



# Signal acceptance in 2lss

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ttH multi-lepton meeting  
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# Generator level acceptance study



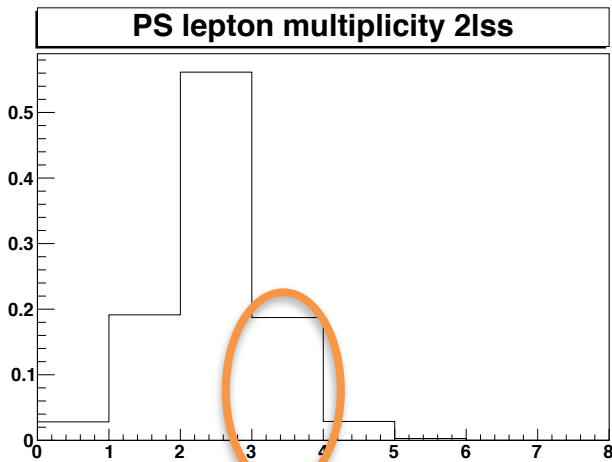
- Starting with signal skim, looking only at  $H \rightarrow WW, ZZ$  tautau decays, categorizing events at gen level into
  - 2lss
  - 3l
  - $\geq 4l$
- Based on robust prompt flags present in miniAOD
- “pure multi-lep signal” skim



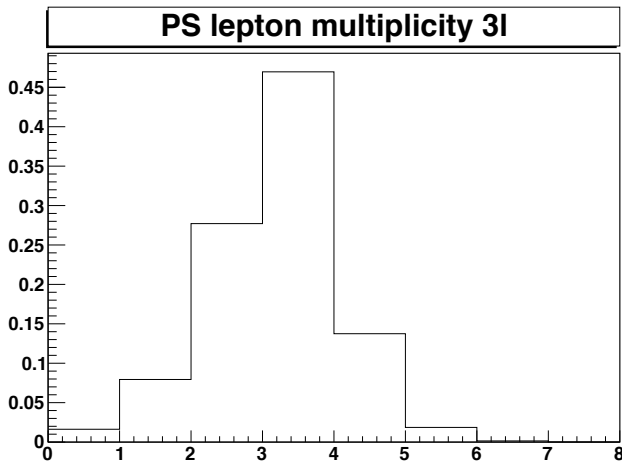
# Preselected lepton multiplicity



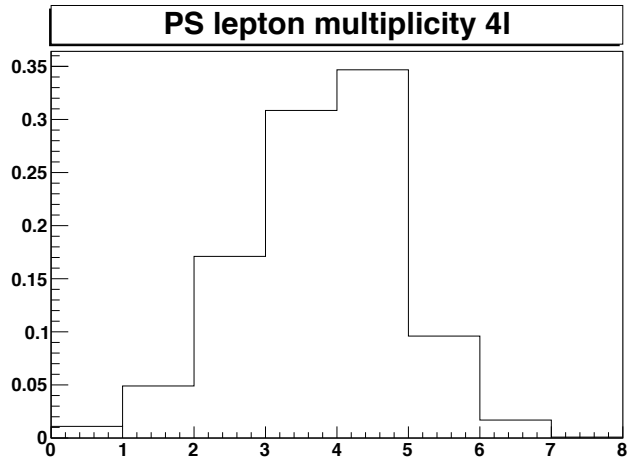
- PS lepton multiplicity by GEN category
- Normalized to 1
- **Extra PS leptons in 2lss**



bin	yield
== 0 PS leptons	3%
== 1 PS leptons	19%
== 2 PS leptons	56%
== 3 PS leptons	19%
== 4 PS leptons	3%



