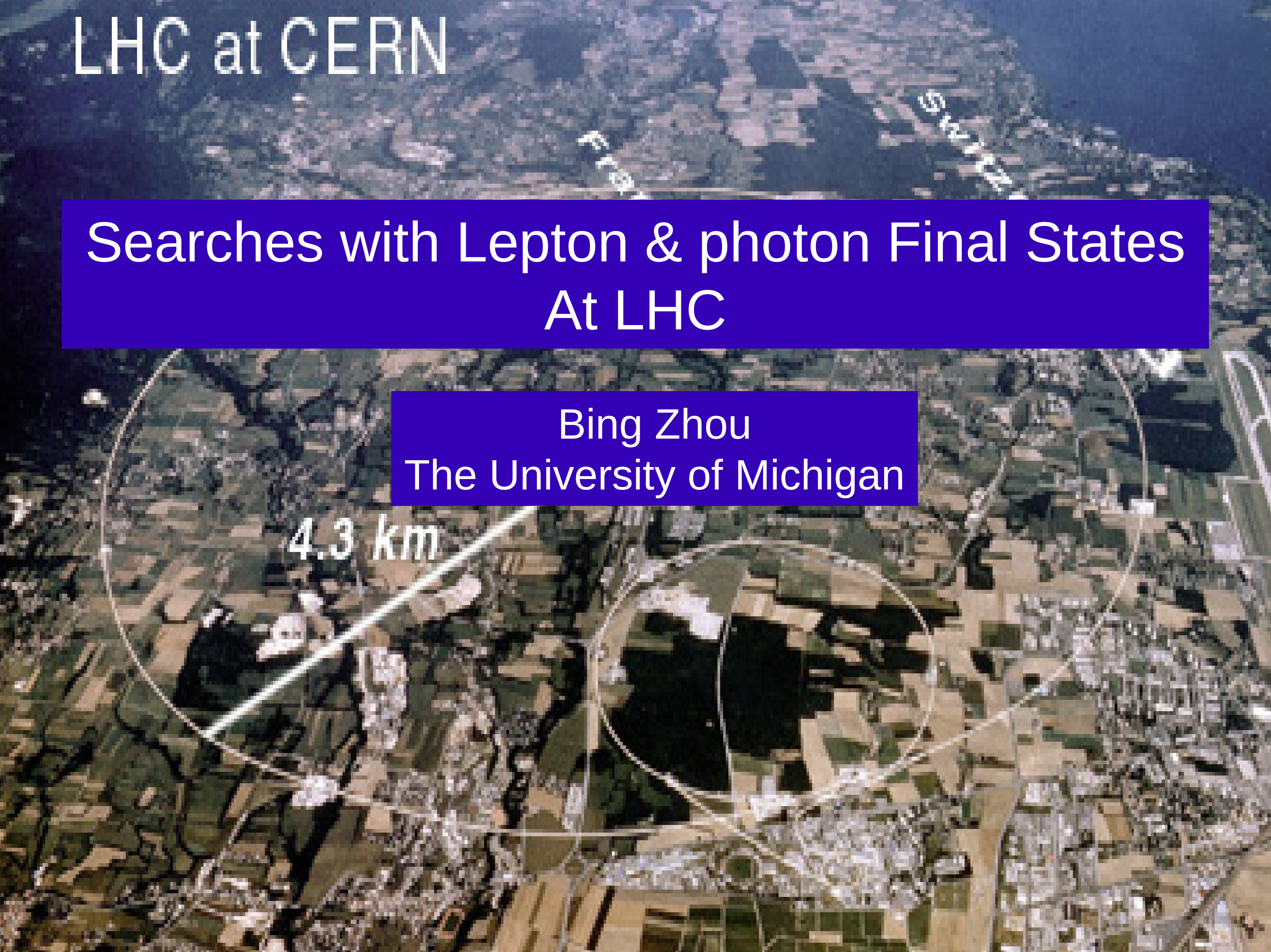
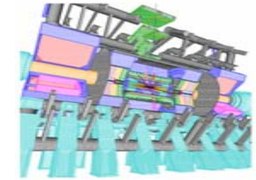
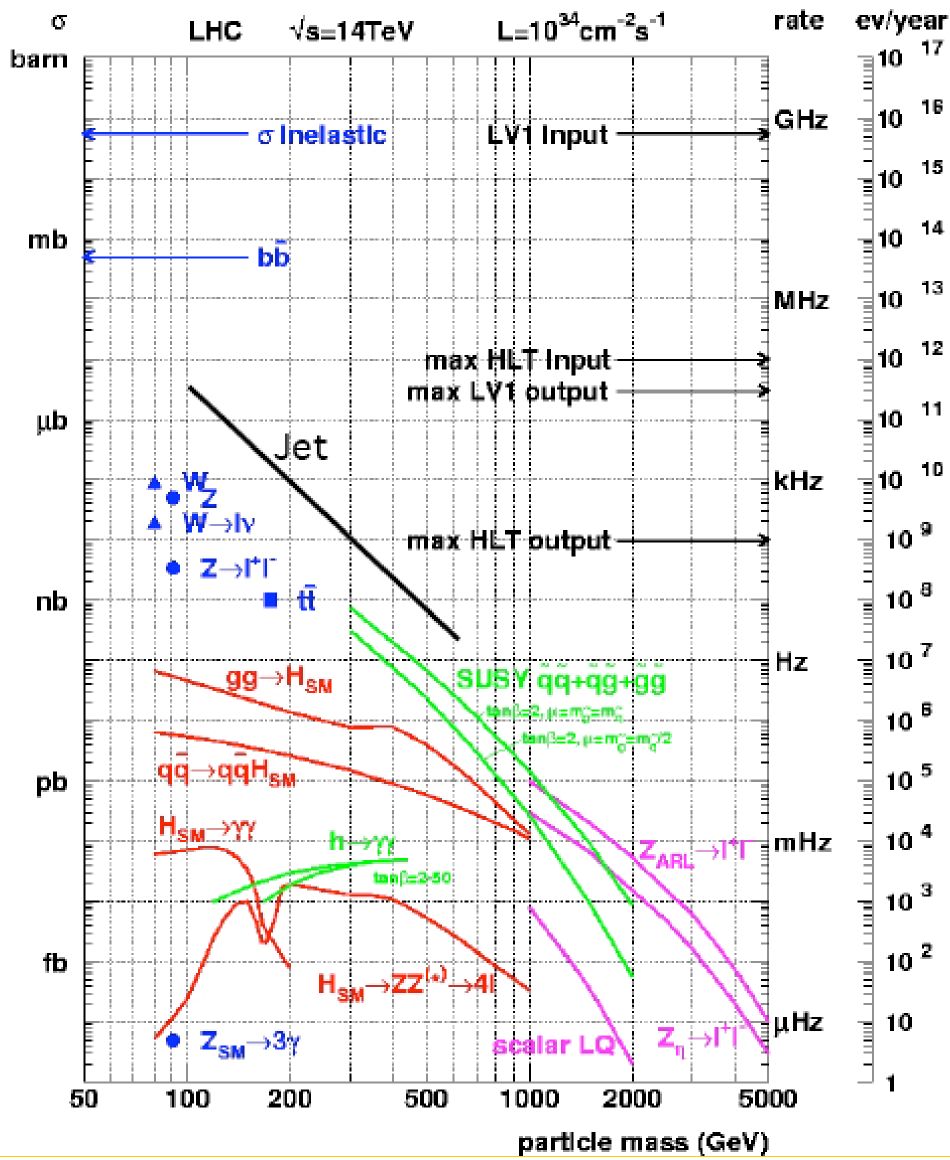


Searches with Lepton & photon Final States At LHC

Bing Zhou
The University of Michigan

LHC Physics





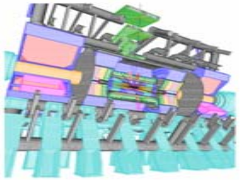
Make great discoveries in TeV energy scale to advance our understanding:

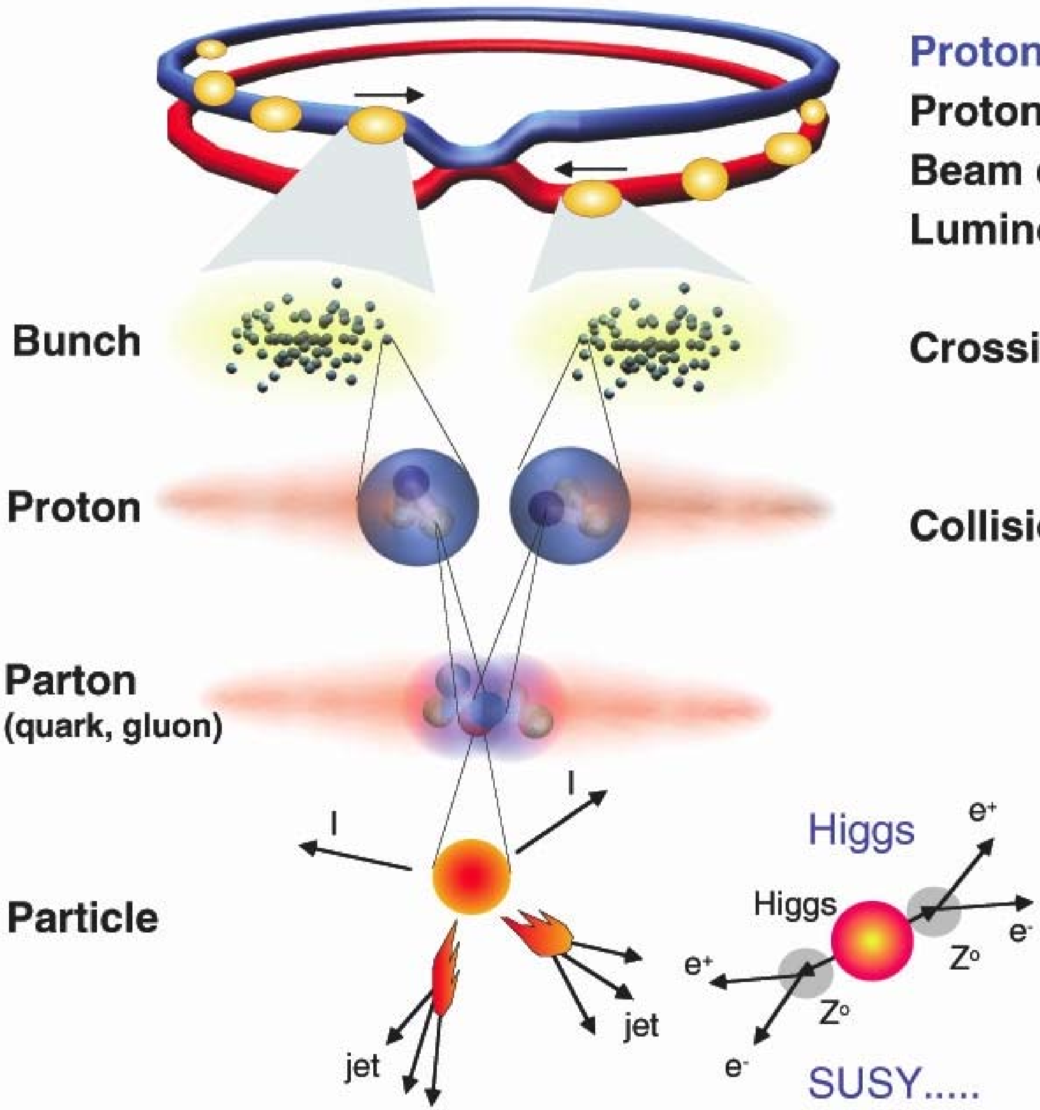
- Electroweak Symmetry Breaking

- Origin of Dark Matter

Physics Models
Higgs
Supersymetry
Technicolor
Extra-Dimension
…

Experiment Challenge at LHC





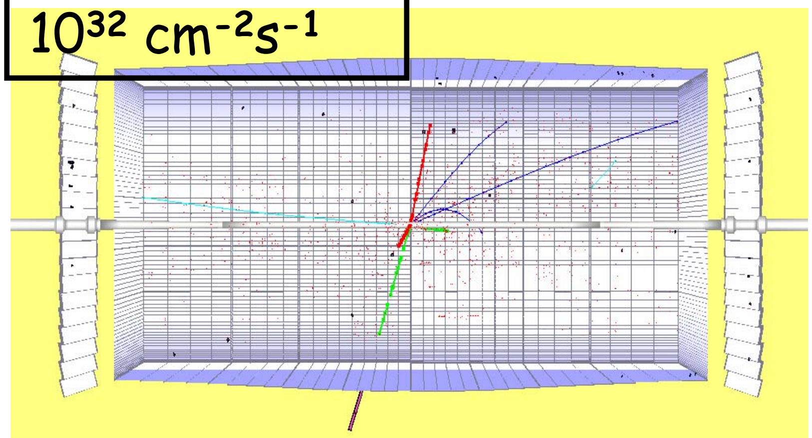
Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

Selection of 1 in
10,000,000,000,000

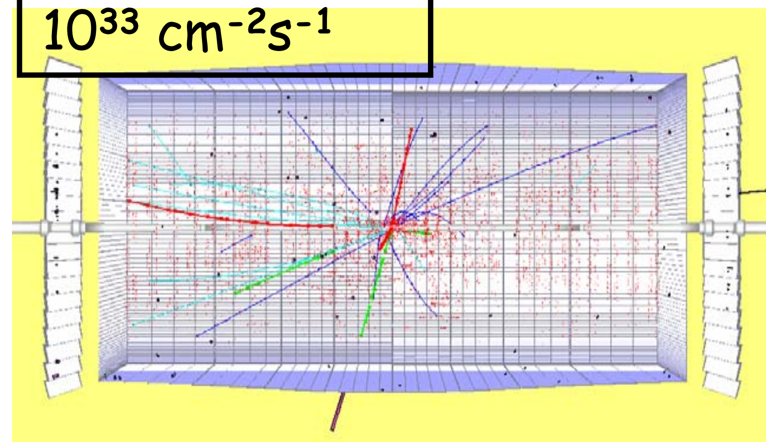
Pile up at different luminosities

$H \rightarrow ZZ \rightarrow \mu\mu ee$ event with M_H= 300 GeV

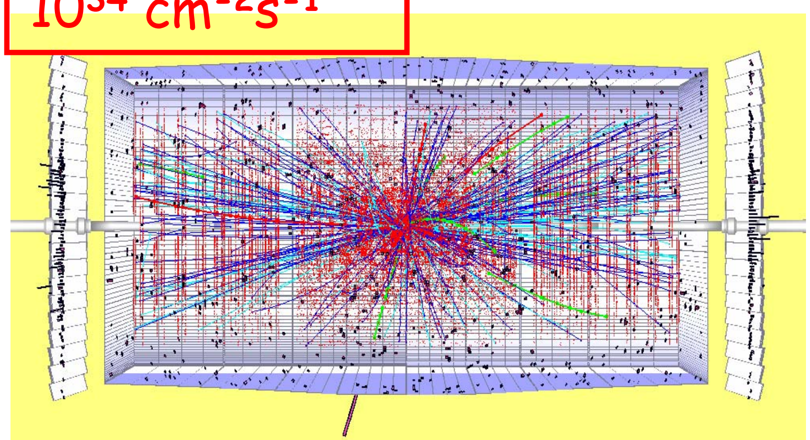
10^{32} cm^{-2}s^{-1}



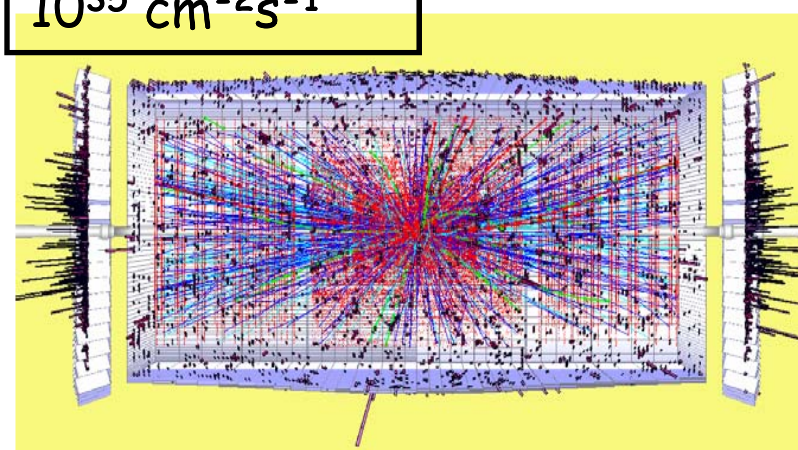
10^{33} cm^{-2}s^{-1}



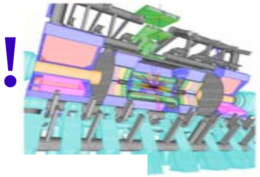
10^{34} cm^{-2}s^{-1}

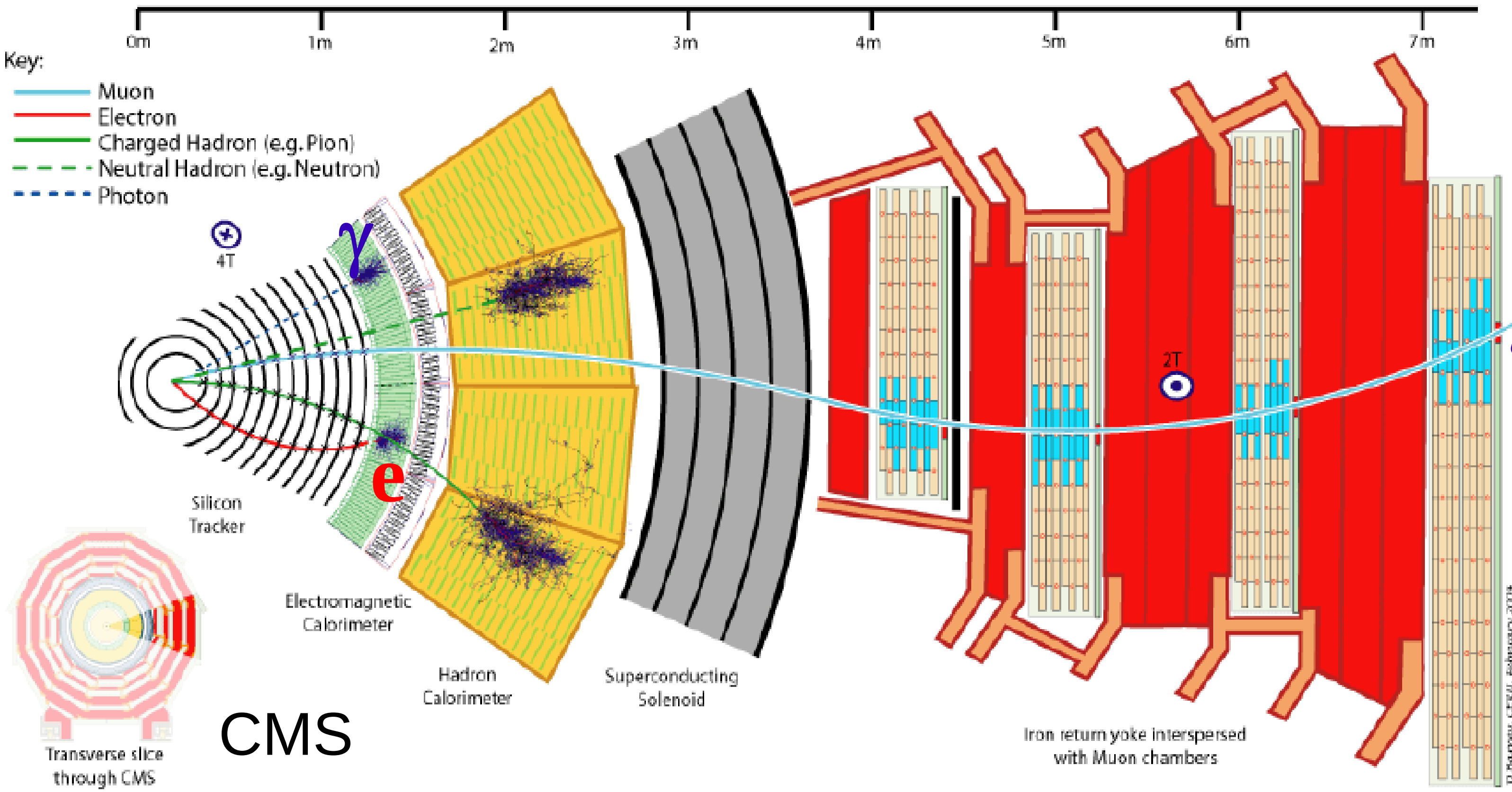


10^{35} cm^{-2}s^{-1}



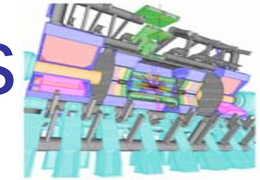
Lepton Signals Are the Keys for Discovery !





