Overview: LHC, ATLAS, CMS

Rainer Stamen (Universität Mainz)

LHC D-Workshop: QCD und Elektroschwache Physik

Karlsruhe, 9th March 2006

- LHC and Running Scenarios
- Physics Objects
- ATLAS and CMS
- The Trigger Issue

LHC

pp collisions:

- high energy
  ($\sqrt{s}$ = 14 TeV)
  7 * Tevatron

- high luminosity
  (10^{34} $cm^{-2}s^{-1}$)
  100 * Tevatron

- high bunch crossing rate (Δt = 25 ns)
  1/16 * Tevatron

- 23 events per bunch crossing

Running Scenarios

simple minded scenario:

- 3 years at L = 10^{33} -> L_{int} = 30 fb^{-1} (pileup = 2.3 ev / crossing)
- 3 years at L = 10^{34} -> L_{int} = 330 fb^{-1} (pileup = 23 ev / crossing)

reality is probably much more complicated:

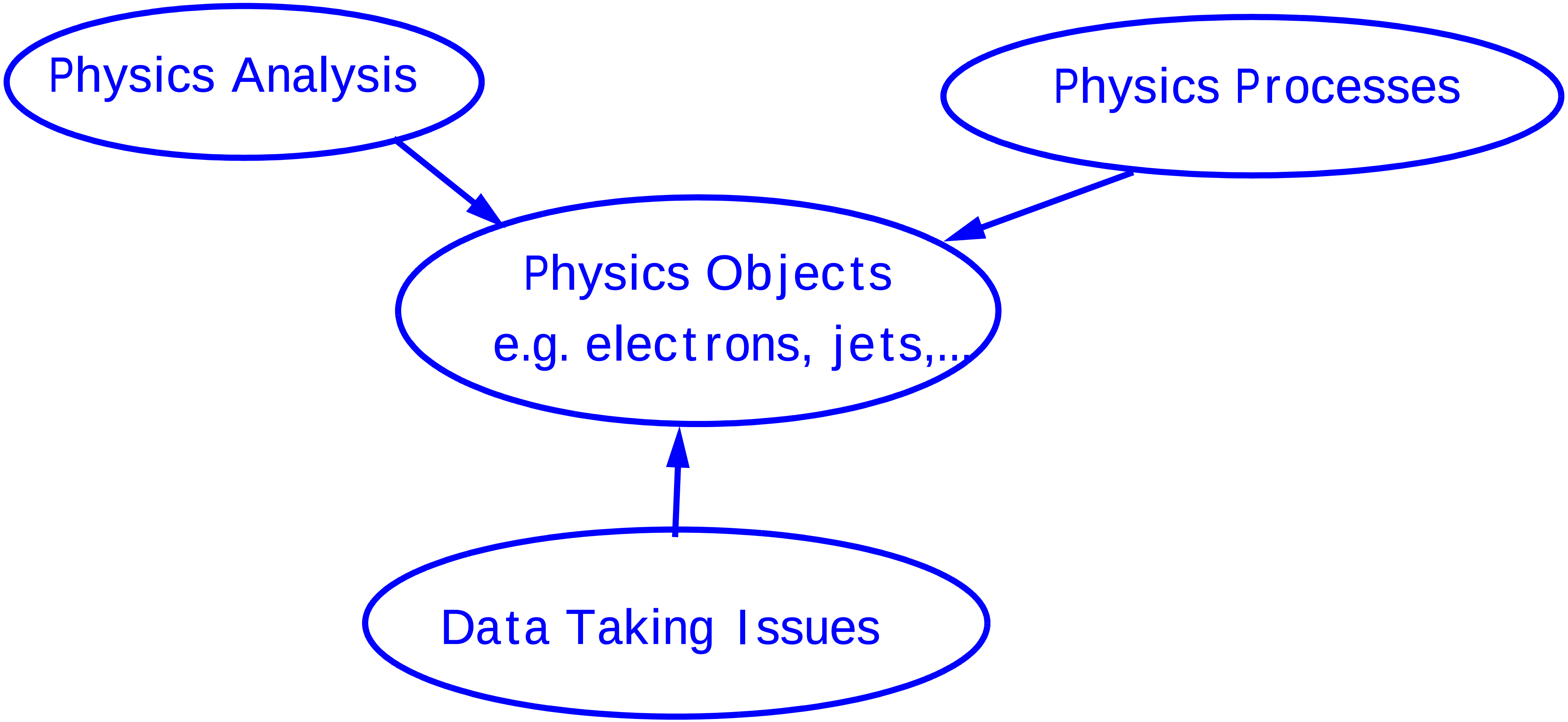
- luminosity profile: e.g. L = 10^{32} -> 10^{33} -> $5*10^{33}$ -> 10^{34}
  - -> impact on data taking conditions (Trigger rate)
  - -> impact on pileup (Physics Analysis)
- number of bunches
  - -> impact on pileup
- luminosity varies within on LHC fill
  - -> impact on data taking conditions
  - -> impact on pileup

Running Scenarios

Expected event rates at production in ATLAS at L = 10^{33} cm^{-2} s^{-1}

Process	Events/s	Events for 10 fb^{-1}	Total statistics collected at previous machines by '07
$W \to e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \to ee$	1.5	10^7	10^7 LEP
$t\bar{t}$	1	10^7	10^4 Tevatron
$b\bar{b}$	10^6	$10^{12} - 10^{13}$	10^9 Belle/BaBar ?
H m=130 GeV	0.02	10^5	?
$\tilde{g}\tilde{g}$ m= 1 TeV	0.001	10^4	---
Black holes m > 3 TeV (M_D=3 TeV, n=4)	0.0001	10^3	---

-> Much larger statistics than anything else produced so far



Physics Analysis
Physics Processes
Physics Objects
e.g. electrons, jets,...
Data Taking Issues

