Limits on New Physics from Γ_W

- Current Data & Extrapolations
- CKM Matrix Elements
- New Particles
- Shifted Couplings
- Concluding Remarks

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Summary of Current Data

Moderately precise measurements of Γ_W come from three sources:

1	LEP 2	2150 ± 91		lineshape
2	Tevatron *'direct'*	2115 ± 105	Run 1	high mass lineshape
3	Tevatron *'indirect'*	2171 ± 52	Run 1	R: $p\bar{p} \to W \to \ell\nu$ / $p\bar{p} \to Z \to \ell\ell$
		2154 ± 68	Run 2	

The LEP 2 results are derived by the LEPEWWG. (See `hep-ex/0212036` Dec-2002)

A preliminary combination of the Run 1 results is given in `Fermilab-FN-0716`.

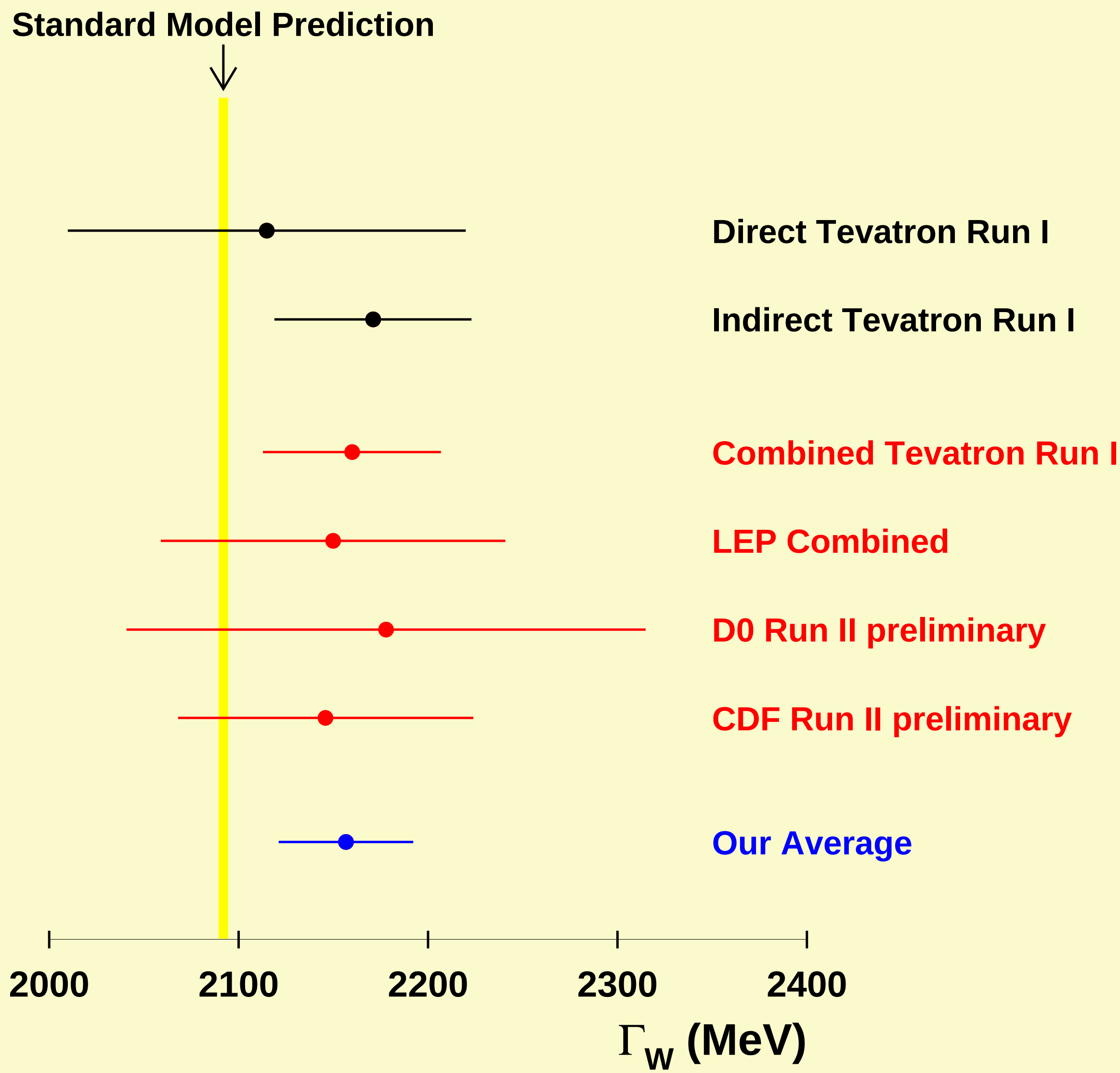
The new Run 2 results are to be presented here at DPF!

