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WÜRZBURG

Search for Signatures of the *Three Site Higgsless Model* at the ATLAS Detector

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ATLAS Experiment
Physics on the TeV-scale at the Large Hadron Collider

FSP 101 ATLAS

PHYSICS AT THE TERA SCALE
Helmholtz-Alliance

Outline

1. *Three Site Higgsless Model*
2. Production of truth level data
3. Detector simulation & analysis cuts
4. *Z'* search
5. *W'* search
6. Conclusions

The *Three Site Higgsless Model* (Chivukula et al. 2006)

- Maximally **deconstructed extra dimension** on 3 sites
  ➔ corresponds to an extended electroweak gauge group:

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SM	**+**	**"*KK*" modes**	
fermions		heavy fermions	$m_F > 3$ TeV
gauge bosons (γ, W, Z)		heavy gauge bosons (W', Z')	380 MeV < m' < ~ 1 TeV

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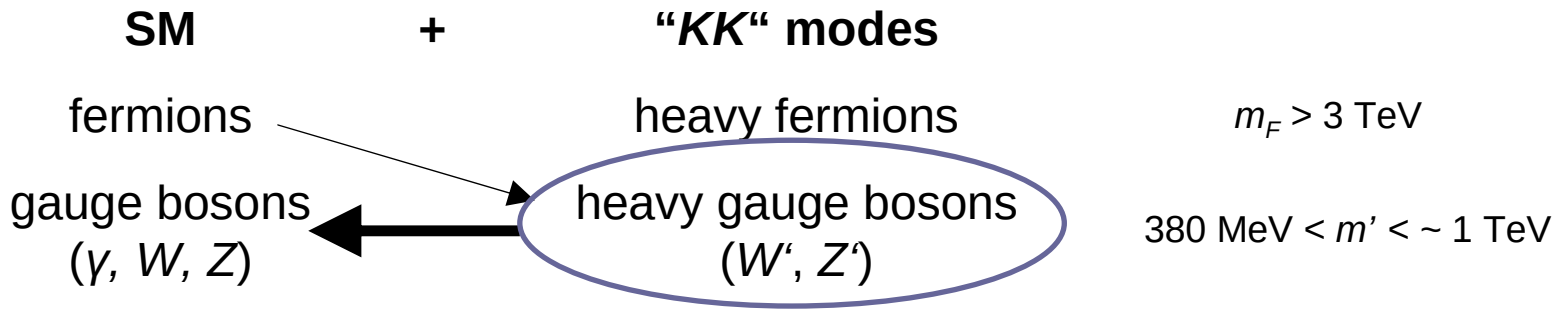

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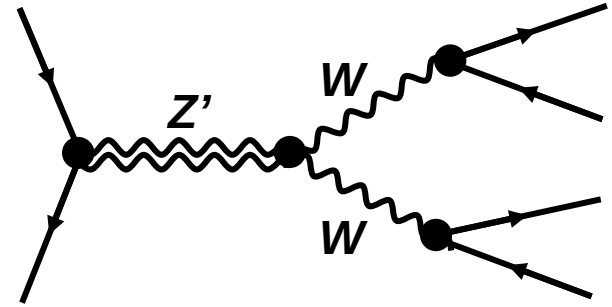
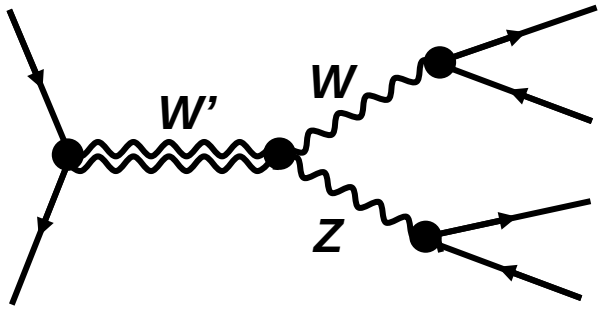
- large coupling to SM gauge bosons (dominant decay channel)

Decay channels and signatures



hadronic → leptonic

jet	*e,μ*	*e,μ*
jet	$E_{T,miss}$	$E_{T,miss}$
jet	*jet*	*e,μ*
jet	*jet*	$E_{T,miss}$



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jet	*jet*	*e,μ*	*e,μ*
jet	*jet*	*e,μ*	*e,μ*

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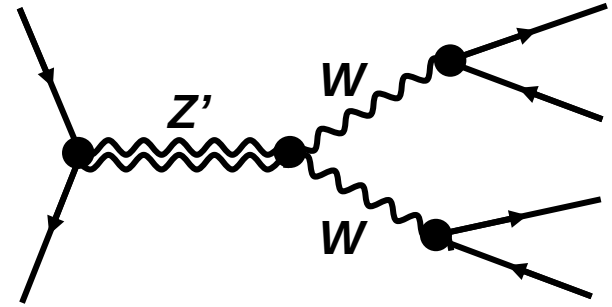

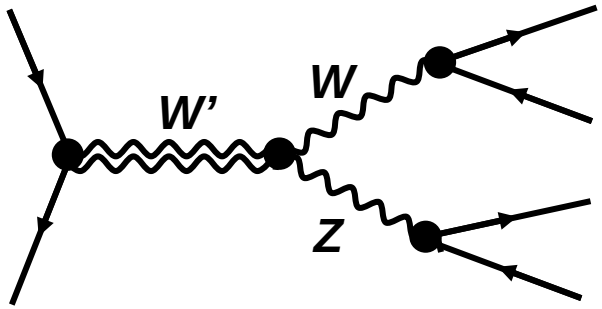

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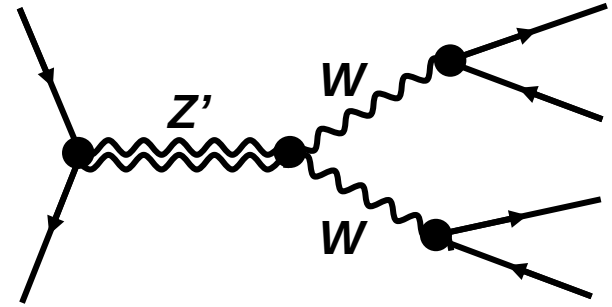
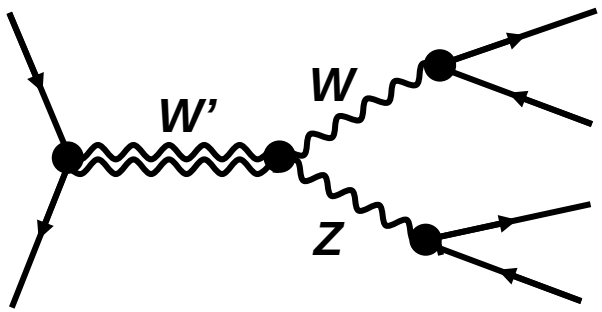
QCD background

branching ratio

Decay channels and signatures





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jet	jet	e,μ	
jet	jet	$E_{T,miss}$	

background !

jet	e,μ	jet	e,μ
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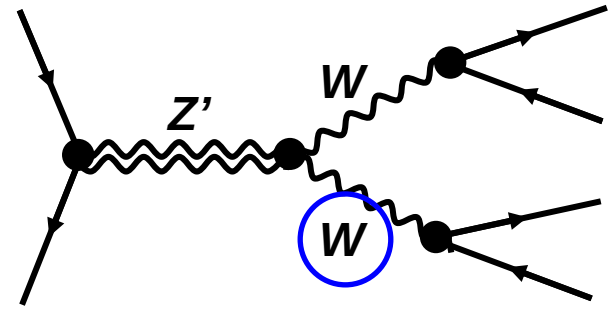

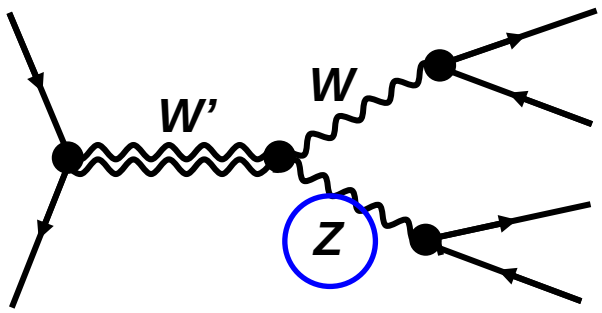

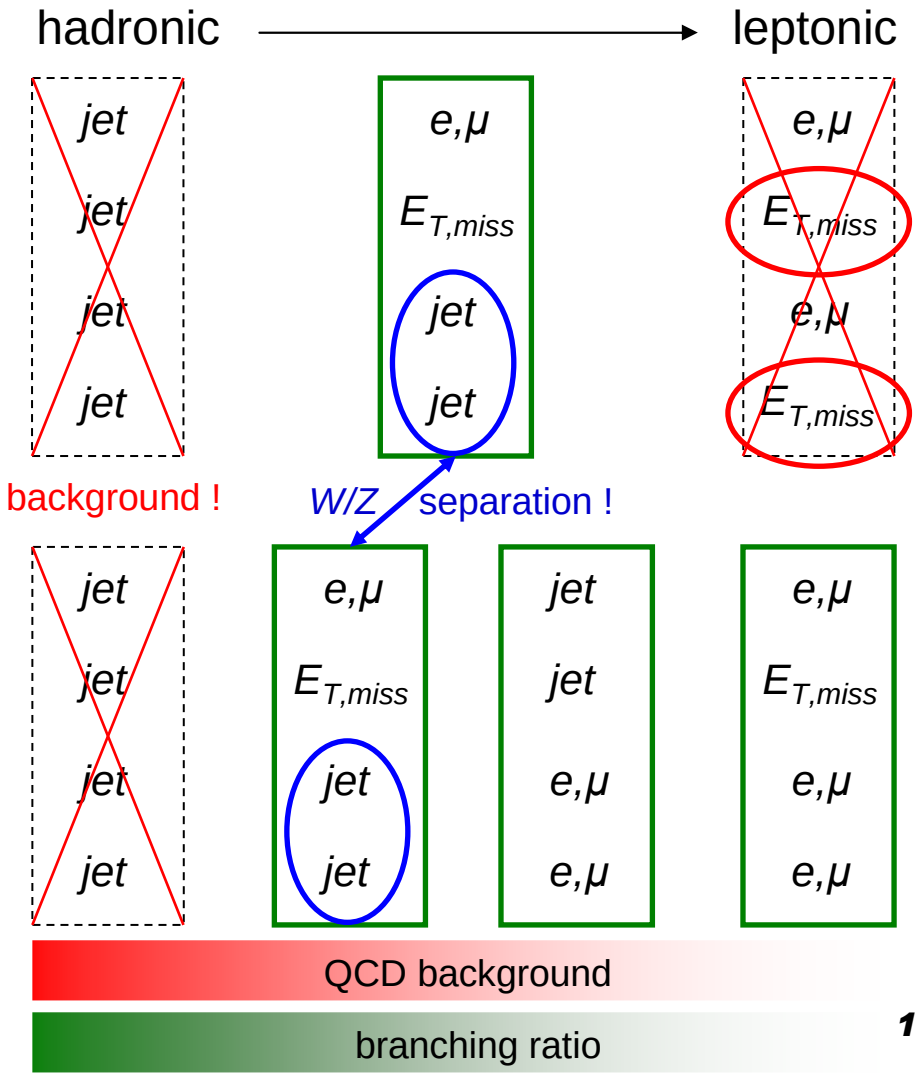

Generation of *Monte Carlo* data with WHIZARD (v1.92)

- ***Three Site Higgsless Model*** implemented **only** into parton level generator **WHIZARD** (C. Speckner)

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$pp \rightarrow lvjj,\ lljj,\ lvll$	$W´/Z´$ signal + irreducible background
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with $j = \{u,d,s,c,b\}$ and $l = \{e,\mu\}$

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Fragmentation of parton level data with PYTHIA (v6.4)

ATLAS detector simulation of private samples with ATLFAST-2 (ATHENA rel. 14.5.0)