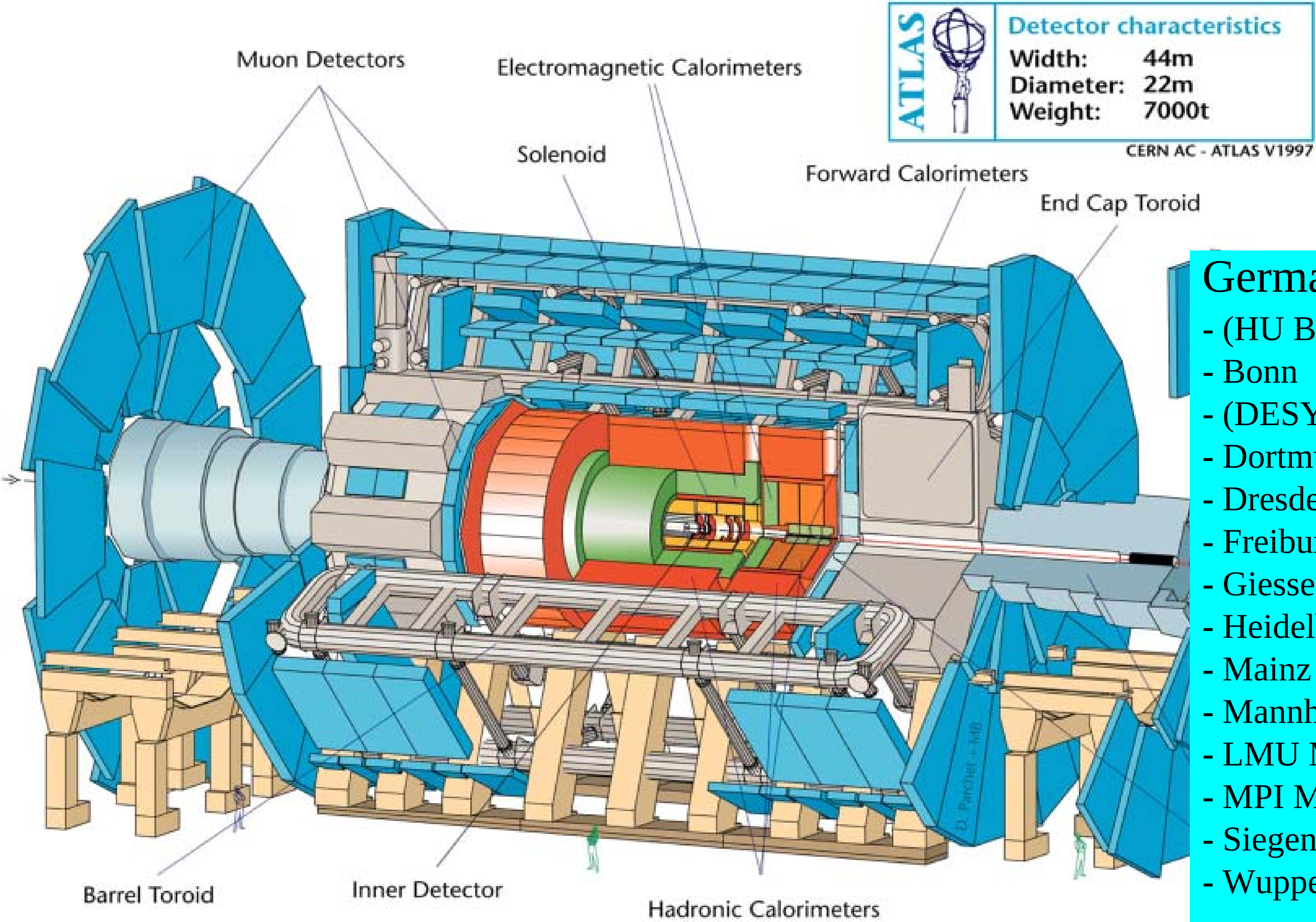
Physics Objects

Some SM Processes	Corresponding Physics Objects
W production	electrons, muons, missing ET
Z production	electrons, muons
Triple gauge couplings	electrons, muons, missing ET
QCD	jets, n jets
prompt photon production	photons

