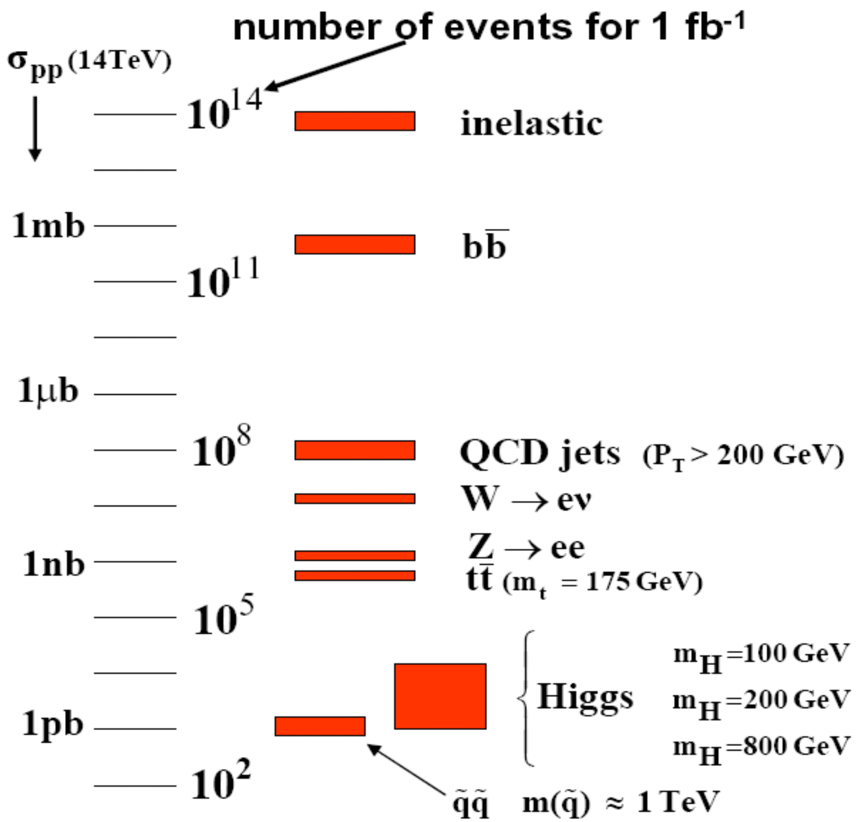
Strategies for early physics with ATLAS at the LHC



NSERC ATLAS Review
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University of Victoria

Getting ready for first LHC collisions

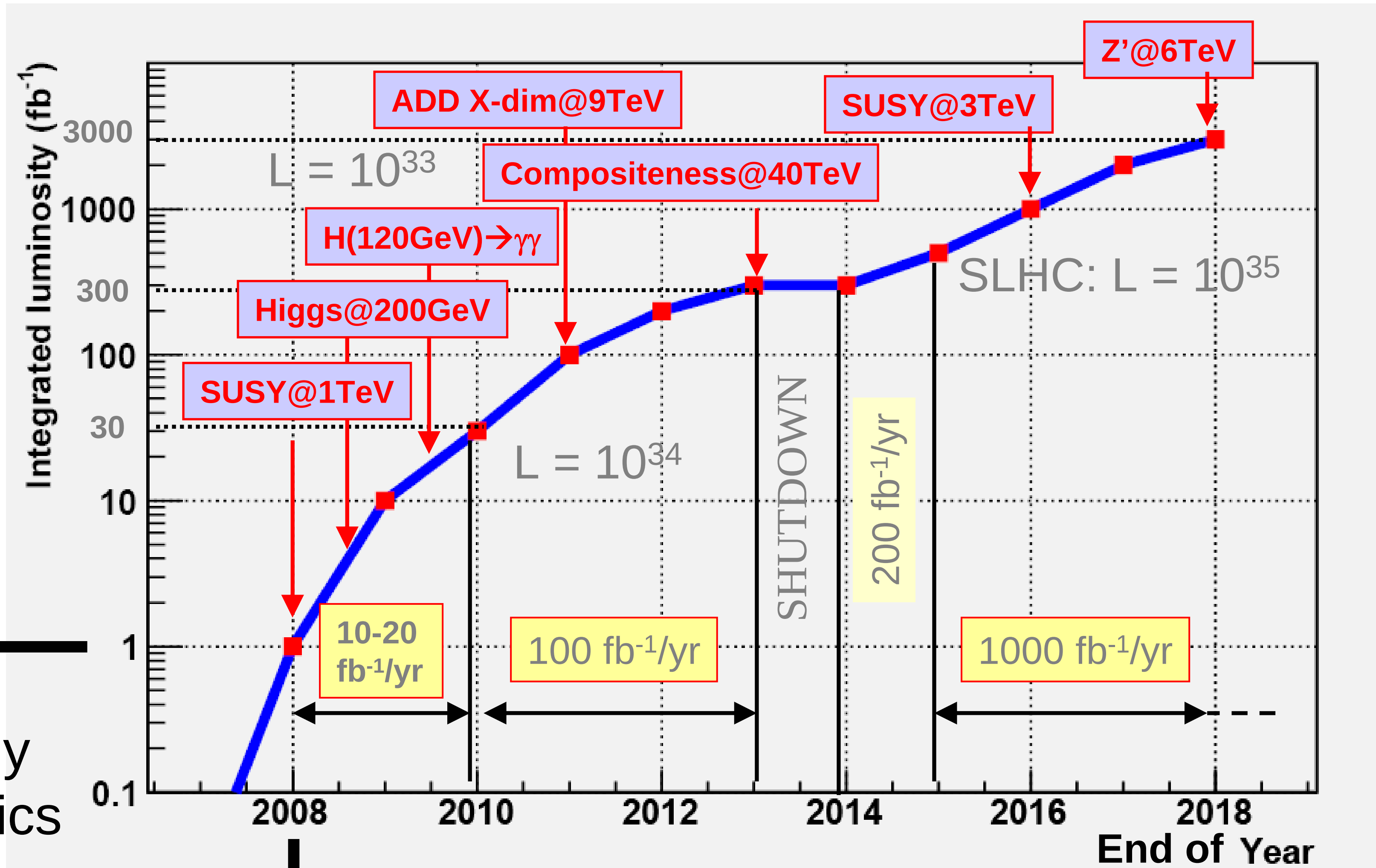
- ATLAS has very ambitious performance goals
  - driven by physics requirements
  - needs time and effort to control the detector at required level
  - final understanding of detector only achievable with LHC collisions
- Pressure to extract results as soon as possible
  - competition with other experiments
  - feedback signs of new physics to HEP community for planning
- Exploit time available before collisions to understand the detector enough to take advantage of the very first data
  - beam tests
  - detector and computing commissioning
  - preparation of calibration and analysis strategies

Initial conditions

- Assume the ATLAS detector installed
- Assume good knowledge of the detector
  - many years of simulation and (combined) beam test studies
  - commissioning at low and high rates
    - electronics pulser systems
    - cosmic rays: detector timing and alignment
    - first injections (beam gas collisions / beam halo muons): more specialized alignment work
- Expected detector performance at first collisions

EM calorimeter response uniformity	~1%
Hadronic calorimeter response uniformity	2 to 3%
$\gamma/e/\mu$ energy scale	0.5 to 2%
Jet energy scale	<10%
Tracker alignment (in $R\varphi$ plane)	20 to 200 μm

