CMS HCAL Phase 2 Upgrade: New Physics Considerations

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Fermilab

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References

- Most of the plots/numbers in this talk are coming from:

REVIEW

The super-LHC

(To appear in Contemporary Physics)

Michelangelo L. Mangano[a*]

arXiv:0910.0030

CERN/LHCC 2007-014
LHCC-G-131
15 March 2007

CMS

Expression of Interest in the

SLHC

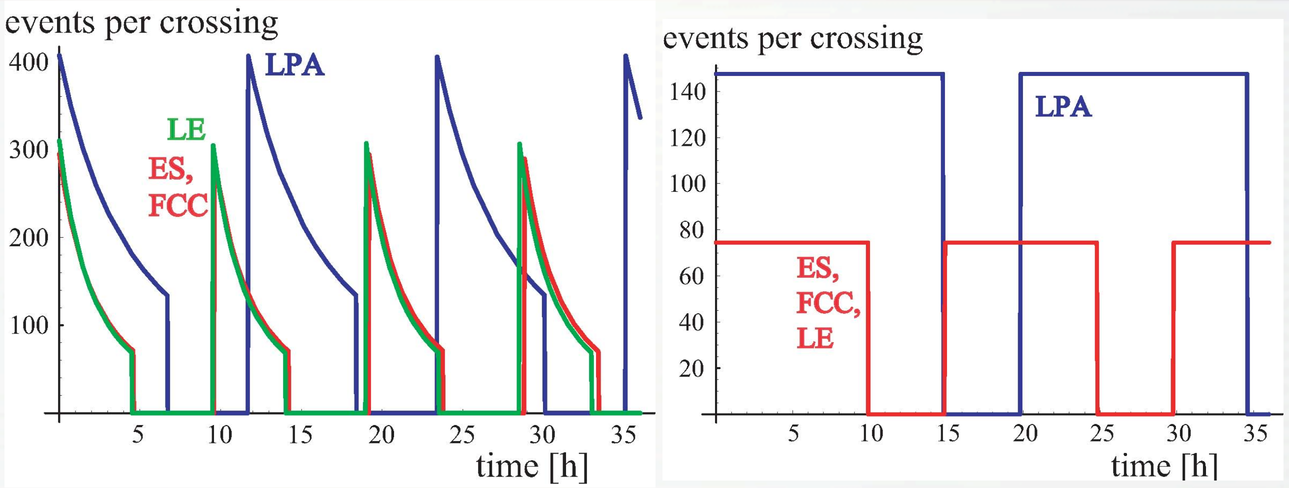
CERN-TH/2002-078
hep-ph/0204087
April 1, 2002

