$m_{\tau\tau}$ working group

Report of the $m_{\tau\tau}$ working group

4th annual workshop of the Helmholtz Alliance

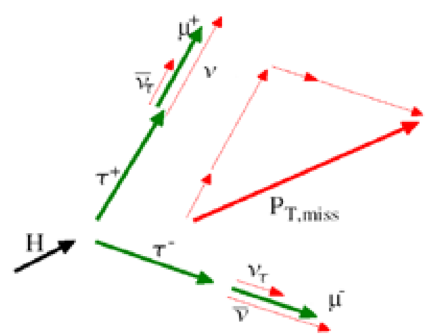
Dresden, 2.12.10

Wolfgang Mader

(on behalf of Michael Kobel)

PHYSICS AT THE TERA SCALE Helmholtz Alliance

TECHNISCHE UNIVERSITÄT DRESDEN



Task of the m_{tt} working group

- **Officially funded within the Helmholtz Alliance since April 2008.**

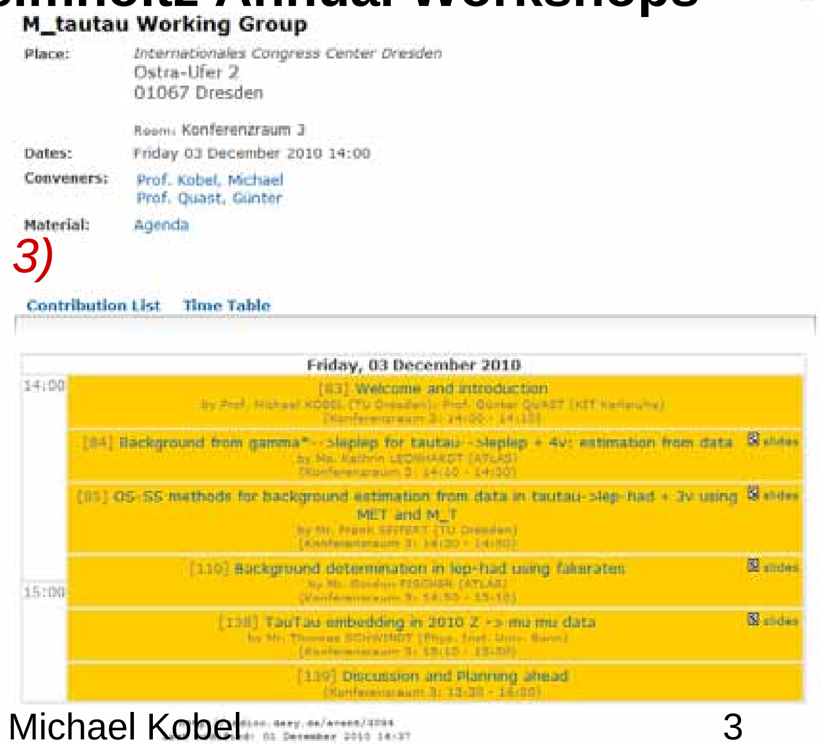
- **Main aims:**
  - *establishing procedures to extract shape and normalisation of tt mass distributions from data*
  - *evaluate the performance of various mass definitions*
  - *develop and verify methods of background extraction from data*
  - *assess experimental and theoretical uncertainties especially for Higgs and SUSY searches*

- **Active Members from**
  - ATLAS (Bonn, DESY, Dresden, Freiburg, Göttingen, München)
  - CMS (Aachen, DESY, Karlsruhe)
  - Other:
    - Theory (… nobody yet this year)
    - ILC, LCD (1 participant at last workshop)

- **Conveners:**
  - Michael Kobel (ATLAS, TU Dresden)
  - Günter Quast (CMS, KIT Karlsruhe)

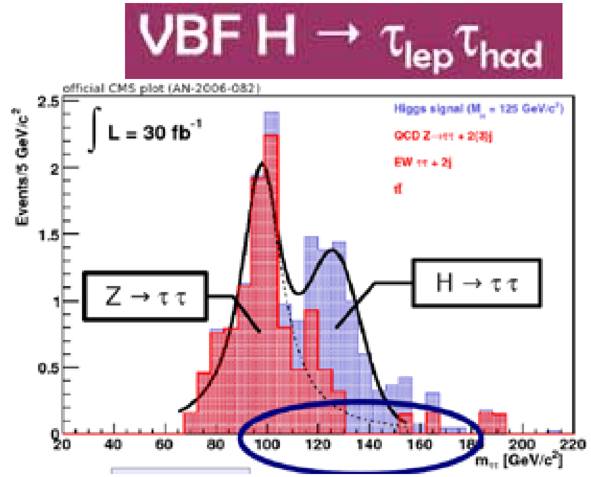
Meetings

- **Two-day workshops twice a year**
  - 21.-22.7.2008 Dresden: 32 participants
  - 26.-27.2.2009 Göttingen: 16 participants
  - 16.-17.7.2009 Bonn: 17 participants
  - 18.-19.2.2010 Karlsruhe: 18 participants
  - 20.-21.9.2010 Mainz: 24 participants
  - 24.-25.3.2011 München: *(to be confirmed tomorrow)*
- **Short intermediate sessions at Helmholtz Annual Workshops**
  - 28.11.2008 Aachen
  - 13.11.2009 Hamburg
  - 03.12.2010 Dresden
    (tomorrow, 14-16h, Konferenzraum 3)
- **…**

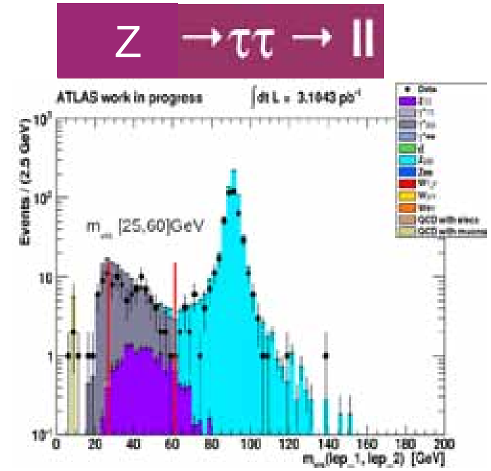


Main Topics

- **Physics channels**
  - Search for h/H/A à tt
    - lep-had, lep-lep, had-had
      - VBF   qq à qq-tt
      - b-ass. bg à b-tt
  - Measure Z àtt
    - lep-had, lep-lep