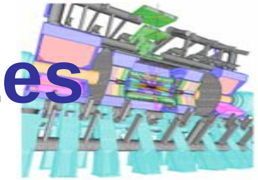
- Lepton identifications: high efficiency, low fake rate
- Excellent energy and momentum resolution
- Trigger at low Pt
- **Clean Signature for new physics discoveries!**
- **Detector can be well understood from $Z \rightarrow \ell^+\ell^-$ events**

Search for New Physics Studies



SM Higgs H^0	Look for final states with ℓ, and γ : $H \to \gamma\gamma$, $H \to bb$ (with tt or W with lepton decays), $H \to \tau\tau$ (via VBF), $H \to ZZ^*/ZZ \to \ell^+\ell^-\ell^+\ell^-$, $\ell^+\ell^-\nu\nu$, $\ell^+\ell^- jj$, $H \to WW^* \to \ell^+\nu\, \ell^-\nu$ or $\ell\nu\, jj$ (via BVF)
Extended Models H^0, h^0, A^0, H^+H^- & $H{++}$, $H{--}$	SM-like: $h \to \gamma\gamma$, bb; $H \to 4\ell$ MSSM-specific: $A/H \to \mu\mu$, $\tau\tau$; $H \to hh$, $A \to Zh$; $H^\pm \to \tau\nu$ $A/H \to \chi^2_0\,\chi^2_0 \to 4\ell$ + missing Energy
Supersummetry	Like-sign leptons, multi-leptons and Jets with Missing E_T
Heavy Q Q	$Q \to W q \to \ell$ + jets
New bosons Z', W'	$Z' \to \ell^+\ell^-$, $W' \to \ell\, \nu$
Technicolor	$\rho_T \to WZ \to \ell\nu\, \ell\ell$, $\rho_T \to W\pi \to \ell\nu bb$
L/Q structure	$Pp \to LQ\, LQ \to \ell q\, \ell q$: High-mass di-leptons, Missing E_T
Extra-dimension	High-mass di-leptons, narrow lepton resonances, Jets+Missing E_T
Composite Models	$pp \to L^+L^- \to ZZ$+2leptons $\to$ 6 leptons, $pp \to ee^* \to ee\gamma$
Strongly-couples Vector-bosons	High mass spectra: $W_LZ_L \to W_LZ_L \to \ell\nu\, \ell\ell$, $Z_LZ_L \to Z_LZ_L \to \ell\ell\, \ell\ell$ $W_LW_L \to Z_LZ_L \to \ell\ell\, \ell\ell$

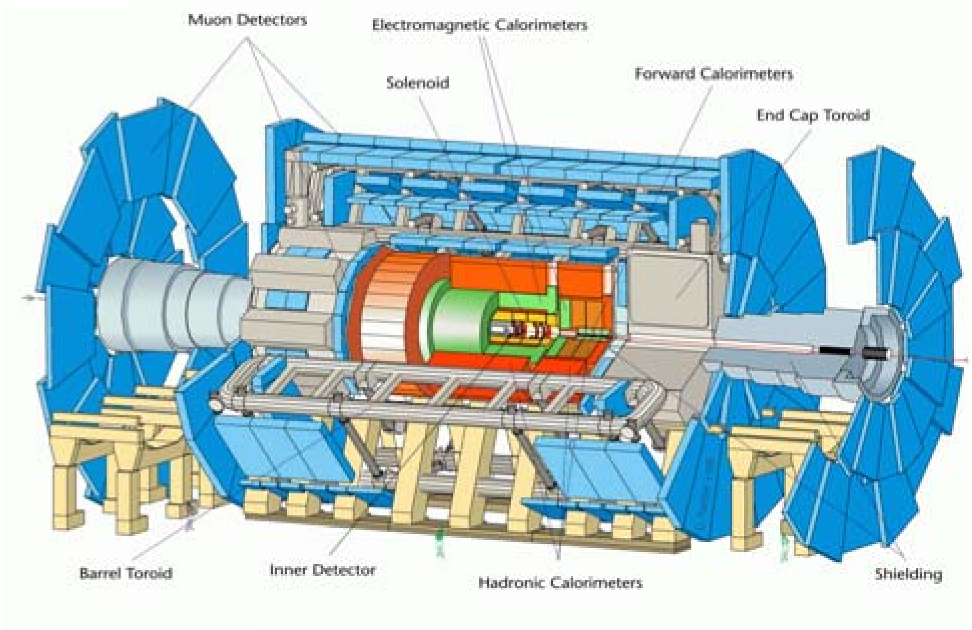
New Physics with Multi-lepton Final States

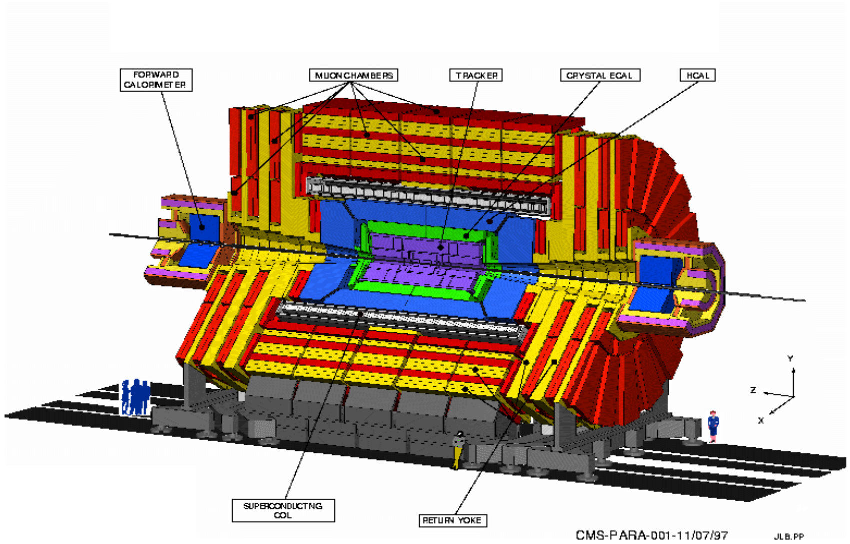


Single lepton	*SM:* *W→* $\ell\ \nu$ *W+jets→* $\ell\nu$ +x **tt/bb →** ℓ **+ x**	**W'→** $\ell\ \nu$ **H→bb +W/tt(with W →** $\ell\ \nu$ **)** **H→WW*→** $\ell\ \nu\ jj$ **(via BVF)** ρ_T **→ W**π **→** $\ell\ \nu bb$ **Q→ W q →** ℓ **+ jets**
Di-lepton	*SM* Z/γ*→ $\ell^+\ell^-$ Z+jets→ $\ell^+\ell^-$+x ***tt/ww*** **→** $\ell^+\ell^-$ **+x**	**H→WW*→** $\ell^+\nu\ \ell^-\nu$ **A/H** → $\mu\mu$, $\tau\tau$ **Like-sign dileptons from SUSY particle decays** **High mass narrow resonances**: Z'→ $\ell^+\ell^-$, **G*→** $\ell^+\ell^-$,… **pp→ LQ LQ →** ℓ**q** ℓ**q** **pp→ ee*→ ee**γ
Triple-lepton	*SM* *WZ→* $\ell\nu\ \ell\ell$	ρ_T **→ WZ →** $\ell\nu\ \ell\ell$ W_LZ_L **→** W_LZ_L **→** $\ell\nu\ \ell\ell$ **pp→ W* →** $\chi_1^+\chi_2^0$**→ W+**χ_1^0 **+ Z***χ_1^0 **→** $\ell\ \ell\ell$ **+ Missing** E_T
Four-leptons	*SM* *ZZ→* $\ell^+\ell^-\ell^+\ell^-$	**H→ ZZ*/ZZ →** $\ell^+\ell^-\ell^+\ell^-$ **A/H** → $\chi^2_0\ \chi^2_0$ → **4**ℓ **+ missing Energy** Z_LZ_L **→** Z_LZ_L **→** $\ell\ell\ \ell\ell$, W_LW_L **→** Z_LZ_L **→** $\ell\ell\ \ell\ell$
Six-leptons		**pp→**L^+L^-**→ ZZ+2leptons → 6 leptons**

ATLAS and CMS Detectors

> 10 years of hard work in design and constructions





ATLAS

Length : ~45 m
Diameter : ~24 m
Weight : ~ 7,000 tons
Electronic channels : ~ 10^8
Solenoid : 2 T
Air-core toroids

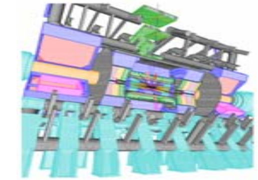
Excellent Standalone Muon Detector

CMS

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

Excellent EM Calorimeter

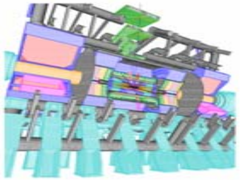
Detector Technologies



- 1987 : first studies
- 1990 : Aachen workshop
- Summer 1992 : Evian workshop
- 1992 ATLAS and CMS Letters Of Intent
- 1997: Technique Design Report
- 1998: Start construction
- 2004: Start intégration and installation
- 2007: First beam

	ATLAS (A Toroidal LHC Apparatus)	CMS (The Compact Muon Solenoid)
TRACKER	Si pixels + strips TRT → particle identification $\sigma/p_T \sim 5\times10^{-4}\ p_T \oplus 0.01$	Si pixels + strips No particle identification $\sigma/p_T \sim 1.5\times10^{-4}\ p_T \oplus 0.005$
EM CALO	Pb-liquid argon $\sigma/E \sim 10\%/\sqrt{E}$ uniform longitudinal segmentation	$PbWO_4$ crystals $\sigma/E \sim 2\text{-}5\%/\sqrt{E}$ no longitudinal segmentation
HAD CALO	Fe-scint. + Cu-liquid argon ($\geq 10\ \lambda$) $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$	Brass-scint. ($\geq$ 5.8+catcher) $\sigma/E \sim 100\%/\sqrt{E} \oplus 0.05$
MUON	MDT, CSC, RPC, TGC $\sigma/p_T \sim 7\ \%$ at 1 TeV standalone	DT, CSC, RPC $\sigma/p_T \sim 5\%$ at 1 TeV combining with tracker

Trigger Tables



Trigger type	ATLAS (GeV) Threshold	CMS (GeV) Threshold
Inclusive isolated e/γ	25	29
Two electrons/Two photons	**15**	**17**
Inclusive isolated muon	20	14
Two muons	**6**	**3**
Inclusive τ-jet	-	86
Two τ-jet	-	59
τ-jet and E^{T}_{miss}	25 and 30	-
1-jet, 3-jets, 4-jets	200,90,65	177,86,70
Jet and E^{T}_{miss}	60 and 60	
Electron and Jet		21 and 45
Electron-Muon	15*10	-
+calibration, monitoring, etc…		

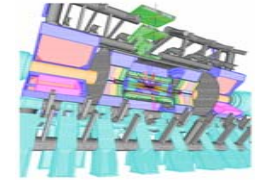
*Typical LVL1 menu for L= $2.10^{33}cm^{-2}s^{-1}$

*all thresholds are adjustable

*multiple signature allow lower thresholds

*total rate ~20kHz (allowing safety margin and deferrals)

Major Challenges



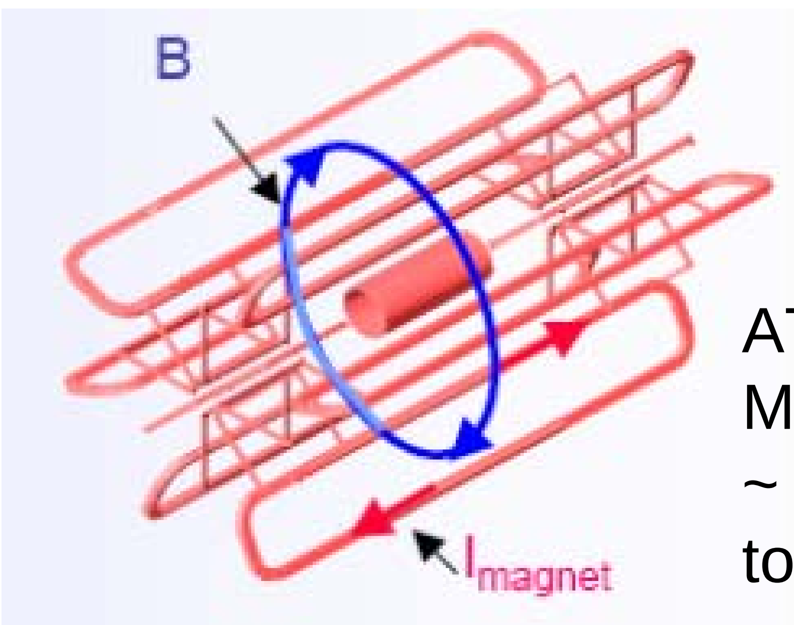
Super conducting magnets:

– CMS :

one solenoid* 6m diameter 13 meter long, field 4T

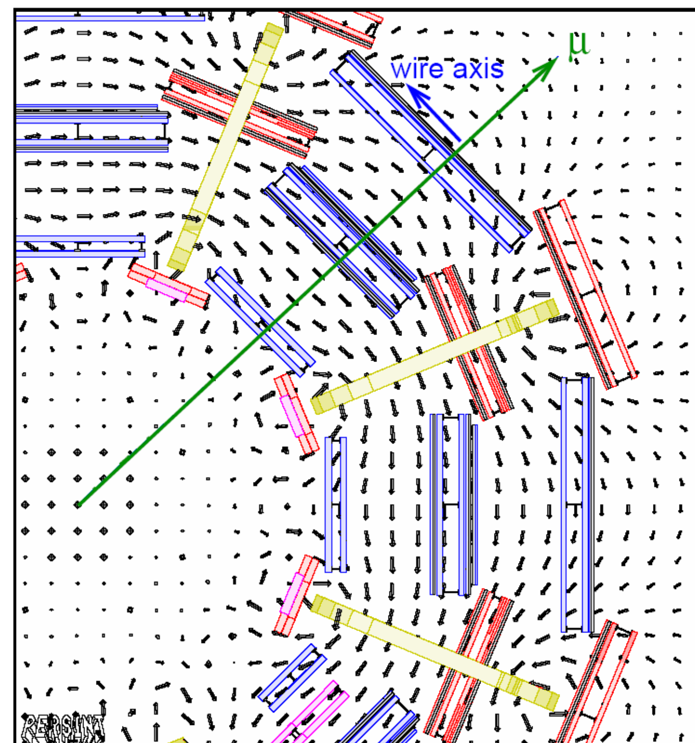
– ATLAS:

- Solenoid* 2.5 m diameter 5m long, field 2T
- Barrel toroid* 8 20m long coils
- 2 endcap toroids 8 5m long coils

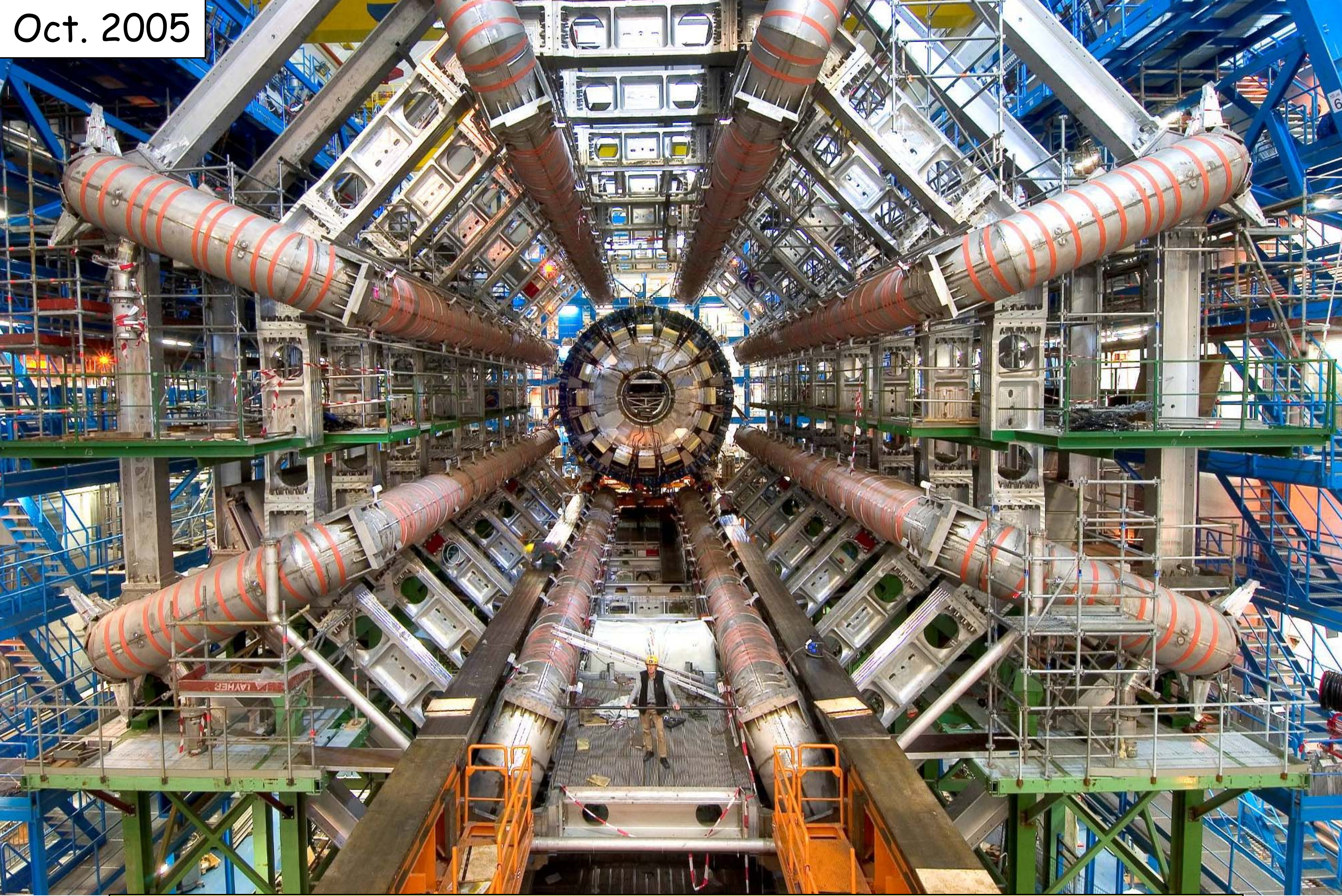


ATLAS Magnets ~ 40% of total cost

$|\eta| < 2.7$



Oct. 2005



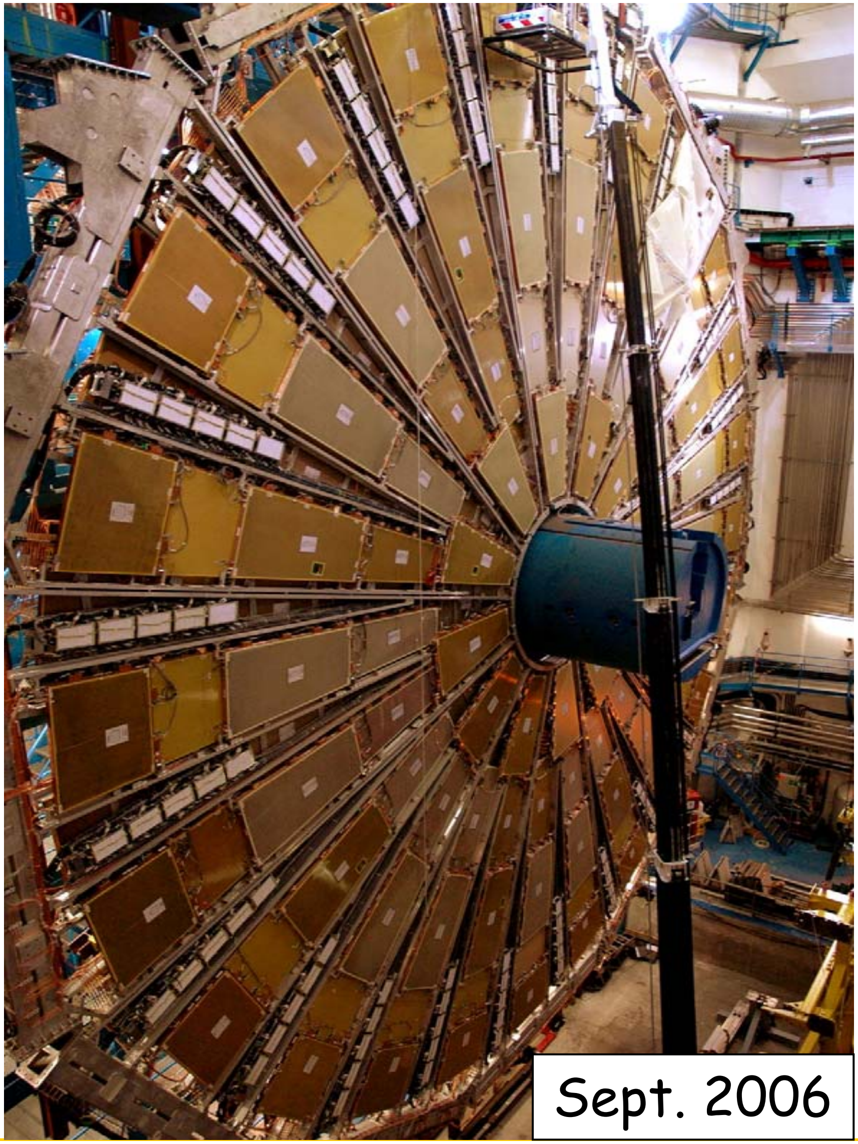
- The last(8-th) Barrel Toroid coil installed in Aug. 2005
- Barrel calorimeter (LAr EM + HAD Fe/Scint. Tilecal) in final position at Z=0 (Nov. 2005)
- Barrel toroid: cool down completed, first tests towards full field started in Sep. 2006

ATLAS

Barrel muon system complete

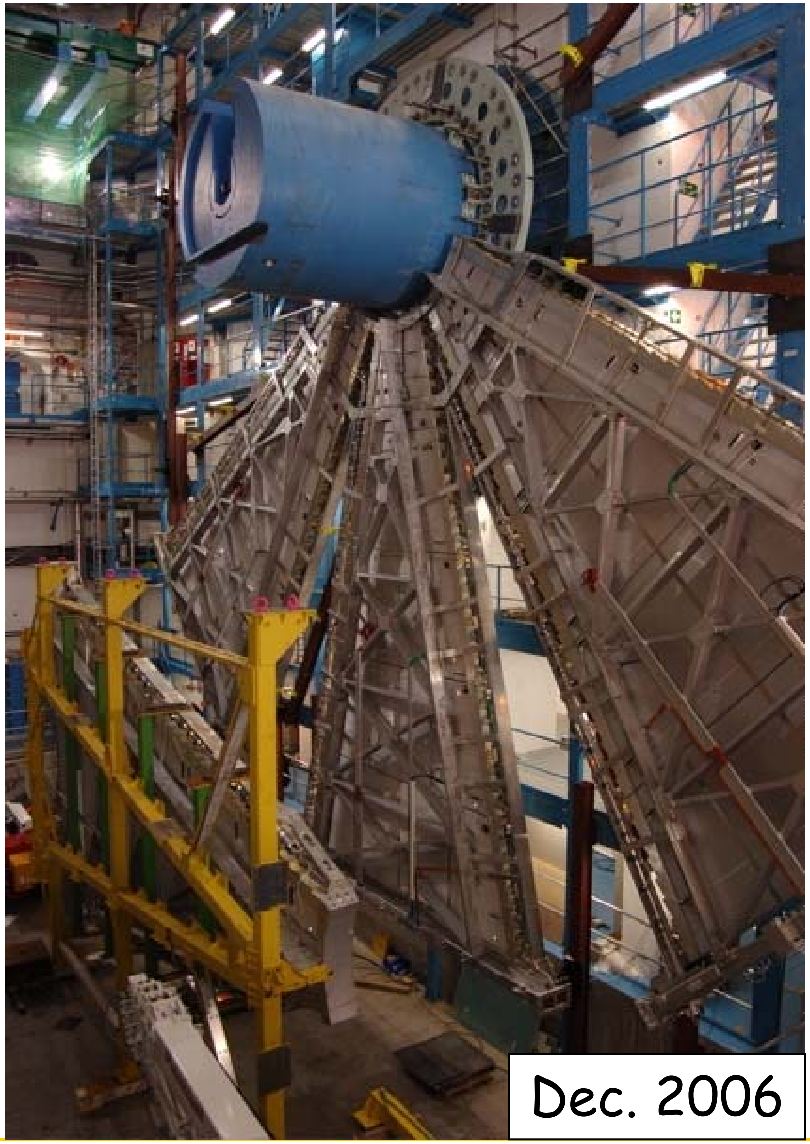
Endcap Muon Big-Wheel installation
Started in June 2006

TGC Big-Wheel (C-1)



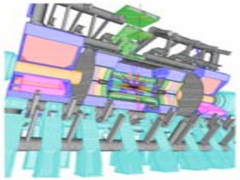
Sept. 2006

MDT Big-Wheel (C)

