H→WW→lνlν at high luminosity: progress report

1. Analysis step-by-step: how it is performed
2. Distributions for leptons, jets, MET etc for test samples
3. Our study and seven options of degraded FCal
4. Plans

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ITEP Moscow, Russia

sFCal analysis workshop, Munich, 14.04.16

Analysis step-by-step - 1

Input: VBF H→WW→lvlv xAODs (different m_H, μ and geometries)

Most of datasets were ready only to 8.04; the last one finished on 11.04

- Creation of DxAODs from xAODs → T. Maier (and A.G.)

  - Use HIGG3D1 derivation for this purpose as we did in HWW group for Run2
  - Factor of ten reduction w.r.t. initial xAOD; its size strongly depends on μ
  - "TopoClusters" can be easily added w/o sizeable increase of DxAOD
  - T. Maier provided Sasha with correct script to produce DxAODs
  - DxAODs might be helpful for all the sFCal analysis community

  all new DxAODs are produced this week for m_H=125 GeV,1000 GeV

  Older test DxAODs were produced from "bad noise" xAODs.

  To be decided at what moment to add TopoClusters (and "AODfixes") to DxAOD

- DxAOD vs xAOD validation for jets and MET

  - jet-by-jet comparison xAOD vs DxAOD for subsample of events by Ilya: OK
  - comparison of jet kinematics for larger sample of events by Tom: OK
  - MET validation is in progress, situation is not clear for us

Analysis step-by-step - 2

- Creation of PxAODs from DxAODs → T. Maier

  - PxAODs are input files for the HWW analysis framework
  - They contain “HWWobjects” after initial (but rather hard) HWW selections
  - Test PxAODs exist for a few “bad noise” samples **with Run2 jet calibrations**
  - HL-LHC related complete calibrations not yet ready; in progress
  - Use jets as they are (directly from collection) is probably option for today
  - Later come to **official calibrations**

IMPORTANT. Clear prescriptions how to integrate calibrations (both for jets and MET) into DxAOD→PxAOD soft/scripts are really needed!

Test PxAODs are produced for m_H=1000 GeV for all μ with FCal geometry and for μ=200 for sFCal-s geometry, but for “bad noise” samples

Suggestion: to produce PxAODs with jets (without extra calibrations) from very recent r76*-r77* DxAODs prepared by Sasha

Analysis step-by-step - 3

- Simple analysis of PxAODs with RootCore (tqroot) → I.T.
  - Creation of basic histograms using ROOT "project" method for CollectionTree
  - Plotting these histograms "by hand" from the histogram files
  - A few minutes at typical SLC6 machine is sufficient to analyze 100K events
- Complete analysis of PxAODs within the HWW framework → A.G.
  - Creation of file with PxAOD descriptions → done for mentioned PxAODs
  - Running HWW analysis to create framework-readable compact file
  - Cutflows and plots after each standard HWW selection step from this file
  - A few minutes at SLC6 machine is sufficient to analyze 1M events
  - Details in A.G. talk today

Run 2 and HL-LHC settings for different objects

- Any trigger is off as we don't know what will be at HL-LHC

  We had of course dedicated trigger in Run 2 studies

- TRT was excluded from muon/electron definition

  Exclusion is performed at the PxAOD creation level

  Reason: no TRT at HL-LHC is expected.

  Note. Cut on lepton p_T is as in Run 2, i.e. $p_T(l)>22$ (15) GeV

- Jets + MET: still used Run 2 definitions/configs for all of this.

  - AntiKt4EMTopoJets, to be changed to AntiKt4LCTopoJets

    Steve is actively working on HL-LHC JES, to be expected soon.
  - 25 (30) GeV for jet p_T in $|\eta|<2.4$ ($|\eta|>2.4$): selection events for PxAOD

    For future: 40 (50) GeV as a minimum requirement to be applied later?
  - JVT cut of 0.64 is used in Run 2 for jets with $p_T<50$ GeV in $|\eta|<2.4$

    Not clear what value should be used for HL-LHC studies…
  - Standard MET is used, what MET should we try instead?

    MET recommendations for HL-LHC are in preparation, discussions are continued

Study for scoping document presented yesterday is a good base

Kinematic variables to study

- Lepton characteristics which are used in HWW studies

  $p_T(l1)$, $p_T(l2)$, $M(ll)$, $p_T(ll)$, $\Delta\eta(ll)$, $\Delta\phi(ll)$; also $\eta(l1)$, $\eta(l2)$

- Jet characteristics which are used in HWW studies

  $p_T(j1)$, $p_T(j2)$, $p_T(j3)$, $\eta(j1)$, $\eta(j2)$, $\eta(j3)$, $M(jj)$, $\Delta Y(jj)$, $\Delta\phi(jj)$

- MET and related quantities

  MET itself, $\Delta\phi(MET, ll)$, $p_T(tot)$ and transverse mass M_T

A few comments about Run 2 and HL-LHC comparisons:

- Plots are normalized to have the same integral
- HL-LHC files: different μ, normal FCal geometry, m_H =1000 GeV (as Run 2); in addition sFCal-s geometry for the highest μ
- We consider separately $e\mu$ + μe (DF), $\mu\mu$ and ee (SF) lepton final states (DF is main final state and Run2 cuts are defined)
- 50K events in initial Run 2 xAOD and 100K in HL-LHC xAODs

Note: in “new” r7699-r77* xAODs we have only 20K events per sample

Our studies and seven degraded FCal options

- sFCal (large gap) option can be ignored?

Not in the list https://indico.mpp.mpg.de/getFile.py/access?sessionId=0&resId=0&materialId=6&confId=4206

- dead FCal options 4, 5, 7 are partially considered earlier by us

https://cds.cern.ch/record/2109008/files/HWWlvlvUpgrade2015new.pdf

- Reduced VBF H signal acceptance by roughly 10% (40%, 70%) respectively
- That studies were based on Run2 VBF H samples, i.e. moderate pile-up.
- options 1 to 7 (priority: 2, 3 and 6) to be tested with HL-LHC samples provided dedicated calibrations with clear prescriptions will be available

Note. In Run2 analysis we are using both normal MET (but with track-based soft term) and fully track-based MET.

Examples of plots/tables based on tqroot analysis

- Fractions of $\mu\mu$, eμ, μe, and ee events passed PxAOD selections
- Jet multiplicities vs μ (all μ for **FCal** and μ=200 for sFCal-s)
- Lepton, jets and MET-related kinematics at different μ including Run2

  For different flavours (DF), i.e. (eμ + μe) events only; ee+$\mu\mu$ in backup
- Jet and MET-related kinematics at μ=200 for FCal and sFCal-s

  For different flavours (DF), i.e. (eμ + μe) events only

Results for m_H =1000 GeV: selection efficiency

Table shows fractions of events after PxAOD **selections**

No derivation

Final state	N(Run2)/ N(xAOD)	N(μ=80)/ N(xAOD)	N(μ=140)/ N(xAOD)	N(μ=200)/ N(xAOD)	N(μ=200)/ N(xAOD)
eμ	0.685	0.677	0.673	0.664	0.657
μe	0.681	0.645	0.627	0.613	0.608
μμ	0.682	0.699	0.691	0.684	0.677
ee	0.659	0.625	0.613	0.600	0.593

Reasonable muon and electron reconstruction efficiency even for μ =200
A bit better efficiency provided derivation step is performed
Some difference eμ vs μe are due to smaller efficiency to low-p_T e?

