Tau polarization in $W \to \tau\nu$ decays at $\sqrt{s} = 13$TeV (preliminary)

Dmitry Kondratyev, Marina Chadeeva

MEPhI, Moscow

Tau Polaization meeting, July 7, 2017

Motivation

- Tau polarization in $W \to \tau\nu$ decays has never been studied before at CMS and at 13 TeV (no published results)
- We study tau polarization in $\tau \to \rho\nu$ channel
- Data: 2016 p-p collizions, 35.6 fb^{-1}
- trigger: HLT_LooseIsoPFTau50_Trk30_eta2p1_MET90

Our study is based on these works:

- Tau polarization in $W \to \tau\nu$ at 7 TeV by ATLAS (result: $P_\tau = -1.06 \pm 0.04(\text{stat})^{+0.05}_{-0.07}(\text{syst})$)
- Tau polarization in $Z \to \tau\tau$ at CMS by V.Cherepanov
- Tau polarization in $Z \to \tau\tau$ at CMS by Y.Takahashi et al. (AN_2016/142)
- Notes on τ reconstruction and ID: JINST 11(01):P01019 (2016), CMS-PAS-TAU-16-002

- SM allows only ν_L and $\tilde{\nu}_R$ (confirmed by experiments by now)
- angular momentum conserves

$\Rightarrow$ we expect determined tau helicity in W rest frame:

$$\left.\begin{array}{lll} \bullet\ \tau_L^- & \text{in} & W^- \to \tau^- \bar{\nu}_\tau \\ \bullet\ \tau_R^+ & \text{in} & W^+ \to \tau^+ \nu_\tau \end{array}\right| \ (J_W = 1)$$

τ polarization:

$$P_\tau = \begin{cases} \dfrac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} & \textit{for} \quad \tau^- \\ \dfrac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} & \textit{for} \quad \tau^+ \end{cases}$$

SM prediction: $P_\tau = -1$ for $W \to \tau\nu$

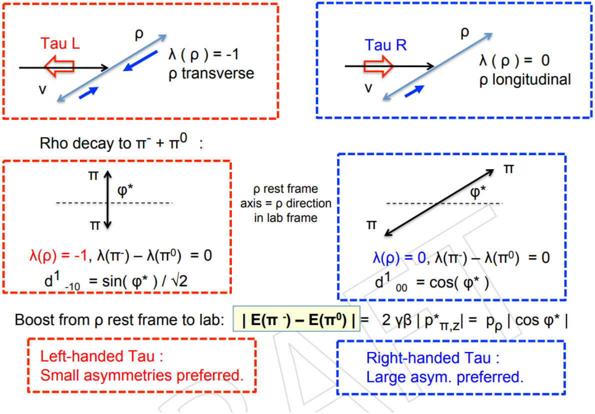
τ decay modes

Decay mode	Meson resonance	BR[%]
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
$\tau^- \to h^- \nu_\tau$		11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	9.5
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other modes with hadrons		3.2
All modes containing hadrons		64.8

Why choosing $\tau^- \to h^- \pi^0 \nu_\tau$?

- branching ratio
- few decay products $\to$ good reconstruction
- sensitivity to τ polarization

Tau polarization observable



(picture from AN2016_142)

Observable: $\Upsilon = 2\frac{p_T^{trk}}{p_T} - 1 \approx \frac{E_T^{\pi^-} - E_T^{\pi^0}}{p_T}$

Tau reconstruction at CMS

Tau leptons are reconstructed using HPS (hadron-plus-strips) algorithm

- algorithm is seeded by jet reconstructed with anti-k_t algorithm
- charged hadrons are reconstructed from tracker
- π^0s are reconstructed as strips in ECAL
- mass window is applied on the invariant mass of reconstructed particles to account for meson resonances
- MVA-based discriminants against e, μ, QCD-jets are applied

Samples

Data: all available 2016 p-p samples, 13TeV (35.6 fb^{-1})

Monte-Carlo: MC is generated using pythia8, where polarization effect is implemented as predicted by the SM

Process	Cross section (pb)	Comments
QCD	720648000	very low statistics, **not used**
W+Jets	61526.7	low statistics, 4 samples united
Drell-Yan	5765.4	
$t\bar{t}$	831.8	
Single top	288.7	Single top; Single top + W
Dibosons	68	WW,WZ,ZZ

Signal ($W \to \tau\nu \to \rho\nu$ events) and background (other events) separated at generator level for visualization purposes.