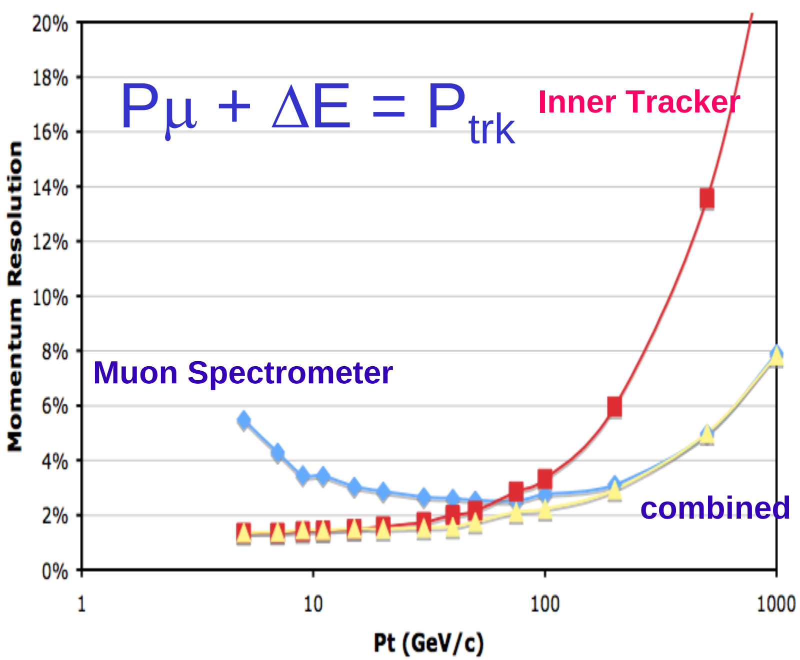


Dec. 2006

High Precision Tracking for Muon Detections

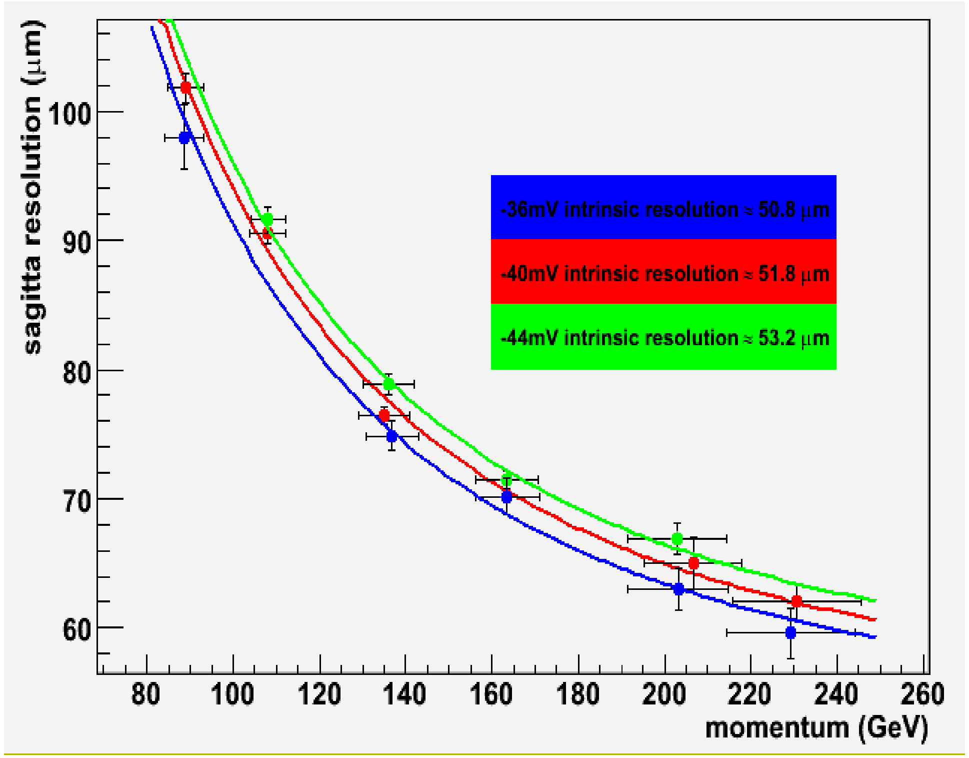


ATLAS



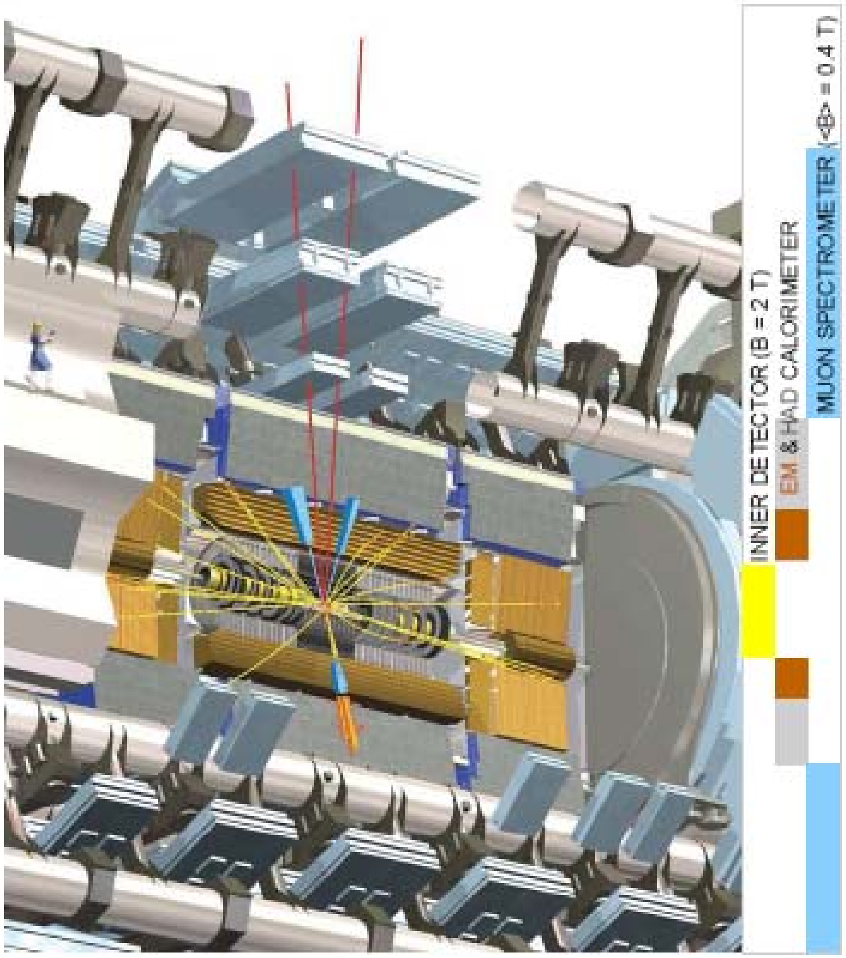
$|h|$ coverage to 2.7,
$\Delta p/p \sim 8\%$ @ 1TeV
$(\Delta s/s \sim 50\ \mu)$

Precision tracking with MDT
With gas pressure of 3 bar



Test Beam results

Muon and Electron Identifications



Muons:

- Muon spectrometer track (MS: trigger + drift-tube chamb.), can be combined with the inner detector track. (ID: silicon detector + TRT)
- Low-p_T muons: ID track combined with MS hits.

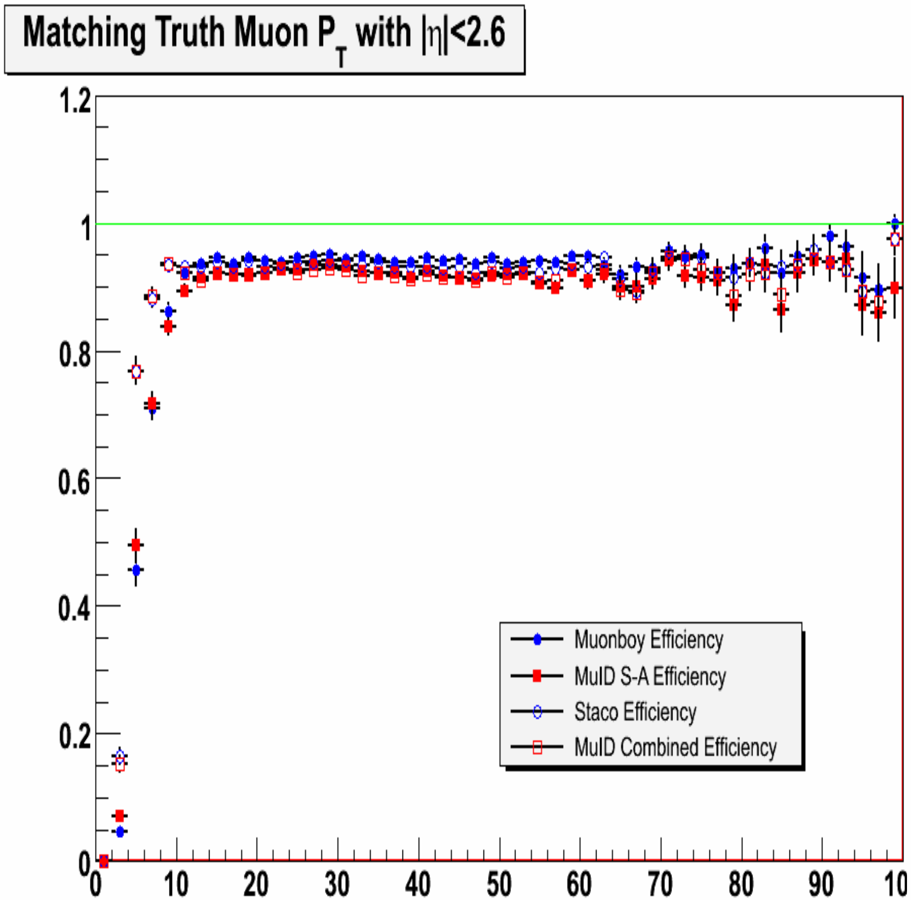
Electrons:

- Shower-shape analysis in the fine-granularity calorimeter, clusters are always matched with the ID track.
- Low-p_T electrons: ID combined with clusters.

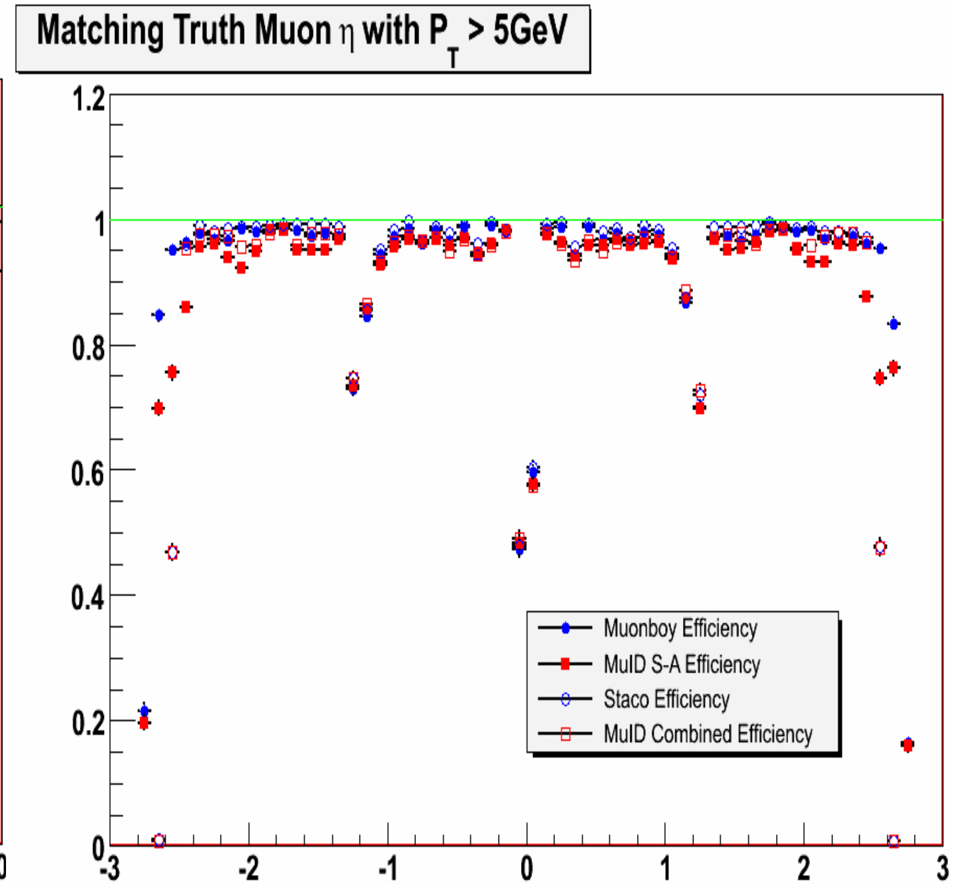
Isolation criteria (given by the calorimeter or by the inner detector): suppressing leptons which come from jets.

ATLAS : Muon Detection Efficience

Study based ATLAS CSC data sample: $Z \rightarrow \mu\mu$

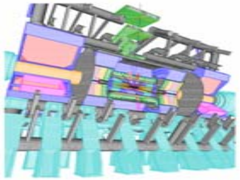


Muon Pt

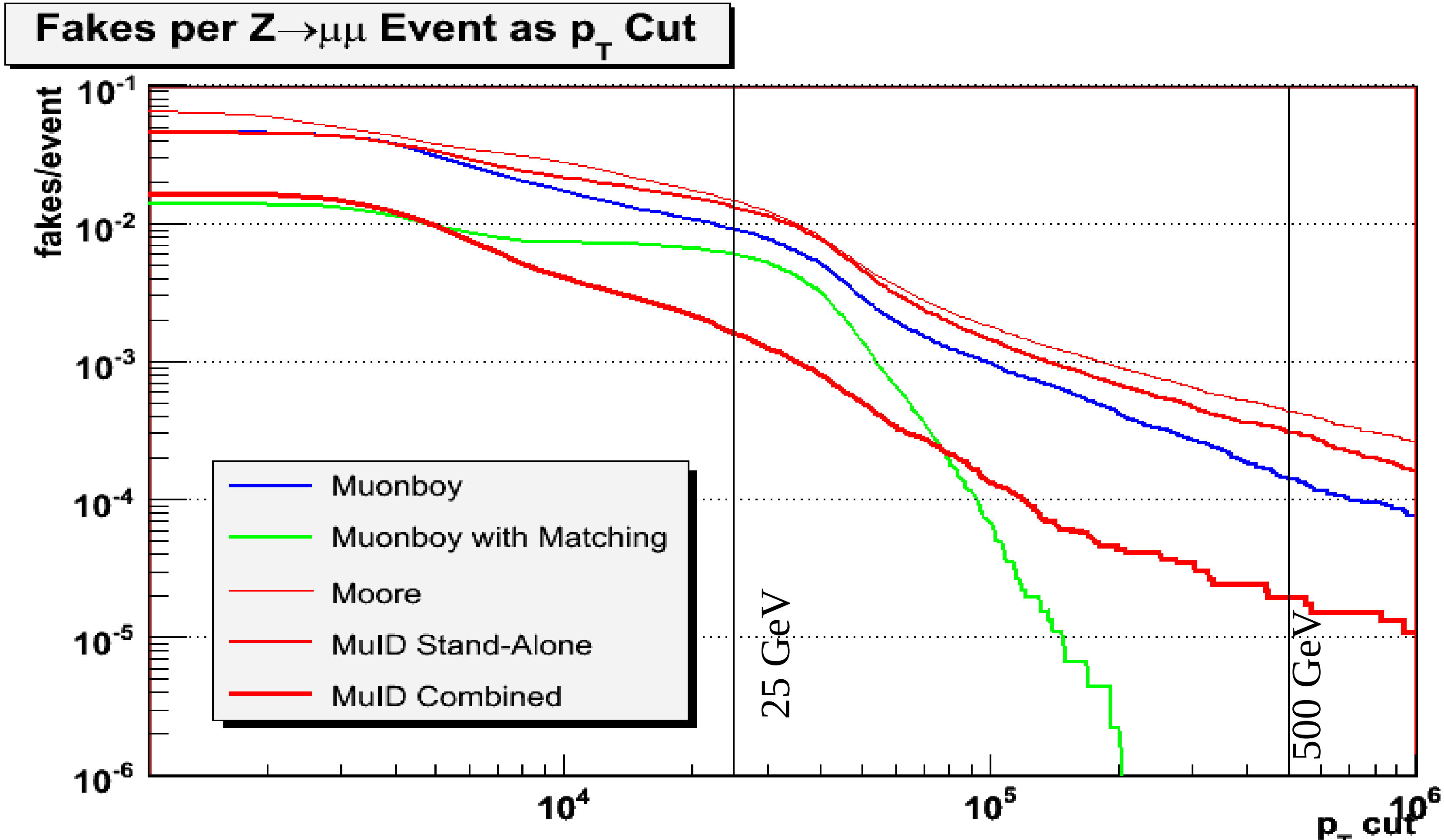


Muon η

Fake μ rate as a function of Muon P_T



Full simulation: tt → μ + x (1M events), Z→ μμ (1M events)

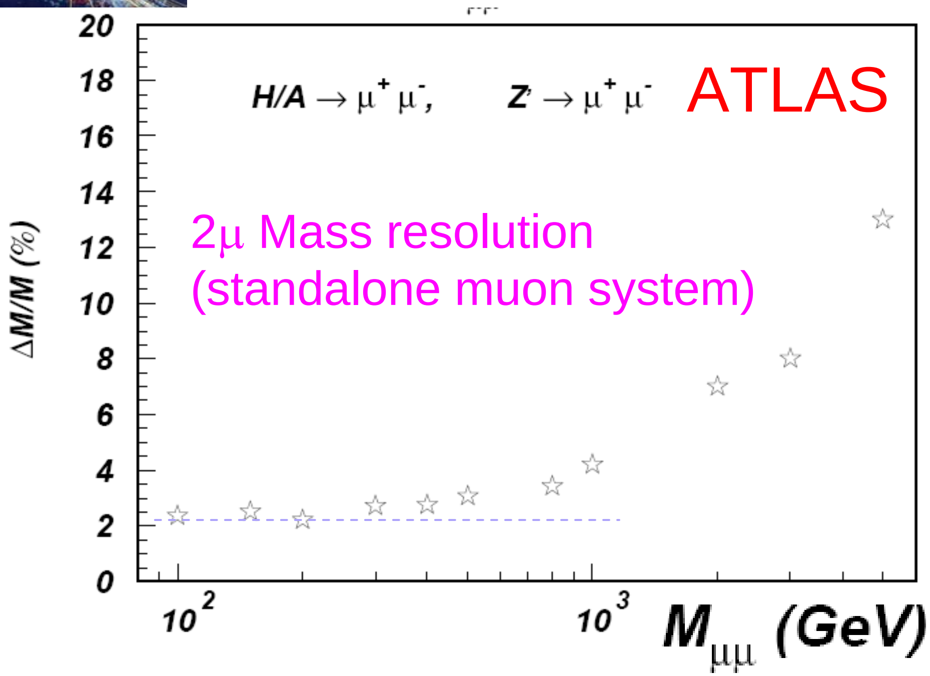


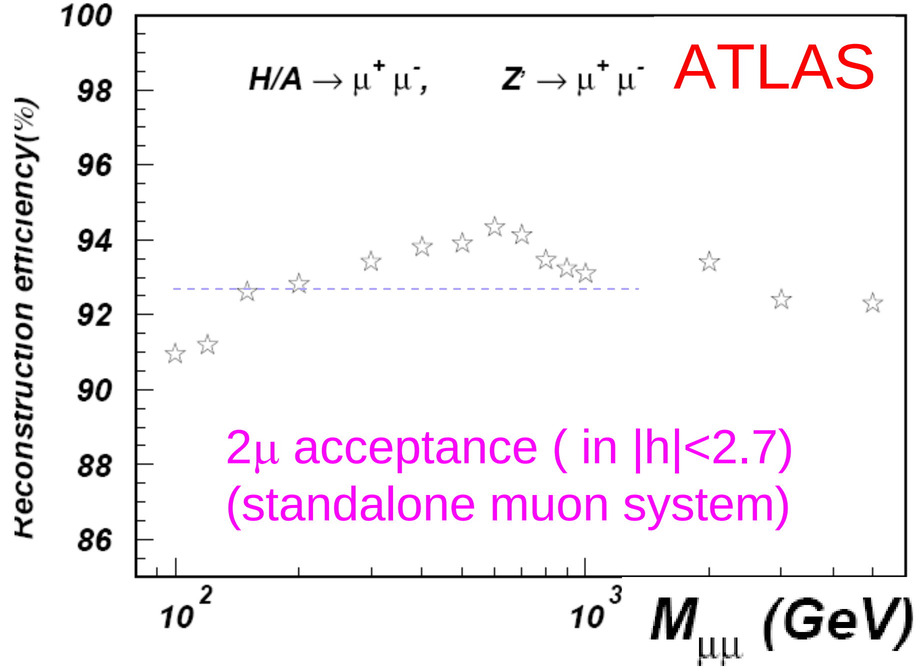
For p_T > 500 GeV,

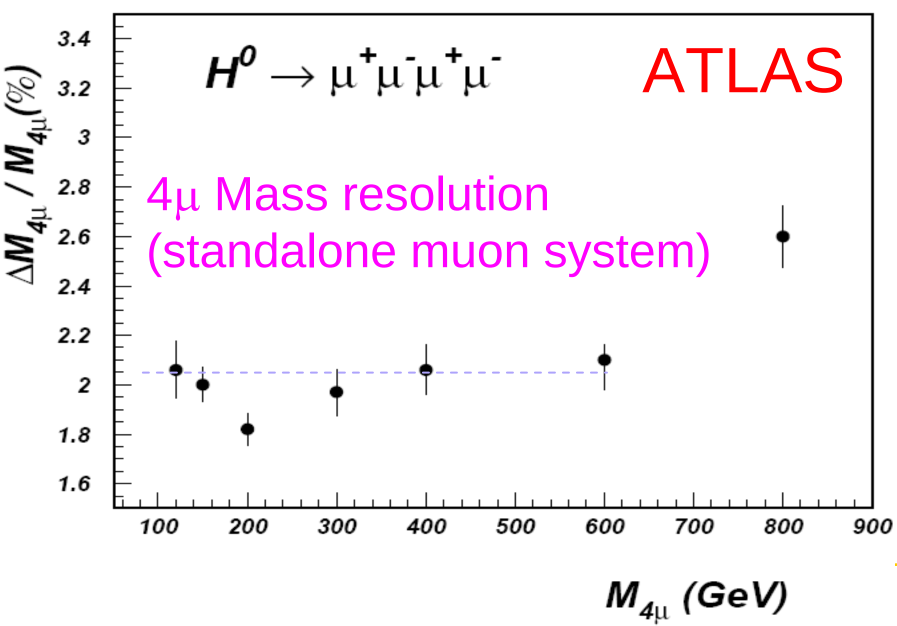
Standalone Muon System: fake rate ~10^{-4}

