Search for supersymmetry with τ leptons in the CMS experiment

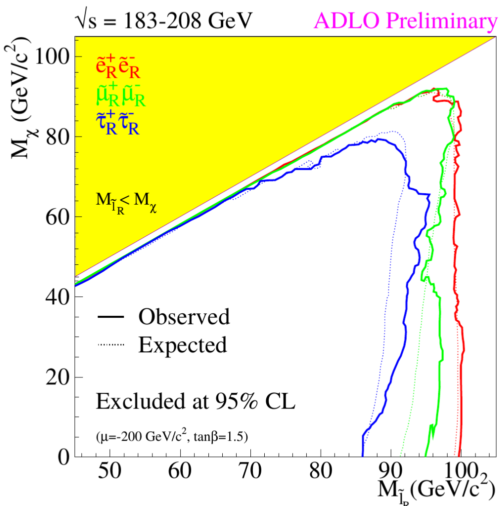
Ilya Bobovnikov, Alexis Kalogeropoulos,

Isabell Melzer-Pellmann, Alexei Raspereza

DPG,Münster, 27-31 March 2017

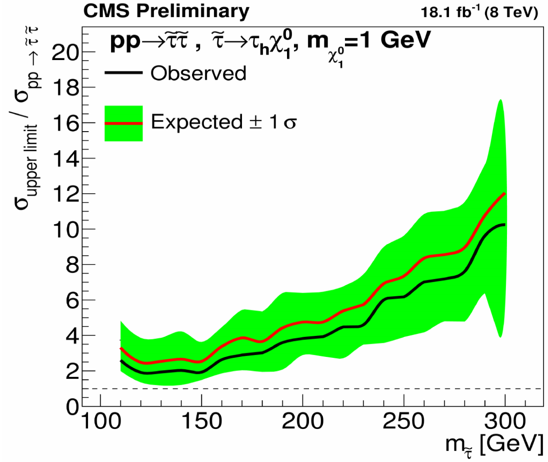
Motivation

LEP results

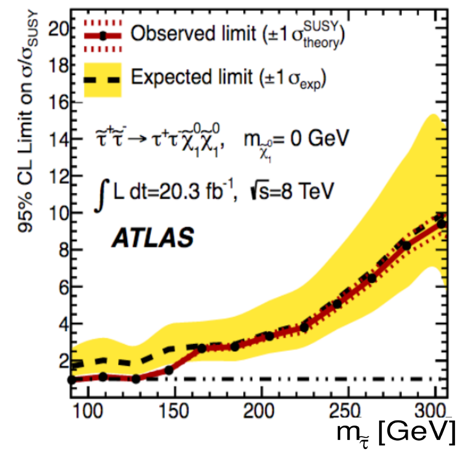


LEP put strong limits on slepton masses

LHC Run1 results



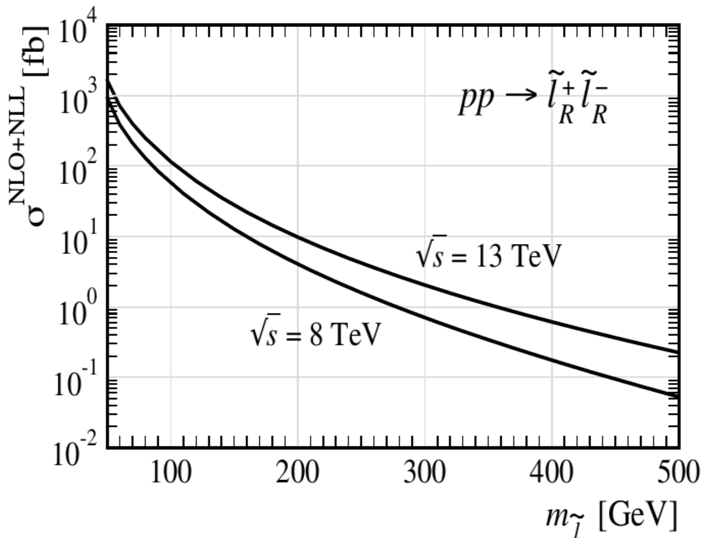
CMS (SUS:14-022)

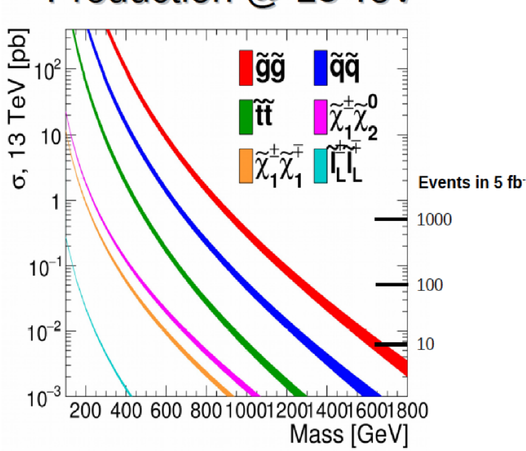


ATLAS (arxiv:1407.0350)

