume [m^3]	8.14	3.04
Total crystal weight [t]	67.4	25.2
Modularity	36 supermodules	4 Dees
1 supermodule/Dee	1700 crystals (20 in ϕ, 85 in η)	5382 crystals
1 supercrystal unit	–	36 crystals

H→ γγ

CMS em calorimeter resolution

Contribution	Barrel (η = 0)	Endcap (η = 2)
Total stochastic term	2.7%/√E	5.7%/√E
Total constant term	0.55%	0.55%
Total noise (low luminosity) in E_T	155 MeV	205 MeV
Total noise (high luminosity) in E_T	210 MeV	245 MeV

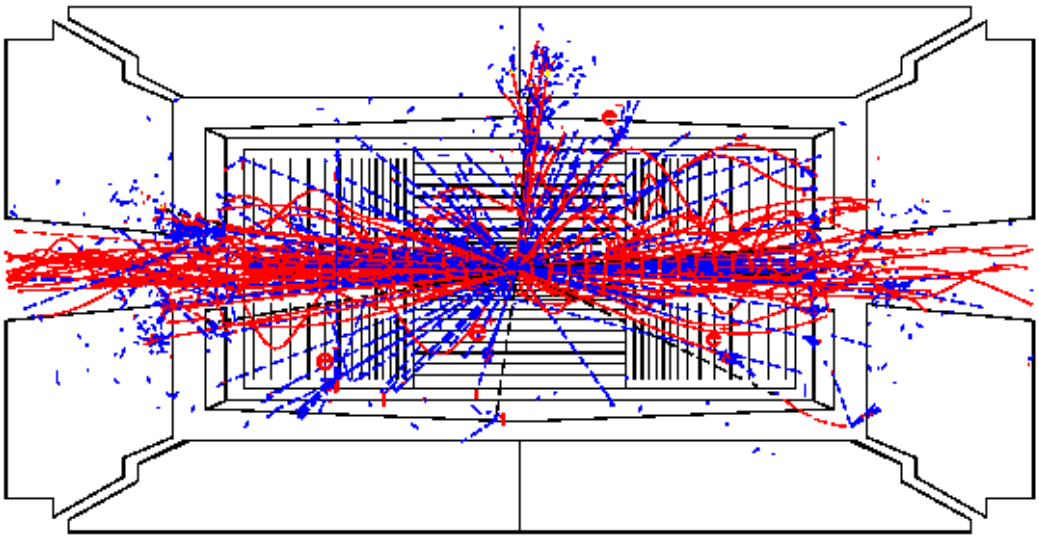


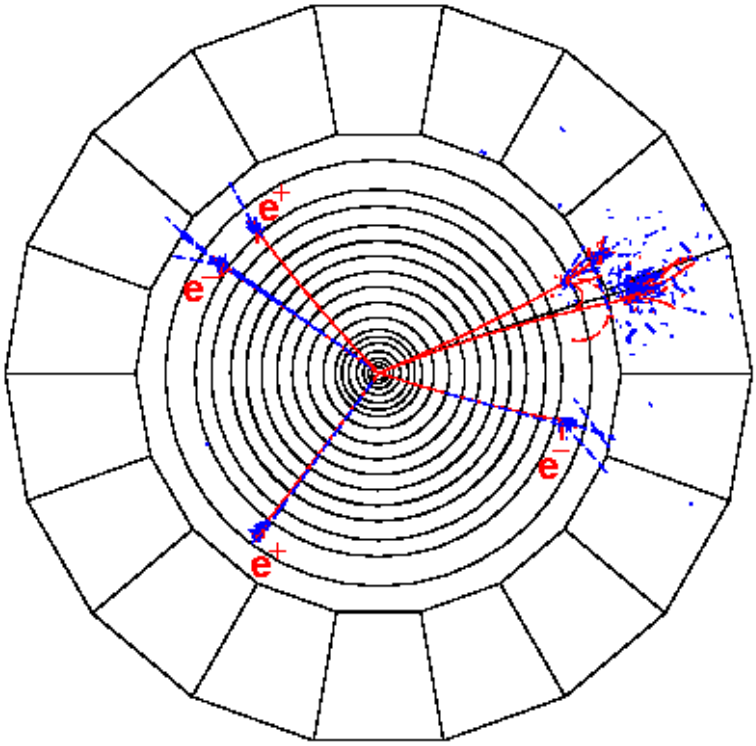
- 130 GeV H → γγ 100 fb^{-1}
  - CMS σ < 1 GeV if can id Higgs vertex
  - ATLAS on the order of 1-2 GeV resolution

