$B_s \to \mu^+\mu^-$

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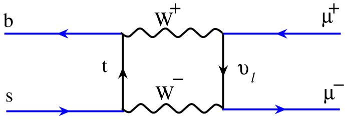
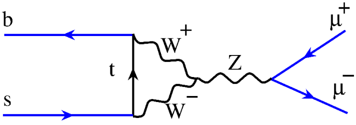
Motivation

- $B_s \rightarrow \mu^+\mu^-$ can only occur through higher order diagrams in Standard Model (SM)
- This decay is not only suppressed by the GIM Mechanism but also by helicity
- SM predicts very low rate with very little SM background ($\mathcal{BR}(B_s \rightarrow \mu^+\mu^-) = 3.4\text{x}10^{-9}$)
- Super symmetry (SUSY) models predict enhancement of this decay by $\tan\beta^6$
- Relatively clean decay channel





$\tan\beta^6$

- $\tan\beta$ = ratio of the two VEV's of the two Higgs in SUSY ($tan\beta^6 = \frac{v_u}{v_d}$)
- Yukawa couplings depend on masses and VEV's $\longrightarrow$

$$m_u = \sqrt{2} y_u v sin\beta \tag{1}$$

and

$$m_d = \sqrt{2} y_d v cos\beta \tag{2}$$

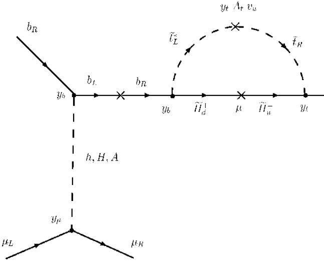
- For large $tan\beta$: $sin\beta \sim 1 \longrightarrow tan\beta \sim \frac{1}{cos\beta}$
- This gives us the following Yukawa coupling for the SUSY diagram:

$$y_b = \frac{m_b}{\sqrt{2}v} tan\beta \tag{3}$$

$$y_t = \frac{m_t}{\sqrt{2}v} \tag{4}$$

$$y_\mu = \frac{m_\mu}{\sqrt{2}v} tan\beta \tag{5}$$

- Result: large $\tan\beta^6$ enhancement of cross section



Leptonic B_s decays

$B_s \to e^+e^-$

- Electron channel will be suppressed by a factor of 200 compared to muon channel
- Electrons are more likely to emit bremsstrahlung complicating reconstruction
- Due to brems invariant mass resolution could suffer

$B_s \to \tau^+\tau^-$

- Taus would have a stronger coupling to the Higgs thus have greater enhancement of rate
- Lifetime of muon is significantly longer than tau ($c\tau = 87\mu$m vs $c\tau = 659$m)
- Taus reconstruction is much more complicated
  - Taus decay channels always have at least one neutrino
  - Taus decay into two neutrinos 40% of the time
  - This will cause worse invariant mass resolution

LHC b production

- LHC originally expected to run at $\sqrt{s} = 14$ TeV and $10^{34}\text{cm}^{-2}\text{s}^{-1}$
  - This would yield approx. 50 times more $b\bar{b}$ pairs per second than the Tevatron
- Luminosity has been lowered to $2\text{x}10^{34}\text{cm}^{-2}\text{s}^{-1}$ as well as the COM energy to $\sqrt{s} = 7$ until 2012
- Three experiments: ATLAS, CMS, and LHCb
  - ATLAS and CMS are general purpose experiments with a solenoidal geometry and a focus on high p_T physics
  - LHCb is a fixed target experiment that specializes in b physics