- combined muons (ID + spectrometer) and ATLAS *seeded cone* jets with $R = 0.4$
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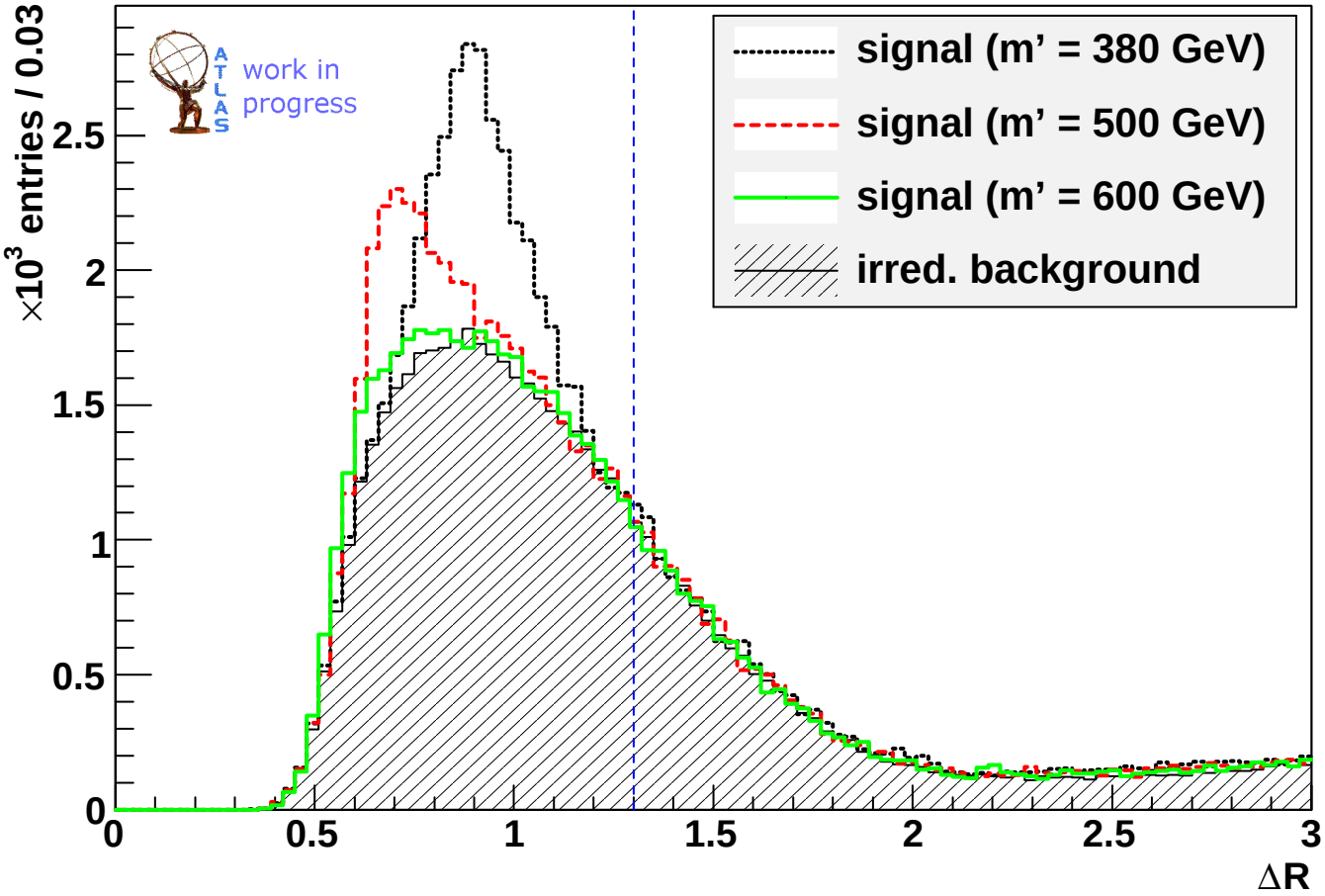
Angular di-jet resolution at ATLAS (*seeded cone* with *R* = 0.4)



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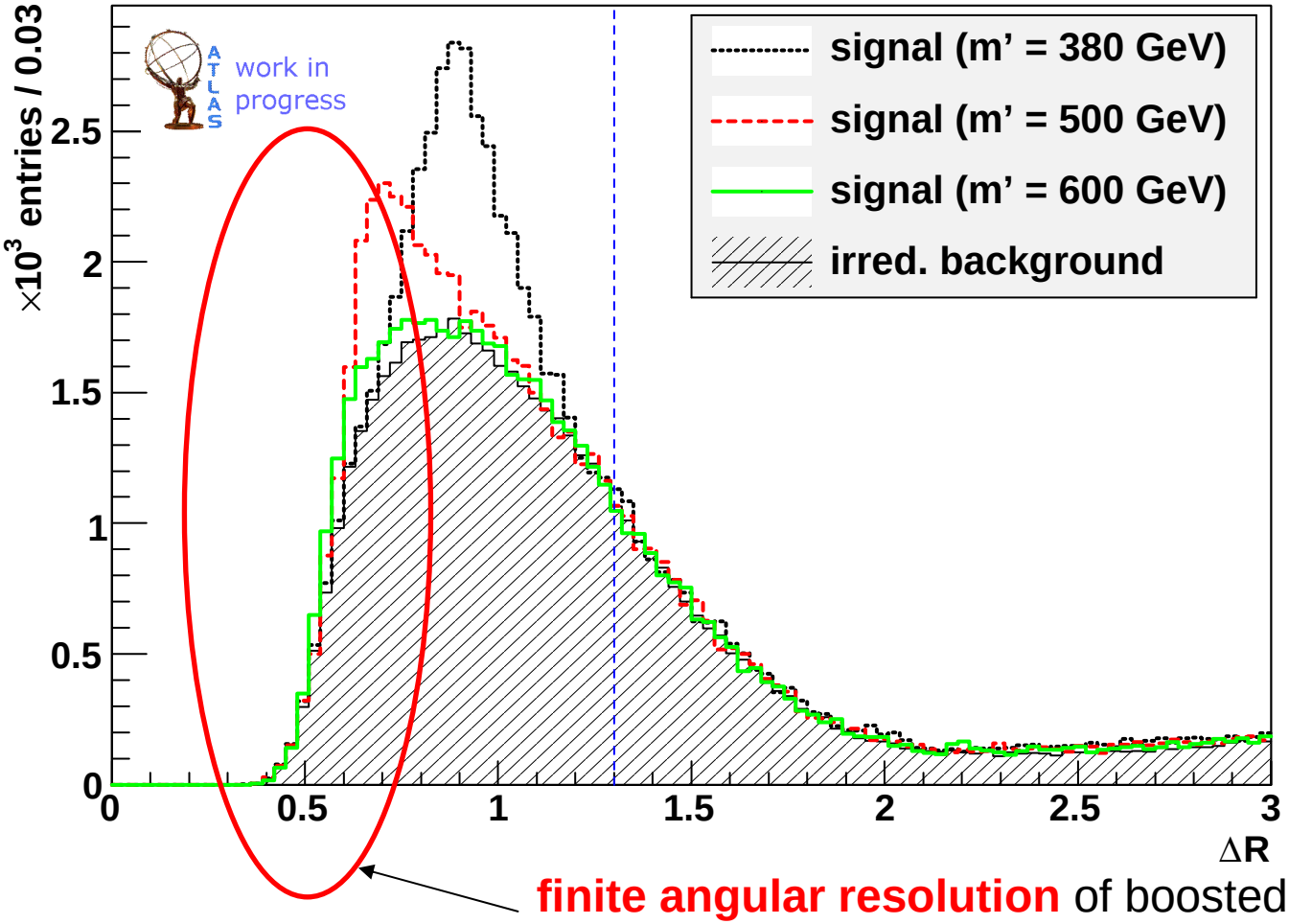
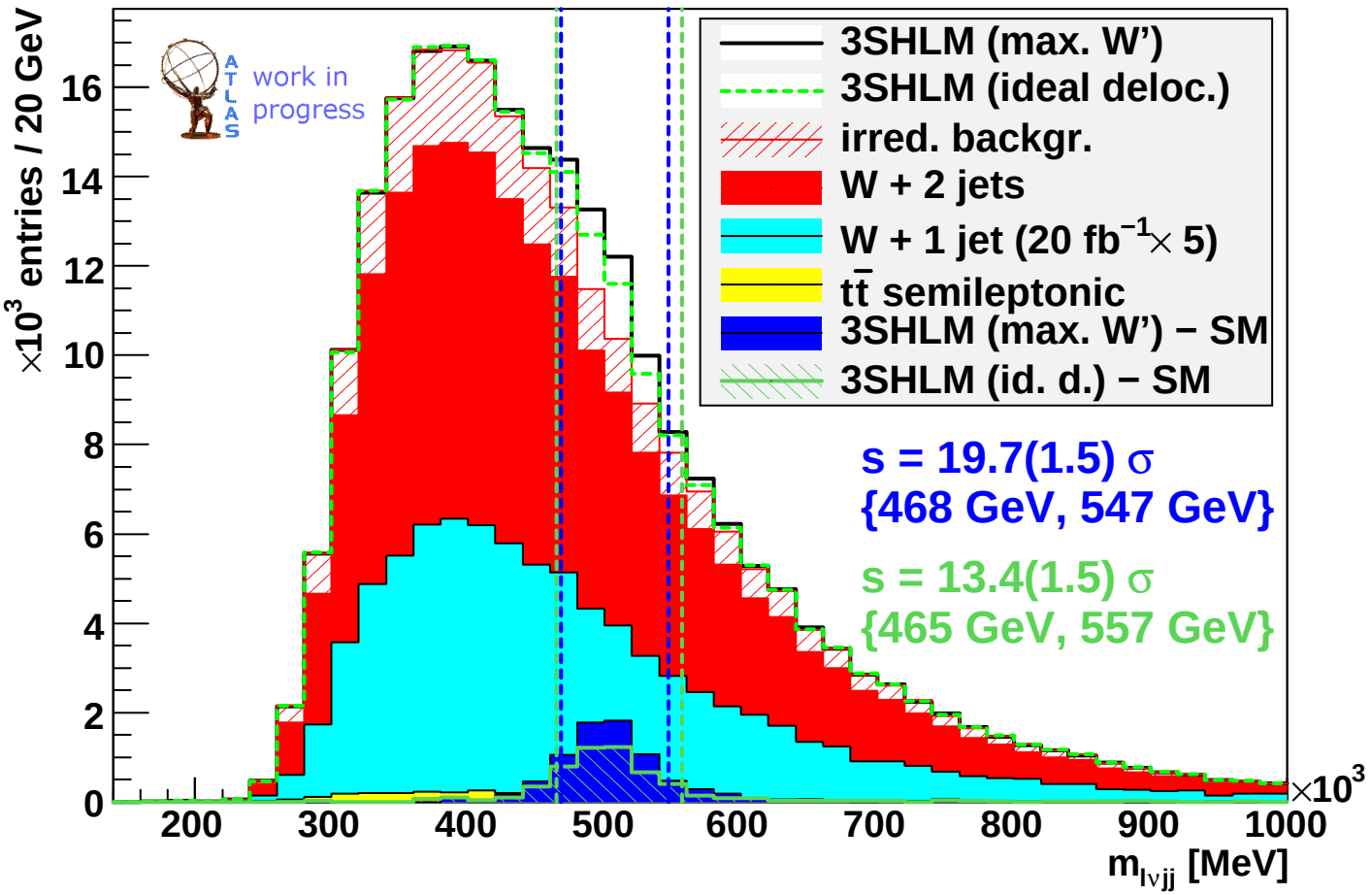


finite angular resolution of boosted jet pairs

➔ governed by the jet algorithm parameter *R*

➔ severe draining of the signal for *m'* > 500 GeV

Z' search: *lνjj* channel with *m'* = 500 GeV



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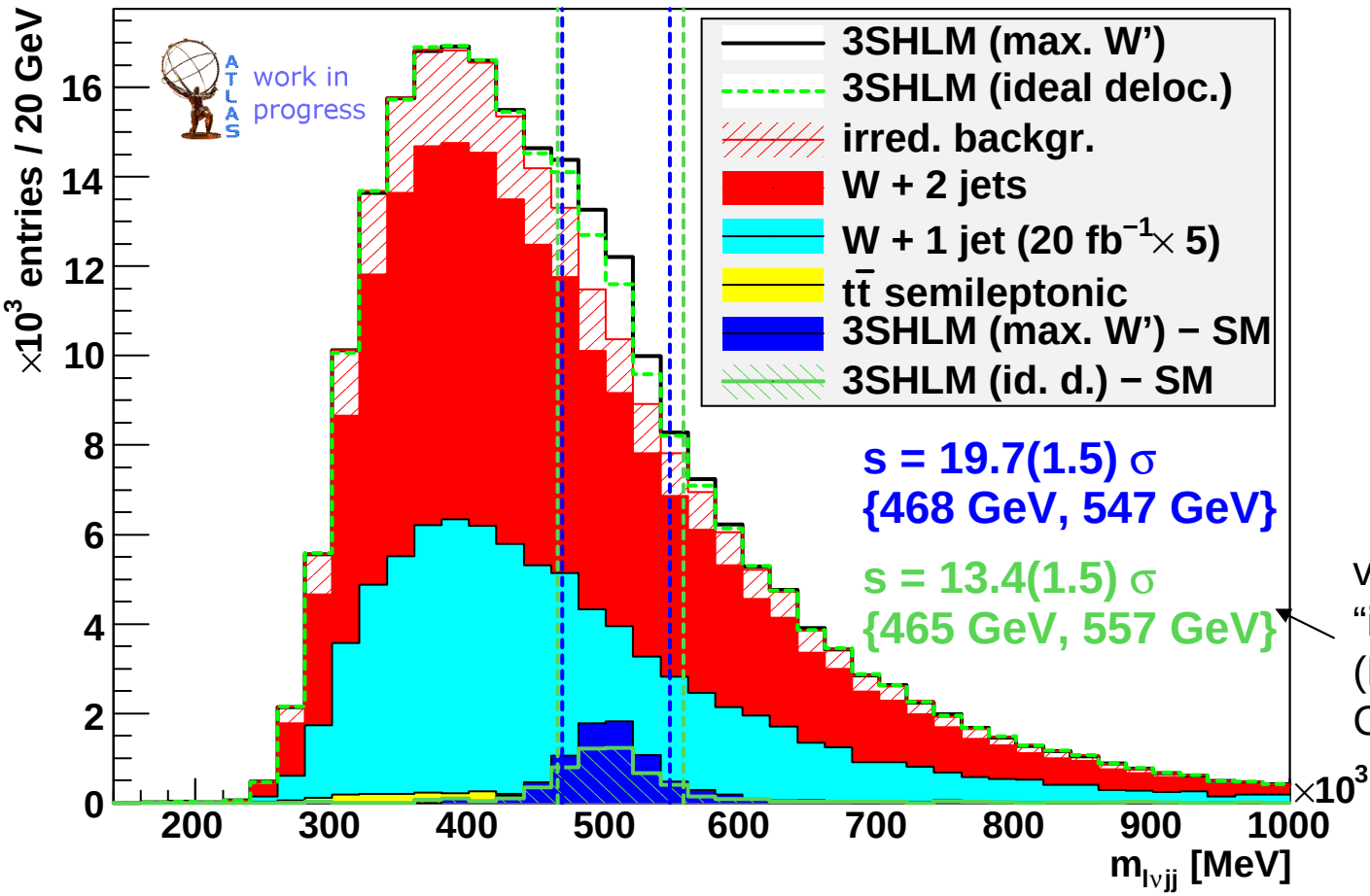