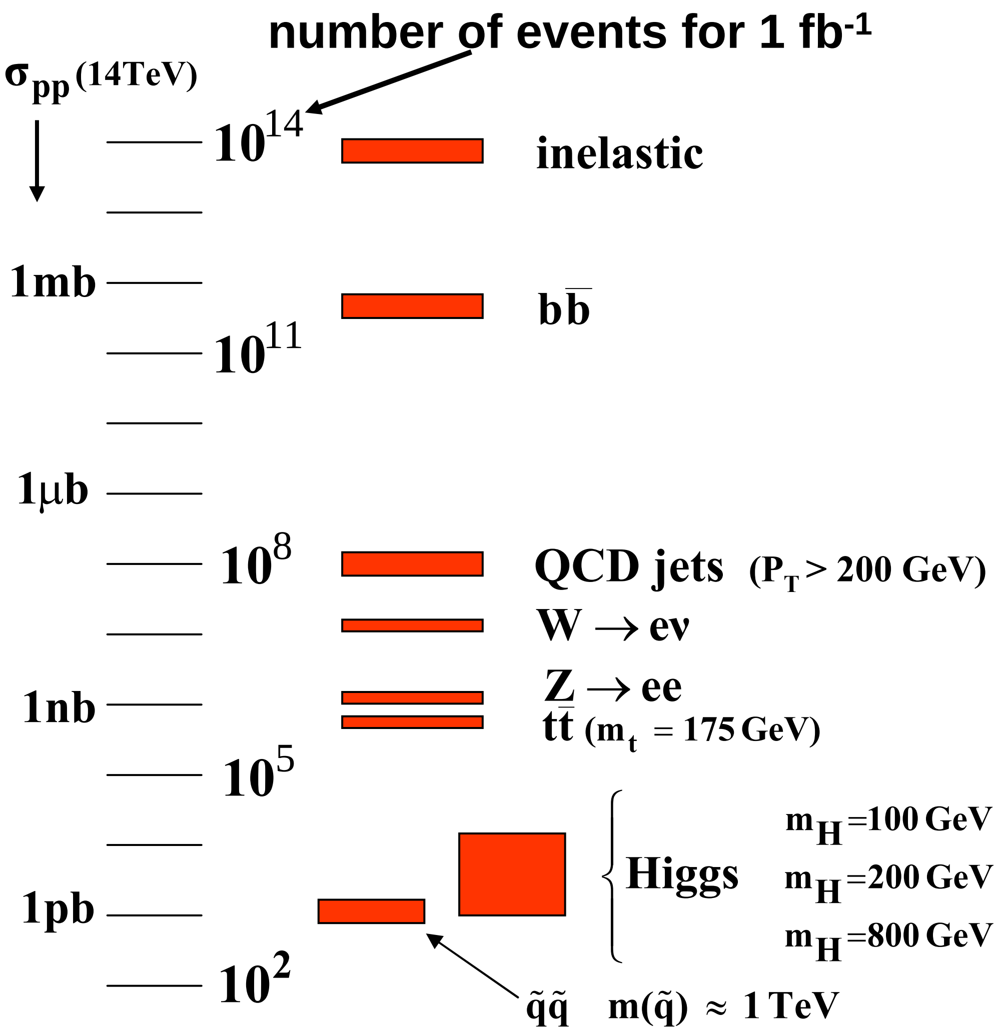
LHC luminosity profile and physics reach



early physics

O(1fb^{-1})

LHC PP Cross Section



- Assume total pp cross section known to ~1% from the TOTEM experiment
- Typical cross sections:

Process	σ
$W \to e\nu$	15 nb
$Z \to ee$	1.5 nb
$\bar{t}t$	800 pb
$\bar{b}b$	500 μb
$\tilde{q}\tilde{q}$ ($m_{\tilde{q}}$ =1 TeV)	1 pb
Higgs (m_H =0.8 TeV)	1 pb

Strategy for first interactions

- First use of in-situ calibration (see Rob McPherson's talk)
  - understand and calibrate detector and trigger in-situ using well known physics samples
- Understand basic SM physics at 14 TeV
  - first checks of Monte Carlo simulations
  - first look at minimum bias events, jet distributions, parton density functions constraints; W, Z, top cross sections; top mass
  - understand detector signatures
- The road to discovery
  - understand SM backgrounds to searches
    - in particular missing E_T distribution
  - focus on robust signatures that could reveal new physics without a complete knowledge of the detector response
    - for example, hunt for mass bumps where more than one sub-detector contribute to the signal

Analyses in Canada for early physics

Topic	Institute
QCD di-jets	Victoria
SM top physics	Carleton
Hadronic top pair decays	Victoria
Anomalous top production	Victoria
Inclusive SUSY; fake / instrumental $\not\!\!E_T$	TRIUMF, Victoria, Toronto
SUSY end-point search	Carleton
Higgs in SUSY decays	Victoria
Two-electron finder for Drell-Yan, Z'	Victoria
Z' or strong interaction resonance in τ channel	Montréal, Toronto, TRIUMF
Black holes	Alberta, TRIUMF
ADD extra dimensions	Toronto
Randall-Sundrum graviton search	Regina, Toronto
Trigger-aware charged Higgs	McGill
Lepton identification and fake rate studies	Toronto

- This list is increasing steadily: new students, research associates, etc.

QCD event shapes and underlying event	Victoria
τ/jet separation and fake rate studies	Regina
W' and Z' studies	Regina

Trigger-aware analyses

- Triggering on interesting events is one of the greatest challenges at a hadron collider
  - All Computer System Commissioning (CSC) studies must be trigger-aware
- Canadian goups lead the efforts to characterize the trigger performance, in particular jet reconstruction 

Trigger jet slice

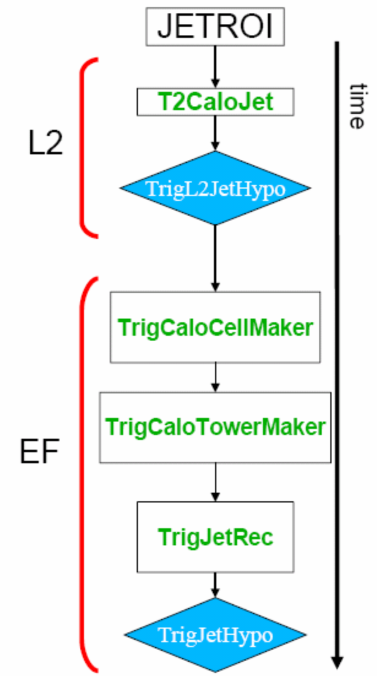
Level1: Custom made electronics.
Produces regions of interest (RoIs)
HLT: RoI algorithms sequence.

L2: TrigT2CaloJet: Fast Cone algorithm
TrigL2JetHypo: Et cut

(L2 time budget: 10 ms per event)

same code libraries as in offline → EF: TrigCaloCellMaker: Data unpacking
TrigCaloTowerMaker: Calorimeter towers
different jet algorithms possible → TrigJetRec: Jets Reconstruction
TrigJetHypo: ET cut

(EF time budget: 1s per event)