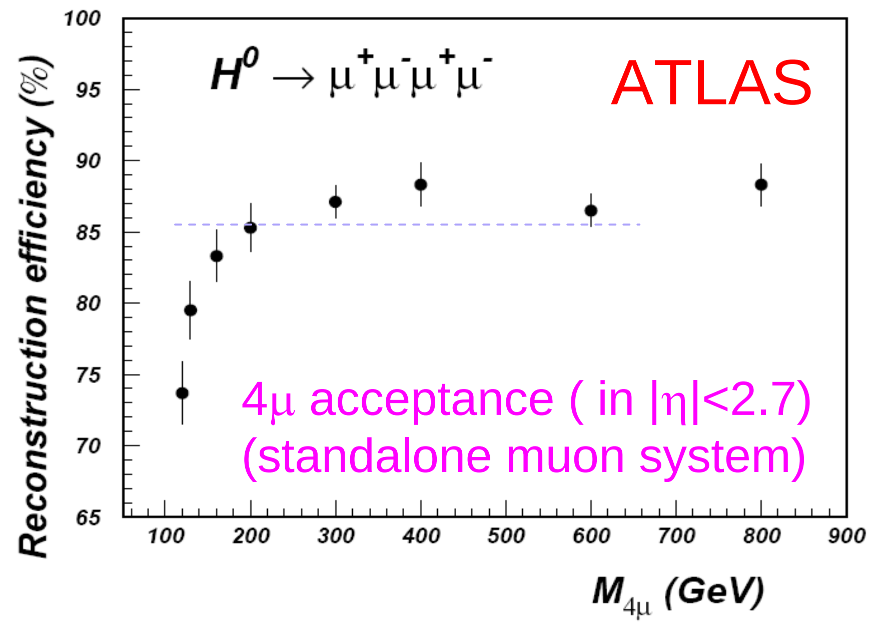
MuID Combined: **fake rate ~ 10^{-5}**

Benchmark Studies on Muon Final States



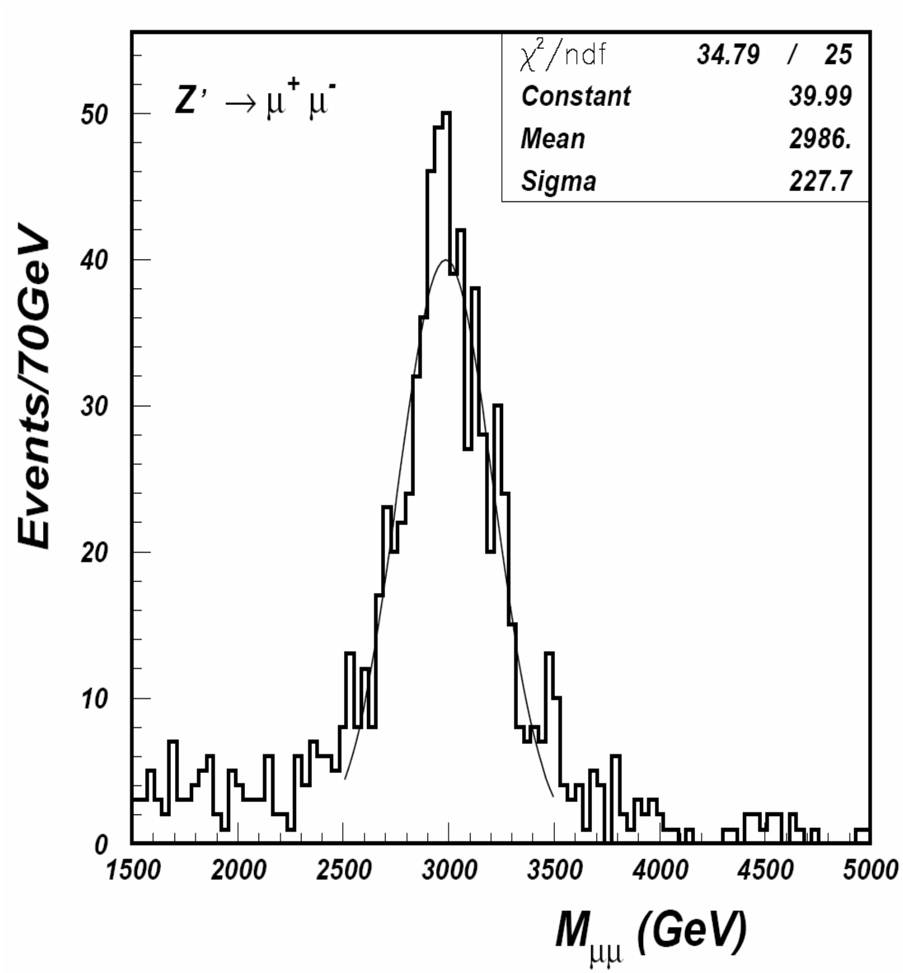




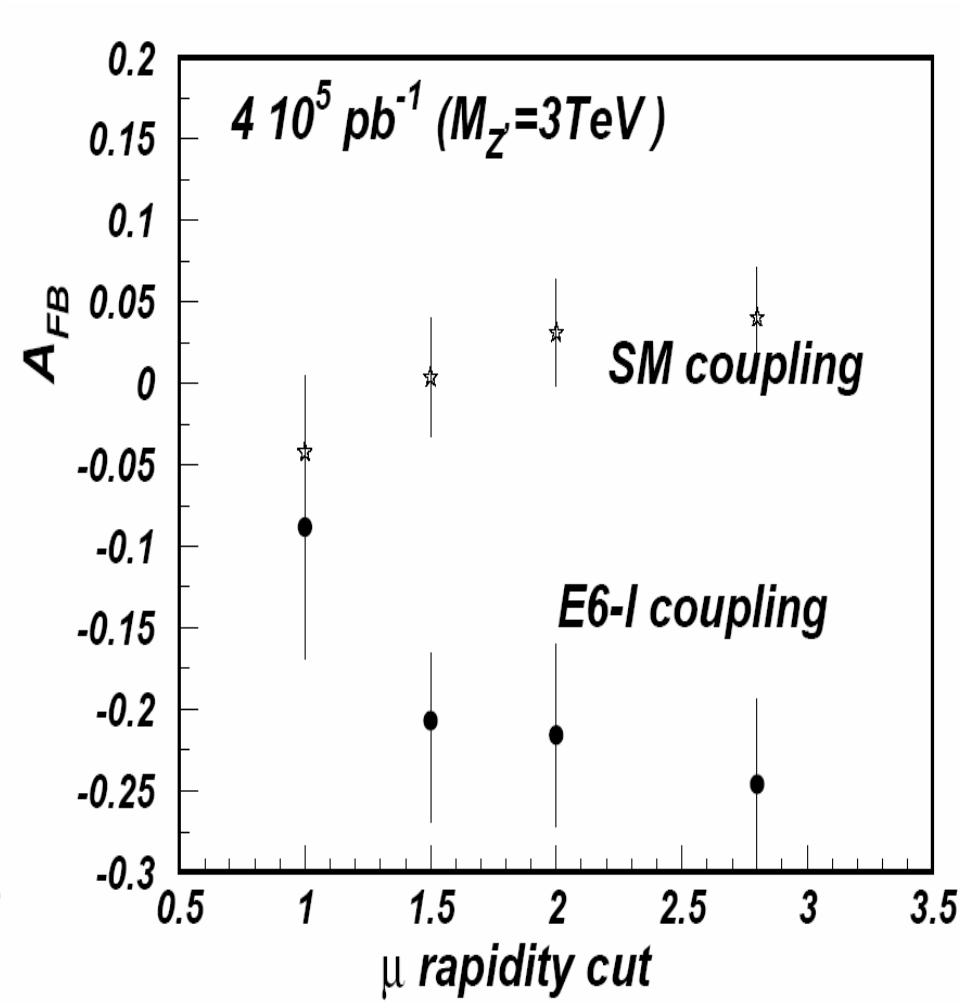


ATLAS: Bench mark: Z' → μμ

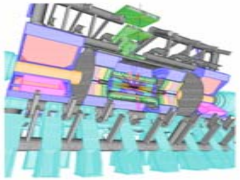
3 TeV Z' mass spectrum



Z' Charge Asymmetry

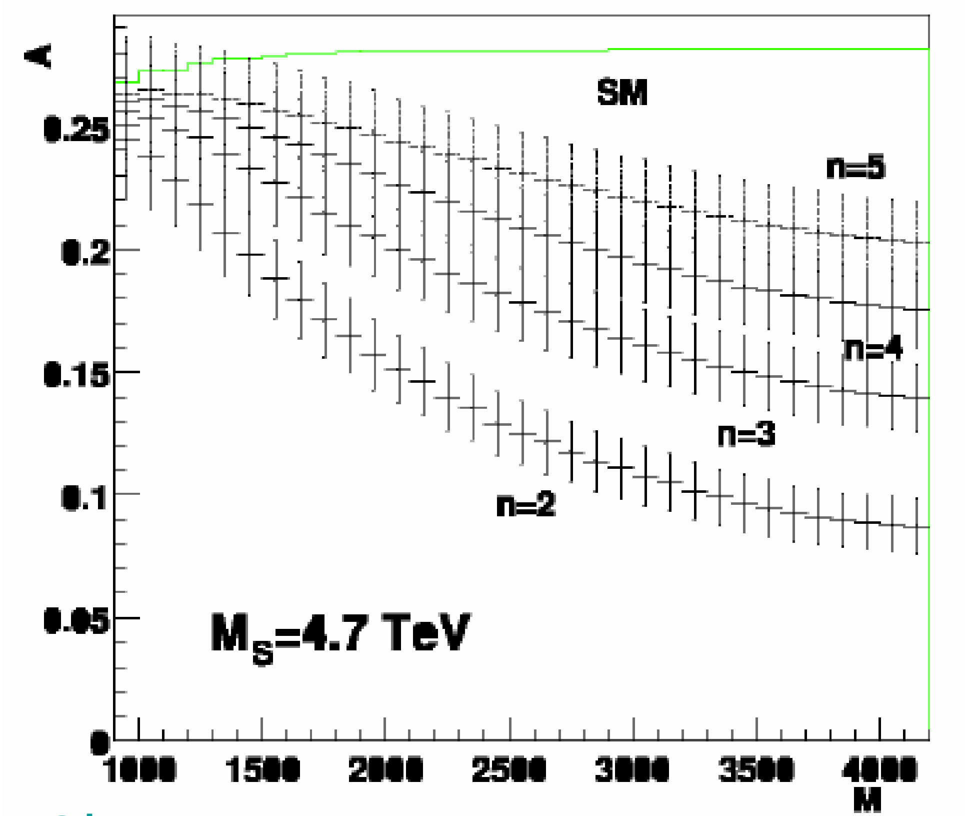


ATLAS: Muon Spectrometer Performance



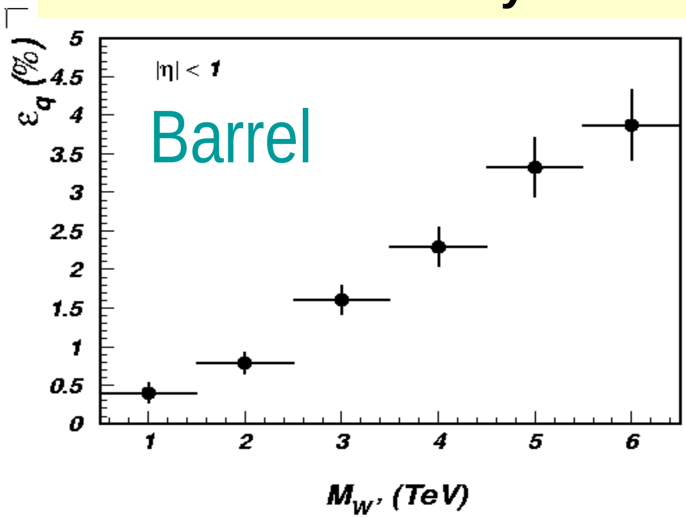
High Pt Muon Charge Identification is Essential for new physics

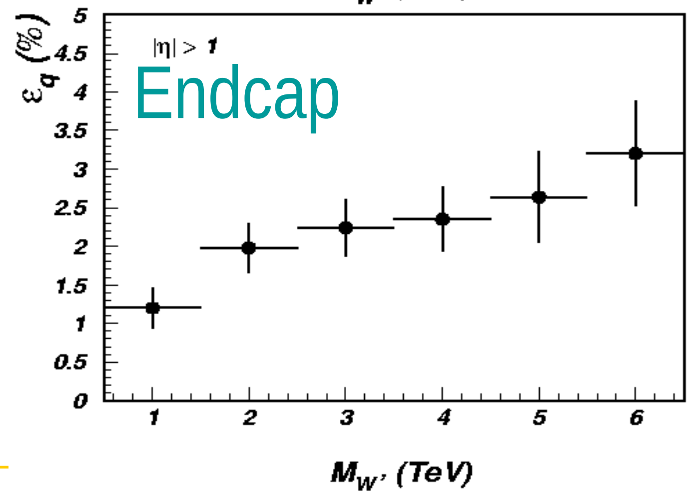
X-dim : dilepton from G* exchange



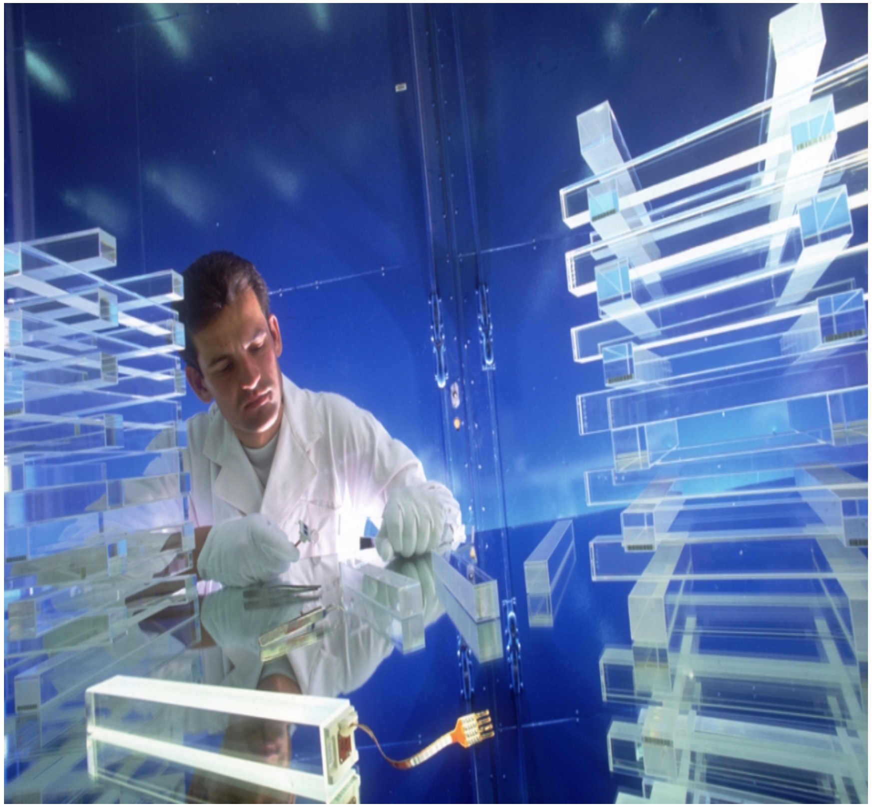
•Charge asymmetry measurement would help to pin-down the 'origin'

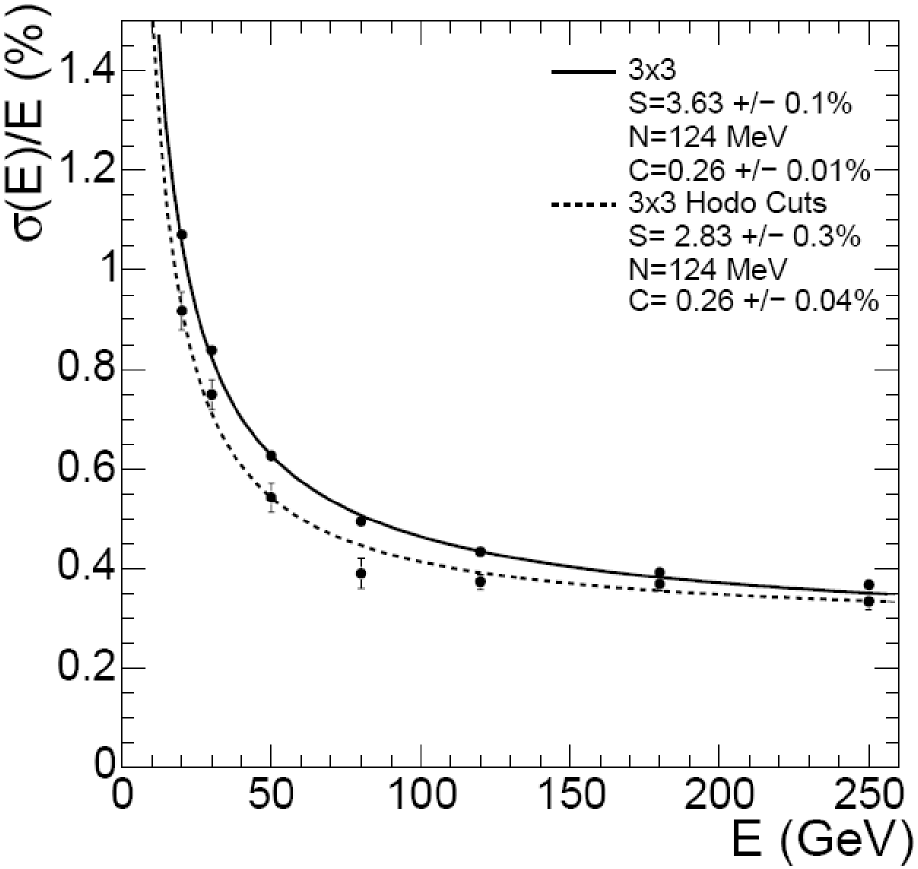
Unique feature of the ATLAS Standalone Muon System