Results for m_H =1000 GeV: jet multiplicity

Table shows fractions of events after PxAOD **selections**

	Run 2			HL-LHC for μ=200		
Final state	**N(>0 jet)**	**N(>1 jet)**	**N(>2 jet)**	**N(>0 jet)**	**N(>1 jet)**	**N(>2 jet)**
eμ	0.900	0.534	0.143	1.000	0.999	0.998
μe	0.895	0.541	0.142	1.000	0.999	0.997
$\mu\mu$	0.901	0.537	0.144	1.000	0.999	0.997
ee	0.902	0.543	0.150	1.000	0.999	0.998

Too high jet multiplicity for μ=200, cuts on jet p_T should be more tight
No difference between ee, eμ and $\mu\mu$ cases

Results for m_H =1000 GeV: jet multiplicity

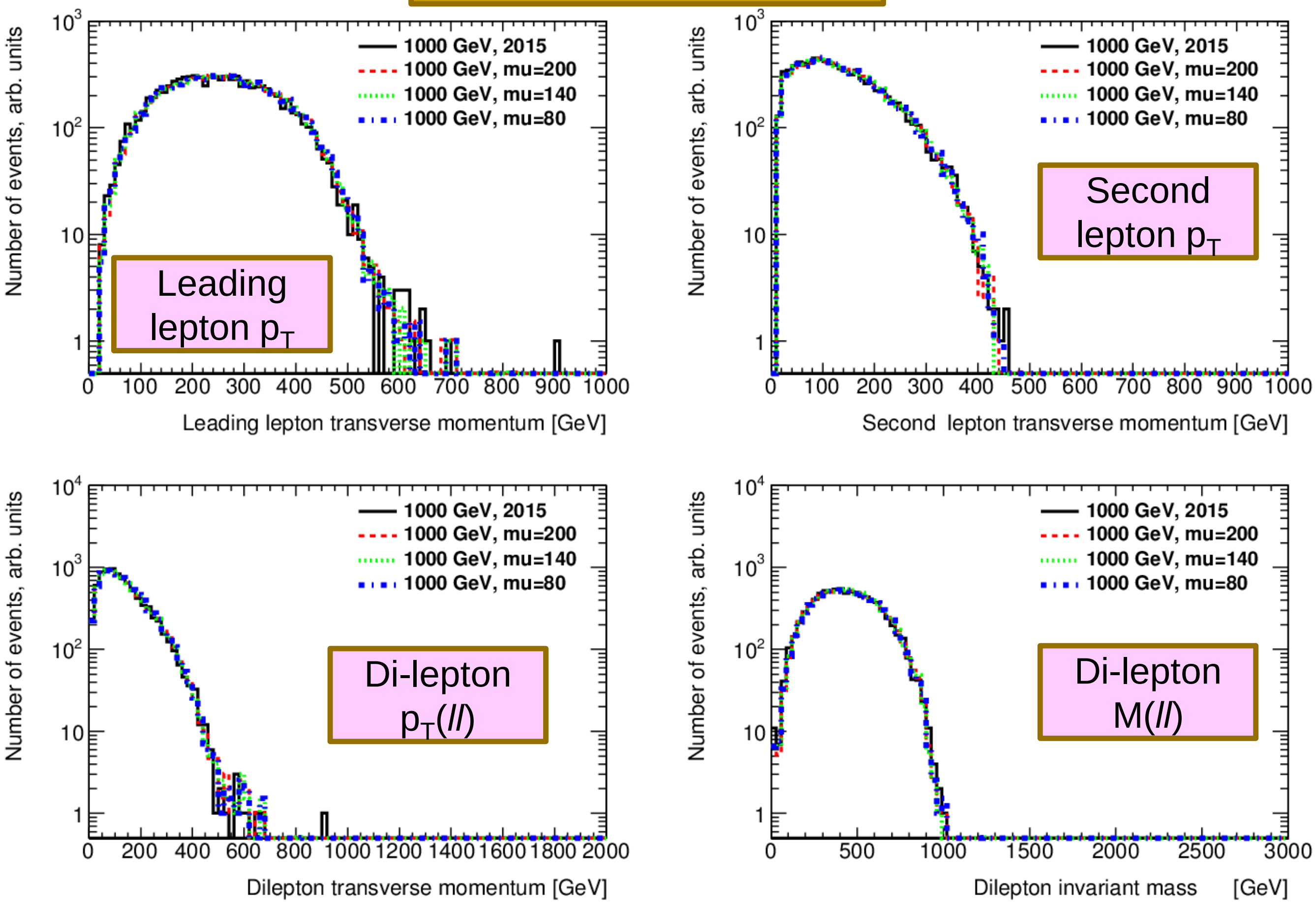
Table shows fractions of events after PxAOD **selections**

	HL-LHC for μ=80			HL-LHC for μ=140		
Final state	**N(>0 jet)**	**N(>1 jet)**	**N(>2 jet)**	**N(>0 jet)**	**N(>1 jet)**	**N(>2 jet)**
eμ	0.986	0.921	0.780	0.999	0.996	0.987
μe	0.985	0.910	0.770	1.000	0.997	0.987
μμ	0.984	0.914	0.769	1.000	0.997	0.988
ee	0.985	0.910	0.766	0.999	0.996	0.987

Strong increase of jet multiplicity with μ step-by-step
No difference between ee, eμ and μμ cases