-> quite similar to physics objects needed for BSM-, Higgs-physics

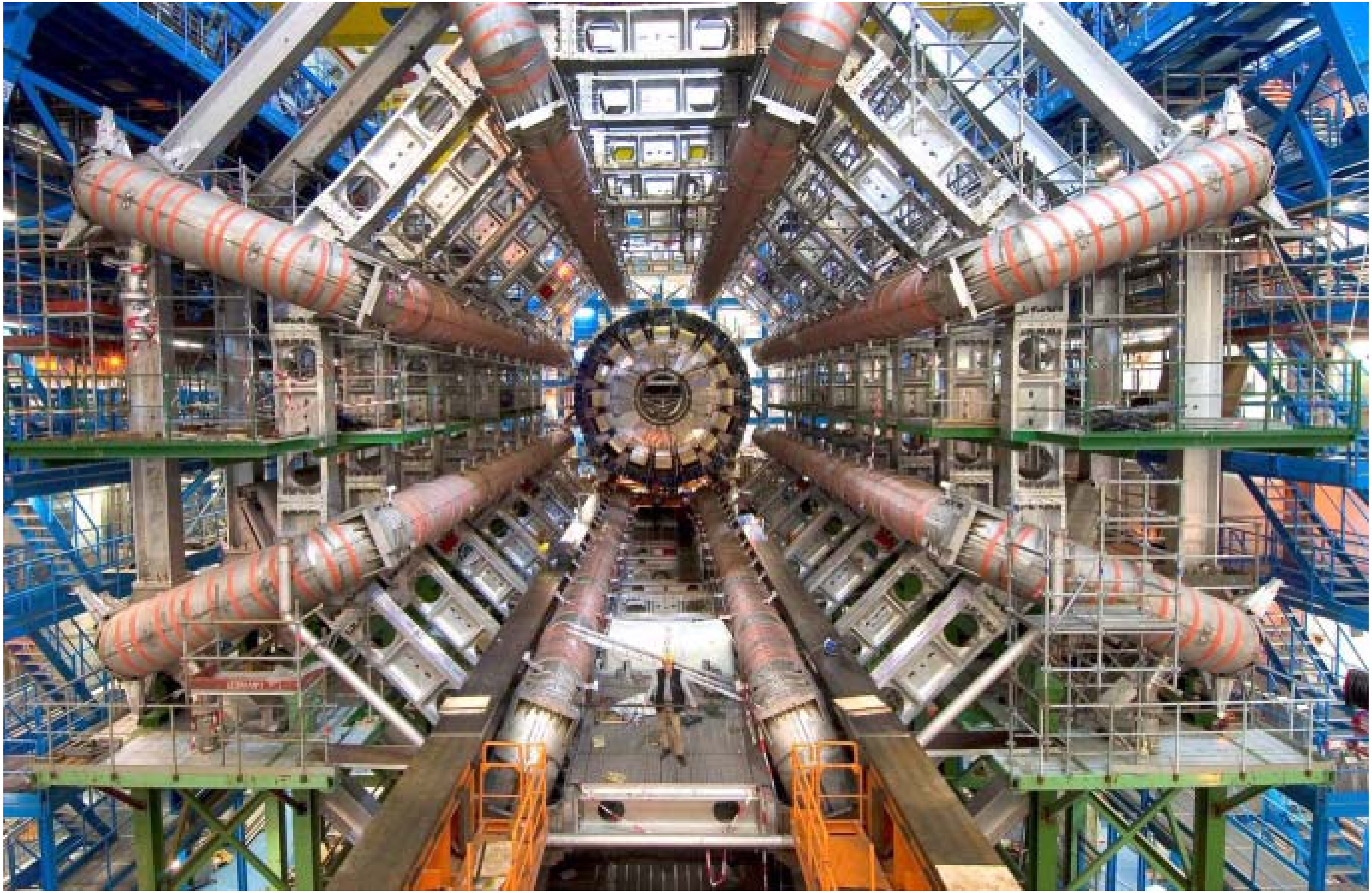
-> however not alway the same p_T range

ATLAS and CMS

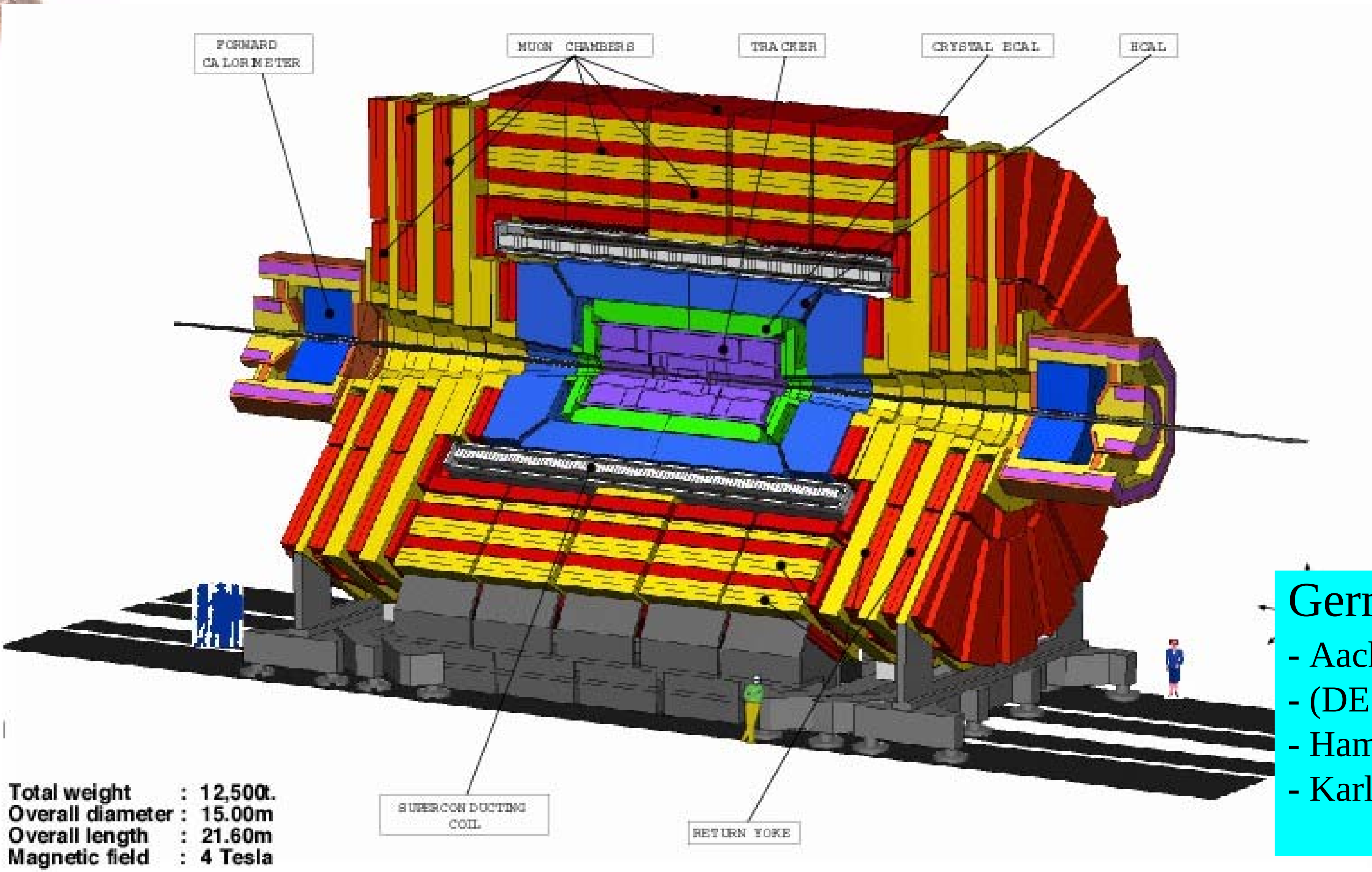


German groups:
- (HU Berlin)
- Bonn
- (DESY)
- Dortmund
- Dresden
- Freiburg
- Giessen
- Heidelberg
- Mainz
- Mannheim
- LMU München
- MPI München
- Siegen
- Wuppertal