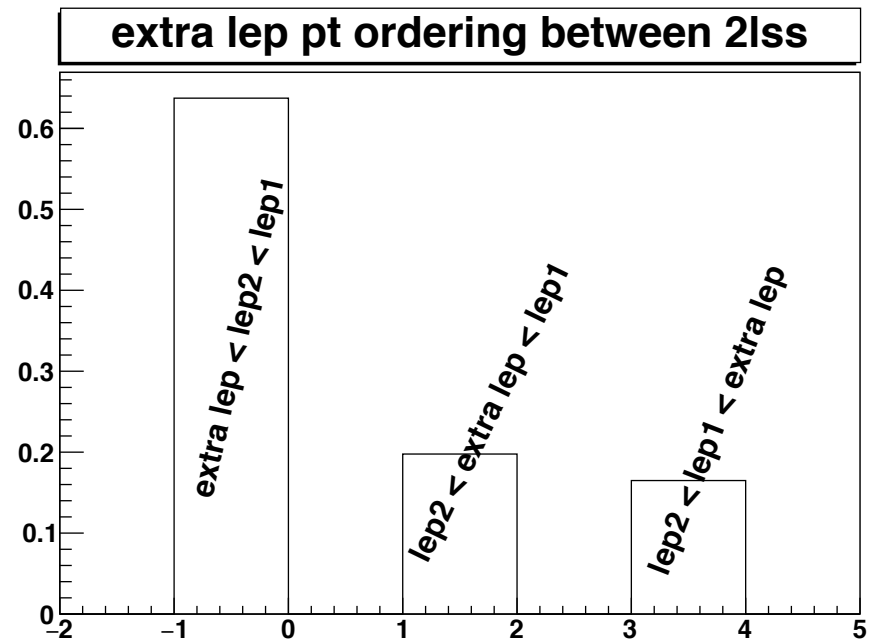
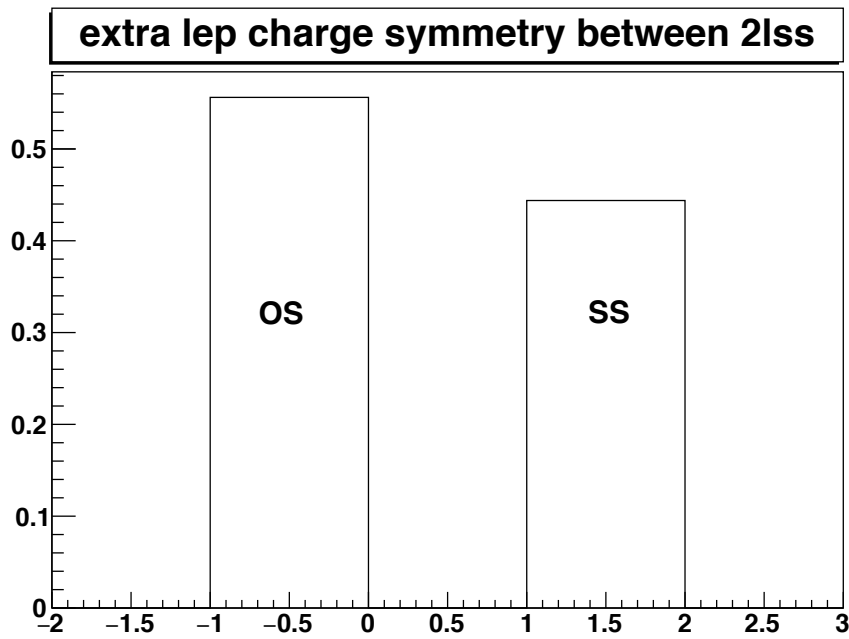
bin	yield
== 0 PS leptons	2%
== 1 PS leptons	8%
== 2 PS leptons	28%
== 3 PS leptons	47%
== 4 PS leptons	14%
== 5 PS leptons	2%



bin	yield
== 0 PS leptons	1%
== 1 PS leptons	5%
== 2 PS leptons	17%
== 3 PS leptons	31%
== 4 PS leptons	35%
== 5 PS leptons	10%
== 6 PS leptons	2%

# Properties of extra PS lep in 2lss

- How often is the charge of the extra lepton opposite to the prompt SS lepton charges?  
- 56% of the time
- How often is the pT of the extra lepton lower than the the pT of the two prompt leptons?  
- **64% of the time**
- Normalized to 1

