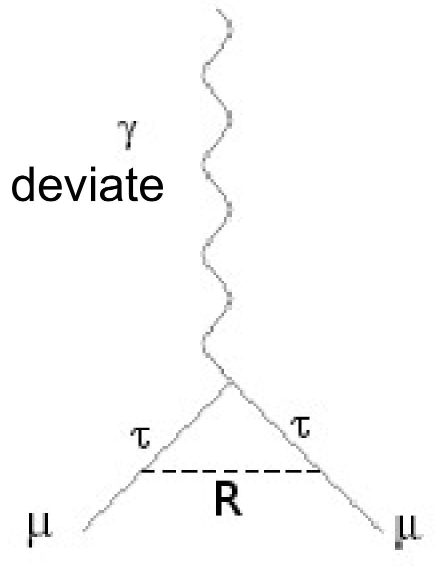
status on LFV $H^0 \rightarrow \tau\mu$

Gérald Grenier,
D0-France meeting
Lyon, May 3rd-4th 2010

Some motivations

Why looking for a μτ resonance ?

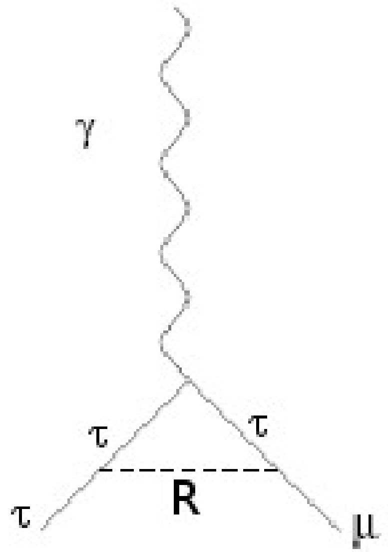


Such a resonance would contribute to the muon (g-2) and deviate it from SM expectation.

$$a_\mu = \begin{cases} 11659208.0(5.4)(3.3)\times 10^{-10} & expt \\ 11659183.4(0.2)(4.1)(2.6)\times 10^{-10} & EW + hadronic + hadronic \end{cases}$$

BSM model with such possible resonnances :

- SUSY RPV with sneutrino-μ-τ coupling
  - NP group looked at sneutrino-e-μ (D0 note 5299)
  - An eμ resonnance would also impact muon (g-2)
- 2HDM
  - Higgs sector can violate Lepton Flavor



But such a resonnance usualy modifies τ → μγ decay.

$$BR(\tau \rightarrow \mu\gamma) < 4.5\times 10^{-8}$$

Getting (g-2) discrepency with small enough τ → μγ decay rate usually requires some tuning.

Data and Trigger and MC

WARNING : old p17

Used MUinclusive skim

Used h-> $\tau(\mu)$ τ analysis trigger and luminosity numbers

from the analysis of January 2007 (1012 pb^{-1})

Background : uses same MC than JET+MET analysis (squaks/gluinos)
P17 portion of Jet+MET MC described in D0 note 5671
Except Z+ jets is normalized to the cross section measured by D0
Published in Phys. Lett. B670, 292 (2009), 0808.1306.

Signal generated with a modified version of PYTHIA 6.409
using the same modification as for
K. A. Assamagan *et.al*. Phys. Rev. D67, 035001 (2003), hep-ph/0207302.

Simulated Higgs mass in GeV (90, 110, 130 and 160)

Object ID

Tau :

- Apply tau ES correction
- Charge ≠ 0
- NN > 0.9/0.9/0.95
- NNelec > NA/0.9/NA
- |deteta| < 2.5
- For type 1 , remove if 1.1 <|eta|<1.4
- Abs (track DCA z – PV z) < 1./1./NA cm
- CHF < 40%
- Sum track Pt > 15/5/15 GeV
- Et/Sum track Pt > 0.7/NA/0.4
- Pt > 15/15/15 GeV

Muon :

- Medium Nseg 3
- Isolation = NPTight
- Track Quality Medium
- Abs (track DCA z – PV z) < 1 cm
- **Pt > 30 GeV**

Smearing muon pt in MC with 'pre' p17 (Z+J/Ψ) values
Applying muid efficiencies corrections

MET :

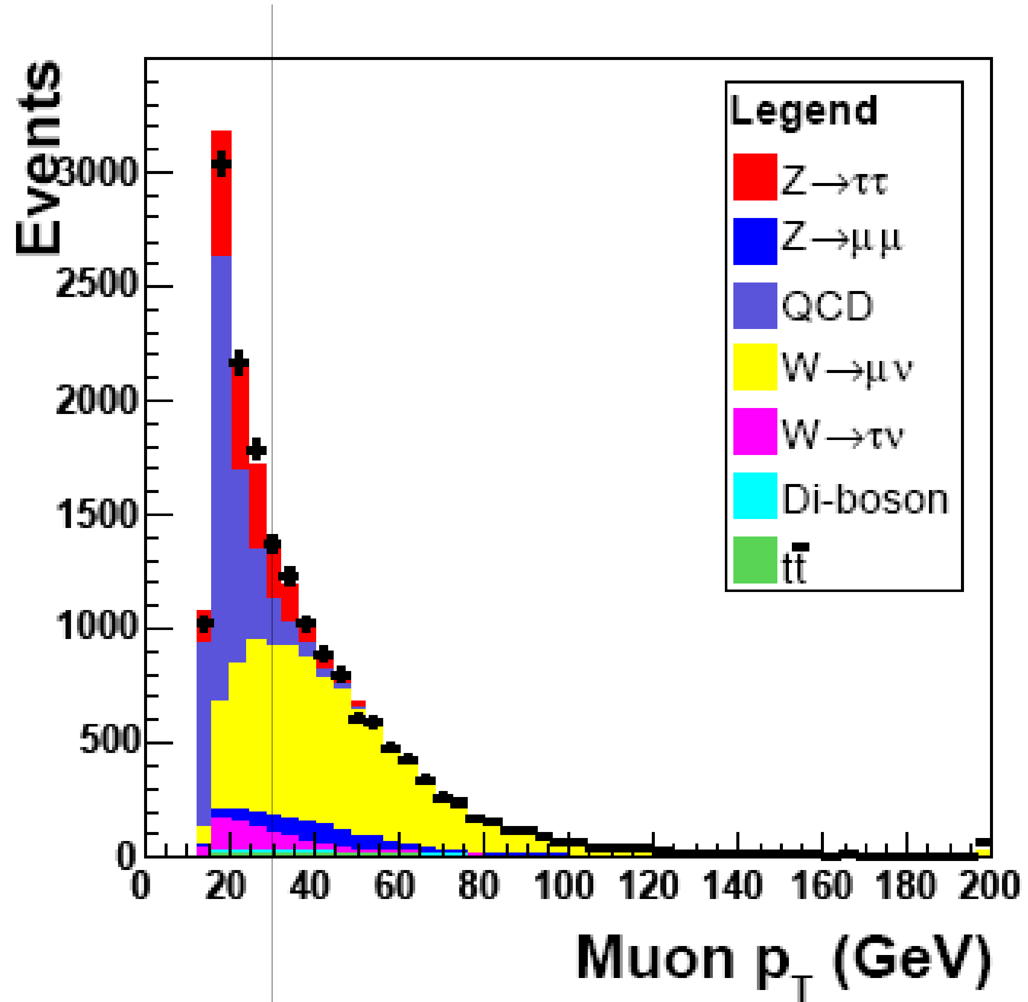
metb corrcalo mu (same as JET+MET analysis)

In MC correct MET for muon smearing

QCD background

Taken from the SUSY H->ττ->μτ_had analysis

Looser muon selection, all tau types, no cut on NN output.



This analysis cut : QCD background should be small

Higgs reconstruction

Assume MET is only due to the neutrinos coming from the tau decay.

Combine tau decay products and MET to form a 'full-reco' tau.
If the tau match a jet, correct MET using tauES.

$$\overrightarrow{P_T^{\tau}} = \overrightarrow{P_T^{\tau\, visible}} + \overrightarrow{P_T^{miss}}$$

$$P_z^{\tau} = P_z^{\tau\, visible}\left(1 + \frac{P_T^{miss}}{P_T^{\tau\, visible}}\right)$$

Combine 'full-reco' tau with a muon removing candidates where 'full-reco' tau and muon share a track.

Remove pairs with same sign tau and muon.

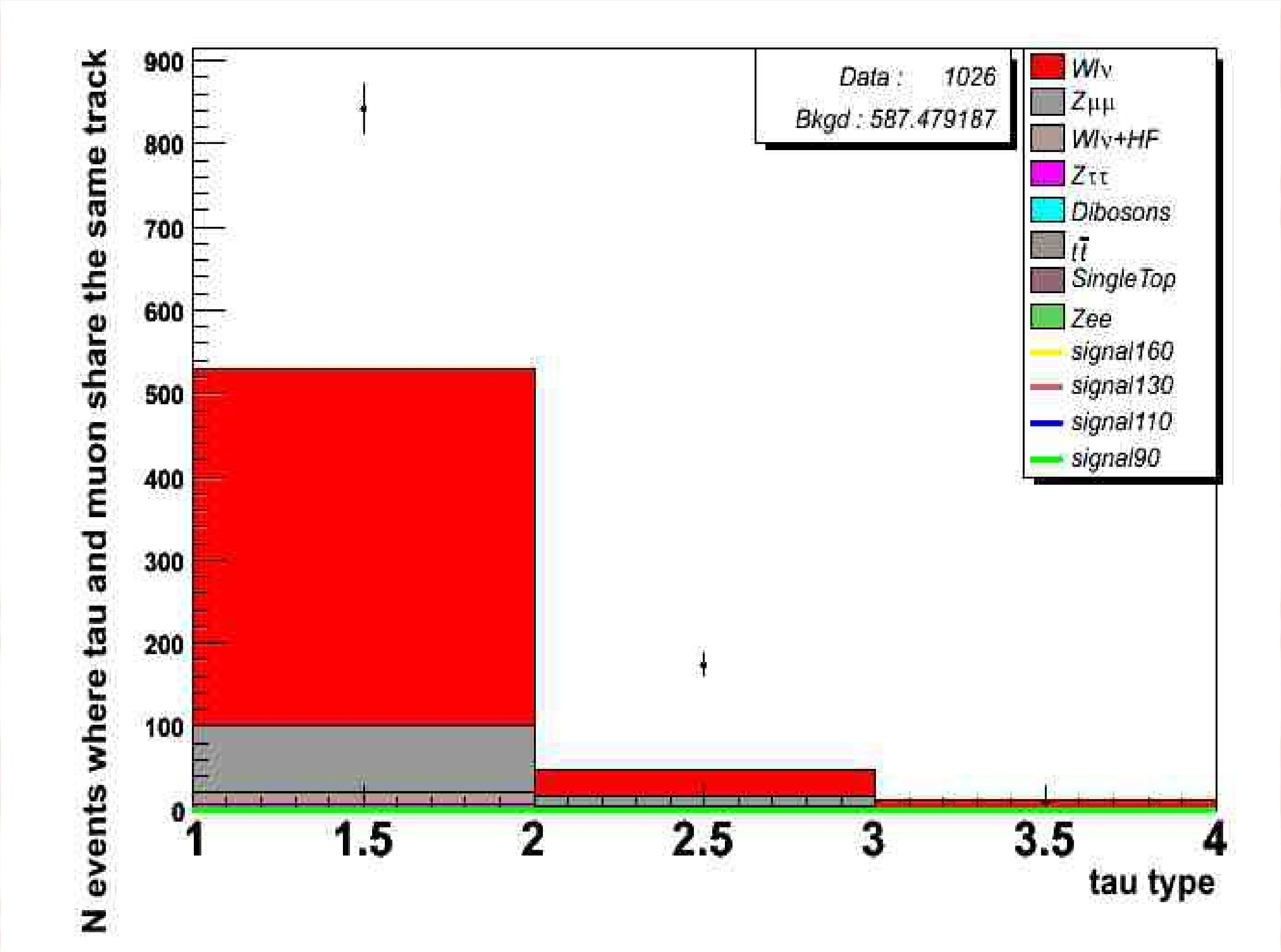
The above formula is true if neutrinos (MET) and tau decay are colinear :