CMS: Manuel Zeise (KIT)

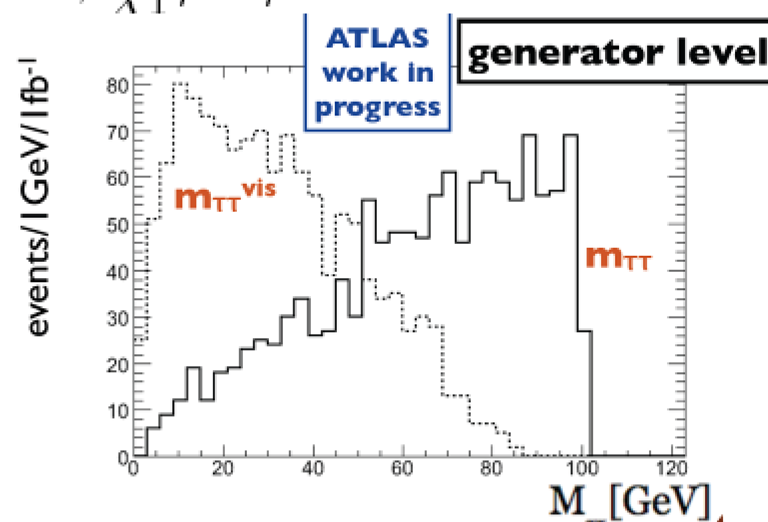


ATLAS: Kathrin Leonhardt (DD)

- Ditau-mass spectrum for $\tilde{\chi}^0_2 \rightarrow \tilde{\tau}^{\pm}_{1,2}\, \tau^{\mp} \rightarrow \tilde{\chi}^0_1 \tau^{\pm}\, \tau^{\mp}$
  - had-had, lep-had, lep-lep
    - measure endpoint
    - is known f($\tilde{c}_2{}^0$, $\tilde{c}_1{}^0$, t masses)

$$m_{\tau\tau}^{max} = \sqrt{\frac{(m(\tilde{\chi}_2^0)^2 - m(\tilde{\tau}_1)^2)\cdot(m(\tilde{\tau}_1)^2 - m(\tilde{\chi}_1^0)^2)}{(m(\tilde{\tau}_1)^2)}}$$

    - (no contributions in 2010)



ATLAS: Carolin Zendler, Christian Limbach (BN)

Recent progress

- ***Work together with first data !***
  (politically not easy, but very fruitful)

- **Extract m_{tt} shapes from data**
  - Reweighting techniques
    - lep-lep
  - Embedding techniques
    - lep-lep and lep-had

- **Evaluate different m_{tt} mass definitions**
  - All channels (Z, VBF h, b-assoc. h)
    - Performance (resolutions, biases)
    - Correlations and cut-dependences

- **Extract m_{tt} background from data**
  - Z à tt
    - ABCD methods
    - OS/SS methods

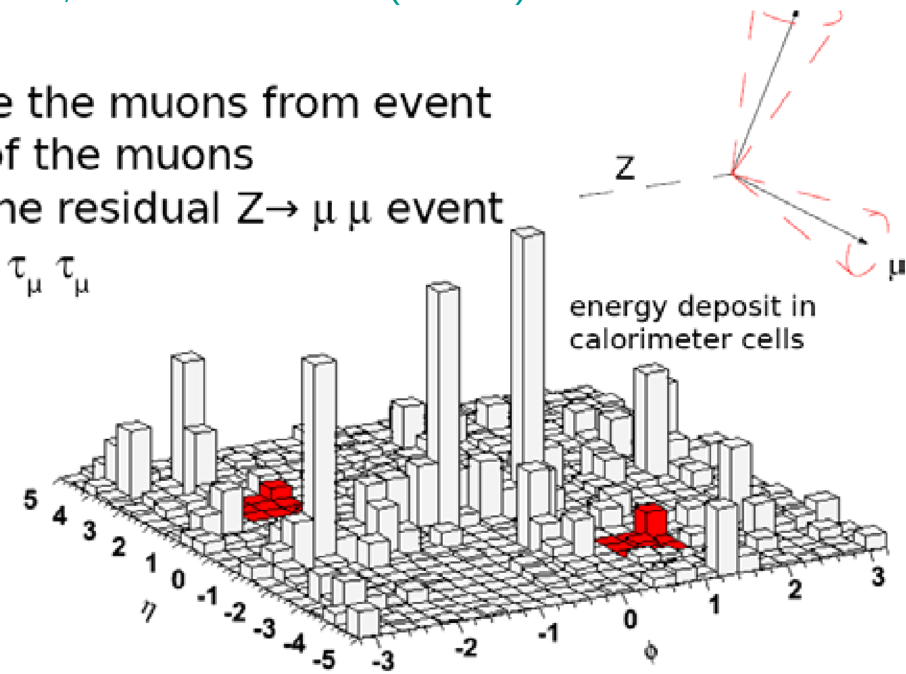
- **… and more**

1) Embedding Technique

KIT: Manuel Zeise (CMS) , BN: Nico Möser, Martin Schmitz, Thomas Schwindt (ATLAS) et al.

Procedure (“embedding technique”)