$H \rightarrow ZZ^* \rightarrow 4e$

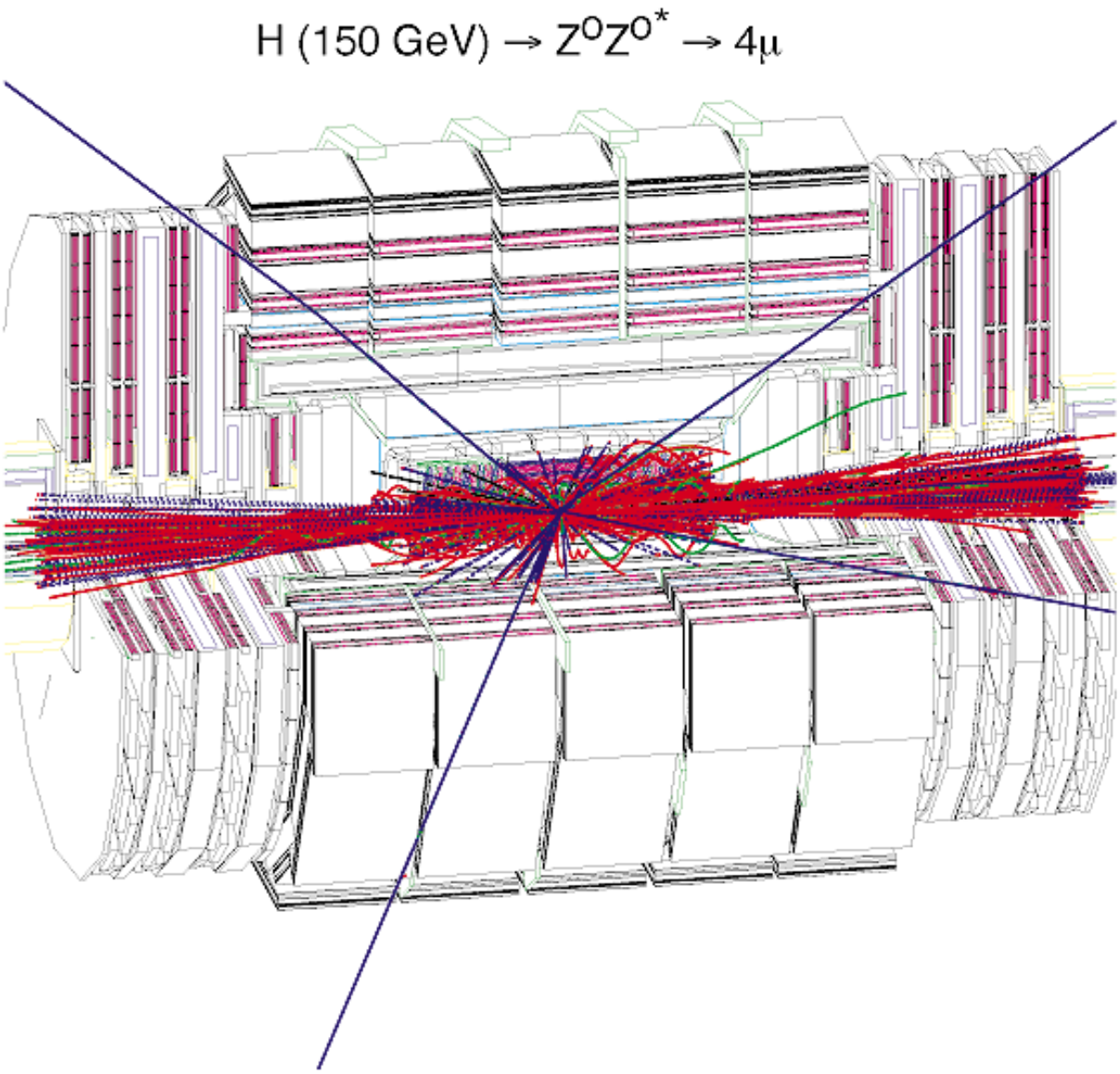
CMS full GEANT simulation of

H(150 GeV) --> ZZ*--> 4e





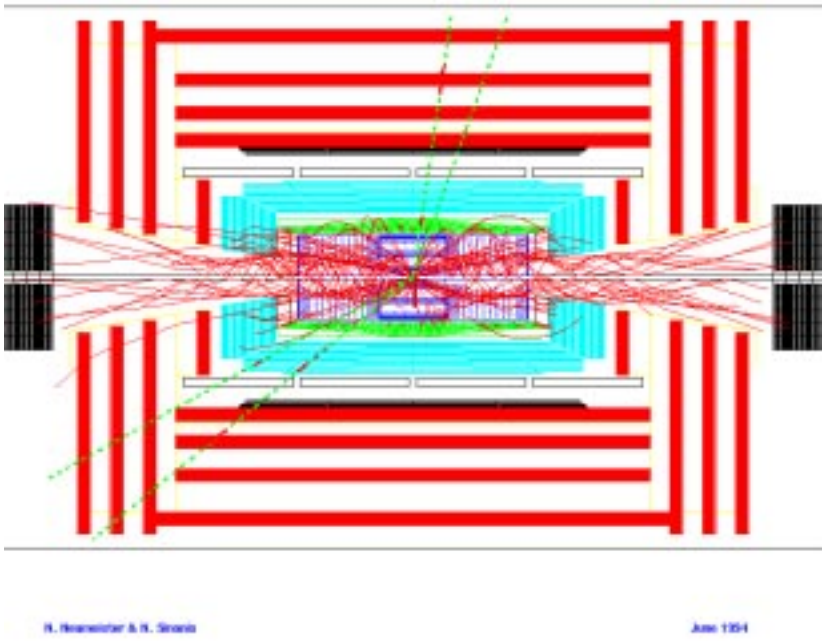
4μ Event

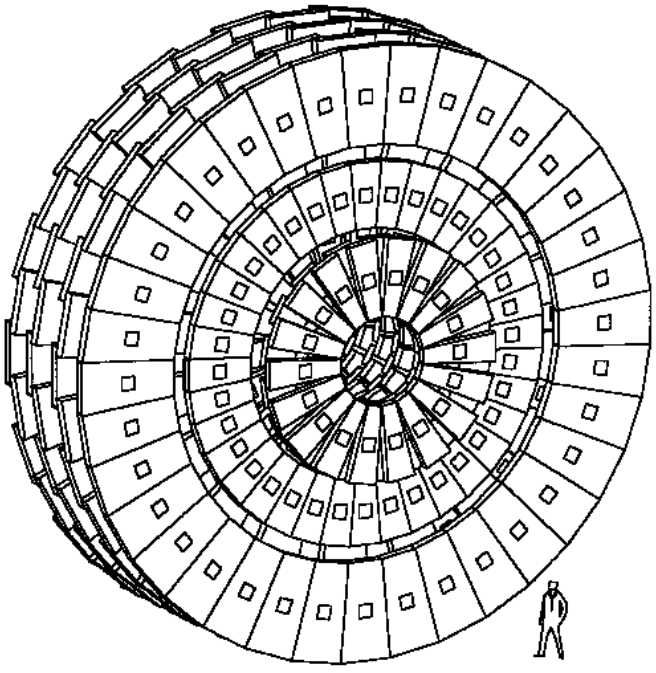


Muon System

CMS

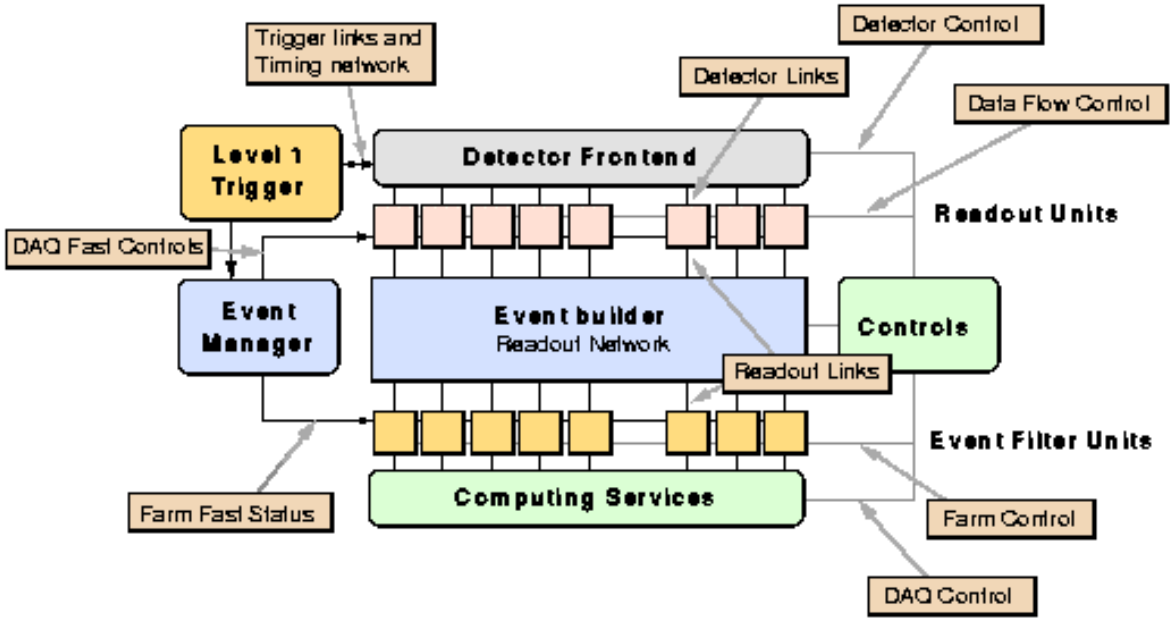
Compact Muon Solenoid





