HL/HE-LHC WG1
Status - Top physics

TopLHCWG Meeting

WG1 conveners:
Patrizia Azzi (CMS) , Stephen Farry (LHCB),
Paolo Nason (TH), Alessandro Tricoli (ATLAS),
Dieter Zeppenfeld (TH)

Goals of the HL-LHC Workshop

From Eckhard Elsen Intro

- Provide a detailed assessment of the physics reach of the upgraded detectors with ~3 ab^{-1}
  - Interplay of detectors for reconstruction
    - Harsh environment – pile-up of 200
  - Careful assessment of the systematic limitations for physics measurements
    - How far can the systematic uncertainty be pushed?

highest experimental potential

- Documented Physics reach will be the basis of any new project at the energy frontier: ILC, HE-LHC, CLIC, FCC
- The Precision of HL-LHC will *talk to other* projects: Belle 2, SHiP, EDM, etc.

- Assess the Physics reach of the Energy Doubler Option with high-field magnets which is the natural step toward a higher energy hadron collider

Expected Contributions to WG1

- WG1 activities includes SM&Top physics
  - **Experimental analysis prospects for HL and HE**
  - **Theoretical predictions for HL and HE**
  - **Goal to prompt collaboration across experiments, and between theorists and experimentalists on specific topics to ensure good coverage and coherence of results**
  -
- Theorists will help define analysis goals and strategies, and will mostly focus on providing predictions for several key processes and interpretations of experimental inputs (e.g. PDF, EFT pseudo-data fits)

- Experimentalists are mostly focused on HL-LHC, but we expect several analyses will be extended to HE-LHC under the same performance assumptions as HL. Few new HE-only analysis are also expected

HL/HE-LHC Reference parameters for YR

- **Reference parameters**
  - **HL-LHC**
    - **$\sqrt{s}$=14 TeV, 3 ab^{-1}** for ATLAS, CMS (LHCb up to 300 fb^{-1})
      - for some processes we may want to show evolution of results for lumi above 3 ab^{-1}
  - **HE-LHC**
    - **$\sqrt{s}$=27 TeV, 15 ab^{-1}**
      - for some processes we may want to show evolution of physics reach vs $\sqrt{s}$, e.g. 24-30 TeV

Organization of Workshop structure and timeline

Steering committee: Michelangelo Mangano (TH, chair), Gavin Salam (TH), Aleandro Nisati (ATLAS), Andrea Dainese (ALICE), Andreas Meyer (CMS)

Working Groups:

1. SM&TOP
2. Higgs
3. BSM
4. Flavour
5. Heavy Ion

Timeline:

- 18-20 June 2018 - Plenary meeting @CERN (table of contents)
- September 2018: Full Draft Chapters (one per WG 150 Pages each)
- December 2018: Submission

HL/HE-LHC YR Organization

YR Steering

Overall Coordination

[Michelangelo Mangano]

+

ATLAS Contact	CMS Contact	LHCb Contact	ALICE Contact	Theory Contact
Aleandro Nisati	Andreas Meyer	Mika Vesterinen	Andrea Dainese	Gavin Salam

WG1: Standard Model

Alessandro Tricoli – ATLAS
Patrizia Azzi – CMS
Stephen Farry – LHCb
Paolo Nason – Theory
Dieter Zeppenfeld – Theory

WG2: Higgs

Marumi Kado – ATLAS
Maria Cepeda – CMS
Phil Ilten – LHCb
Stefania Gori – Theory
Francesco Riva – Theory

WG3: BSM

Monica D'onofrio – ATLAS
Keith Ulmer – CMS
Xabier Cid Vidal – LHCb
Patrick J Fox – Theory
Riccardo Torre – Theory

WG4: Flavour Physics

Alex Cerri – ATLAS
Sandra Malvezzi – CMS
Vladimir Gligorov – LHCb
Jorge Camalich – Theory
Jure Zupan – Theory

WG5: Heavy Ions

Zvi Citron – ATLAS
Yen-Jie Lee – CMS
Michael Winn – LHCb
Jan Fiete Grosse-Oetringhaus – ALICE
Urs Wiedemann – Theory
John Jowett – LHC

WG1 Documentation

- TWiki pages: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG1
  - List of Contributors per section: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG1#Draft_Table_of_Contents_of_repor
  - Table with experimental analysis phase spaces: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG1#Fiducial_Phase_Spaces
    - Input to theorists to start calculations with same phase spaces as in experimental analysis
    - We invite more experimental teams to post more entries

Fiducial Phase Spaces:

Here follows a table with selection cuts applied by different analyses to define the fiducial phase space.