ATLAS and CMS

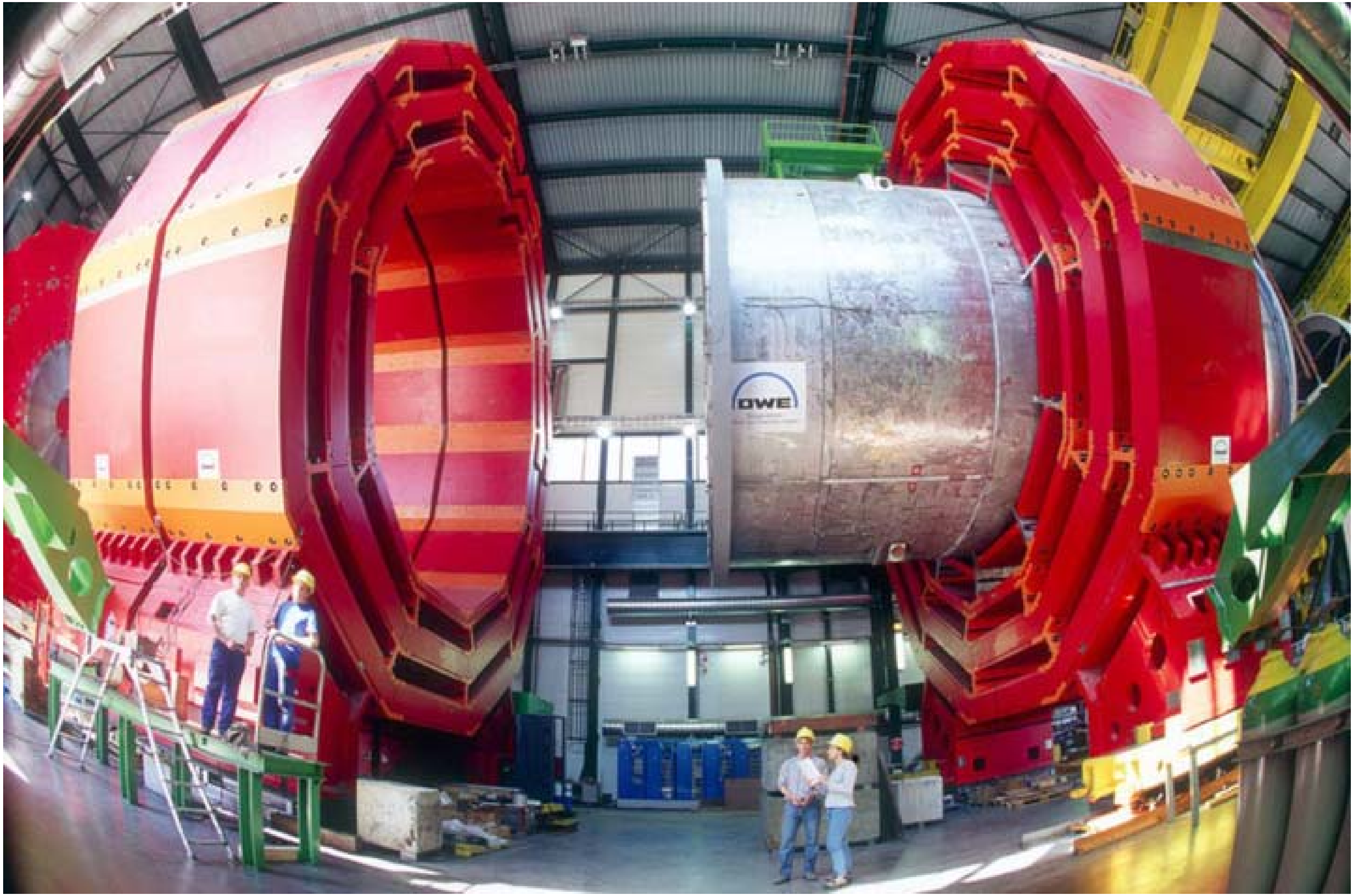


ATLAS and CMS



German groups:
- Aachen
- (DESY)
- Hamburg
- Karlsruhe

ATLAS and CMS



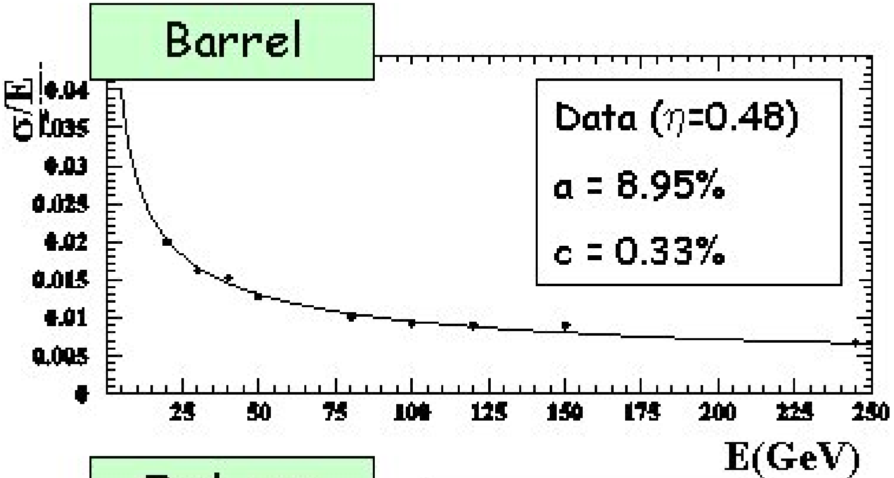
ATLAS and CMS

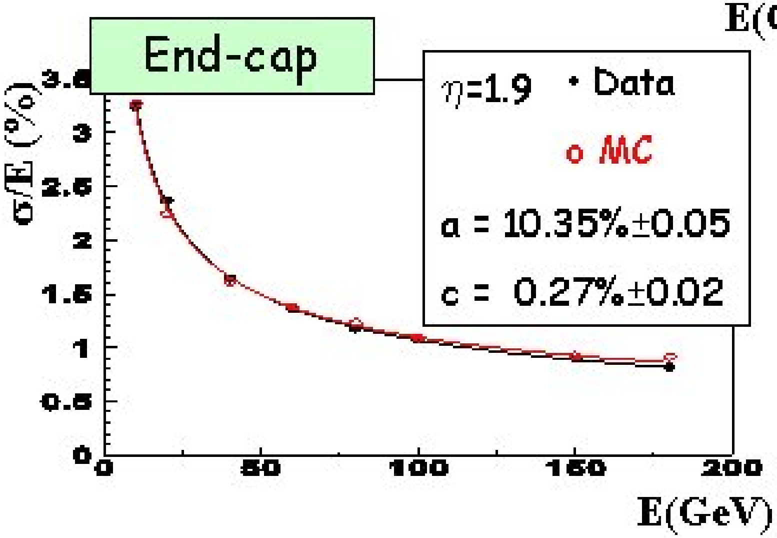
	ATLAS	CMS
MAGNET (S)	Air-core toroids + solenoid in inner cavity Calorimeters outside field 4 magnets	Solenoid Calorimeters inside field 1 magnet
TRACKER	Si pixel + strips TRD → particle identification B=2T $\sigma/p_T \sim 5\times10^{-4}\, p_T \oplus 0.01$	Si pixel + strips No particle identification B=4T $\sigma/p_T \sim 1.5\times10^{-4}\, p_T \oplus 0.005$
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 segm.