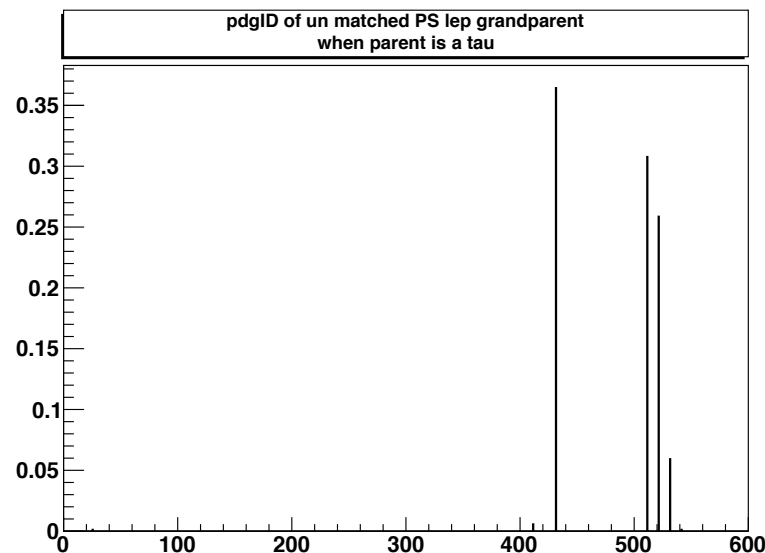
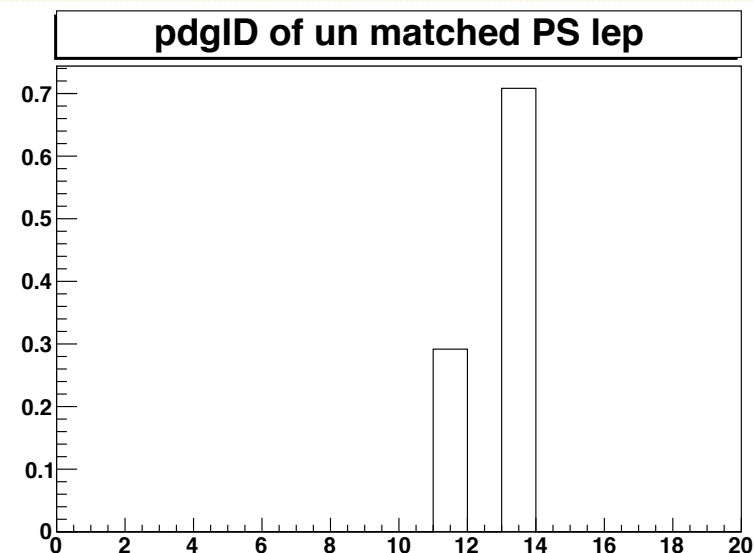
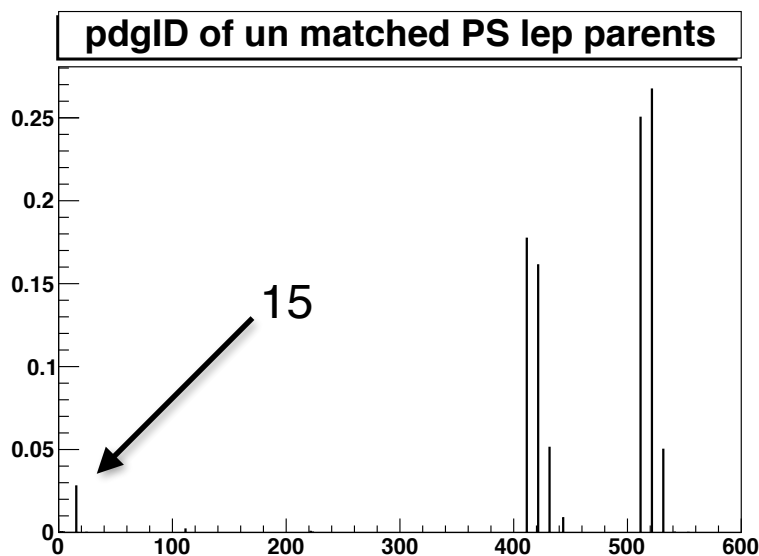




# Origins of “extra” PS leptons in 2lss



- When # PS leptons  $> 2$  in 2lss
- pdg ID of the particle, parent, grandparent of the extra unmatched PS lepton(s)
- hists normalized to 1





# Recovering extra PS leptons in 2lss



- Since the extra PS leptons in 2lss are coming from non-prompt/hadronic parents they are very unlikely to pass the 3l,4l selections
- To avoiding complicating the FR sideband, can recover up to:  $19\% \times 0.64 = \mathbf{12\%}$  of 2lss events assuming
  - They fail the 3l signal selection
  - The leading 2 leptons pass 2lss selection
- Proposal: modify 2lss selection to accept these events