Process	Experiment	Main Contact	Selection requirements
ssWW	ATLAS	Claire Lee	2 same-charge leptons p_T > 25 GeV; m_{ll} > 20 GeV; MET> 40 GeV; 2 jets pT > 30 GeV; deta(jet,jet) > 2.4; m_{jj} > 500 GeV; centrality > 0
Tt-gamma	ATLAS		1 photon p_T > 25 GeV; 1 (2) lepton p_T > 25 GeV; >= 4 (2) jets p_T > 25 GeV; >= 1 bjets; dR(photon,jet) > 0.4; dR(photon,lepton) > 1.0; for single(di) lepton channel
s-channel	ATLAS		1 electron or muon p_T > 30 GeV, exactly 2 b-tagged jets abs(eta)<2.5 and p_T > 30 GeV. MET > 35 GeV and mT(W) > 30 GeV
VBS WZ	ATLAS	Corinne Goy	Fully leptonic : 3l with Pt>15 GeV and abs(eta) <4.0 , one with Pt>25 GeV, SFOC leptons compatible with Z mass (10 GeV) , 3rd lepton with Pt>20 GeV and W transverse Mass (3rd lepton + missing ET) > 30 GeV , 2 jets in opp. hemisphere with Pt> 30 GeV and abs(eta_jet)<3.8 , Mjj > 500 GeV
WWW	ATLAS	Nenad Vranjes	Fully leptonic : 3l with Pt>30 GeV and abs(eta) <4.0 , Phi(Pt_lll, Ptmiss)>2.5, OS leptons compatible with Z mass (15 GeV), at most 1 jet with Pt>30 GeV, and abs(eta) <2.5; b-jet veto with Pt>30 GeV, and abs(eta) <2.5 ; Semileptonic : 2l with Pt>20 GeV and abs(eta) <4.0, at least two jets pT>30 GeV, and abs(eta) <2.5, dilepton mass > 40 GeV, Ptmiss > 80 GeV, deta(jet,jet) < 2.5, 60 < mjj < 120 GeV, 3rd lepton veto Pt>6 GeV, and abs(eta) <2.5, b-jet veto with Pt > 30 GeV, and abs(eta) <2.5

Chapter draft

- Skeleton of WG1 chapter draft is already in overleaf
    - Strategy: contributors will provide convenors with LaTex text and we will integrate it in overleaf
- Target for whole chapter: ~150 pages.
- Page allocation per section is approximate
    - Introduction - 10 pages
    - Theoretical Tools 25 pages
        - MC Generators (5 pages), High Order QCD calculations (5 pages), EW corrections (5 pages), PDF tools (5 pages), EFT tools (5 pages)
    - Electroweak processes - 35 pages
        - Vector boson fusion processes (5 pages), Vector Boson scattering (10 pages), Triboson production (5 pages), Precision EW measurements (10 pages), Forward EW physics (5 pages)
    - Strong Interactions - 26 pages
        - Jets and photons (8 pages), Ultimate Parton Densities (10 pages), Forward and Soft QCD physics (8 pages)
    - Top Physics - 36 pages
        - Top cross section (5 pages), Top properties (10 pages), Top couplings (5 pages) , Top mass (8 pages), FCNC (8 pages)
    - Effective coupling interpretations - 10 pages

Table of contents with contributions and pages

1. **Introduction** (10 pages)
2. **Theoretical tools** (15 pages)
   a. **MC Generators** (3 pages)
   Contributors: Fabio Maltoni (TH)
   b. **High Order QCD calculations** (3 pages)
   Contributors: Giulia Zanderighi (TH)
   c. **EW corrections** (3 pages)
   Contributors: Marek Schoenherr, Marco Zaro, Davide Pagani (TH)
   d. **PDF tools** (3 pages)
   Contributors: Lucien Harland Lang, Jun Gao, Juan Rojo (TH)
   e. **EFT tools** (3 pages)
3. **Electroweak processes** (35 pages)
   a. **Vector boson fusion processes** (5 pages)
   Contributors: Cruz Martinez, Karlberg, Figy (TH)
   b. **Vector Boson scattering** (10 pages)
   Contributors: Reuter, Sekulla (TH, Whizard), Rauch, Zeppenfeld (TH, VBFNLO), Pellen (TH, EW corr.), Claire Lee (ATLAS, SS WW), Uplap (CMS, SS WW), Bing Li, Yusheng Wu (ATLAS, ZZ), Charlot (CMS ZZ), Corinne Goy, Lucia Di Ciaccio (ATLAS, WZ), Terashi, Les, Nitta, Cavaliere (ATLAS, WV semileptonic)
   c. **Triboson production** (5 pages)
   Contributors: VBFNLO team at KIT for theory, Pellen (TH EW corr.), Schoenherr, Zaro (TH), Bakos, Nenad Vranjes (ATLAS), Lawhorn (CMS)
   d. **Precision EW measurements** (10 pages)
   Contributors: --- VV production: Heinrich, Pires, Matthias Kerner, Stephan Jahn and Stephen Jones, Wiesemann (TH, HO QCD), Sally Dawson, Ian Lewis, Baglio (TH) for aTGC limits Kristin Lohwasser (ATLAS), Valerie Lange (ATLAS), A. Tricoli (ATLAS) --- Weak Mixing Angle: Arie Bodek, Aleko Khukhunaishvili, Ping Tan, Rhys Taus, Alexander Savin (CMS), Stefano Camarda, Ludovica Aperio Bella, Bruno Lenzi (ATLAS), William Barter, Tara Shears (LHCb) --- W Mass Maarten Boonekamp (ATLAS), Mika Vesterinan (LHCb), Fulvio Piccinni, Giancarlo Ferrera, Alessandro Vicini (TH) --- EW fits: Jorge de Blas, Marco Ciuchini, Enrico Franco, Luca Silvestrini, Maurizio Pierini, Laura Reina, Satoshi Mishima (TH)
   e. **Forward EW physics** (5 pages)
   Contributors: -- light-by-light and photon-induced processes: Johanna Gramling Kristof Schmieden (ATLAS), Lucian Harland-Lang (TH)

