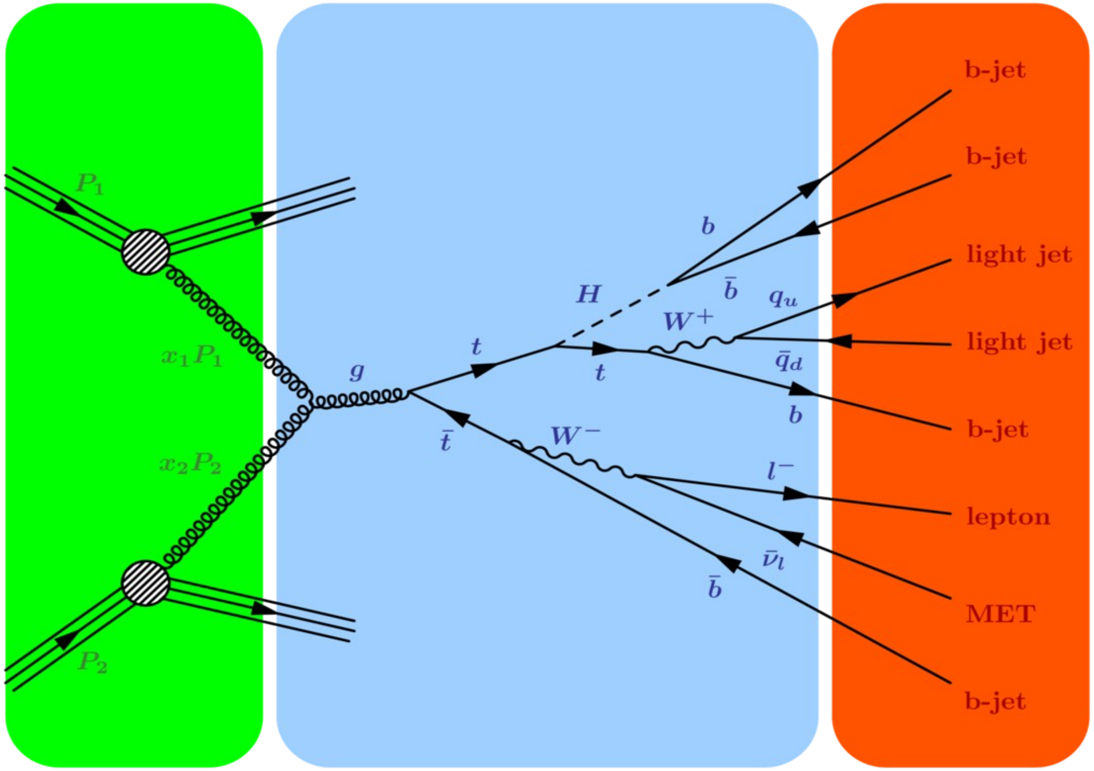
MEM discussion: ATLAS $t\bar{t}(H\rightarrow b\bar{b})$ experience



Olaf Nackenhorst
University of Geneva

EPJC 75 (2015) 349

Not a perfect world

- The ideal world
  - Machine Learning (ML)
    - The underlying physics model can be learned using MC simulation
  - Matrix Element Method (MEM)
    - Describes perfectly the underlying physics of the observed data

  → **A perfect ML & MEM should give you the same answer**

- The real world
  - Machine Learning
    - MC simulations are not perfect, training statistic is limited
    - Input information blurred by resolution & acceptance affects, syst. uncertainties
  - Matrix Element Method
    - Computational constraints demand simplifications & approximation
    - Acceptance & combinatorial ambiguities largely affects input