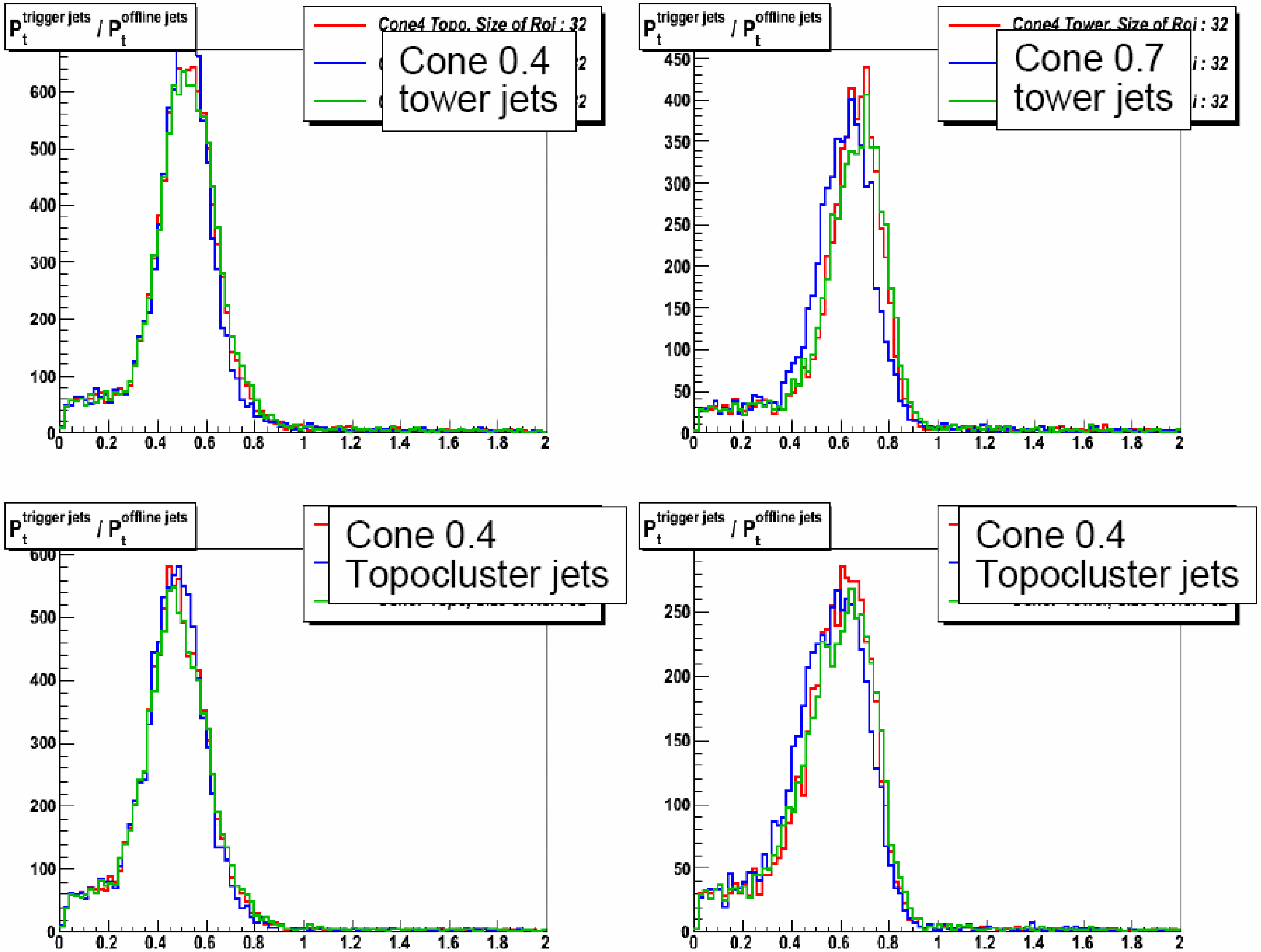
Event filter jet reconstruction

- Event Filter (EF) jet calibration comparison

$$\frac{p_{\mathrm{T}}^{\mathrm{trig}}}{p_{\mathrm{T}}^{\mathrm{offline}}}$$

for di-jet samples and small ROI of 0.4×0.4

for three different offline calibrations



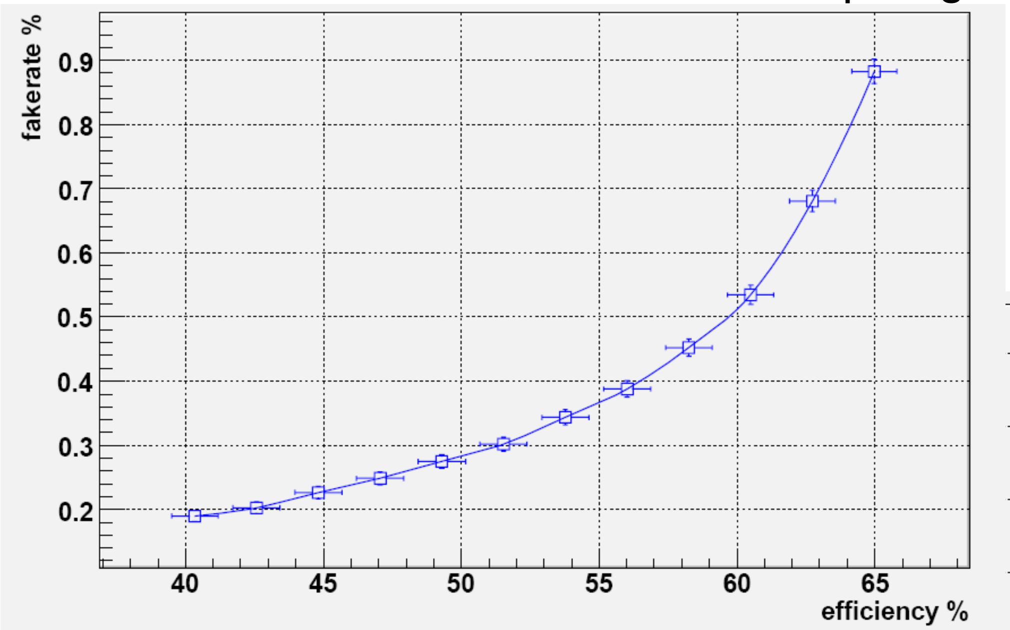
Trigger menus for jets

- For performance studies
  - j20 ; j20kt ; 2j20 ; 3j20; 4j20
  - the 1,2,3,4 thresholds can be tunes simultaneously
  - compare k_T and cone jet algorithms when analysing AOD/ESD
- Low luminosity
  - J160 ; 2J120 ; 3J65 ; 4J50
  - these signatures are available for trigger aware analyses

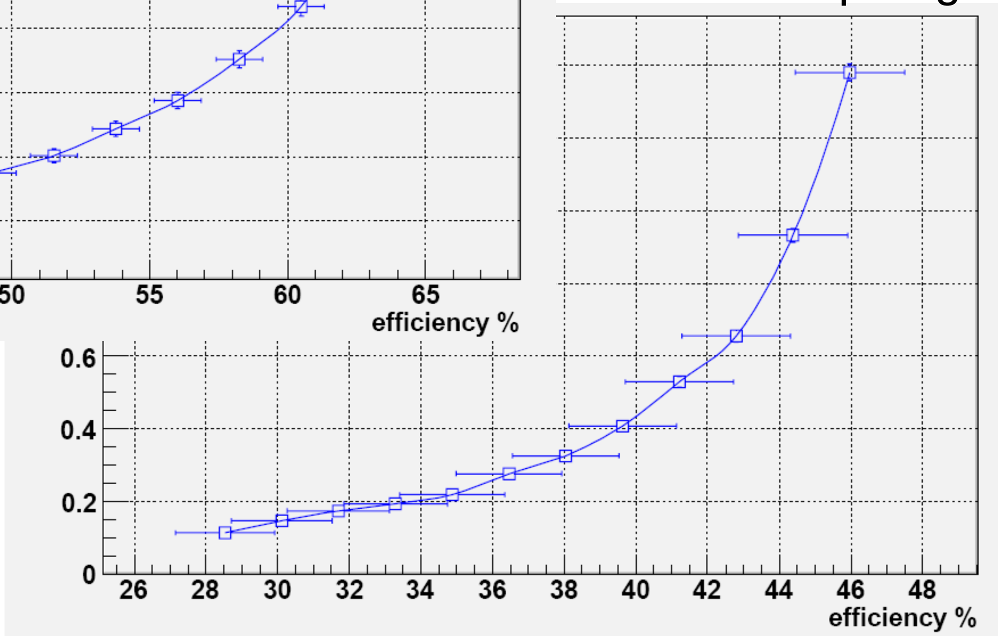
tau/jet separation studies

- samples used
  - $Z \rightarrow \tau\tau$ and $W \rightarrow \tau\nu$
  - di-jet samples