# Original 2lss selection



- $P_t > 20, 20$
- $== 2 \text{ PS} \ \&\& \ == 2 \text{ tight}$
- same sign
- $\geq 4$  jets
- $\text{MET LD} > 0.2$
- $\text{lep1 pt} + \text{lep2 pt} + \text{MET} > 100$
- Z veto (10 GeV window) for ee
- charge flip for muons and electrons
  - $\text{track pt} / \text{error track pt} > .2$  (mu)
  - $\text{isGsfCtfScPixChargeConsistent} = \text{true}$  (ele)



# Proposed 2lss selection



- Same as original selection except changing from:
  - $= 2PS \text{ AND } = 2t$
- to:
  - $(= 2PS \text{ AND } = 2t) \text{ OR } (= 3PS \text{ AND } = 2t \text{ AND } PS_{lep3.pt} < tight_{lep2.pt})$
- Where
  - $PS_{lep3.pt} < PS_{lep2.pt} < PS_{lep1.pt}$
  - $tight_{lep2.pt} < tight_{lep1.pt}$
- Requiring the third PS lepton have the lowest pt does not complicate the FR calculation



# RECO event selections

- numerator = events passing event selection
- denominator = events in gen category

Original 2lss selection

	<i>GEN 2lss</i>	<i>GEN 3l</i>	<i>GEN <math>\geq 4l</math></i>
<i>RECO 2lss selection</i>	<b>9.7%</b>	0%	0.4%
<i>RECO 3l selection</i>	3%	<b>8.6%</b>	3.8%
<i>RECO 4l selection</i>	1.2%	5.1%	<b>15.2%</b>

New 2lss selection

	<i>GEN 2lss</i>	<i>GEN 3l</i>	<i>GEN <math>\geq 4l</math></i>
<i>RECO 2lss selection</i>	<b>11.9%</b>	0%	0.4%
<i>RECO 3l selection</i>	3%	<b>8.6%</b>	3.8%
<i>RECO 4l selection</i>	1.2%	5.1%	<b>15.2%</b>



# RECO event selections event yields by GEN category



- Yields are # of events passing each RECO selection by GEN category
- 23% increase in events in 2lss when adopting new 2lss selection

Original 2lss selection

	<i>GEN 2lss</i>	<i>GEN 3l</i>	<i>GEN <math>\geq 4l</math></i>
<i>RECO 2lss selection</i>	<b>3702</b>	15	144
<i>RECO 3l selection</i>	505	<b>2809</b>	1253
<i>RECO 4l selection</i>	30	219	<b>653</b>