Uncertainties and trigger

Uncertainties

- Statistical (Data, MC)
- Luminosity uncert. – 6.2%
- Cross-section uncert. – 5%

Trigger

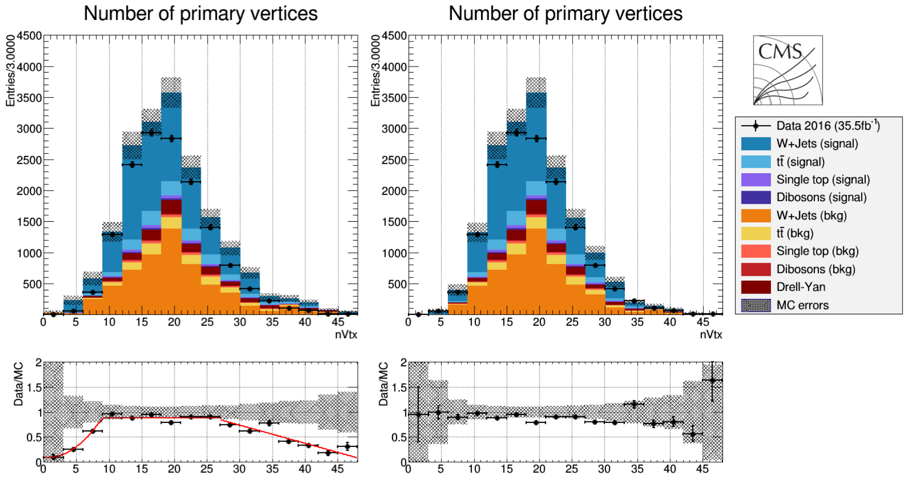
HLT triggers in 13 TeV datasets either tight or prescaled. We haven't yet implemented prescale factors, which is why tight trigger is used:

HLT_LooseIsoPFTau50_Trk30_eta2p1_MET90

Event selection

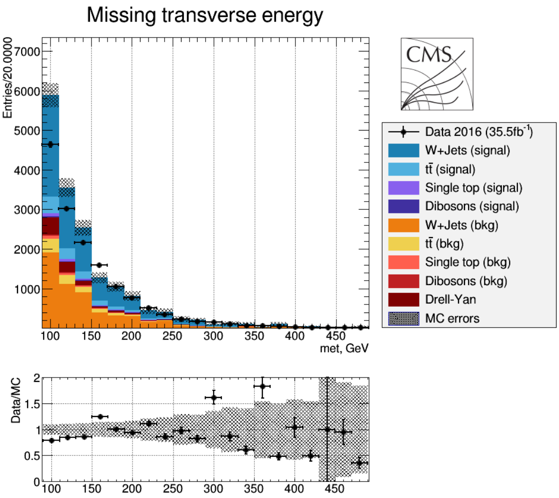
- no electrons or muons with $p_T > 15 GeV$
- τ candidate:
  - decay mode: $\tau \to \rho\nu$
  - HLT cuts:
    - $p_T^{\tau} > 50 GeV$
    - $p_T^{trk.} > 30 GeV$
    - $|\eta| < 2.1$
    - $E_T^{miss.} > 90 GeV$
- dicriminants:
  - medium MVA τ isolation
  - tight muon rejection
  - tight electron rejection
- $p_T^{\pi^0} > 30 GeV$ – to keep Υ distribution symmetric

Pile-up reweighing



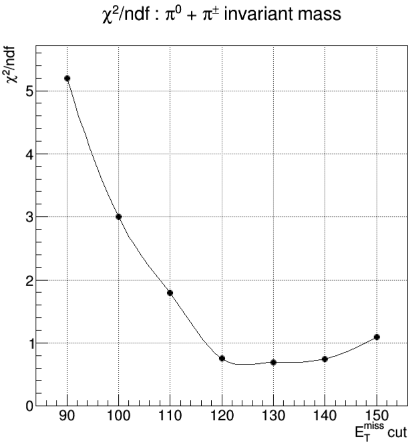
nVtx distributions before (left) and after (right) PU reweighing