vanishing $g_{W'ff}$
"**ideal delocalization**"
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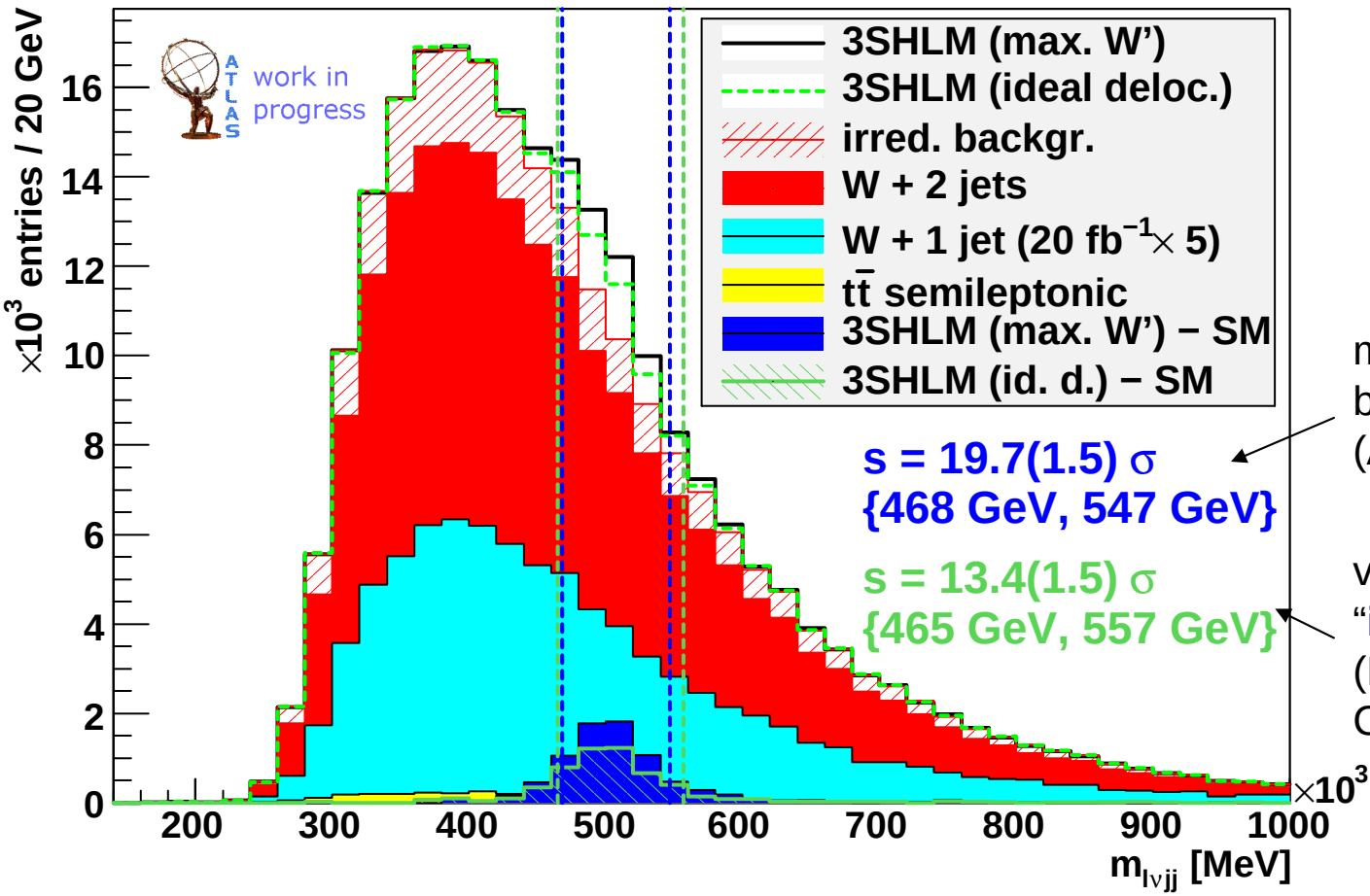

maximal $g_{W'ff}$ allowed by EWPT at 1-loop (Abe et al. 2008)

vanishing $g_{W'ff}$ "**ideal delocalization**" (EWPT at tree level, Chivukula et al. 2006)

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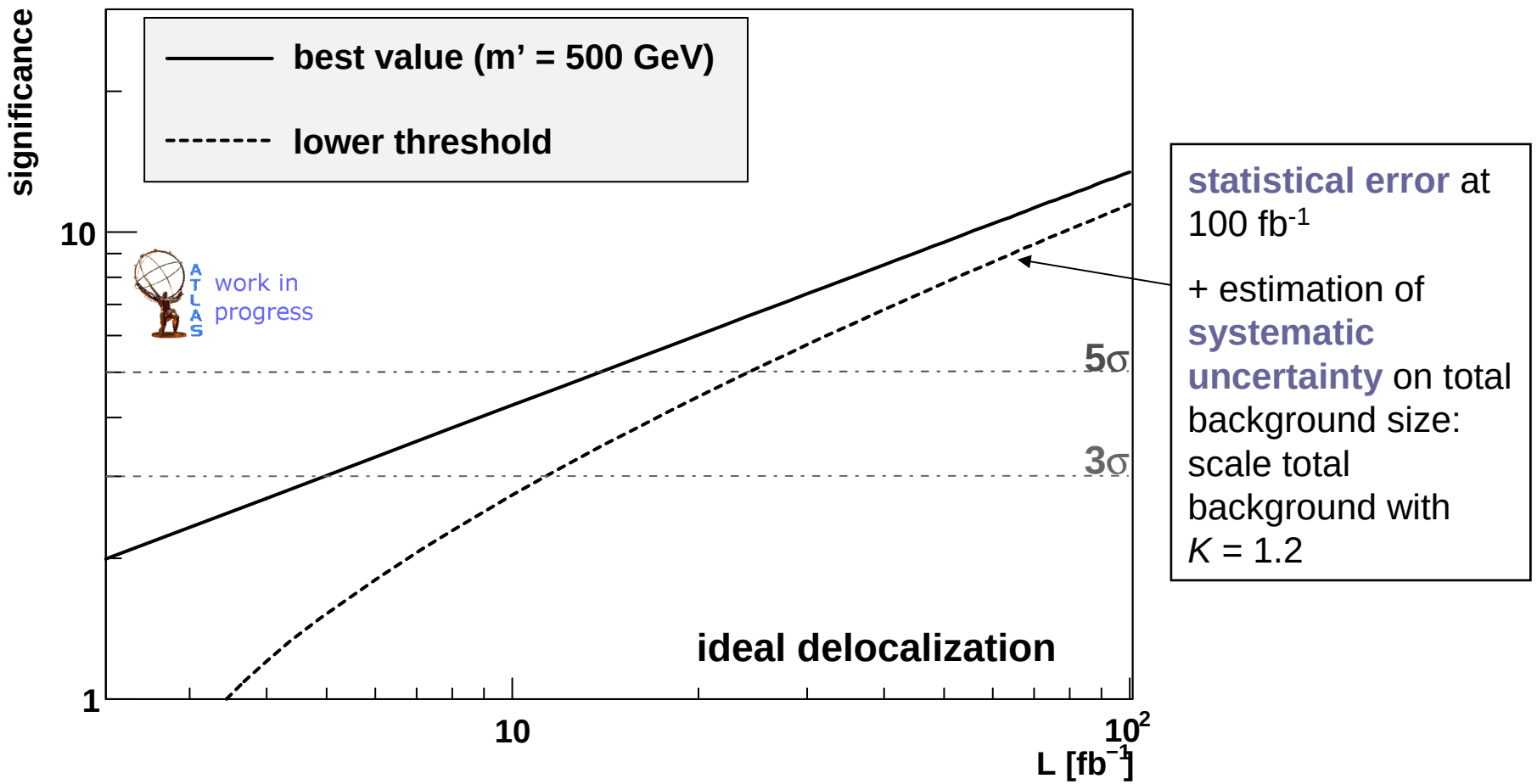

statistical error at 100 fb^{-1}

+ estimation of **systematic uncertainty** on total background size: scale total background with K = 1.2

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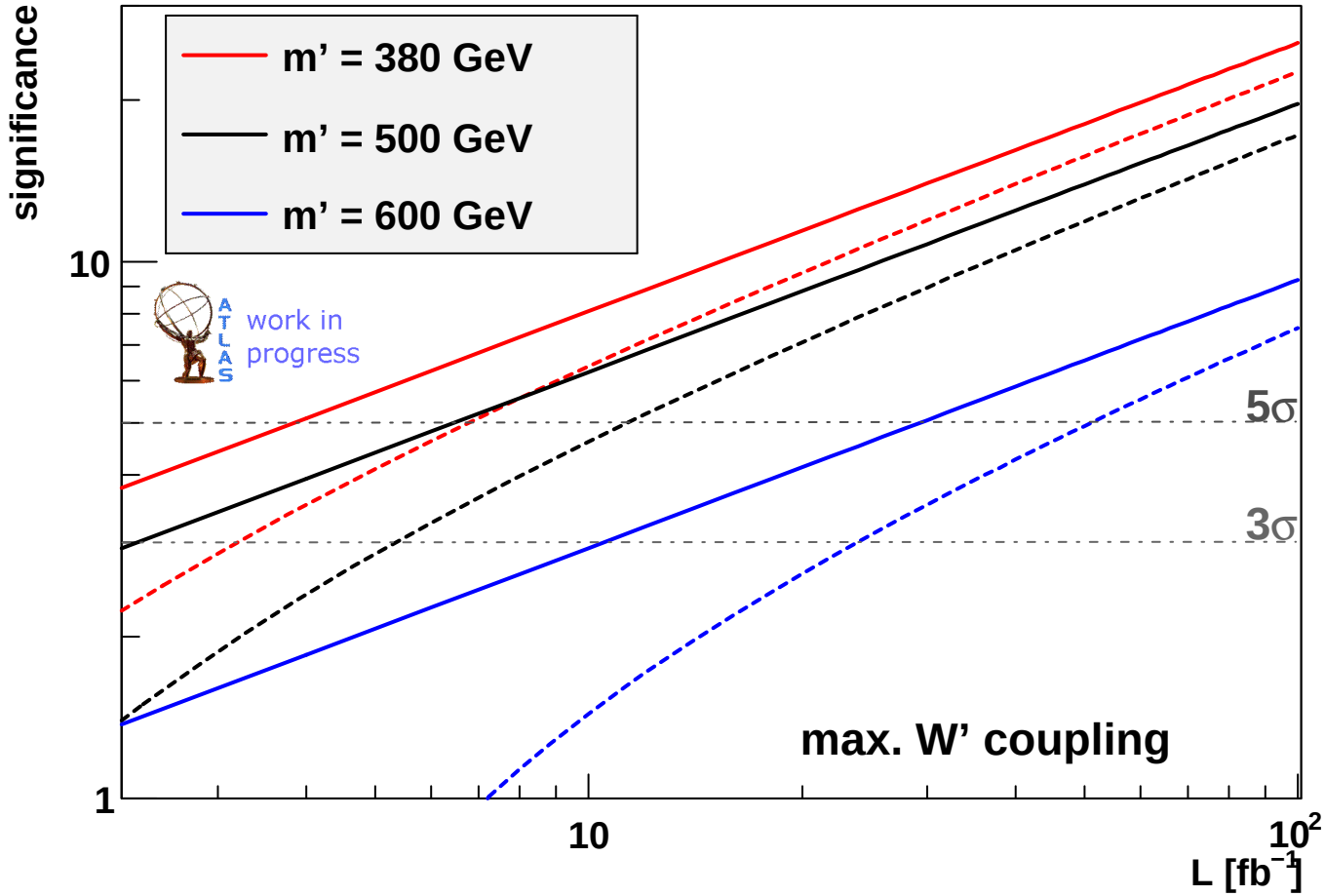