Only one point excluded at 8TeV @ 20 fb^{-1}

SUSY LHC cross sections

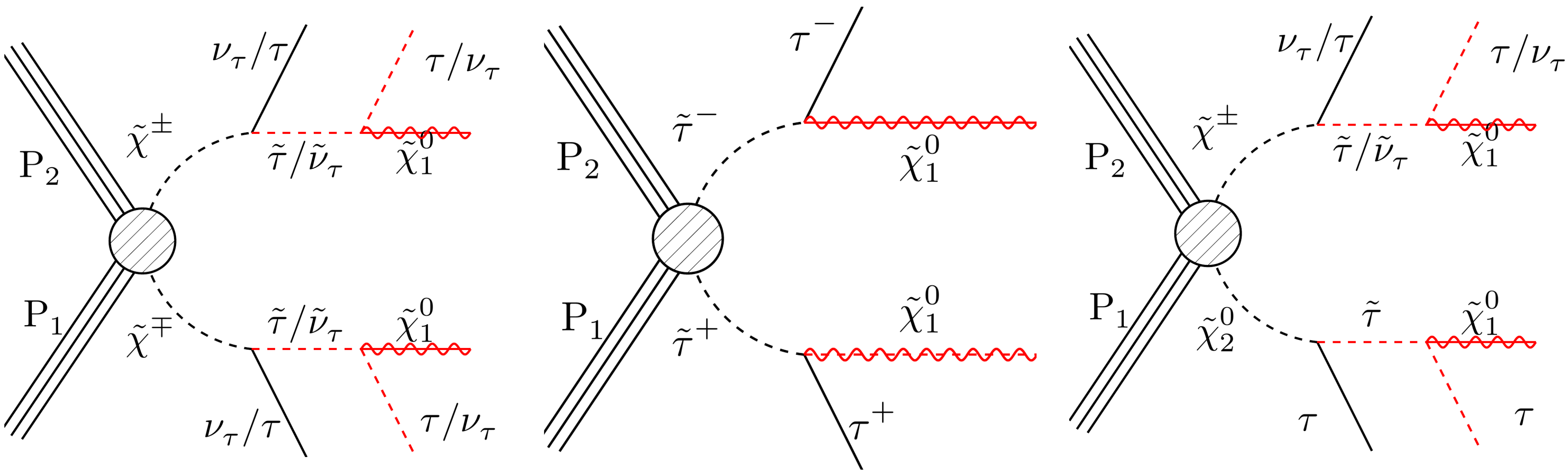




(LPC EWK workshop intro talk)

The cross section is the lowest of all SUSY particles

Models and topologies



Channel	Signature	$\mathcal{BR}$
$0-\ell$	$2\tau_h + \not{E}_T$	$0.65^2 = 0.42$
$1-\ell$	$\tau_\ell \tau_h + \not{E}_T$	$2 \times (0.35 \cdot 0.65) = 0.46$
$2-\ell$	$2\tau_\ell + \not{E}_T$	$0.35^2 = 0.12$

Experimental signature

- Missing transverse energy depends on model parameters
- Small number of jets and no b-tagged jets

Event selection

Baseline selection

- **For μτ, eτ channels**
  - well identified isolated muon or electron, that fires single lepton trigger
  - well identified isolated τ-lepton
  - opposite charge
  - $0.3 < \Delta R < 3.5$
- **For eμ channel**
  - Well identified isolated muon **and** electron, that fire cross trigger (two lepton trigger)
  - opposite charge
  - $\Delta R > 0.3$
- 3rd lepton veto and dilepton veto
- $N_{jet} \leq 1$ and $N_{b\text{-}tag} = 0$
- $20 < M_T < 60$ GeV or $M_T > 120$ GeV (μτ, eτ)

  (to suppress Wjets bkg.)
- $M_{ll} < 30$ GeV and $100 \text{ GeV} < M_{ll} < 250$ GeV (eμ)

  (to suppress DY bkg.)

$\Delta R^2 = \Delta\varphi^2 + \Delta\eta^2$, where $\Delta\varphi$ and $\Delta\eta$ are distances between leptons in (φ,η) plane

$$M_T = \sqrt{2P_T^{\ell} E_T^{\text{miss}}(1 - cos(\Delta\Phi(\ell, E_T^{\text{miss}}))}$$

M_T was initially introduced at UA1 to measure M_W ($M_T < M_W$)

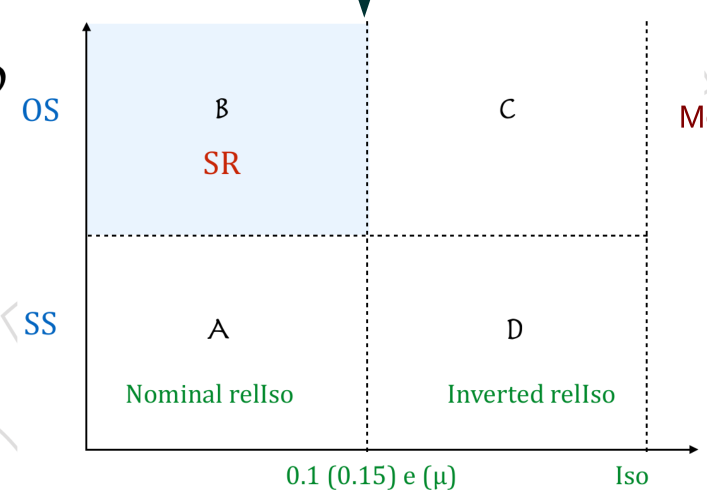
Additional cuts to increase signal to background ratio are applied (called as **Signal Region cuts**)

Backgrounds estimations

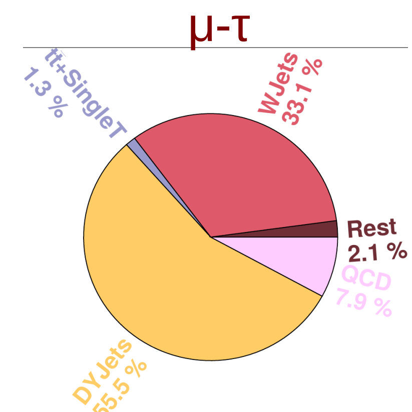
Background	Shape	Norm.	Selection of CR
TTJets	MC(corrected)	CR	μ-e + cuts (92% pur.),Norm~0.95
WJets	MC(corrected)	CR	μ-τ + cuts (85% pur.),Norm~0.96
DYJets	MC(corrected)	CR	μ-μ + cuts (99% pur.): Norm~0.945
Rest	MC(corrected)	-	-
QCD	Region A	C/D	**A** Same Sign, Nominal relIso **B**, Opposite Sign, Nominal relIso (SR) **C** ,Opposite Sign, Inverted relIso **D**, Same Sign, Inverted relIso