Will add the following cut on

$|\Delta\phi\ (\tau \text{ decay, MET})|$

Higgs selection : tracks

Remove candidates where the tau and the muon have the same track.

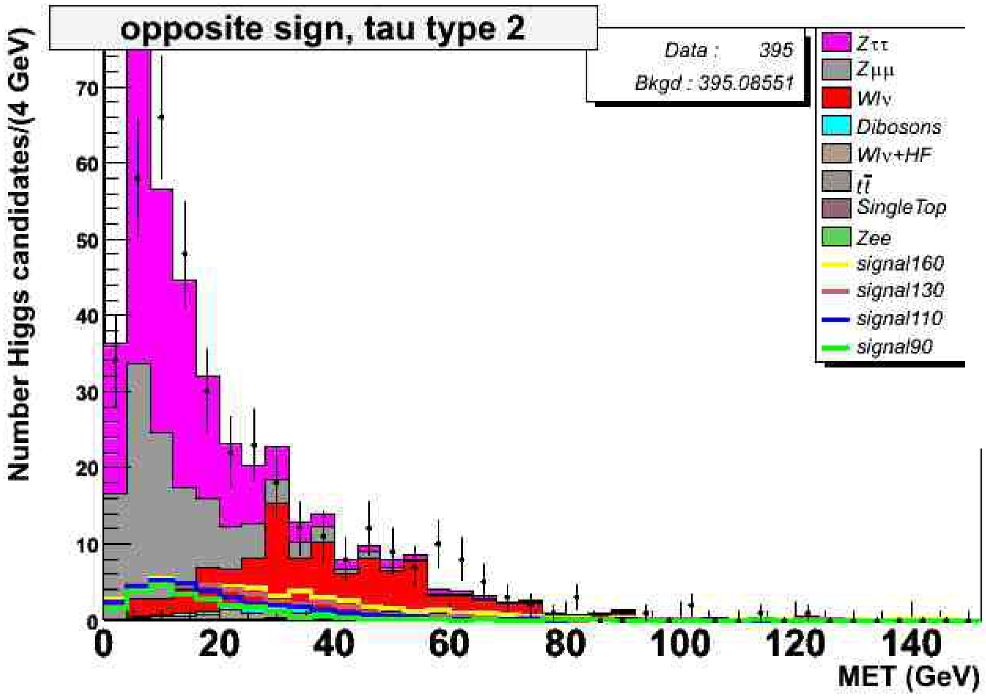


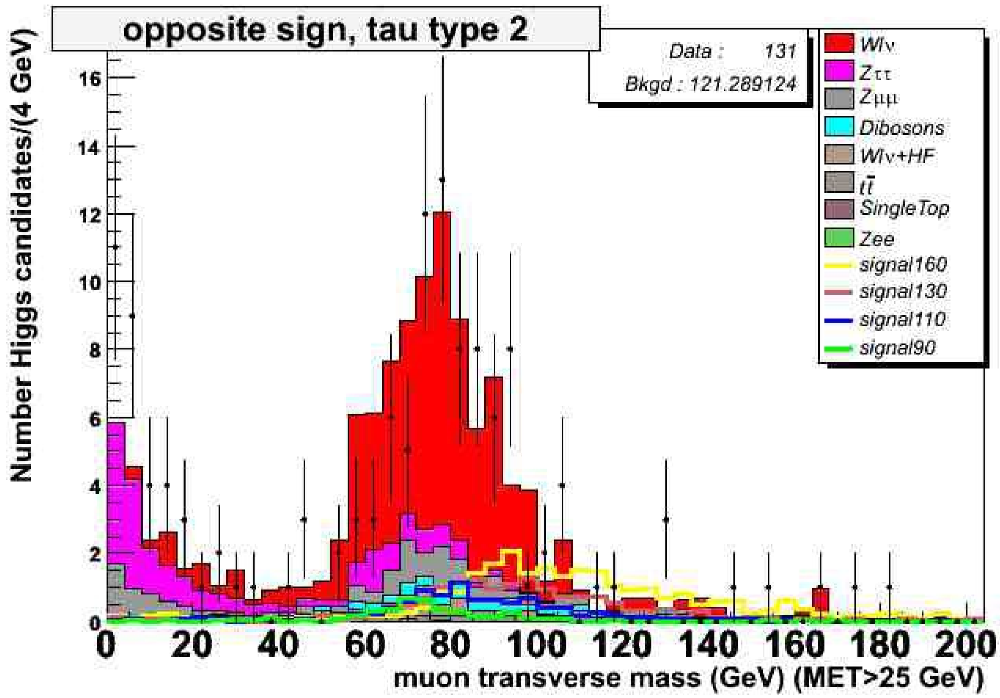
Higgs selection : anti W

Remove candidates if mu+MET is compatible with a W.

mu+MET is compatible with W if :

- MET > 25 GeV
- And transverse mass > 40 GeV
- And | $\Delta\phi$ (μ,MET) | < 2.9 rad