CDF	2146 ± 78 MeV	$\to$ G. Manca & A. Varganov
DØ(*)	2178 ± 137 MeV	$\to$ G. Steinbrueck

Interesting Point: All of these values fall **above** the SM expectation –

$$\Gamma_W^{\rm SM} = 2092.1 \pm 2.5 \text{ MeV}.$$

(*) *We have calculated Γ_W from the public DØ σ measurements in the electron channel.*



The SM expectation is taken from PDG, Chapter 10 (2002).

Three distinctly different methods lead to values falling above the SM expectation (yellow band).

We have combined all these measurements to obtain:

$$\Gamma_W^{\mathrm{NWU}} = 2156 \pm 36 \text{ MeV}$$

We want to compare to

$$\Gamma_W^{\mathrm{SM}} = 2092 \pm 2 \text{ MeV}.$$

The difference is

$$\Delta\Gamma = 64 \pm 36 \text{ MeV},$$

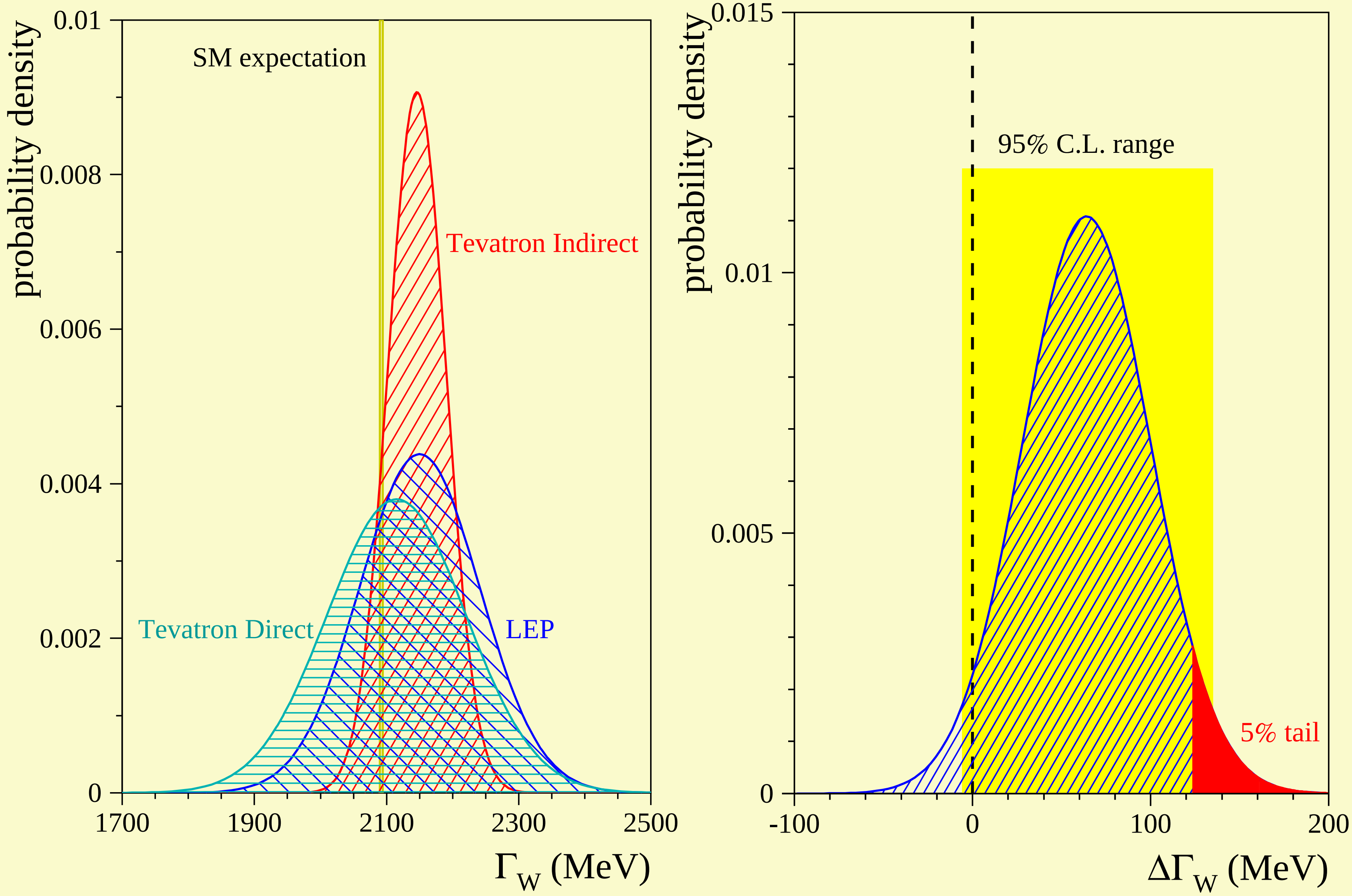
which is 1.8σ above zero.