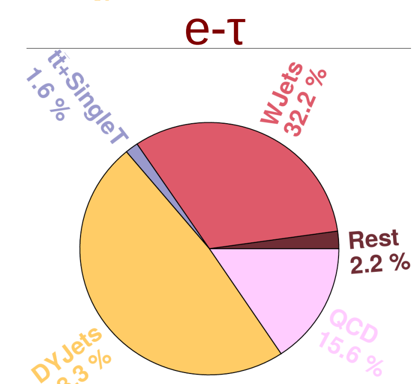
Very limited number of events from QCD MC

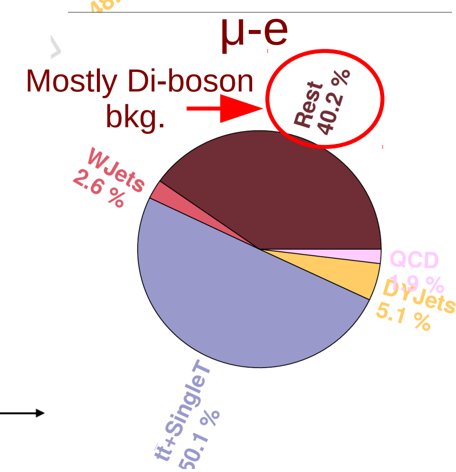
$$N_{\mathcal{B}} = N_{\mathcal{A}} \cdot N_{\mathcal{C}} \,/\, N_{\mathcal{D}}$$



- Subtract all other processes in each region (taken from MC)
- Inverted relIso gives high QCD purity
- Search variables are expected to be uncorrelated with leptons charge

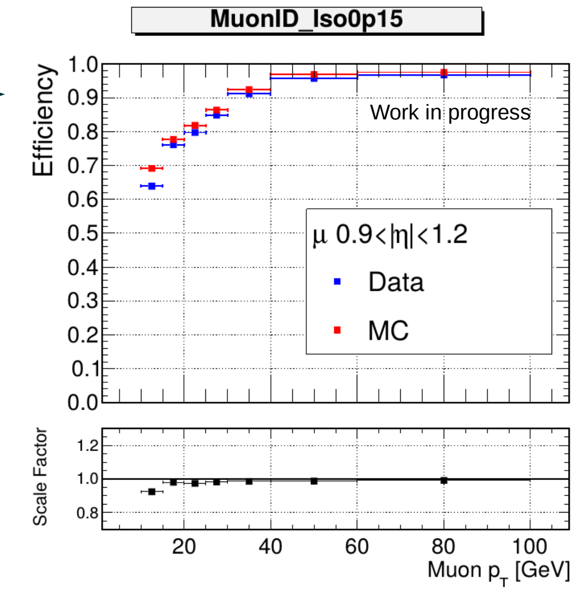


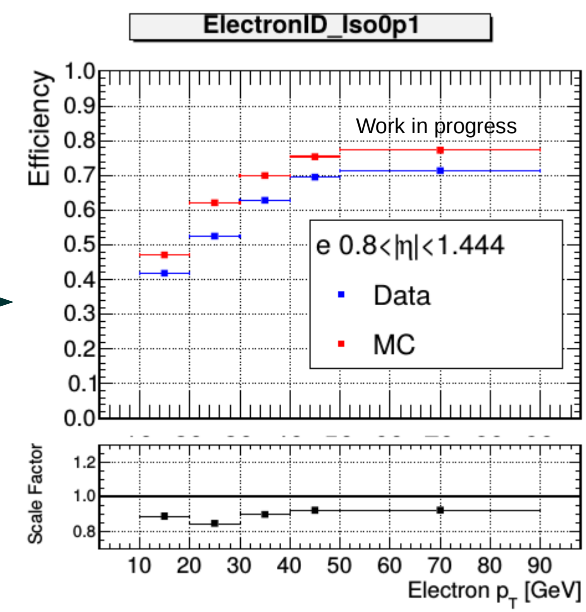


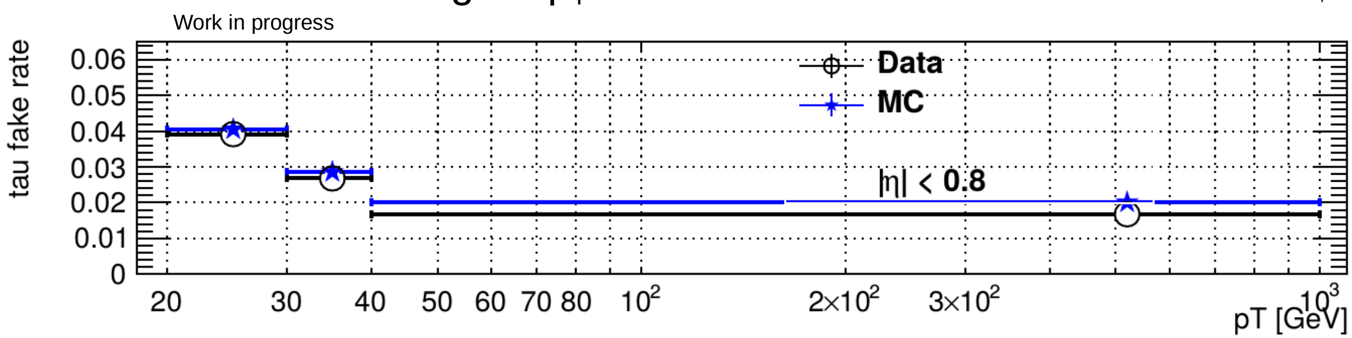


Corrections

- **Trigger and Lepton scale factors** (efficiencies have been obtained with *Tag & Probe* method from Z → μμ and Z → ee selection)
- **Muon and Electrons Tau fake rate**: these are obtained from the TAU POG.
- **Tau fake rate**: Measuring the jets→tau fake from a Wjets enriched CR Applying nominal preselection of μ-τ
- **Top p_T reweighting**: to improve modelling of the top quark p_T spectrum
- **Z recoil corrections**: corrections to the the parallel and perpendicular parts of the E_T^{miss} (extracted from Z → μμ selection, applied to Z-jets and W-jets events)
- **Z p_T corrections**: applied to describe the disagreement of data and simulation at high Z p_T