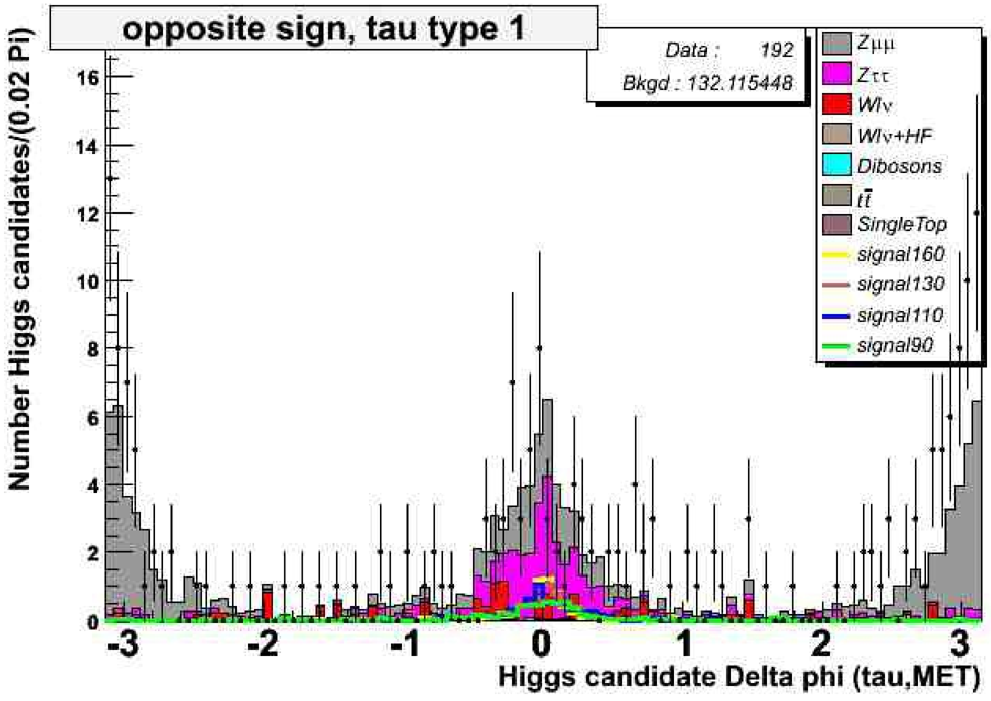


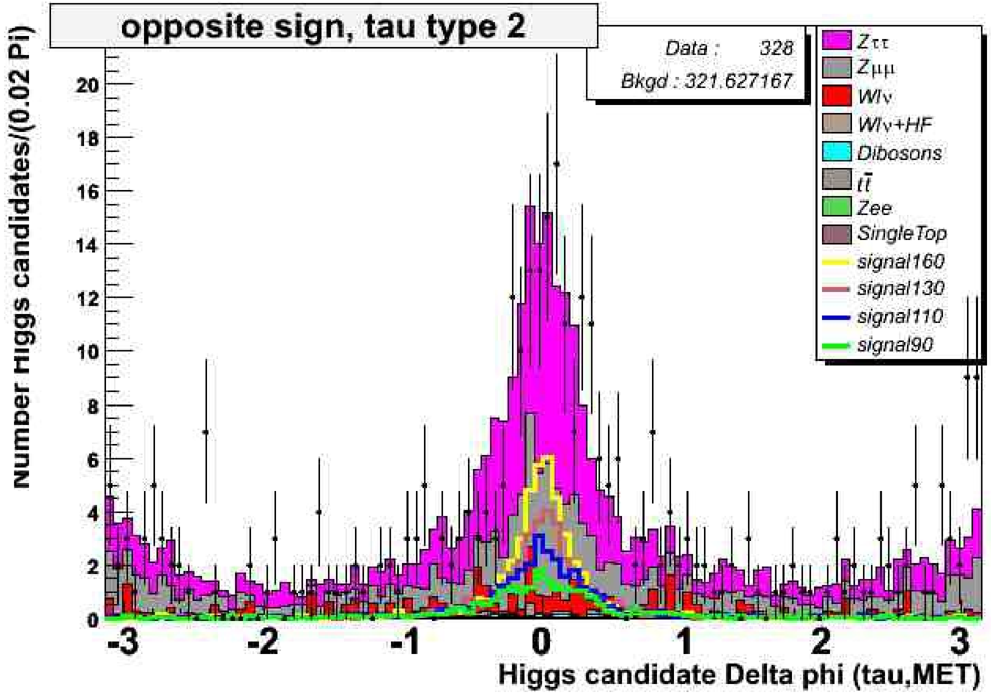


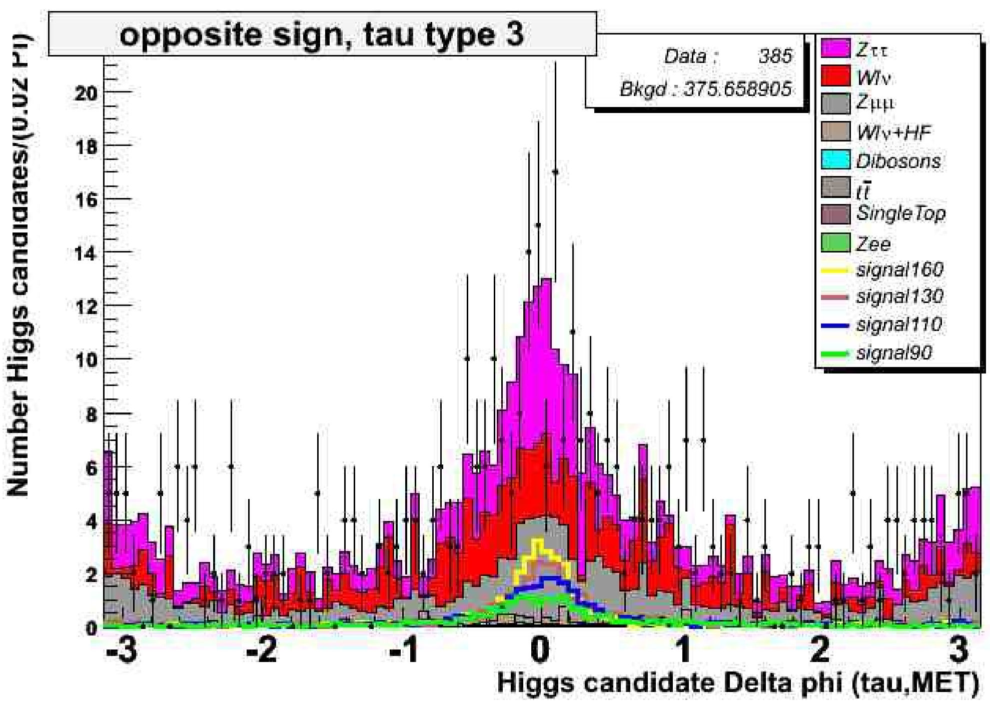
Higgs selection : |Δφ (τ decay, MET)|

Remove candidates if

|Δφ (τ decay, MET)| > 0.5 rad

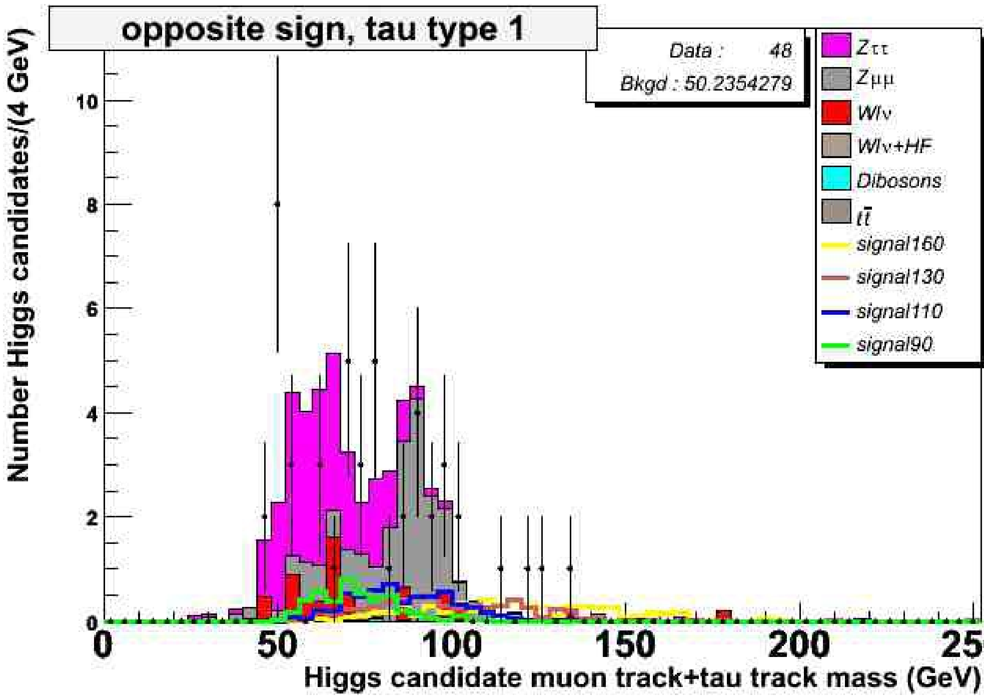


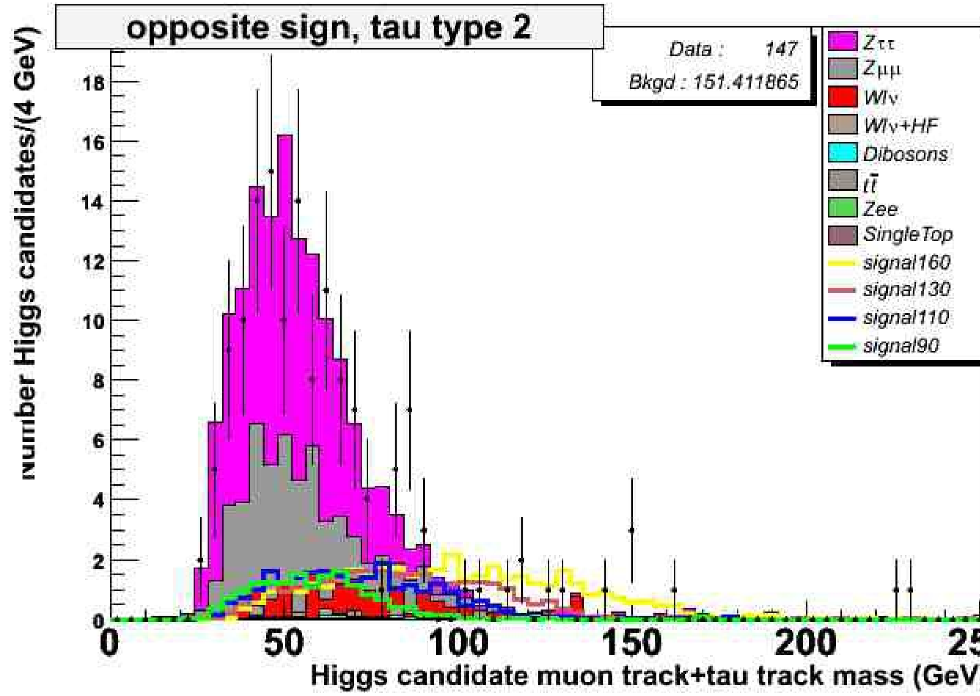


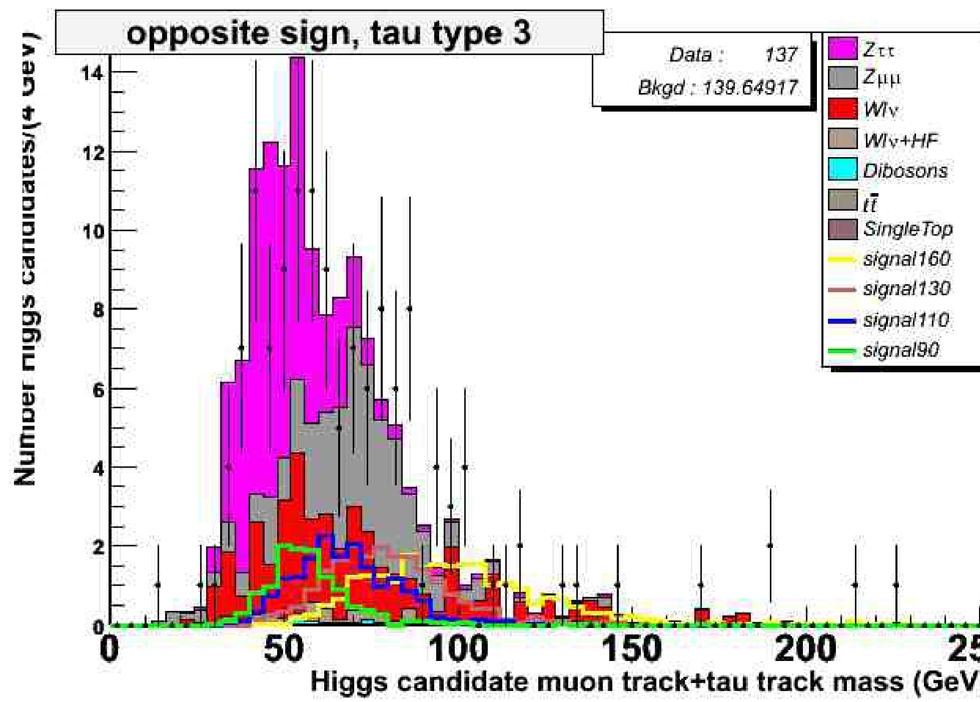


Higgs selection : anti Z

Remove candidates if mass of muon track and highest Pt tau track is Z compatible (between 80 GeV and 110 GeV).