Table of contents with contributions and pages

tt cross section

Alexander Mitov

Cavendish Laboratory

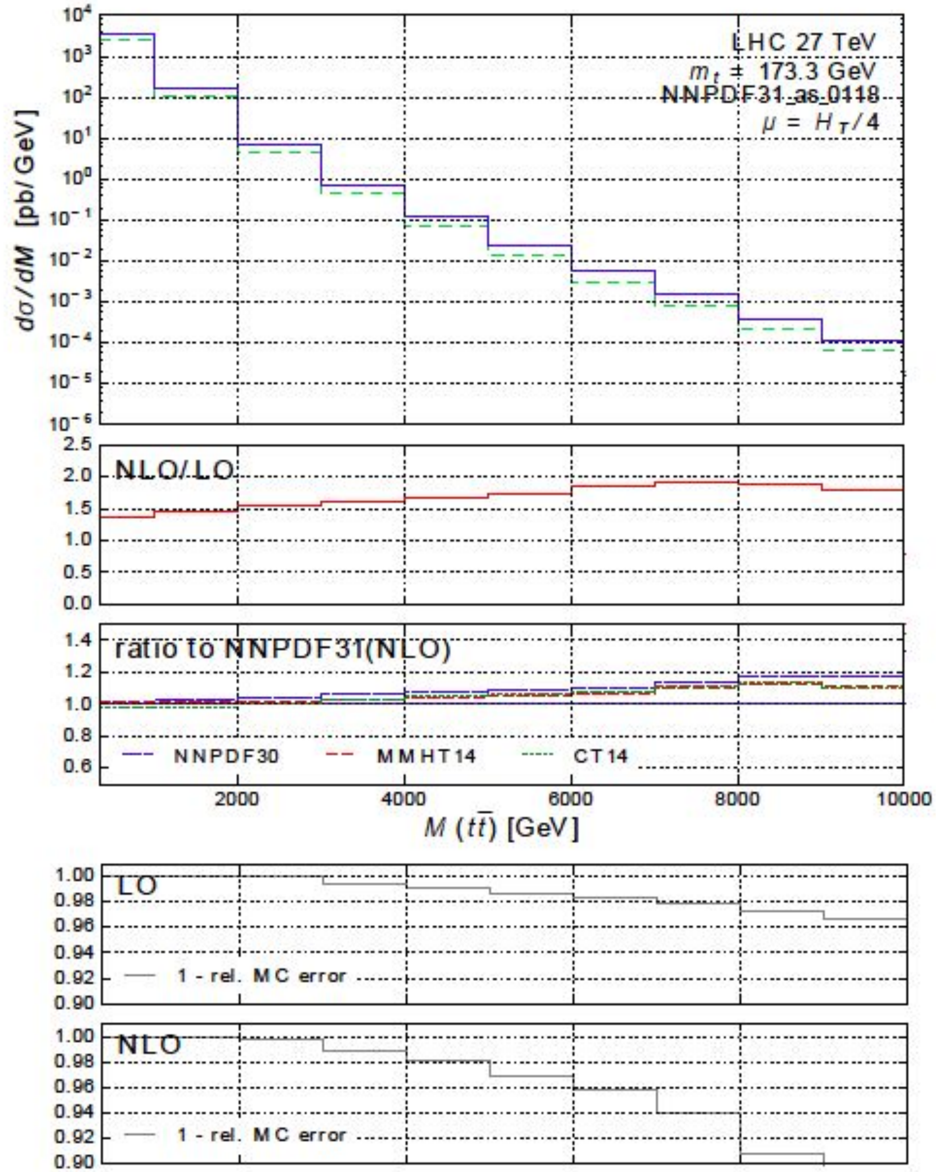
UNIVERSITY OF CAMBRIDGE

On behalf of:

- O. Hindrichs (CMS), S. Farry (LHCB), F. Deliot (ATLAS)
- P. Nason, A. Mitov, M. Zaro (TH)

Differential reach in M_{tt}

- ✓ At LHC at 27 TeV very large M_{tt} can be reached
- ✓ Estimates at LO and NLO:
  - ✓ 10% effect in the tails from NNPDF3.1 w/r to older sets
  - ✓ MC error can be handled up to M_{tt}~10TeV
  - ✓ The dynamic scales behave OK (at least) up to 10 TeV
  - ✓ Very modest growth of scale error