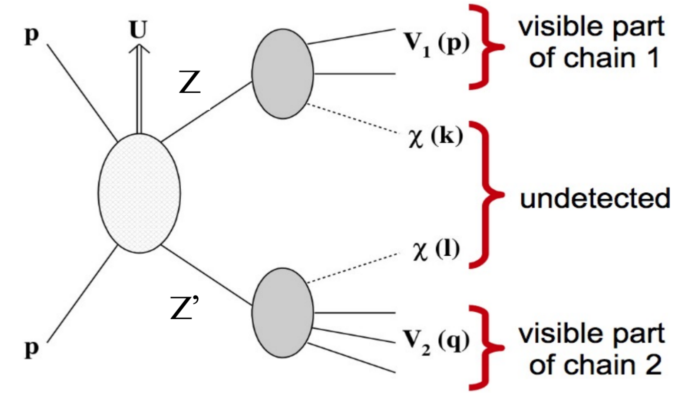


Search variables

- **E_T^{miss}** – missing transverse energy
- **$M_{T2Lester}$** – modification of the commonly used M_{T2} (Very useful in asymmetric case, **$M_{T2Lester} \geq M_{T2}$**)

  (arXiv : 1411.4312)

$$M_{T2}^2 = \min_{\vec{k}_T + \vec{l}_T = \text{tot miss } \vec{p}_T} \left\{ \max\left[M_T^2(\text{chain 1}), M_T^2(\text{chain 2}) \right] \right\} \leq m_Z^2$$



- ***D_ζ*** – Discriminant used in legacy Higgs searches

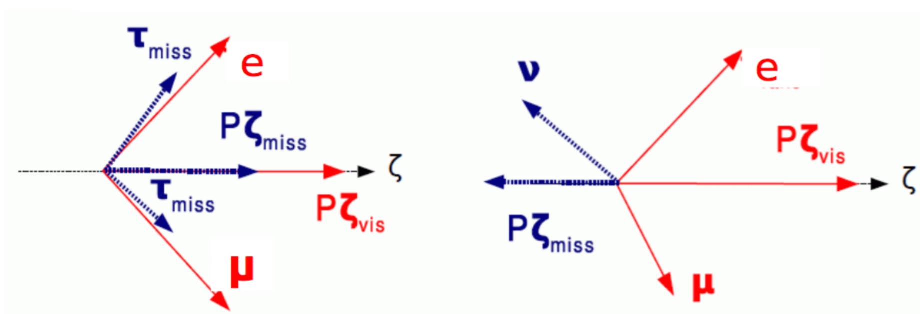
$$D_\zeta = P_\zeta^{\text{miss}} - \alpha P_\zeta^{\text{vis}}$$

$$P_\zeta^{\text{miss}} = \vec{p}_T^{\text{miss}} \cdot \vec{\zeta} \text{ and } P_\zeta^{\text{vis}} = (\vec{p}_T^{\ell_1} + \vec{p}_T^{\ell_2}) \cdot \vec{\zeta}$$

ζ – bisector between the direction of the electron and that of the muon

α = 0.85 (optimized value)