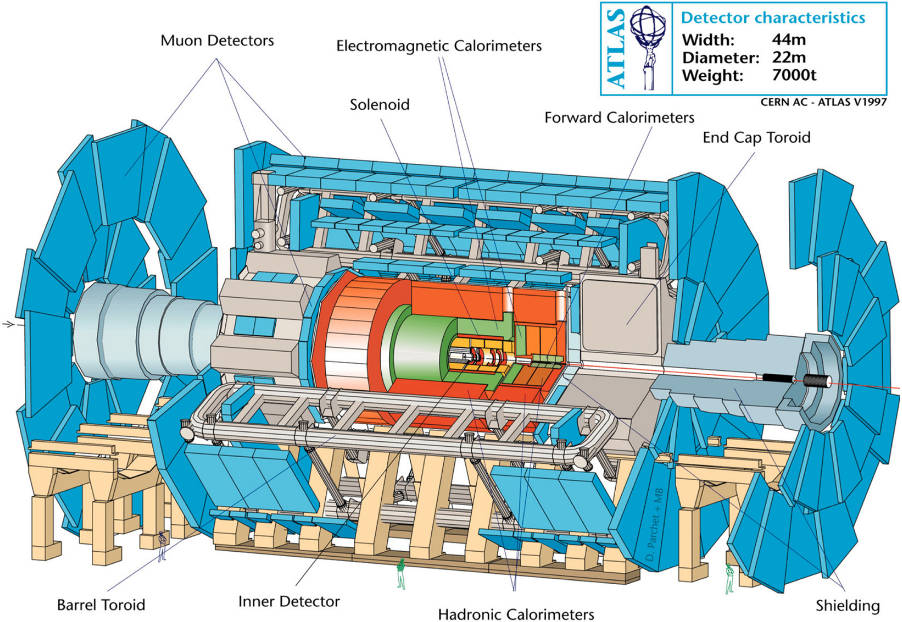
CDF Detector Capabilities

- Tevatron is high luminosity machine ($3.5\text{x}10^{32}\text{cm}^{-2}\text{s}^{-1}$)
- Will remain at the luminosity frontier until 2012-2013
- A di-muon trigger with a p_T threshold of 1.5 GeV (2.0 GeV for more higher η muons)
- 700K channel pixel detector
  - $R\phi$ resolution of 35 micron
- Outer track is a drift chamber with hit resolution of 146 micron
- Muon system is a patchwork of detectors
  - CMU and CMX cover about $|\eta| < 1.2$
  - 250 micron resolution in drift direction

Current Limits

CDF has set the current limit for $B_s \to \mu^+\mu^-$ at $\mathcal{BR}(B_s \to \mu^+\mu^-) = 3.6\text{x}10^{-8}$ for 3.7 fb^{-1} at 90% CL. Improvements are expected with 6-8 fb^{-1}.

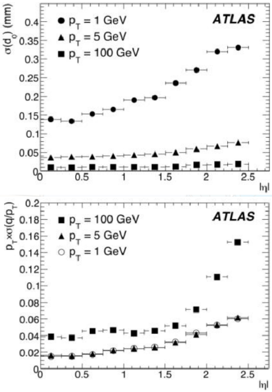
ATLAS



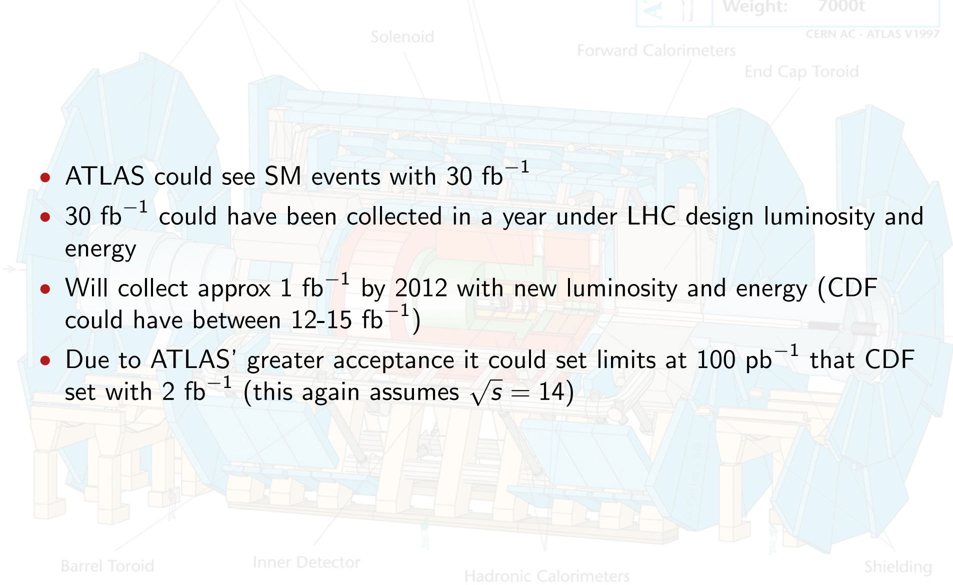
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding
D. Parchet + MB

ATLAS Detector Capabilities

- A di-muon trigger will be used with a p_T threshold between 3-6 GeV
- 80 million channel pixel detector
  - 3 barrel layers and 6 forward layers
  - $R\phi$ resolution of 12 micron and z resolution of 60 micron
  - $|\eta| < 2.5$ coverage
- Outer silicon strip tracker has $R\phi$ resolution of 16 micron while having a z resolution of 580 micron
- Muon system is meant to be stand alone tracking system
  - $|\eta| < 2.7$ coverage
  - Uses different types of sub detectors for different purposes
  - Momentum resolution of 2-5 % at 10 GeV