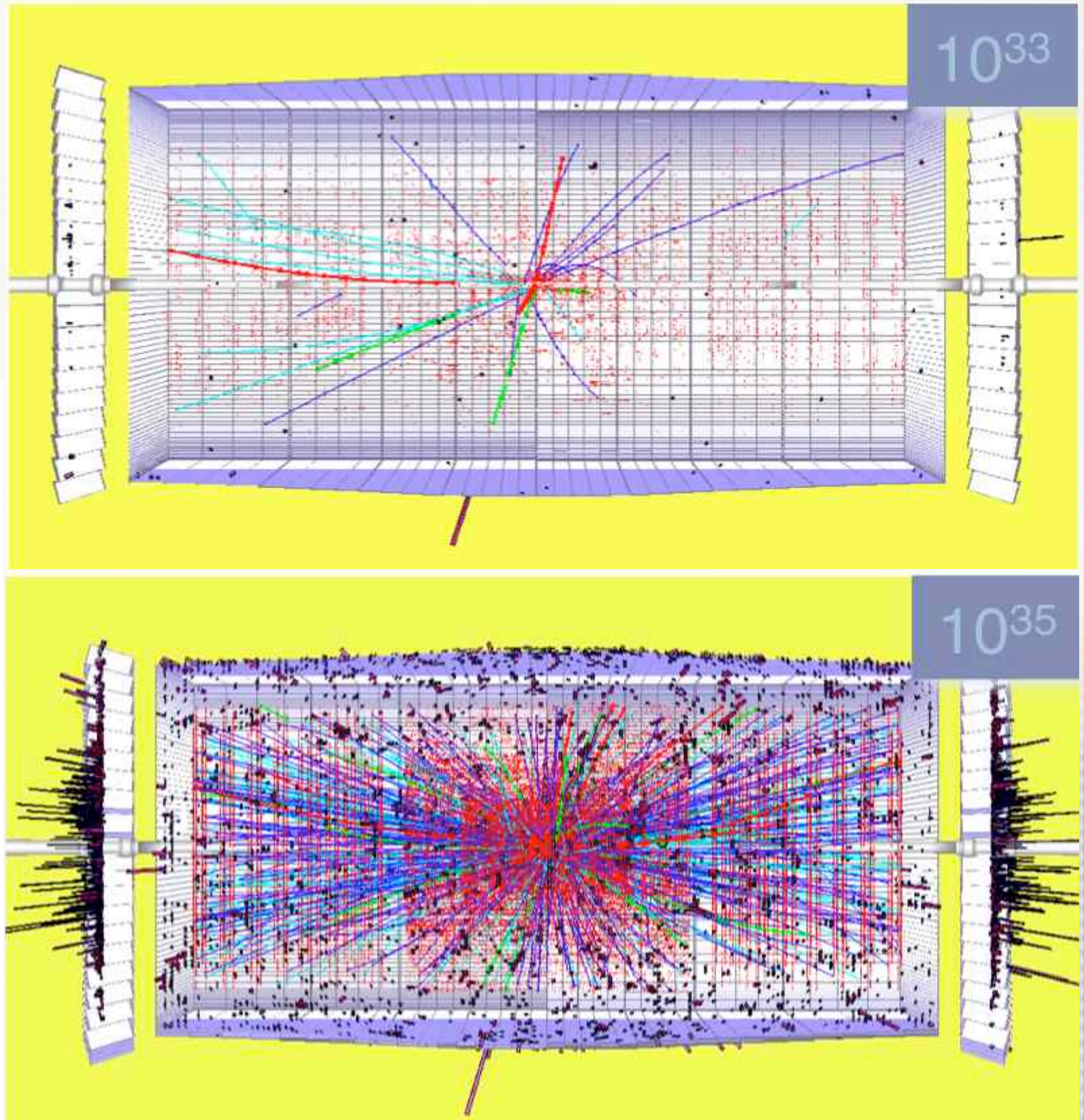
PHYSICS POTENTIAL AND EXPERIMENTAL CHALLENGES OF THE LHC LUMINOSITY UPGRADE