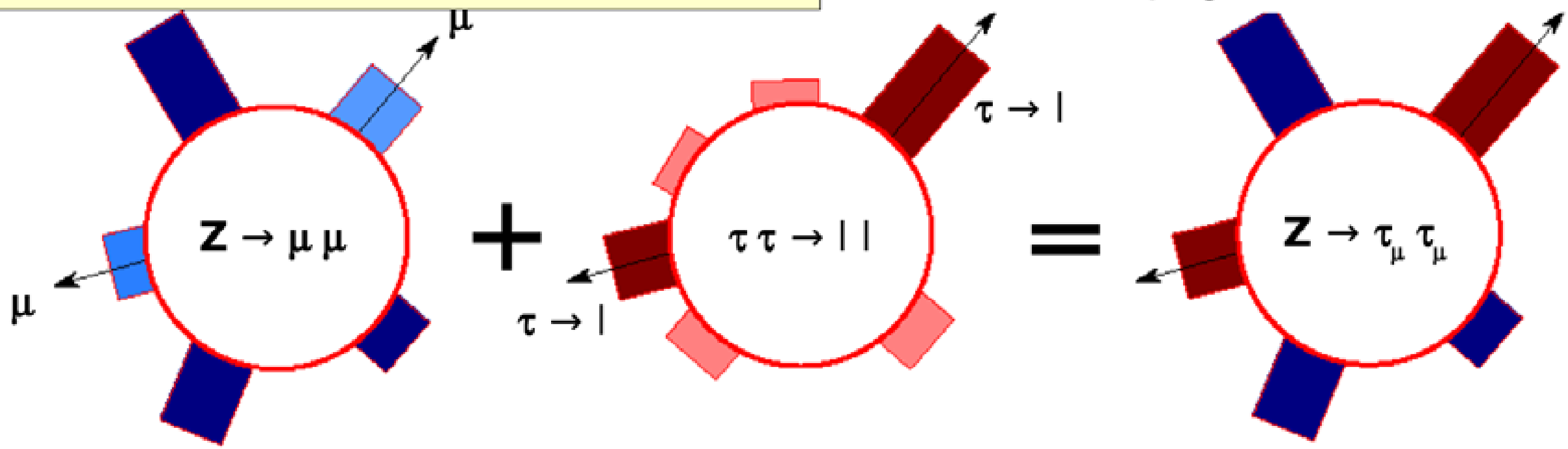
- take a real $\gamma^*/Z \rightarrow \mu\,\mu$ event and remove the muons from event
- simulate two taus with the kinematics of the muons
- overlay the result of the tau reco with the residual $Z \rightarrow \mu\,\mu$ event
- re-reconstruct to get an artificial $\gamma^*/Z \rightarrow \tau_\mu\,\tau_\mu$



Overlay

a) replace all hits in the tracker and in the calorimeter associated to the muons and the tau decay products

b) replace only the deposited energy in the calorimeter cells in a cone around the muon direction

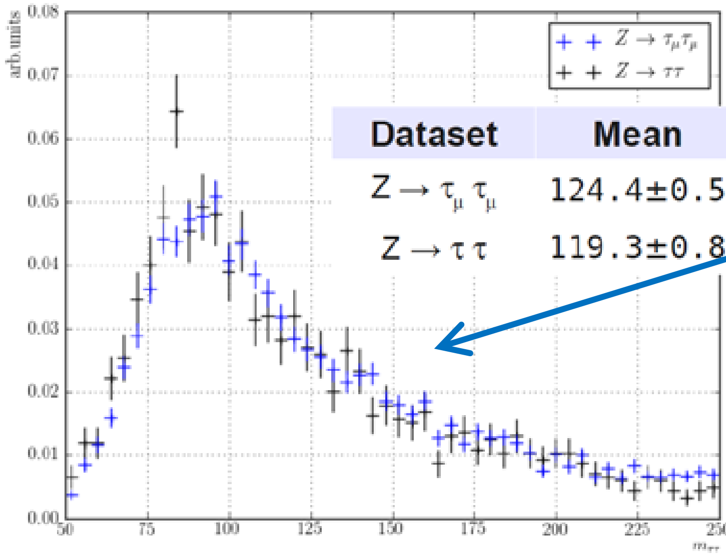


Embedding became standard tool in both ATLAS and CMS

- CMS (Manuel Zeise (KIT, 02/10), Agni Bethani (DESY, 09/10)

Mass distribution

di-tau mass distributions
(using coll. approx., see slide 15)



- cuts and selection criteria as described on the slides before
- transformation to $Z \to \tau\tau \to \mu + \text{jet}$
- tau decays with Tauola to get correct spin correlations

Dataset	Mean	RMS
$Z \to \tau_\mu \tau_\mu$	124.4±0.5	46.4±0.4
$Z \to \tau\tau$	119.3±0.8	44.1±0.6

shift towards larger masses is hardly visible as the distributi has a long tail

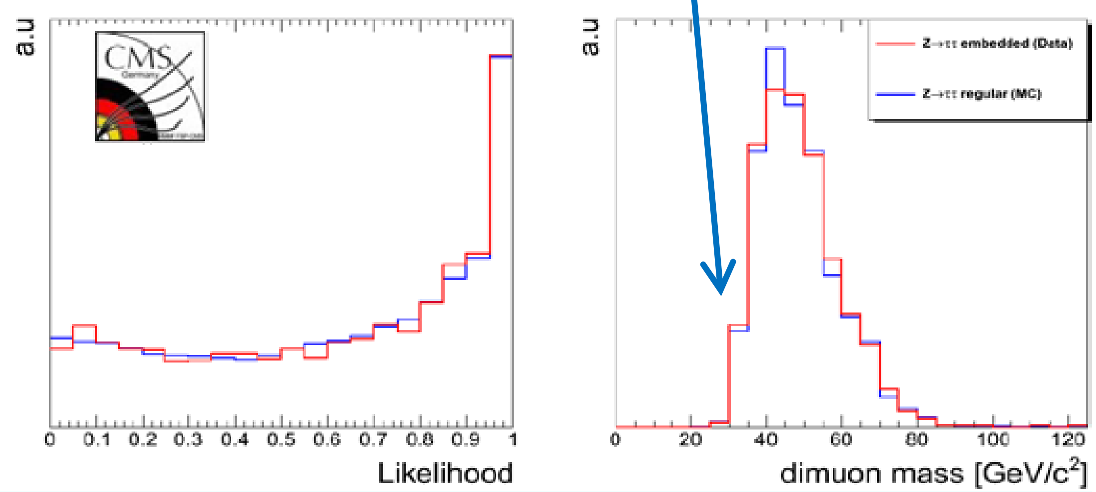
$Z \to \tau_\mu \tau_\mu$ reproduce $Z \to \tau\tau$ within statistical uncertainties