HAD CALO	Fe-scintillator + Cu-liquid argon (10 λ) $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$	Cu-scint. (> 5.8 λ + catcher) $\sigma/E \sim 65\%/\sqrt{E} \oplus 0.05$
MUON	Air → $\sigma/p_T \sim 7$ % at 1 TeV standalone	Fe → $\sigma/p_T \sim 5\%$ at 1 TeV combining with tracker

different experimental approaches (control systematics)

-> better precision than many existing detectors

ATLAS and CMS





ATLAS Test beam

$$\sigma_E/E = a/\sqrt{E} \oplus c \oplus n/E$$

For every tested points:

Barrel	End-cap
a < 10%	a < 12.5%
c < 0.4%	c < 0.5%

- Within specifications
- Good agreement with MC

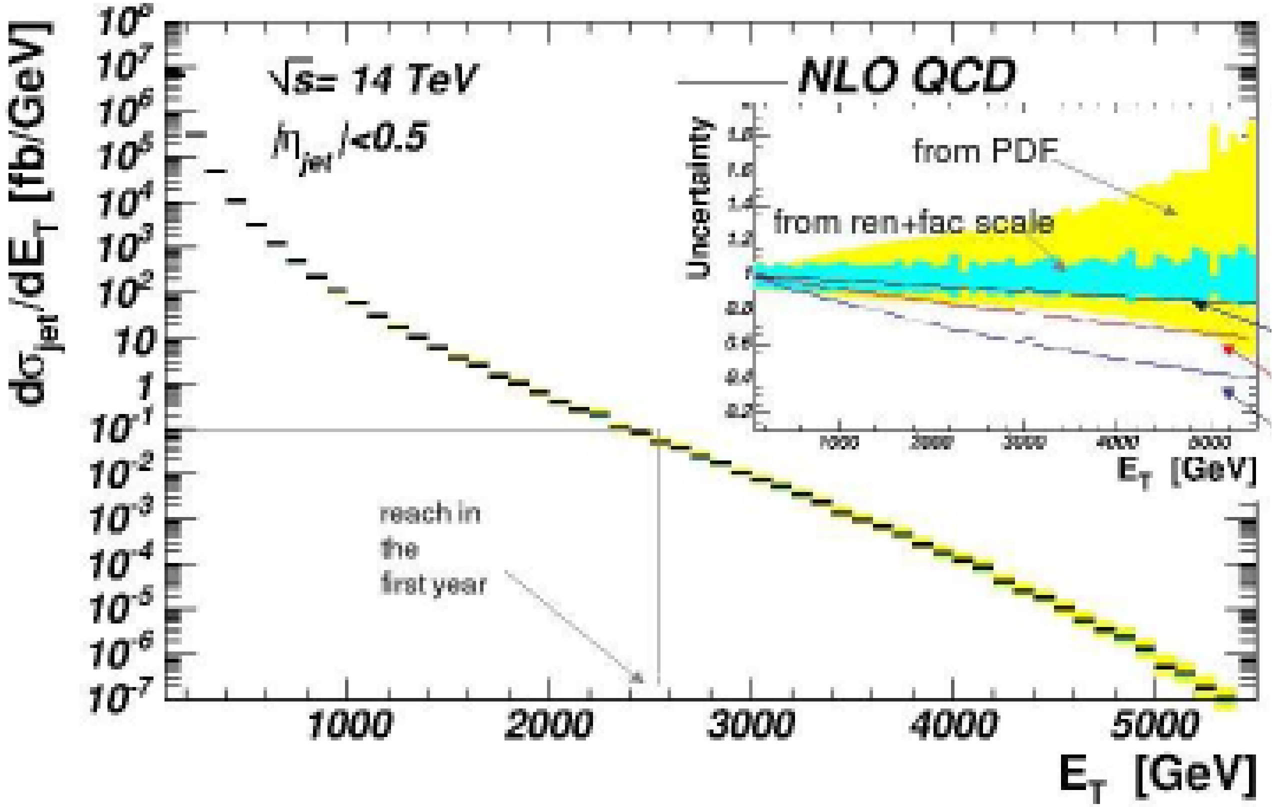
For $|\eta|< 2.5$ (precision region):