Higgs selection : number of candidates

Tau Type 1

cut level	data	total SM	Zee	Single Top	$t\bar{t}$	Dibosons	$Wl\nu$+HF	$Z\tau\tau$	$Z\mu\mu$	$Wl\nu$	Signal $\sigma = 1$ pb Higgs mass in GeV 160	130	110	90
Tracks	220	160.2	0	0.01	0.7	1.5	2.3	35.1	86.8	33.8	7.5	7.7	7.4	6.4
anti W	192	132.1	0	6×10^{-4}	0.2	0.9	1.1	34.0	83.2	12.8	6.3	6.4	6.7	5.6
$\Delta\phi$	48	50.0	0	0	0.05	0.3	0.3	23.1	20.3	5.9	5.7	5.7	5.7	4.4
Anti Z	36	33.6	0	0	0.04	0.3	0.2	20.8	7.4	4.8	4.7	3.7	3.1	3.5

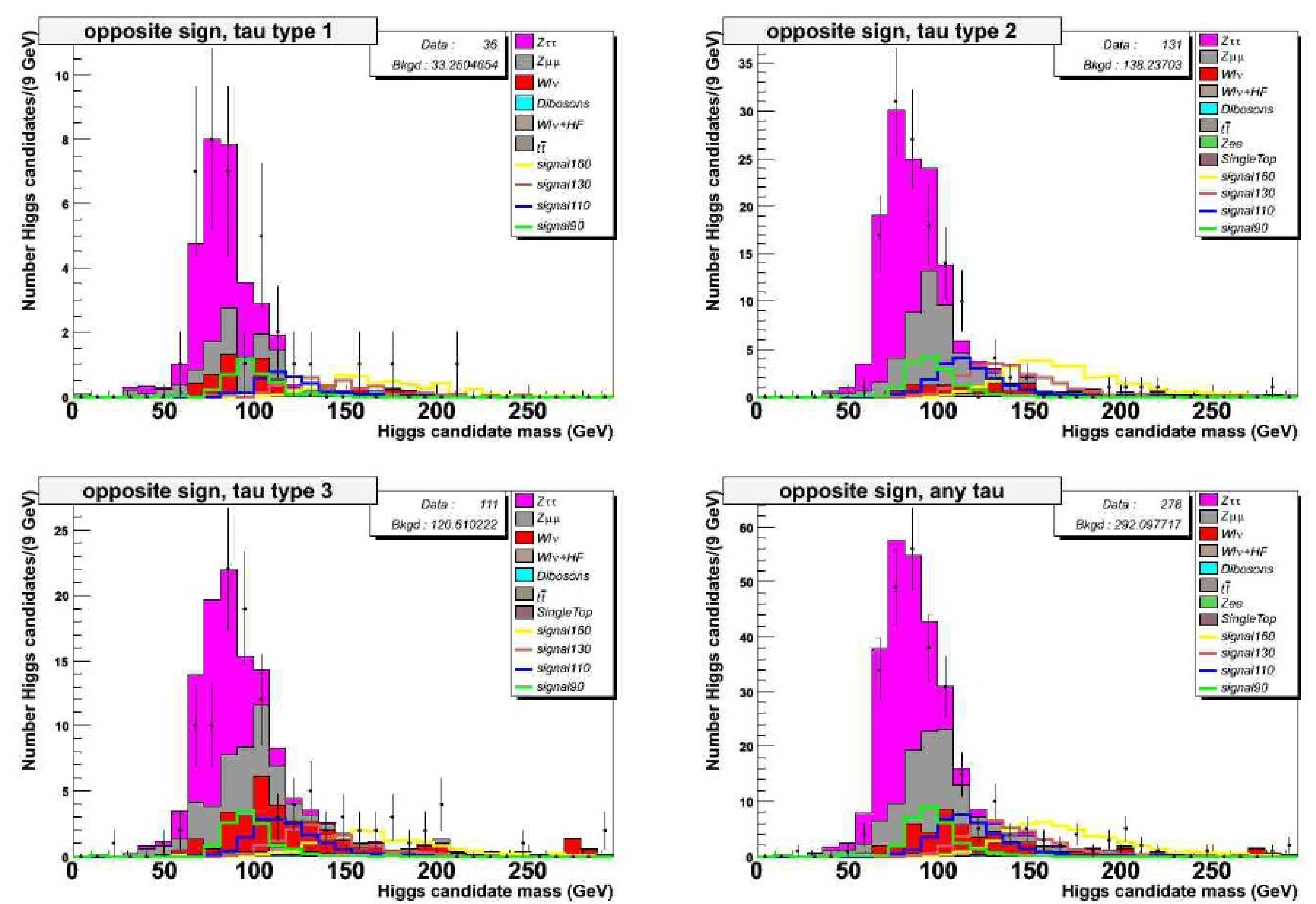
Tau Type 2

cut level	data	total SM	Zee	Single Top	$t\bar{t}$	Dibosons	$Wl\nu$+HF	$Z\tau\tau$	$Z\mu\mu$	$Wl\nu$	Signal $\sigma = 1$ pb Higgs mass in GeV 160	130	110	90
Tracks	395	395.1	0.06	0.1	5.2	8.4	7.6	170.2	112.9	90.7	53.7	40.8	33.4	22.6
anti W	328	321.6	0.06	0.03	1.9	3.8	4.2	167.0	109.0	35.7	46.0	35.7	30.5	21.3
$\Delta\phi$	147	150.7	0.06	0.009	0.5	1.5	1.6	87.6	46.6	12.9	39.2	28.3	23.2	15.3
Anti Z	132	140.0	0.06	0.007	0.4	1.2	1.1	83.3	43.3	10.6	30.8	21.7	18.0	14.0

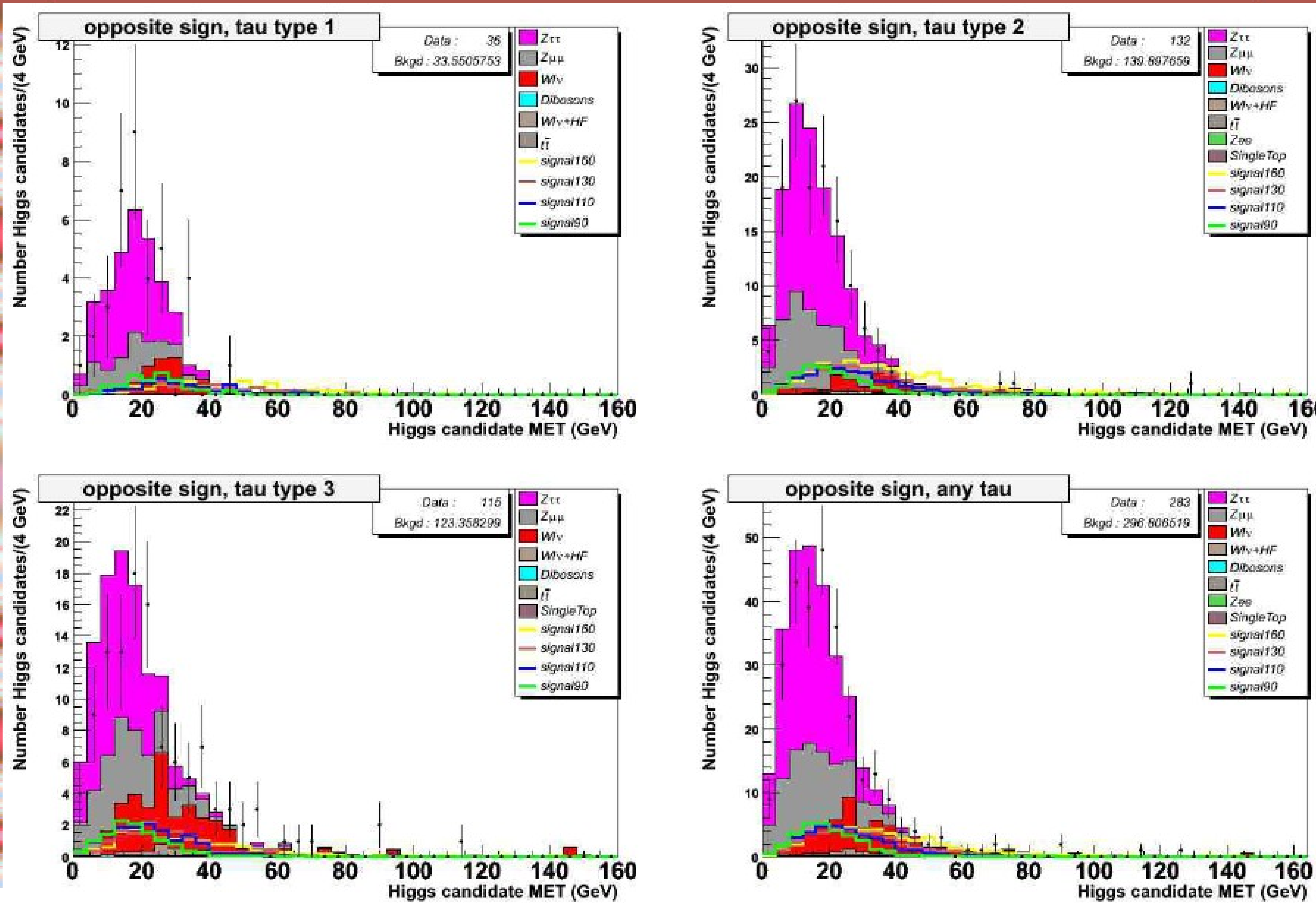
Tau Type 3

cut level	data	total SM	Zee	Single Top	$t\bar{t}$	Dibosons	$Wl\nu$+HF	$Z\tau\tau$	$Z\mu\mu$	$Wl\nu$	Signal $\sigma = 1$ pb Higgs mass in GeV 160	130	110	90
Tracks	576	582.7	0.02	0.3	6.2	9.9	30.5	137.2	118.7	279.8	33.4	30.4	26.6	18.8
anti W	385	375.7	0.0001	0.1	2.2	4.4	13.3	134.0	108.1	113.6	29.9	27.4	23.9	17.5
$\Delta\phi$	137	138.5	0	0.02	0.4	1.2	3.9	56.4	40.4	36.3	22.7	19.6	17.0	11.5
Anti Z	115	123.4	0	0.02	0.3	1.1	3.1	55.5	31.7	31.6	15.5	12.9	14.0	11.3