The 95% CL interval is

$$-6 < \Delta\Gamma < 135 \text{ MeV},$$

and the upper limit is

$$\Gamma_W^{\mathrm{new}} < 123 \text{ MeV}.$$



Three methods fall above SM.

Error ranges from combined value

What are the ingredients to Γ_W?

$$\text{Total} = \text{Leptonic} + \text{Hadronic}$$

$$\Gamma_W = 3\,\Gamma_W^0 + 3\,(1 + \frac{\alpha_s}{\pi}) \sum_{[\text{no top}]} |V_{q\,q'}|^2\ \Gamma_W^0$$

$$\Gamma_W^0 = \frac{1}{48}\,g^2\,M_W$$

points of interest:

- sum over *some* CKM matrix elements
- possibility of additional decay channels
- coupling constant g and mass M_W

CKM Matrix Elements

Only the first two rows contribute – *ud us cd cs ub cb*

The last two are much smaller than the others.

Taking the current values from the RPP, error analysis shows that V_{cs} contributes nearly all of the uncertainty to the sum $\sum_{[\text{no top}]} |V_{q\,q'}|^2$.

By those numbers, $\sum_{[\text{no top}]} |V_{q\,q'}|^2 = 2.040 \pm 0.027$,

which is consistent with 2.

Can the measured value of Γ_W help test this sum rule?

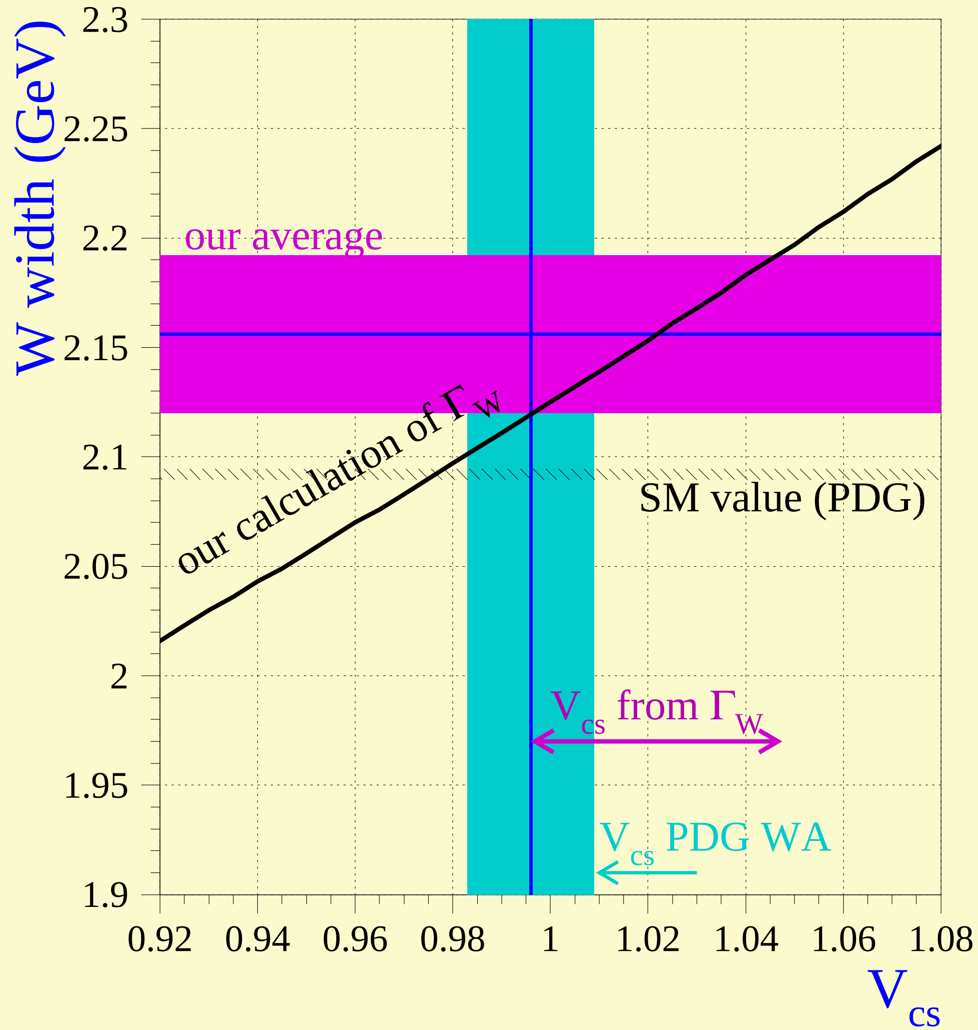
$\longrightarrow$ Can Γ_W be used to constrain V_{cs}?