Goal:
- Lepton E,p scale: 0.02% precision
- Jet energy scale: 1% precision

ATLAS and CMS

Physics examples:

inclusive jet production



profit from

high energy

high luminosity

precision detectors

expectations for

300 fb^{-1}

E_T of jet	Events
> 1 TeV	$4 \cdot 10^6$
> 2 TeV	$3 \cdot 10^4$
> 3 TeV	400

ATLAS and CMS

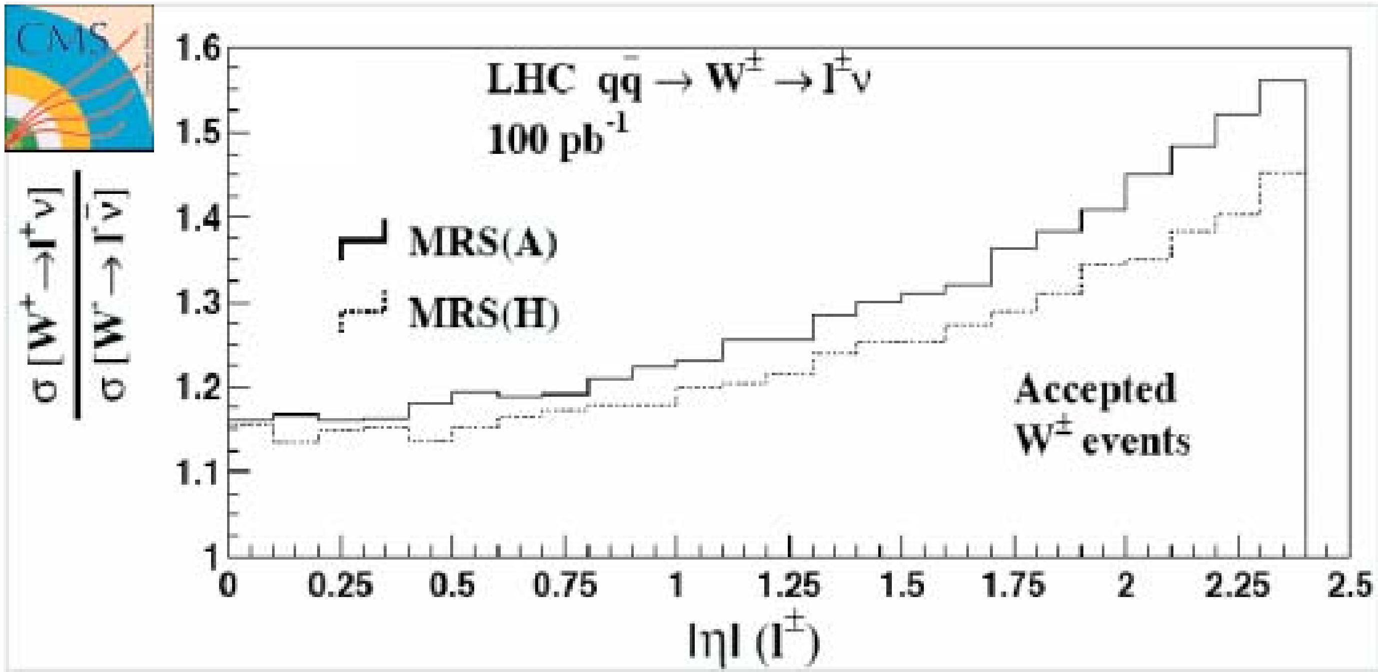
Physics examples:

W production ratios

- sensitiv to u(x)/d(x) ratio

profit from

precision detectors



ATLAS and CMS

Physics examples:

W mass determination

	CDF RunIb 30K evts, 84pb^{-1} MeV	ATLAS 60M evts, 10fb^{-1} MeV
Statistics	65	<2
Lepton E-p scale	75	15
Energy resolution	25	5
Recoil model	37	5
Lepton id.		5
P^T_W	15	5
PDF	15	10
W width		7
Radiative decays	20	<10
Background	5	5
TOTAL	113	< 25

The big difference!