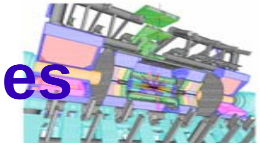


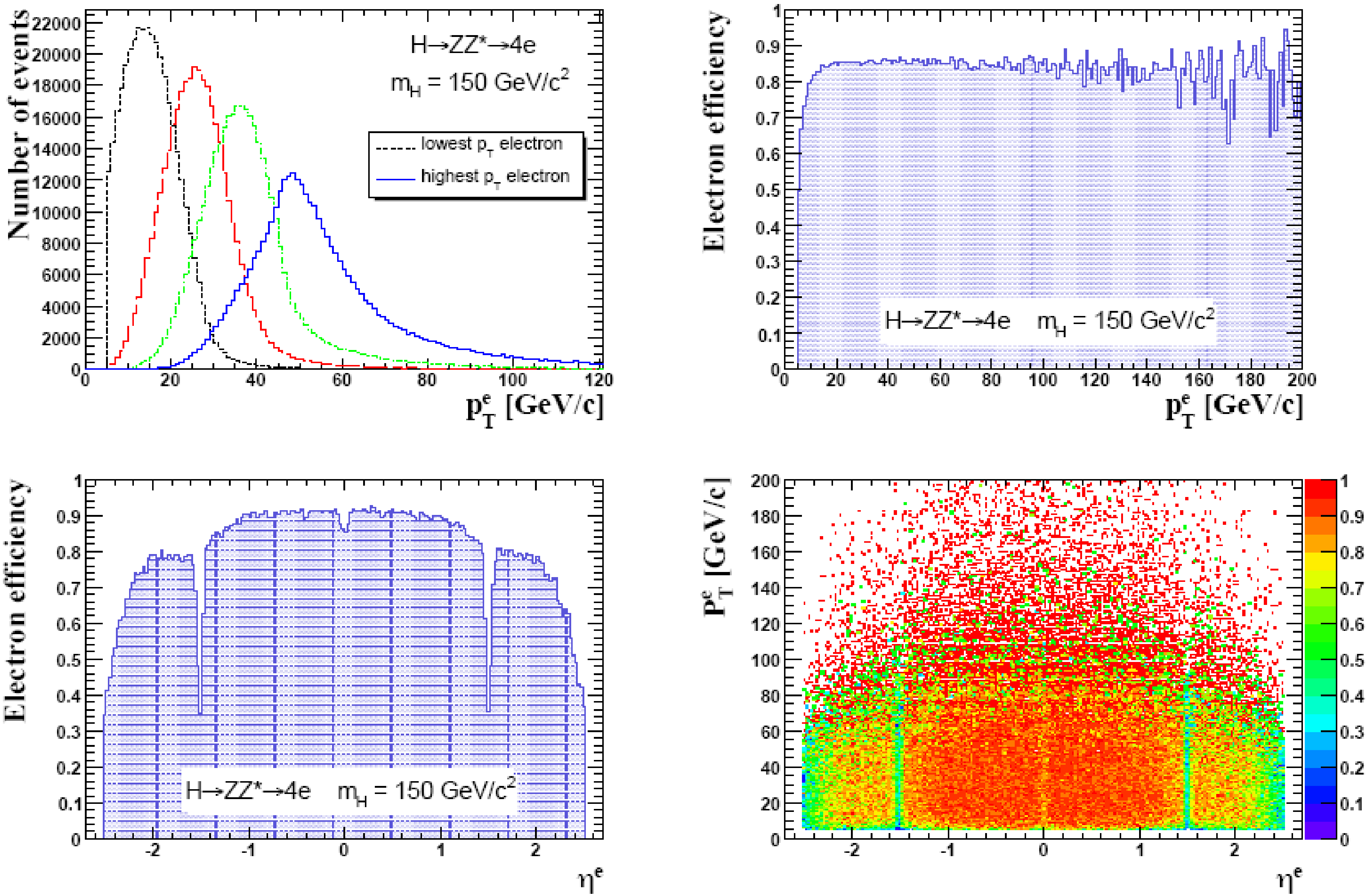
CMS: ECAL Energy Resolution



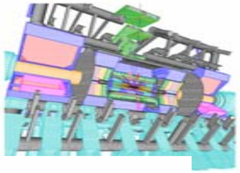


CMS: Electron Detection Performance Studies

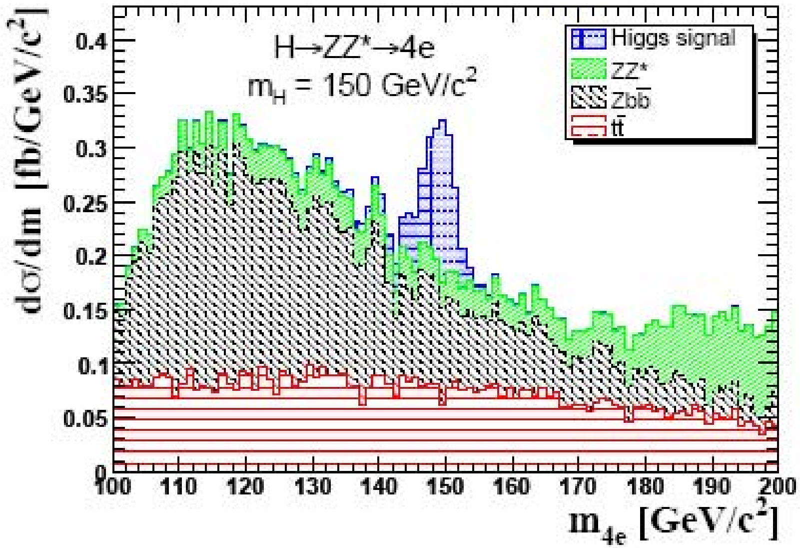




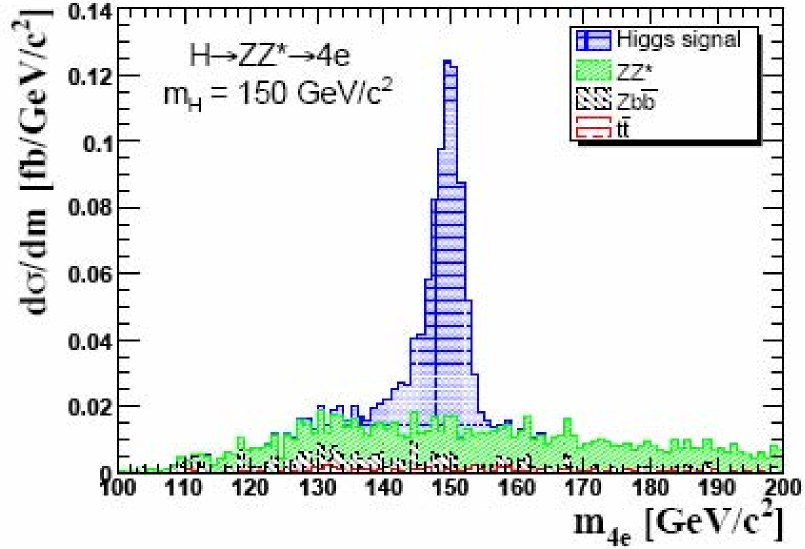
CMS: Benchmark Studies: H → 4e



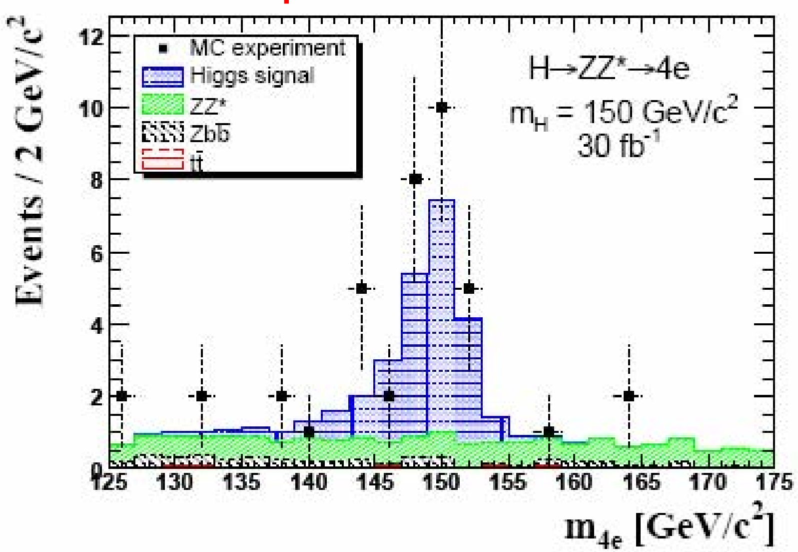
Before the cuts



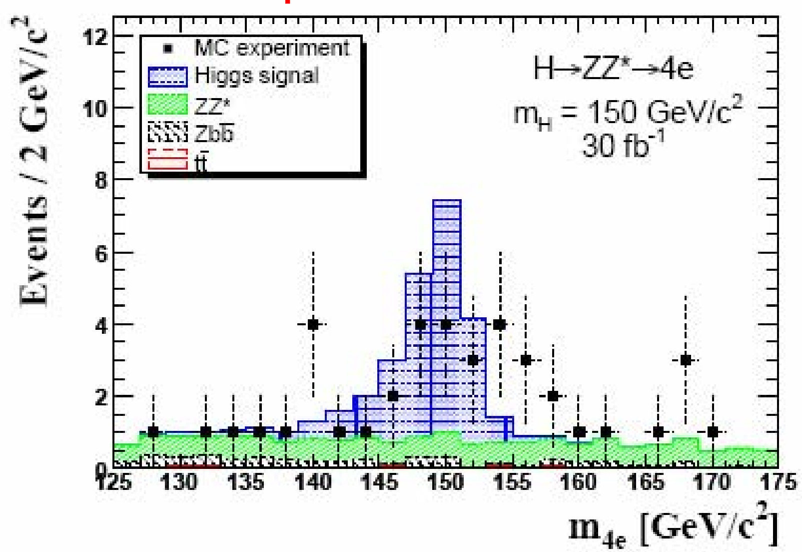
After the cuts



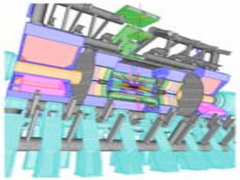
MC experiment

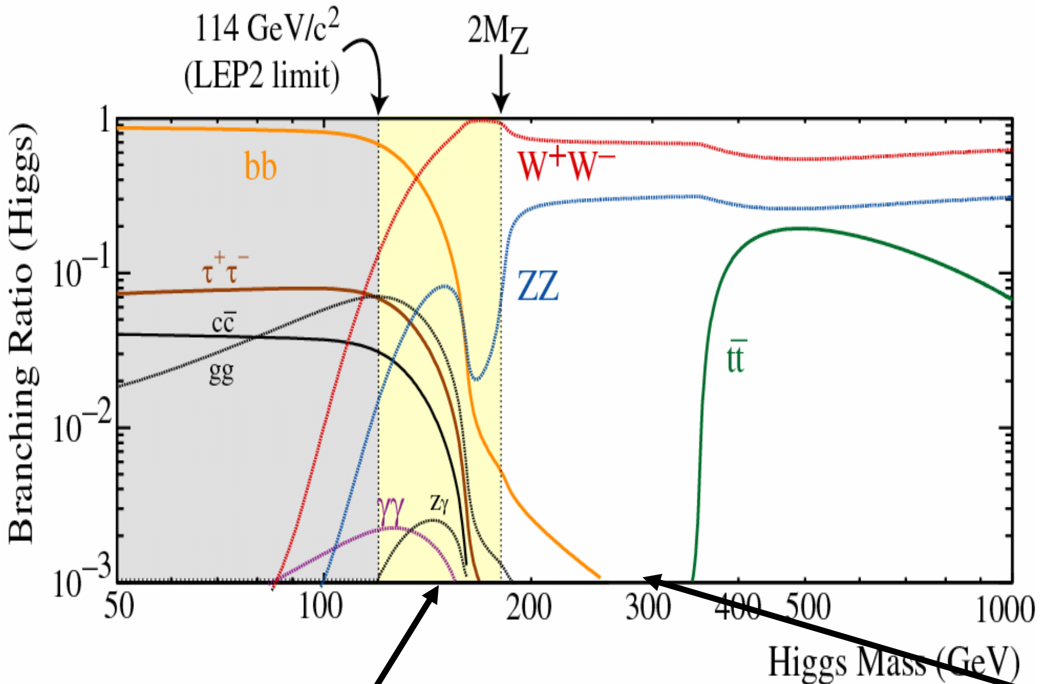


MC experiment



Higgs Discovery Channels at LHC





Dominant BR for $m_H < 2m_Z$:
σ (H $\rightarrow$ bb) $\approx$ 20 pb;
σ (bb) $\approx$ 500 μb
for m(H) = 120 GeV
$\rightarrow$ no hope to trigger or extract fully hadronic final states
$\rightarrow$ look for final states with ℓ, γ (ℓ = e,μ)

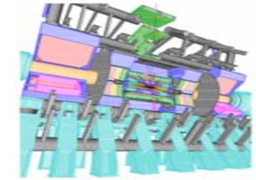
Low mass region: m(H) < 2 m_Z :

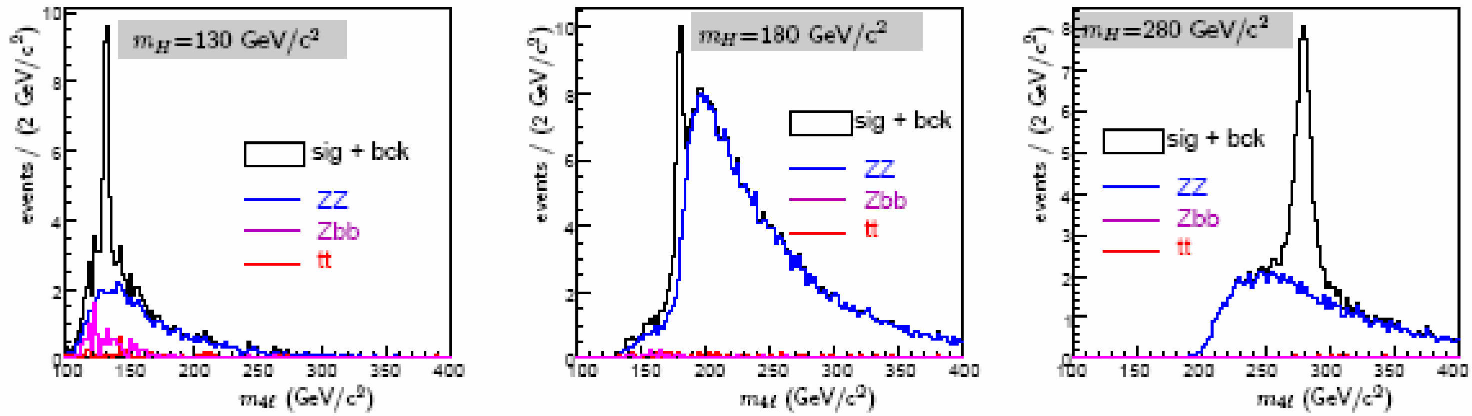
H $\rightarrow$ $\gamma\gamma$: small BR, but best resolution
H $\rightarrow$ bb : good BR, poor resolution ➔ ttH, WH
H $\rightarrow$ ZZ* $\rightarrow$ 4ℓ
H $\rightarrow$ WW* $\rightarrow$ $\ell\nu\ell\nu$ or $\ell\nu jj$: via VBF
H $\rightarrow$ $\tau\tau$: via VBF

m(H) > 2 m_Z :

H $\rightarrow$ ZZ $\rightarrow$ 4ℓ
qqH $\rightarrow$ ZZ $\rightarrow$ $\ell\ell$ $\nu\nu$ *
qqH $\rightarrow$ ZZ $\rightarrow$ $\ell\ell$ jj *
qqH $\rightarrow$ WW$\rightarrow$ $\ell\nu jj$ *
* for m_H > 300 GeV forward jet tag

ATLAS: Z→ 4leptons



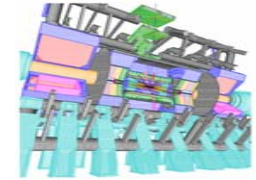


FULL SIMULATION	m_H =130 GeV ($\delta m = \pm 5$ GeV)	m_H =160 GeV ($\delta m = \pm 6$ GeV)	m_H =180 GeV ($\delta m = \pm 7$ GeV)	m_H =280 GeV ($\delta m = \pm 20$ GeV)
N_{signal} (gg+VBF)	21.5±0.1	26±1	28.1±0.3	67.4±0.1
$N_{qq\rightarrow ZZ}$ (×1.3 f. $gg \rightarrow ZZ$)	11.3±0.3	11.4±0.3	27.3±0.5	40.4±0.6
$N_{Zb\bar{b}}$	2±2	2±2	1±1	0±2
$N_{t\bar{t}}$	0±0.4	0±0.4	0.5±0.4	0±0.4
Significance (no K) $\mathcal{L}$ for 5σ discovery	5.0±0.3 30 fb^{-1}	5.5±0.5 25 fb^{-1}	4.7±0.2 37.5 fb^{-1}	8.8±0.4 11 fb^{-1}

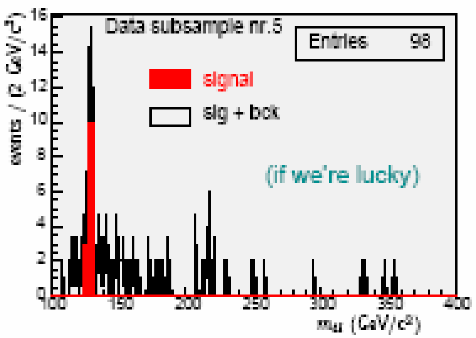
Differences between muon and electron reconstruction ⇒

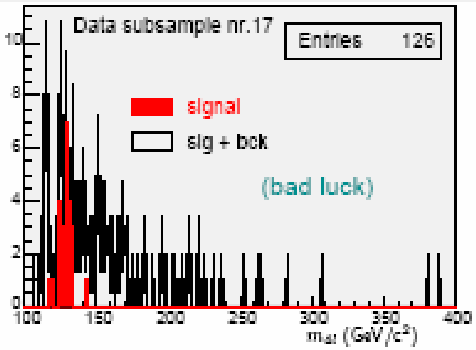
FULL SIMULATION	$H \rightarrow 4e$	$H \rightarrow 4\mu$	$H \rightarrow 2e2\mu$	total
Significance m_H =130 GeV/c^2	1.9	2.6	3.2	5.0

Ensemble tests



Acctual 4ℓ-mass distribution at 30 fb^{-1} will look more like this:

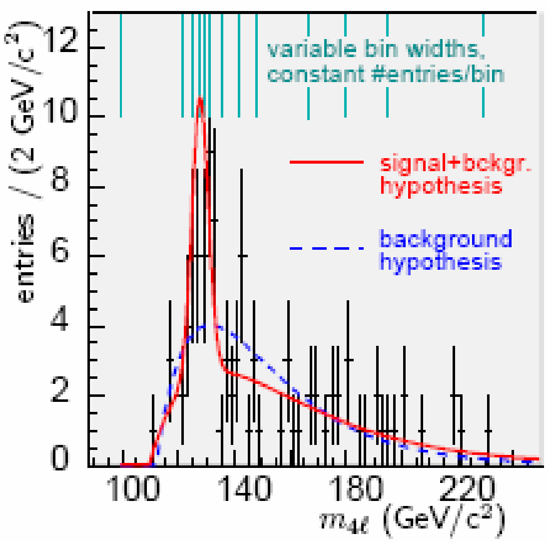




Small number of entries ⇒ variable bin width instead of equidistant bins for the fit of the (S+)B-functions.

Ensemble test of the fit performance (60 subsamples, 25 fb^{-1} each):

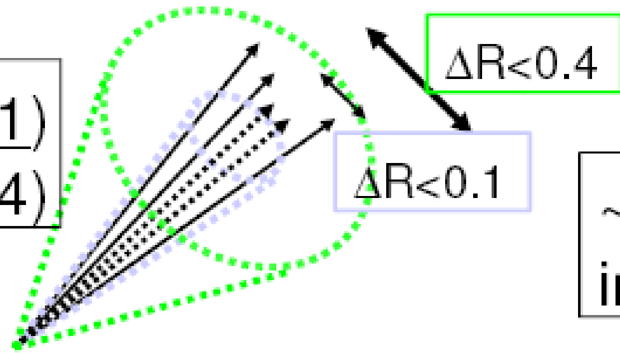
$$f_b(m_k) = N_b \cdot \alpha^2 (m_k - \epsilon) e^{-\alpha(m_k - \epsilon)}; \quad f_s(m_k) = \frac{N_s}{\sqrt{2\pi}\sigma} \cdot e^{-\frac{(m_k-\mu)^2}{2\sigma^2}}$$



	fit results	remark
$N_{good\ fits}$	54	max. 60
$\langle N_s - N_s^{true} \rangle$	2	$\langle N_s^{true} \rangle$=23
$\langle N_b - N_b^{true} \rangle$	3	$\langle N_b^{true} \rangle$=86
$\left\langle \frac{\chi_b^2 - \chi_{s+b}^2}{\chi^2_{s+b}} \right\rangle$	1.6	hypothesis test
$\langle$Signf.$\rangle = \frac{N_s}{\sqrt{Var(N_s)}}$	2.9±0.6	"δm"-signf. 4.1±0.3

τ ID: Fraction of Energy in ΔR<0.1

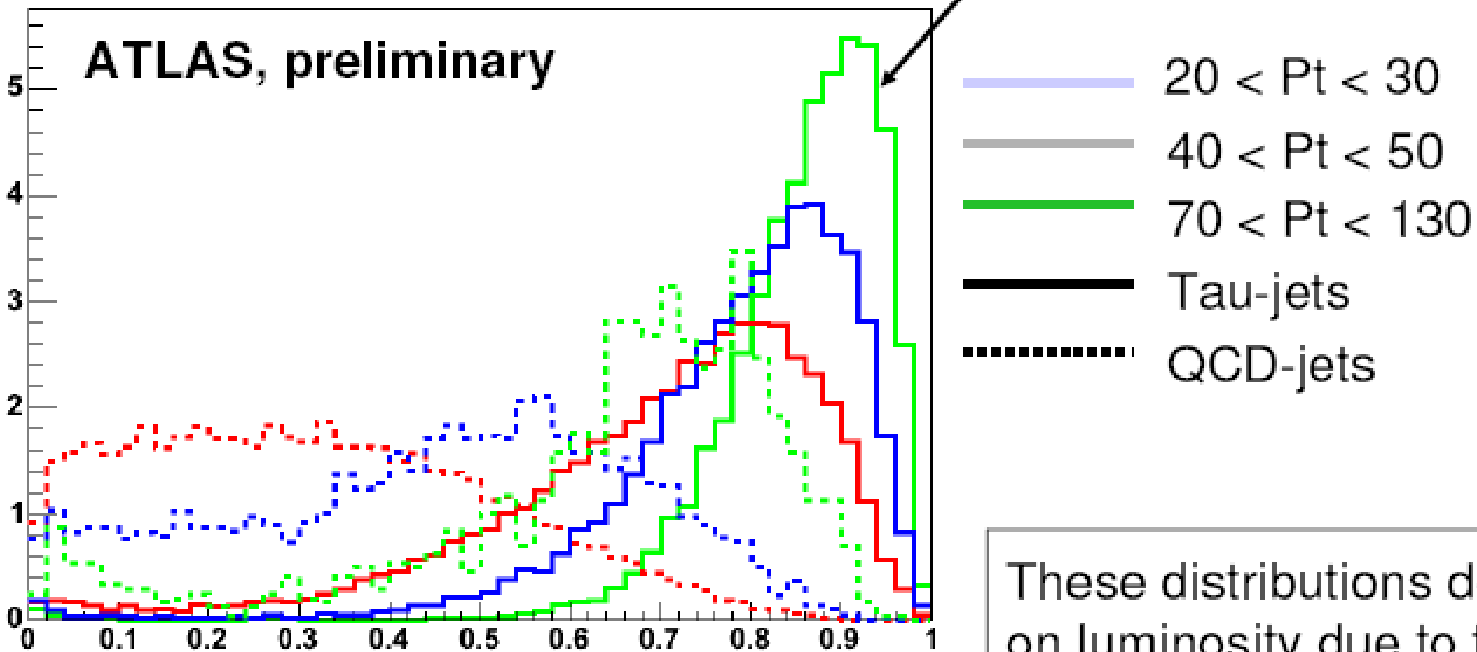
$$\frac{\Sigma E_T(\Delta R<0.1)}{\Sigma E_T(\Delta R<0.4)}$$



(transverse energy)

~90% of energy are deposited in ΔR<0.1. -> narrow jet

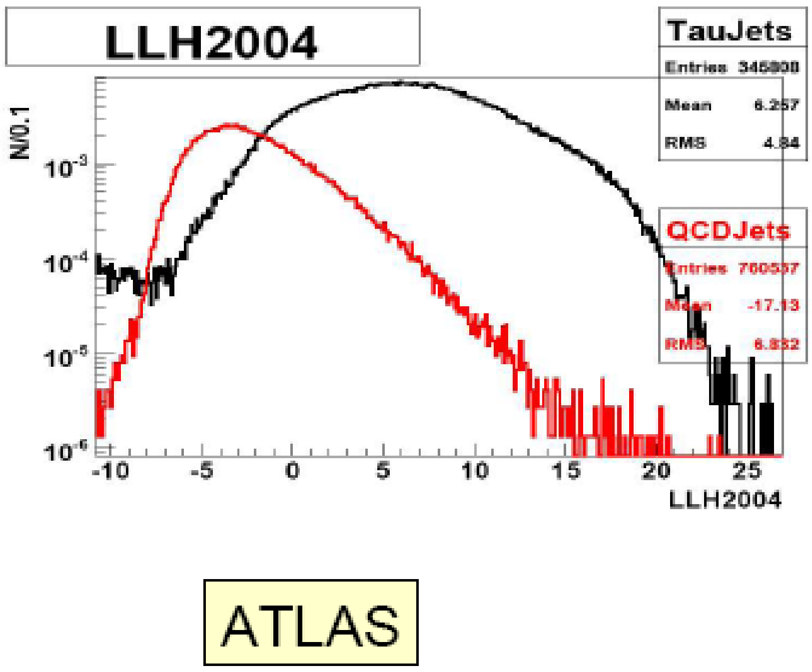
for tauID

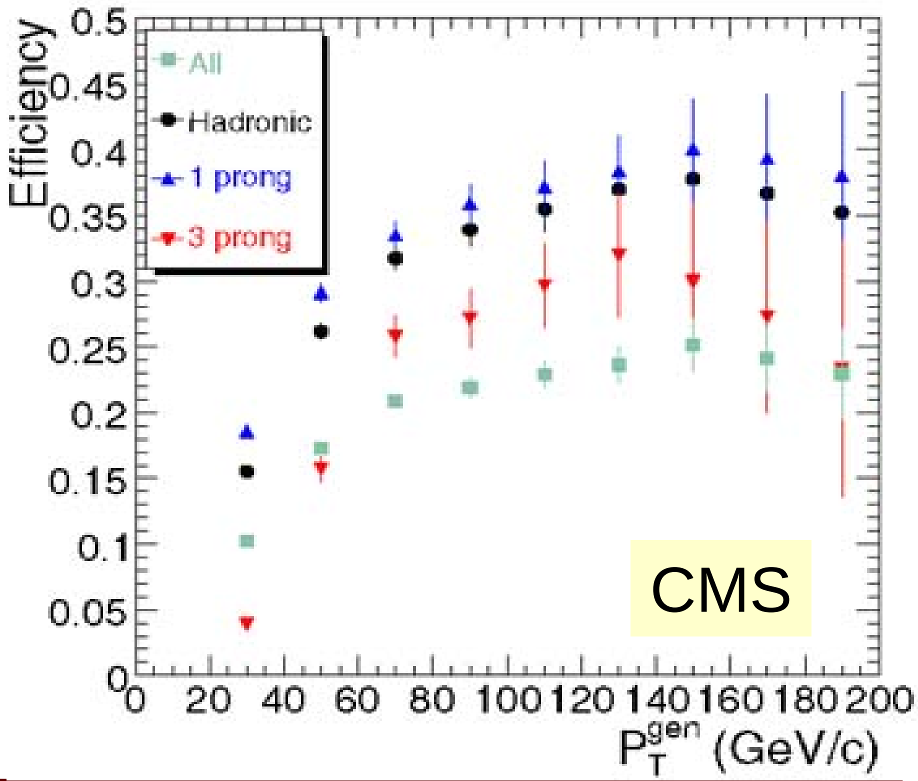


These distributions depend on luminosity due to the pile-up.