E_T^{miss} distribution



Excess of MC events in $E_T^{miss} < 150$ GeV region

E_T^{miss} cut optimization

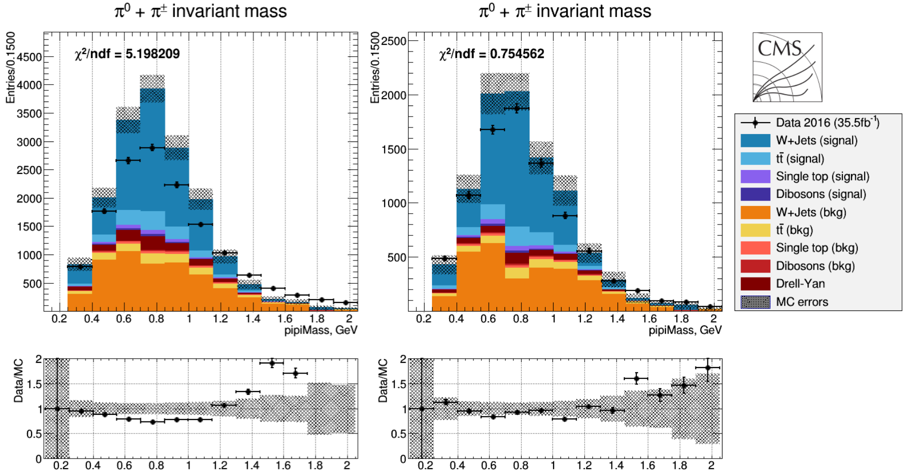


Select minimal E_T^{miss} cut where $\chi^2/n.d.f < 1.5$

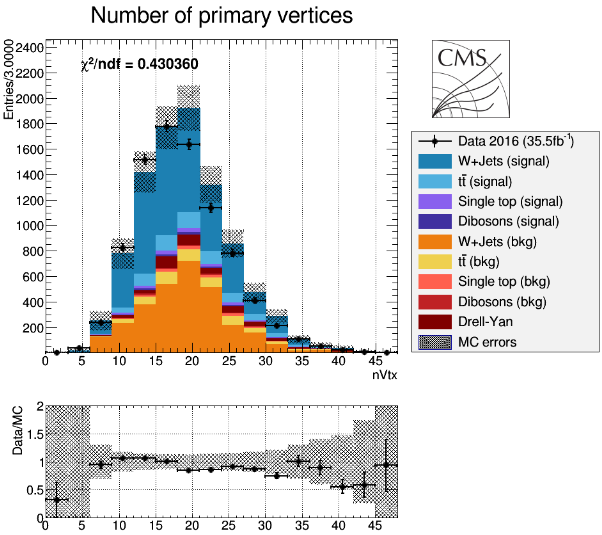
$\Rightarrow E_T^{miss} > 120$

E_T^{miss} cut optimization

Tau visible mass distribution before and after $E_T^{miss} > 120$ cut

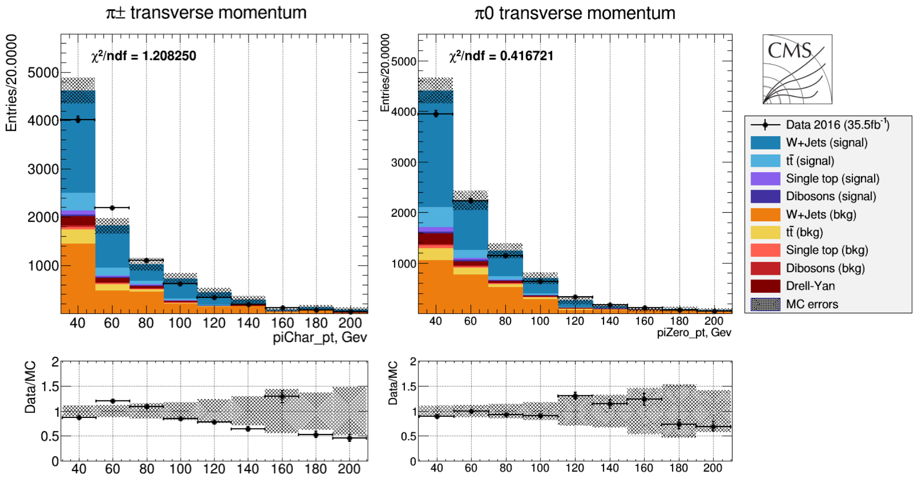


Check that nVtx distributions agree after the E_T^{miss} cut



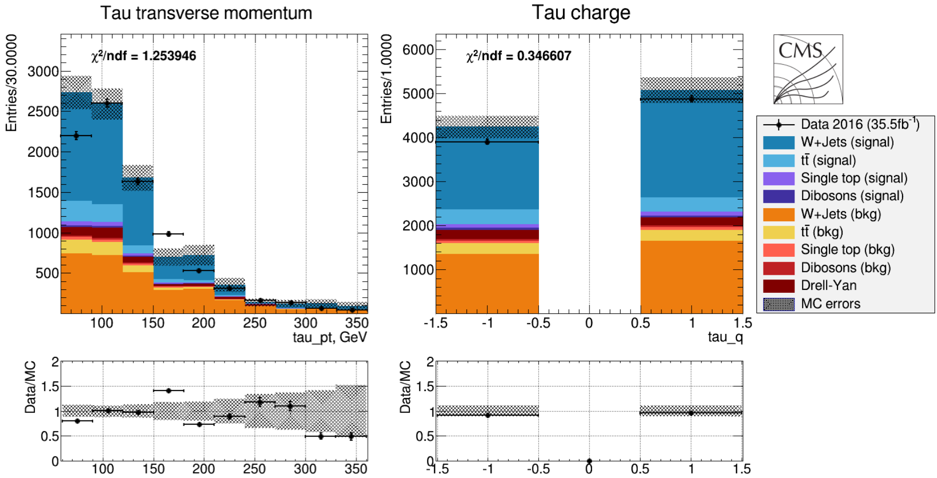
Results

$p_T(\pi^{\pm})$ distribution (left) and $p_T(\pi^0)$ distribution (right)



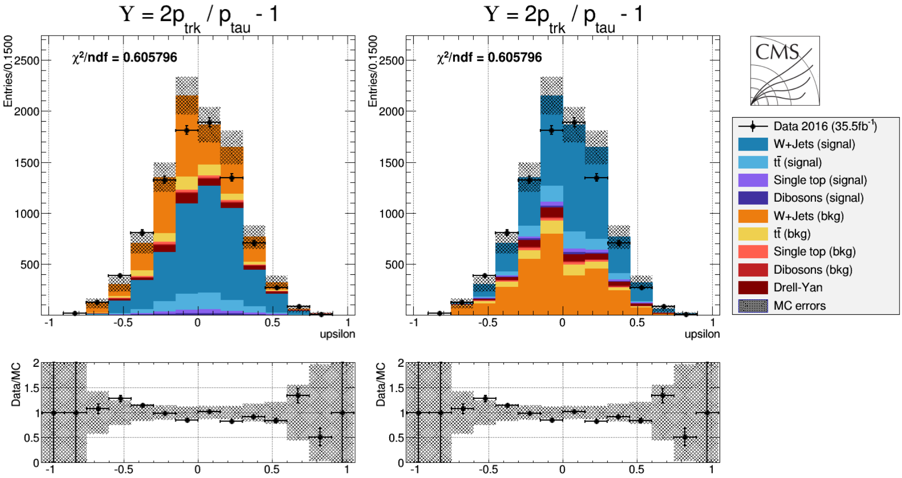