1 prong τ



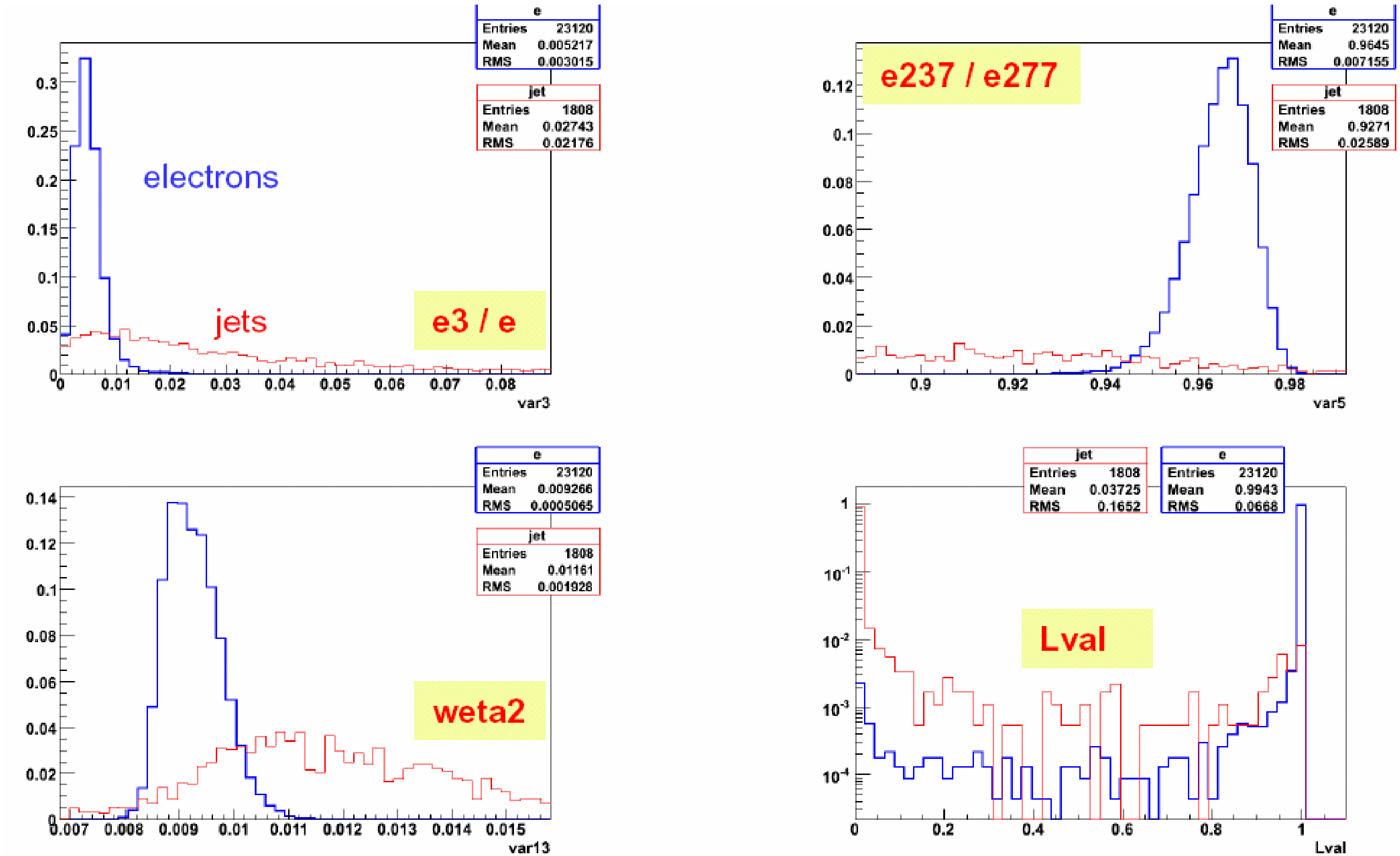
3 prong τ



Athena 12.0.31

Electron ID and fake rate studies

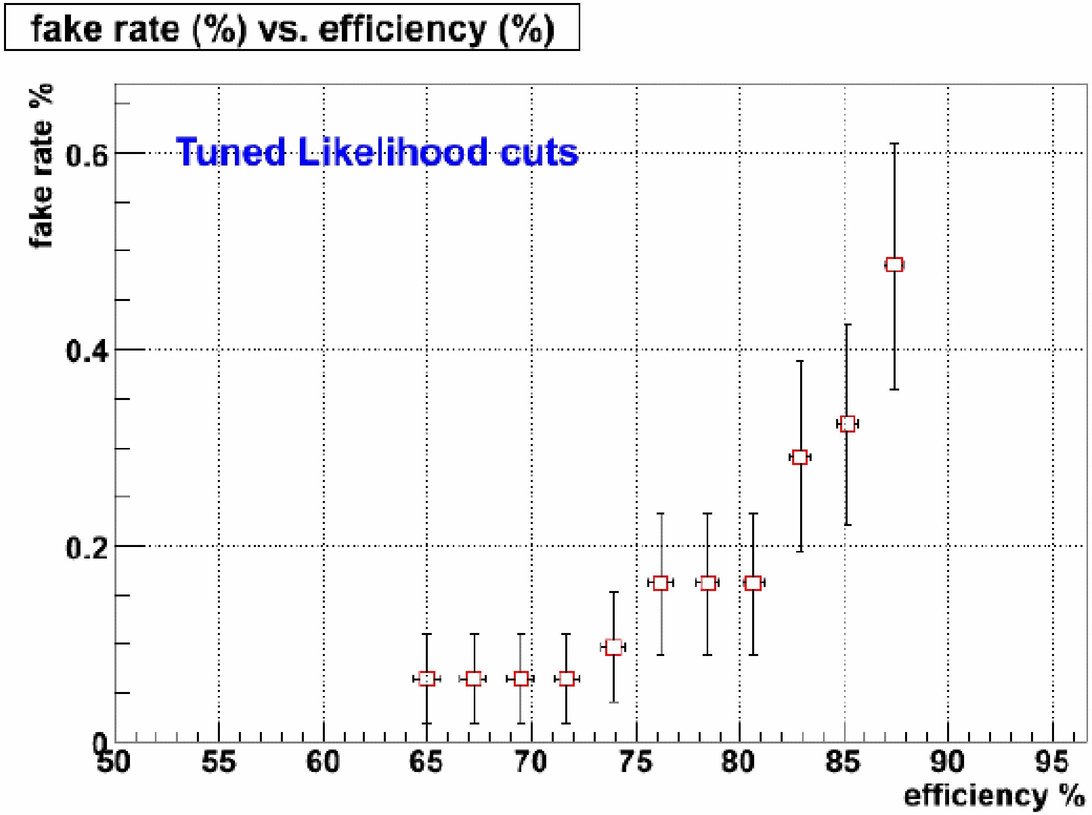
- Electron identification using likelihood
  - distribution of some likelihood variables and the likelihood estimator
  - $0 < |\eta| < 1.3$



Electron ID and fake rate studies

Likelihood efficiency studies

- $1.3 < |\eta| < 1.6$



Missing E_T studies

- Missing E_T is expected to be a key signature for most theories beyond the SM, such as SUSY or extra dimensions
  - in SUSY, Missing E_T is associated to a (new) weakly interacting particle, such at the lightest SUSY particle (LSP)
  - Thorough understanding of missing E_T measurement essential to many studies, in particular missing E_T tails
- SM source of missing E_T must be studied carefully
  - processes involving neutrinos
- Instrumental source of missing E_T can have many causes
  - known holes in the detector acceptance
  - unknown or poorly known material distributions
  - energy miscalibration
  - electronics problems