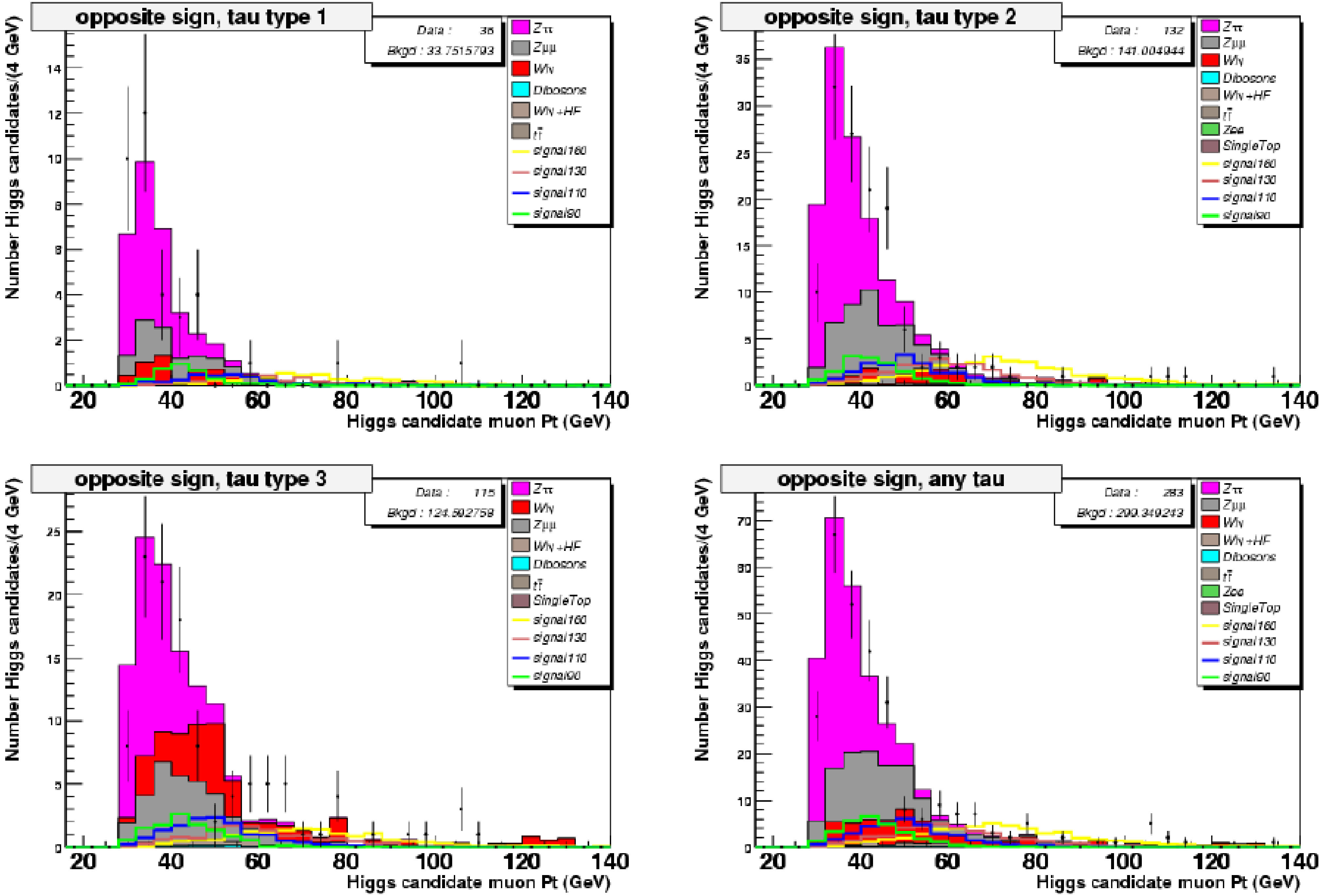
Higgs candidate mass



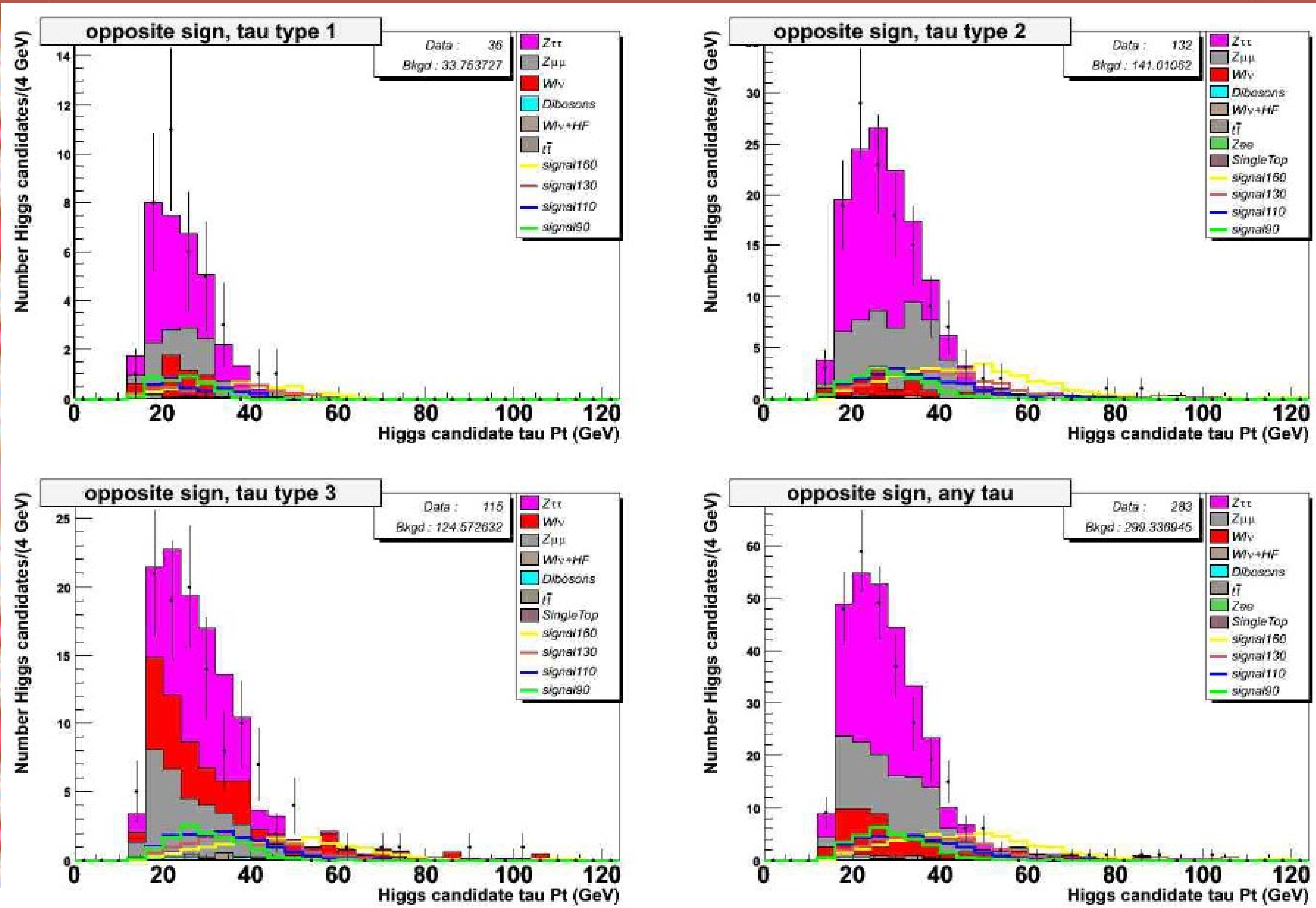
Higgs candidate MET



Higgs candidate muon Pt



Higgs candidate tau Pt



Systematics

From H->$\tau\tau$ analysis :

Luminosity	6.1%
Trigger	3%
Muon track match	2.1%
Muon Id	0.5%
Tau track match	4%

Other systematics :

muon Pt semearing		0.35% (SM) and 1.4%(signal)
PDF		12.8 % (SM) and 34.5% (signal)
tau Id		2.7% (type 1), 1.0% (type 2) and 2.9% (type 3) (D0 note 5408)
tau ES	SM MC	7.3% (type 1), 2.1% (type 2) and 3.2% (type 3) (D0 note 5468)
tau ES	signal MC	2.8% (type 1), 0.9% (type 2) and 3.4% (type 3)

g-2 results

a_μ^{exp} = 11 659 208.0(6.3) x 10^{-10} Phys.Rev. D73, 072003 (2006)

There is a discrepency betwwen this result and the theory.
The difference is compatible with 2HDM-III contribution at 95% C.L.
if
$2.8 \times 10^{-10} \leq \Delta a_\mu \leq 44.5 \times 10^{-10}$
With
$\Delta a_\mu = a_\mu^{2HDM-III} - a_\mu^{SM}$