We compute Γ_W with V_{cs} as a free parameter and compare to $\Gamma_W^{\rm meas}$ with a χ^2 test.

The inferred value
$V_{cs} = 1.022 \pm 0.025$
is consistent with the PDG value
$V_{cs} = 0.996 \pm 0.013$.

Combining them, we obtain
$V_{cs} = 1.00 \pm 0.012$.

If the uncertainty on Γ_W were reduced to 10 MeV, V_{cs} could be 'measured' to
$\delta V_{cs} \sim 0.007$.



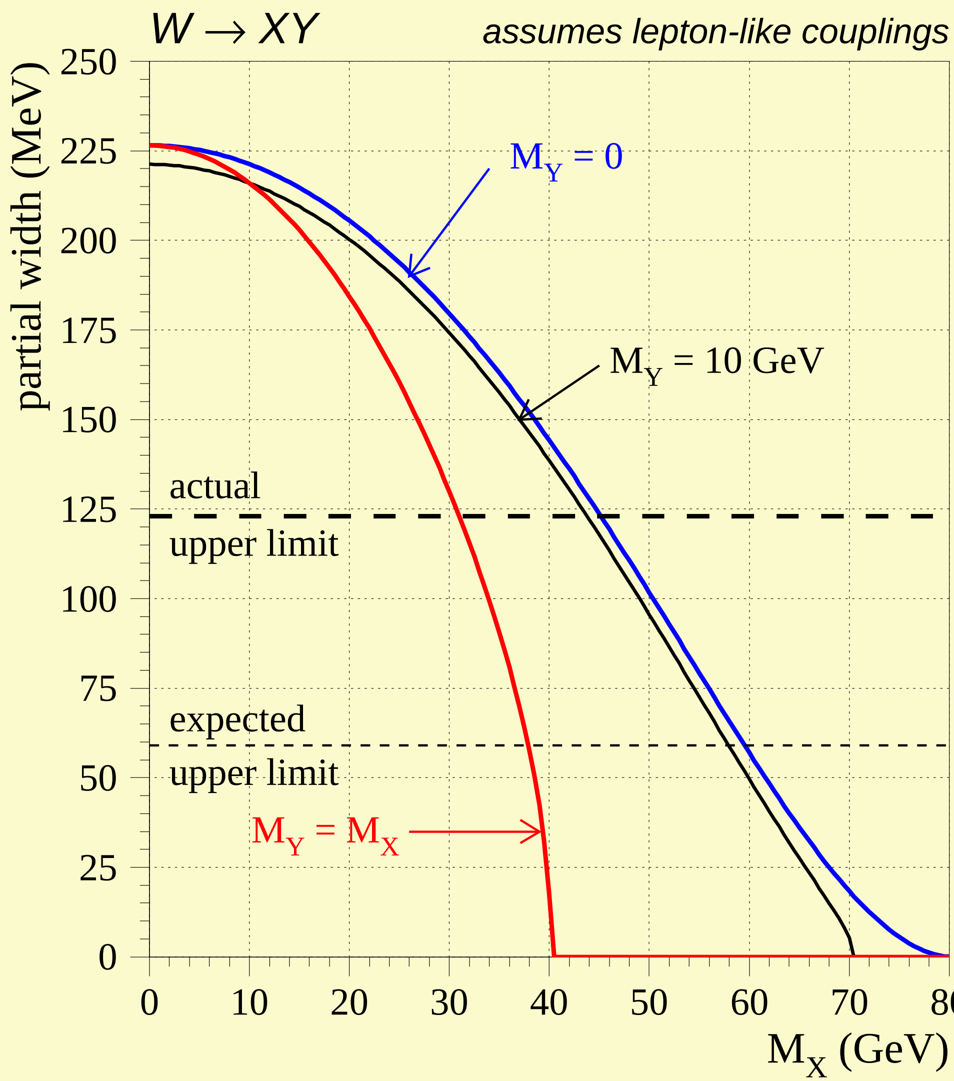
New Particles

We consider two possibilities:
fermions or scalars.