other distributions in the back

2010-02-18 Manuel Zeise

- **Collinear Mass (MC study)**
- **Visible Mass (first data!)**

Regular $Z\to\tau\tau$ (MC) vs. Artificial $Z\to\tau_\mu\tau_\mu$



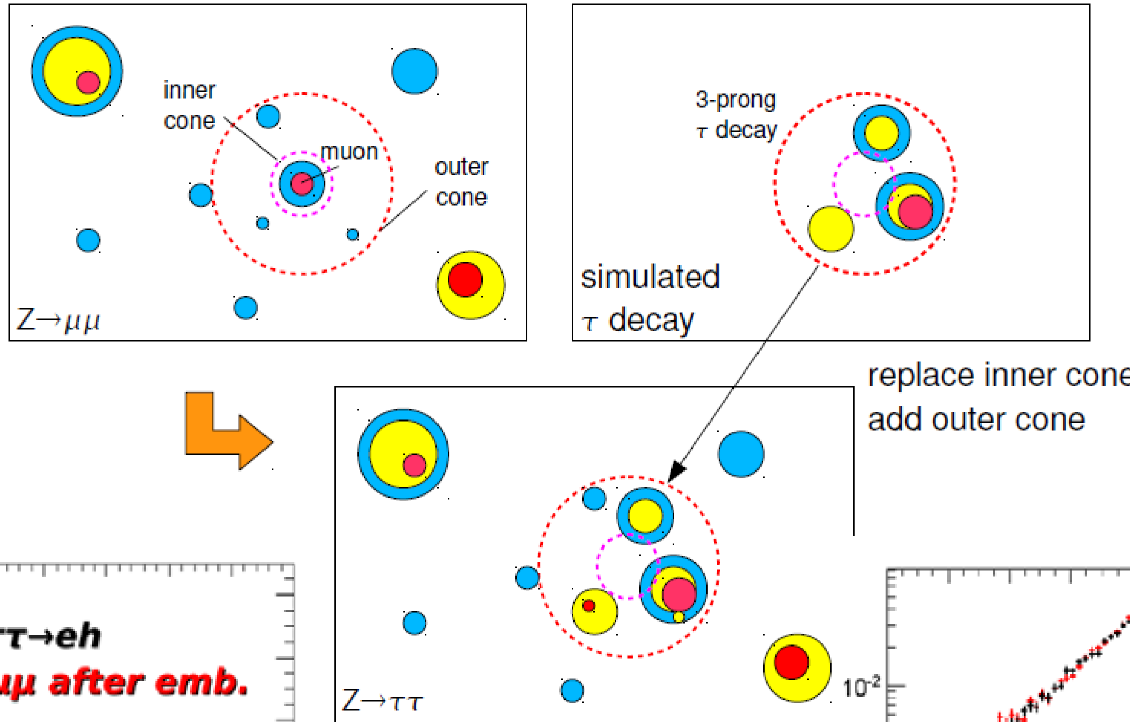
Visible mass and likelihood distributions

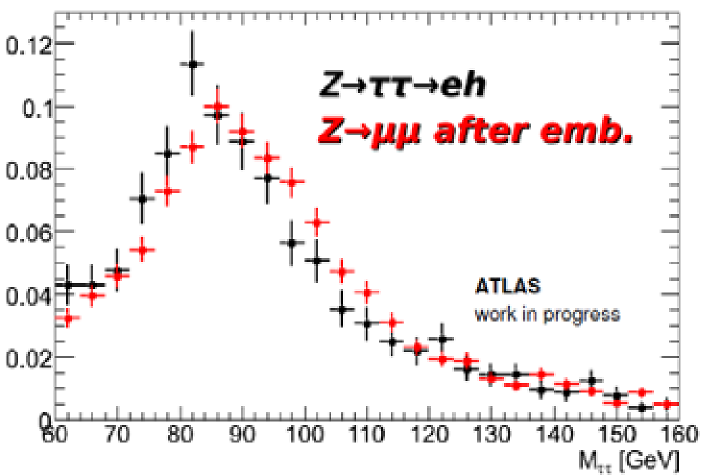
The shapes of the distribution show nice agreement

ATLAS

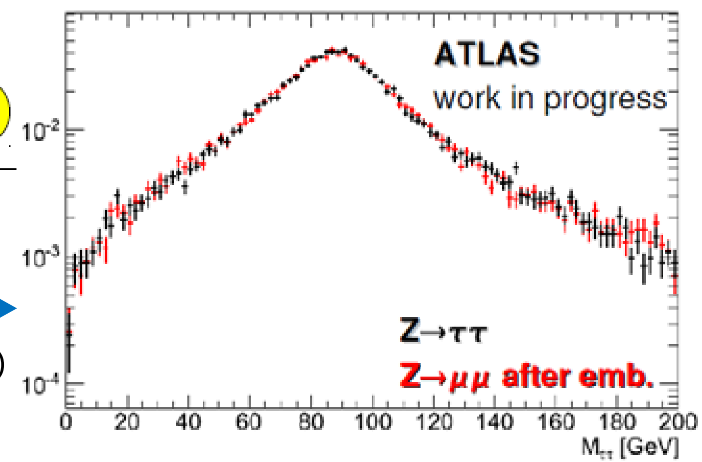
- Nico Möser (BN, 09/10): Solution of mass shift (+ of more „features“…)

  … so try more sophisticated approach:





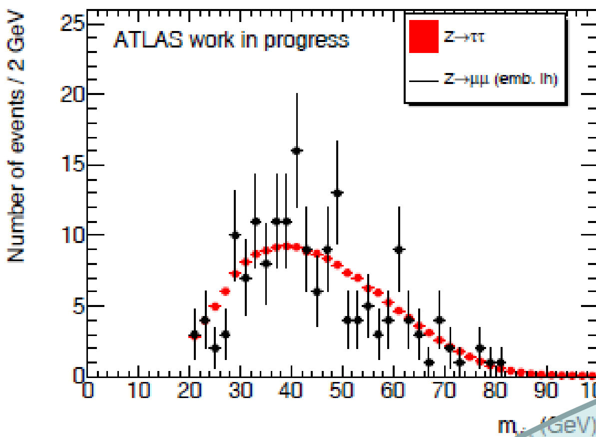
Standard Method (1 cone) → Sophisticated Method (inner+outer cone)