Constrain "in situ" mainly $Z \rightarrow ee$

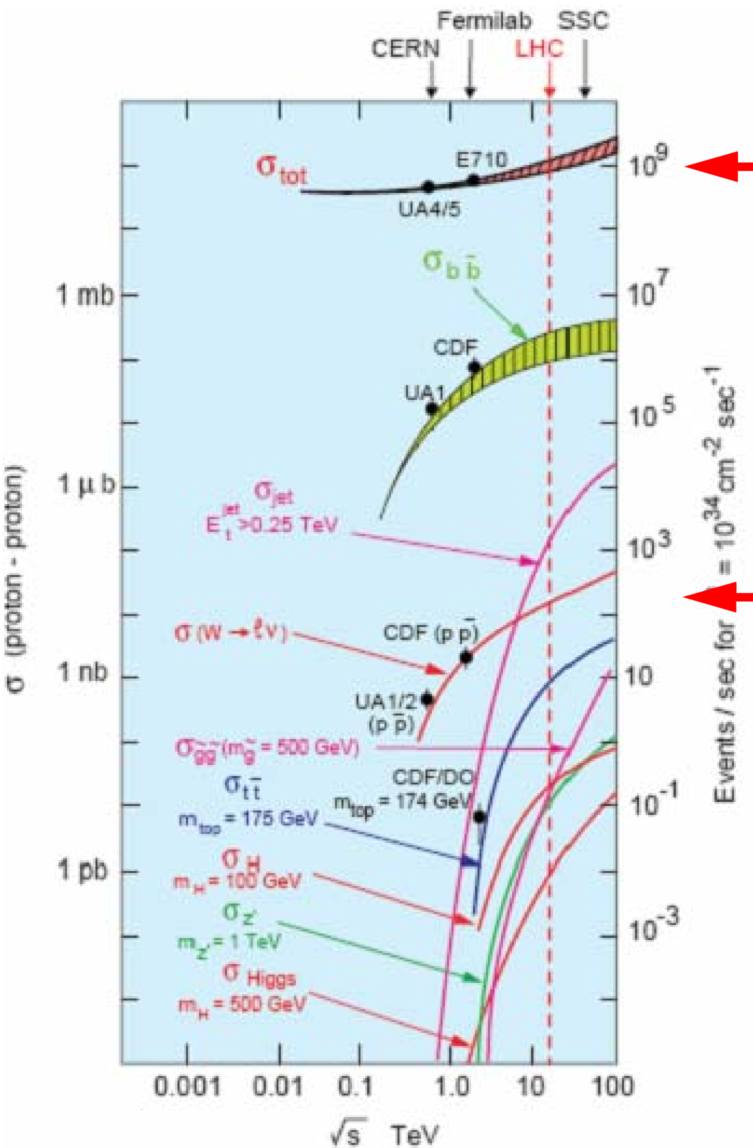
LHC combination ~ 15 MeV

profit from

high luminosity

precision detectors

The Trigger Issue



Interaction rate 1 GHz

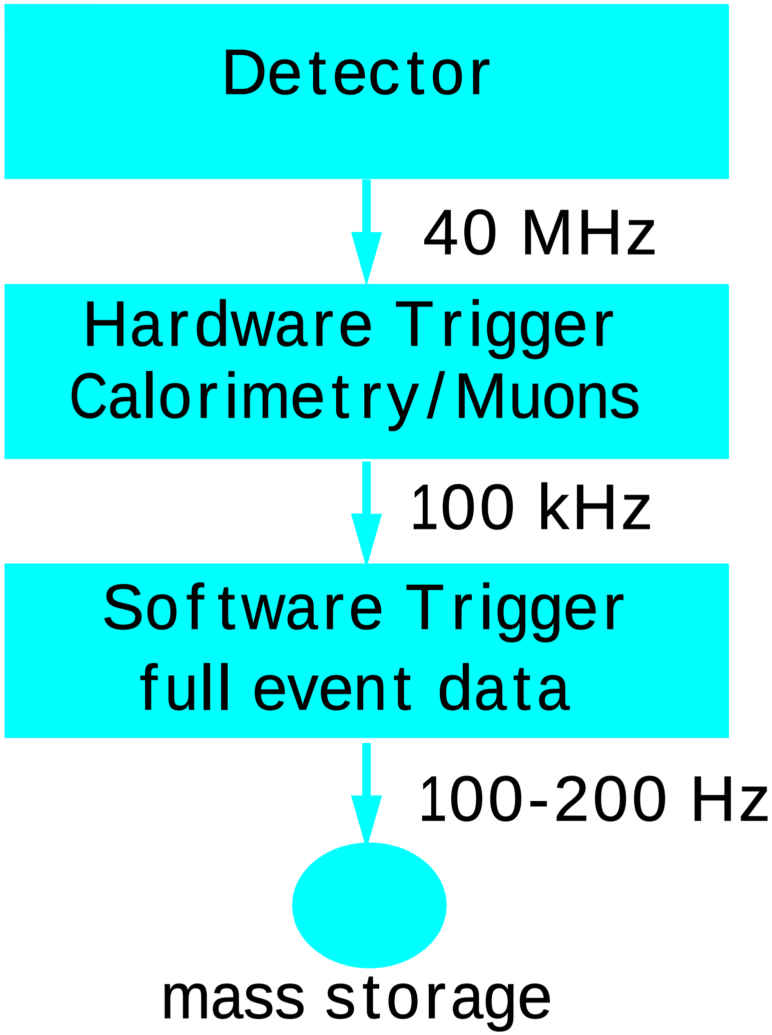
40 MHz crossing * 23 int. per crossing

readout rate (100 - 200 Hz)

Both experiments are bandwidth limited

-> large reduction needed online

The Trigger Issue



The main interest of ATLAS and CMS is Higgs and BSM physics

SM physics has to fit into the concept

- similar physics objects
- high p_T (i.e. low rate)
- use free bandwidth at low luminosity

The Trigger Issue

A possible trigger scenario (ATLAS)

Object	Physics coverage	Low Luminosity 2×10^{33} cm^{-2}s^{-1}	Rates (Hz)
Electrons	Higgs, new gauge bosons, extra dimensions, SUSY, W, top	e25i, 2e15i	~40
Photons	Higgs, extra dimensions, SUSY	γ60, 2γ20i	~40
Muons*	Higgs, new gauge bosons, extra dimensions, SUSY, W, top	μ20i, 2μ10	~40
	Rare b-decays (*e.g.*, $B\rightarrow\mu\mu X$, $B\rightarrow J/\Psi(\Psi')X$)	2μ6 + μ^+ μ^- + mass cut	~25
Jets	SUSY, compositeness, resonances	j400, 3j165, 4j110	~20
Jet+missing E_T	SUSY, leptoquarks	j70 + xE70	~5
Tau+missing E_T	Extended Higgs models (*e.g.*, MSSM), SUSY	τ35i + xE45	~10
Others	Prescaled, calibration, monitoring		~20
Total HLT Output Rate			~200