Single top cross section studies

Fabrizio Caola, Irina Cioara, Kevin Finelli,
Matthias Komm, Emanuele Re

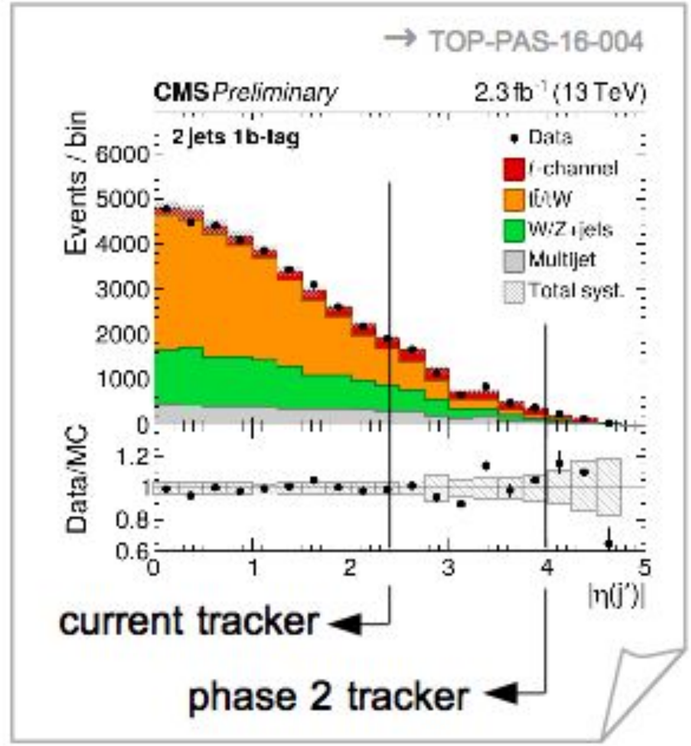
HL/HE-LHC WG1 Meeting -- Top physics

02 May 2018

Prospects

For t-channel

- gains at HL-LHC with 3/ab
  - increased stat. precision (differential measurements not yet limited by syst. uncertainties)
  - high coverage of tracker ($|\eta| < 4$)
    - → lower jet energy scale uncertainty
    - → suppress backgrounds further by requiring forward-jet to fail b-tagging



- potential outline of analysis
  - event selection: e/μ + 2 jets with 1 b-tag
  - require transverse W boson mass of $m_{\mathrm{T}}(\mathrm{W}) > 50$ to reject multijet events
  - samples: t-channel, W+jets & ttbar, tW (ideally at NLO); fast detector simulation with Delphes
  - model multijet events using extrapolated shape from 13 TeV analysis
  - fit distribution of $|\eta(j')|$ with pseudo data to estimate uncertainty on signal yield
  - unfold to parton level (optionally: particle level) using TUnfold
  - target: top quark p_{T}, rapidity & polarization angle (optional: differential charge ratio)

Four-top studies at the HL/HE LHC

Marco Zaro,
Frederic Deliot, Giovanni Zevi della Porta
HE-HL LHC Working Group - WG1 - Top Physics
02/05/2018

Updated preliminary results: Complete NLO to 4top @27TeV

Preliminary

	σ[fb]	LO_{QCD}	$LO_{QCD}+NLO_{QCD}$	LO	LO + NLO	$\frac{LO(+NLO)}{LO_{QCD}(+NLO_{QCD})}$
13	$\mu = H_T/4$	$6.83^{+70\%}_{-38\%}$	$11.12^{+19\%}_{-23\%}$	$7.59^{+64\%}_{-36\%}$	$11.97^{+18\%}_{-21\%}$	1.11 (1.08)
	σ[fb]	LO_{QCD}	$LO_{QCD}+NLO_{QCD}$	LO	LO + NLO	$\frac{LO(+NLO)}{LO_{QCD}(+NLO_{QCD})}$
27	$\mu = H_T/4$	$45.34^{+59\%}_{-35\%}$	$71.31^{+16\%}_{-20\%}$	$48.57^{+54\%}_{-33\%}$	$73.94^{+15\%}_{-18\%}$	1.07(1.04)
	σ[pb]	LO_{QCD}	$LO_{QCD}+NLO_{QCD}$	LO	LO + NLO	$\frac{LO(+NLO)}{LO_{QCD}(+NLO_{QCD})}$
100	$\mu = H_T/4$	$2.37^{+49\%}_{-31\%}$	$3.98^{+18\%}_{-19\%}$	$2.63^{+44\%}_{-28\%}$	$4.18^{+17\%}_{-17\%}$	1.11 (1.05)

δ[%]	$\mu = H_T/8$	$\mu = H_T/4$	$\mu = H_T/2$
LO_2	−26.0	−28.3	−30.5
LO_3	32.6	39.0	45.9
LO_4	0.2	0.3	0.4
LO_5	0.02	0.03	0.05
NLO_1	14.0	62.7	103.5
NLO_2	8.6	−3.3	−15.1
NLO_3	−10.3	1.8	16.1
NLO_4	2.3	2.8	3.6
NLO_5	0.12	0.16	0.19
NLO_6	< 0.01	< 0.01	< 0.01
$NLO_2 + NLO_3$	−1.7	−1.6	0.9