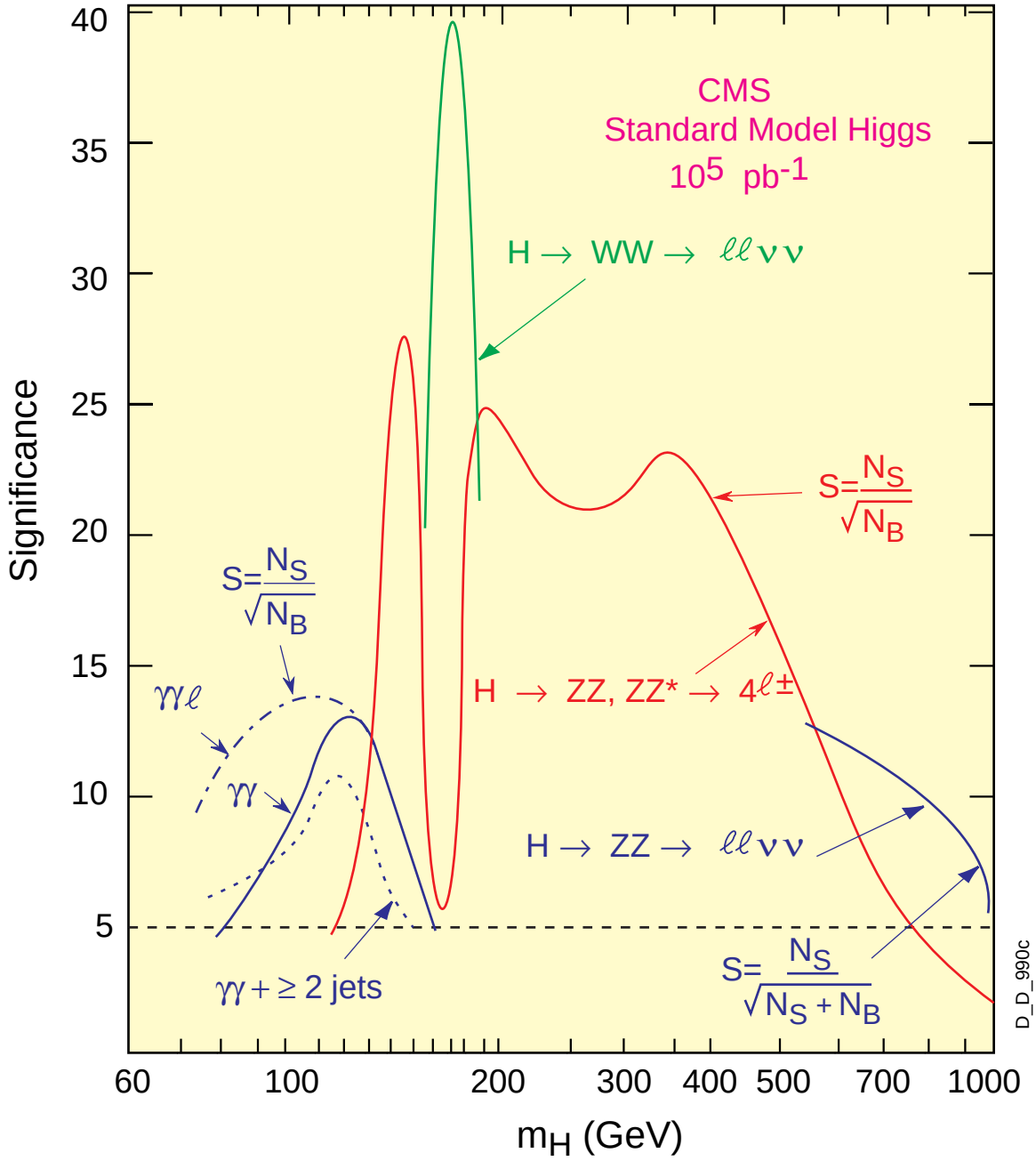
CMS Trigger/DAQ

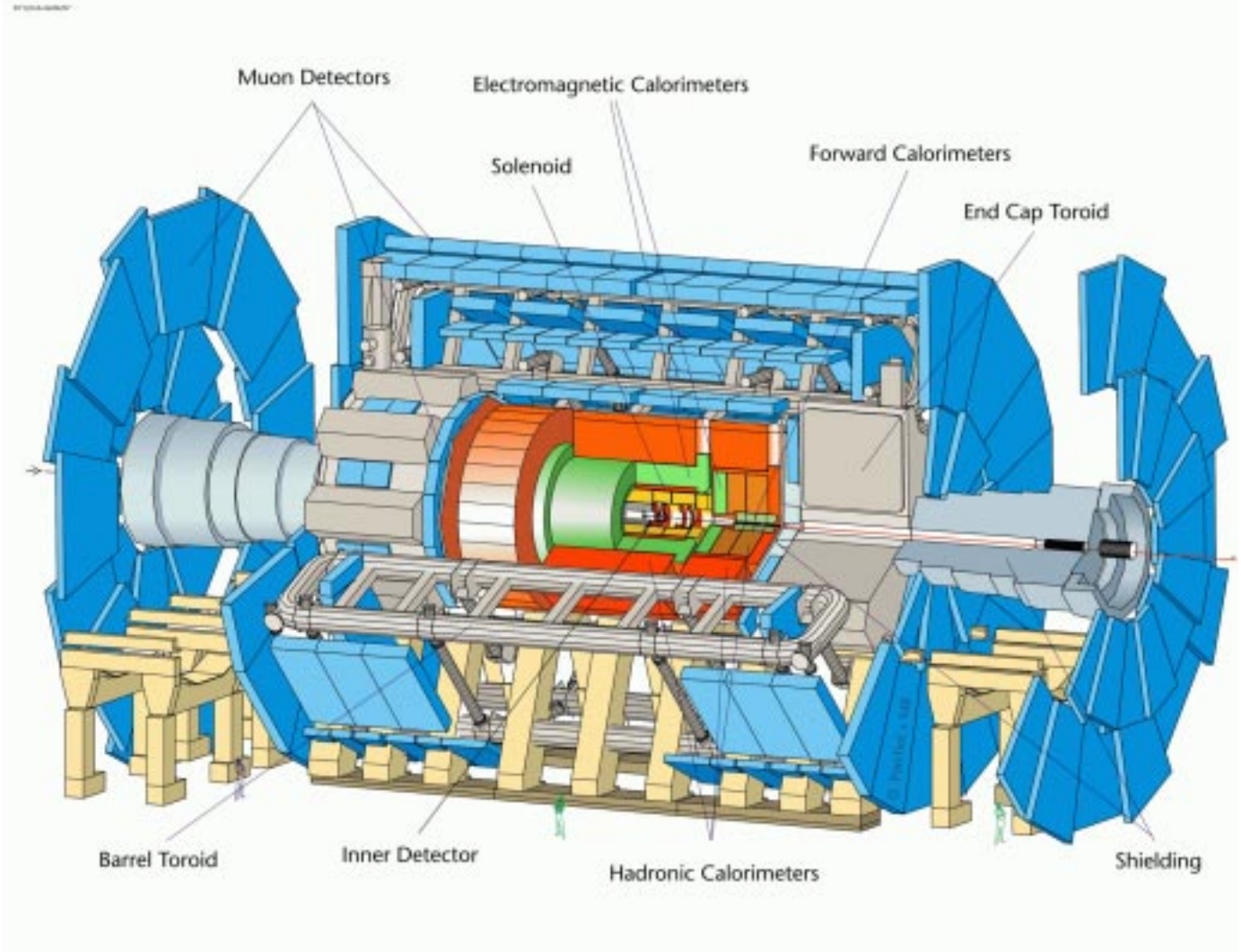
- 40 MHz crossing rate ⇒ 1 GHz interactions
- < 100 kHz L1 rate
- < 10 kHz “L2” rate
- < 100 Hz L3 rate to storage medium



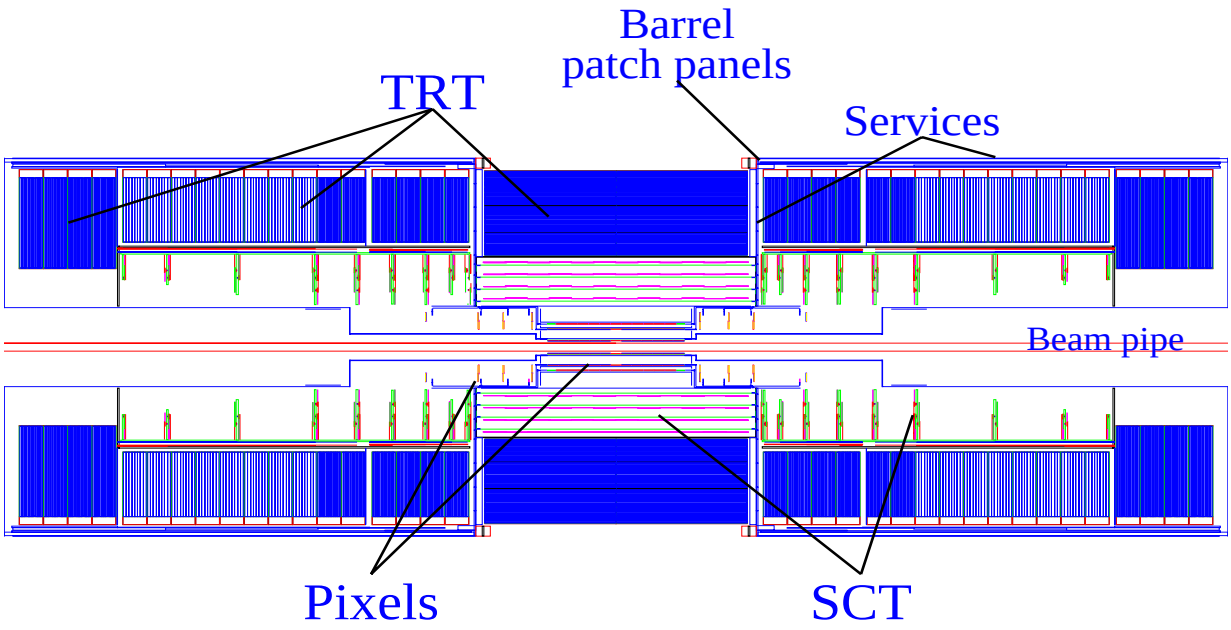
CMS data acquisition main parameters	
Average event size	= 1 MByte
Level-1 Maximum trigger rate	100 kHz
No. of Readout units (200-5000 Byte/event)	1000
Event builder (1000×1000 switch) bandwidth	= 500 Gbit/s
Event filter computing power	= $5 \cdot 10^6$ MIPS
Data production	= TByte/day
No. of readout crates	= 300
No. of electronics boards	= 10000