  → **Synergy of both methods still beneficial**

ATLAS ttH experience

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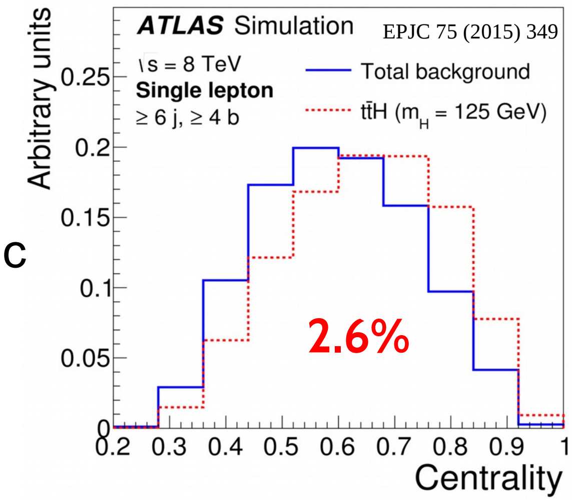
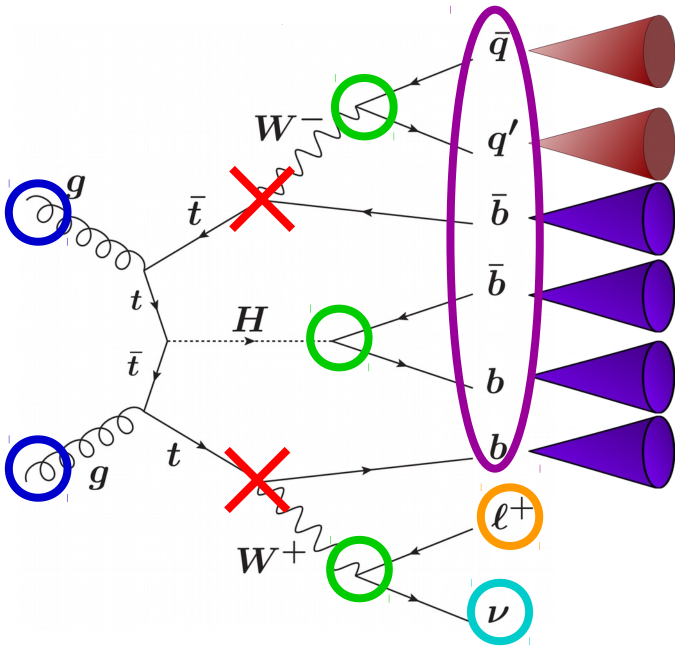
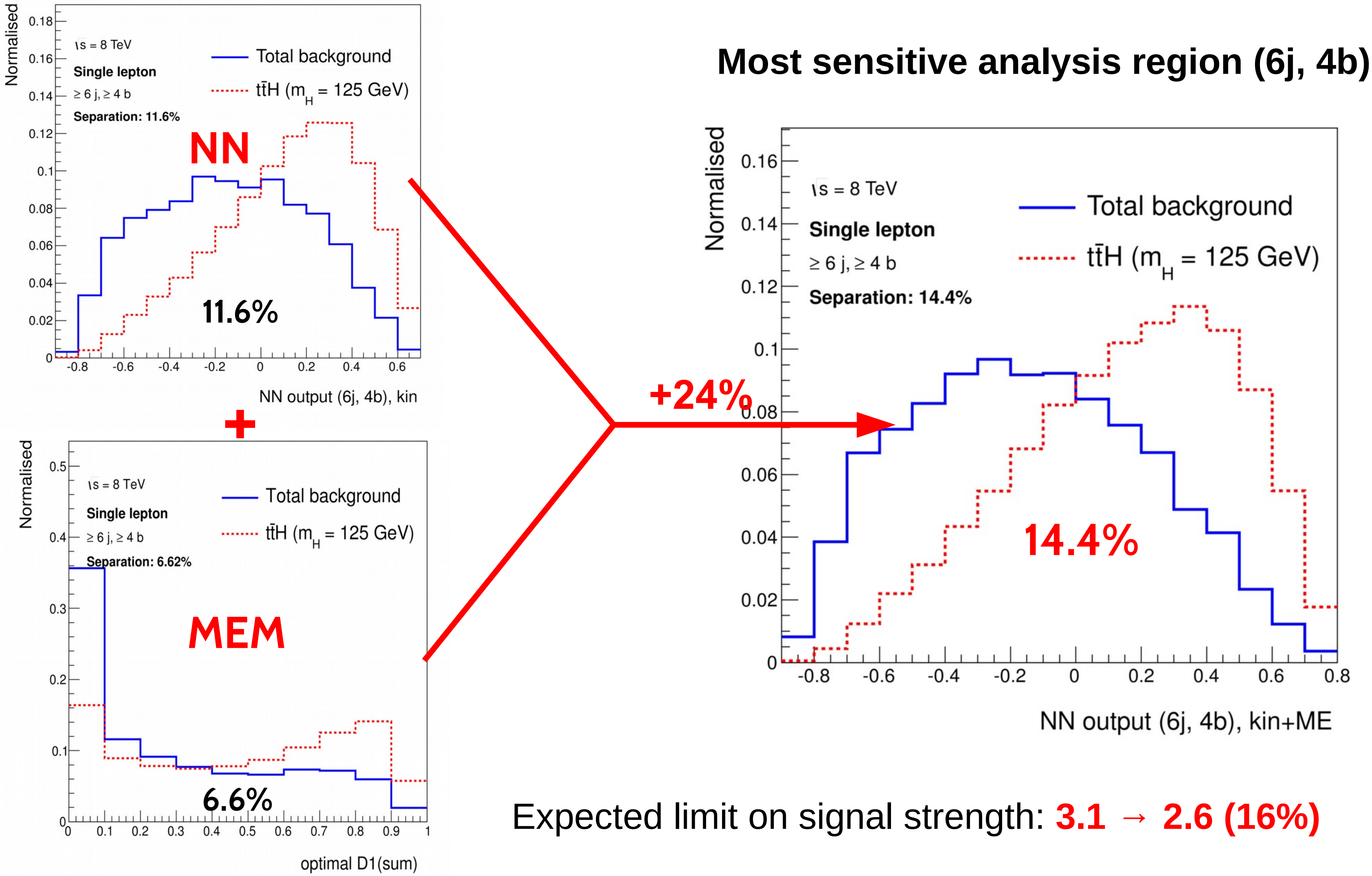
- Machine Learning (Neural Network)
  - Signal & main background ($t\bar{t}b\bar{b}$) kinematically similar
  - Difficult to find good features, selection reduces statistic
  - > 300 input variables tested, saturation ~ 10 variables



- Matrix Element Method
  - Even at LO computationally prohibitive
  - Many simplifications & approximations
    - Reduction of dimensionality (40 → 6)
    - Optimization of ME calculation
    - Phase space reduction & alignment
    - Reduction of assignment permutations
  - Integration time reduction at precision costs
    - 24h → **2 min per event**



Hybrid NN+MEM



Expected limit on signal strength: **3.1 → 2.6 (16%)**

Conclusion & Open Questions

- Both MEM & ML output contains **valuable & unique information**
  - Loss of information is unavoidable in both methods
- Combination of both methods natural & most complete answer
  - **16% improvement** corresponds to a large amount of data (>10 fb^{-1}@8TeV = $$)
- Disadvantage of combination ML+MEM
  - Need to run MEM on large MC statistic (6M nominal) required for training
  - Tiny signal → many systematic variations of background to consider

→ **62M total** number of events → **2M CPUh (236 CPUy)** in 2 month real time

- Overcoming computational constraints
  - Further simplify model or dedicated MEM region (loss of information)
  - Highly parallelize CPU computation (challenging bookkeeping & inflexible)
  - Use GPUs instead of CPUs (limited by available GPUs)
  - Use of look-up tables (non-trivial interpolation and parametrization of PS)