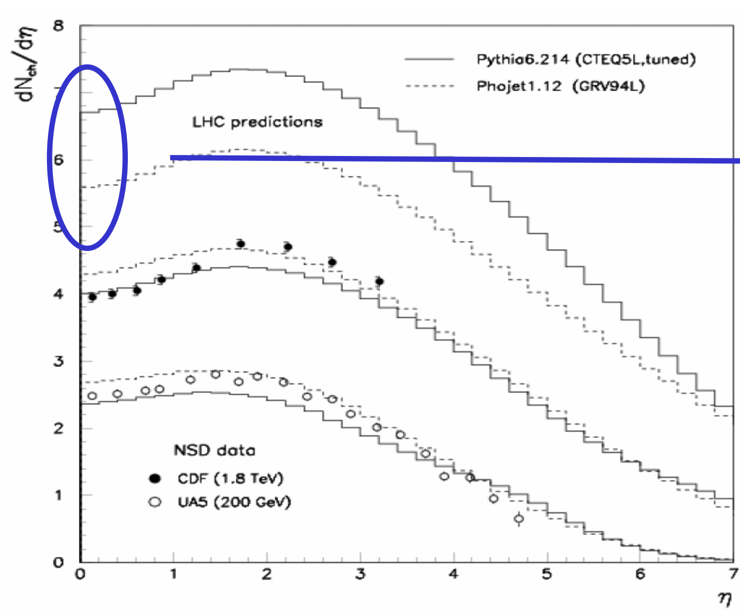
Missing E_T fake rate studies

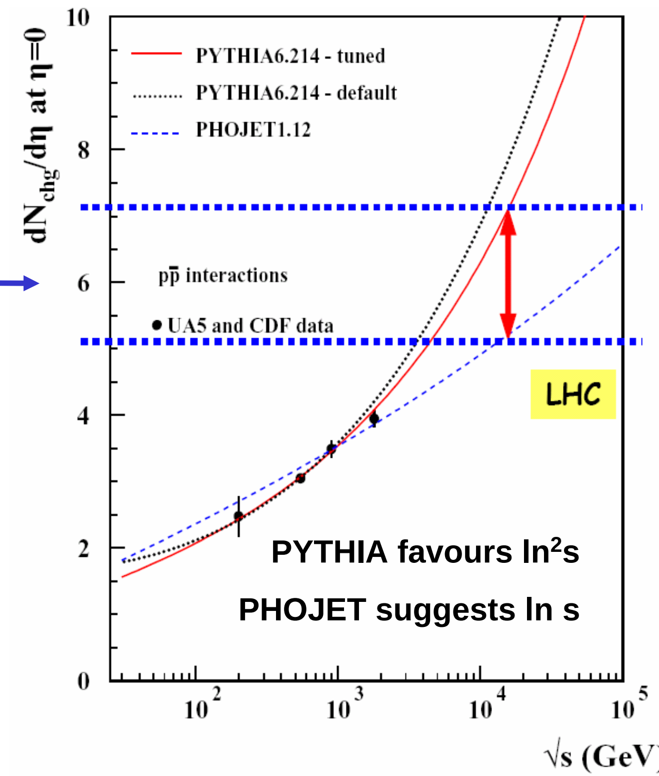
- Tools have been developed to study instrumental fake missing E_T . 
  - simulated data produced with a number of calorimeter channels turned off or at reduced voltage
    - control crates, high-voltage lines, readout lines
  - compare simulated data with and without degraded calorimeter
    - for processes with and without genuine missing E_T
  - learn how to detect such problems
  - understand the effect on the missing E_T distribution (tails)
- Learn how to correct the calorimeter (and jet) energy
- Use corrections in inclusive searches for missing E_T signal beyond the SM
  - for example SUSY, extra dimensions

Minimum-bias events

- One of the very first measurements
  - Modelling of pileup event crucial for high p_T studies
  - extrapolating from Tevatron to LHC
  - in principle, only requires a few days of data
  - energy dependence of dN/dη ?

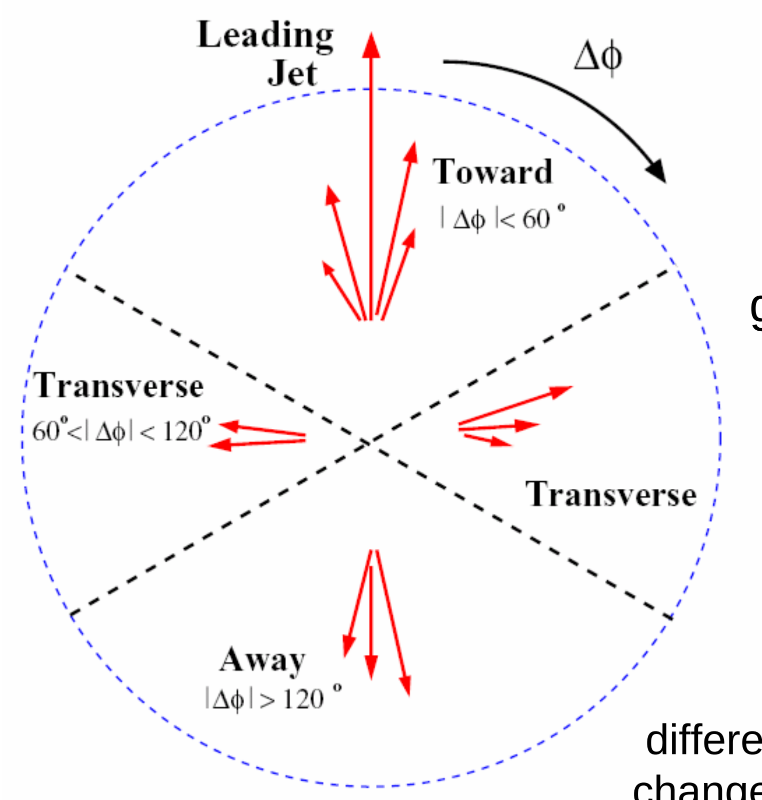
charged particle density at η = 0





Underlying event

- Also one of the very first measurements
  - Modelling of underlying event crucial for high p_T studies
- Look at tracks in the region transverse to jet activity



select $N_{jets} > 1$ $p_T^{jet} > 10$ GeV $|\eta_{jet}| < 2.5$

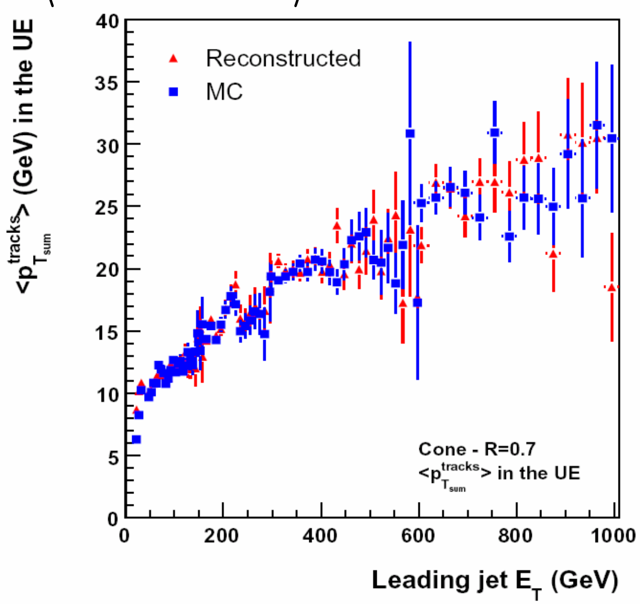
$p_T^{track} > 1$ GeV $|\eta_{track}| < 2.5$