Lepton kinematics in H→WW→lνlν events: DF-case

FCal geometry



No sizeable differences between spectra at 2015 year and high μ conditions

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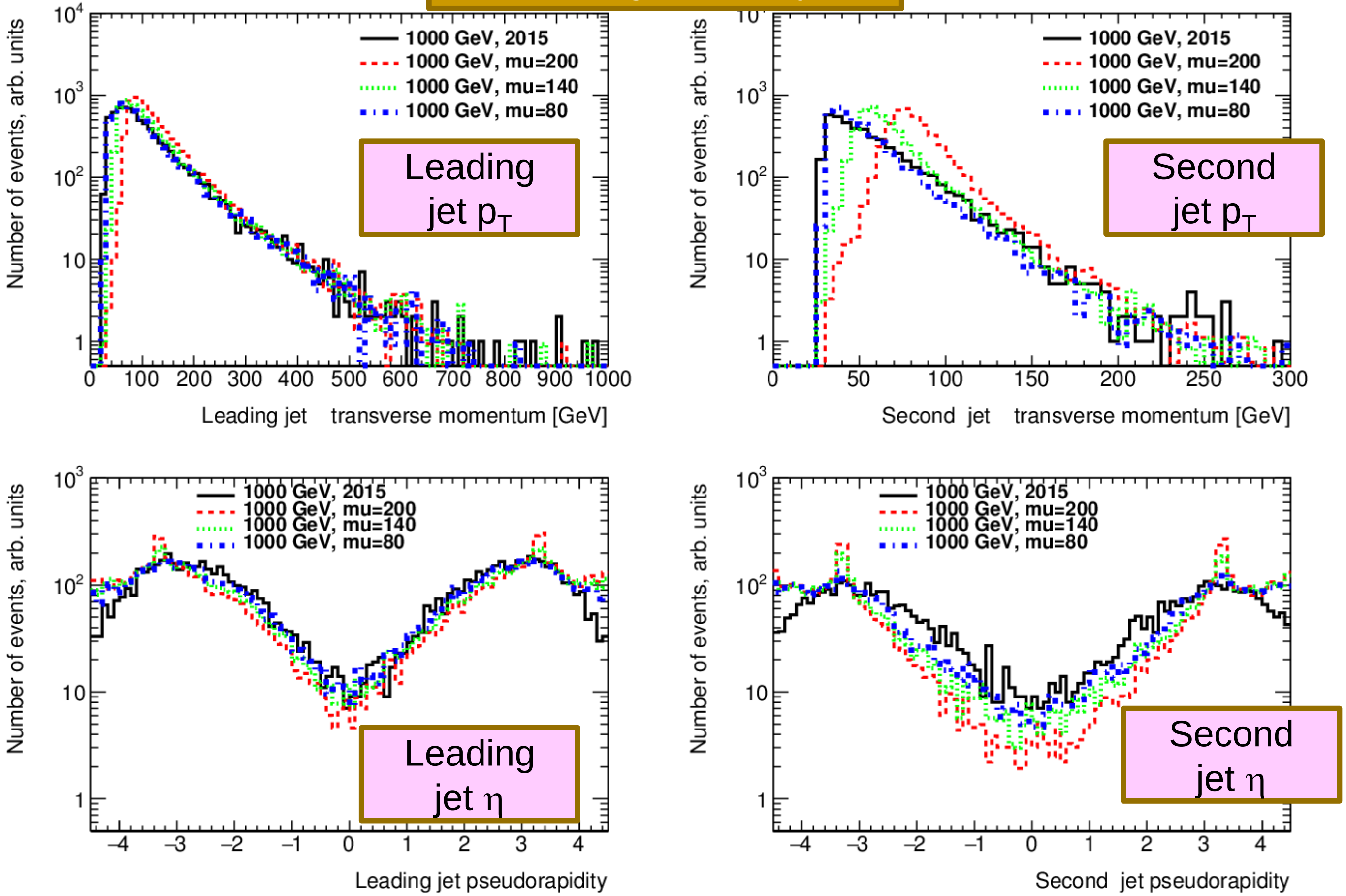
Jet kinematics in H→WW→lνlν events: DF-case

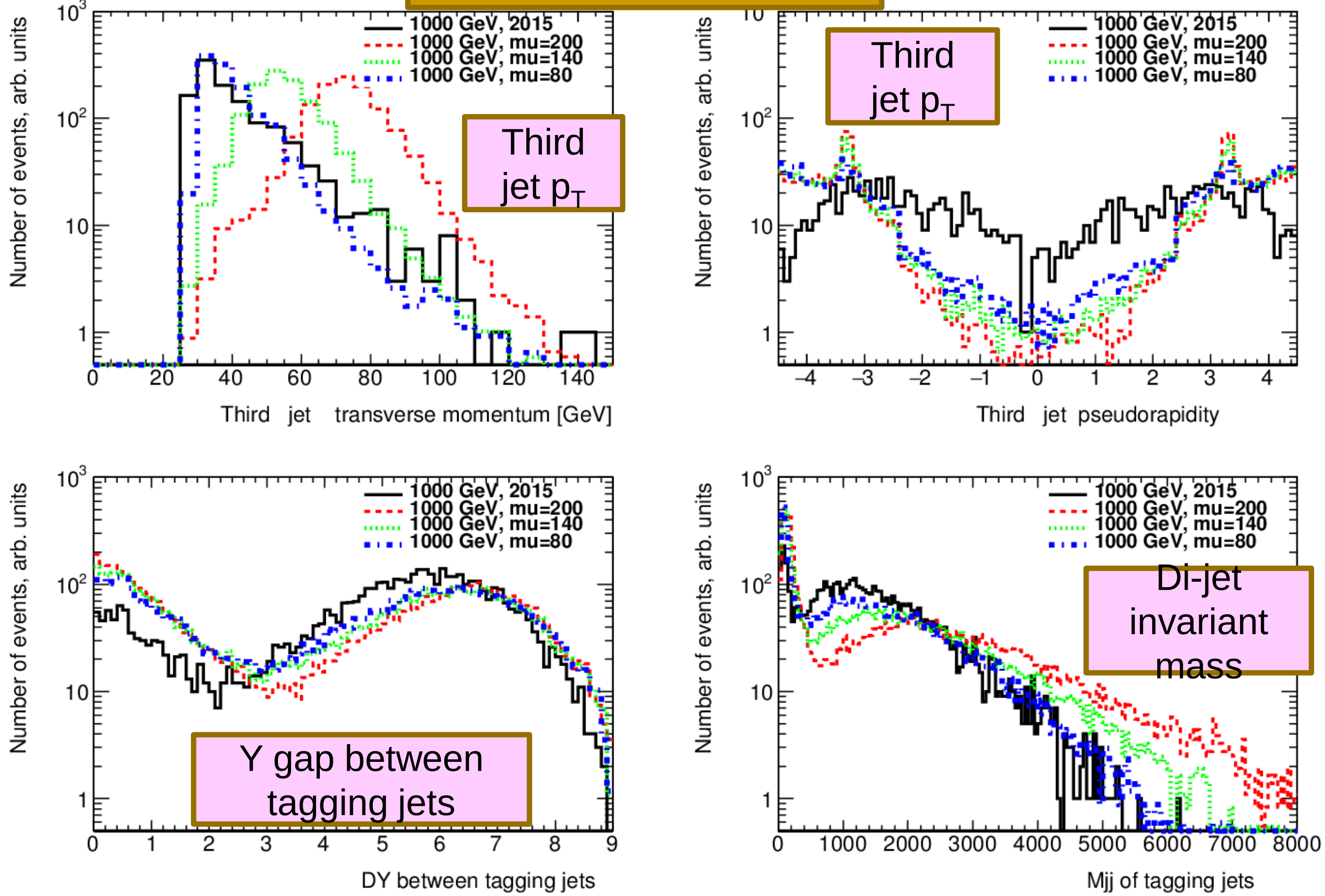
FCal geometry



Much harder jet p_T at higher luminosity, especially for μ=200
Much more forward jets at high μ, increasing with μ
"bunny ears" at EC/FCal boundary appear at μ=140, their increase at μ=200