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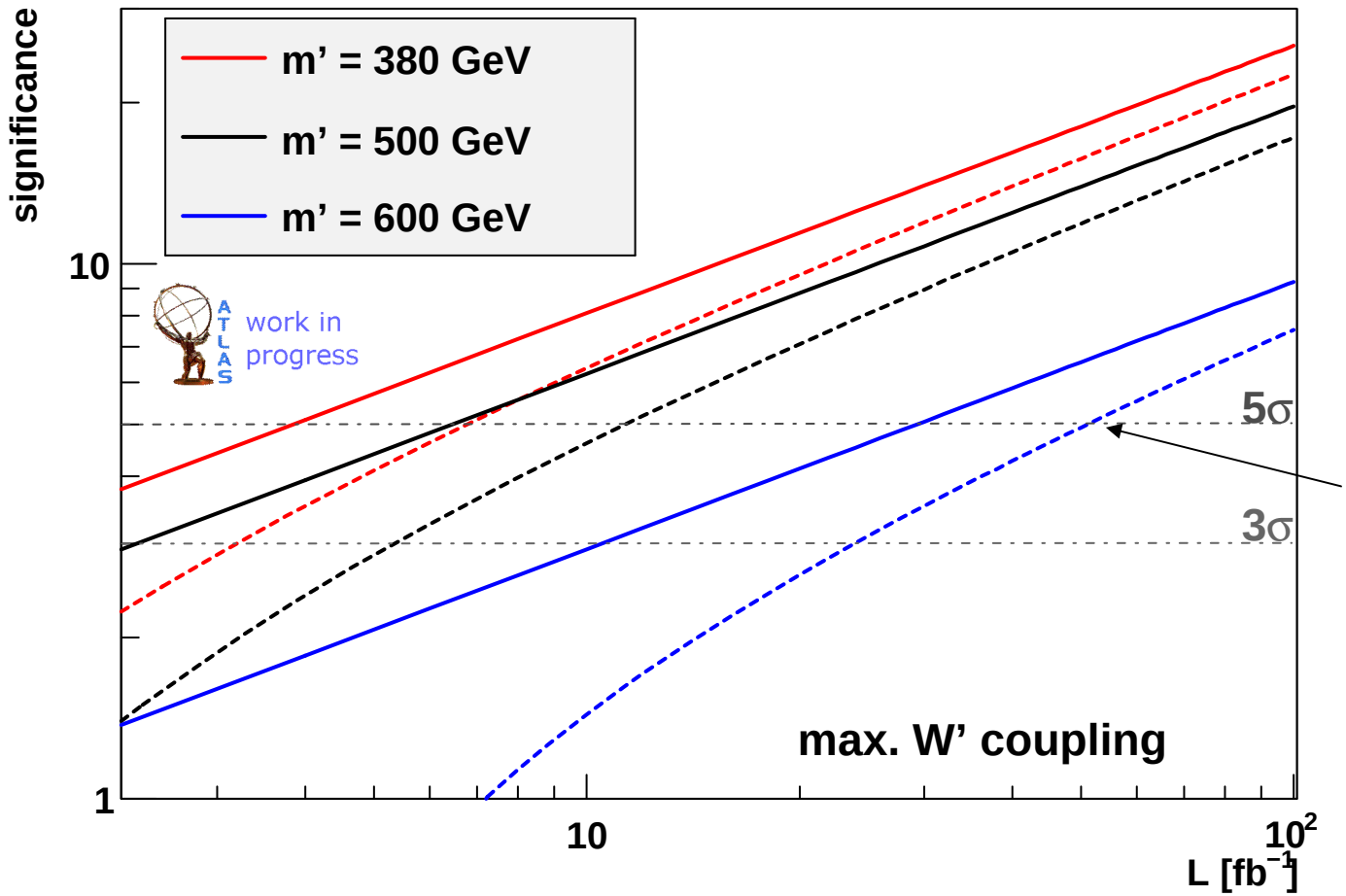
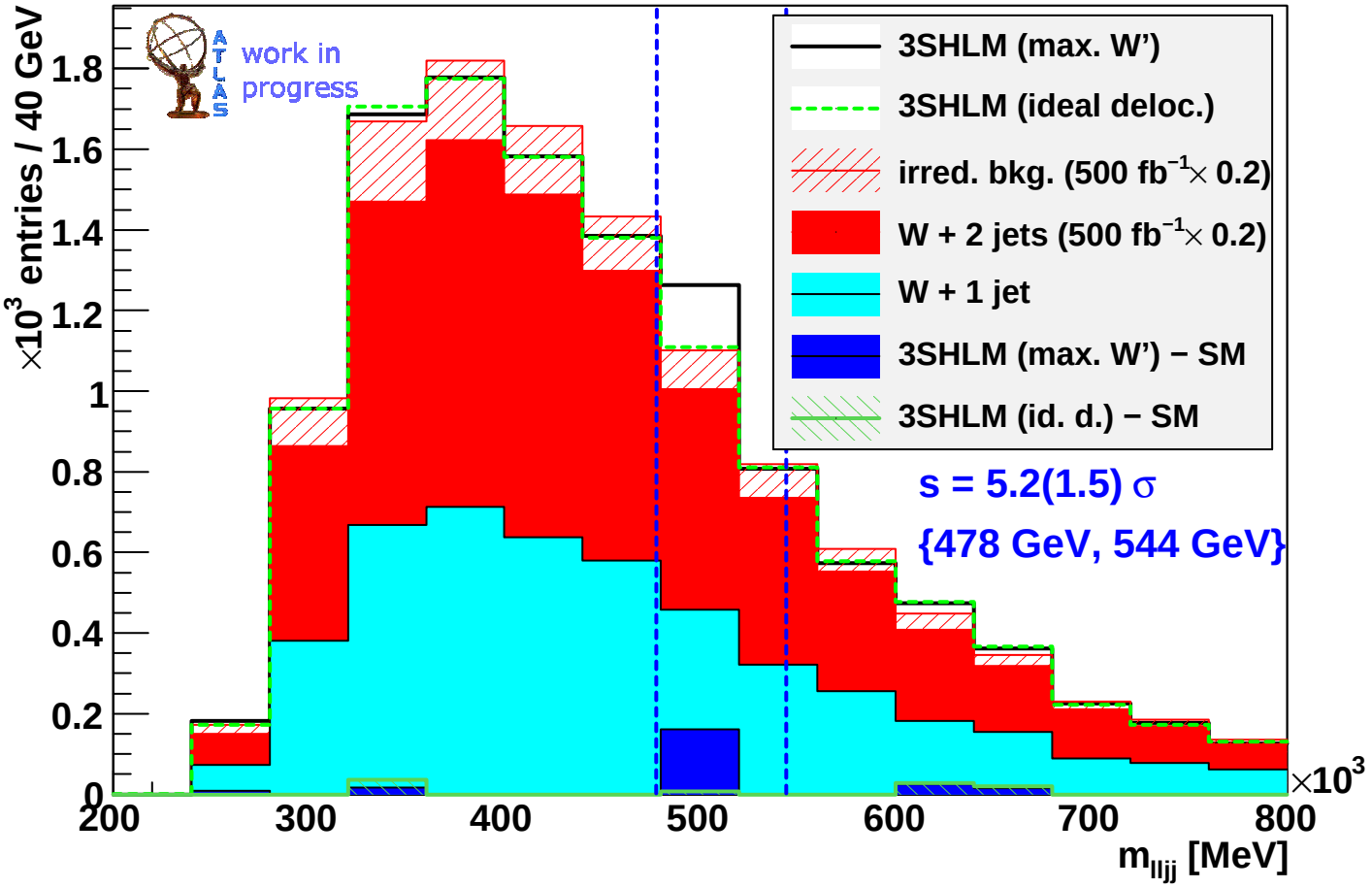


Loss of signal for large *m'* due to finite di-jet resolution

W' search: *lljj* channel with *m'* = 500 GeV



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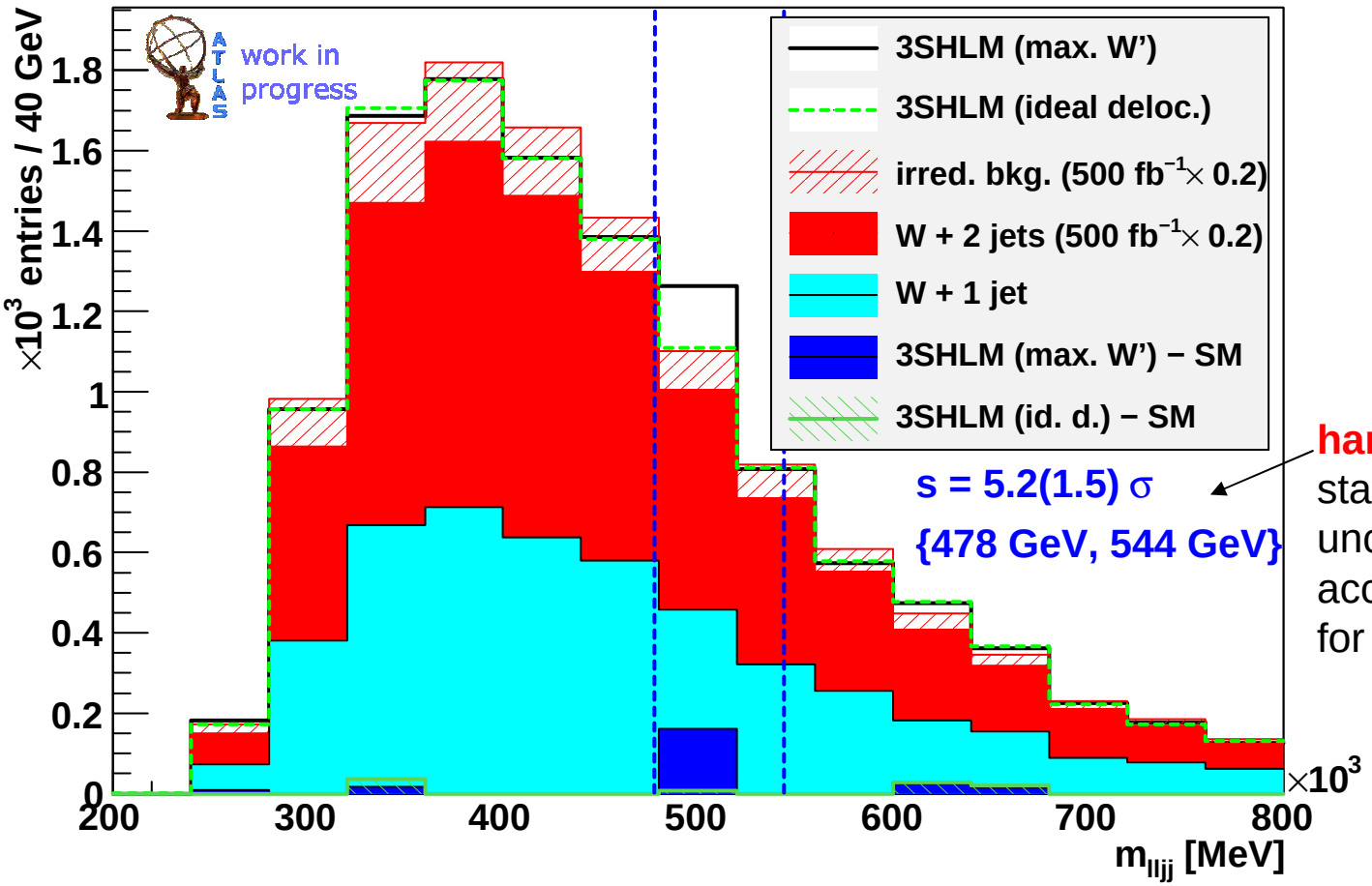
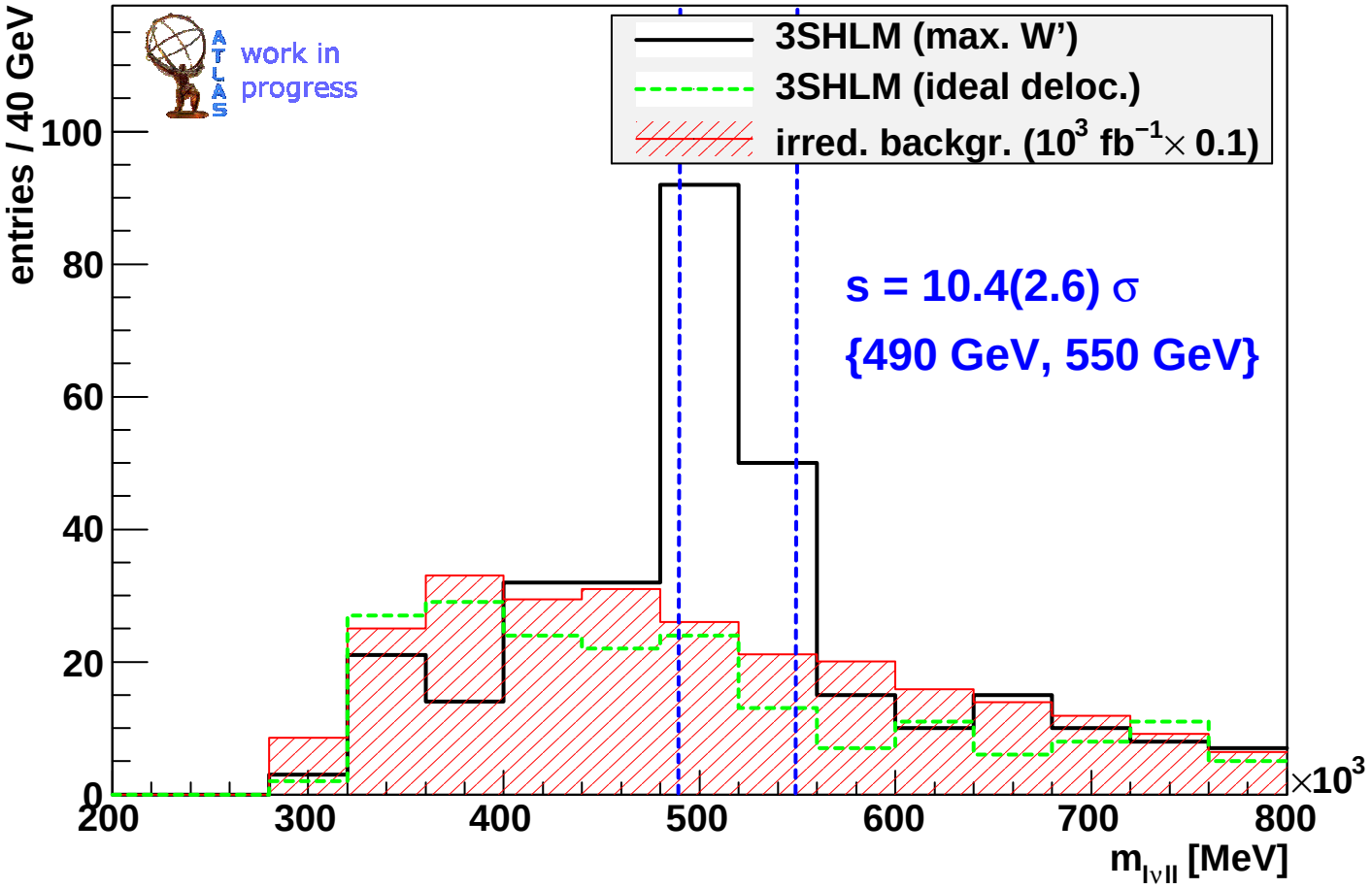