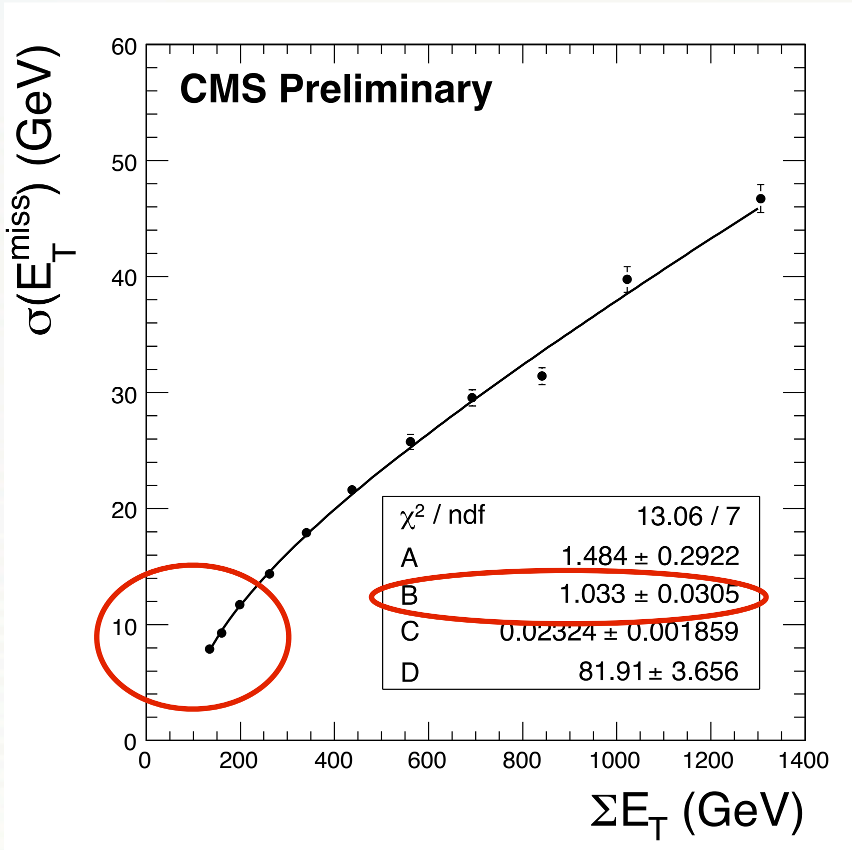
Conveners: F. Gianotti [1], M.L. Mangano [2], T. Virdee [1,3]