CMS SM Higgs


CMS
Standard Model Higgs
10^5 pb^{-1}
$H \to WW \to \ell\ell\nu\nu$
$S=\frac{N_S}{\sqrt{N_B}}$
$H \to ZZ, ZZ^* \to 4\ell^{\pm}$
$H \to ZZ \to \ell\ell\nu\nu$
$\gamma\gamma\ell$
$\gamma\gamma$
$\gamma\gamma + \geq 2$ jets
$S=\frac{N_S}{\sqrt{N_S+N_B}}$
Significance
m_H (GeV)
40
35
30
25
20
15
10
5
60
100
200
300
400
500
700
1000
D_D_990c

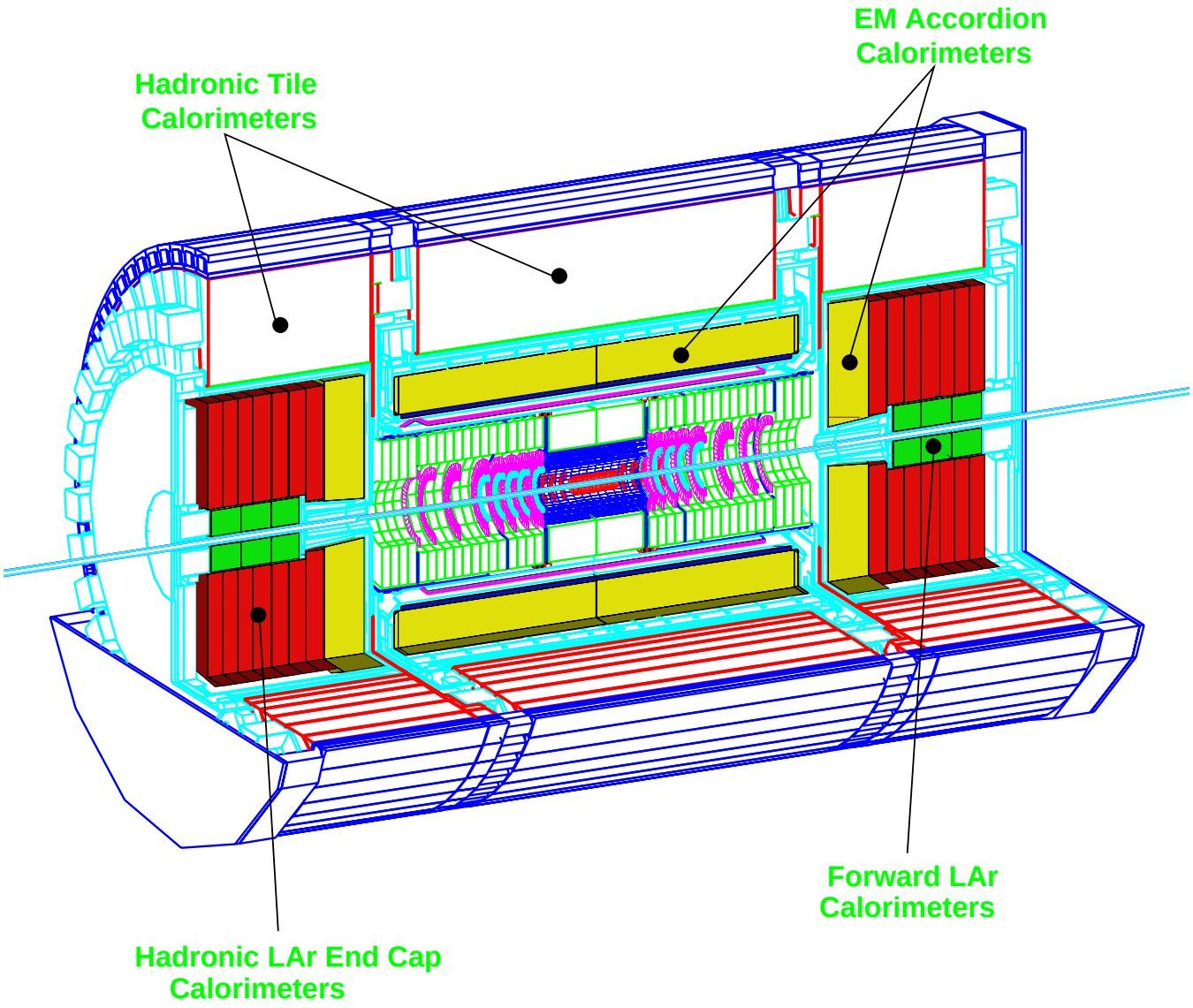

ATLAS
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

ATLAS Inner Detector