hardly significant with statistical/systematic uncertainties taken into account (even worse for other *m'*)

W' search: *lvll* channel with *m'* = 500 GeV



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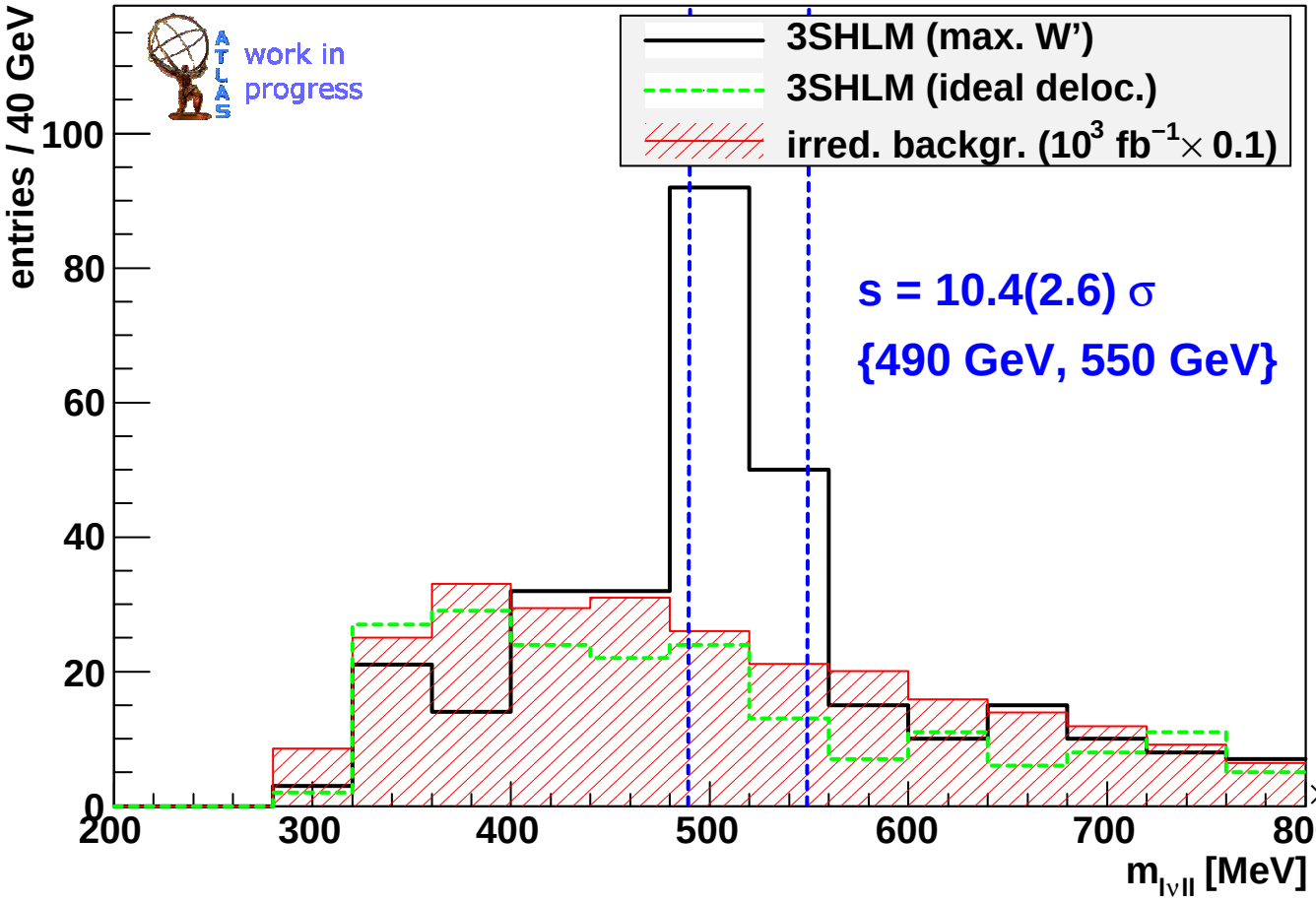

m' [GeV]	*s* [σ]
380	6.5(2.1)
500	10.4(2.6)
600	7.7(2.4)

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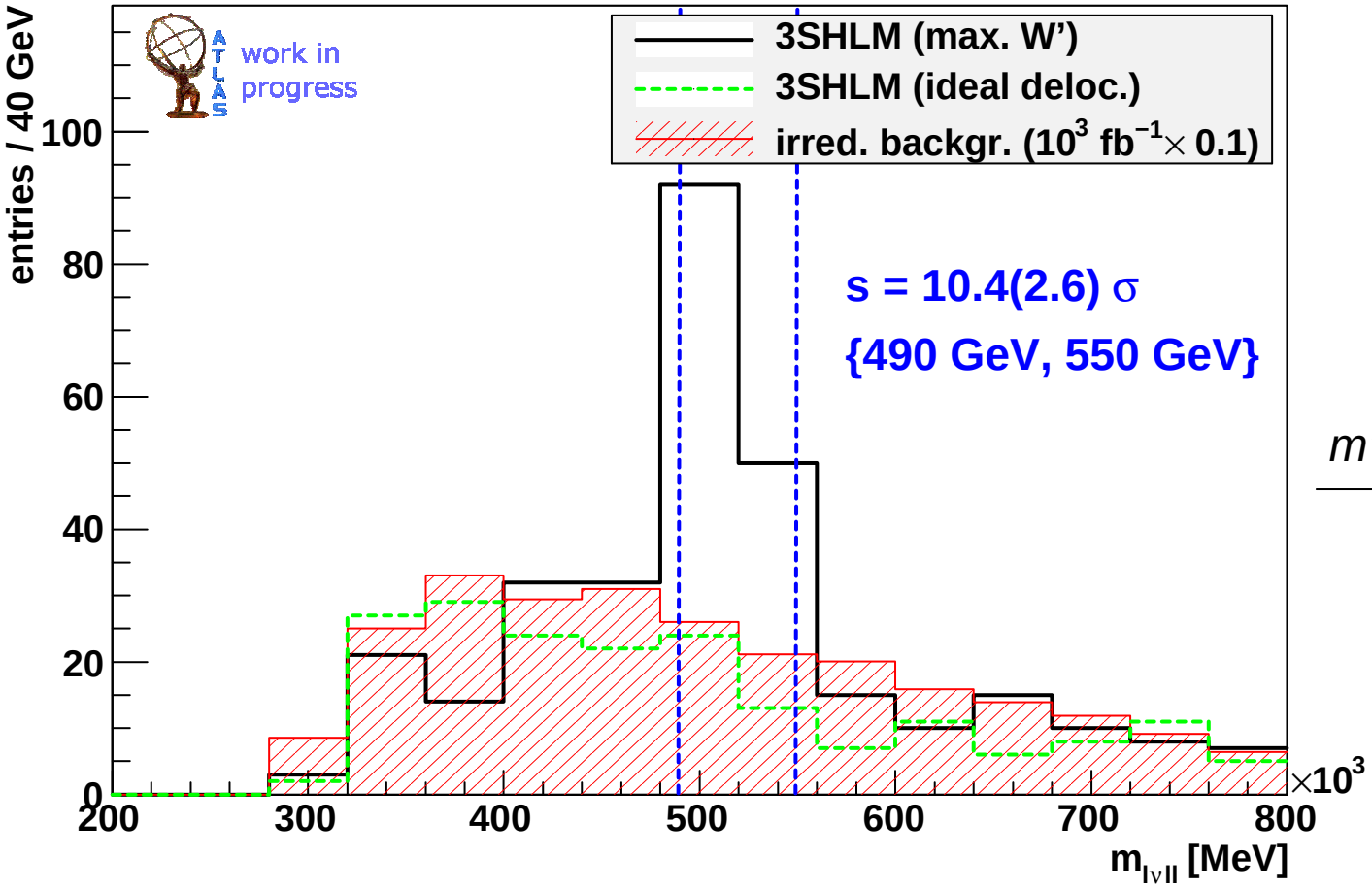

m' [GeV]	*s* [σ]
380	6.5(2.1)
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all **significant**
with 3-5σ

Conclusions

• relevant channels *W'* → *WZ* and *Z'* → *WW* last mentioned in TDR Vol. 2 (**1999**)

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- **W/Z separation** in the semi-leptonic *lvjj* channel **works in principle** (backup…) but suffers from poor $g_{W'ff}$ in the 3SHLM

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- **W/Z separation** in the semi-leptonic *lvjj* channel **works in principle** (backup…) but suffers from poor $g_{W'ff}$ in the 3SHLM

- **validation** for WHIZARD signal in progress
  → see talk at ATLAS MC generator meeting from 11/03 to be found at http://indico.cern.ch/conferenceDisplay.py?confId=70484
  → official backgrounds for L = 100 fb^{-1} **not available**, need to be produced (**general interest** in these backgrounds !?!)