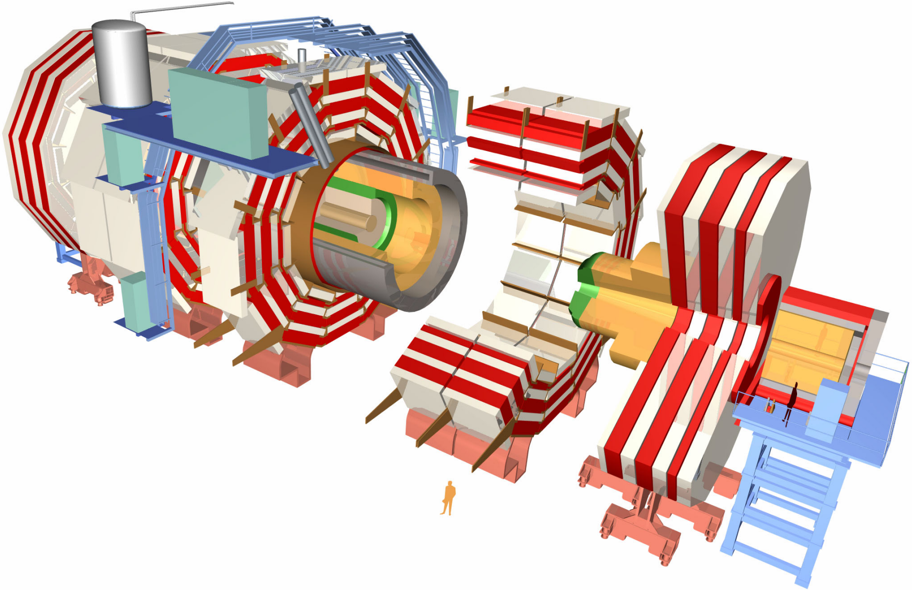


ATLAS Potential for Setting Limits



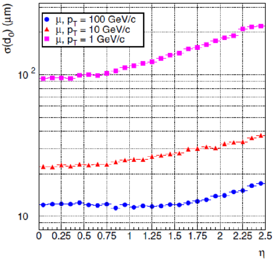
- ATLAS could see SM events with 30 fb^{-1}
- 30 fb^{-1} could have been collected in a year under LHC design luminosity and energy
- Will collect approx 1 fb^{-1} by 2012 with new luminosity and energy (CDF could have between 12-15 fb^{-1})
- Due to ATLAS' greater acceptance it could set limits at 100 pb^{-1} that CDF set with 2 fb^{-1} (this again assumes $\sqrt{s} = 14$)