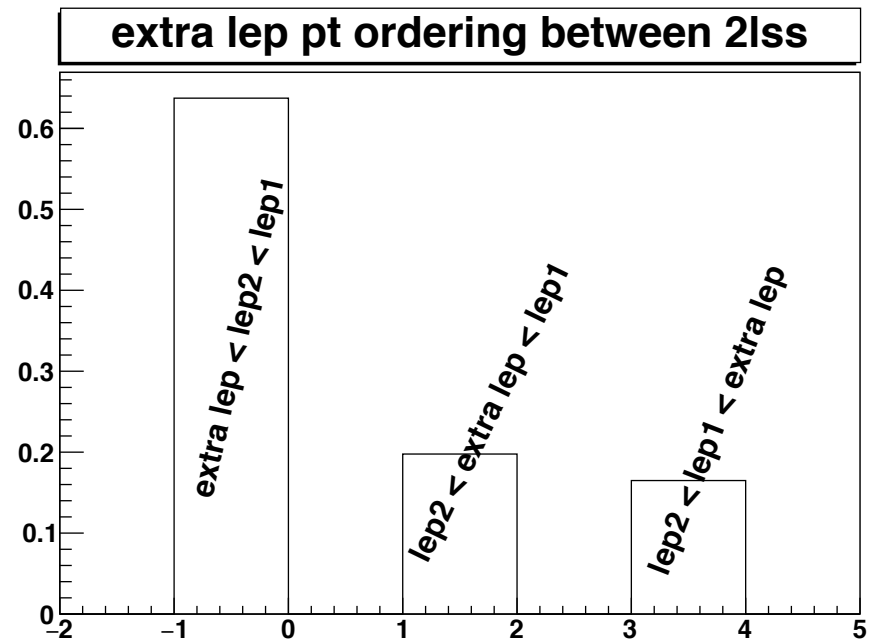
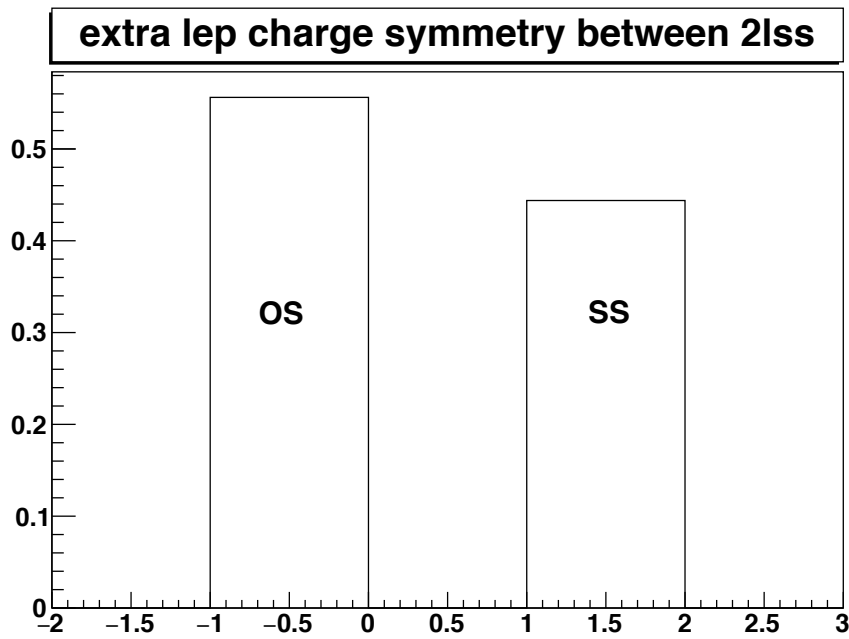
New 2lss selection

	<i>GEN 2lss</i>	<i>GEN 3l</i>	<i>GEN <math>\geq 4l</math></i>
<i>RECO 2lss selection</i>	<b>4562</b>	15	144
<i>RECO 3l selection</i>	505	<b>2809</b>	1253
<i>RECO 4l selection</i>	30	219	<b>653</b>

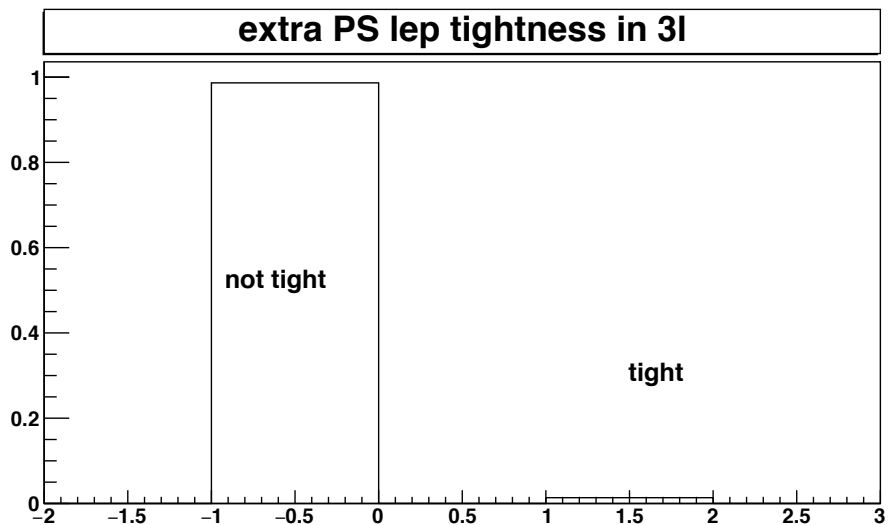
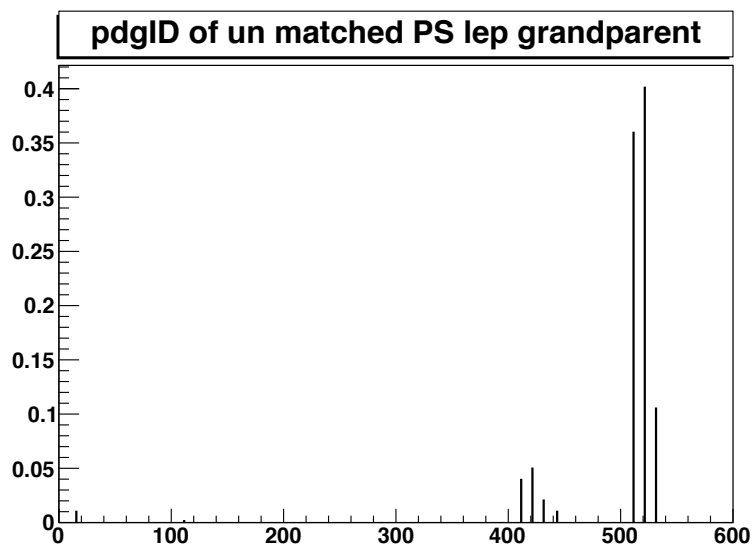
- Running over Spring '15 MC
  - $S = ttH$
  - $B = t\bar{t}b + t\bar{t}W$
- @  $3 \text{ fb}^{-1}$ 
  - $[S/\sqrt{B}]_{\text{old 2lss selection}} = 0.396$
  - $[S/\sqrt{B}]_{\text{new 2lss selection}} = 0.444$
- @  $10 \text{ fb}^{-1}$ 
  - $[S/\sqrt{B}]_{\text{old 2lss selection}} = 0.723$
  - $[S/\sqrt{B}]_{\text{new 2lss selection}} = 0.810$
- **12% improvement in  $S/\sqrt{B}$  (for 2lss only) with new selection**
  - $S/\sqrt{B}$  calculated with events passing 2lss selection only, no further signal extraction/discriminators applied
  - No lepton flavor categorization (ee,  $\mu\mu$ , e $\mu$ )
  - No hadronic tau multiplicity categorization