References

- R.S. Chivukula et al.: *Phys. Rev. D* **74**, 075011 (2006).
- R.S. Chivukula and H. Simmons: *Phys. Rev. D* **75**, 0702218 (2007).
- T. Ohl, C. Speckner: *Phys. Rev. D* **78**, 095008 (2008).
- T. Abe, S. Matsuzaki, M. Tanabashi: *Phys. Rev. D* **78**, 055020 (2008).
- ATLAS Collaboration (G. Aad et al.): *ATLAS Technical Design Report Volume II*, CERN/LHCC 99-15 (1999).
- ATLAS Collaboration: *Expected Performance of the ATLAS Experiment* (arXiv:0901.0512v2 [hep-ex]) (2009).
- ATLAS TWiki: twiki.cern.ch/twiki/bin/view/Atlas/WebHome
- ROOT User‘s Guide & Reference Guide: root.cern.ch

Reconstruction of the Neutrino Momentum

Assumptions:

- neutrino (*p*) and charged lepton (*q*) stem from an ***on-shell W***
- missing transverse momentum in event originates exclusively from the neutrino, which escapes measurement, i. e. $p_T = E_{T,miss}$

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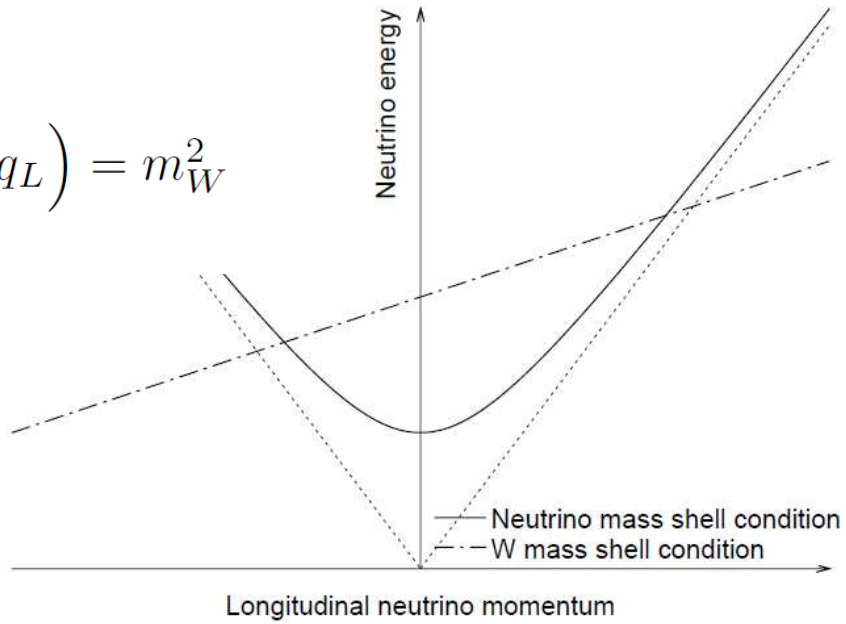
➔ **2 mass shell conditions for 2 unknowns** (p_0 and p_L)**:**

$$p^2 = p_0^2 - E_{T,miss}^2 - p_L^2 = 0$$

$$(p+q)^2 = 2\left(p_0 q_0 - \vec{E}_{T,miss} \cdot \vec{q}_T - p_L q_L\right) = m_W^2$$



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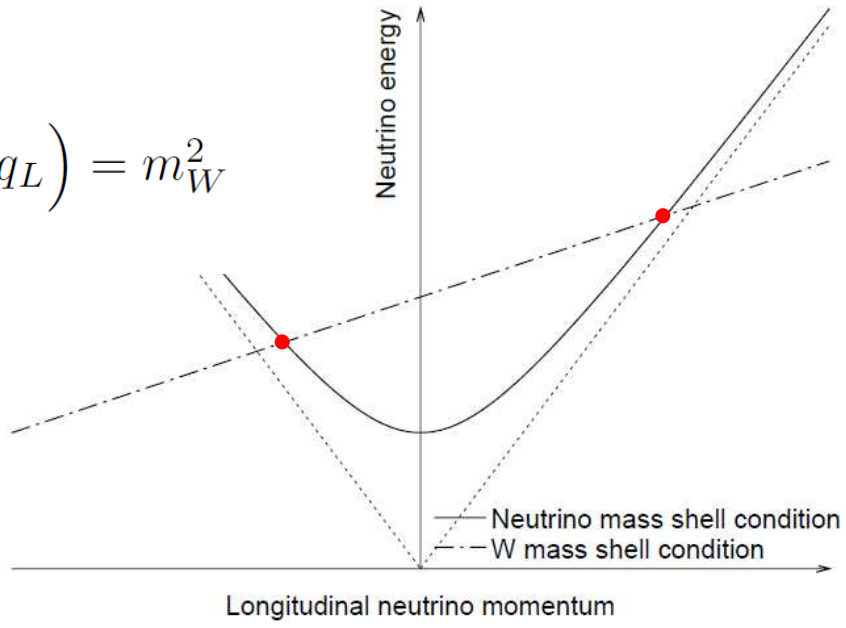
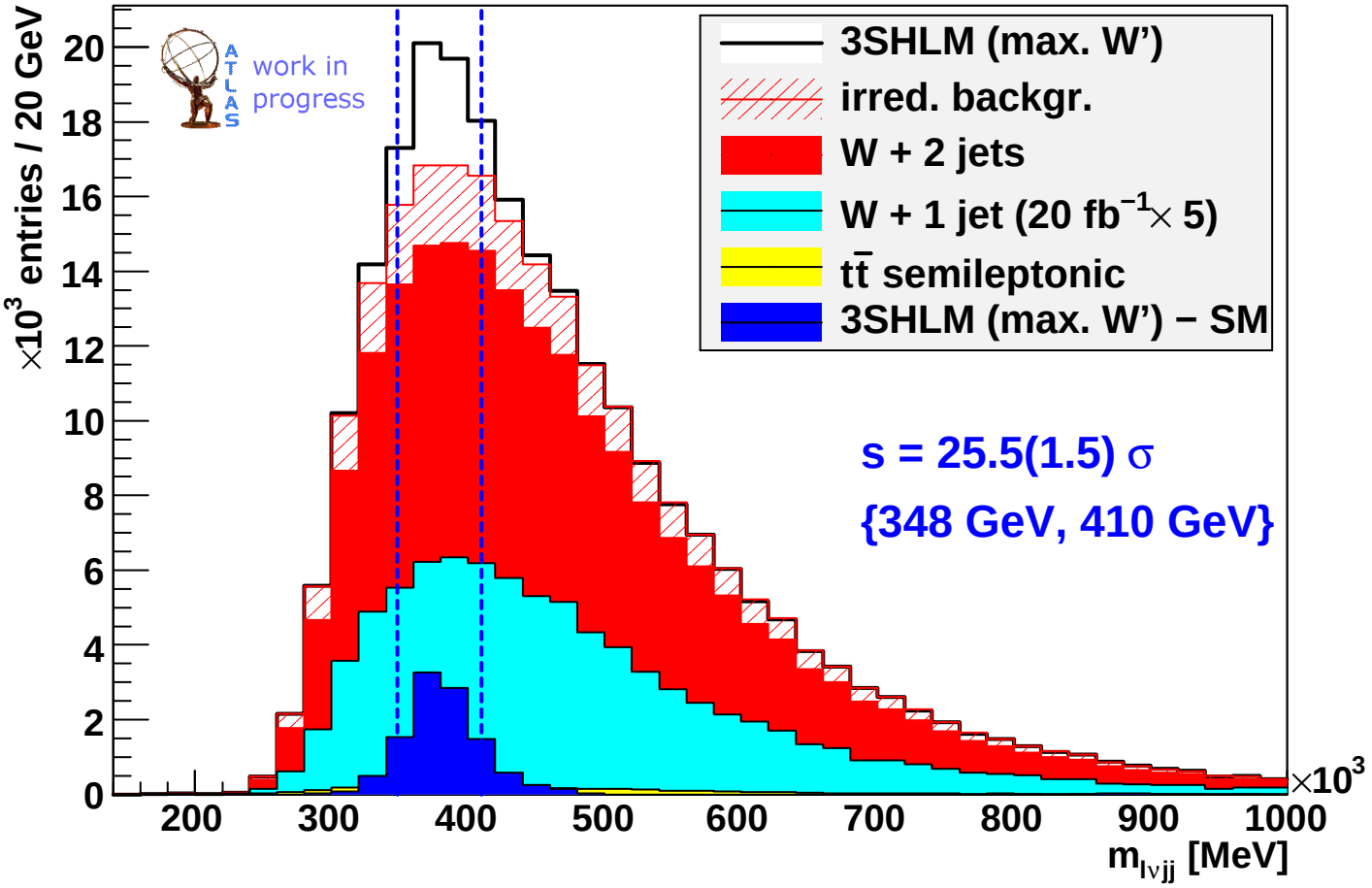
➔2 solutions in general

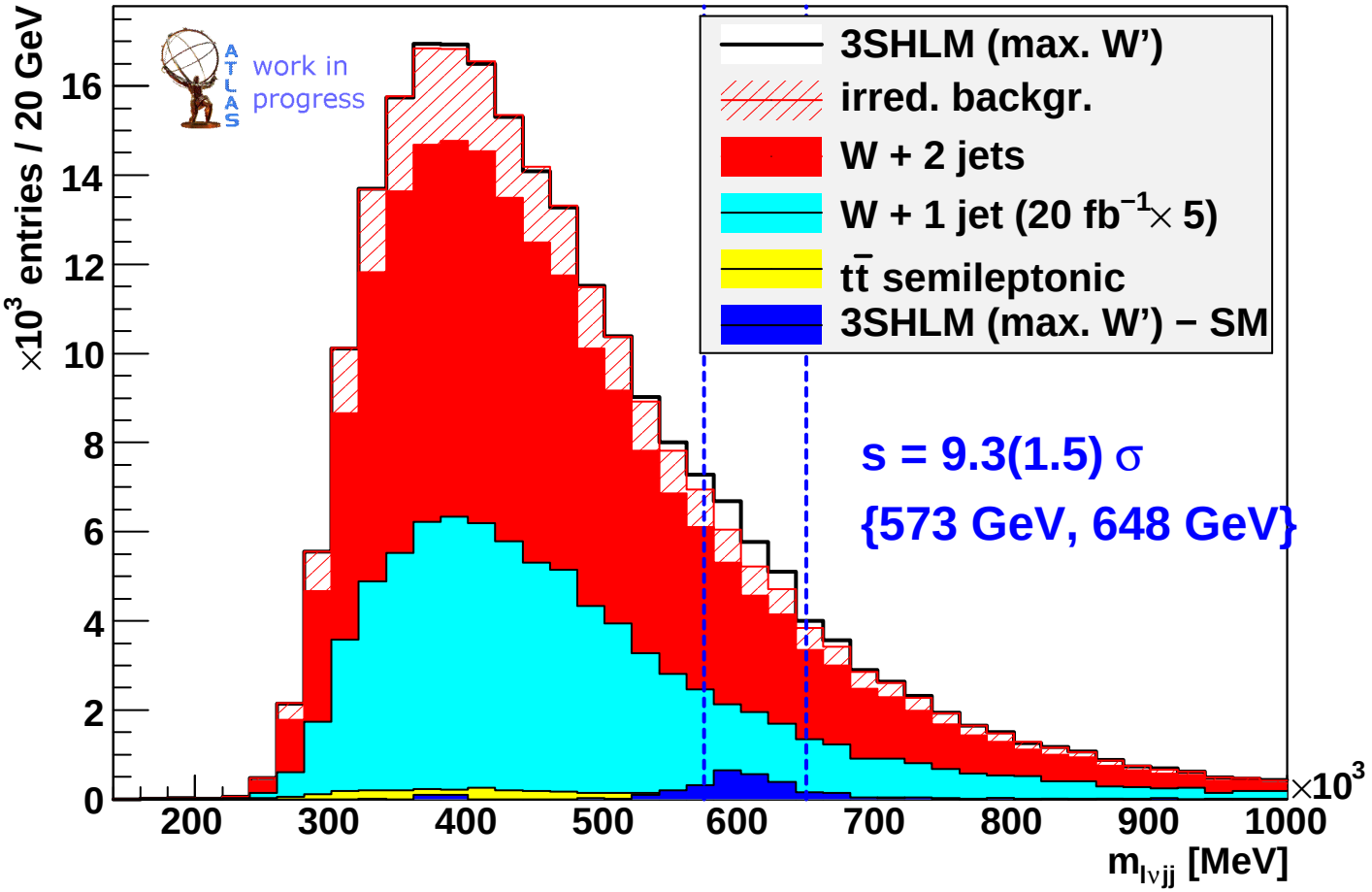
➔ **possibility:**
take both solutions into account (effectively doubling the background)



