What we would like to measure?

- Because there is no specific physics process to be studied, general purpose detector(s) is a must for an energy frontier machine

- In order to set benchmarks different process are used: top studies, Higgs/SUSY discovery, etc. Let's consider"recent" top quark discovery

- In order to discover top quark both CDF and D0 had to detect: leptons (e/μ), jets, tag b-quarks (leptons or displaced vertex), and neutrinos (missing E_t):

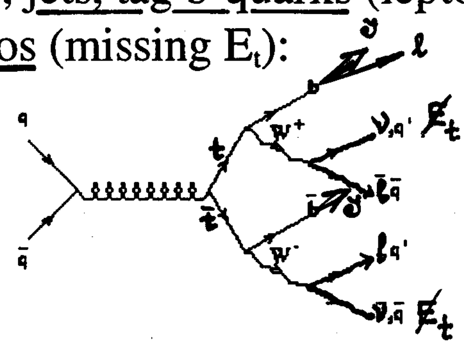


Figure 1: Tree level top quark production by $q\bar{q}$ annihilation followed by the Standard Model top quark decay chain.

Decay mode	Branching ratio
$tt \longrightarrow (q\bar{q}'b)(q\bar{q}'b)$	36/81
$t\bar{t} \longrightarrow (qq'b)(e\nu\bar{b})$	12/81
$t\bar{t} \longrightarrow (q\bar{q}'b)(\mu\nu\bar{b})$	12/81
$tt \longrightarrow (qq'b)(\tau\nu b)$	12/81
$t\bar{t} \longrightarrow (e\nu b)(\mu\nu\bar{b})$	2/81
$tt \longrightarrow (e\nu b)(\tau\nu\bar{b})$	2/81
$tt \longrightarrow (\mu\nu b)(\tau\nu b)$	2/81
$t\bar{t} \longrightarrow (e\nu b)(e\nu\bar{b})$	1/81
$tt \longrightarrow (\mu\nu b)(\mu\nu b)$	1/81
$tt \longrightarrow (\tau\nu b)(\tau\nu b)$	1/81

So, we needed tracker (e/μ, vertex), calorimeter (jets, electrons), and muon system

What we would like to measure (continue)

- LHC detectors are optimized for Higgs search as well as broad class of Standard Model and new physics. For ATLAS detector the goals set for detector elements are:

Detector component	Minimally required resolution, characteristics	η coverage	
		Measurement	Trigger
e.m. calorimetry	$10\%/\sqrt{E} \oplus 0.7\%$	± 3	± 2.5
Preshower detection	Enhanced γ–π^0 and γ–jet separation, direction measurements, and b-tagging with electrons	± 2.4	
Jet and missing E_T Calorimetry			
barrel and end-cap	$50\%/\sqrt{E} \oplus 3\%$	± 3	± 3
forward	$100\%/\sqrt{E} \oplus 10\%$	$3 < \lvert\eta\rvert < 5$	$3 < \lvert\eta\rvert < 5$
Inner detector	30% at $p_T = 500$ GeV	± 2.5	
	Enhanced electron identification	± 2.5	
	τ- and b-tagging	± 2.5	
	Secondary vertex detection at initial luminosities	± 2.5	
Muon detection	10% at $p_T = 1$ TeV in stand-alone mode at highest luminosity	± 3	± 2.2

For heavy objects $\varepsilon \sim$ solid angle
$|\eta| \lesssim 3 \rightarrow 90\%$

- The major difference for VLHC detectors will be considerable (~7) [3÷10] increase in maximum energy of objects to be measured: jets, electrons, and muons.

Summary of existing collider detectors

- Similar overall design: central solenoid field, precision tracker, high resolution calorimetry and sophisticated muon system

- CDF/D0 vs ATLAS/CMS (factor of 7 in energy and 50 in luminosity)

- Calorimeter sizes are about the same: showers are ~ln(E)

- Considerably more sophisticated detectors:
  - Keep high momentum resolution: $\sigma_p/p \sim p \cdot \frac{\sigma_{det}}{B \cdot L^2}$
  - Keep occupancies low: larger number of channels
  - Cope with factor of 5 faster beam crossings
  - Use radiation hard detectors

- We will compare detector operating conditions at LHC and VLHC in order to understand problematic areas

Events pile-up

- Events overlapp creates serious problems for track reconstruction and vertex finding

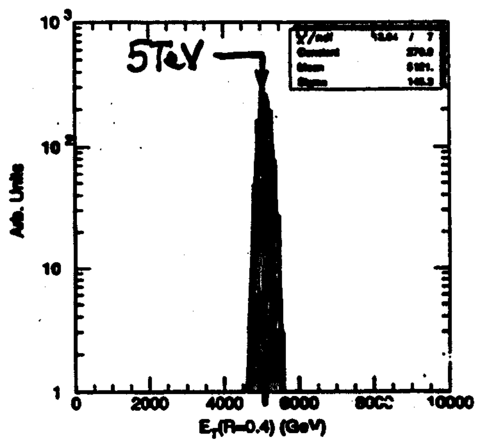
- Create "pedestal" background (with fluctuations) in calorimeter

↳ event
* of events : statistics
Luminosity + bunch to bunch...

↱ $5 \cdot 10^{35}$

Combining 1000 events gives Gaussian distribution.

For $\sqrt{s} = 100\,\text{TeV}$, $R = 0.4$:



CALORIMETER E_T IN CONE $R = 0.4 = \sqrt{\Delta\eta^2 + \Delta\phi^2}$

Fluctuations from pileup events large $\pm 145\,\text{GeV}$.

Comparable to jet pileup limit. • $10^{34} \rightarrow 100\,\text{GeV}$ •
$\pm$ a few GeV

- Luminosity above 10^{34} creates very high radiation doses and seriously deteriorate detector performance

Summary

- Considerable amount of work has been done on detectors for high energy pp colliders which could be directly or after minor modifications used for VLHC: in terms of energy Stage 1 is equal to SSC and in terms of luminosity to LHC.

- While in central region radiation doses look "reasonable", forward detectors will have very high radiation fluxes (Monday, July 9 meeting). Going to 10^{35} is difficult: Jorgen Hansen on SLHC.

- Pileup of events is creating serious problems for detection: bunch crossing below 20ns?

- Cost of detectors and construction time reduction is very important.

- What R&D is needed to improve detectors performance and reduce cost?

- Stage 1 VLHC detectors (40TeV @ 10^{34}) are "doable" based on SSC/LHC experience. What is most natural upgrade path from Stage 1 to Stage 2 (175TeV @2. 10^{34})?