Pileup Effects

- Even with luminosity leveling N of interactions per crossing is overwhelming: >100
  - Resembles HI collisions
- Calorimeter-wise there are two effects:
  - Extra energy in a jet cone (linear in N): ~100 GeV and fluctuating
  - Worsening of MET resolution as a sqrt(N) (sampling term)
  - $\sigma(ME_T)$ ~ 10 GeV → 100 GeV





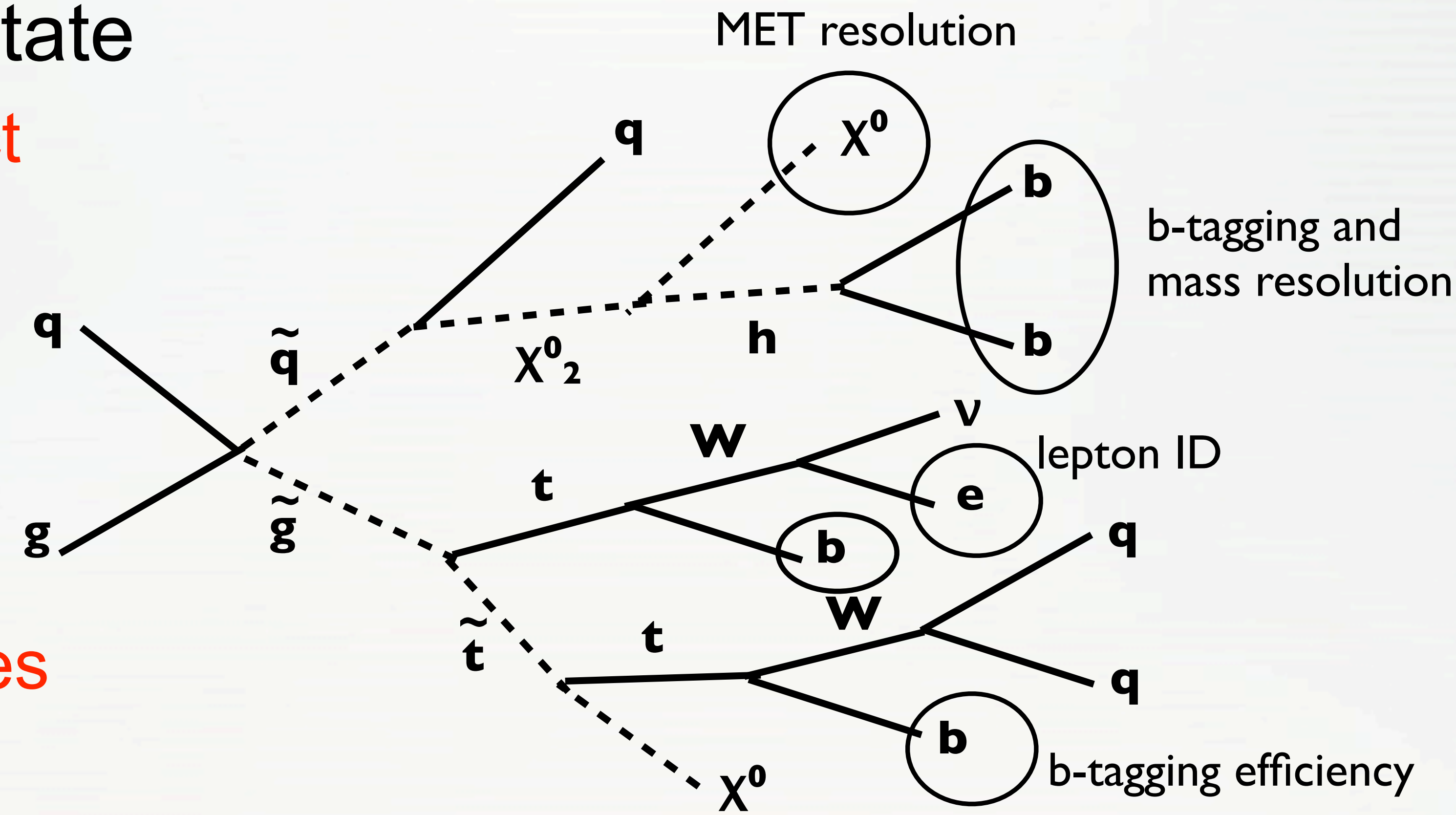


Pileup and HCAL Granularity

- Given a fixed jet cone size, the overwhelming effect on the jet energy resolution is fluctuation of the pileup within the cone
- Perhaps more advanced jet algorithms could decrease the effect, but only so slightly
- Particle flow techniques can be used to remove contribution of tracks from non-primary vertex, but it’s not very efficient, given small luminous region and >100 vertices