δ[%]	$\mu = H_T/8$	$\mu = H_T/4$	$\mu = H_T/2$
LO_2	−22.2	−24.4	−26.5
LO_3	25.8	31.1	36.8
LO_4	0.2	0.3	0.4
LO_5	0.0	0.1	0.1
NLO_1	14.3	57.3	93.8
NLO_2	6.2	−2.4	−11.2
NLO_3	−10.0	−2.7	6.3
NLO_4	2.8	3.5	4.3
NLO_5	0.2	0.3	0.3
NLO_6	< 0.01	< 0.01	< 0.01
$NLO_2 + NLO_3$	−2.8	−5.1	4.9

δ[%]	$\mu = H_T/8$	$\mu = H_T/4$	$\mu = H_T/2$
LO_2	−18.7	−20.7	−22.8
LO_3	26.3	31.8	37.8
LO_4	0.05	0.07	0.09
LO_5	0.03	0.05	0.08
NLO_1	33.9	68.2	98.0
NLO_2	−0.3	−5.7	−11.6
NLO_3	−3.9	1.7	8.9
NLO_4	0.7	0.9	1.2
NLO_5	0.12	0.14	0.16
NLO_6	< 0.01	< 0.01	< 0.01
$NLO_2 + NLO_3$	−4.2	−4.0	2.7

ttX studies for the HL/HE-LHC

Eleni Vryonidou
CERN TH

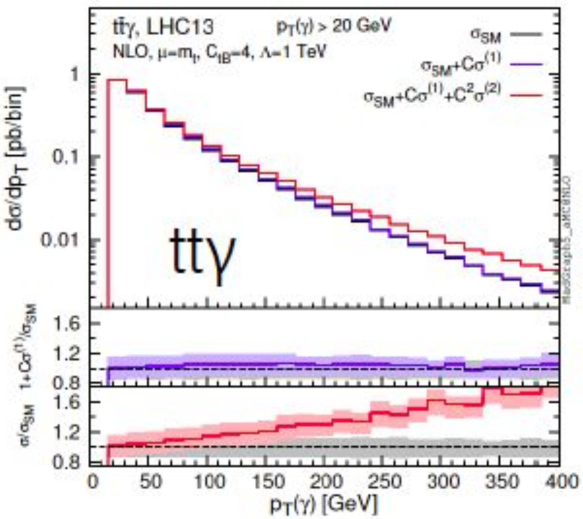
European
Commission

ttX group:
Y. Li, A. Onofre, M. Llacer (ATLAS)
R. Shoefbeck (CMS)
E.Vryonidou (Theory)

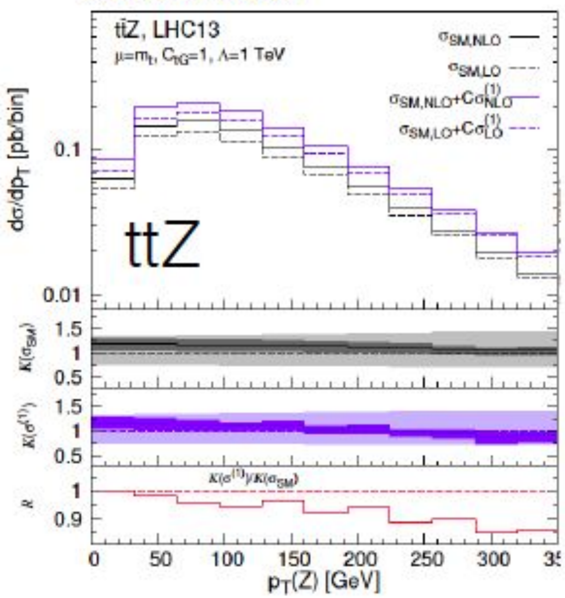
HL/HE-LHC
WG1
2/5/18

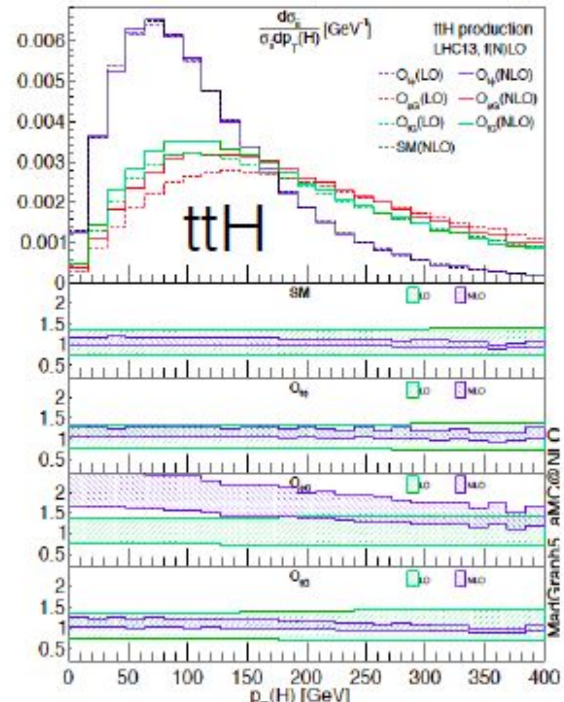
From February meeting:

HL/HE-LHC prospects

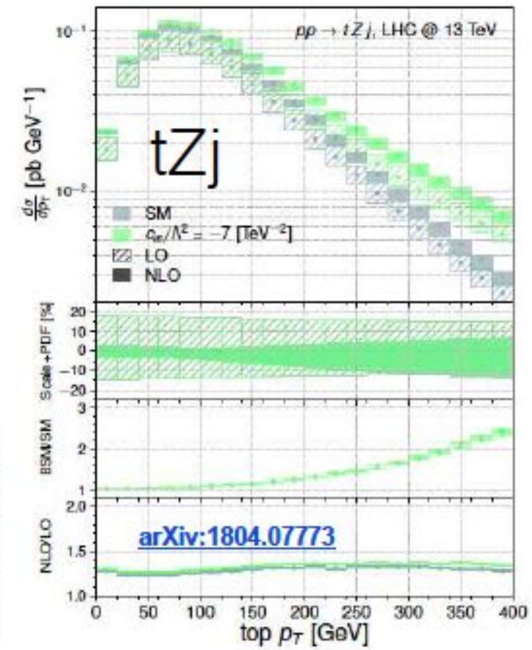


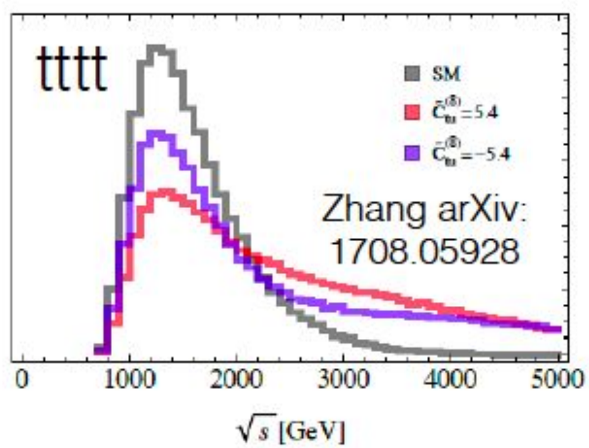
arXiv:1601.08193





arXiv:1607.05330





Importance of differential measurements in particular for high threshold processes ttV, ttH,tttt,tZj for HL/HE-LHC

E.

Top Mass Measurements

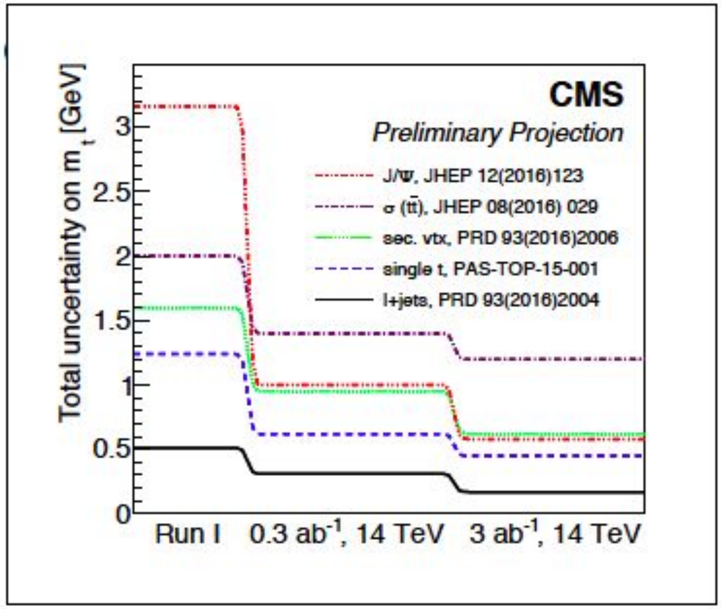
P. Nason

CERN and INFN, sez. di Milano Bicocca

CERN, May 2$^{\rm nd}$ 2018

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^3LO 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

Top FCNC @ HL/HE-LHC

J. Andrea, L. Dudko, A. Durglishvili, D. Hirschbuehl,
P. Mandrik, K. Skovpen

HL/HE-LHC WG1 Meeting / Top physics

May 2, 2018

5. Results : *4p, 12 figs*

- Describe the procedure of the limit extraction
- *Show final NN discriminators optimised for the search for up and charm-FCNC couplings, 2x2 figs*
- *Show 2d limits on couplings and BRs (up vs charm), 2x2 figs*
- *Show 1d limits as a function of the integrated luminosity, 2x2 figs*
- Summarise projections for BR upper limits considering various systematics scenarios
- Constrain EFT operators from the obtained limits
- Discuss results in comparison to existing projections