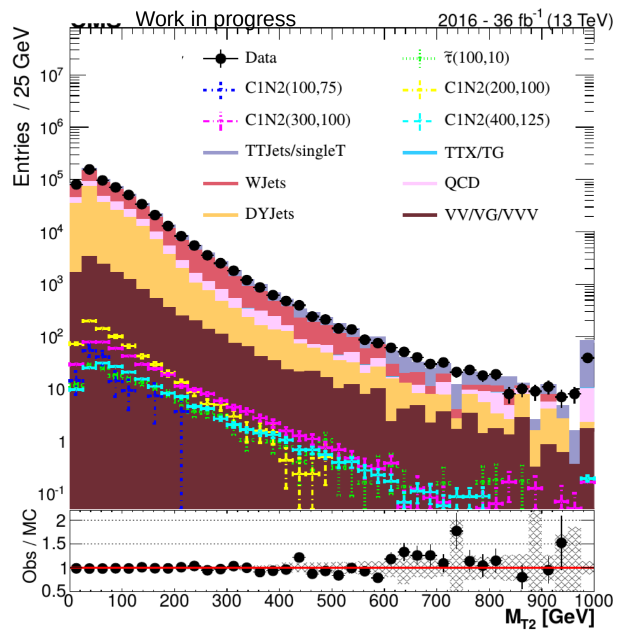
DYJets **TTJets,WJets (signal)**

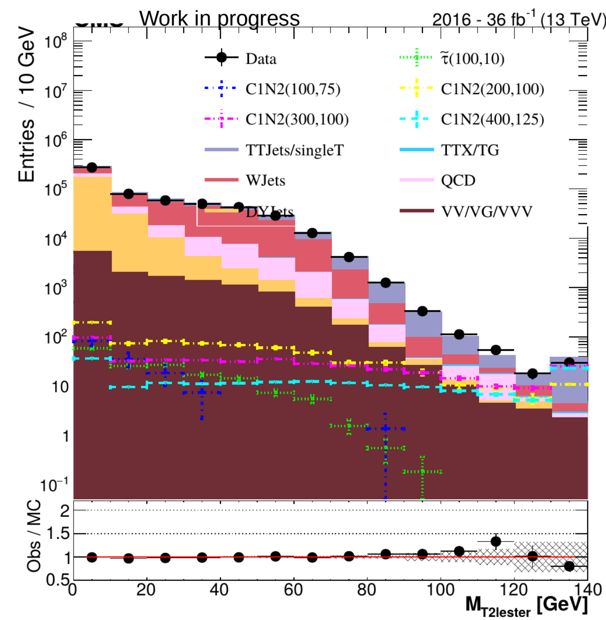


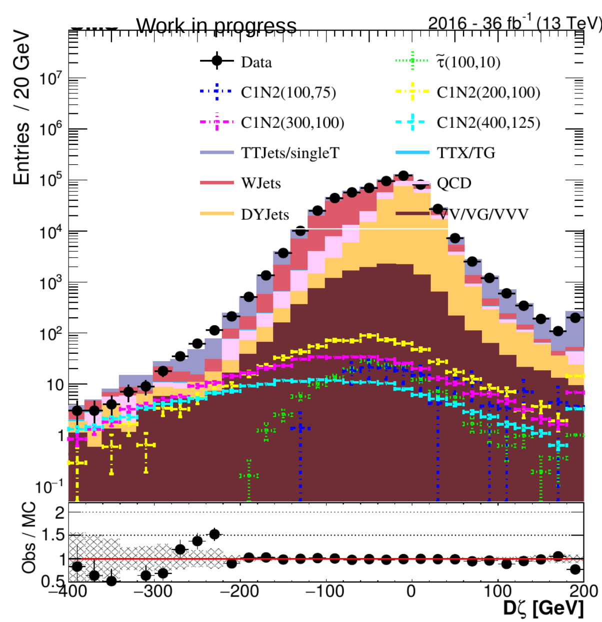
Control plots (μ-τ)