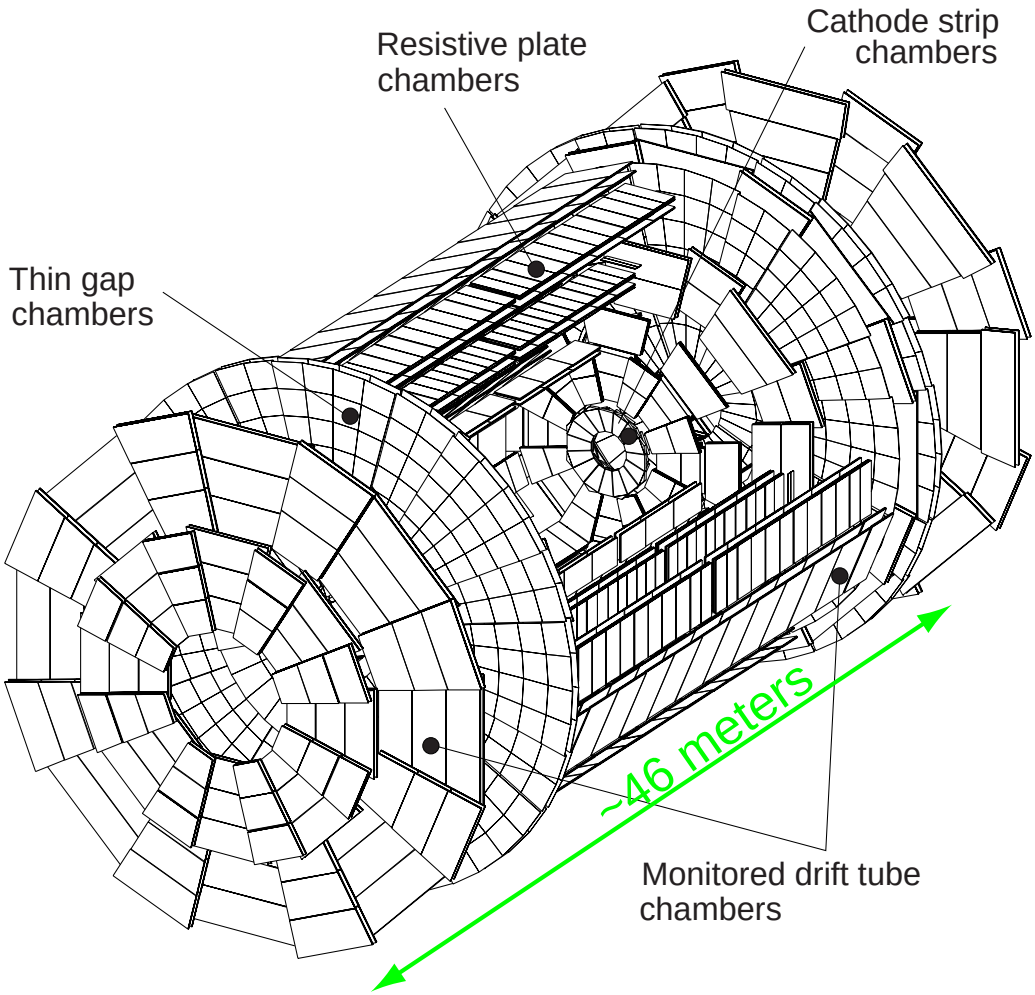


System	Description	Area [m^2]	Resolution		Channels (10^6)	η coverage
			$\sigma(r\phi)$	$\sigma(rz)$		
Pixels	1 Replaceable Barrel layer	0.2	12 μm	66 μm	16	±2.5
	2 Barrel layers	1.4	12	66	81	±1.7
	5 end-cap disks per side	0.7	12	77	43	1.7-2.5
Si Strips	4 barrel layers	34.4	16	580	3.2	±1.4
	9 end-cap wheels per side	26.7	16	580	3.0	1.4-2.5
TRT (36 straws per track)	Axial barrel straws			170	0.1	±0.7
	Radial end-cap straws			170	0.32	0.7-2.5