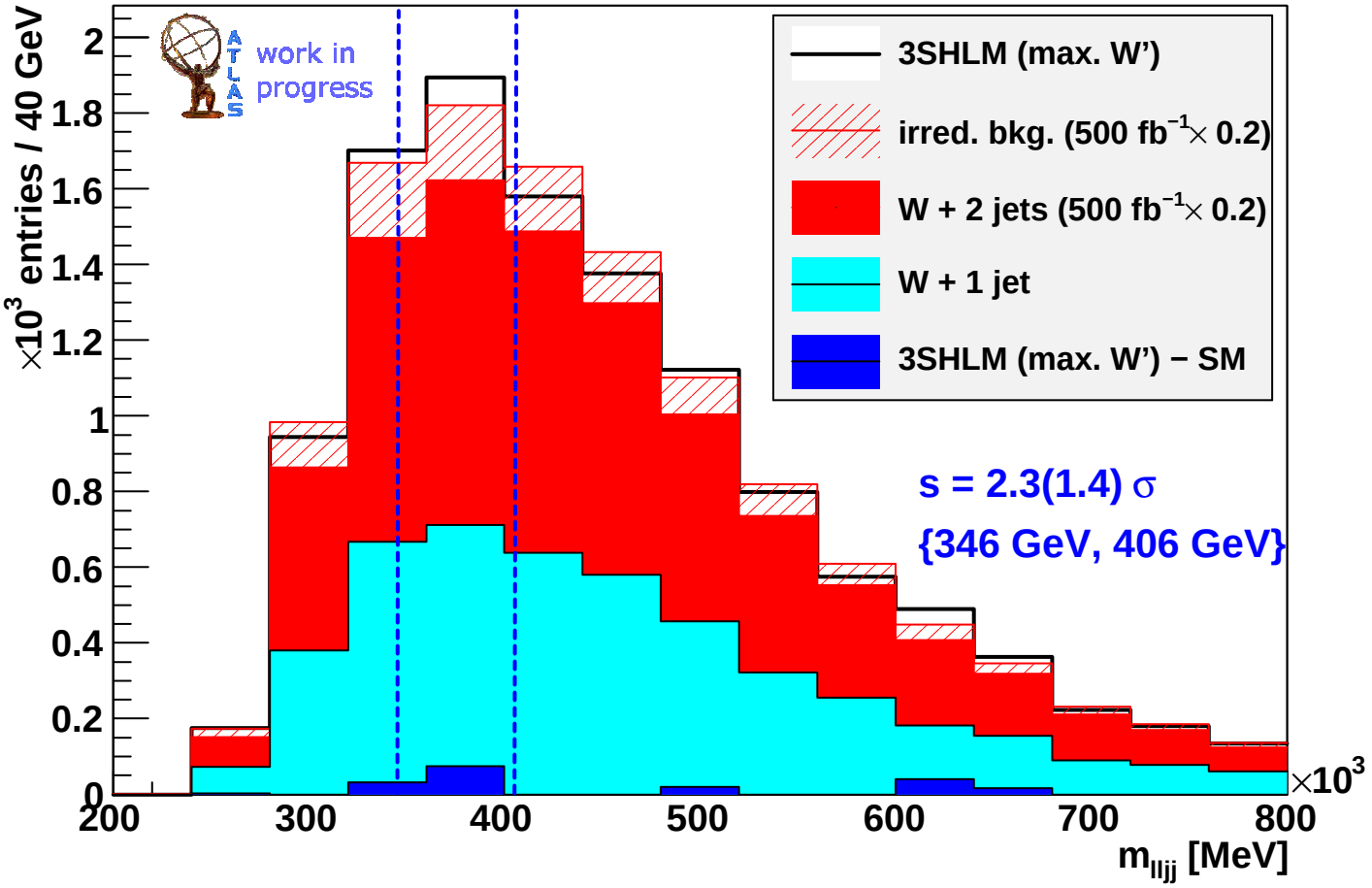
Z' search: *lvjj* channel with *m'* = 380 GeV



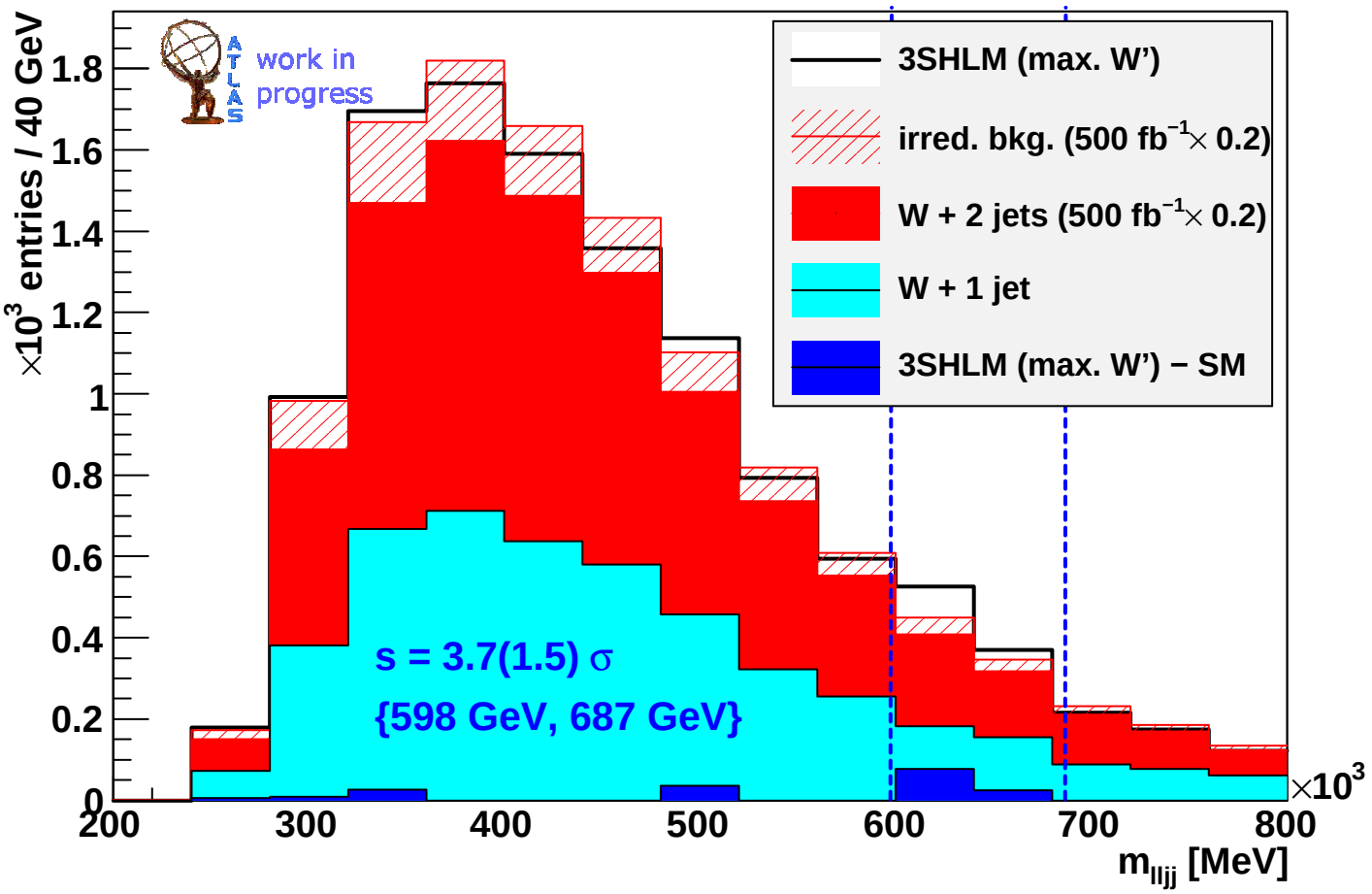
Z' search: *lvjj* channel with *m'* = 600 GeV



W' search: *lljj* channel with *m'* = 380 GeV



W' search: *lljj* channel with *m'* = 600 GeV



W' search: Separation of *W/Z* jet resonances in the *lvjj* channel (Ohl, Speckner 2008)

- Remember: ***W' and Z' add up*** in the *lvjj* channel because of degeneracy
  ➔ separable only by **separation of *W* and *Z* in the jets**

- Basic idea:
  1) get to know the experimental shapes and widths of *W* and *Z*
  2) model probability distribution functions according to these shapes
  3) calculate the entanglement of *W* and *Z* by integrating over the pdf's:

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measured numbers of gauge bosons

$$\begin{pmatrix} \tilde{N}_W \\ \tilde{N}_Z \end{pmatrix} = \begin{pmatrix} T_{WW} & T_{WZ} \\ T_{ZW} & T_{ZZ} \end{pmatrix} \begin{pmatrix} N_W \\ N_Z \end{pmatrix}$$

true numbers of gauge bosons

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probability distribution function of boson *j*

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cut window of boson *i*

probability distribution function of boson *j*

  4) invert *T* to get the true counts from measured ones:

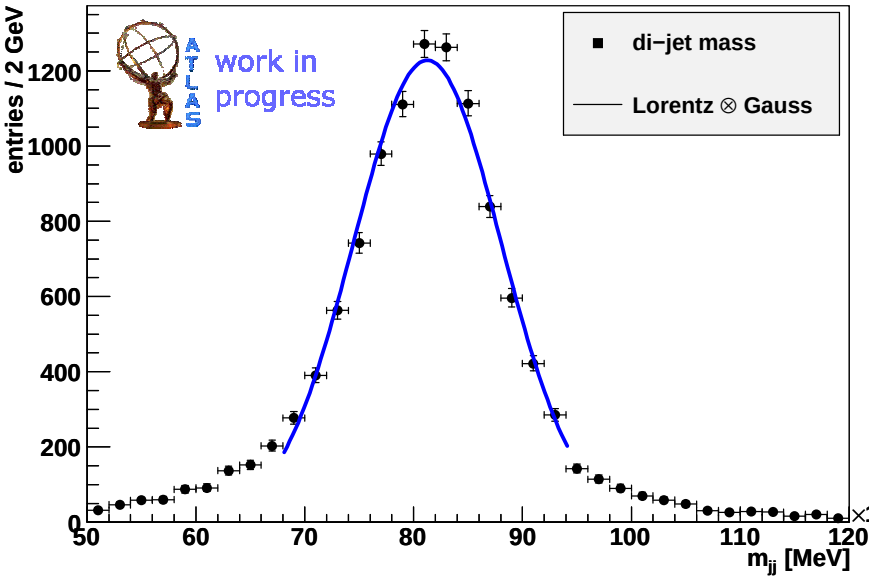
$$N_i = \sum_j \left(T^{-1}\right)_{ij} \widetilde{N}_j$$

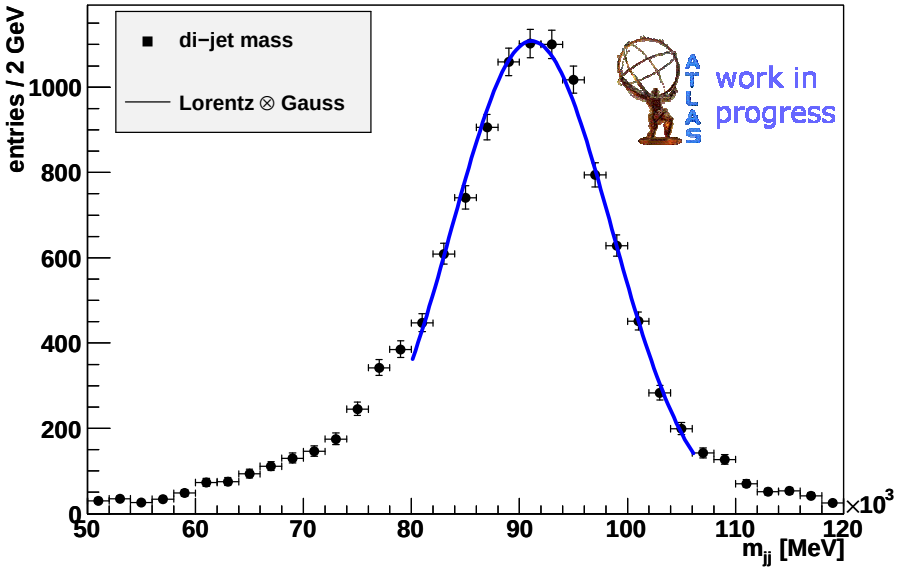
W' search: Separation of *W/Z* jet resonances in the *lνjj* channel (Ohl, Speckner 2008)

1+2) find experimental shapes and widths and model pdf's

➔ use simulated dummy *W/Z* samples

➔ fit pdf's to resonances **with restricted fit range**:





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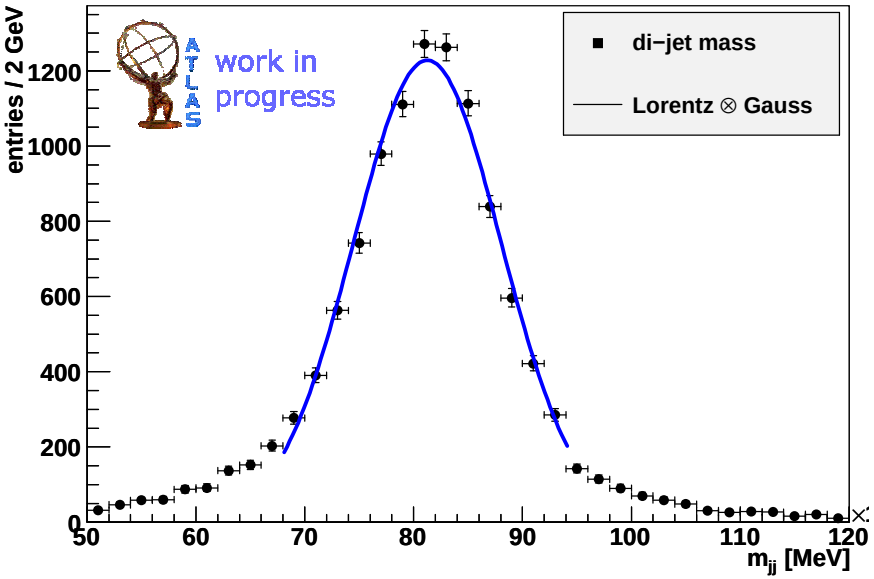
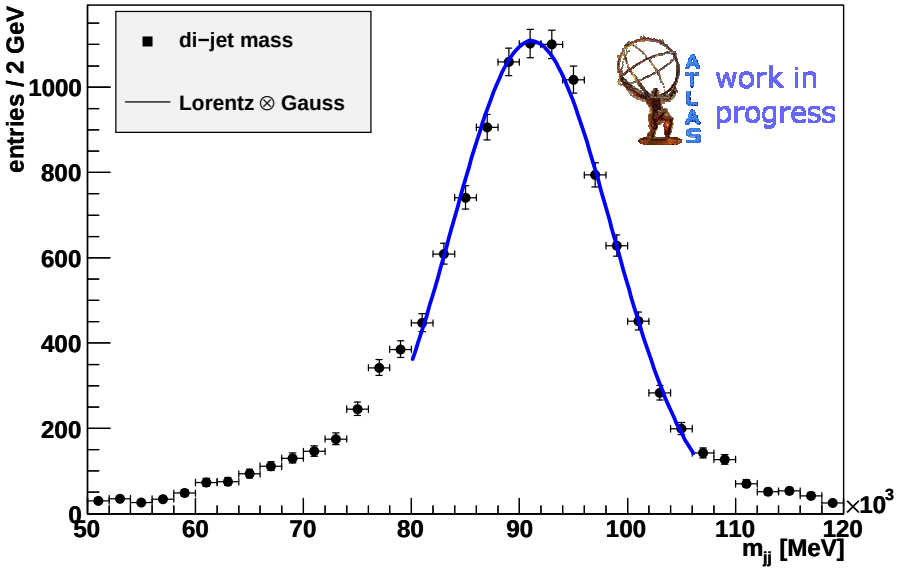




fit results (mean values and Gaussian resolutions, intrinsic widths from PDG):

m_W = 81.26(8) GeV
σ_W = 6.76(8) GeV

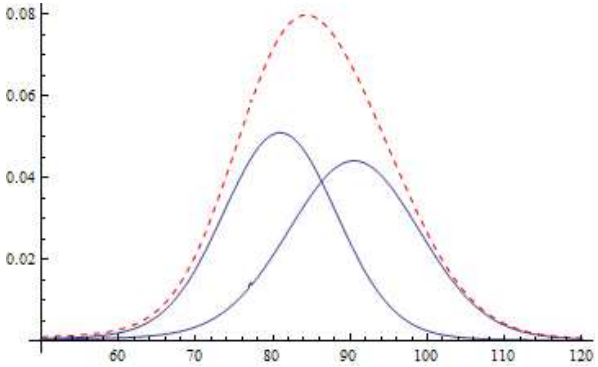
m_Z = 91.2(1) GeV
σ_Z = 7.3(1) GeV

W' search: Separation of *W/Z* jet resonances in the *lvjj* channel (Ohl, Speckner 2008)

3) integrate over pdf's:

➔ *W* cut window = {60 GeV, 85 GeV}

➔ *Z* cut window = {86 GeV, 111 GeV}



$$\Longrightarrow \quad T = \begin{pmatrix} 0.72 & 0.27 \\ 0.24 & 0.69 \end{pmatrix}$$

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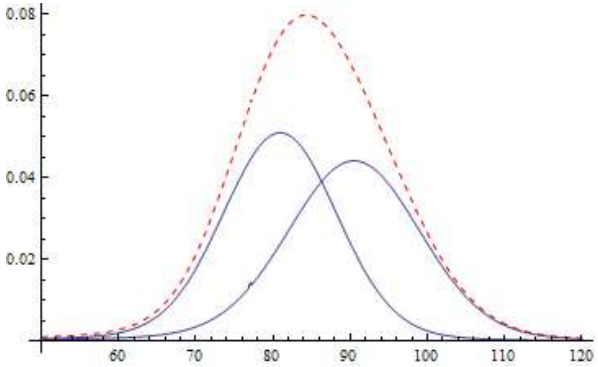

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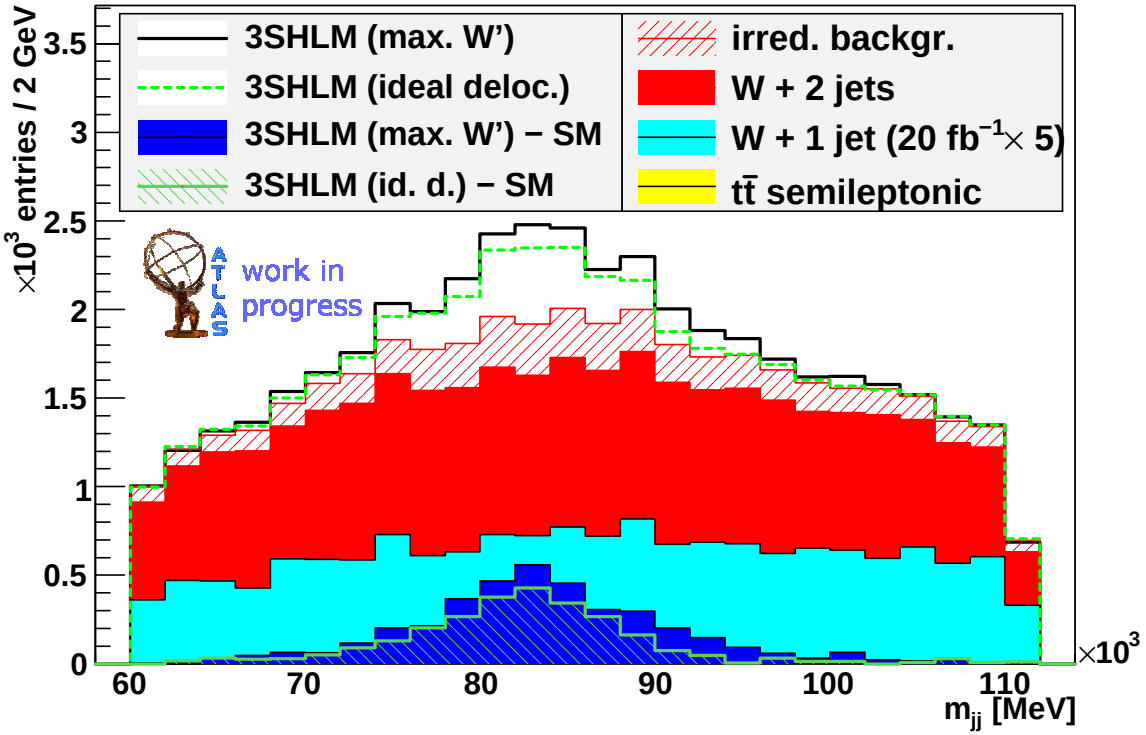
4) invert *T* Matrix numerically:

$$T^{-1} = \begin{pmatrix} 1.6 & -0.62 \\ -0.55 & 1.7 \end{pmatrix}$$

W' search: *W/Z* Separation results (470 GeV < *m'* < 530 GeV)



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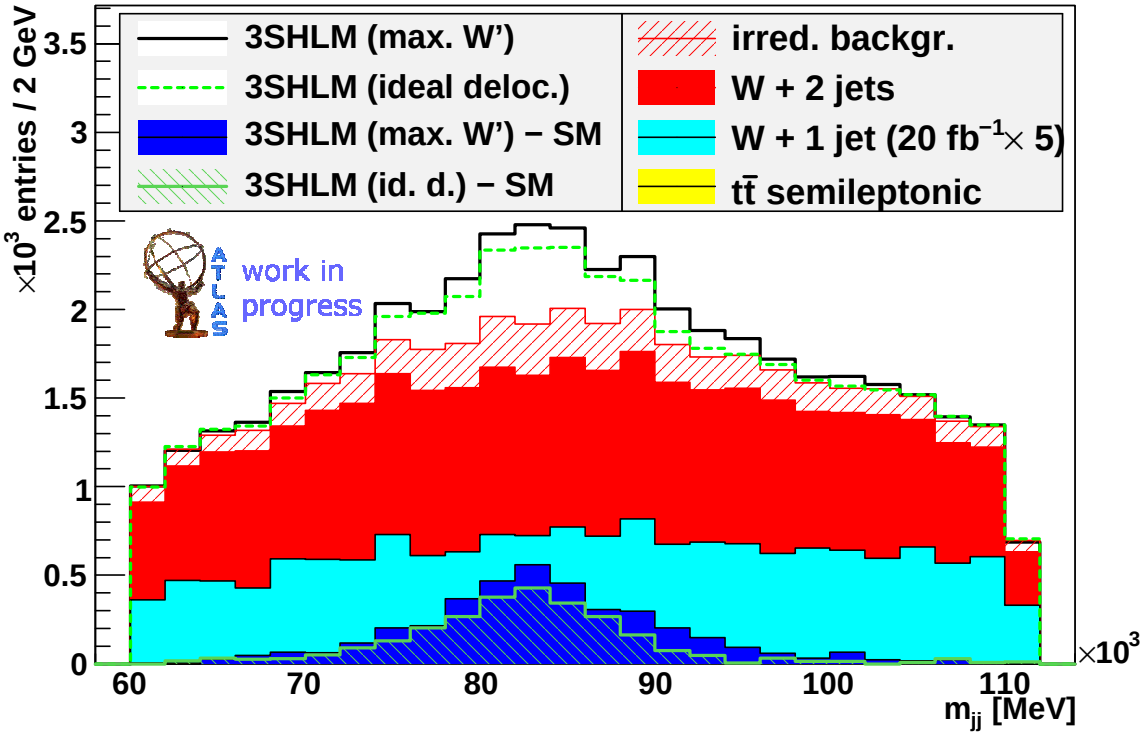

ideal delocalization				
i	$\tilde{N}_i$	$\tilde{s}_i$	N_i	s_i
W	1992	6.8	2771	5.6
Z	693	2.4	1	0.001

maximal $g_{W'ff}$				
i	$\tilde{N}_i$	$\tilde{s}_i$	N_i	s_i
W	2585	8.8	3334	6.7
Z	1336	4.6	717	1.4

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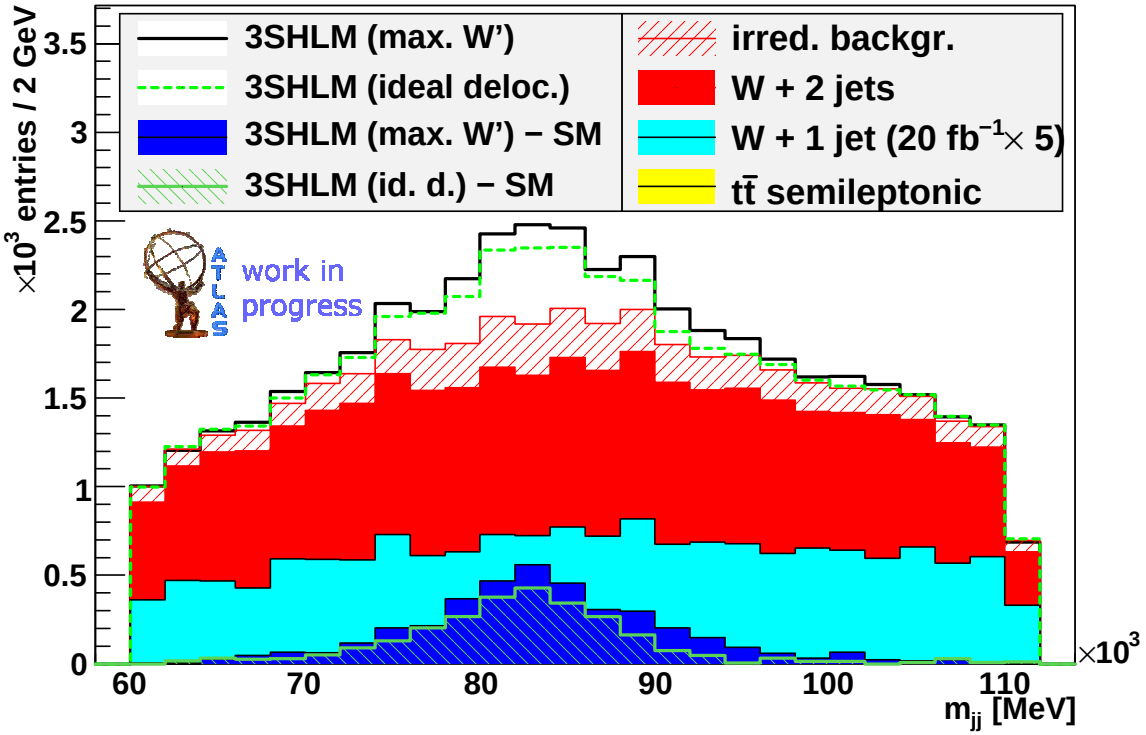

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