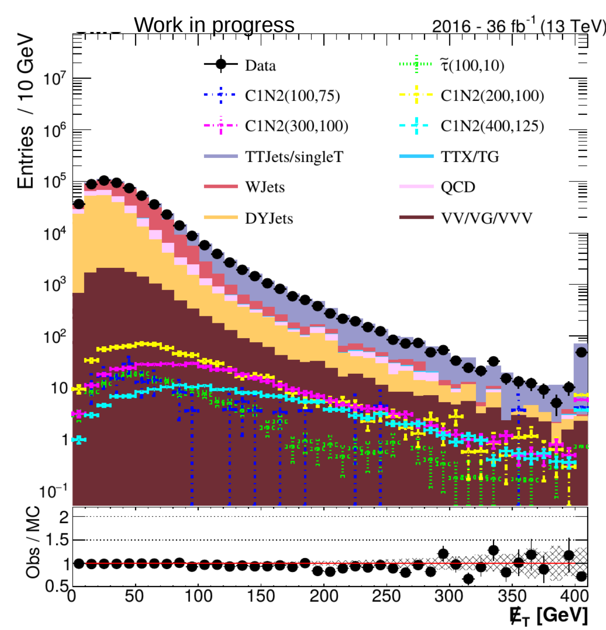
Distributions after baseline selection

Agreement between data and MC looks good





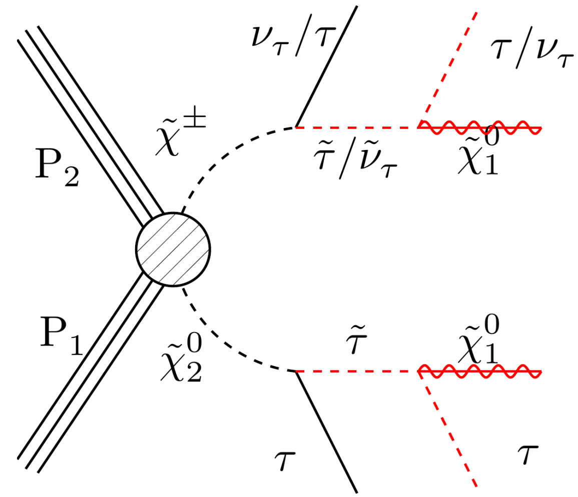


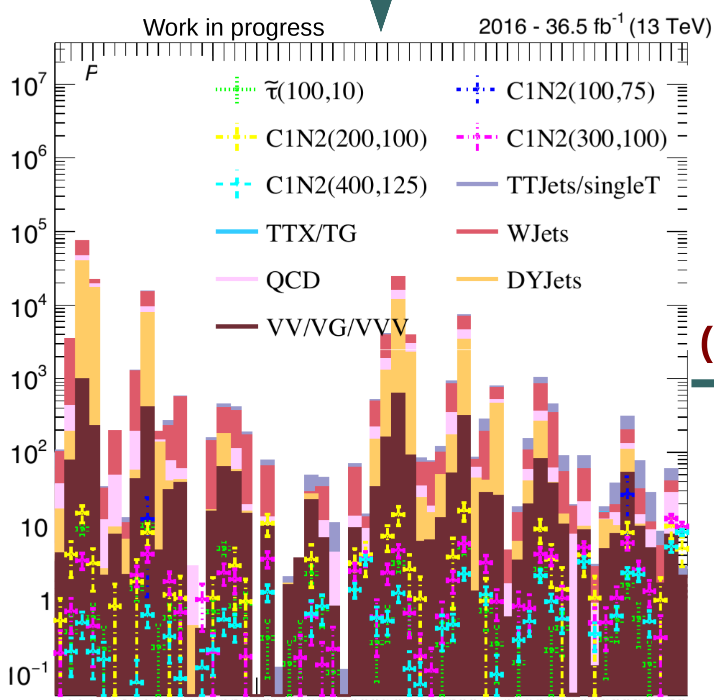


Limits

To derive limits

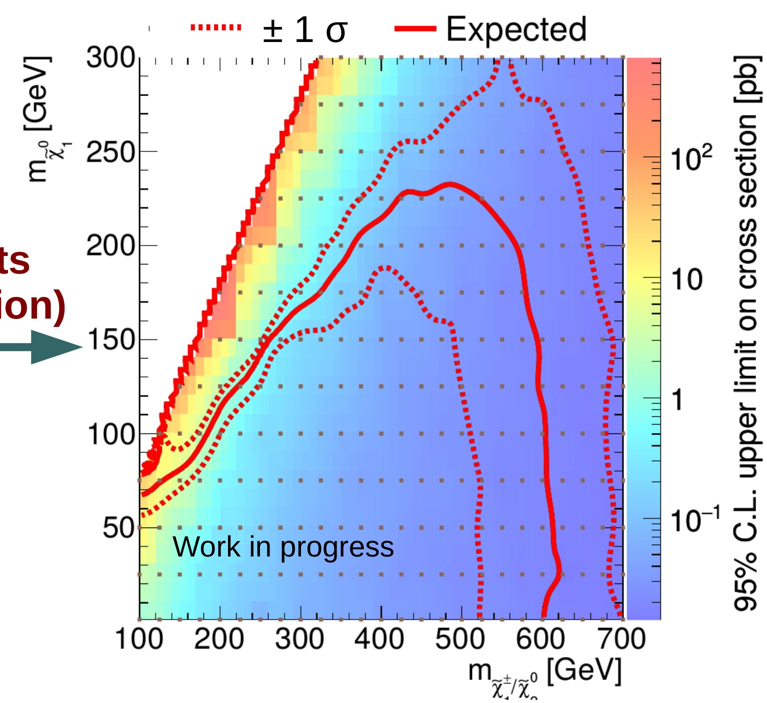
- Binning choice of search variables was based on sensitivity studies
- Form 1D template (58 bins) from main variables





calculate expected limits (after systematic estimation)

no observed limits since data are blinded



No sensitivity to direct $\tilde{\tau}$ production has been achieved

Summary

- Search for SUSY in events with τ leptons in the final state with 13 TeV data taken in 2016
- Various background estimation techniques
- Signal region optimization
- Results are interpreted in terms of simplified SUSY model and expected exclusion limits are calculated
- Plan to improve selection technique τ to be sensitive to direct $\tilde{\tau}$ production

Stay tuned!

Backup

Event selection

Triggers

Channel	Triggers
μ-τ	HLT_IsoMu24
e-τ	Ele25_eta2p1_WPTight
μ-e	Mu23_TrIsoVVL_Ele12_CaloIdL_TrackIdl_IsoVL Mu8_TrIsoVVL_Ele23_CaloIdL_TrackIdl_IsoVL Mu23_TrIsoVVL_Ele12_CaloIdL_TrackIdl_IsoVL_DZ Mu8_TrIsoVVL_Ele23_CaloIdL_TrackIdl_IsoVL_DZ

Preselection cuts

	muons(μ-τ)	electrons(e-τ)	taus	muons (μ-e)	electrons(μ-e)
Id	Medium	non-trigMVA	MVATight	medium	non-trigMVA
P_T>(GeV)	25	26	20	10(24)	24(13)
|η|<	2.4	2.1	2.3	2.4	2.5
|dxy|<(cm)	0.045	0.045	-	0.045	0.045
$\|d_z\|$<(cm)	0.2	0.2	0.2	0.2	0.2
RelIso <	0.15	0.1	-	0.15	0.1
Pair	OS with 0.3 < ΔR < 3.5			OS with ΔR > 0.3	

Baseline selection

- 3rd lepton veto and dilepton veto
- $N_{jet} \leq 1$ and $n_{b\text{-}tag} = 0$
- 20 < MT < 60 GeV or MT > 120 GeV (μτ, eτ)

  (to reject Wjets bkg.)
- M_{ll} < 30 GeV and 100 GeV < M_{ll} < 250 GeV (eμ)

  (to reject DY bkg)

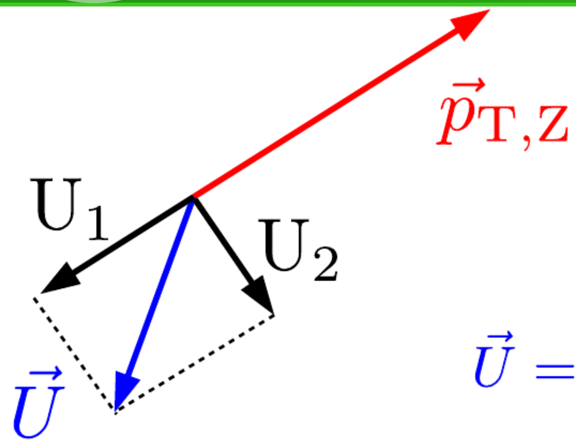
Signal region selection

- $\Delta|\eta|_{ll} < 2$, $M_{ll} > 20$ GeV
- $M_{Tsum} > 30$ GeV
- $p_T(l) < 200$ GeV (eμ)

Additional cuts for 1 jet category

- $\Delta|\eta|(J_0, l) < 3$
- $\Delta R\,(J_0,\tau) < 4$ (μτ, eτ)