# Properties of 4th PS lep in 3l

- How often is the charge sum of the 4 PS  $\neq 0$ ?
  - 56% of the time
- How often is the pT of the extra lepton lower than the the pT of the three prompt leptons?
  - **64% of the time**
- Normalized to 1



# percentage of 4th PS lepton in 3l





# Summary



- To be repeated with:
  - preselection
  - lep MVA
  - synchronization
  - trigger selections +  $p_T$  thresholds
- Further improvements to 2l selection being evaluated
- Studying similar techniques in 3l



# Backup





# Samples



- ttH:
  - ttHJetToNonbb\_M125\_13TeV\_amcatnloFFFX\_madspin\_pythia8\_mWCutfix/RunIISpring15DR74-Asympt25ns\_MCRUN2\_74\_V9-v1/MINIAODSIM
- ttbar:
  - TTJets\_TuneCUETP8M1\_13TeV-amcatnloFFFX-pythia8/RunIISpring15DR74-Asympt25ns\_MCRUN2\_74\_V9-v1/MINIAODSIM
- ttW:
  - TTWJetsToLNu\_TuneCUETP8M1\_13TeV-amcatnloFFFX-madspin-pythia8/RunIISpring15DR74-Asympt25ns\_MCRUN2\_74\_V9-v1/MINIAODSIM



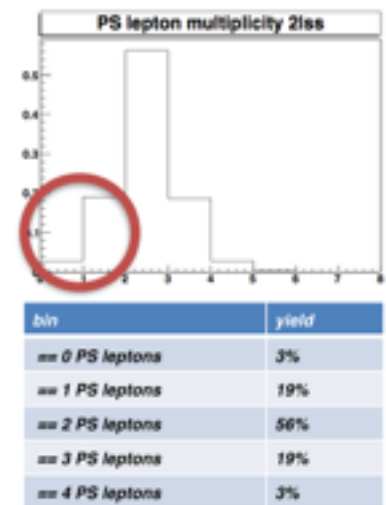


# Selection definitions



- Muons
  - Preselection
    - $p_T > 5$ ,  $|\eta| < 2.4$
    - isGlobalMuon OR isTrackerMuon
    - isPFMuon
  - Tight selection
    - Medium ID
- Electrons
  - Preselection
    - $p_T > 7$ ,  $|\eta| < 2.5$
    - passes eleMVA ID
    - num missing inner hits  $\leq 1$
  - Tight selection
    - pass conversion veto
    - num missing inner hits = 0
- Common
  - Preselection
    - $|d_{xy}| < 0.05$ ,  $|d_z| < 0.1$
    - remove electrons within  $dR \leq 0.05$  of preselected muons
  - Tight selection
    - lepMVA  $> 0.8$
- Note: no isolation used in preselection