ATLAS Calorimeters

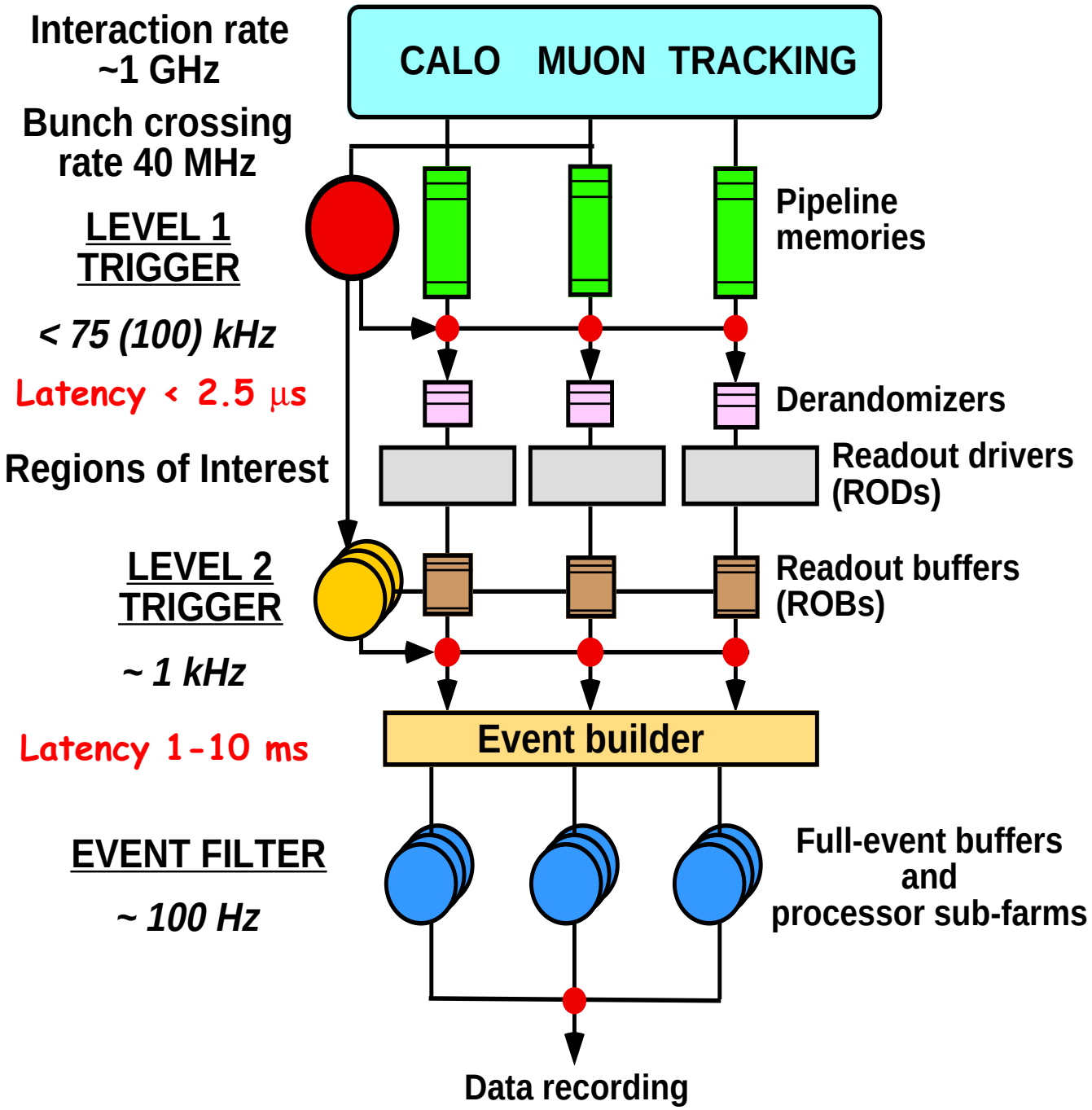


ATLAS Muon System

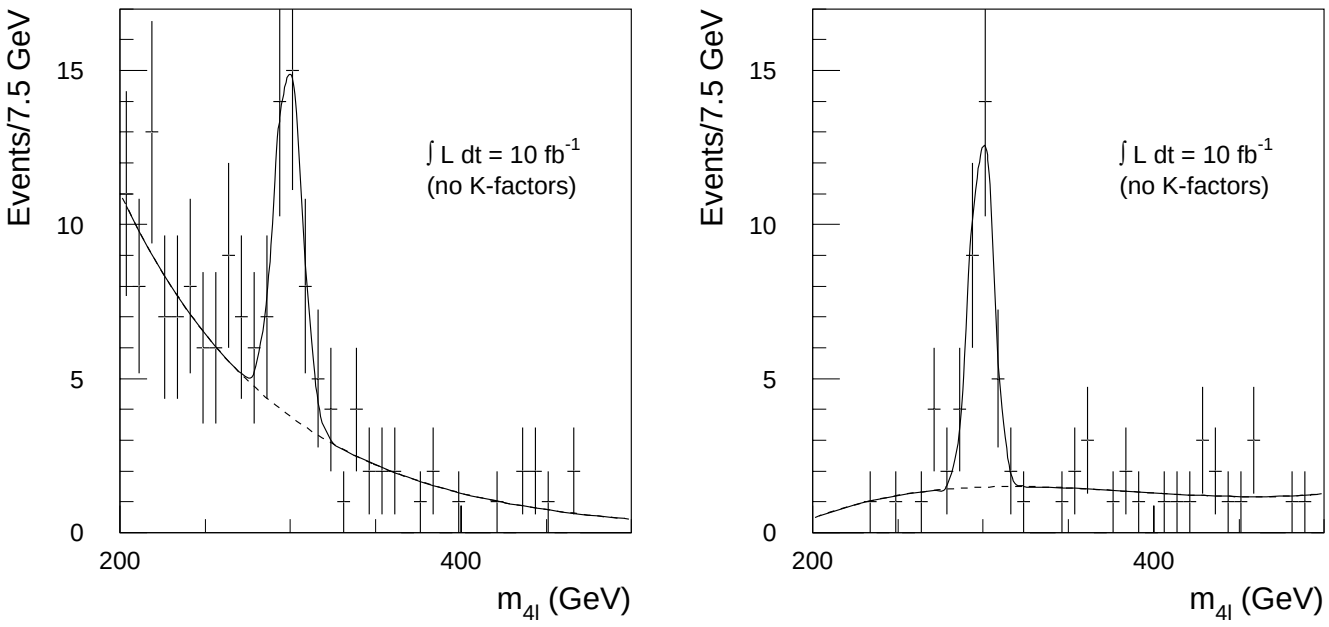


- Monitored Drift Tubes (most of the η range)
  - ~80 μm resolution/wire in bending direction
- Cathode Strip Chambers ($2 < |\eta| < 2.7$)
  - high granularity for innermost, high-rate planes
- Resistive Plate or Thin Gap Chambers ($|\eta| \leq 2.4$)
  - identify bunch crossing
  - trigger w/ well-defined pt cutoffs
  - orthogonal track coordinate to 5-10 mm resolution