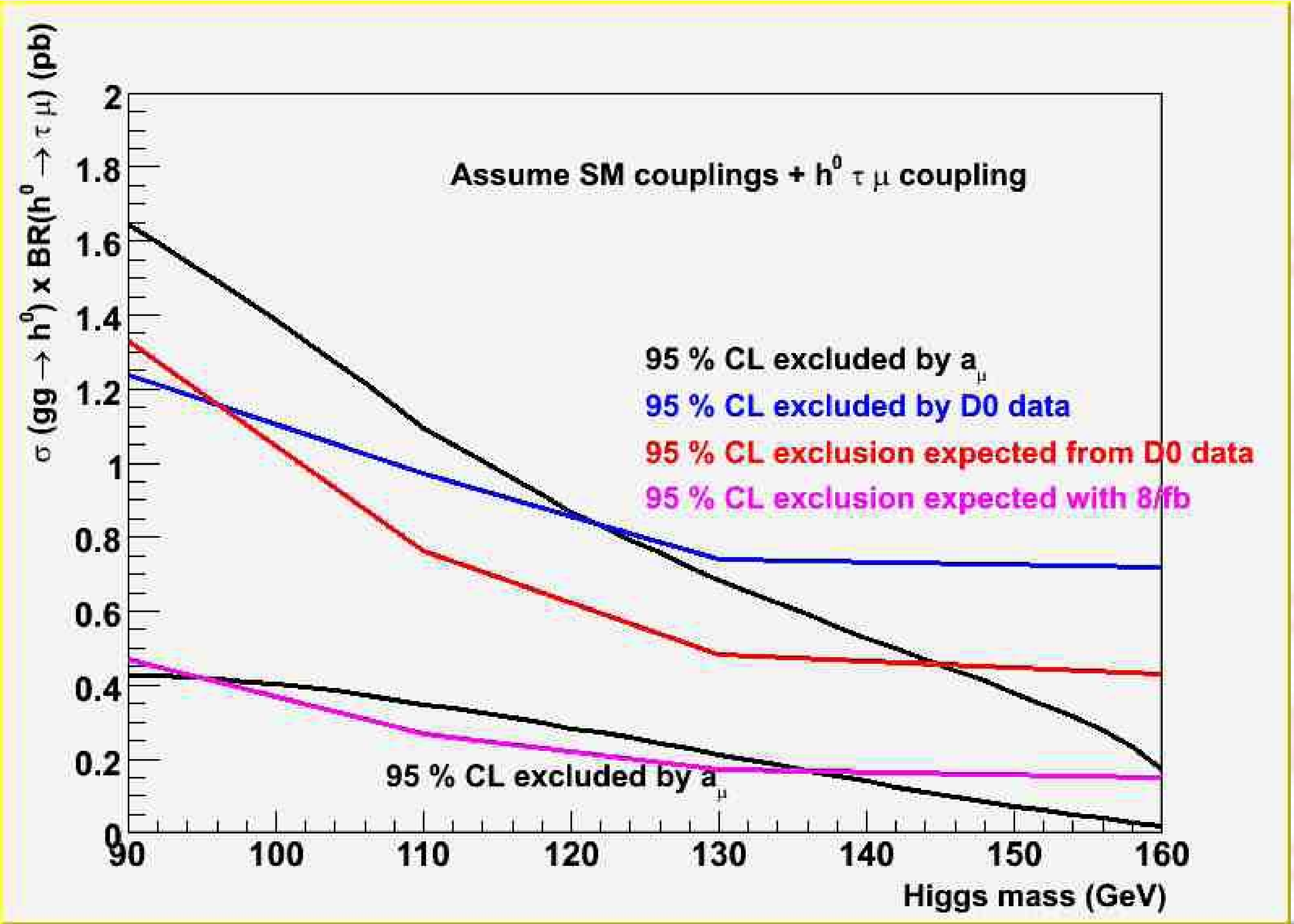
The above inequalities transforms in limits on the higgs-tau-mu coupling

$$\frac{\Gamma(h^0/H^0 \to \mu\bar{\tau})}{\Gamma_{SM}(h^0_{SM} \to \tau\bar{\tau})} = \Delta a_\mu^{N\mu\tau h} \frac{8\pi^2 v^2}{m_\mu^2 m_\tau^2 \int_0^1 \frac{x^2(1-x)+x^2(m_\tau/m_\mu)}{m_\mu^2 x^2 + x\left(m_\tau^2 - m_\mu^2\right) + (1-x) m_h^2} dx} \frac{\left(1 - \frac{(m_\tau+m_\mu)^2}{m_h^2}\right)^{\frac{3}{2}} \left(1 - \frac{(m_\tau-m_\mu)^2}{m_h^2}\right)^{\frac{1}{2}}}{\left(1 - \frac{4m_\tau^2}{m_h^2}\right)^{\frac{3}{2}}}$$

With assumptions on Higgs production, one can try to translate this into cross section limits.

Limits

Reasonnable data-SM prediction agreement.
Limits derived using COLLIE version 3.6.



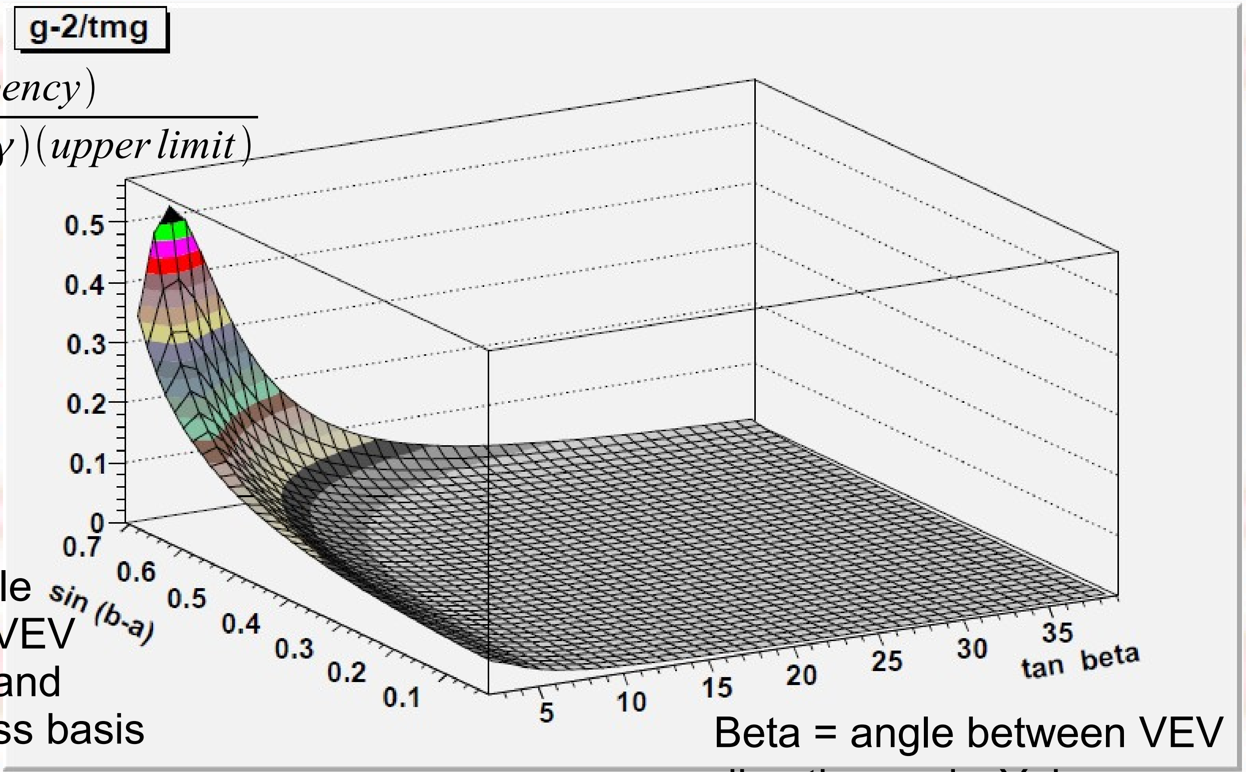
Taking into account more recent constraints.

The (g-2) business is rather old. The Pierre-Antoine thesis is rather old.

Updates were needed. Got help from Sacha Davidson → arXiv:1001.0434v2 [hep-ph]

More stringent results come from $\tau \to \mu\gamma$ BR measured by B-factories.
The $\tau \to \mu\gamma$ BR mostly excludes the 2HDM model from explaining the (g-2) discrepency

$$\frac{(g-2)_\mu(2\mathrm{HDM})/(g-2)_\mu(discrepency)}{BR(\tau\to\mu\gamma)(2\mathrm{HDM})/BR(\tau\to\mu\gamma)(upper\ limit)}$$

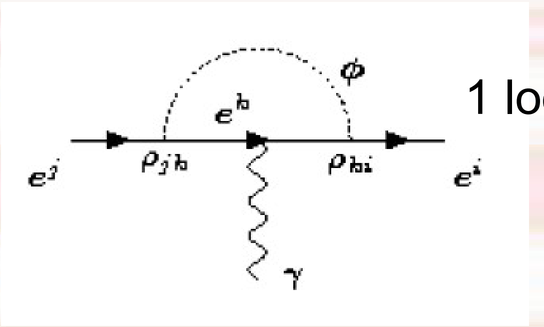


b-a = angle between VEV direction and higgs mass basis

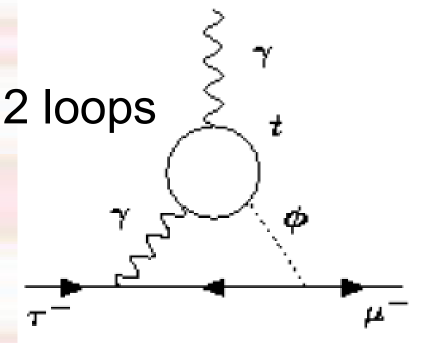
Beta = angle between VEV direction and τ Yukawa direction

Taking into account more recent constraints.

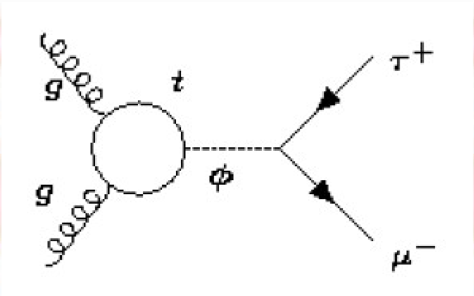
The $\tau \to \mu\gamma$ BR puts also strong constraints on the $h^0 \to \tau\mu$ production at hadron colliders.