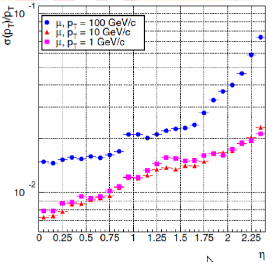
CMS



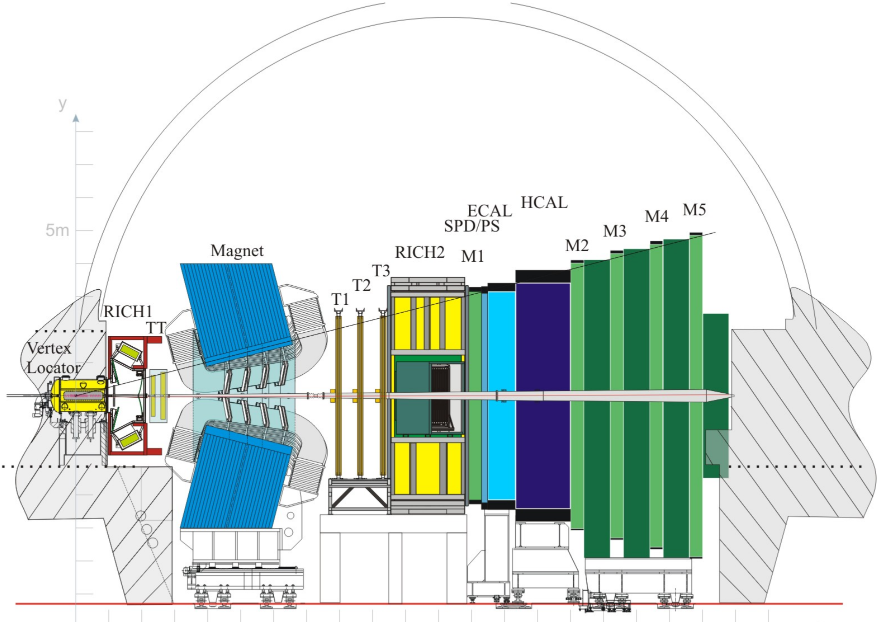
CMS Detector Capabilities

- Di-muon trigger at 3 GeV
- 66 million channel pixel detector
  - 3 barrel layers and 4 forward layers
  - $R\phi$ resolution of similar to ATLAS but z resolution of 17 micron
  - $|\eta| < 2.2$ coverage
- Outer silicon strip tracker is similar to ATLAS's
- Muon system is meant to be stand alone tracking system
  - $|\eta| < 2.4$ coverage
  - Uses different types of sub detectors for different purposes
  - Momentum resolution of 8-15% at 10 GeV



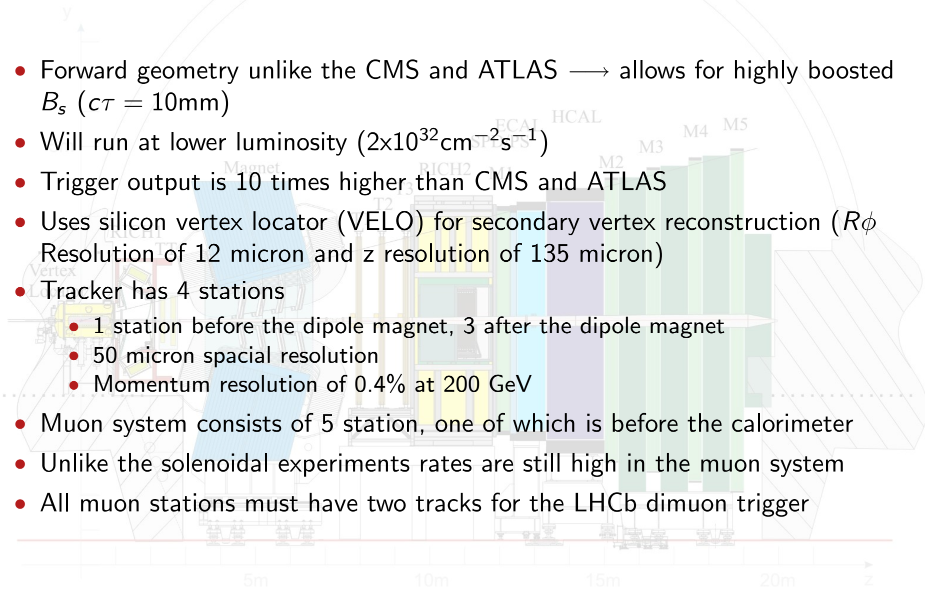


LHCb


y
5m
Magnet
RICH1
TT
Vertex
Locator
T1
T2
T3
RICH2
M1
ECAL
SPD/PS
HCAL
M2
M3
M4
M5

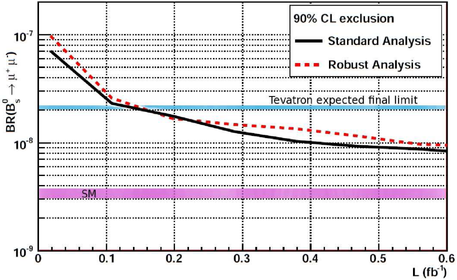
LHCb Detector Capabilities

- Forward geometry unlike the CMS and ATLAS $\longrightarrow$ allows for highly boosted B_s ($c\tau = 10$mm)
- Will run at lower luminosity (2x10^{32}cm^{-2}s^{-1})
- Trigger output is 10 times higher than CMS and ATLAS
- Uses silicon vertex locator (VELO) for secondary vertex reconstruction ($R\phi$ Resolution of 12 micron and z resolution of 135 micron)
- Tracker has 4 stations
  - 1 station before the dipole magnet, 3 after the dipole magnet
  - 50 micron spacial resolution
  - Momentum resolution of 0.4% at 200 GeV
- Muon system consists of 5 station, one of which is before the calorimeter
- Unlike the solenoidal experiments rates are still high in the muon system
- All muon stations must have two tracks for the LHCb dimuon trigger



LHCb Potential for Setting Limits

- LHCb requires less luminosity to achieve limits of ATLAS, CMS, and CDF
- LHCb should be able to compete with CDF limits by 2012



Parameter	ATLAS	CMS	LHCb
$\sigma_{\mu\mu}$[MeV]	67	43	20
N_{sig}	7	6	30
N_{bkg}	20	14	183