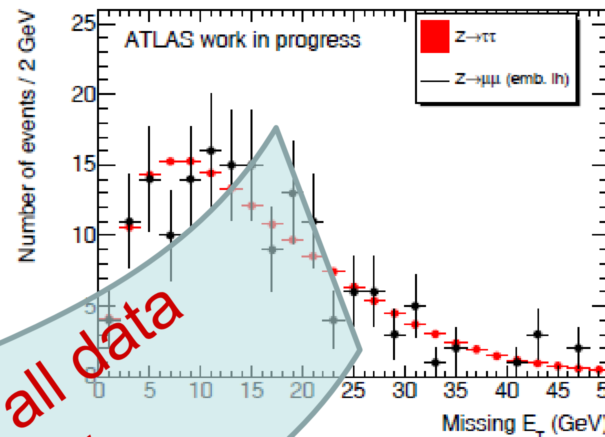


ATLAS

- Thomas Schwindt (BN, 09/10): comparison w/ first 3 pb^{-1} at 7 TeV

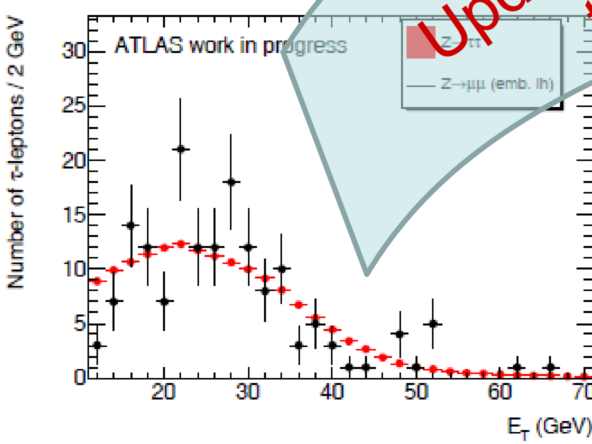
Embedding data: Event observables

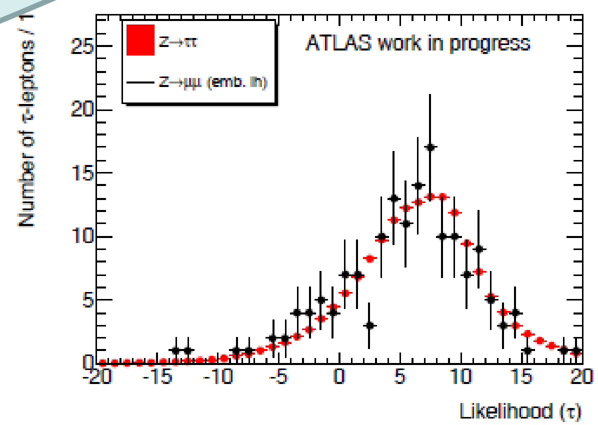




Update with all data tomorrow

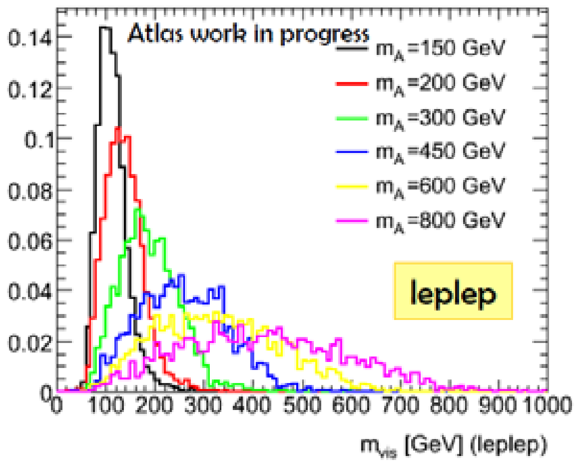
Embedding data: Tau observables

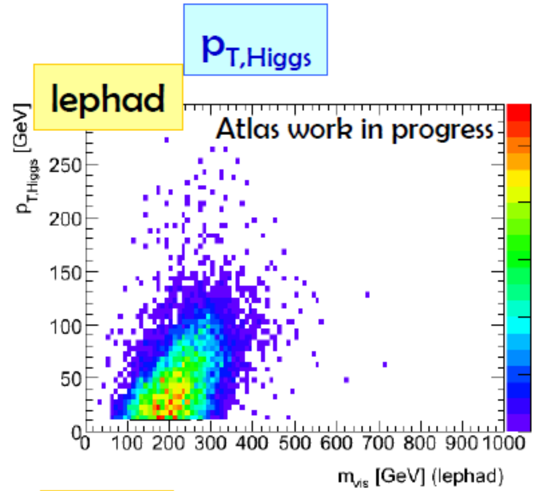


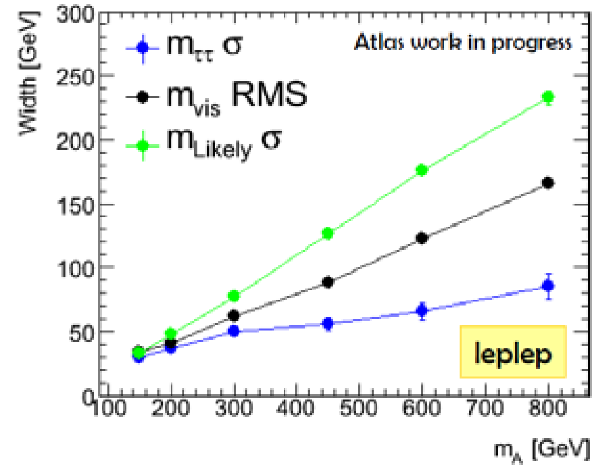


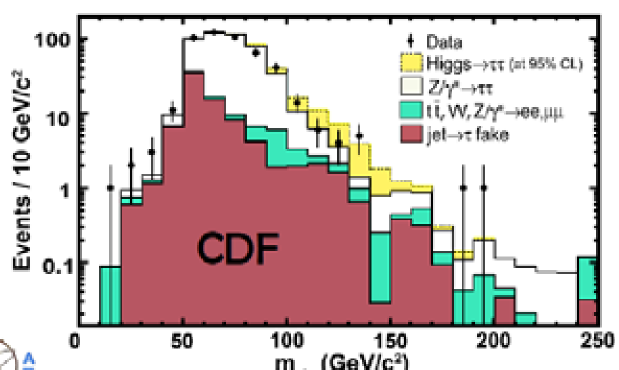
2) Performance of mass definitions

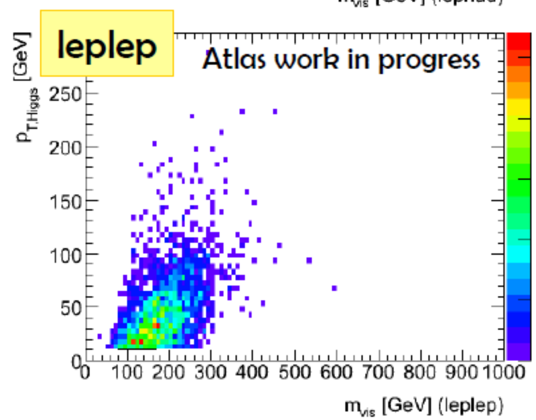
- **Complete and detailed studies by**
  - Jana Schaarschmidt (DD,02/10) for b-assoc. b+g à b+h/H/A à b+tt
  - Vera Stalter (FR,09/10) for VBF h/H/A à tt and Z à tt