good agreement between generated and full reconstruction

Can be used to tune simulations

different UE models can change the reconstructed top mass by up to 5 GeV

$\langle p_{Tsum}^{tracks\ in\ UE} \rangle$ vs $p_T^{leading\ jet}$

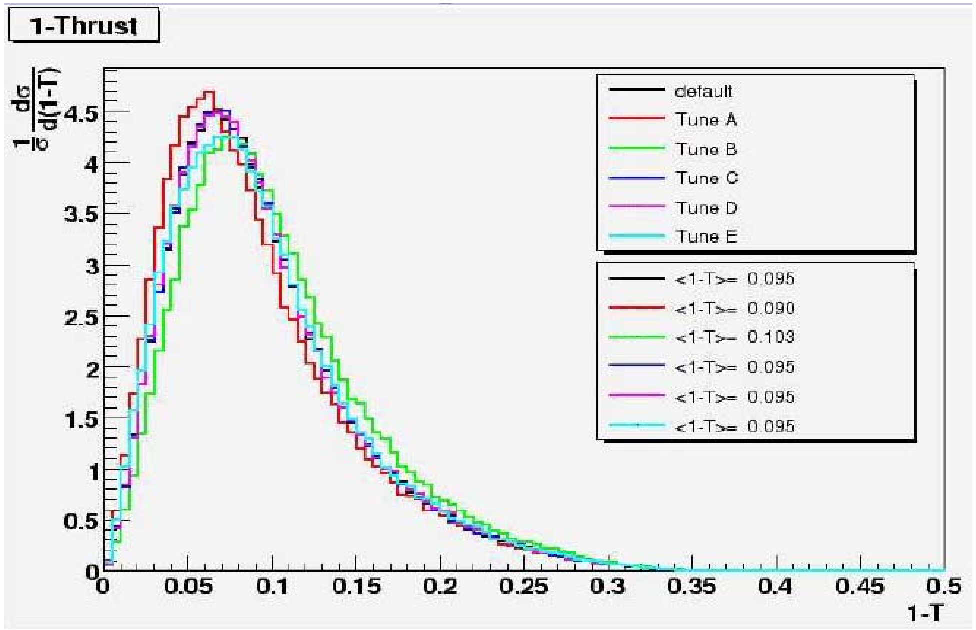


QCD event shapes

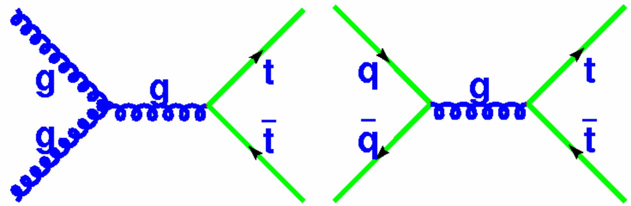
- Event shape variables under investigation
  - special event shape variables for pp collision
  - for example: thrust

$$T_{\perp,g} = \max_{\vec{n}_\perp} \frac{\sum_i |\vec{p}_{\perp,i} \cdot \vec{n}_\perp|}{\sum_i |\vec{p}_{\perp,i}|}$$

- Thrust found sensitive to underlying event MC tune
  - potentially, an independent method to tune the MC



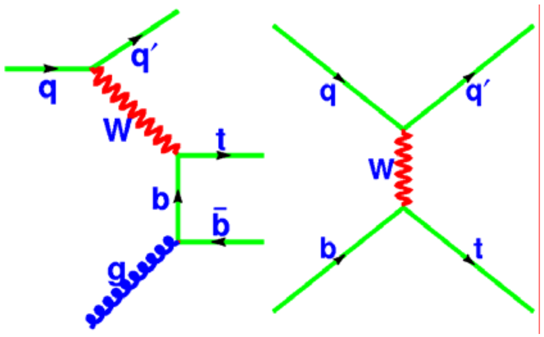
Top Quark Production



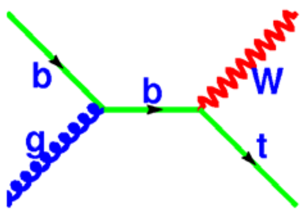
LHC is a top factory...

$t\bar{t}$ production = 833 pb Nucl. Phys B 529 (1998) 524

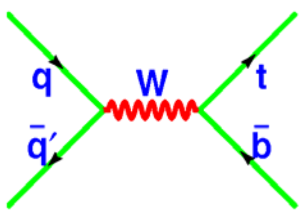
≈ 10^6 $t\bar{t}$ pairs produced for 1 fb^{-1}



Wg fusion ≈ 245 pb



Wt production ≈ 60 pb

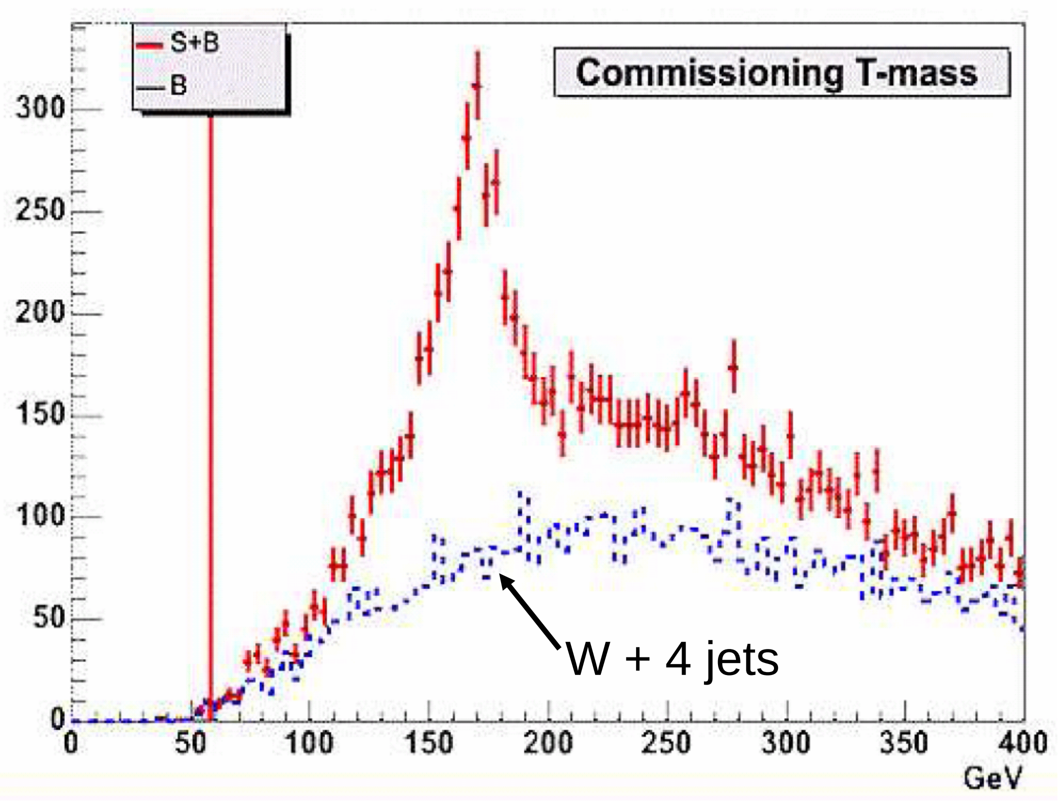


W* channel ≈ 10 pb

Electroweak single top production

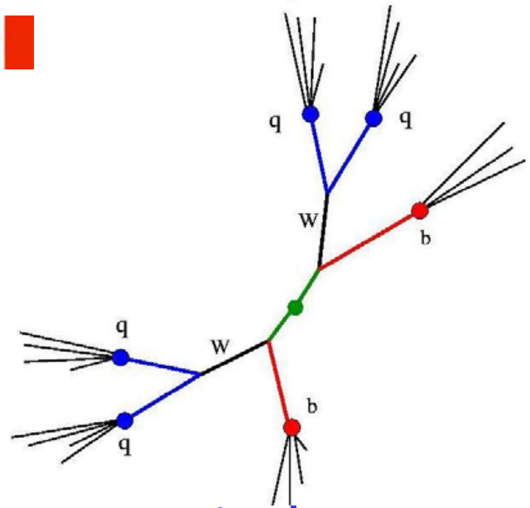
Top mass

- Reconstructed top mass, without b-tagging, with 150 pb^{-1}
  - aim at extremely simple and robust selection criteria
  - one isolated e or μ with $p_T > 20$ GeV
  - missing $E_T > 20$ GeV
  - exactly 4 jets
    - $\Delta R = 0.4$
    - $|\eta| < 2.5$
    - $p_T > 40$ GeV
  - cut efficiency ~ 4.5%
  - top mass obtained from the three jets with the max p_T sum
  - systematics limited
    - in 175 GeV
    - out 167 +/- 0.8 GeV