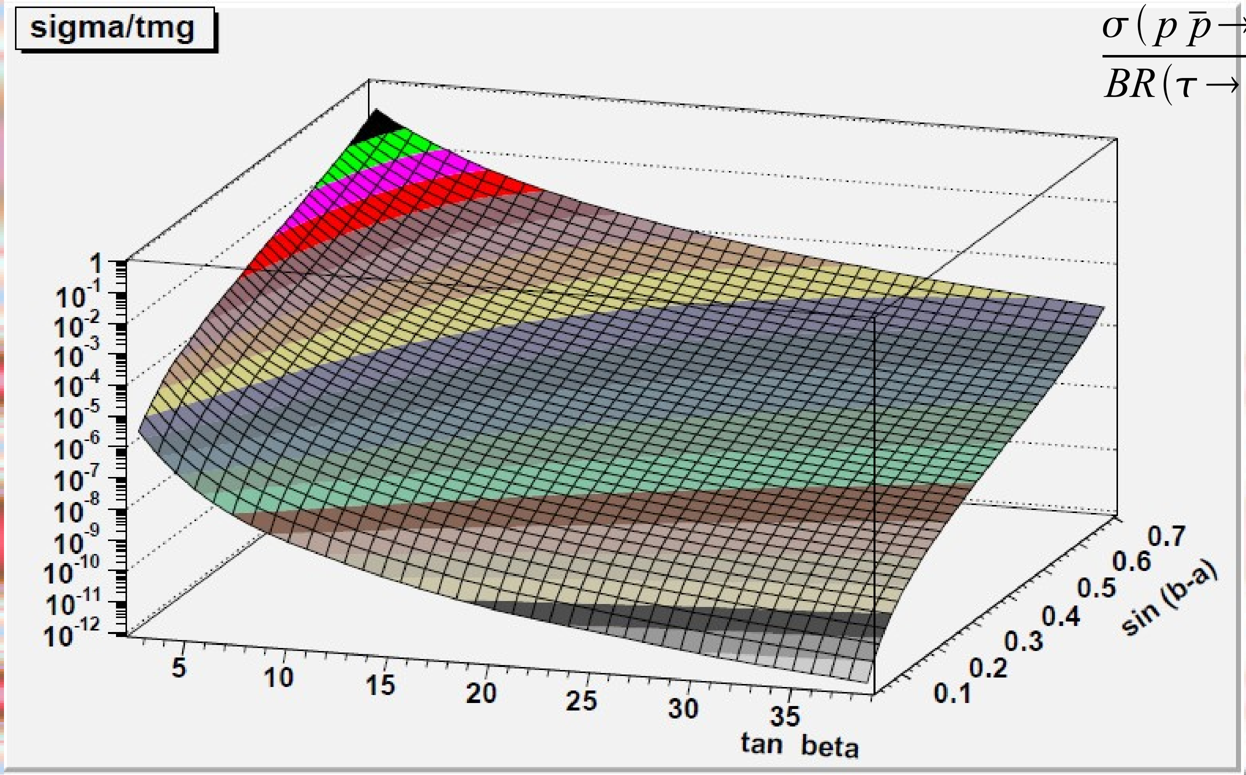
1 loop ~ 2 loops



similar



$$\frac{\dfrac{\sigma(p\bar{p}\to h\to\tau\mu)}{\sigma(p\bar{p}\to h_{SM}\to\tau\tau)} \Big/ \dfrac{SM\ h\to\tau\tau\ limit}{SM\ h\to\tau\tau\ prediction}}{BR(\tau\to\mu\gamma)(\mathrm{2HDM}) / BR(\tau\to\mu\gamma)(upper\ limit)}$$



$\dfrac{SM\ h\to\tau\tau\ limit}{SM\ h\to\tau\tau\ prediction}$ is taken from D0 note 5845-CONF ($\tau\tau$qq)

And then ?

The current p17 1/fb analysis is rather old stuff.
The analysis programs might not run anymore (SL upgrades).

Final states for μ τ_had are already looked for.

Wish : setting up a collaboration :
– others provides analysis tools with more recent data set
– Lyon (me and P.L) provides MC signals and interpretation of results.

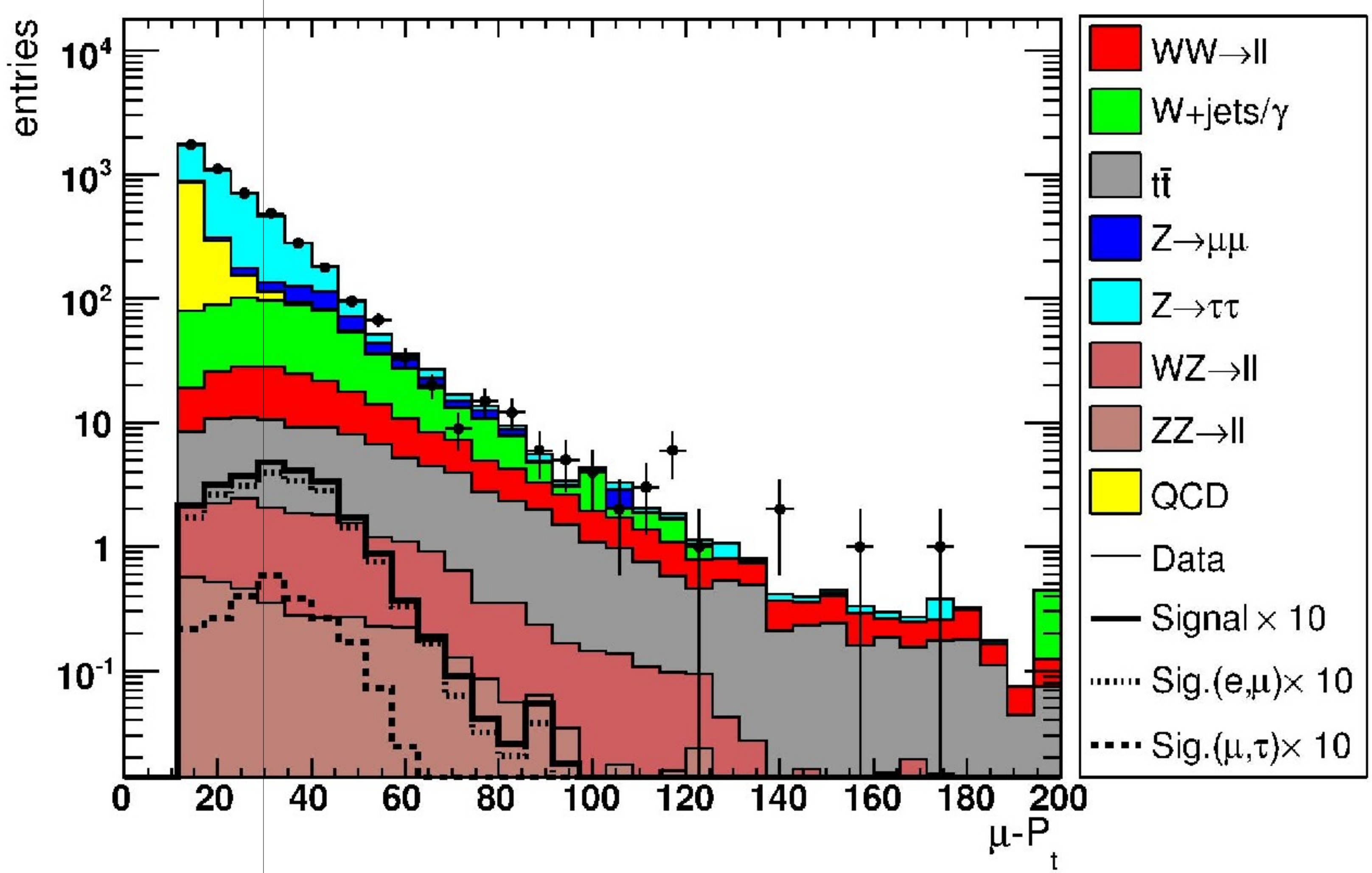
Goal : publish.

Backup

QCD background

Taken from H->WW->$\mu\tau$+jets analysis (D0 note 5332)

Looser muon selection, similar tau selection but only type 1 and 2

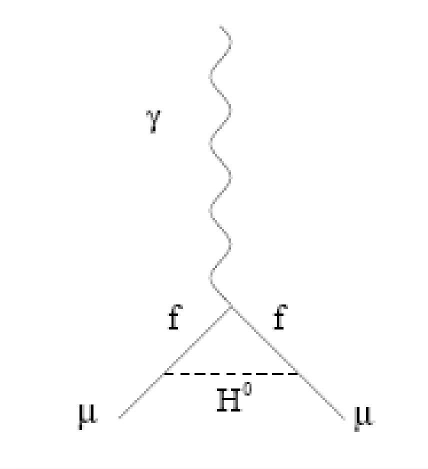


This analysis cut : QCD background should be removed.

2HDM-III and muon g-2

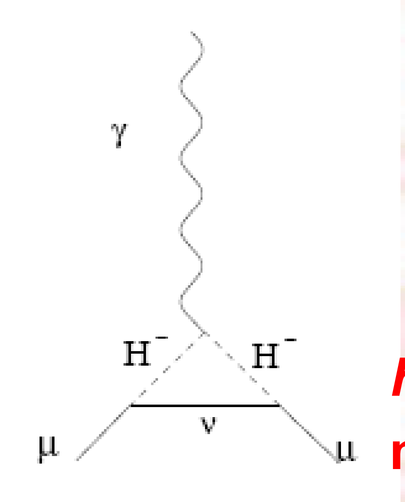
(based on original work from P.A. Delsart, A. Deandrea and K. Assamagan, Phys Rev D67, 035001 (2003))

Higgses contribution to the muon anomalous magnetic moment $a_\mu=(g_\mu-2)/2$



$$\Delta a_\mu^N = \frac{h_{\mu f}^2 m_\mu^2}{8\pi^2}\int_0^1 \frac{x^2(1-x) \pm x^2(m_f/m_\mu)}{m_\mu^2 x^2 + x(m_f^2 - m_\mu^2) + (1-x)m_H^2}dx$$