Jet kinematics in H→WW→lνlν events: DF-case

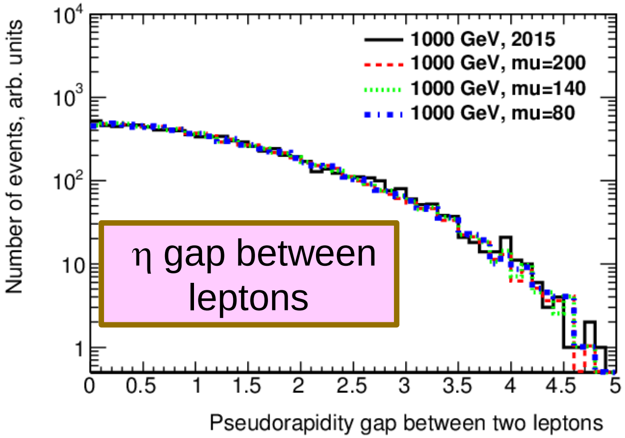
FCal geometry

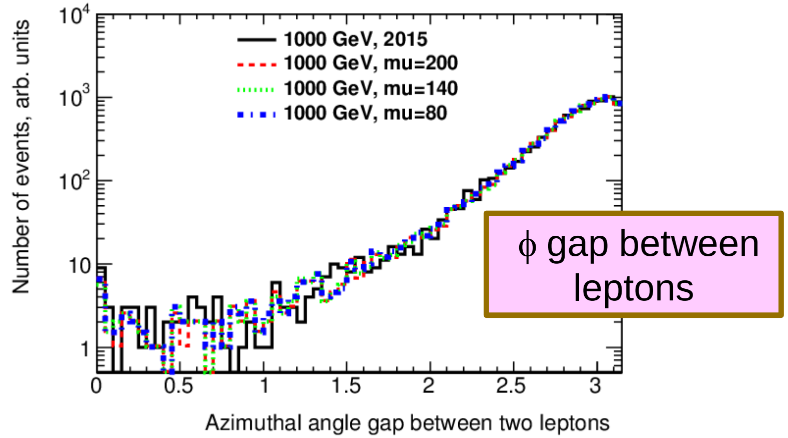


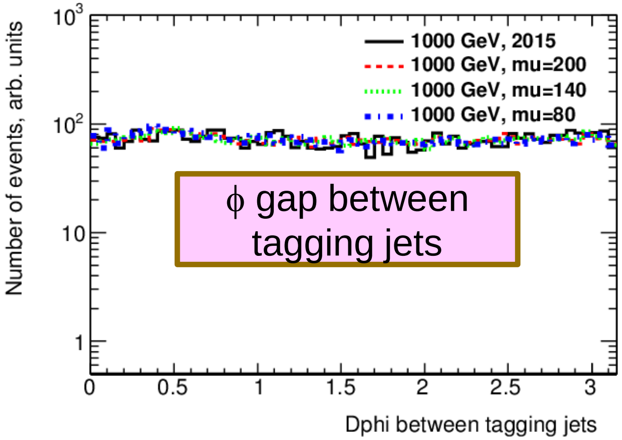
Much harder third jet p_T at high lumi, "bunny ears" at EC/FCal boundary
More events with low and high ΔY and M(jj) especially at μ=200

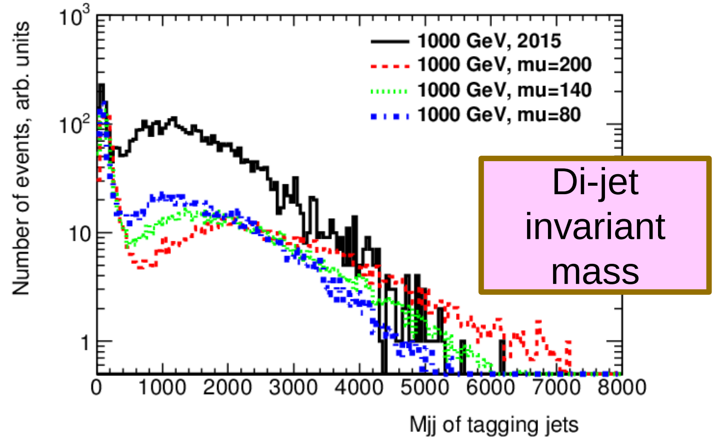
Kinematics in H→WW→lνlν events: DF-case

FCal geometry









No sizeable differences between spectra for leptons and $\Delta\phi(jj)$
More events with low and high M(jj) at μ=200

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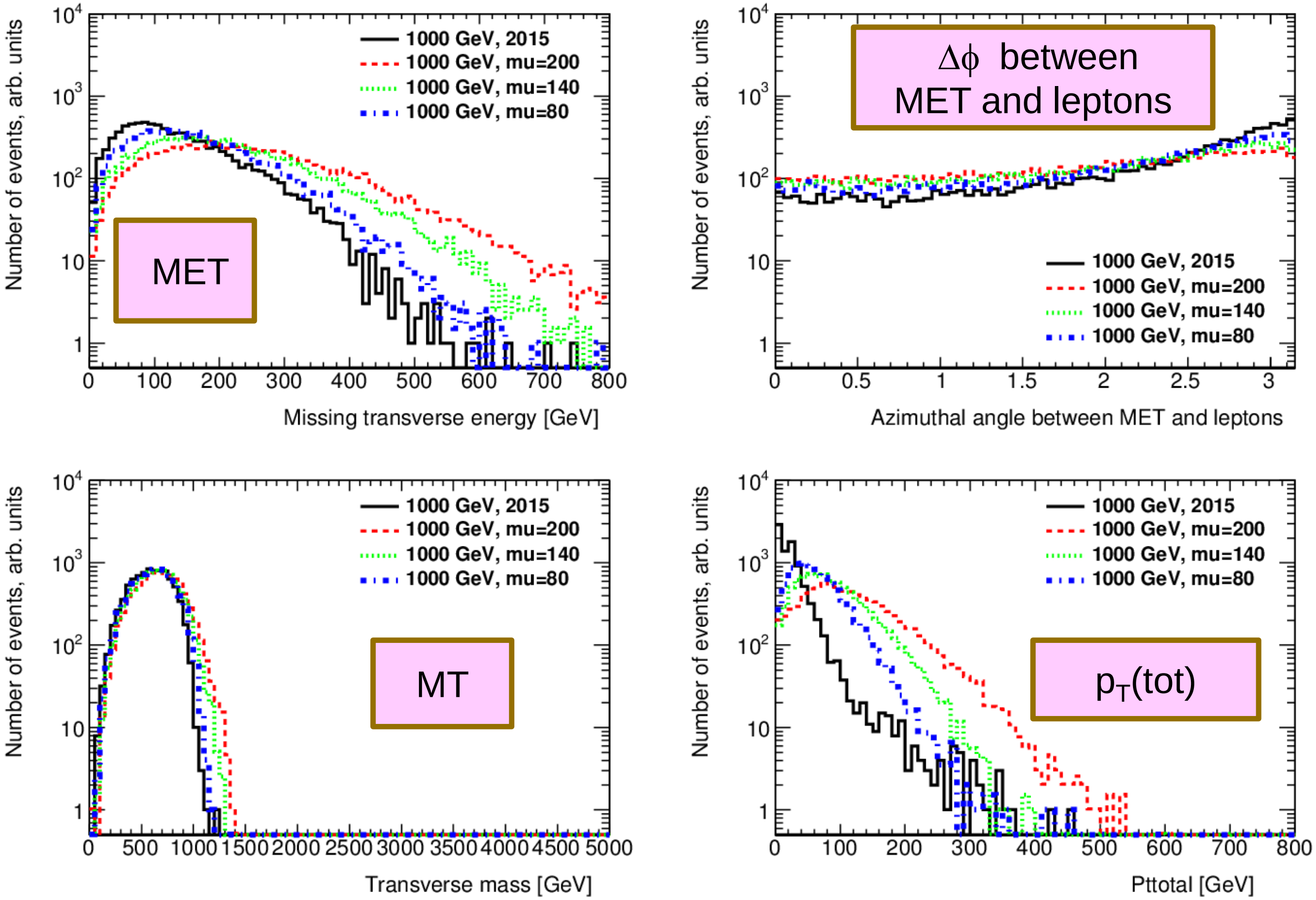
MET and MT in H→WW→lνlν events: DF-case