- Overall PS efficiency by GEN category
  - ss2l: **84%**
  - 3l: **87%**
  - $\geq 4l$ : **87%**
- PS efficiency on following slides evaluated for raw leptons in events in the 0,1 PS lepton bins on slide 3





# Analyzing preselection cut efficiencies in 2lss 0,1 PS lep events



- NOT CUT FLOW
- numerator = # of PAT leptons removed by corresponding cut only
- denominator = total # of PAT leptons in skim

## Electrons

<i>Cut</i>	<i>% of unmatched raw PAT objects removed</i>
<b><i>pT &gt; 7</i></b>	<b>49%</b>
<b><i>ele MVA ID</i></b>	<b>92%</b>
<b><i>  eta   &lt; 2.5</i></b>	<b>1%</b>
<b><i>num missing inner hits ≤ 1</i></b>	<b>5%</b>
<b><i>  dxy   &lt; 0.05</i></b>	<b>17%</b>
<b><i>  dz   &lt; 0.1</i></b>	<b>17%</b>
<b><i>minilso &lt; 0.4</i></b>	<b>54%</b>

## Muons

<i>Cut</i>	<i>% of unmatched raw PAT objects removed</i>
<b><i>pT &gt; 5</i></b>	<b>75%</b>
<b><i>isPFMuon</i></b>	<b>24%</b>
<b><i>  eta   &lt; 2.4</i></b>	<b>5%</b>
<b><i>isGlobalMuon OR isTrackerMuon</i></b>	<b>4%</b>
<b><i>  dxy   &lt; 0.05</i></b>	<b>14%</b>
<b><i>  dz   &lt; 0.1</i></b>	<b>35%</b>
<b><i>minilso &lt; 0.4</i></b>	<b>42%</b>



# Analyzing uncorrelated preselection cut efficiencies in 2lss 0,1 PS lep events



- Numerator = # of objects failing cut when it passes all other cuts
- Denominator = # of objects in skim
- objects = raw PAT leptons

Electrons

Cut	% of objects failing <i>ONLY</i> this cut
$pT > 7$	0
ele MVA ID	13%
$ \eta  < 2.5$	0
num missing inner hits $\leq 1$	0
$ d_{xy}  < 0.05$	2%
$ d_z  < 0.1$	1%
minilso $< 0.4$	0

Muons

Cut	% of objects failing <i>only</i> this cut
$pT > 5$	25%
isPFMuon	2%
$ \eta  < 2.4$	3%
isGlobalMuon OR isTrackerMuon	0
$ d_{xy}  < 0.05$	1%
$ d_z  < 0.1$	2%
minilso $< 0.4$	0

\*not adjusted for negative weights



# Categorized acceptance



yield = # of events in category remaining after cut / total # of events in category  
cutting on PAT leptons  
'PS' and 'tight' defined on slide 4

## 2lss gen events

<i>cut</i>	<i>yield</i>
<b>== 2 PS leptons</b>	<b>58%</b>
<b>≥ 2 PS leptons</b>	<b>84%</b>
<b>&gt; 2 PS leptons</b>	<b>26%</b>
<b>== 2 tight leptons</b>	<b>31%</b>
<b>≥ 2 tight leptons</b>	<b>32%</b>
<b>&gt; 2 tight leptons</b>	<b>1%</b>

## 3l gen events

<i>cut</i>	<i>yield</i>
<b>== 2 PS leptons</b>	<b>23%</b>
<b>== 3 PS leptons</b>	<b>53%</b>
<b>≥ 3 PS leptons</b>	<b>72%</b>

## ≥ 4l gen events

<i>cut</i>	<i>yield</i>
<b>== 2 PS leptons</b>	<b>15%</b>
<b>== 3 PS leptons</b>	<b>30%</b>
<b>== 4 PS leptons</b>	<b>39%</b>
<b>≥ 4 PS leptons</b>	<b>51%</b>

- Overall PS efficiency by GEN category (no matching)
  - ss2l: **36%**
  - 3l: **45%**
  - $\geq 4l$ : **50%**
- PS efficiency on following slides evaluated for raw leptons in events in the 0,1 PS lepton bins on slide 3