  - Multiple scattering of ~1 GeV tracks further complicates this
  - Neutral particles can’t be removed at all
- Consequently, increase in transverse segmentation does not help much; however may benefit from increased longitudinal segmentation (remove/decrease energy contributions from the inner layer?; remove “shallow” jets)

Figures of Merit

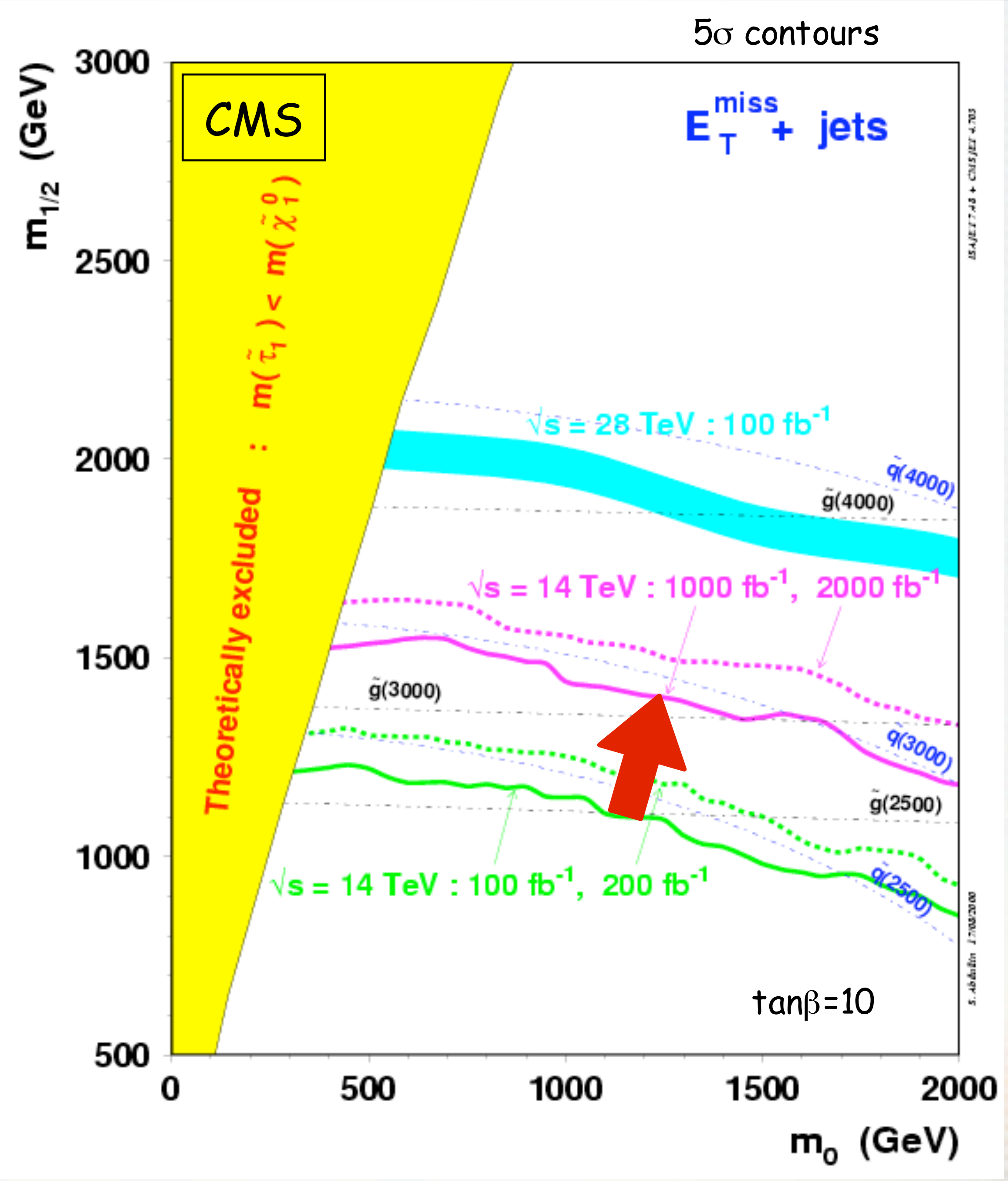
- Example: SUSY mass reconstruction
- Four b-jets + e + ME_T final state
  - 20% efficiency drop per object results in 0.8^5 = 33%
  - 20% worse mass resolution results in a factor of 1.5 in statistics
  - Altogether: x5 in statistics compared to the LHC - washes out the increase in luminosity