Σ=9

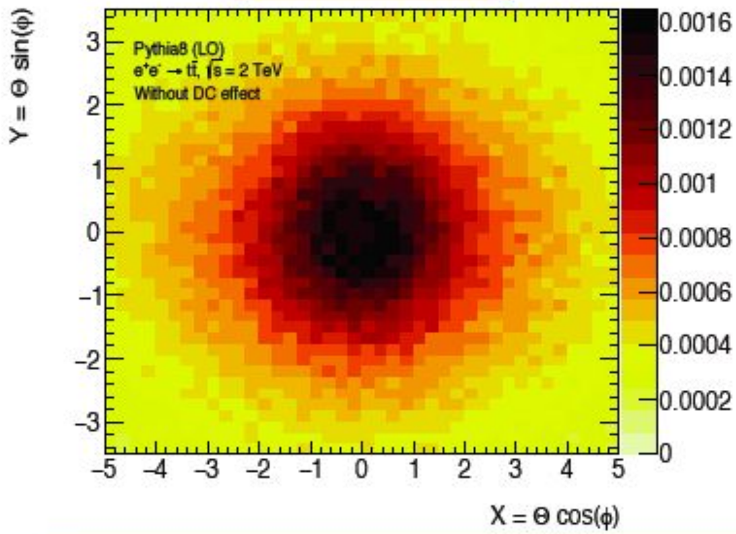
HL-LHC: Deadcone Plans

Ian Connelly, James Howarth, Michele Selvaggi, Jacob Rawling,
Yvonne Peters

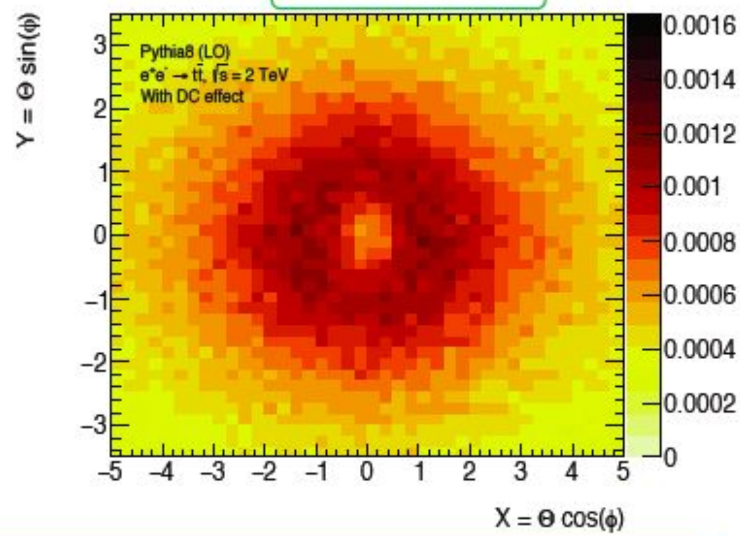
What is the dead-cone effect?

MANCHESTER 1824
The University of Manchester

Deadcone Effect Off



Deadcone Effect On



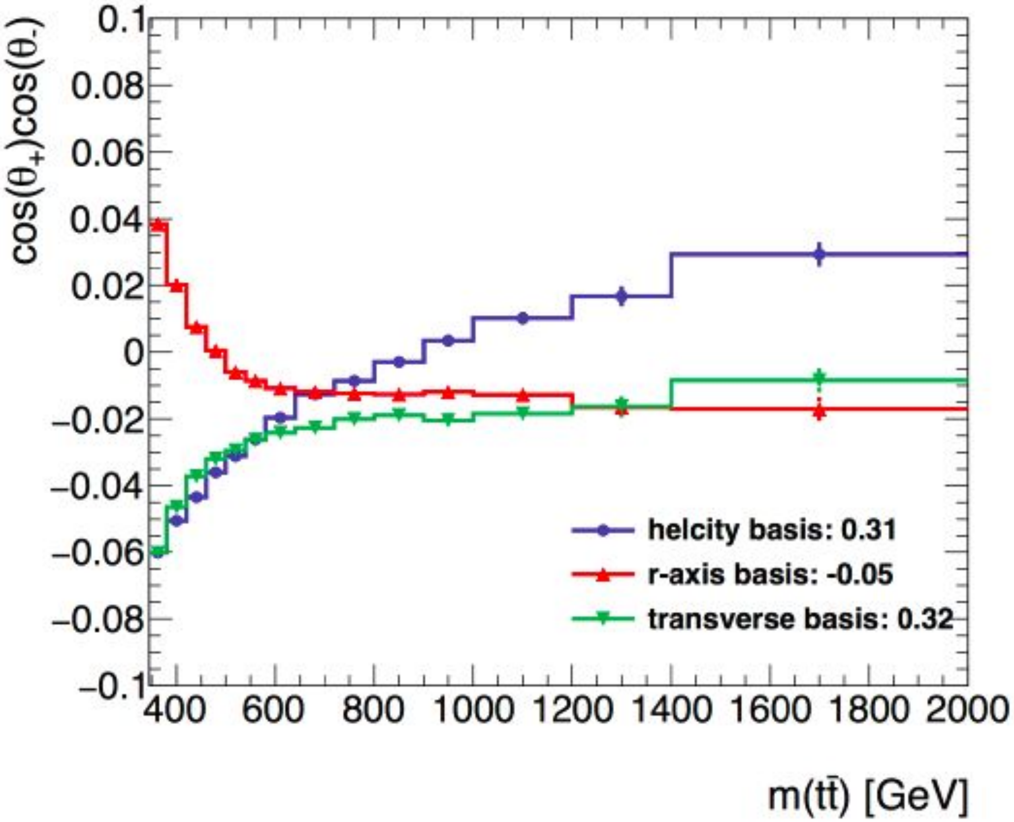
The Dead Cone Effect: Radiation from a massive particle with mass m and energy E is supressed for emission angles $\theta \lesssim \theta_D = \frac{m}{E}$