- m_{Likely} largest width
- $m_{\tau\tau}$ smallest width
- other masses can only compete with $m_{\tau\tau}$ for very low values of m_A

Systematic comparison of different mass definitions

⇨ Correlations of mass with $p_{T,miss}$ and $p_{T,Higgs}$

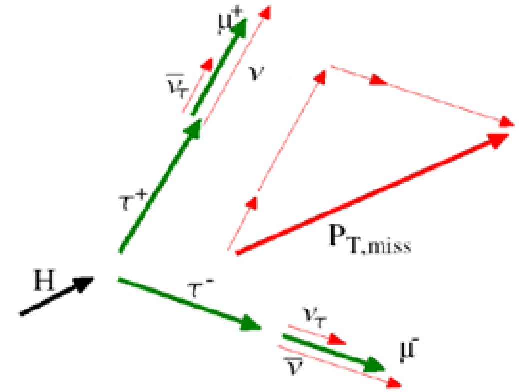
Study of x_1,x_2 and cos(Df $_{ll}$) cuts (Vera Stalter, FR, 09/10)

in collinear mass definition

	Old cuts	New cuts
x_1,x_2 :	[0; 0.75] →	[0; 1]
$\Delta\phi_{ll}$:	cos[-0.9; 0.9] →	[0;165°]

with change of x_1,x_2 and cos($\Delta\phi_{ll}$) cuts:

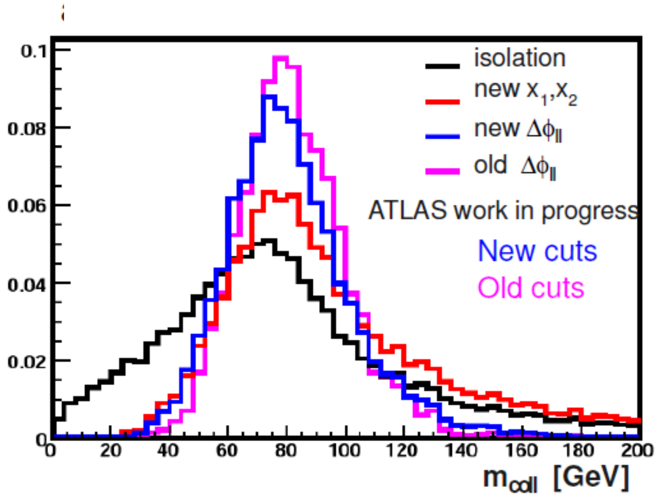
- 2.6× higher efficiency
- little influence on m_{coll} shape

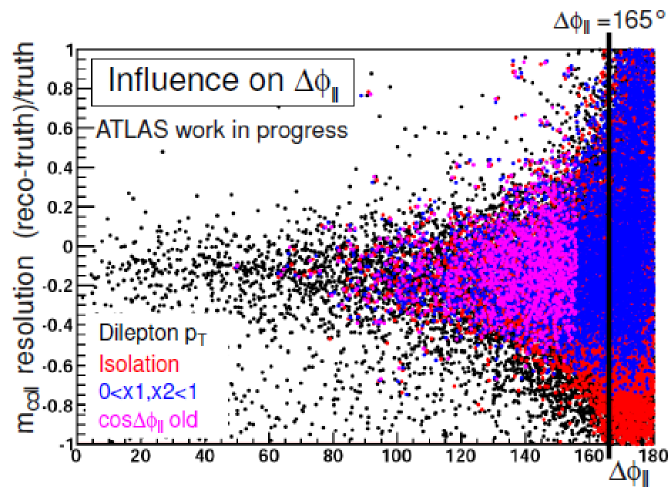


$x = p_{T,l} / p_{T,\tau}$

$0 < x < 1$

$$m_{\tau\tau} = \frac{m_{\ell\ell}}{\sqrt{x_1 \cdot x_2}}$$



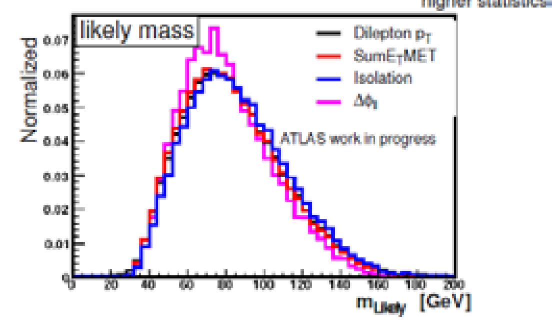


Z → ττ → ll

(Pythia)

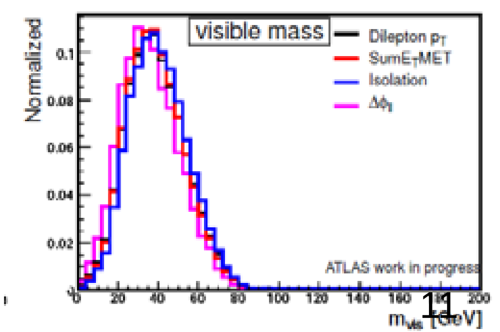
Using Z→ ττ → ll cuts with $\Delta\phi_l$ in [0; 170°]

higher statistics



For other mass definitions

- If bad conditions for collinear mass reconstruction:
  - → alternative masses → no x_1,x_2 and $\Delta\phi_{ll}$ cuts necessary
  - → m_{likely} roughly centered around m_Z, large tails
  - → m_{vis} , m_T, m_{ll} not centered around m_Z