- Must have reasonably similar performance of the upgraded detector compared to the LHC one
- Efficiency: reliance on tracking; much higher granularity
- Jet energy resolution: must use PFlow-like techniques - longitudinal

Heavy SUSY

- The reach in terms of squark/gluino mass can be extended by ~500 GeV (20%) with x10 statistics
  – Resembles Tevatron Run II vs. Run I situation
- Not too strongly motivated theoretically
  – Also note that cold DM searches have good sensitivity in this regime
- Yet, worth looking, particularly if hints are seen at the LHC
  – Can aid the LHC by tackling on difficult SUSY scenarios (via squark and neutralino decays)
- Signatures involve energetic (>100 GeV) central jets, leptons, and ME_T
- Pile-up not likely to be a problem but leakage in HO will be an issue
  – Higher depth segmentation
  – Good hermeticity (no HB/forward crack)
  – Very forward (HF) coverage is not likely to be of great importance

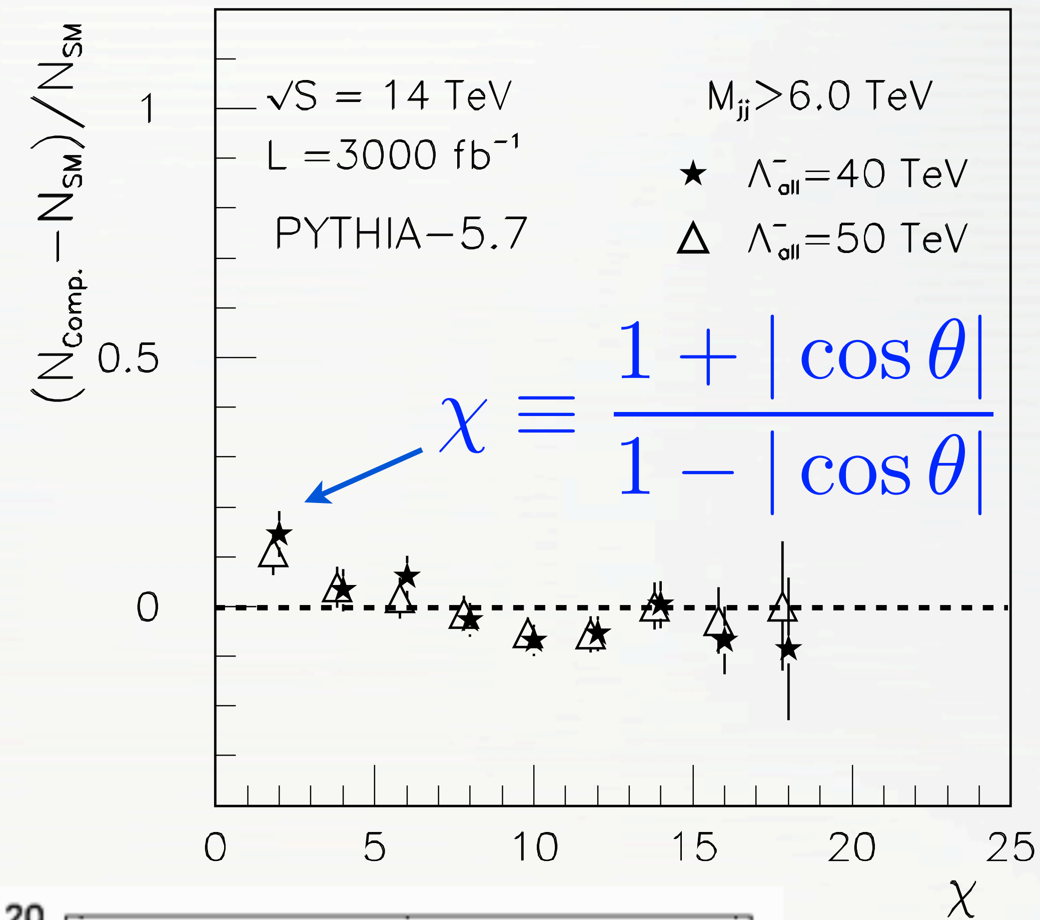


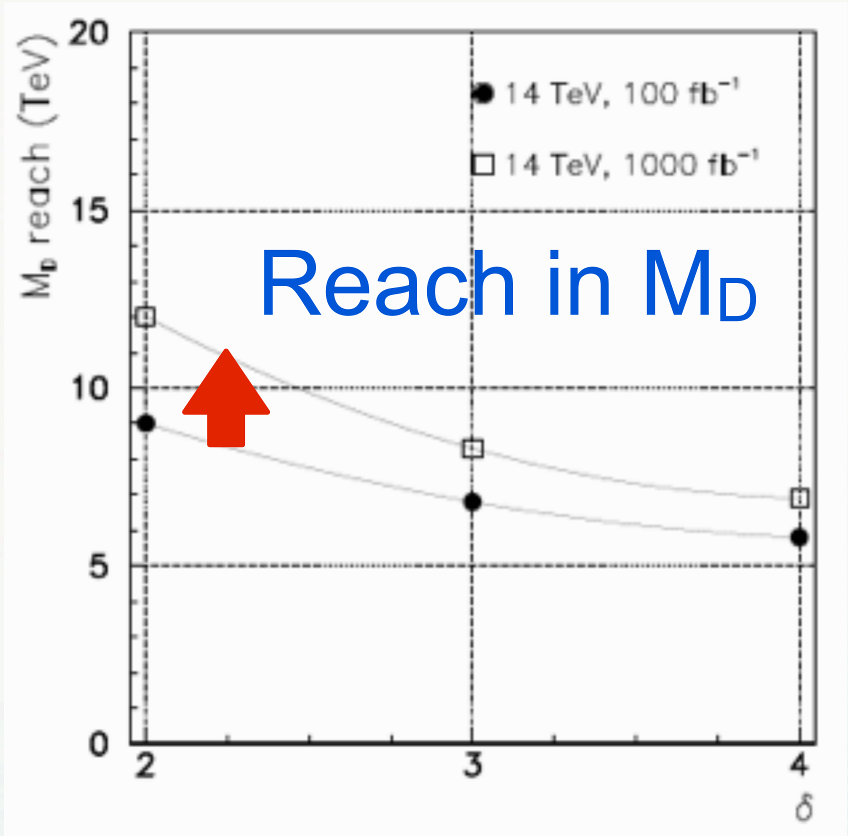
Compositeness (including ED)