MET recoil corrections

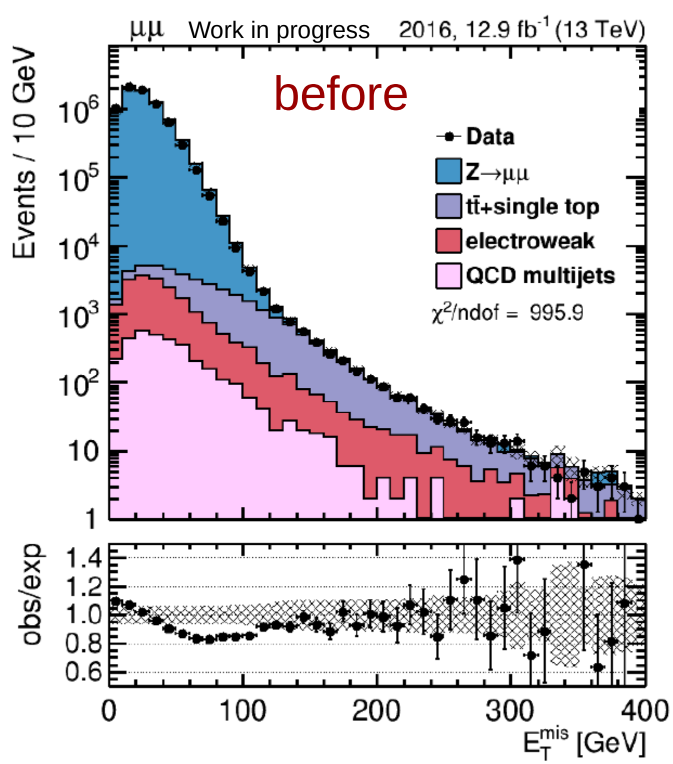


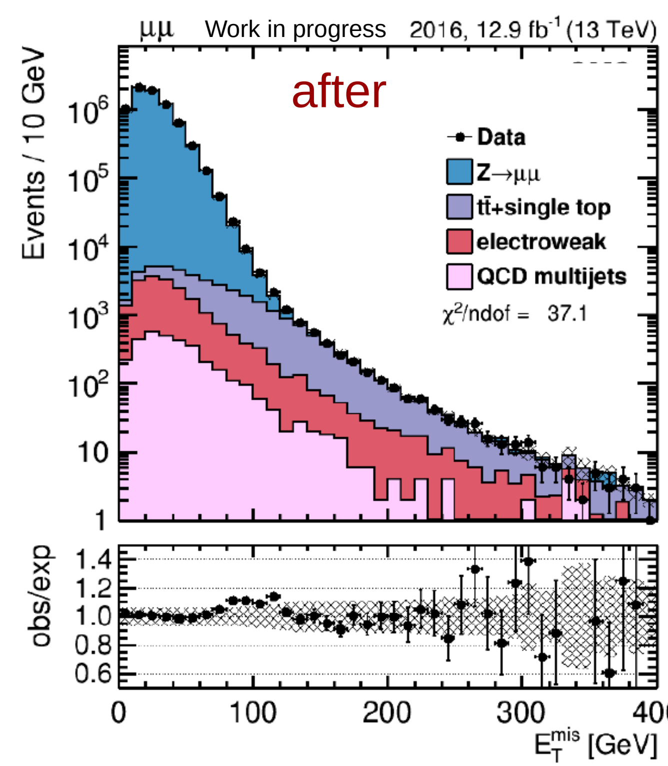
From Francesco Costanza and Alexei Raspereza (AN-16-274)

Z+Jets, Z → μμ events
⇒ no neutrinos

$$\vec{U} = \vec{E}_{\mathrm{T}}^{\mathrm{mis}} = -\vec{H}_{\mathrm{T}} - \vec{p}_{\mathrm{T},\mu\mu}$$

U_1 and U_2 are studied in dependence of Zp_T and jet multiplicity.
The method attempts to precisely reproduce shapes of the hadronic recoil distributions in data (corrects both response and Resolution)

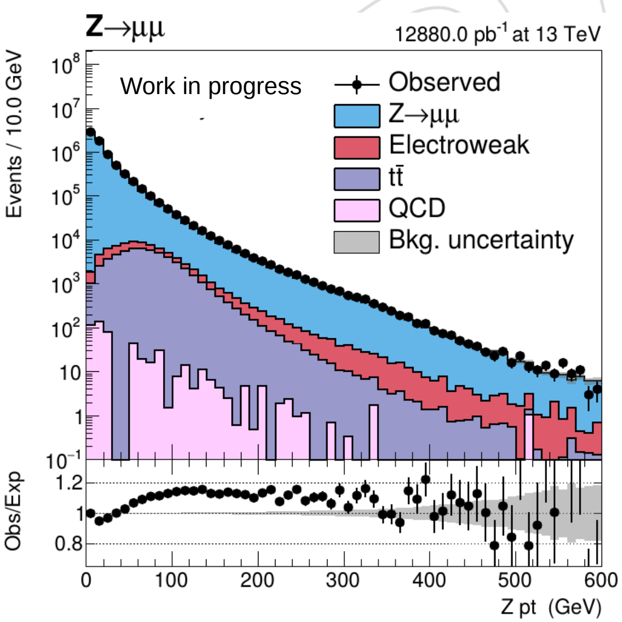




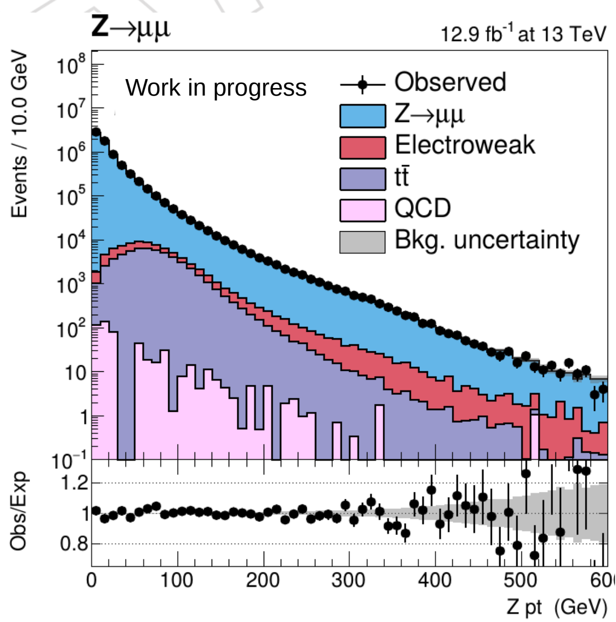
Zp_T correction

Z (mass, p_T) corrections from Adinda De Wit and Rebecca Lane DY MC (AN-16-274)

MC $Z \rightarrow \tau\tau$ process does not model the data well at high Z p_T and high invariant mass. From $Z \rightarrow \mu\mu$ weights are derived such that the overall normalization is preserved.