Top mass from the fully hadronic channel

- Try to reconstruct the top mass from ttbar events in the fully hadronic channel (6 jets)
  - NLO: 369 pb

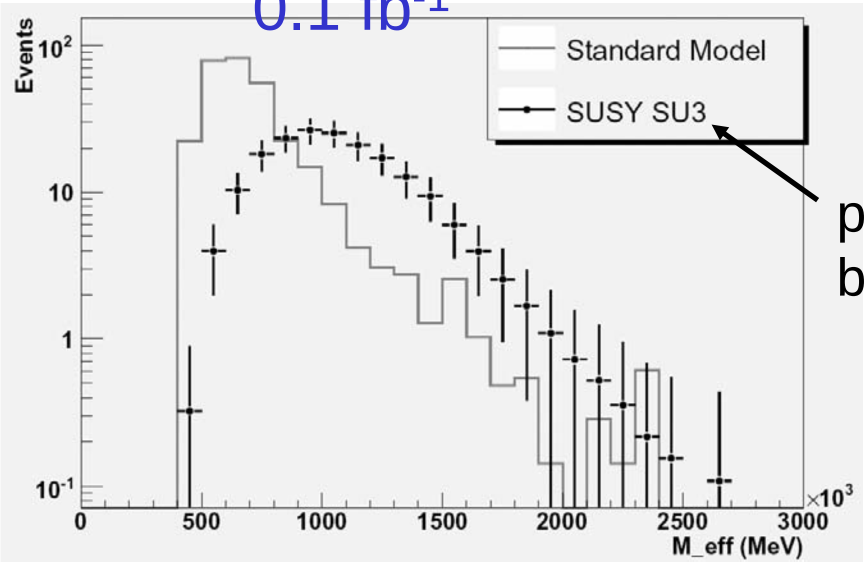


- Attempt without b-jet tagging
  - uses only calorimeter information
  - developing selection criteria
  - kinematic fit on 6 jets
- Background samples have been generated
  - QCD mlutijet
  - W + jets
  - non fully hadronic ttbar
- Preliminary results show that this is difficult to achieve
  - may need to use at least one b-tag
  - may also need to extend analysis using 5 jets

SUSY searches: effective mass

- Emphasis on *R*-parity conserving mSUGRA model
- Plan to perform both inclusive and exclusive searches
  - SM backgrounds include W/Z + jets, QCD multijets, ttbar and single top
- Inclusive searche example: effective mass
  - study of $M_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + P_{\mathrm{T1}} + P_{\mathrm{T2}} + P_{\mathrm{T3}} + P_{\mathrm{T4}}$

0.1 fb^{-1}

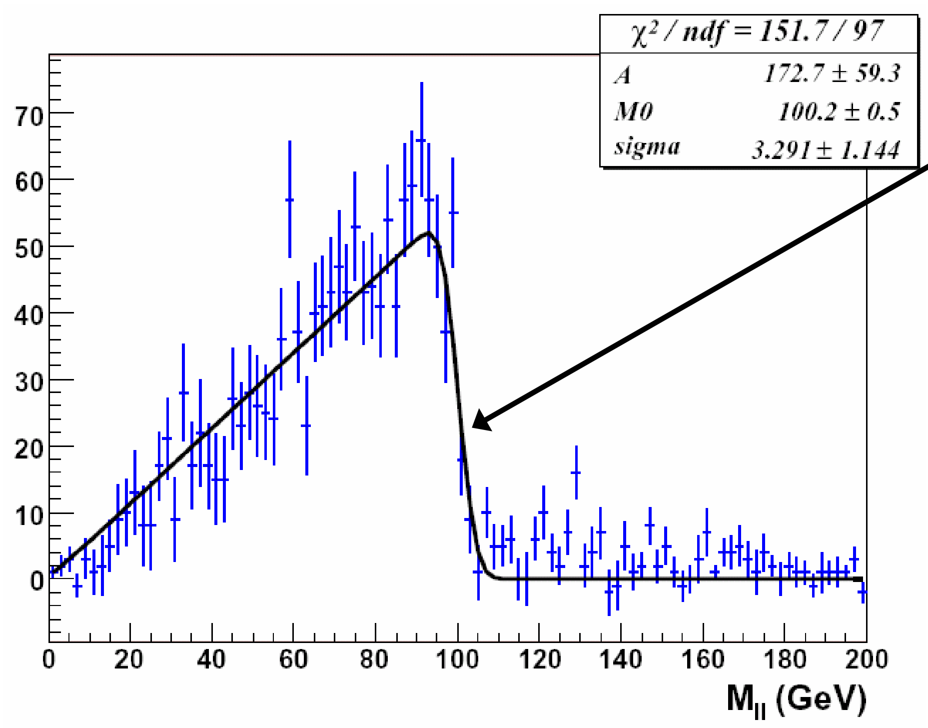


point in bulk region

SUSY searches: dilepton endpoint

- Exclusive search example: dilepton endpoint
  - search for the next to lightest SUSY particle (NLSP)
  - decay mode $\tilde{\chi}_2^0 \rightarrow \tilde{\ell}^{\pm} \ \ell^{\mp} \rightarrow \tilde{\chi}_1^0 \ \ell^+ \ \ell^-$
  - look at M_{ll} : sharp edge (endpoint) expected

$$M_{\ell\ell}^{\max} = M\left(\tilde{\chi}_2^0\right)\sqrt{1-\frac{M^2\left(\tilde{\ell}_R\right)}{M^2\left(\tilde{\chi}_2^0\right)}}\sqrt{1-\frac{M^2\left(\tilde{\chi}_1^0\right)}{M^2\left(\tilde{\ell}_R\right)}}$$



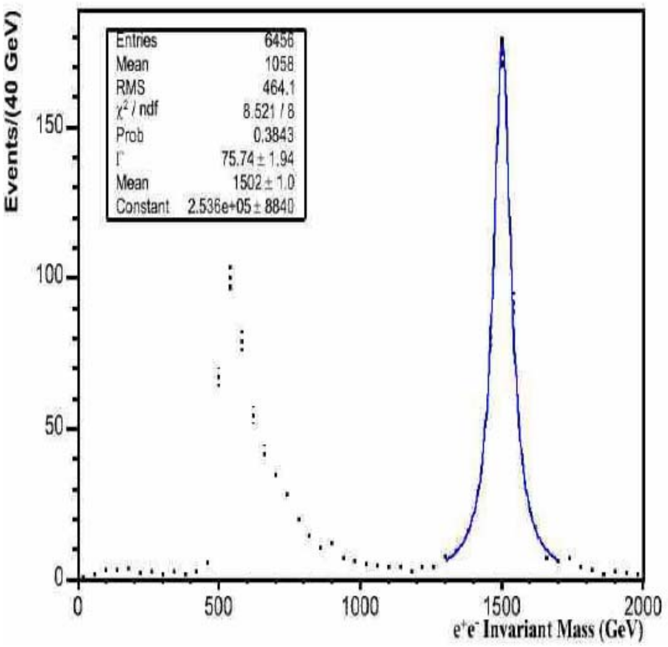
- for SU3, the endpoint is expected at 100.3 GeV
- flavour-subtracted
  - $e^+e^- + \mu^+\mu^- - e^+\mu^- - \mu^+e^-$
- 2.45 fb^{-1}