τ-ID efficiencies

- Construct variable that combines all cut variables
- Compare signal and bckgnd
- Can vary cut to get need rejection

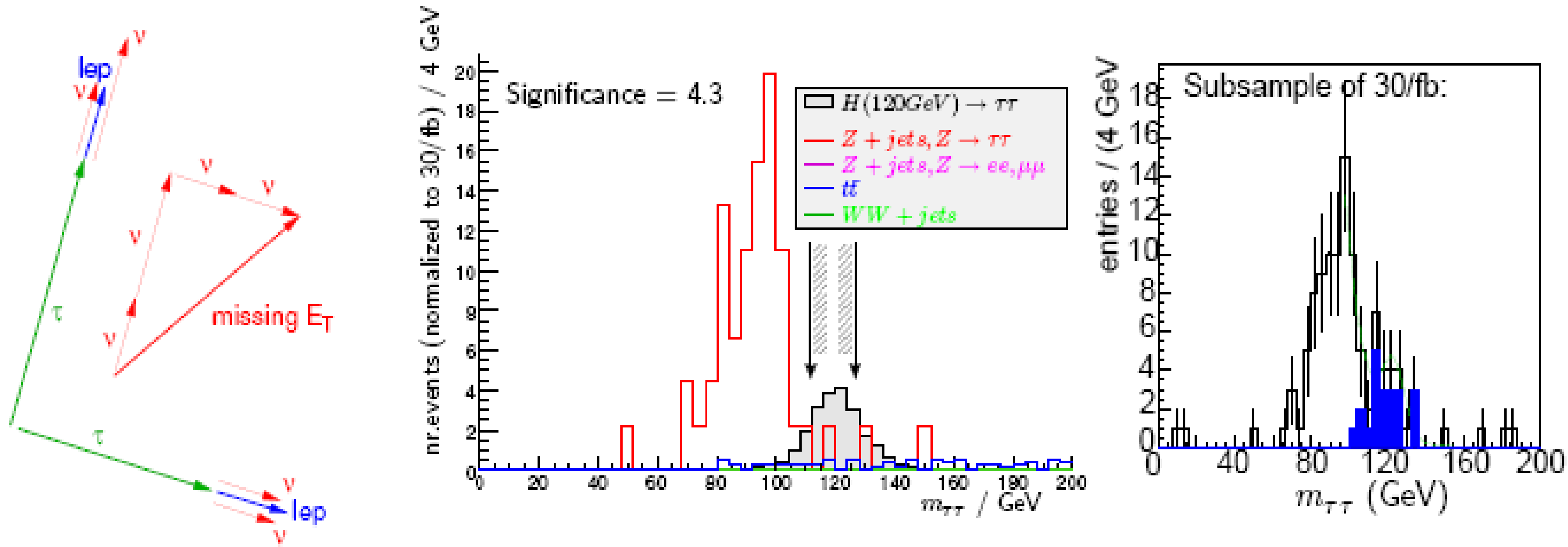




VBF H→ ττ Reconstruction

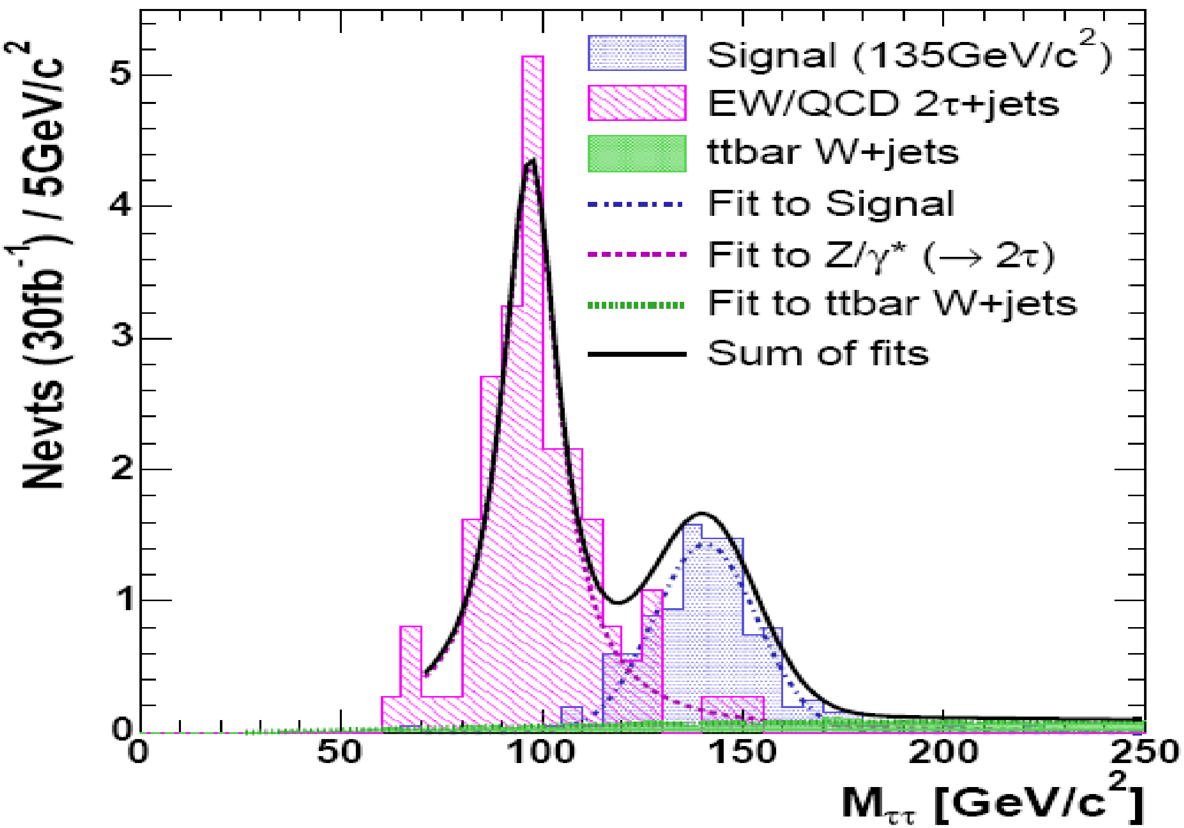
Mass peak reconstruted by means of the collinear approximation:

- $m_H \gg m_\tau$, so products of τ-decays fly in the direction of τ-s.
- Possible to calculate the four-momenta for τ-s.



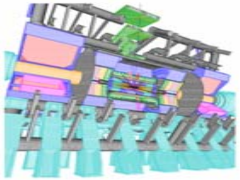
Similar sensitivity observed also in the semi-leptonic channel,
$H \rightarrow \tau\tau \rightarrow (\ell\nu\nu)(hadrons)$.

CMS Studies: H → ττ



M_H [GeV]	115	125	135	145
Production σ [fb] $\sigma \times BR(H \to \tau\tau \to lj)$ [fb]	4.65×10^3 157.3	4.30×10^3 112.9	3.98×10^3 82.38	3.70×10^3 45.37
N_S at 30 fb^{-1} N_B at 30 fb^{-1}	10.5 3.7	7.8 2.2	7.9 1.8	3.6 1.4
Significance at 30 fb^{-1} ($\sigma_B = 7.8\%$)	3.97	3.67	3.94	2.18
Significance at 60 fb^{-1} ($\sigma_B = 5.9\%$)	5.67	5.26	5.64	3.19

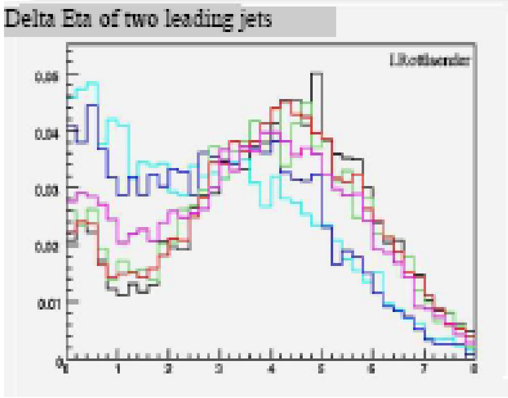
Remarks on forward Jet tagging

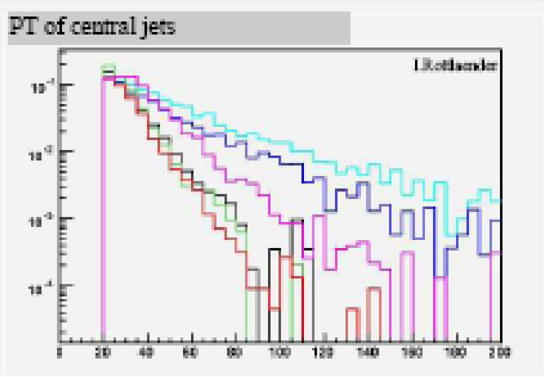


The searches in the VBF channels strongly rely on a good understanding of the jet distributions:

- Theory: underlying event uncertainties.
- Experiment:
  Pile-up affects the rapidity gap between two forward jets.
  Jet energy calibration (cross-section depends on the $p_T^{jet} - cuts$).

Comparison of different generators → hint for systematic uncertainties:





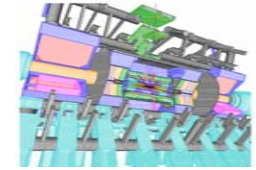
PYTHIA 6.323, new showering model; BUG
PYTHIA 6.323, old showering model; BUG

PYTHIA 6.403, new showering model
PYTHIA 6.403, old showering model

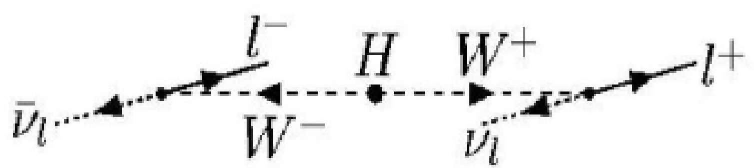
HERWIG

Final evaluation of the generators and det. perf. to be done with data.
($Z + jets$: handle for the jet distributions;
reference for the Higgs VBF cross-section (same depend. on the p_T^{jet} -cuts).

H → WW → dileptons+MET

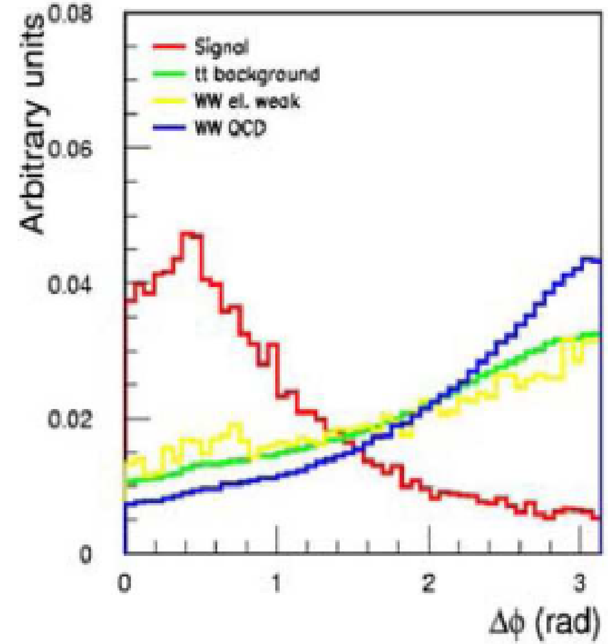


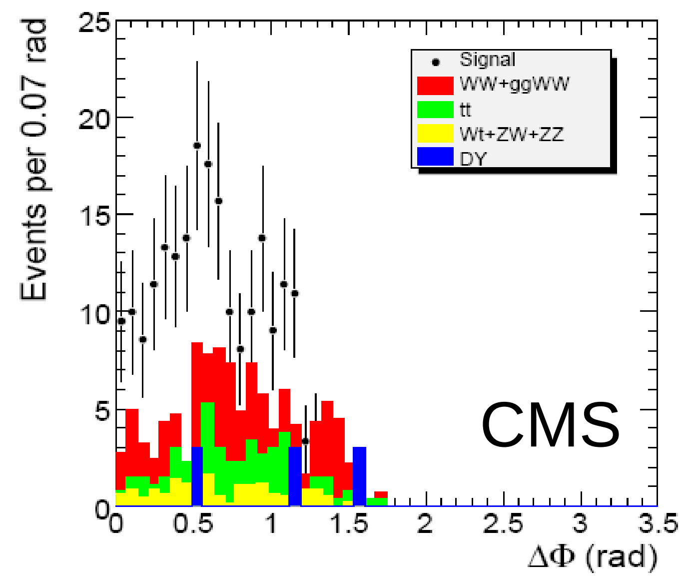
- $BR(H \to WW)$ is nearly 98% for a Higgs boson with $m_H \approx 160$ GeV.
- Backgrounds from $WW, t\bar{t}, WZ$.
- Use the lepton spin correlations:



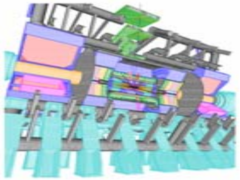
- No mass peak, have to use m_T:

$$m_T = \sqrt{2 p_T^{\ell\ell} \not{E}_T (1 - \cos \Delta\phi)}$$





If Higgs is Light



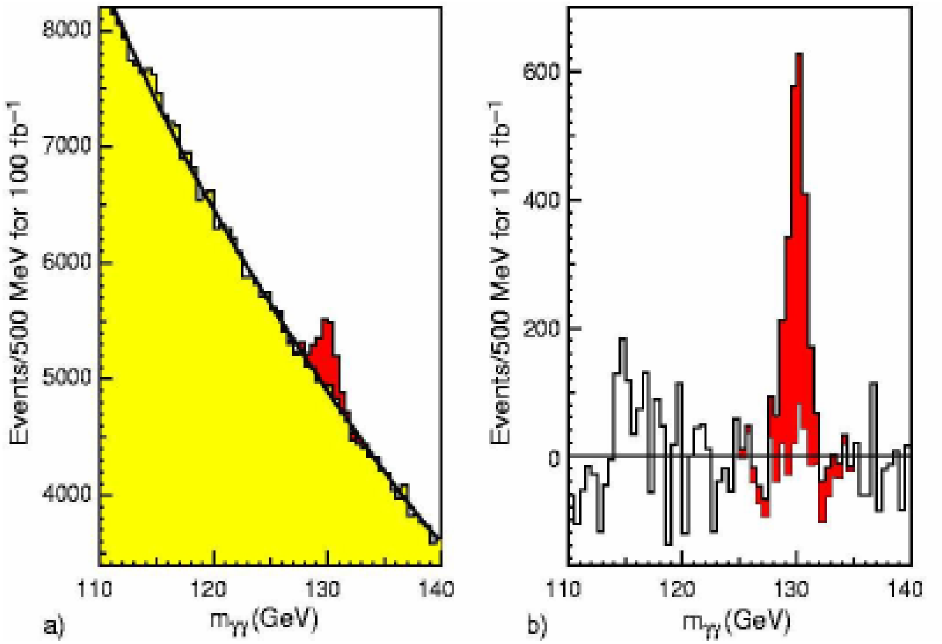
How good an EM Calorimeter
Do we need for H→ γγ ?

Benchmark process: H → γ γ

$$m_{\gamma\gamma} = \sqrt{2E_{\gamma 1}E_{\gamma 2}\left(1-\cos\theta_{\gamma 1,\gamma 2}\right)}$$

$$\frac{\Delta m_{\gamma\gamma}}{m_{\gamma\gamma}} = \frac{1}{2}\left[\frac{\Delta E_{\gamma 1}}{E_{\gamma 1}} \oplus \frac{\Delta E_{\gamma 2}}{E_{\gamma 2}} \oplus \frac{\Delta\theta_{\gamma\gamma}}{\tan\left(\theta_{\gamma\gamma}/2\right)}\right]$$

(δθ limited by interaction vertex measurement)

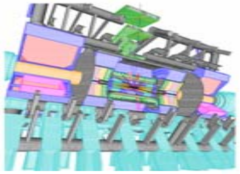


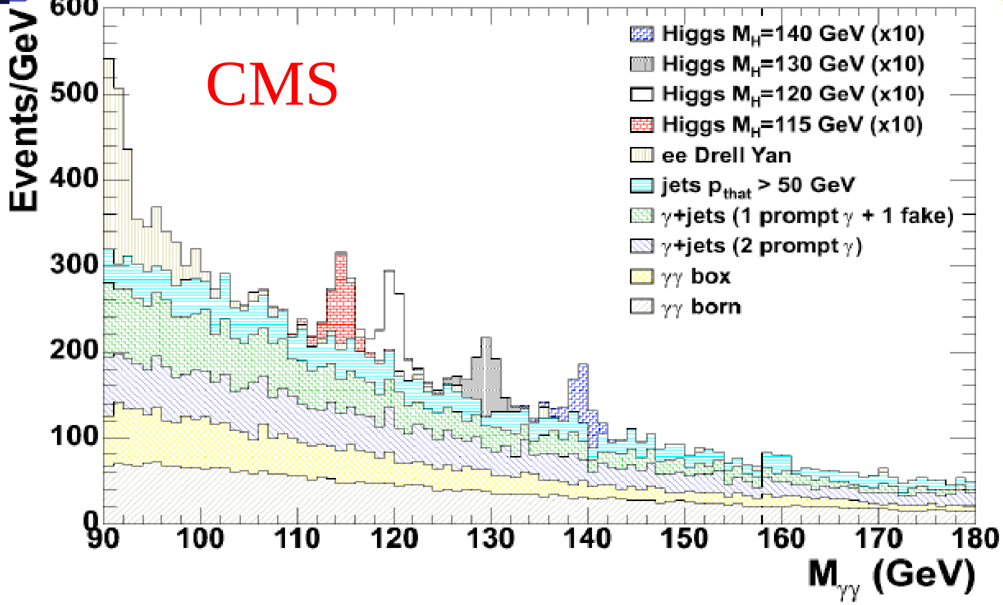
CMS Resolution : σ_E / E = a / √ E ⊕ b ⊕ c/ E

Aim:		Barrel	End cap
Stochastic term:	a =	2.7%	5.7%
Constant term:	b =	0.55%	0.55%
Noise: Low $\mathcal{L}$	c =	155 MeV	770 MeV
High $\mathcal{L}$		210 MeV	915 MeV

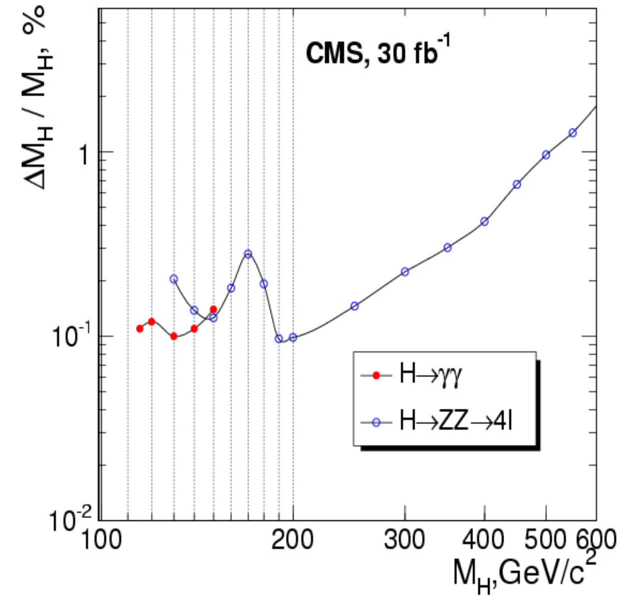
At 100 GeV : 0.27 ⊕ 0.55 ⊕ 0.002 ≅ 0.6%

H → γγ



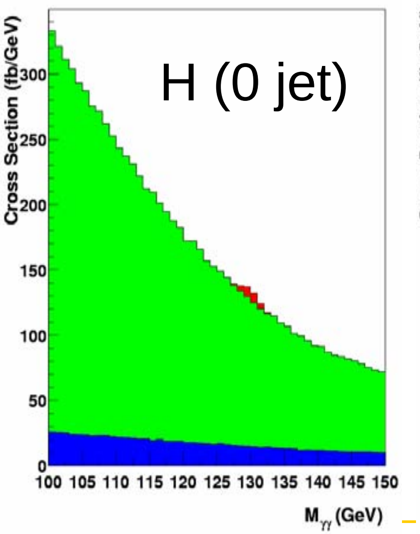


CMS
Events/GeV
Higgs M_H=140 GeV (x10)
Higgs M_H=130 GeV (x10)
Higgs M_H=120 GeV (x10)
Higgs M_H=115 GeV (x10)
ee Drell Yan
jets p_that > 50 GeV
γ+jets (1 prompt γ + 1 fake)
γ+jets (2 prompt γ)
γγ box
γγ born
M_γγ (GeV)

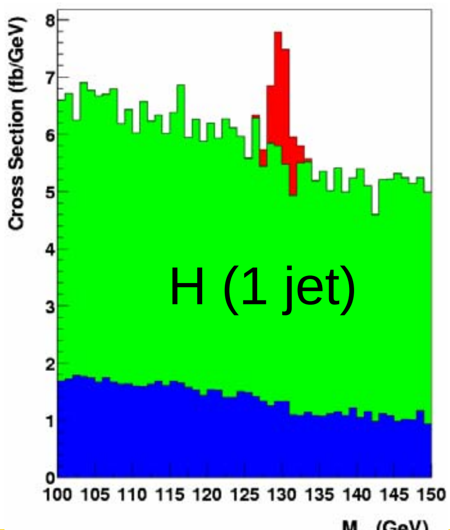


CMS, 30 fb^-1
ΔM_H / M_H, %
H→γγ
H→ZZ→4l
M_H,GeV/c^2

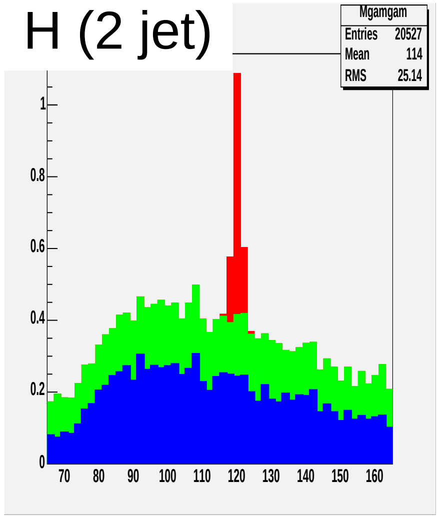
ATLAS



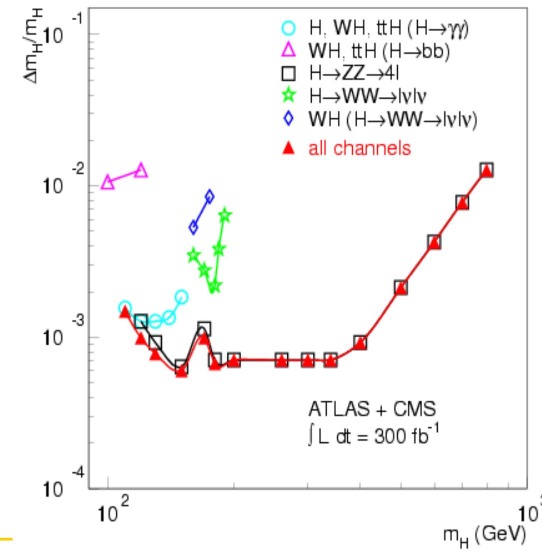
H (0 jet)
Cross Section (fb/GeV)
M_γγ (GeV)



H (1 jet)
Cross Section (fb/GeV)
M_γγ (GeV)

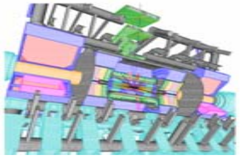


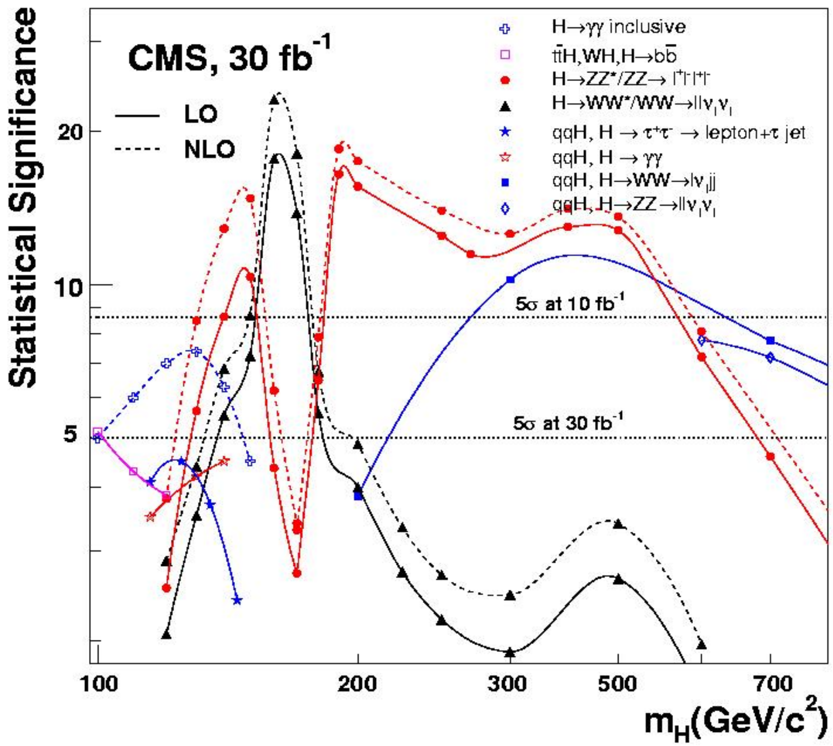
H (2 jet)
Mgamgam
Entries 20527
Mean 114
RMS 25.14