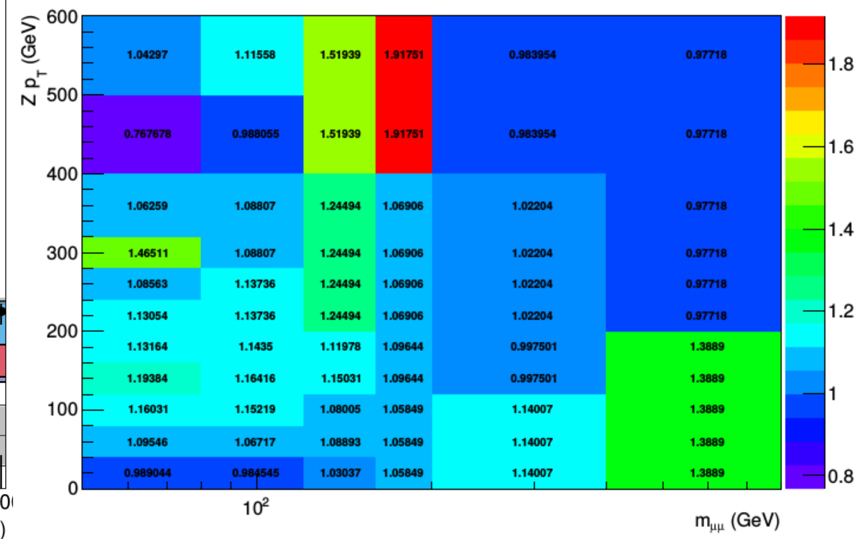


(a) Without Z reweighting



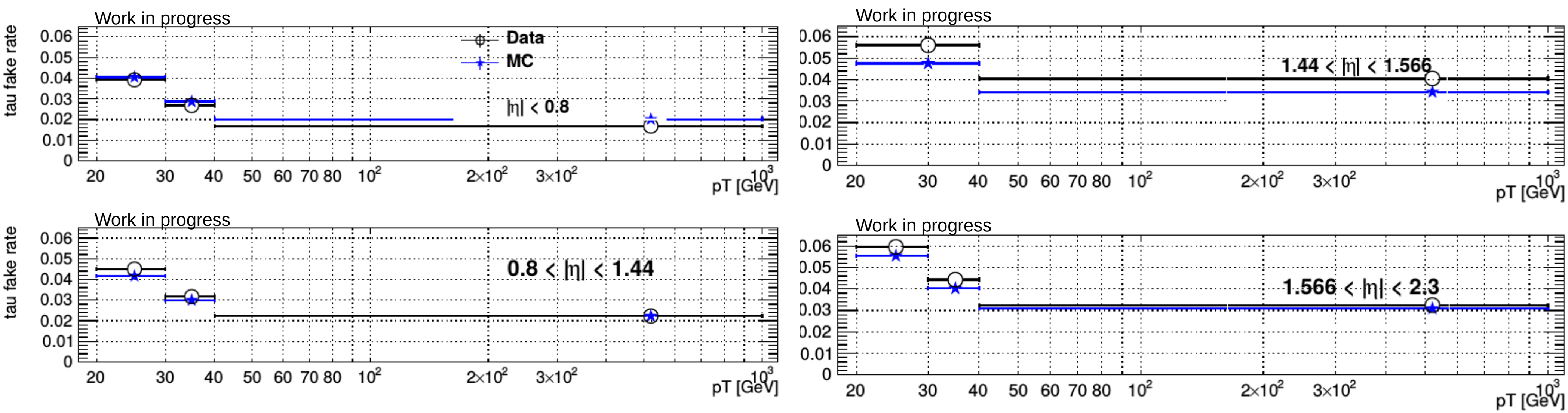
(b) With Z reweighting

Weights in 2D bins
(M_{ll} vs Zp_T maps)



Jets→ tau fake rate measurements

- Measuring the jets → tau fake from a Wjets enriched CR
- Applying nominal preselection of μ-τ
- Additional cuts to to reject bkg and increase Wjets purity
- ratio of "Tight"/"Loose" is formed
  - "Loose" is loosely selected τ candidates
  - "Tight" is τ candidates passing the nominal τ ID criteria



Signal regions

E_T^{miss}	$M_{T2Lester}$	$D\zeta$	SR ($i + 29 \times n_{jet}$)	Category
<40	<40	<-150	1	× 0,1 Jets
		>-150 & <-100	2	
		>-100 & <0	3	
		>0	4	
	>40	<-150	5	
		>-150	6	
>40 & <80	<40	<-150	7	
		>-150 & <-100	8	
		>-100 & <50	9	
		>50	10	
	>40 & <80	<-150	11	
		>-150 & <-100	12	
		>-100	13	
	>80	>-500	14	
>80 & <120	<40	<-100	15	
		>-100	16	
	>40 & <80	<-150	17	
		>-150 & <-100	18	
		>-100	19	
	>80 & <120	>-500	20	
	>120	>-500	21	
>120	<40	<-150	22	
		>-150 & <-100	23	
		>-100	24	
	>40 & <80	<-150	25	
		>-150 <-100	26	
		>-100	27	
	>80 & <120	>-500	28	
	>120	>-500	29	

DRAFT