inclusive approach

not to miss unexpected processes

fits also for SM physics

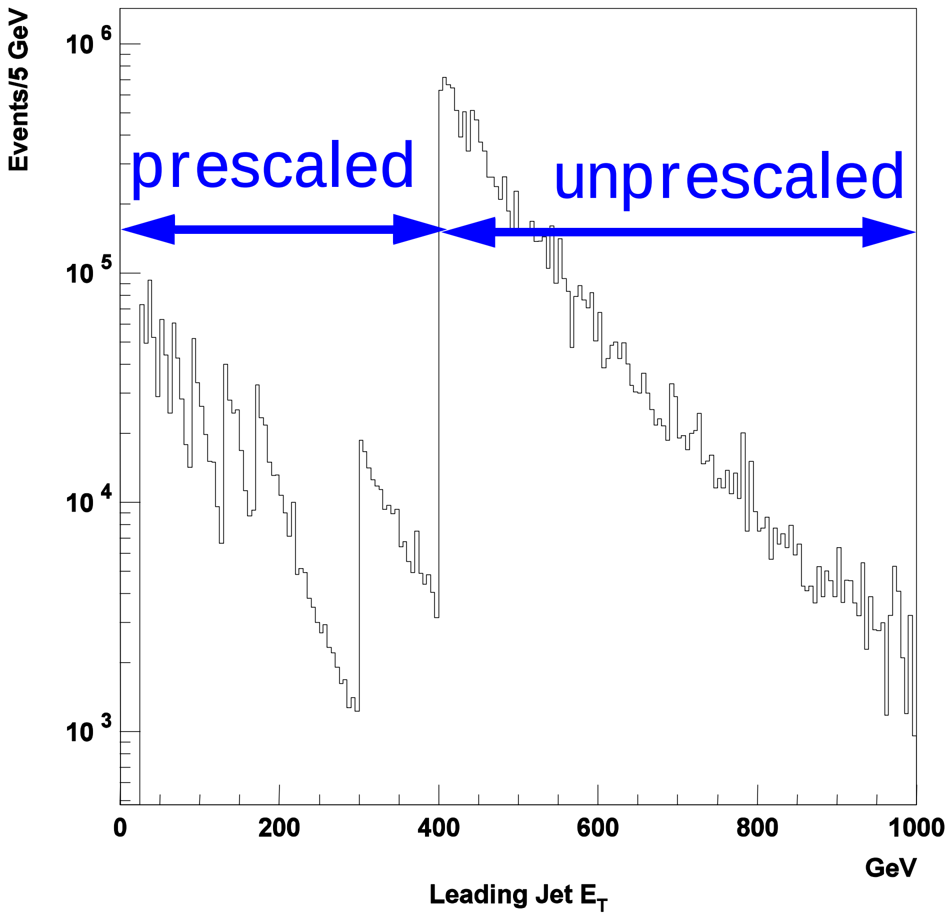
thresholds ok for obvious SM processes

This scenario might easily change (higher lumi, machine background,...)

- other threshold
- other priority

The Trigger Issue

Prescaling Example: Jet Triggers



high pT jets are all taken

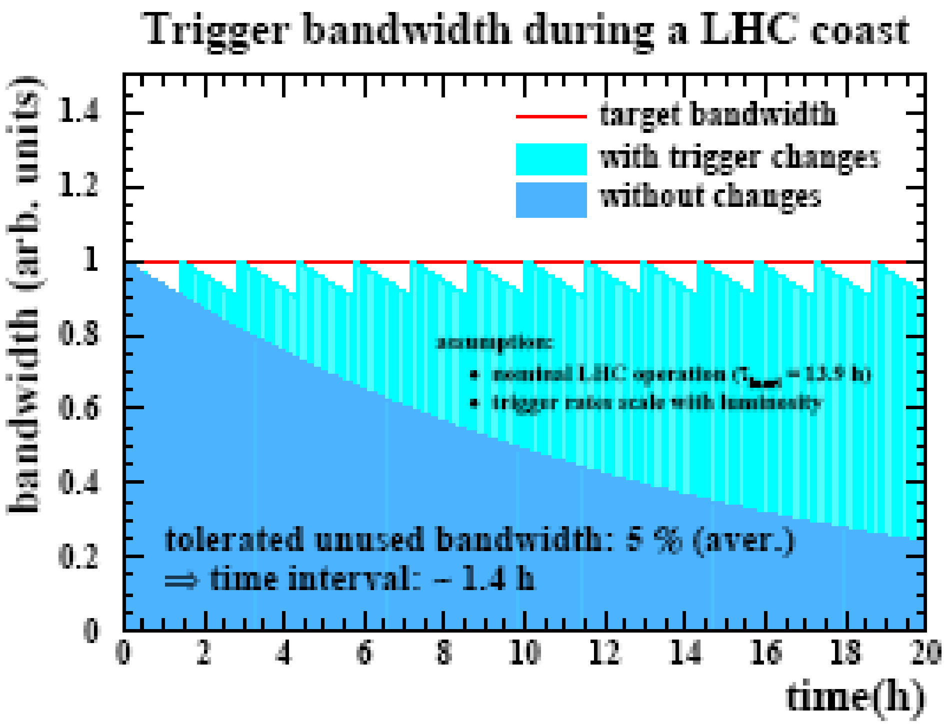
only a fraction of low p_T jets is taken

same concepts applies to other physics objects (electrons, muons,...)

reasonable for many SM measurements

The Trigger Issue

Prescaling impact on data taking:



Luminosity changes within a LHC fill

-> bandwidth gets free
-> change trigger setup
-> more bandwidth for “low profile“ physics

- > change prescales of triggers

The Trigger Issue

Triggering standard model physics in a nutshell

- high pT physics (e.g. jets)
  -> no problem
- precision physics (W mass)
  -> possible
  -> many dependencies
    (thresholds, Luminosity, background conditions,...)

Summary

- LHC provides us with high energy and luminosity
  -> several orders of magnitude w.r.t. Tevatron
- ATLAS and CMS are precision detectors
  -> unreached precision (energy scales,...)
- Standard Model physics is still a tough job
  -> get the precision
- Getting the data to tape is a challange
  -> seems ok for many SM processes