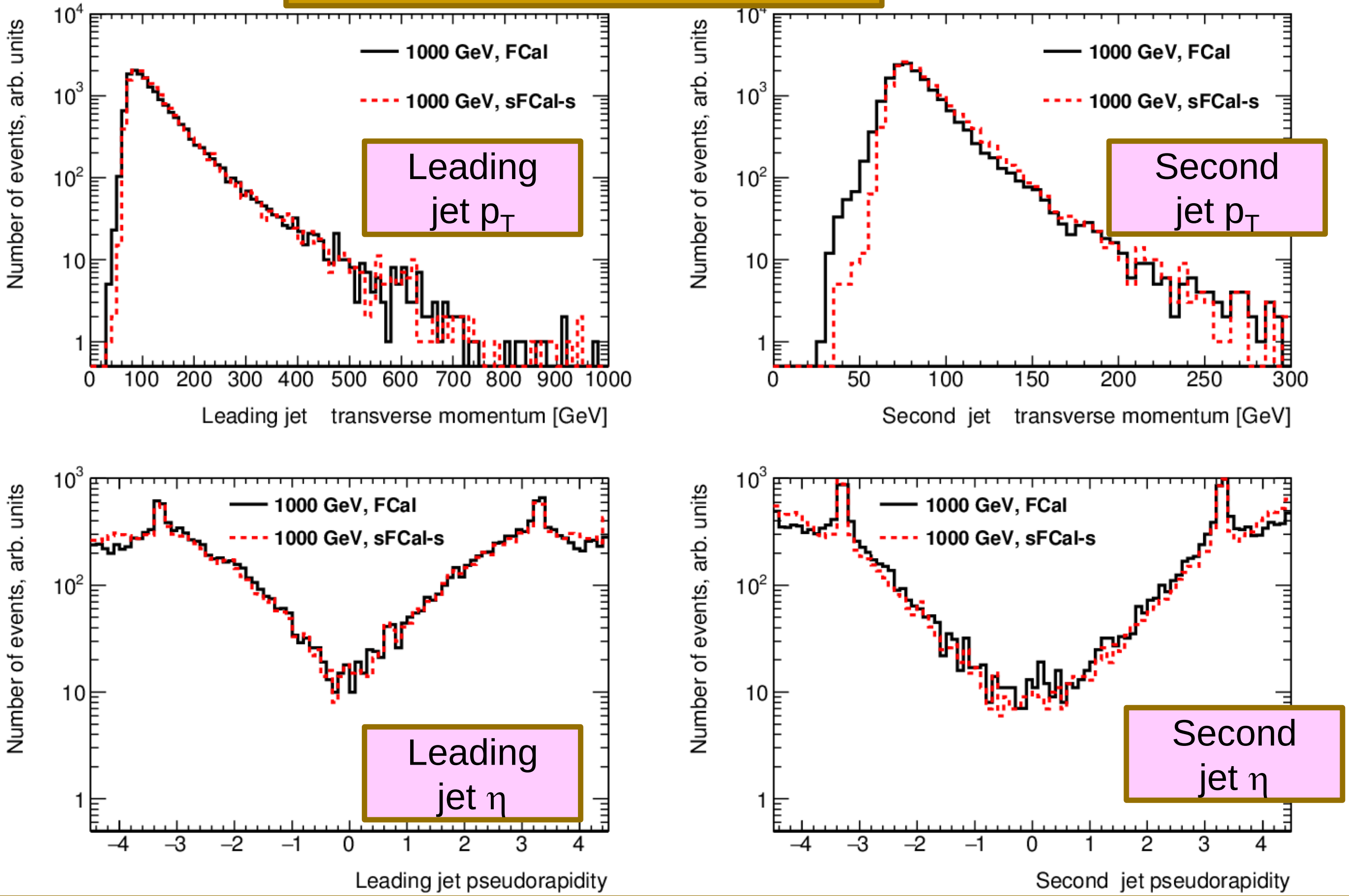
FCal geometry



Much harder MET, p_T(tot) and harder MT-spectra at higher μ
Smaller azimuthal angle between MET and leptons at higher μ

Jet kinematics in H→WW→lvlv events: DF-case

μ=200, FCal vs sFCal-s



More forward jets in the sFCal case
Jet p_T spectra are changed in the region around 50 GeV for sFCal case
“bunny ears” at η=3.3 are similar for FCal and sFCal cases

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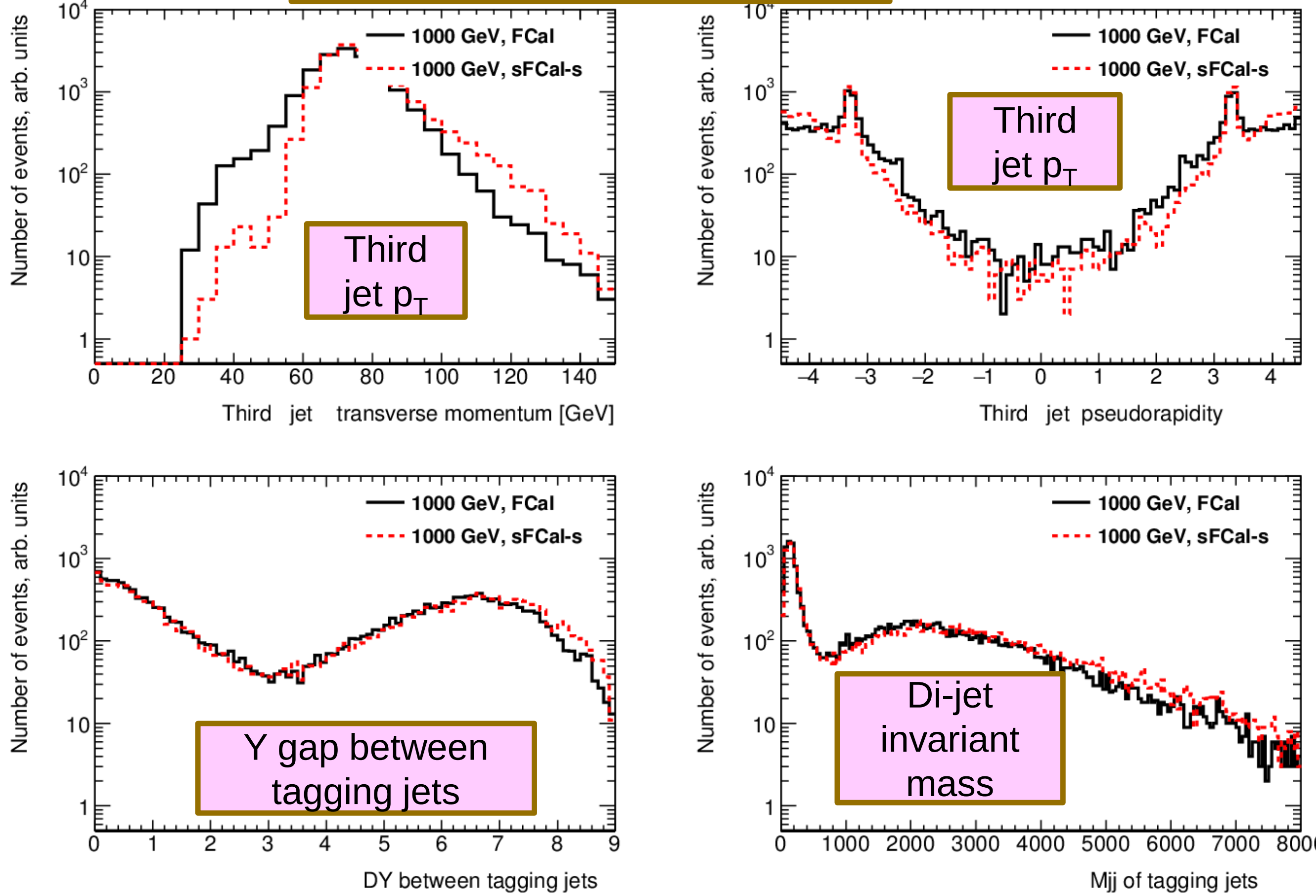
Jet kinematics in H→WW→lνlν events: DF-case