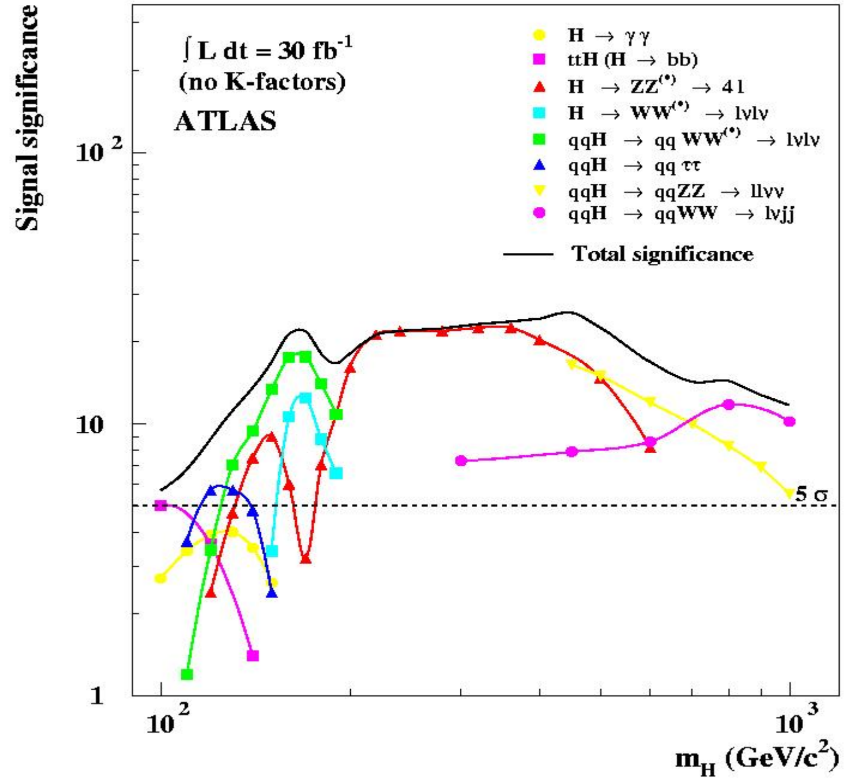


Δm_H/m_H
H, WH, ttH (H→γγ)
WH, ttH (H→bb)
H→ZZ→4l
H→WW→lνlν
WH (H→WW→lνlν)
all channels
ATLAS + CMS
∫L dt = 300 fb^-1
m_H (GeV)

Discovery Sensitivity





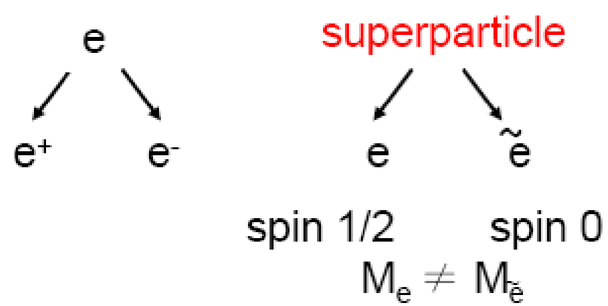


CMS PTDR		ATLAS		
NLO cut based	NLO optimized*	TDR (LO)	New, NLO Cut based	New, NLO likelihood
6.0	8.2	3.9	6.3	8.7

SUSY: Supersymmetric Extensions of SM

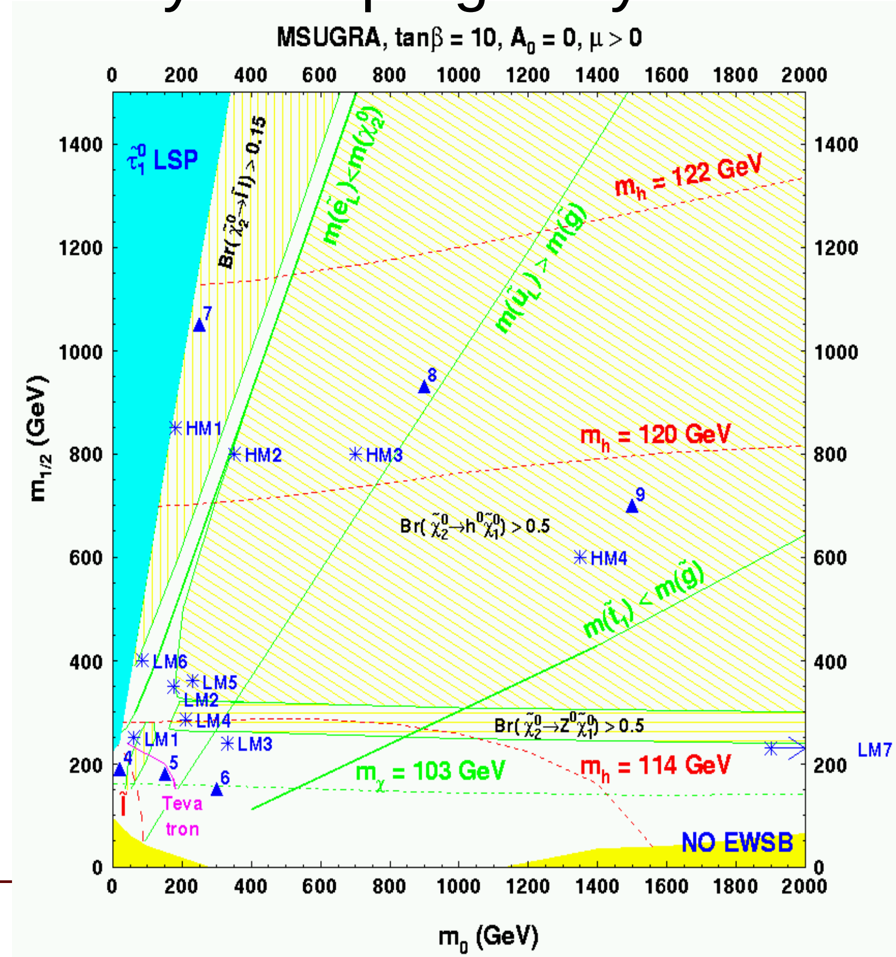
- Provide candidate particles for Dark Matter (LSP)
- Higgs mass calculable
- Unification
- Path to gravity: local supersymmetry → supergravity

Symmetry between
fermions (matter) and bosons (forces)
"Undiscovered new symmetry"



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

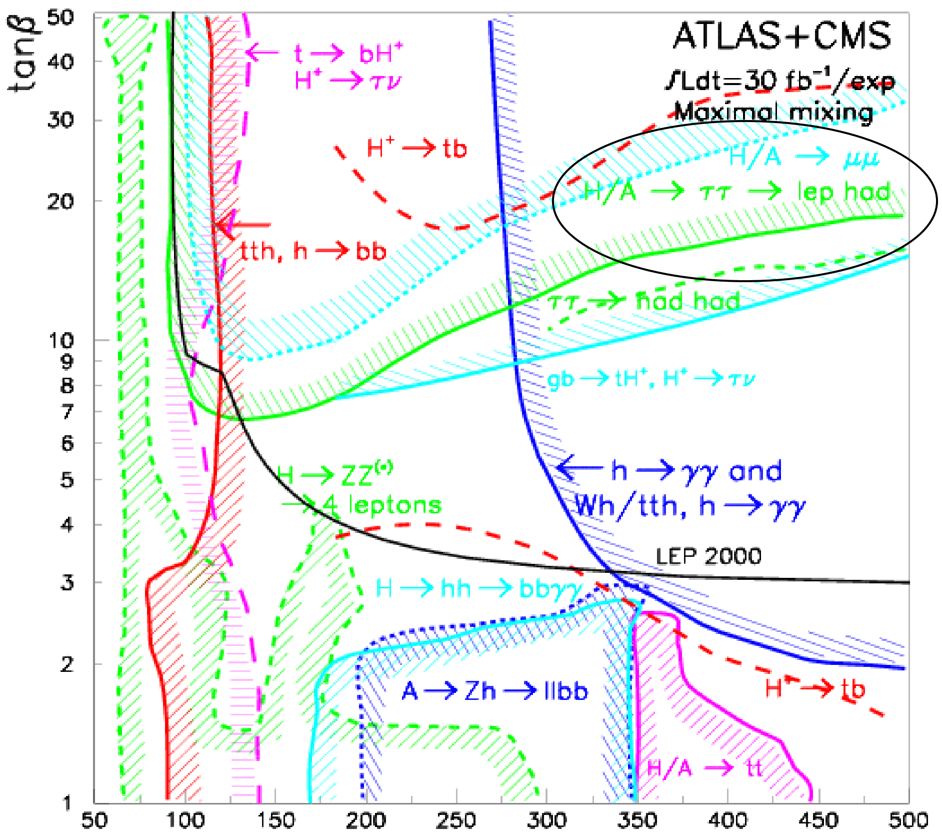
Need study many benchmark points…



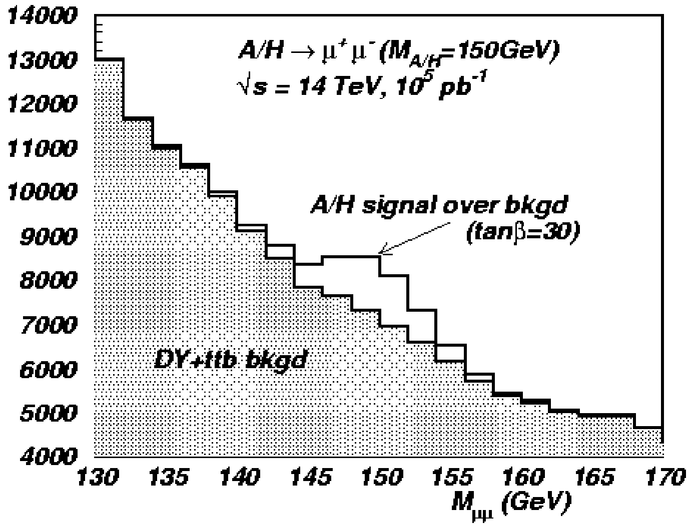
MSSM Higgs Discovery Potential

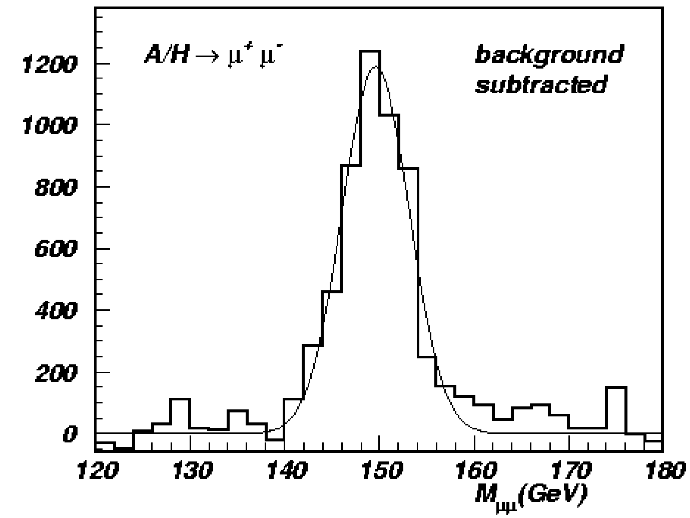
At large tan β:
decays into WW, ZZ and $\gamma\gamma$ are suppressed.

Plane fully **covered** with **30 fb^{-1}**

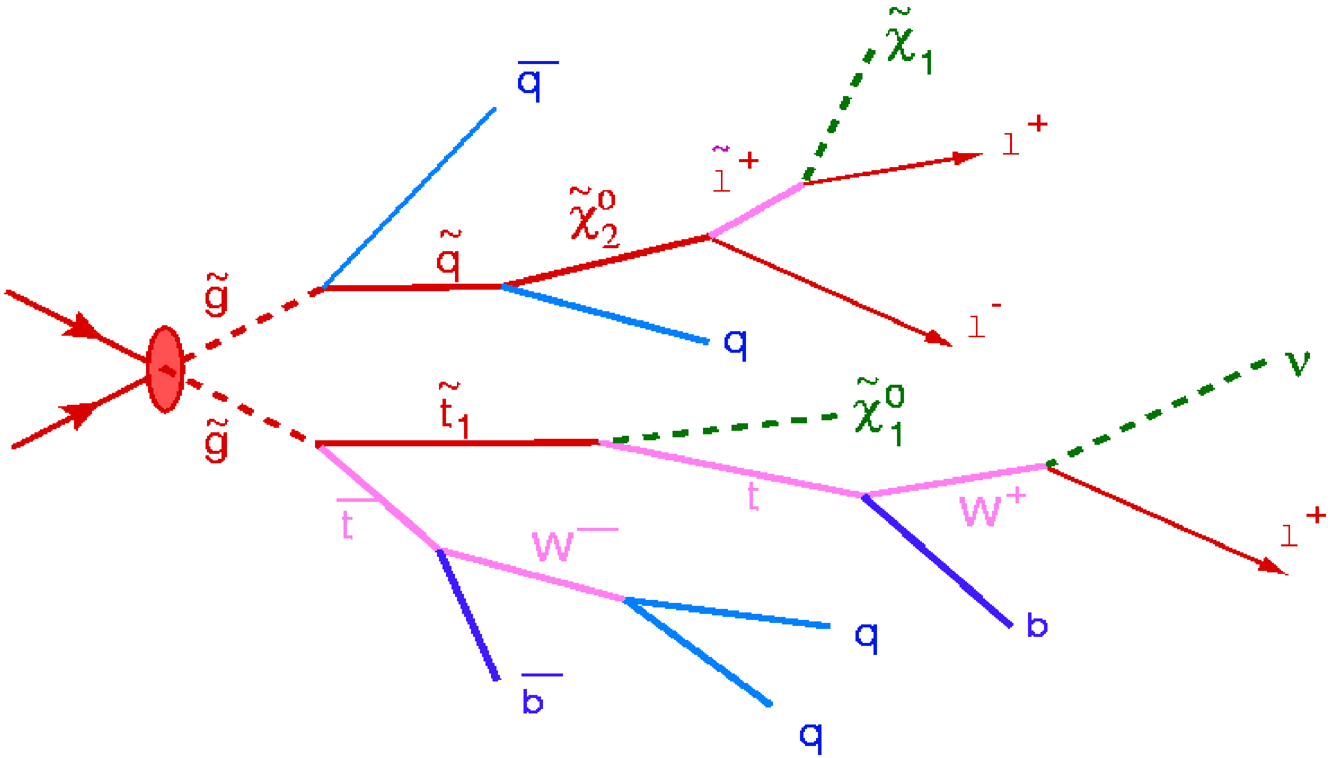


5σ discovery contours



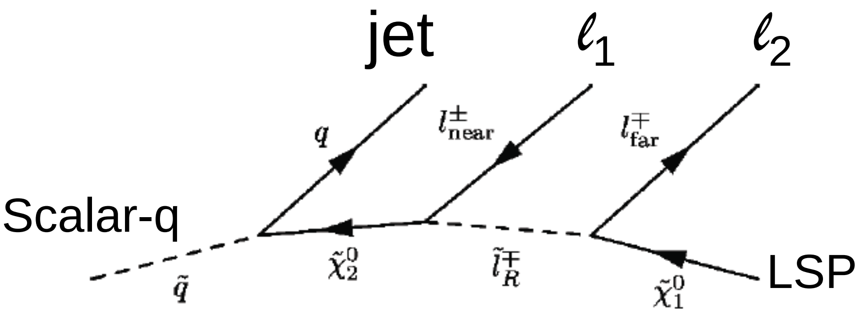


Early discovery of SUSY?



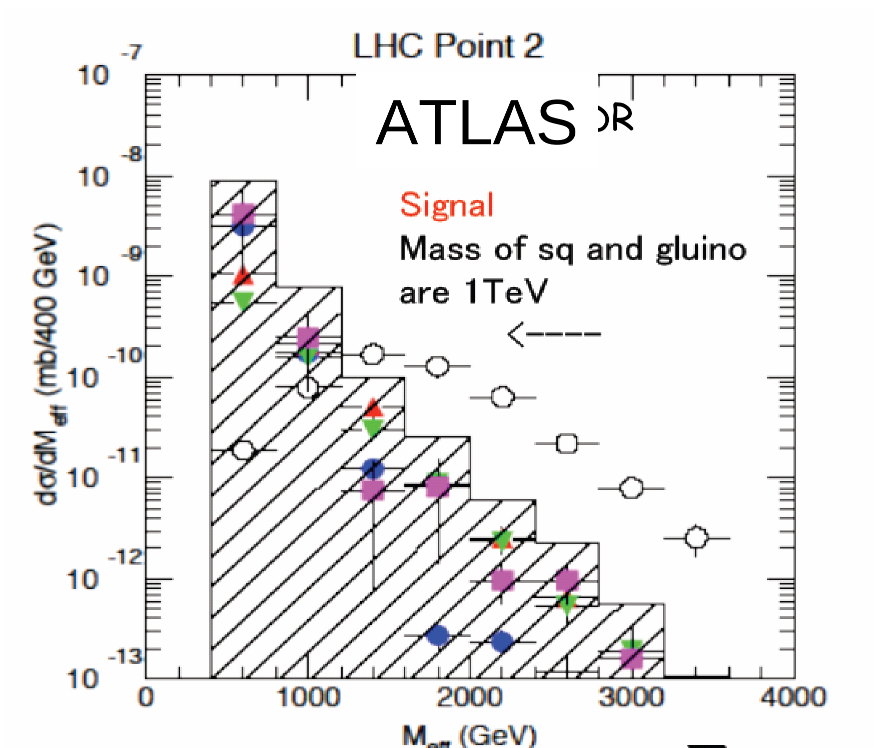
3 isolated leptons
+ 2 b-jets
+ 4 jets
+ E_t^{miss}

SUSY Discovery Signals

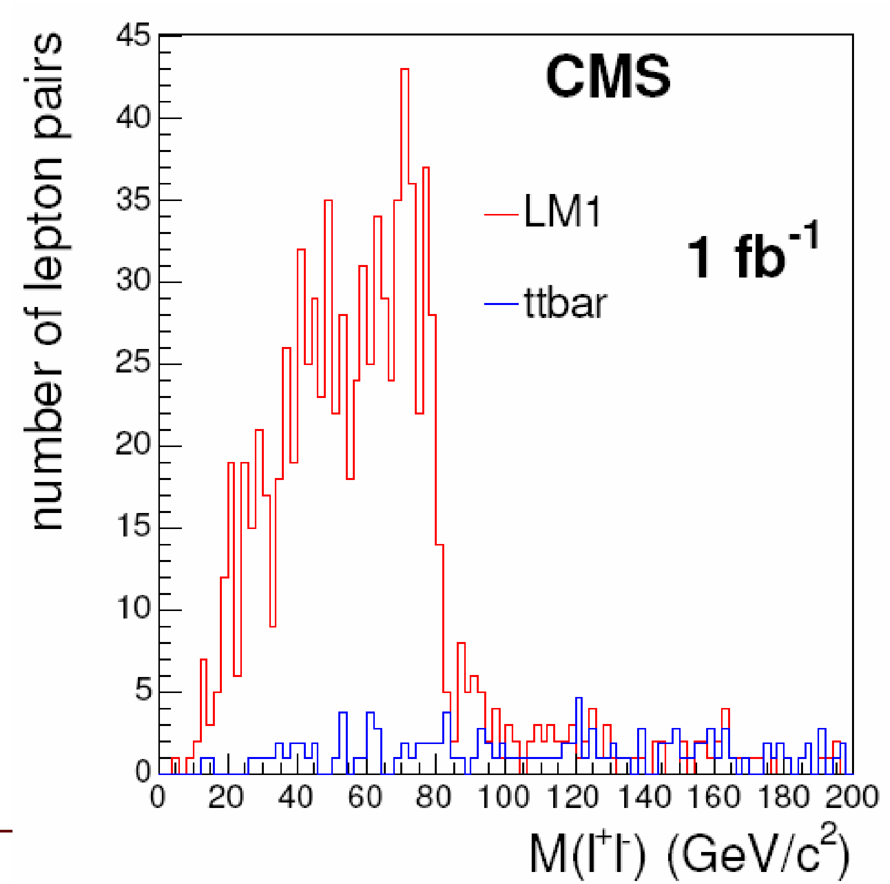


The distribution of the invariant mass of the two leptons can be shown to have a kinematic edge

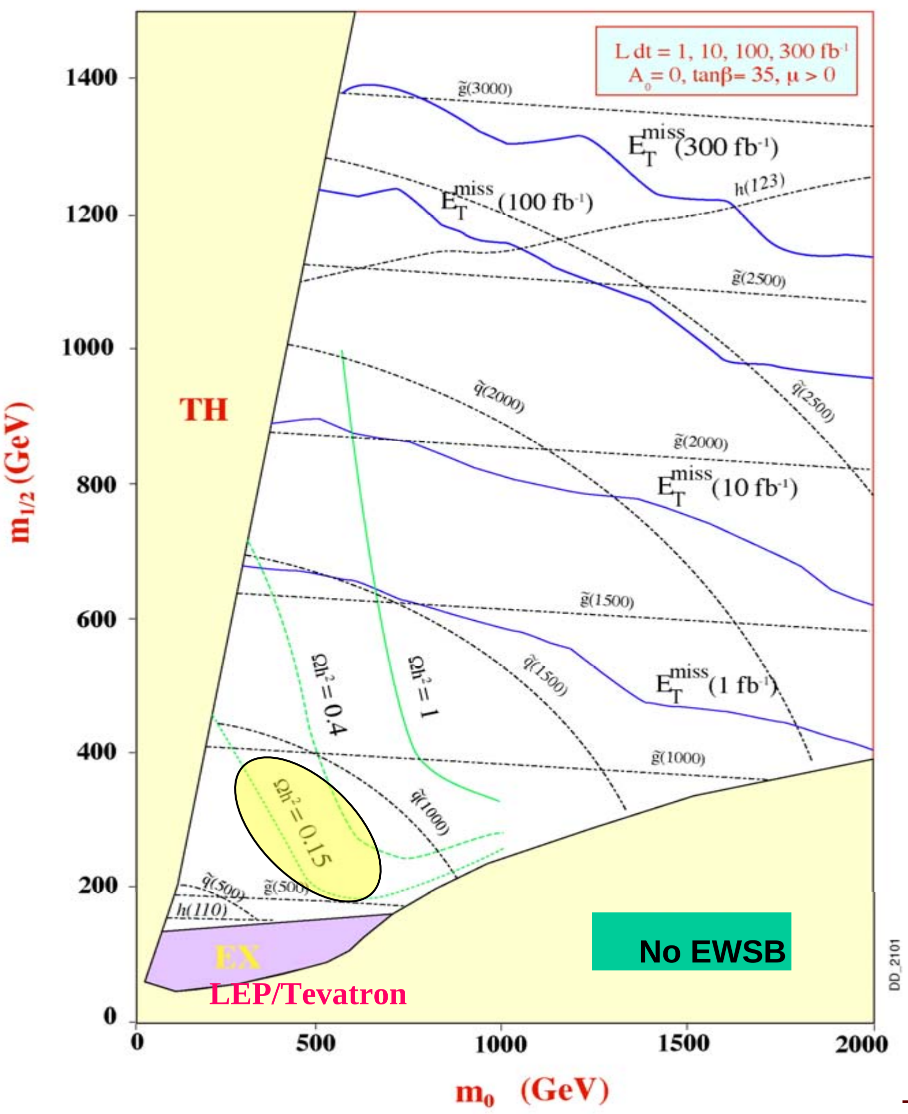
$$(m_{ll}^{\rm max})^2 = \frac{(m^2_{\tilde{\chi}^0_2} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}^0_1})}{m^2_{\tilde{l}_R}}$$