Results

$p_T(\tau_{vis.})$ distribution (left) and tau charge assymetry (right)



Result

(this is the same plot but with different order of MC samples)



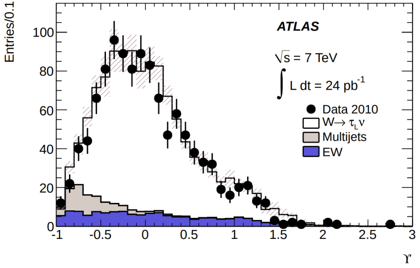
Conclusion:

Data is in agreement with SM within uncertainties

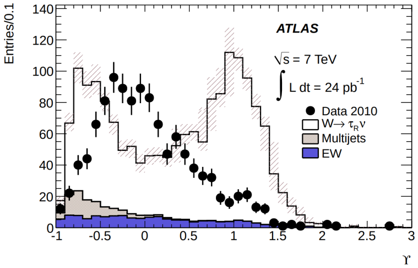
Future plans:

- Implement prescale factors for HLT and use soft trigger to increase MC statistics
- Generate sample with right-handed τ^-
- Calculate the value of polarization P_τ

ATLAS Collaboration, Eur.Phys.J.C (2012) 72:2062



(a) Left-handed



(b) Right-handed

$$P_\tau = -1.06 \pm 0.04(\text{stat})^{+0.05}_{-0.07}(\text{syst})$$