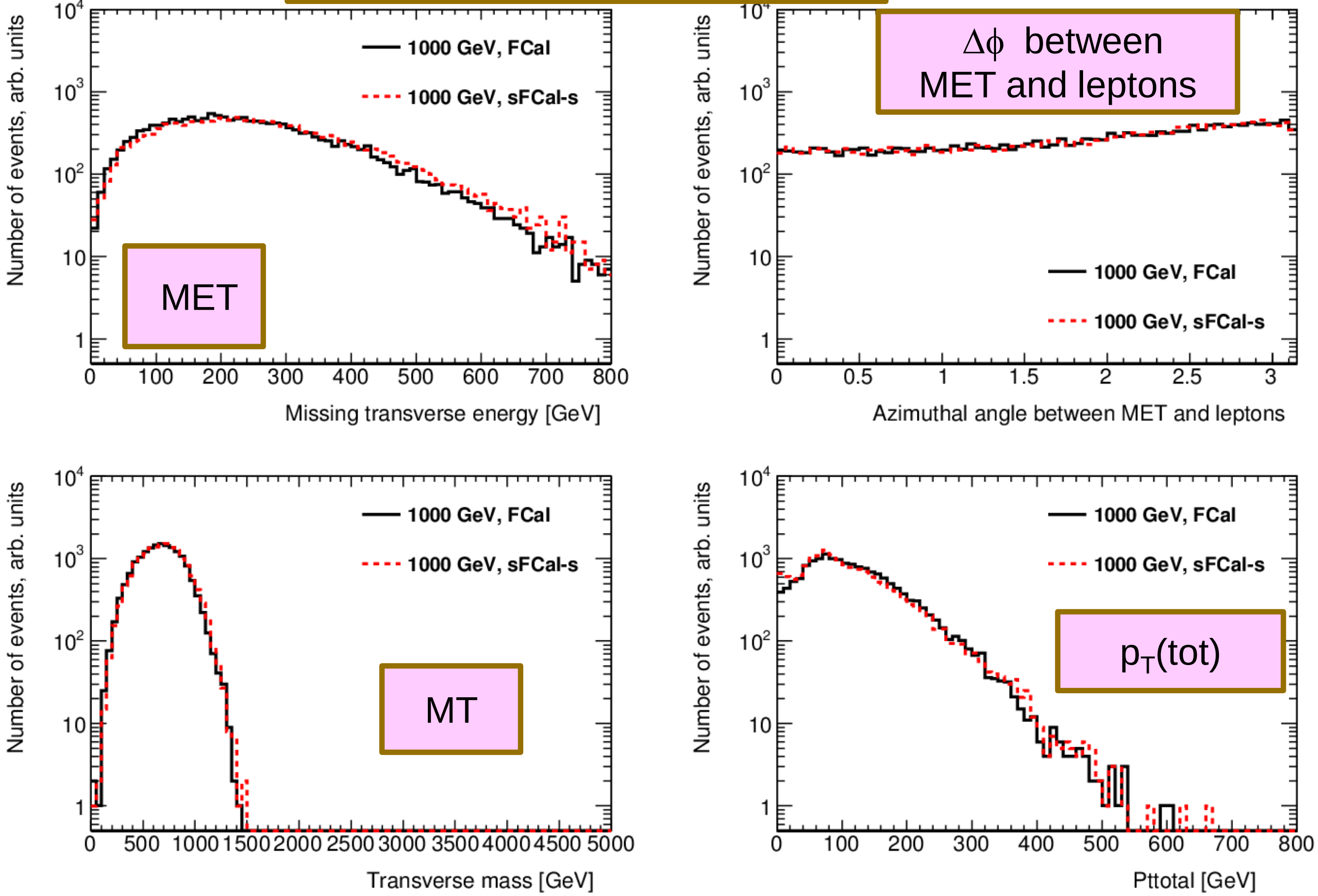
μ=200, FCal vs sFCal-s



Harder third jet p_T for the sFCal w.r.t. FCal case
For Y(jj) and M(jj) spectra differences between geometries are not big

MET and MT in H→WW→lνlν events: DF-case

μ=200, FCal vs sFCal-s



A bit larger MET in the case of sFCal geometry
Other spectra look similar except p_T(tot) at small values

Conclusion/observations

First comparison of kinematics in Run 2 and high μ MC samples for VBF H→WW→lvlv at m_H =1000 GeV is performed

xAOD→DxAOD (HIGG3D1)→PxAOD steps look successful; the derivation step brings us O(1%) more events with high-p_T di-leptons

- Lepton kinematics look very similar despite 13 vs 14 TeV energy

Some exception: slight difference in some distributions in the ee-only case

- MET and related quantities kinematics look very different at high μ

- MET itself and p_T(tot) spectra are much harder due to huge pile-up
- Transverse mass M_T is also higher due to bigger MET
- MET from sFCal is a bit higher than from FCal

- Jet kinematics has very significant change at high μ

Average jet p_T strongly increases due to huge pile-up in forward region
For the same reason big maxima in jet η–spectra at $|\eta|$=3.3
More jets in sFCal than in FCal, harder p_T-spectra

