# Top Mass Measurements

P. Nason

CERN and INFN, sez. di Milano Bicocca

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# The Top Mass SubgroupOutline

- Frederic Derue, J. Zahreddine (ATLAS)
- Jan Kieseler (CMS)
- Gennaro Corcella, Andre Hoang, Paolo Nason (Theorists)

Frederic Derue, J. Zahreddine (ATLAS):
Top quark mass measurements with $t\bar{t}$ events with $J/\psi \to \mu^+\mu^-$ in the final state.

- Use correlation between $m_t$ and the mass of the $lJ\psi$ system, using templates from simulation.
- Since the mass uses only leptons, the error on JES/JER should be reduced.
- CMS result: $173.5 \pm 3(\mathrm{stat}) \pm 0.9(\mathrm{sys})$.
- At $3\mathrm{ab}^-1$, the statistical error should go to 0.15; (errors dominated by systematics, exp. $b$ fragmentation).
- Derue and Zahreddine are working on a similar analysis at 13 TeV.

Jan Kieseler (CMS):

- Some projections for High Luminosity already available for CMS.
- More possible studies:
  - Mass from boosted top jets (proposed by Hoang and collaborators)
  - Differential top mass measurements (still statistically limited)
  - (both not yet covered).

# Strategies considered for Extrapolation

## 'Standard' methods

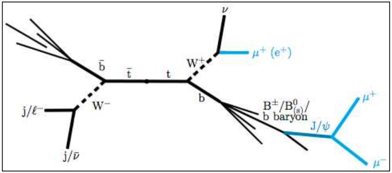
- Reconstruct invariant 3-jet mass (l+jets)
- Single top

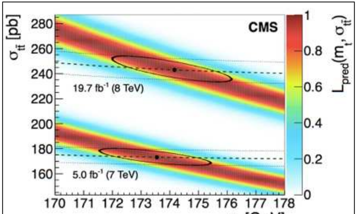
## Track-based observables

- Use tracking and vertices
- J/Psi, $m_{svl}$

## Pole mass from cross-section

- Use dependence of NNLO prediction on the top-quark pole mass



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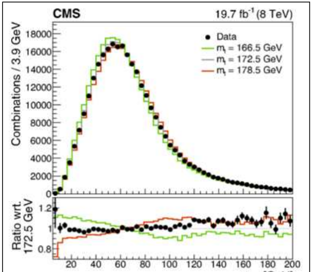

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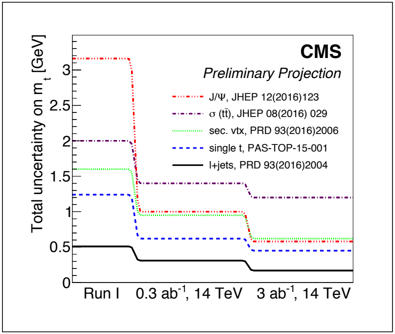
# Assumptions on Systematics

- Modelling (efforts already performed/started)
  - Full NLO MC, well understood and studied
  - Differential studies of the top-quark mass (differential $m_t$)
    - Better understanding of non-perturbative effects / tunings
  - Measurements of UE and b-fragmentation studies (directly in top-quark events)
  - Differential cross-section measurements
    - Allow to distinguish between NLO generators / constrain them and confirm NNLO predictions
  - Use differential (2D) NNLO k-factors to improve NLO MC (e.g. top $p_T$)

- Experimental effects
  - Differential $m_t$
    - Give insight into JES and detector effects in various corners of phase space.
    - Useful model to estimate how statistical precision of data-driven constraints on experimental systematics evolves.
  - In-situ calibration using more than $m_W$ (3D fits)
  - Increasing pile-up assumed to be mitigated by increased top cross-sections → assume statistics to scale only with luminosity

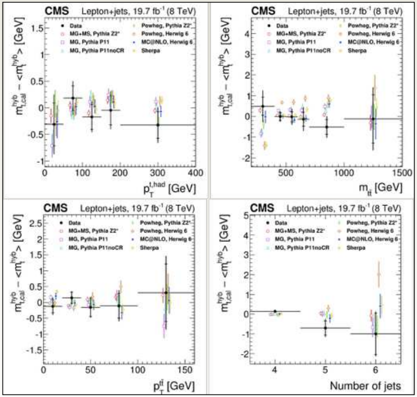
# Projections

- Clear benefit from statistics for J/Psi
- Moderate improvement for pole mass from cross sections
  - Ultimately limited by luminosity uncertainty and theory uncertainty (no N$^3$LO assumed)
- Single top:
  - Benefit from statistics and modelling improvements
- ‘standard’ l+jets
  - Benefit from differential studies constraining modelling




- All MC mass analysis will go well below 1 GeV uncertainty.
  - Differences in production/decay mechanism may be visible
- Likely even more analyses techniques become available not covered here
  - More in-situ constrains

# Some More Possible Studies

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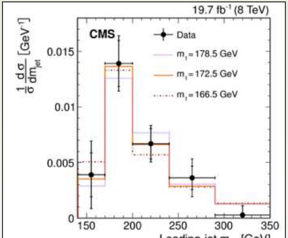


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- Mass from boosted top jets
  - Provides advantages w.r.t. interpretation
- Differential top mass measurements
  - Still statistics limited
- Both are not (yet) covered

# Theory

Contributors: Gennaro Corcella, Andre Hoang, Paolo Nason.

Two broad areas have been identified:

- Interpretation of direct top mass measurements. These are the measurements that attempt to reconstruct a top mass peak, and are at the moment the most precise. Since they rely upon a Monte Carlo generator for the extraction of the top mass, an issue arises upon the interpretation of its results. Two basic questions are
  - When using a LO Monte Carlo, do we extract a LO mass (i.e. do we expect corrections of order $\alpha_s m_t$ at NLO level?).
  - Is there a way to relate the Monte Carlo parameter to a well defined field theoretical mass definition? (Pole mass, $\overline{\mathrm{MS}}$ mass, MSr mass, etc.)
  - How do we quantify the related uncertainties?

# Theory

Proposed studies:

- Corcella
  - Study of fragmentation uncertainties in hadronic observables
  - Propose observables to calibrate in situ the MC generators
  - Simulation of fictitious top-flavoured hadrons
- Hoang
  - Conceptual studies:
    - parton shower dependence, cutoff dependence, intrinsic MC top mass dependence;
    - Hadronization model (intrinsic MC top mass dependence on hadronization? cutoff dependence?)
    - matching (impact on resonance behaviour)
    - open conceptual issues: systematics of finite lifetime effects, colour reconnection
  - Practical studies:
    - To which extent uncertainties can be quantified (anything missing?)
    - When using the pole mass or MSr mass matters
    - Calibration studies

- Nason:
  - Conceptual studies of top mass measurements in simplified field-theoretical models.
  - Monte Carlo studies using NLO+PS generators of increasing accuracy, interfaced with different shower models.

# Alternative mass measurements

- Currently have large errors
- Are there error sources that can be reduced with High Luminosity?
- Are there theretical hard limits on precision?

## General considerations

- Most of these issues are not specific to the High Luminosity phase.
- We should make an effort to imagine what will be the situation 10 years from now. To what extent the theoretical errors will be reduced?
- To what extent measurements with different methods will give us confidence that we have the right theoretical interpretation?
- Given the limited space (5 pages) dedicate to top mass measurements in the report, how much space shall be devoted to this?

I believe we should decide now on an indicative limit for the number of pages in the theory part, so that we know from the beginning what we can cover.