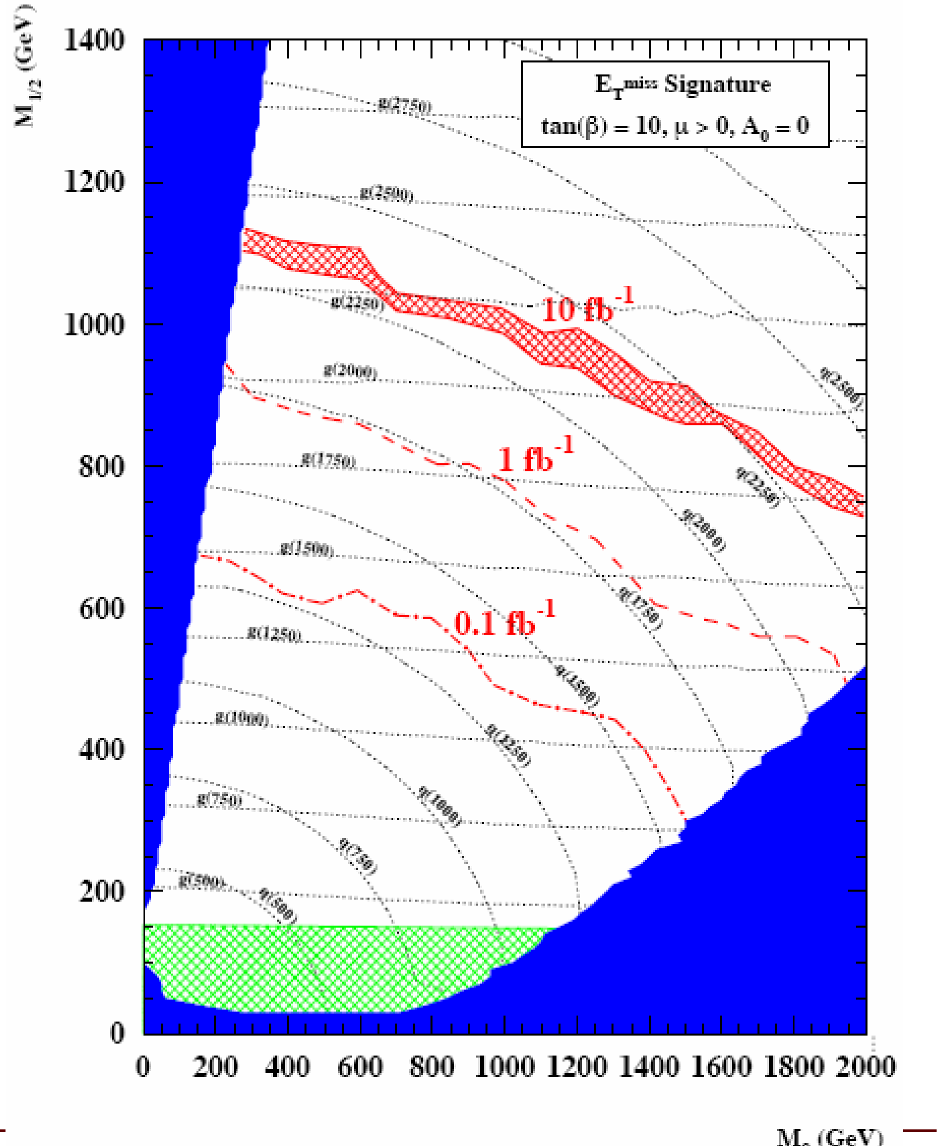


$= \not{E}_T + \sum P_T$



Discovery Potential of SUSY (mSUGRA)





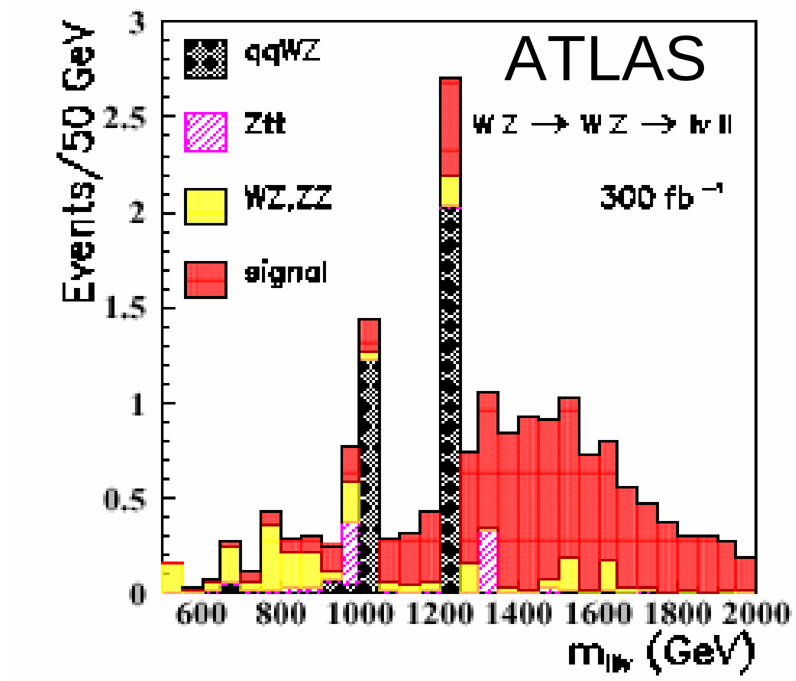
Strongly-Coupled Vector Boson System

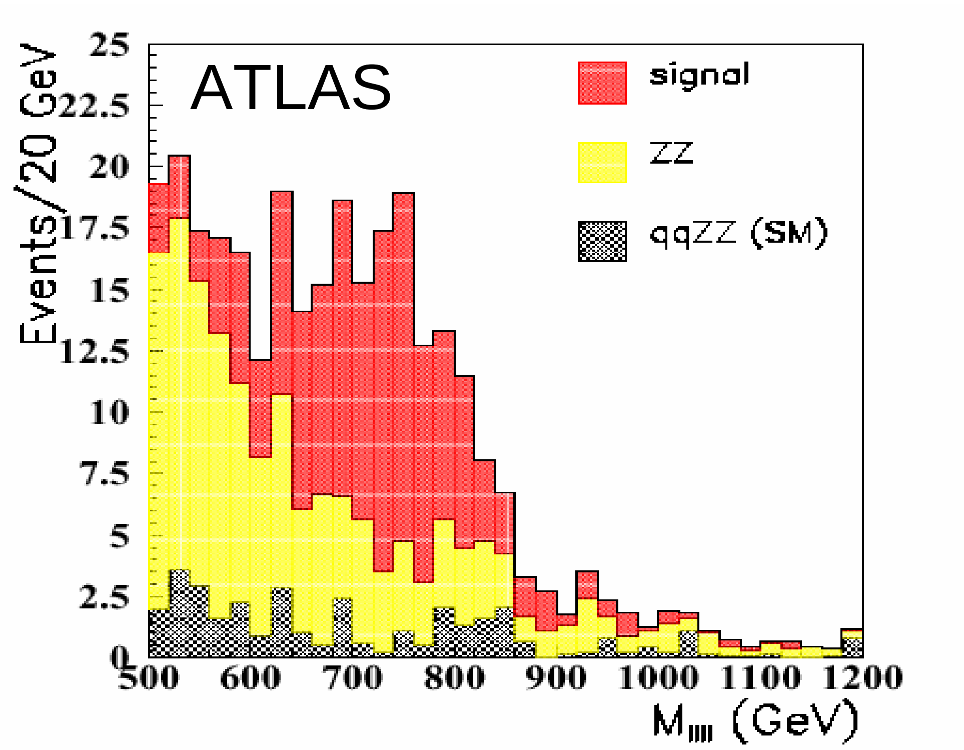
No light Higgs boson? Study Longitudinal gauge boson scattering in high energy regime (the L-component which provides mass to these bosons).

$W_L Z_L \longrightarrow W_L Z_L \longrightarrow l\,\nu\,ll$

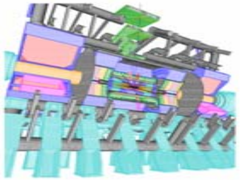
$W_L W_L \to Z_L Z_L \to$ 4 leptons
$Z_L Z_L \to Z_L Z_L \to$ 4 leptons

S / B = 6.6/2.2





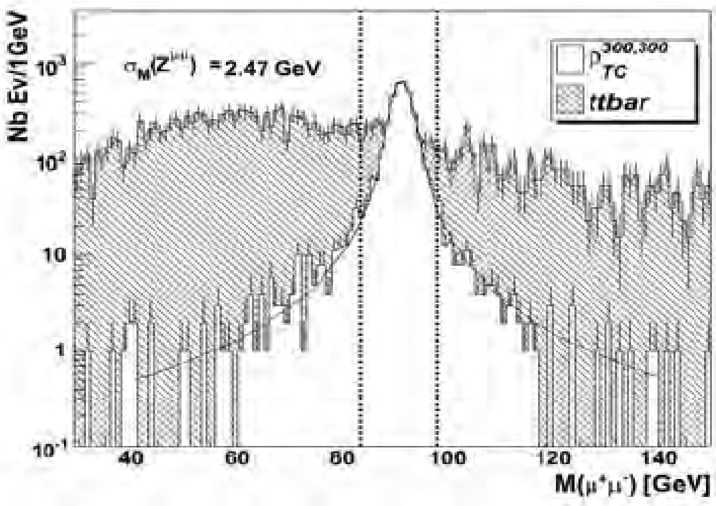
Strong Symmetry Breaking: Technicolor

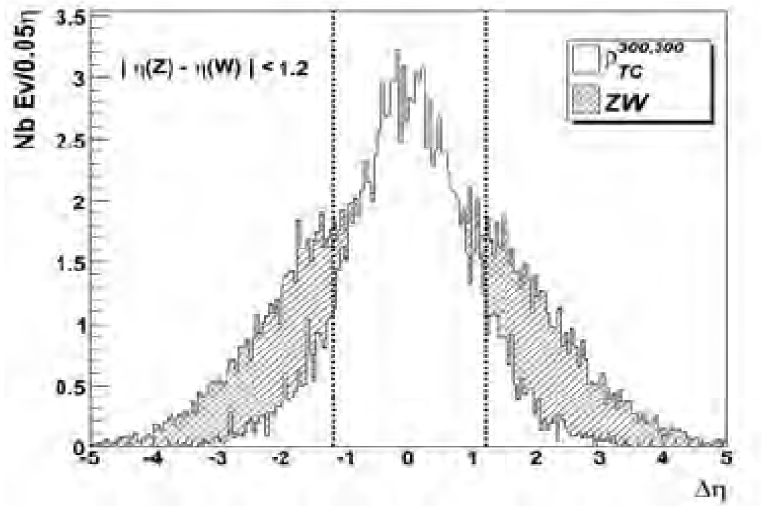


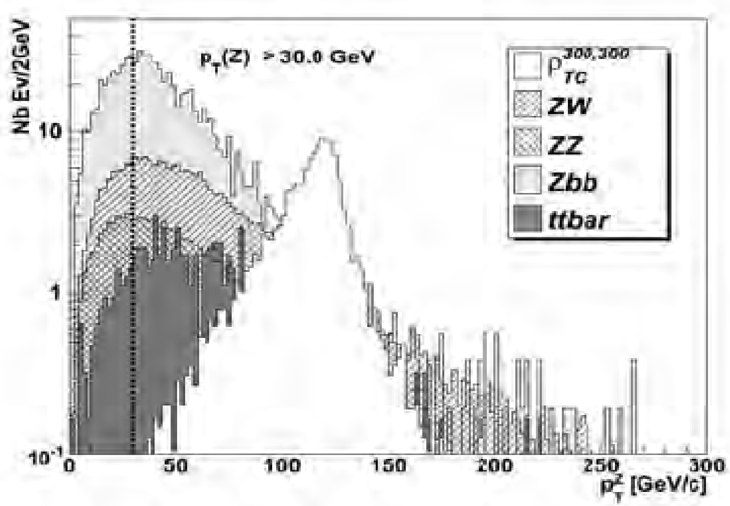
No fundamental scalar Higgs (it is a new strong force bounded state)

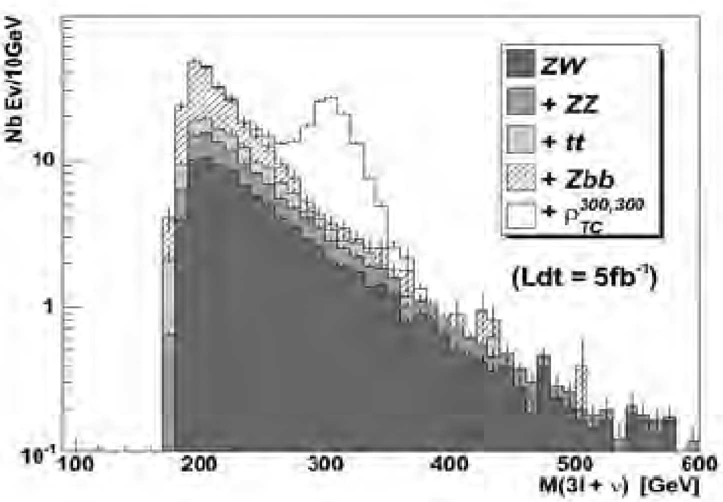
Technicolor predicts existence of technihadron resonance: $\rho_T \rightarrow WZ \rightarrow \ell\ell\ell+\nu$

CMS

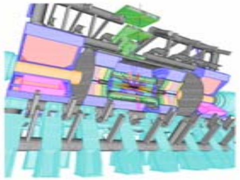




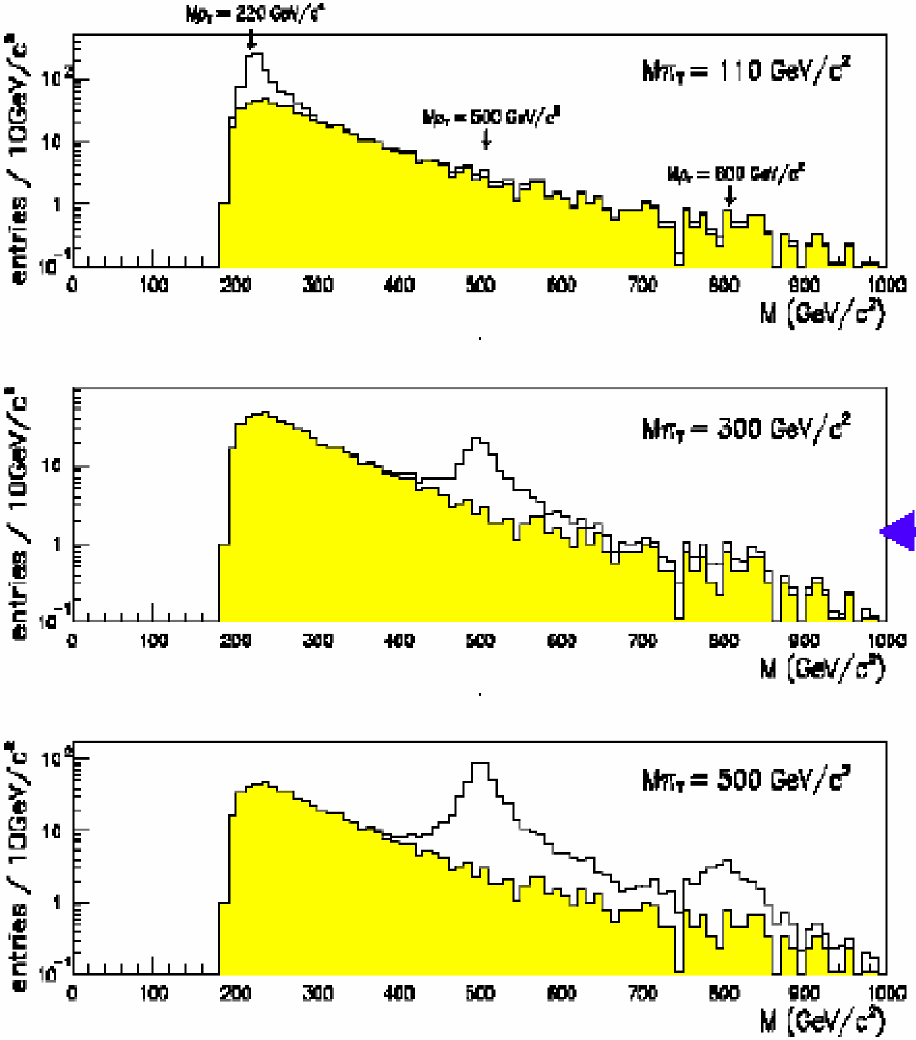




Muons in Technicolor Model



Reconstructed invariant mass for $\rho_T \to WZ \to l\nu ll$ channel.
Solid line is signal. Filled area is background.

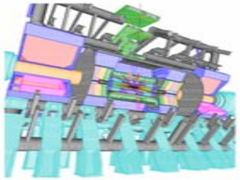


Lower limits required for 5σ significance with 30 fb^{-1} :
in some cases,
signals are below observability,
but combination of signals
could provide strong evidence.

$\rho_T \to WZ \to l\nu ll$ for 30 fb^{-1}
(a) $\sigma \times BR_{model}$ = 0.16 fb
$\sigma \times BR_{5\sigma\ discovery}$ = 0.025 fb

$\rho_T \to W\pi \to l\nu bb$ for 30 fb^{-1}
(c) $\sigma \times BR_{model}$ = 0.064 fb
$\sigma \times BR_{5\sigma\ discovery}$ = 0.15 fb

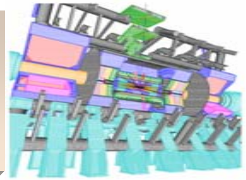
List of New Physics Reaches at LHC



SM Higgs	100 GeV ～ 1 TeV (30 fb^{-1})
MSSM Higgs	covers full (m_A, $\tan\beta$)
SUSY (squark, gluino)	~ 3 TeV (300 fb^{-1})
New gauge bosons (Z')	~ 5 TeV (100 fb^{-1})
Quark substructure (Λ_C)	~ 25/40 TeV (30/300 fb^{-1})
q*, l*	~ 6.5/3 TeV (100 fb^{-1})
Large ED (M_D for n=2,4)	~ 9/6 TeV (100 fb^{-1})
Small ED (M_C)	~ 6 TeV (100 fb^{-1})
Black holes	< 6 ~ 10 TeV

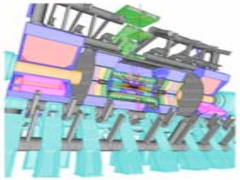
Any one of those would change the understanding of our universe !

Looking forward data



The LHC Schedule

- LHC will be closed and set up for beam on August 31, 2007
  - LHC commissioning will take time!
- First collisions expected in November 2007
  - A short pilot run
  - Collisions will be at injection energy ie cms of 0.9 TeV
- First physics run in 2008
  - ~ 1 fb^{-1}? 14TeV!
- Physics run in 2009 +…
  - 10-20 fb^{-1}/year
  - $\Rightarrow$100 fb^{-1}/year



General References

ATLAS Physics TDR

http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/TDR/access.html

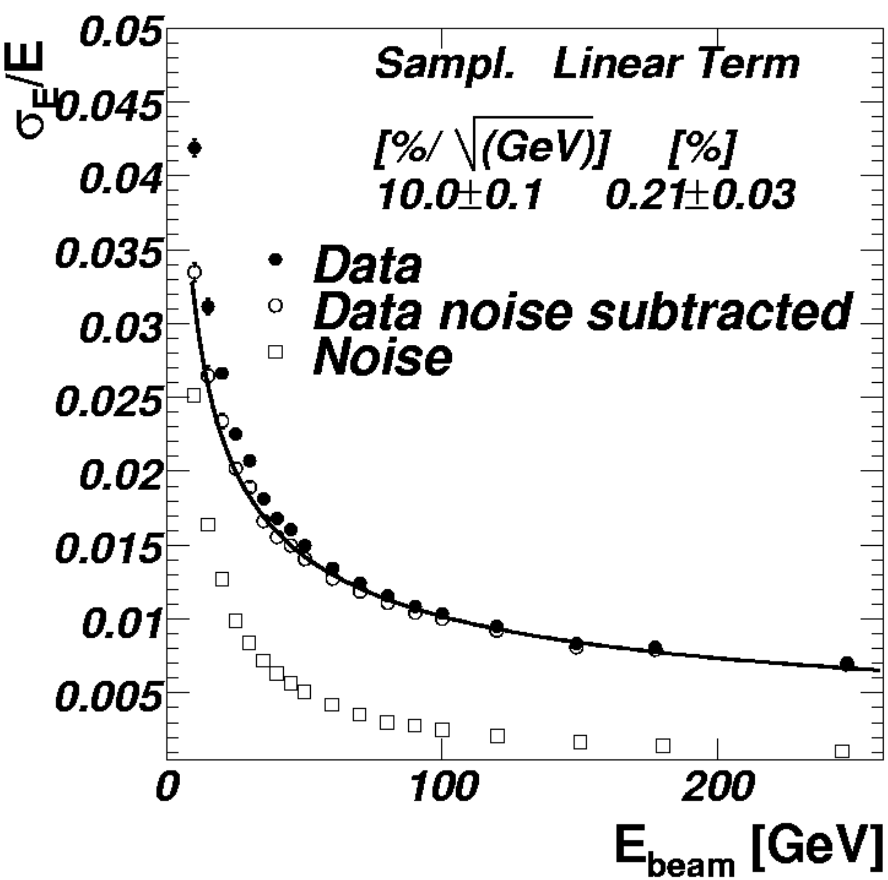
CMS Physics TDR

http://cmsdoc.cern.ch/cms/cpt/tdr/

Additional slides

ATLAS: ECAL Energy Resolution

Resolution with new reconstruction at η=0.68



Local energy resolution well understood since Module 0 beam tests and well reproduced by simulation :

-Sampling term given by lead/argon sampling fraction and frequency : quality control measurements during construction

- Noise term under control

- Local constant term (within a cell) given by impact point correction

→Uniformity is at 1% level quasi online but achieving ATLAS goal (0.7 %) needs a lot of work, and most of the time was used to correct for setup problem…

CMS: Muon Detection Resolution