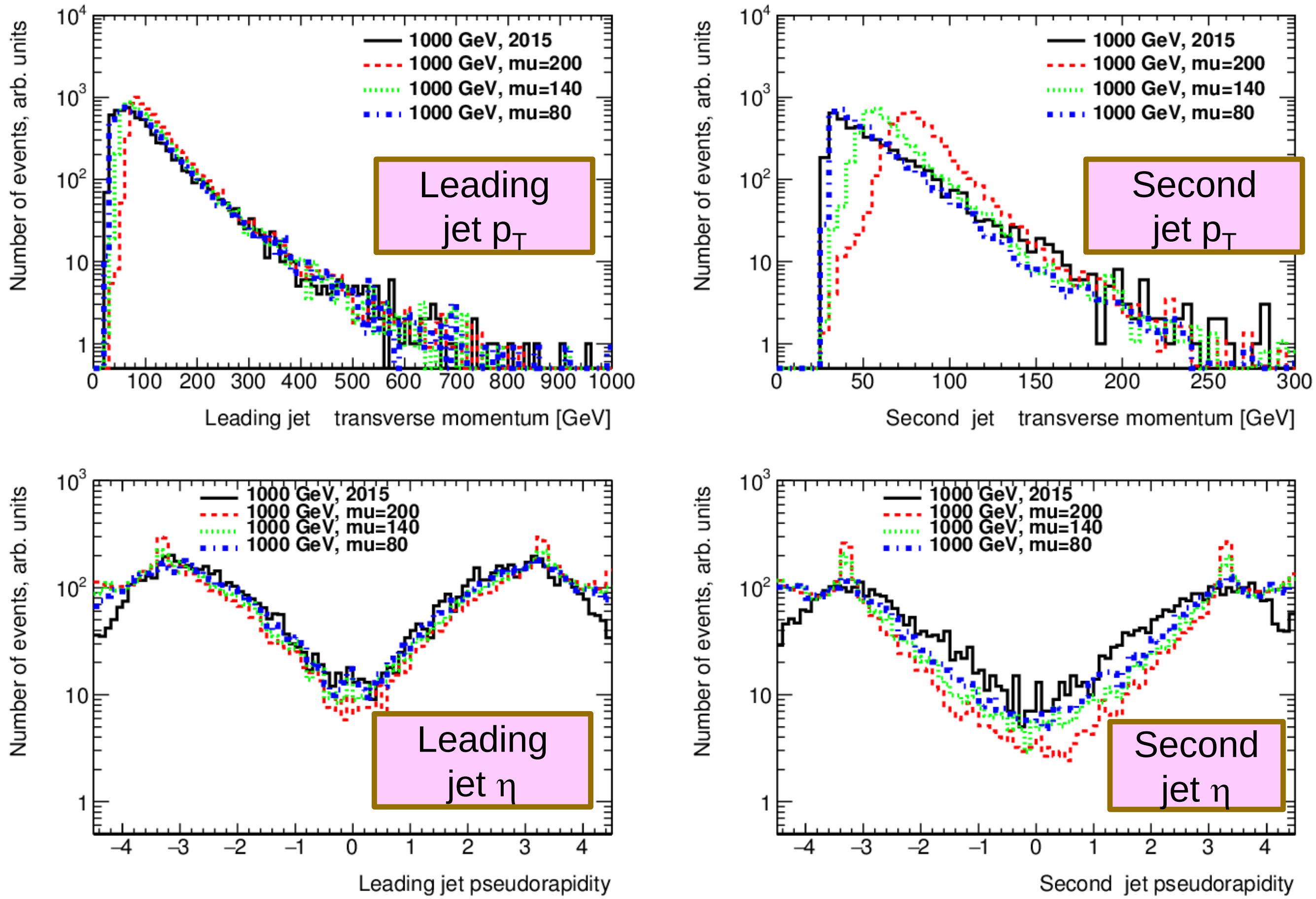
Jet and MET should be properly calibrated

Short-term plans

- Finishing to create DxAODs for r7699-r77* (all geometries, all μ, m_H =125 GeV and 1000 GeV)
- Production of PxAODs from them w/o jet calibrations and with AODfix(?)
- New round of DxAODs (with TopoClusters added), better to do from corrected xAODs (recreated or rereconstructed from clusters)
- Analysis of these PxAODs with RootCore and HWW framework
- Next steps will depend on situation with jet/MET calibrations…

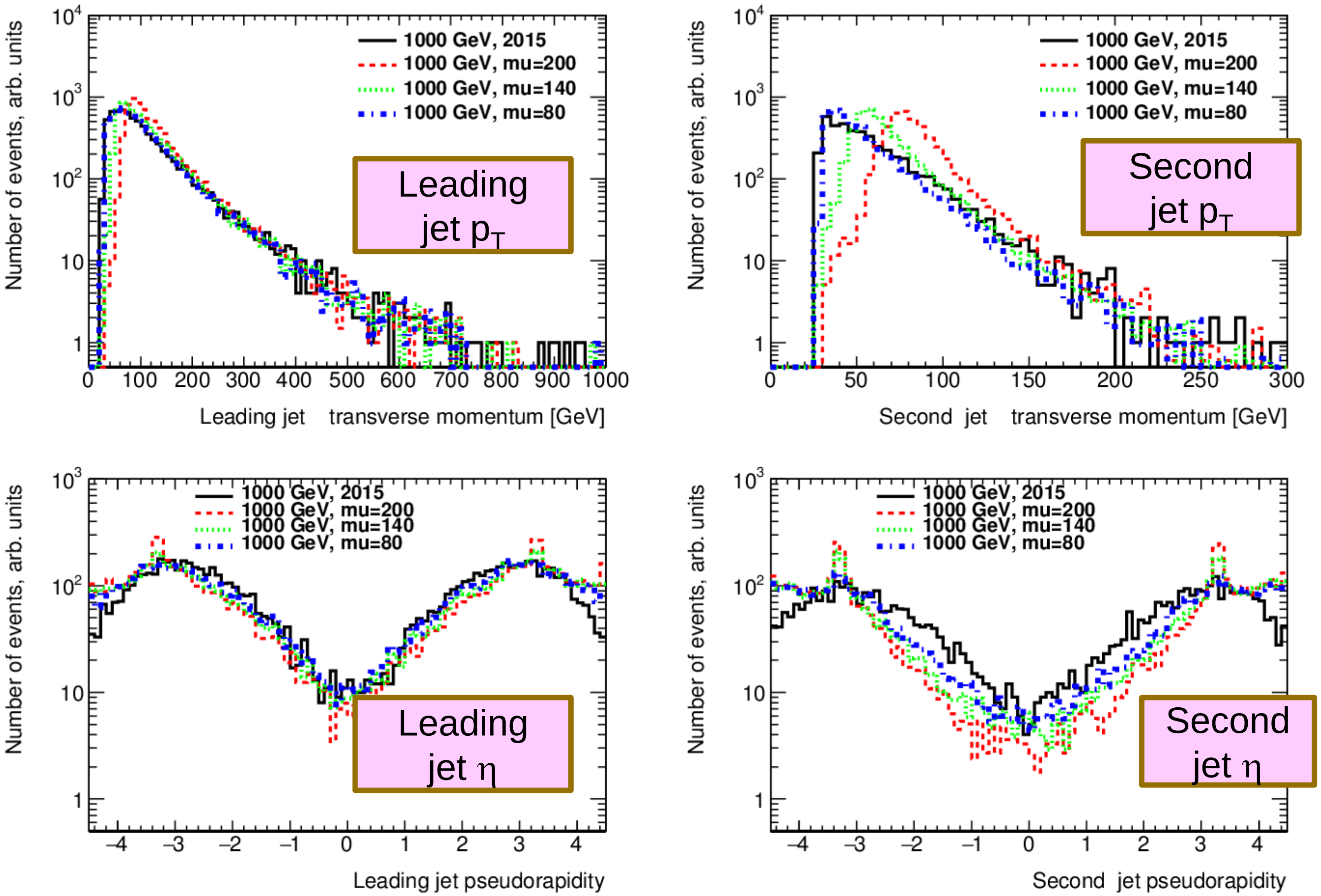
Backup slides

Jet kinematics in H→WW→lνlν events: μμ-case



Much harder jet p$_T$ at high luminosity, especially for second jet
Much more forward jets at high μ, "bunny ears" at EC/FCal boundary

Jet kinematics in H→WW→lνlν events: ee-case



Much harder jet p_T at high luminosity, especially for second jet
Much more forward jets at higher μ, "bunny ears" at EC/FCal boundary