- **Never** been measured
- Fundamental predication of radiation in gauge invariant QFTs
- Hard to measure experimentally– $\theta_D \ll 1$ **EXCEPT** in tops!

HL-LHC and HE-LHC top: Spin Correlations & Charge Asymmetry

Pieter David, Andrea Giammanco, **Jay Howarth**, Alex Mitov, Liam Moore, Marcel Vos

Spin Correlation



- Here is an example of the kind of plot we would like to produce.
- Spin correlation, in this case using cos(**θ**)cos(**θ**), as a function of m(ttbar).

Remarks on HE-LHC and Simulation

- **LHC physicists have the best know-how & simulation+analysis experiences to develop work and investigate physics potential of the "energy upgrade" of the LHC, HE-LHC**
  - Simulation tools have been prepared for HL-LHC physics studies in Experimental TDR's for LHC Phase-II upgraded detectors
  - Particle-level MC studies are important: provide expected cross-section/rates of the most important physics objects produced at HE-LHC
- **HE-LHC studies can be:**
  1) **Integrated HE-LHC studies:** HE-LHC studies can be included in HL-LHC analyses to compare the physics results obtained for a given physics process assuming these two colliders. Performance of the LHC Upgrade Detectors can be assumed for both scenarii for simplicity
  2) **Standalone HE-LHC studies:** are also welcome, especially from theorists: here you can consider the performance of a generic detector at present/future hadron colliders
     - ***Delphes* simulation package** is default tool to include a generic modern hadron collider detector response in the simulation studies
- **DELPHES** configuration for a generic detector is available: this page will also contain info on general MC samples that may become available for HE-LHC https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HLHEWG_MC
- The FCC-hh Software group is available to provide Delphes-ing of common HE samples (Michele Selvaggi, Clement Helsens) http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_helhc_v01.php

WG1 work organization strategy

- Collection of topics from interested parties on public google doc:
  - https://tinyurl.com/yaew28lx
  - Agendas have been filled starting from this
  - Now is the time to come up with new additions!
- Set of intermediate working meetings split up by block of topics:
  - Agendas: Top: https://indico.cern.ch/event/702718/m EW: https://indico.cern.ch/event/702716/ , QCD: https://indico.cern.ch/event/702715/, EW precision: https://indico.cern.ch/event/702717/
    - Helpful to meet with the interested parties and setup “focused groups” by topic that would comprise experimentalists and theorists
  - Agendas: Top: https://indico.cern.ch/event/721943/, QCD: https://indico.cern.ch/event/721948/, EW: https://indico.cern.ch/event/721951/
    - More of a discussion about actual implementation of contente in the final report.
- Currently preparing for the June plenary meeting:
  - Experiments might not have new results already approved. Will think of a proper format to be able to discuss relevant common topics anyway.
  - Common sessions planned with Higgs and with Flavor

Current Activities

- February / March meetings helped list analysis topics and identify contributors
- Since then we have attempted to bring together interested parties across experimental and theory communities on specific topics
    - To prompt discussions on specific topics
    - Share of experience, tools, MC samples and workload among contributors
    - If you have not received e-mails from us that linked you to other collaborators, let us know!
- Immediate goal is to advance studies as fast as possible
    - Experimental HL-LHC analyses will need collaboration approval and need to keep on schedule
    - Stand-alone HE-LHC studies, that do not need collaboration approval, have looser time-scale but should get in shape soon
    - Theoretical calculations should become available (e.g. tables) soon to be used in experimental analyses
    - Experimental systematics approach should become available soon as well
    - Plan now for inputs needed from experimental groups for pseudo-data interpretations, e.g. distributions and uncertainties for PDF and EFT
- Work in parallel on chapter layout and sections that discuss theoretical tools

Conclusions

- The WG1 covers many topics also common to the rest of the overall HL/HE-LHC workshop: SM, QCD and Top physics
  - Will provide all the cross-sections also for HE
- The final volume will be of around 150pages which is very small for the amount of topics.
  - Experimental analyses and theoretical studies will all have to appear in full detail in separate public documents (that would become “Volume 2)
  - In the Volume of the WG1 there is only space for the discussion of the conclusions
  - We would like to avoid repetition of similar results and comparison between experiments will be exploited if motivated
- Focus of the work is the overall physics case of the HL/HE-LHC effort.
  - It is NOT a remake of all the analyses available now
  - We are making an informed choice about which topic are necessary and would profit of the high lumi or the higher energy