ATLAS Trigger & DAQ

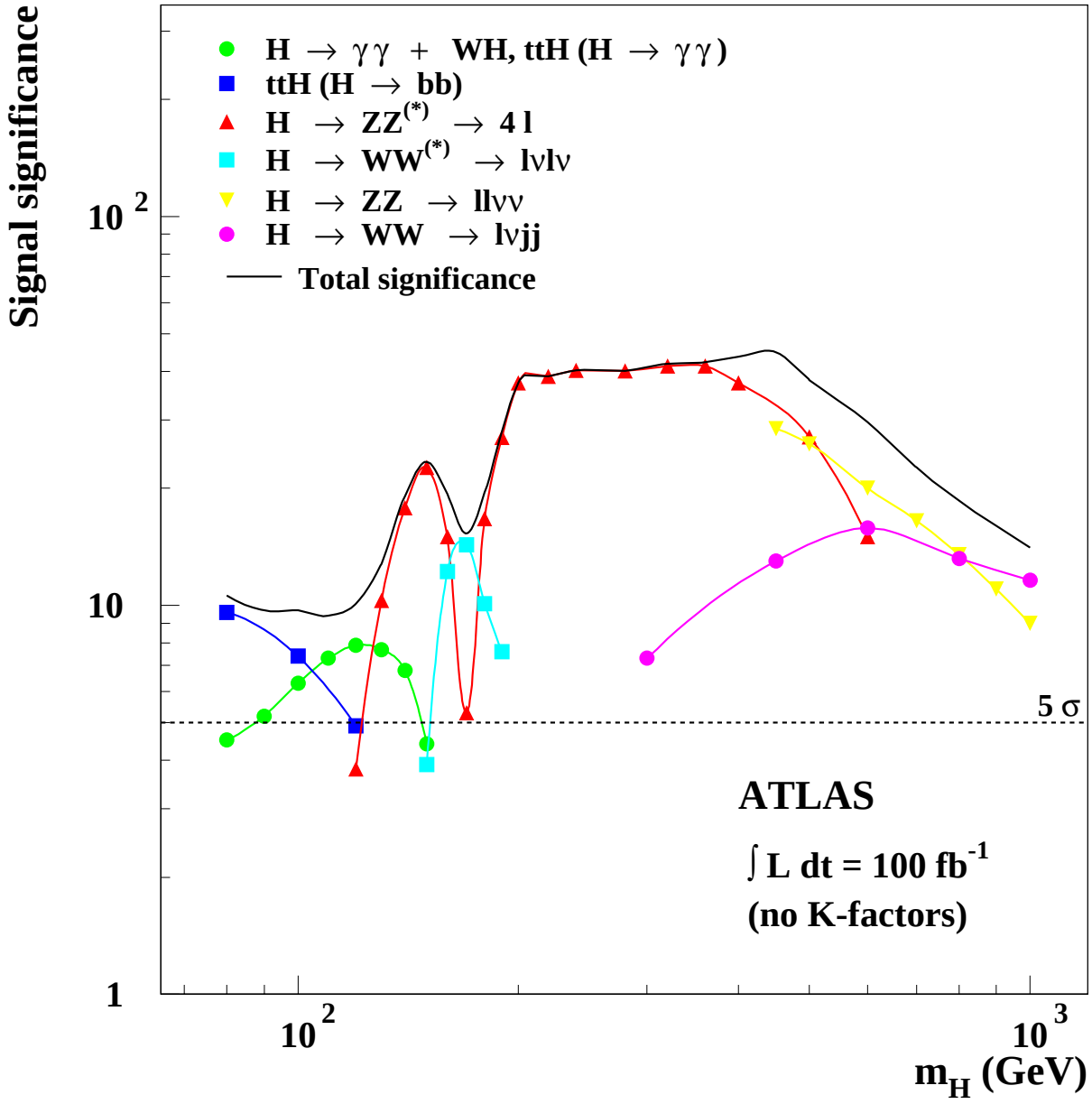


ATLAS H → ZZ → 4l

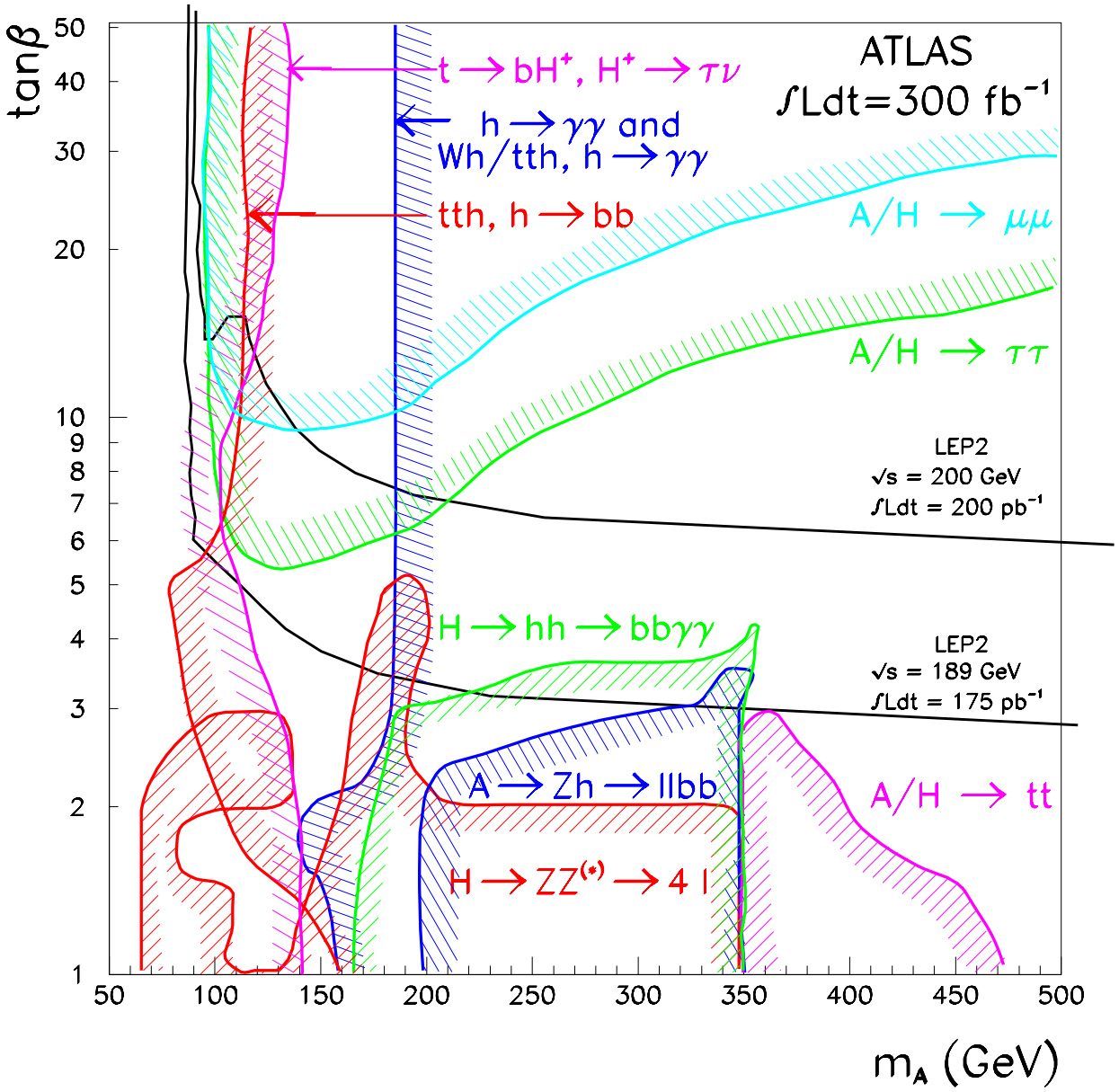


(left: no p_T^Z cut, right: with p_T^Z cut)

ATLAS SM Higgs



ATLAS MSSM Higgs



Conclusions

- Hadron Collider Experiments are capable of both discovery and precision measurement
- The current planned Tevatron and LHC experiments are designed to handle huge data rates and track densities.
- These experiments are poised to make a wide range of significant discoveries and measurements
- These are exciting times