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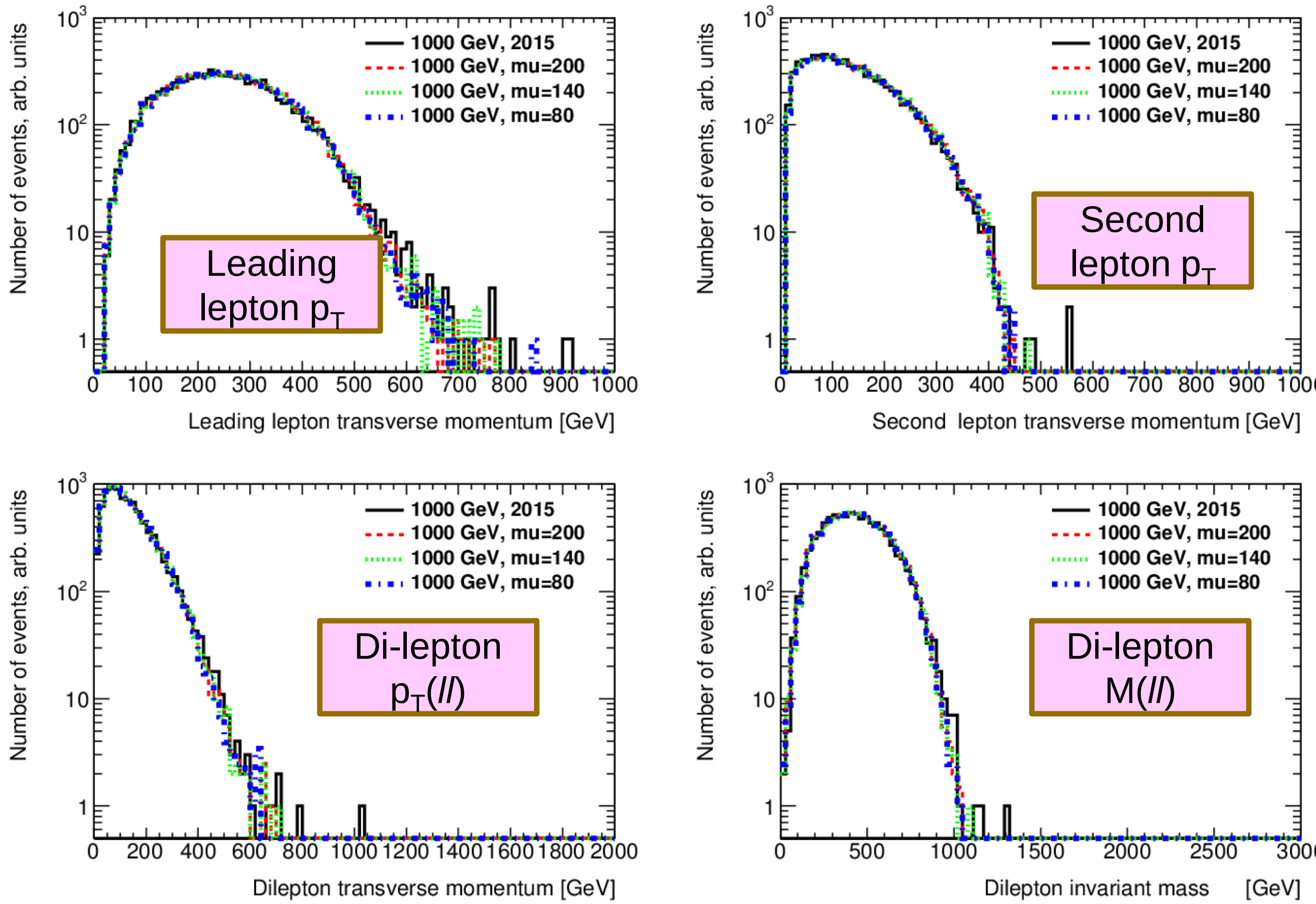
Lepton kinematics in H→WW→lνlν events: μμ-case



No sizeable differences between spectra at 2015 year and high μ conditions

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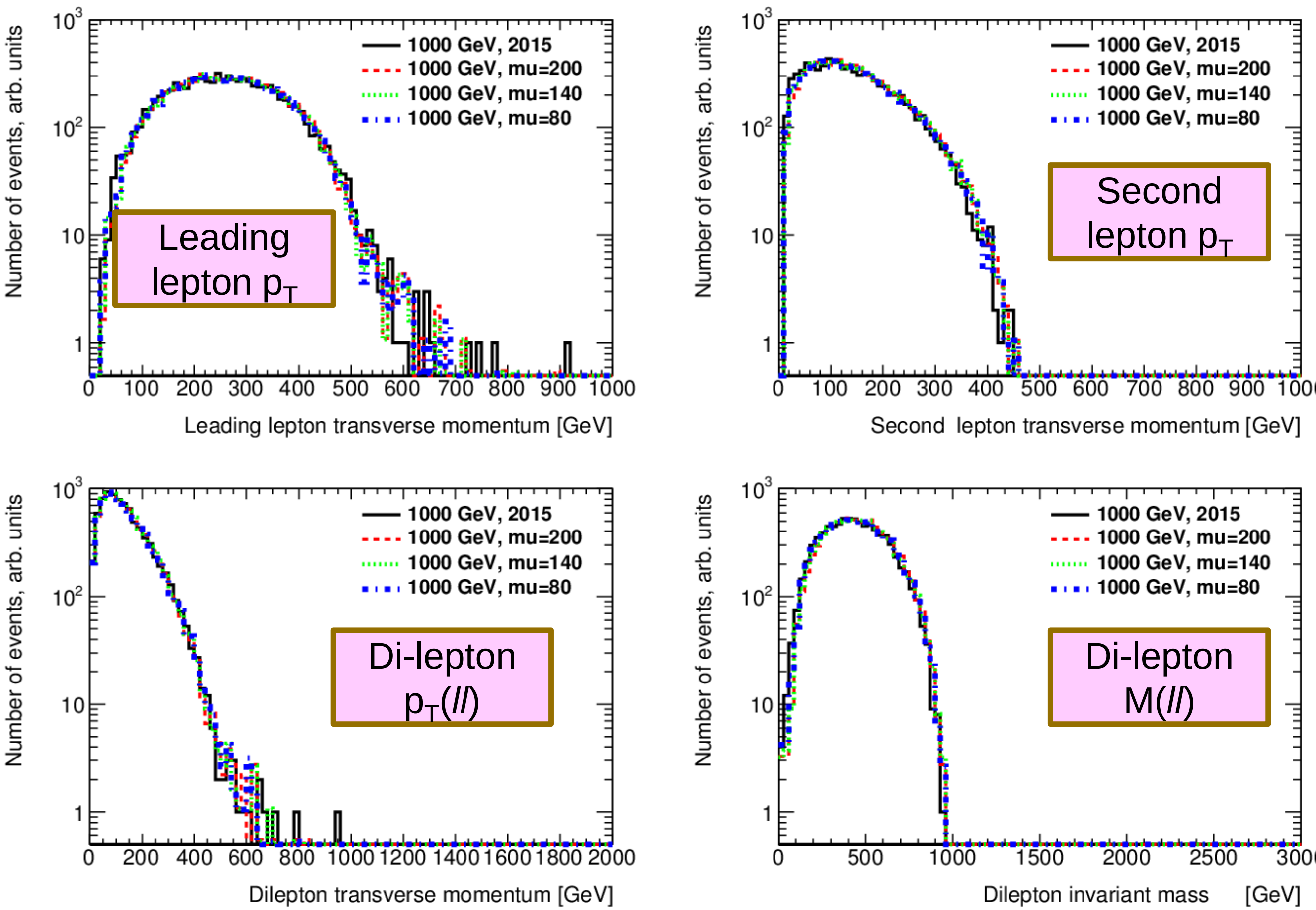
Lepton kinematics in H→WW→lvlv events: ee-case



No big differences between spectra at 2015 year and high μ conditions
However slightly harder M(ll) and p_T(l2)-distributions

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