- Much of the reach improvement comes from lepton channels
  - Mostly beyond the scope of this talk
  - Track isolation can be used instead of calorimeter isolation to cope with lepton fakes in the presence of large pile-up
- Importance of forward region for high-mass resonances is quite limited
- For jetty channels, angular distribution is a powerful tool (central jets)
  - Moderately high jet rapidity coverage (|η| < 2.0-2.5) is desired
  - 50% improvement over LHC can be achieved

Scenario	14 TeV 300 fb^{-1}	14 TeV 3000 fb^{-1}
Λ(TeV)	40	60

- Monojet channel offers ~20% improvement in sensitivity to large ED
  - Similar requirements as for SUSY

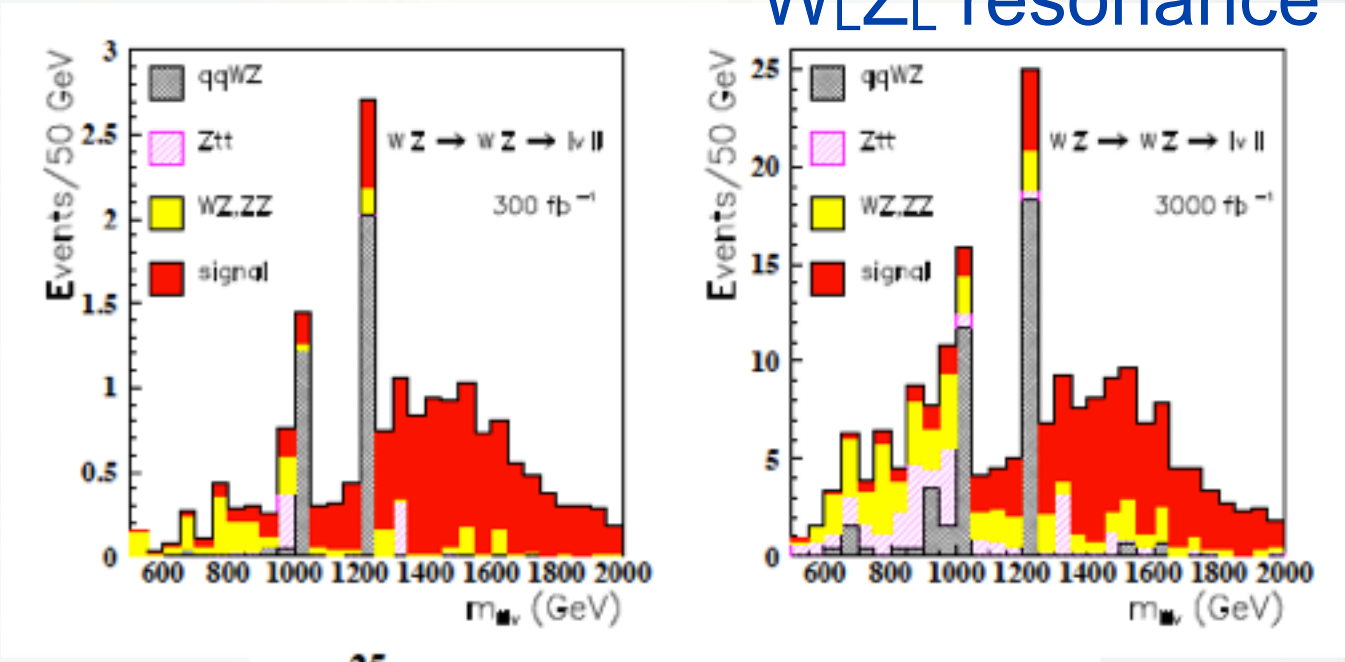


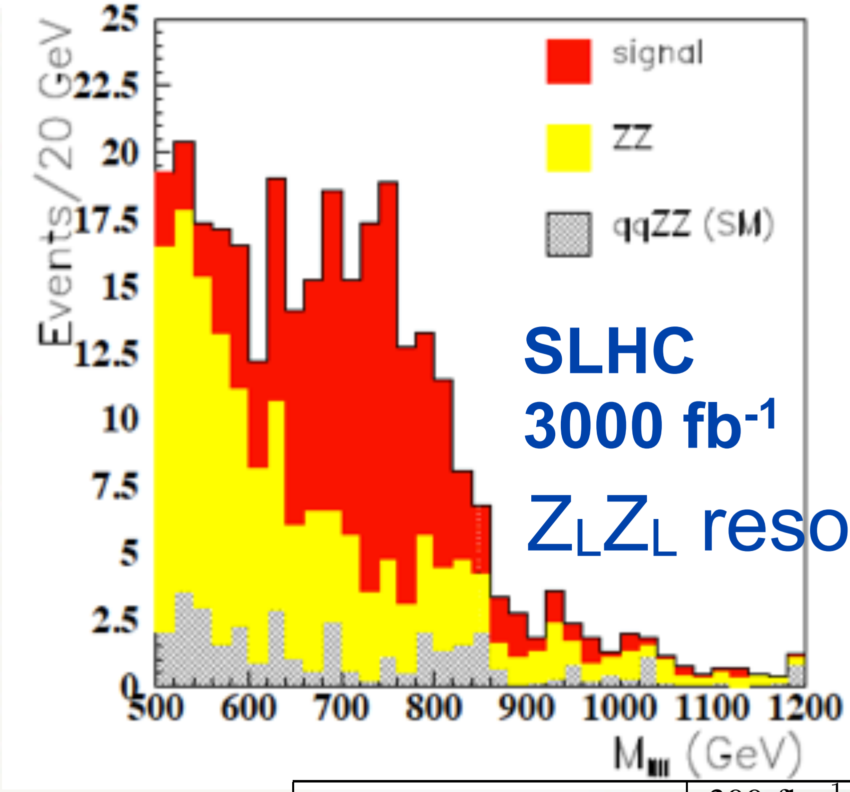


Strong VV Scattering

- What if Higgs is not found at the LHC?
- Need to understand the unitarization of $V_L V_L$ (V = W, Z) scattering, which may shed light on why Higgs is not seen
- Mainly studied in leptonic channels, but must have forward jet tagging |η| > 2.0-3.0 to reduce overwhelming backgrounds
  - Requires an HF-like device capable of detecting E > 400-500 GeV jets
  - Could be very hard at rapidities >3.0-3.5
  - Extending HE replacement to rapidities ~3.5 may solve the problem