3) Estimation of backgrounds with data

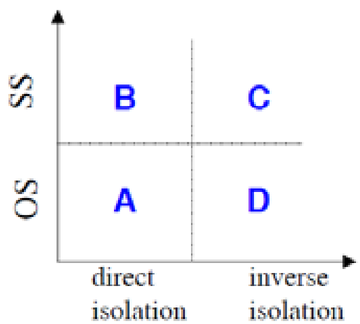
„ABCD methods“

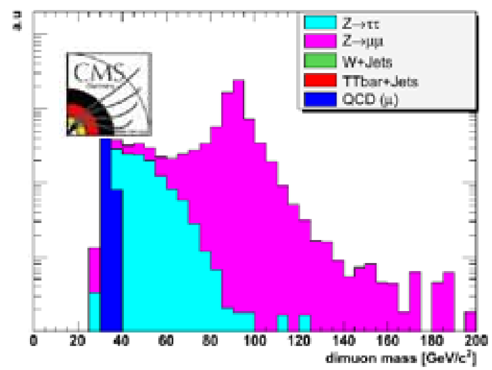
- CMS: QCD in $Z \to \tau\tau \to \mu\mu + 4\nu$
  (A.Raspereza, DESY, 09/10)

First Look at Data (1.7 pb^{-1})

Second largest background after $Z \to \mu\mu$:

QCD fraction is 20%

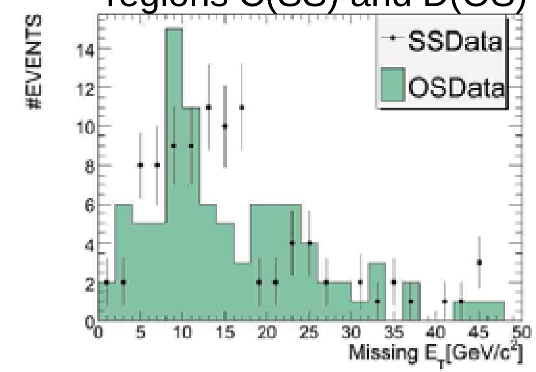


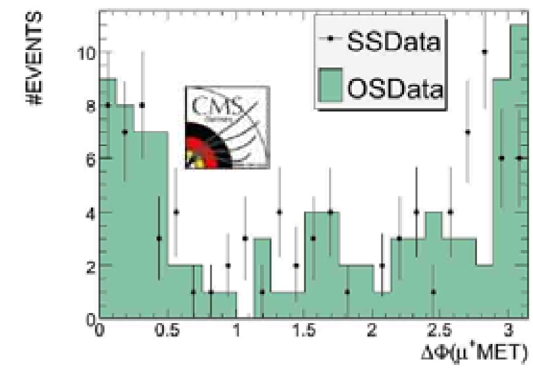


A : signal region

B, C, D : pure QCD (purity>97%)

regions C(SS) and D(OS)

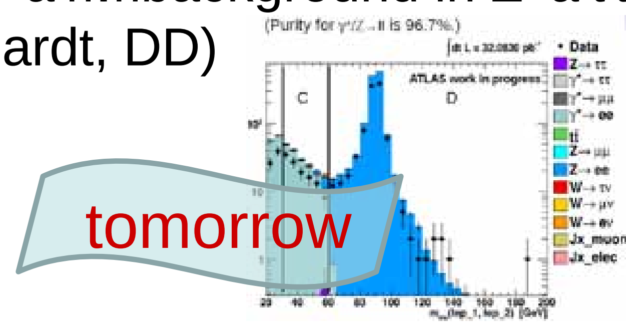




If after selection opposite sign and same sign have same properties :

$$A = B \cdot D/C$$

- ATLAS: $\gamma^* \to \mu\mu$ background in $Z \to \tau\tau \to \mu\mu + 4\nu$ (Ratio method!)
  (K. Leonhardt, DD)



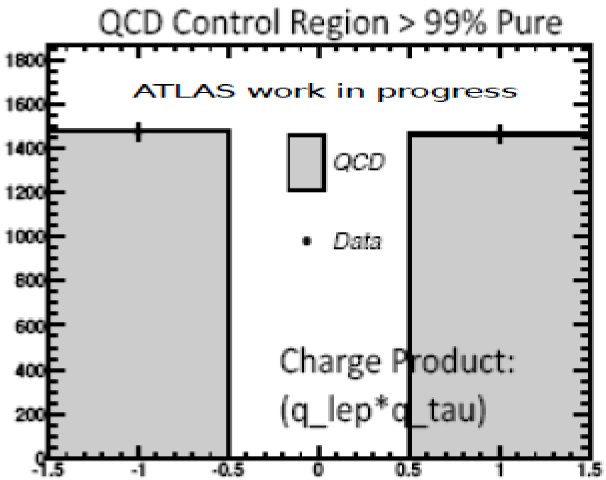
Central assumption is that F does not change From the control region (C – D) to the signal region(A – B).

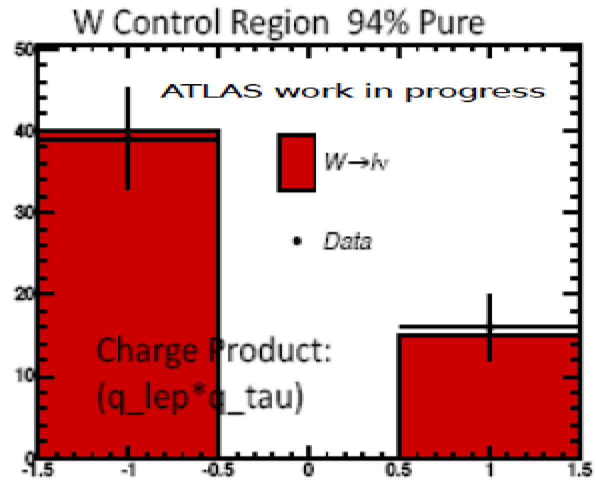
$$\tilde{D} = F \cdot \tilde{C}$$
$$\tilde{B} = F \cdot \tilde{A}$$

$$\tilde{X} = \frac{X_{Data}}{X_{MC}}$$
$$X = A, B, C, D$$

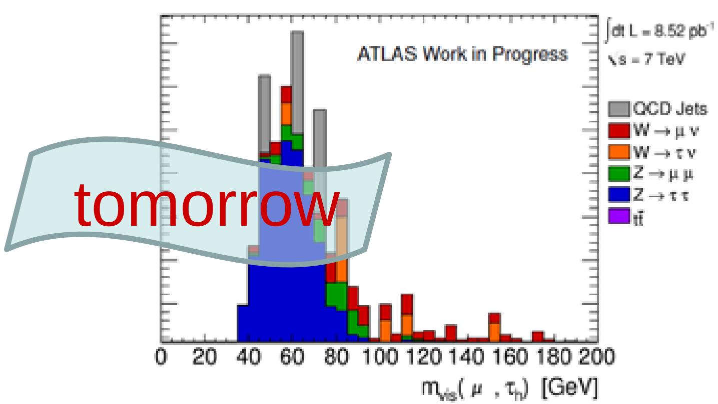
Opposite sign (OS) / Same signs (SS) Methods