+ (-) for the neutral scalar (pseudo-scalar) higgs

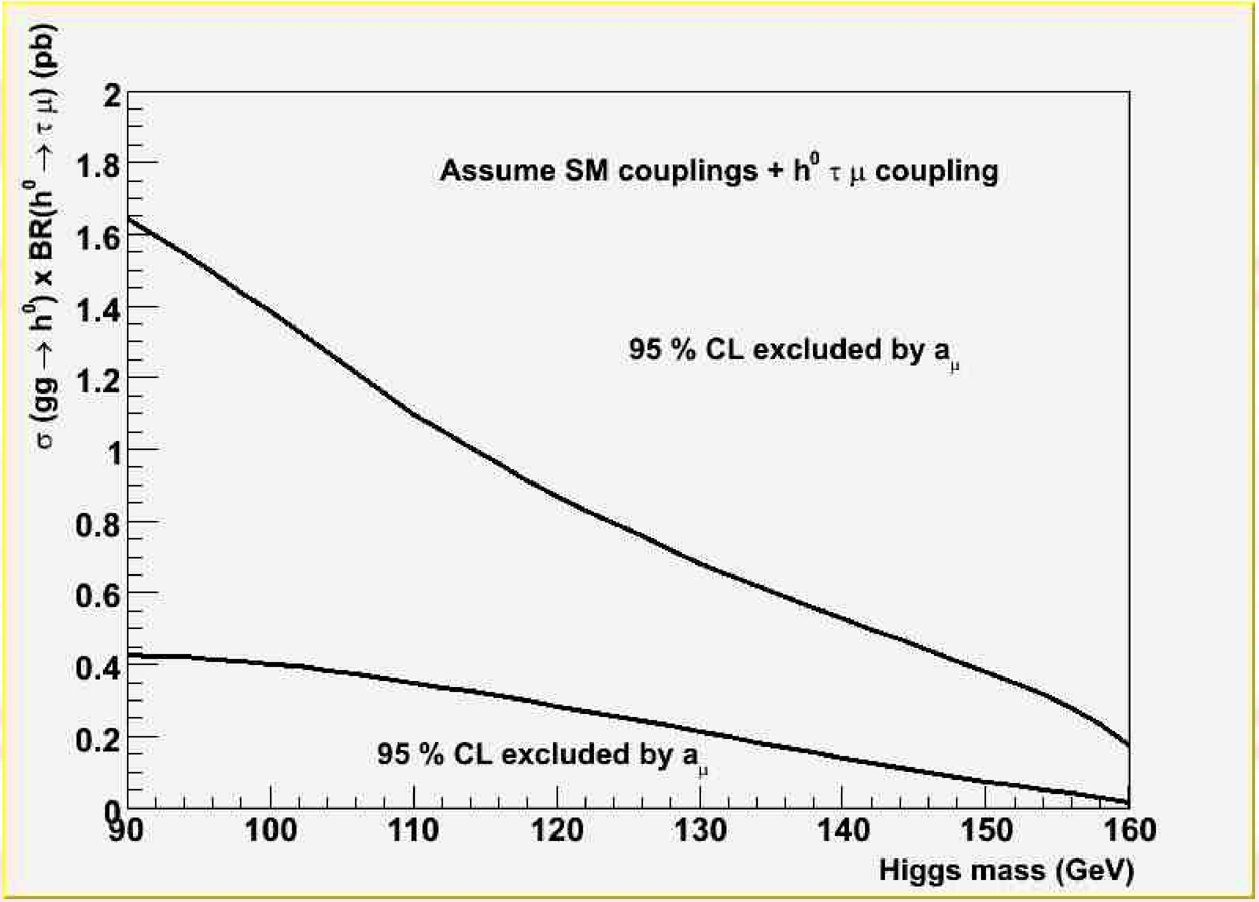


$$\Delta a_\mu^C = \frac{h_{\mu\nu}^2 m_\mu^2}{8\pi^2}\int_0^1 \frac{2x^2(x-1)}{m_\mu^2 x^2 + x(m_H^2 - m_\mu^2)}dx$$

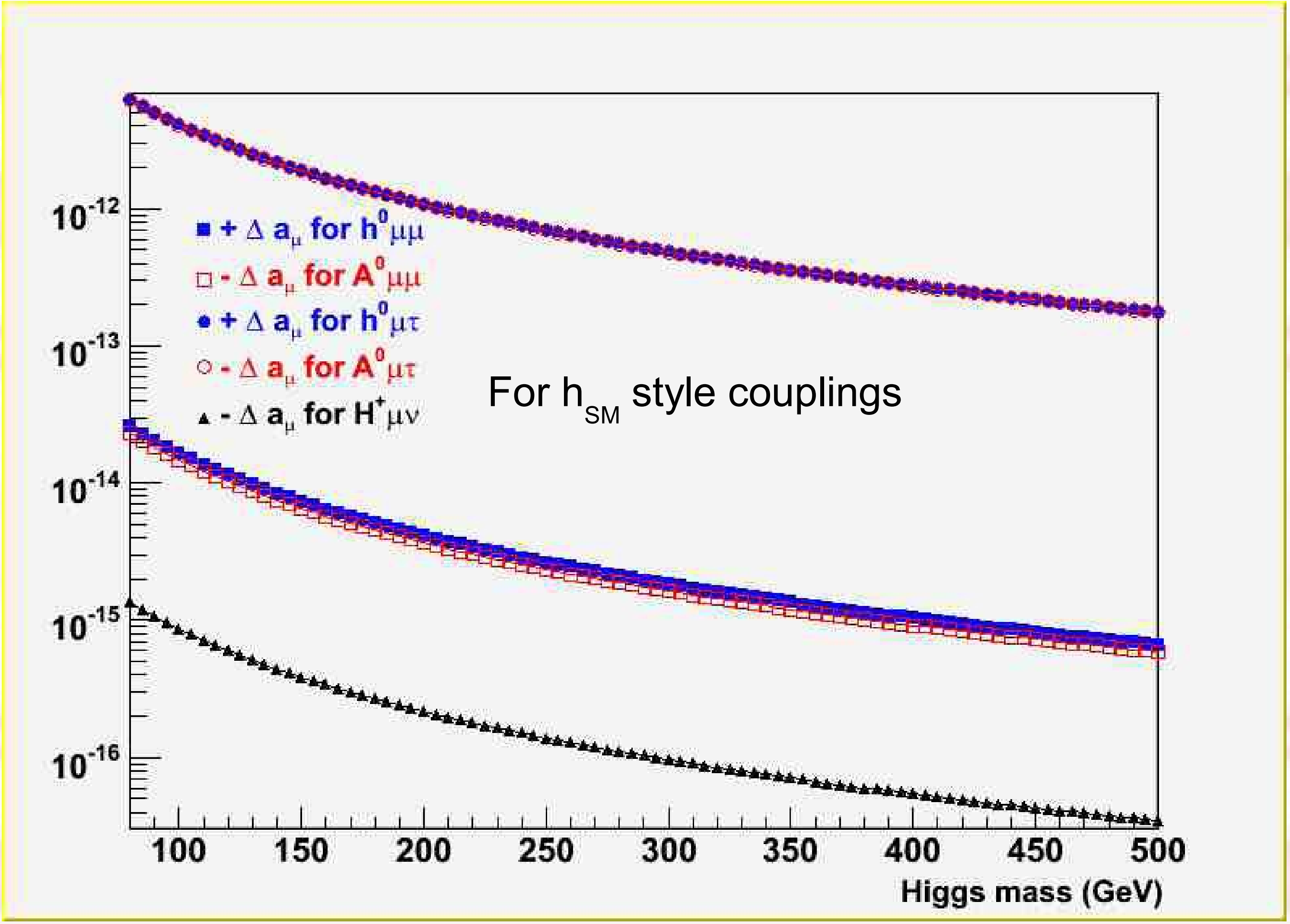
***h_{ij}* are Yukawa couplings : due to mass hierarchies, the main contribution comes from the H-τ-μ coupling.**

g-2 results

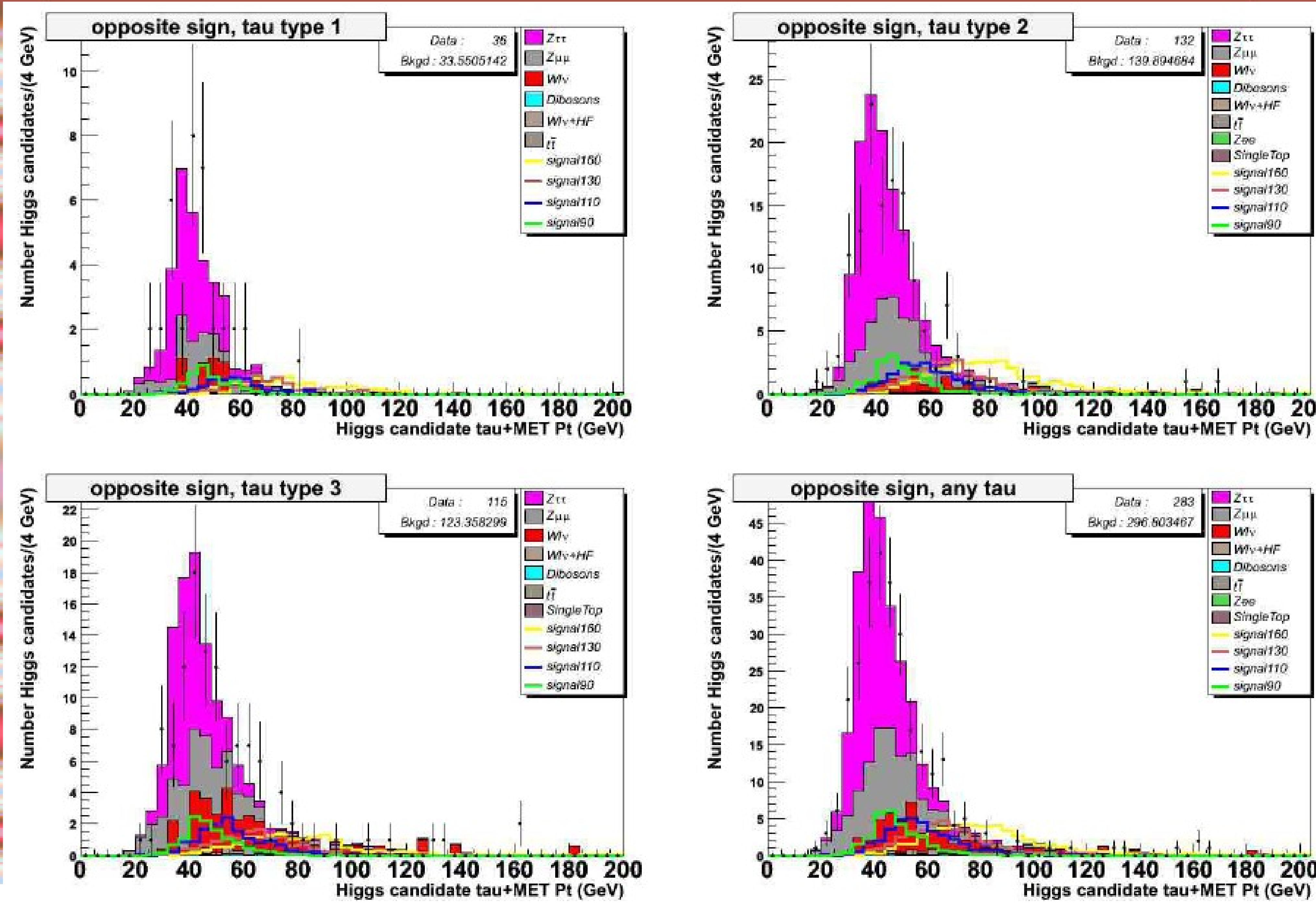
Exemple : if we assume that only one higgs contributes (one is light and the other are very heavy), then :



2HDM-III and muon g-2



Higgs candidate tau+MET Pt



Higgs candidate Higgs Pt