  - Additional challenge: central objects typically have moderate E_T ~ 50-100 GeV; ME_T is similarly low and may be very hard to reconstruct reliably

$W_L Z_L$ resonance





SLHC
3000 fb^{-1}

$Z_L Z_L$ resonance

Non-resonant
$W^+_L W^+_L$

Model	300 fb^{-1} 14 TeV	3000 fb^{-1} 14 TeV
Background	7.9	44
K-matrix Unitarization	14	87
Significance	3.0	7.6
Higgs, 1 TeV	7.2	42
Significance	1.8	4.5

Conclusions

- LHC → SLHC upgrade offers *limited increase in reach* in a number of new physics models (~20-50% in terms of mass/ energy scale)
- In most cases the objects to be studied are heavy and decay into *very energetic central leptons/jets*, thus not very sensitive to pile-up effects
- EB/HB technology is *reasonably adequate* for signal detection; however the HO importance will increase
- Higher longitudinal segmentation in HCAL may help as well
- Mind the gap! Gap between barrel and end-caps may result in serious deterioration in ME_T capacities
- While for many new phenomena calorimeter coverage up to $|\eta| < 2.0\text{-}2.5$ is adequate, forward jet tagging is essential for strong vector boson scattering studies and would require extension of *forward calorimetry* to $|\eta| \sim 3.5$