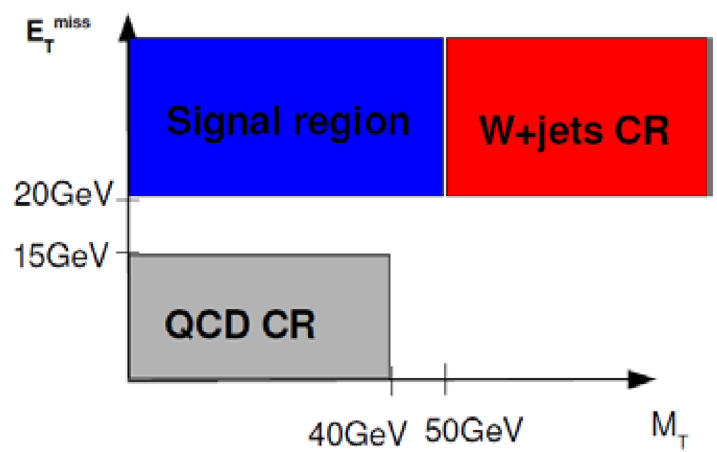
- ATLAS QCD in Z à t t à lep-had + 3n
  (G.Fischer, DESY, 09/10, et al.)





- F.Seifert , DD





Further activities

- **Backgrounds via fake rates**
  (G.Fischer, DESY)

For the full description we need 12 equations
→ equations = unknown variables

$$
\begin{pmatrix}
1&0&0&0&0&0&1&1&1&0&0&0\\
0&1&0&0&0&0&1&1&1&0&0&0\\
0&0&1&0&0&0&1&1&1&0&0&0\\
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0&0&0&0&0&0&0&0&0&1&1&1\\
0&0&0&0&0&0&0&0&0&1&1&1
\end{pmatrix}
\times
\begin{pmatrix}
S1 = 100\\ S2 = 100\\ S3 = 100\\ S4 = 100\\ S5 = 100\\ S6 = 100\\ QCD\_OS = 100\\ W\_OS = 100\\ Z\_OS = 100\\ QCD\_SS = 100\\ W\_SS = 100\\ Z\_SS = 100
\end{pmatrix}
=
\begin{pmatrix}
ID1\_OS = 400\\ ID2\_OS = 400\\ ID3\_OS = 400\\ ID4\_OS = 400\\ ID5\_OS = 400\\ ID6\_OS = 400\\ ID1\_SS = 300\\ ID2\_SS = 300\\ ID3\_SS = 300\\ ID4\_SS = 300\\ ID5\_SS = 300\\ ID6\_SS = 300
\end{pmatrix}
$$

tomorrow

- **Comparisons to disentangle CMS-ATLAS detector effects**
  (N.Möser, BN, ATLAS; M.Zeise, KIT, CMS, 02/10): MC-based, same cuts

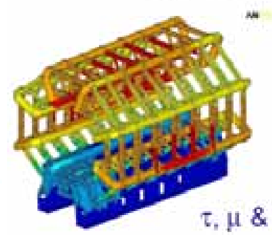
Reconstruction

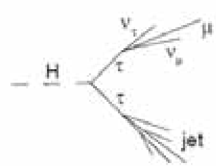
Muon
- $p_T^\mu > 15$ GeV
- $|\eta^\mu| < 2.1$
- reasonable ID:
  - global muon
  - ECAL isolation, pi-Veto

Tau
- $p_T^\tau > 20$ GeV
- $|\eta^\tau| < 2.1$
- reasonable Tau-IDs
- $dR(\mu,\tau) > 0.7$

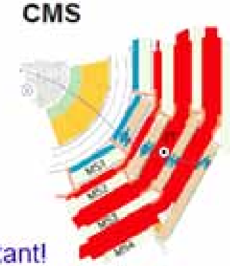
„reasonable" refers to standard selection cuts as used in the CMS/ATLAS analyses

ATLAS



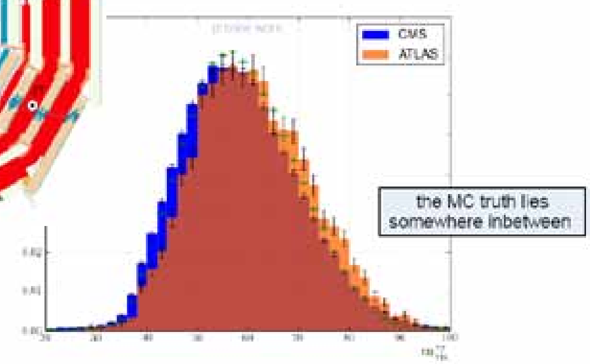


CMS



τ, μ & MET reconstruction important!

Visible Mass



General remarks

- ***Most active analysis working group in Helmholtz alliance***
  - *so far 5 two-day workshops, 3 intermediate meetings*
  - *20+ active people, increasing tendency*
  - *Unique exchange of experiences between ATLAS and CMS*

- ***Philosophy***
  - *Work on *methods and tools*, not on signal extraction*
  - *Profit from what is done anyway, but add wider perspectives*
  - *Don't add (too many) extra tasks (people are busy)*
  - *schedule meetings in "calm" phases*

- ***Talk approval policy by experiments***
  - *ATLAS:*
    - *central review procedure for "student talks"*
    - *a bit tedious, but by now well established*
  - *CMS:*
    - *less central, few open issues*

URLs

- ***Please inform yourself at:***
- **Homepage:**
  - http://tautauag.phy.tu-dresden.de/
- **Wiki:**
  - https://wiki-mtautau.terascale.de/index.php
- **Meeting dates and agendas:**
  - http://www.terascale.de/calendar/ à Alliance Indico
    - Physics at the Terascale > Research Topics > RT1: Physics Analysis > Working Groups (https://indico.desy.de/categoryDisplay.py?categId=152)
- **Subscription of mailing list:**
  - https://lists.desy.de/sympa/subscribe/hgfa-mtautauag
    à has to be done actively by *You*