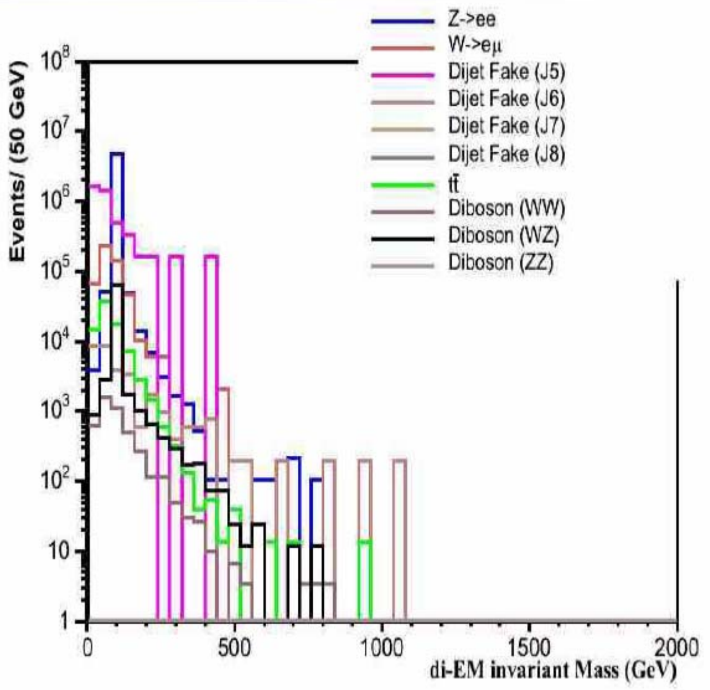
SUSY searches: anomalous top production

- Physics BSM, such as SUSY, can lead to anomalous (non-SM) top quark production
  - can have different kinematic distributions then SM ttbar or single top
- Inclusive search for top quark production, non assuming SM kinematics, is under way 
  - attempting to use hadronic top decays and constrained kinematic fit
    - W and top mass constraints
  - dominant background seems to be SM ttbar where one top decays semi-leptonically
- In some SUSY models anomalous top production can be a potential discovery channel below 1 fb^{-1}.
- Early'ish physics

Z' and W' studies

- Many theories predict new gauge bosons
  - backgrounds: ttbar, dijet, W+jets, Z+jets, dibosons, Drell-Yan
- Analyses involve muon and electron performance at very high p_T (> 1TeV)... "earlyish" physics.
- Example: Z' $\rightarrow$ ee
  - here normalized for 10 fb^{-1}





Comments and Conclusions

- We are aggressively getting ready for first collisions
  - take advantage of our ATLAS detector expertise
  - ATLAS Canada computing in fast progress (see M. Vetterli's talk)
  - we need to increase our presence at CERN
- Canadian involvement in early physics analyses
  - broad range of interests
    - trigger
    - jets, leptons, missing E_T signatures
    - SM processes
    - first search for evidence of BSM physics
  - integrated in ATLAS working groups
  - strong involvement in CSC notes preparation
  - frequent regional Canadian meetings

Extra slides

Total proton-proton Cross Section

$$\text{total}\begin{cases}\text{elastic} \quad pp \to pp \\ \text{inelastic...}\begin{cases}\text{diffractive.........}\begin{cases}\text{single diffractive} \quad pp \to pX \\ \text{double diffractive} \quad pp \to ppX\end{cases} \\ \text{non-diffractive} \quad pp \to X\end{cases}\end{cases}$$

$$\sigma_{tot} = \sigma_{elas} + \sigma_{s.dif} + \sigma_{d.dif} + \sigma_{n.dif}$$

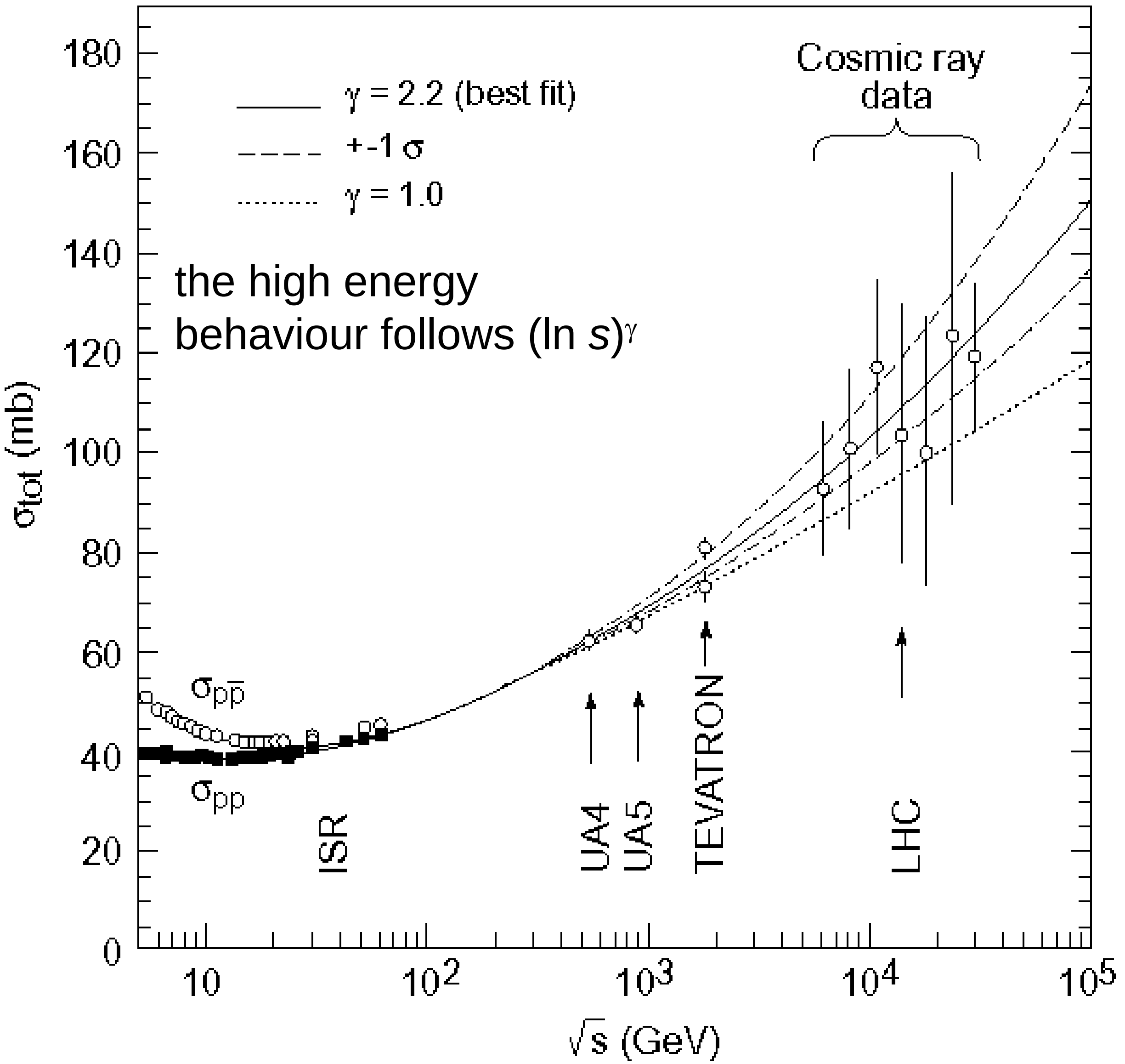
Elastic: both hadrons are not broken up to form new hadrons.

Diffractive: one (or both) hadron gets excited to a more massive state with the same quantum numbers which subsequently decays, as in $p \to N^* \to p\pi$.

A double pomeron exchange event is equivalent to a central diffractive event, a special type of double diffractive event.

Total Cross Section

The total cross section for $p\bar{p}$ and pp scattering



TOTAL CROSS SECTION AND LUMINOSITY. By G. Matthiae (Rome U., Tor Vergata & INFN, Rome). 2002. 16pp.
Prepared for 3rd International Symposium on LHC Physics and Detectors (LHC 2001), Chia, Sardinia, Italy, 25-27 Oct 2001.
Published in **Eur.Phys.J.direct C4S1:13,2002**

Top mass

- Top mass and the underlying event

different underlying event models can shift the top mass by up to 5 GeV