Consider $W \to XY$ where X and Y have the quantum numbers of a fourth generation lepton pair.

Sensitivity is in the 30 – 60 GeV range with *no assumptions* about how these events would appear in the detector.

The actual upper limit is much higher than expected because Γ_W^{meas} is significantly higher than Γ_W^{SM}.

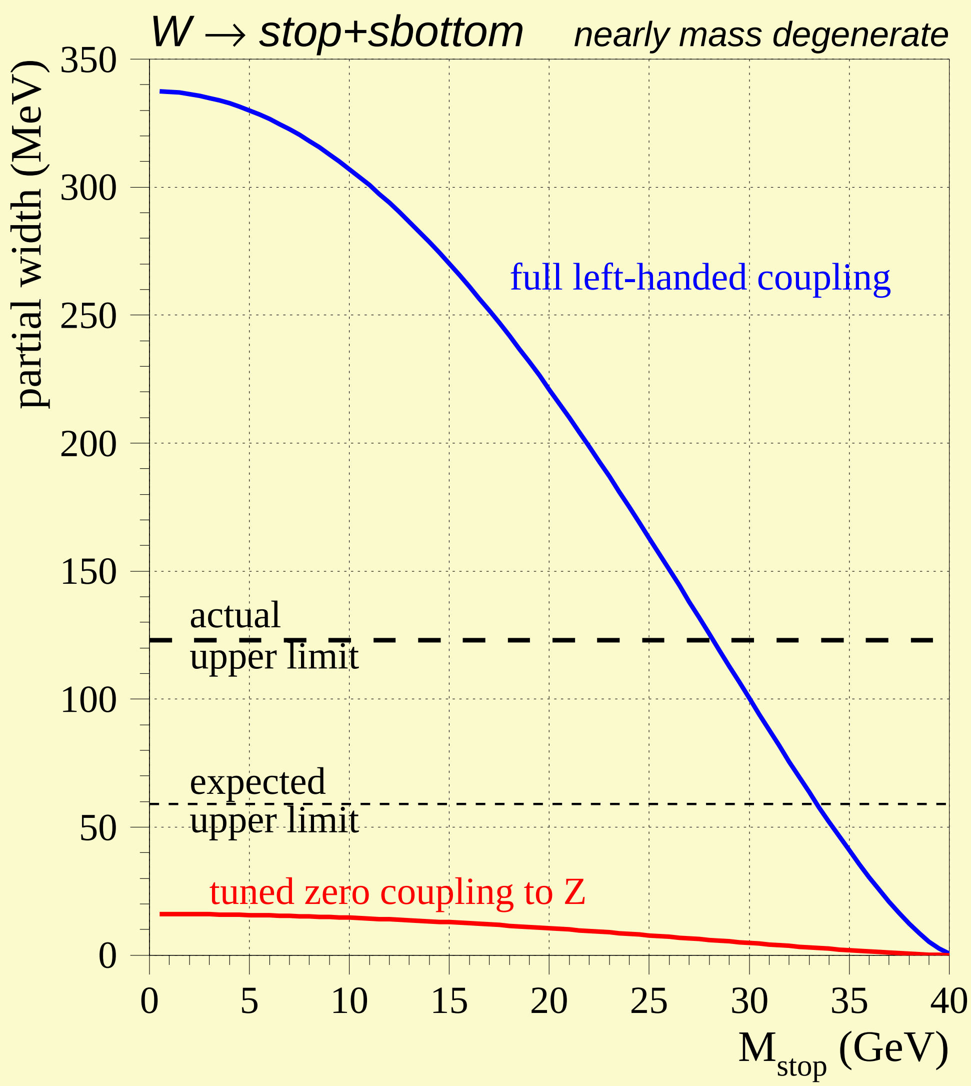


Decays to scalars are phase space supressed relative to fermions. In some specific cases, however, there can be a large enhancement from N_{color}.

Consider $W \to \tilde{t}_1 \tilde{b}_1^*$ where $\tilde{t}_1$ and $\tilde{b}_1$ are the lightest scalar partners of the top and bottom quarks.

The partial width can be relatively large. But if one asks for a complete decoupling of both squarks from the Z boson, there is a factor 25 suppression due to the field content of the squarks.

The partial widths for $\tilde{\tau}_1 \tilde{\nu}_\tau$ are about $3 \times \Gamma_{\tilde{t}\tilde{b}}$ when decoupled from the Z.



A Shift in the Coupling Constant?

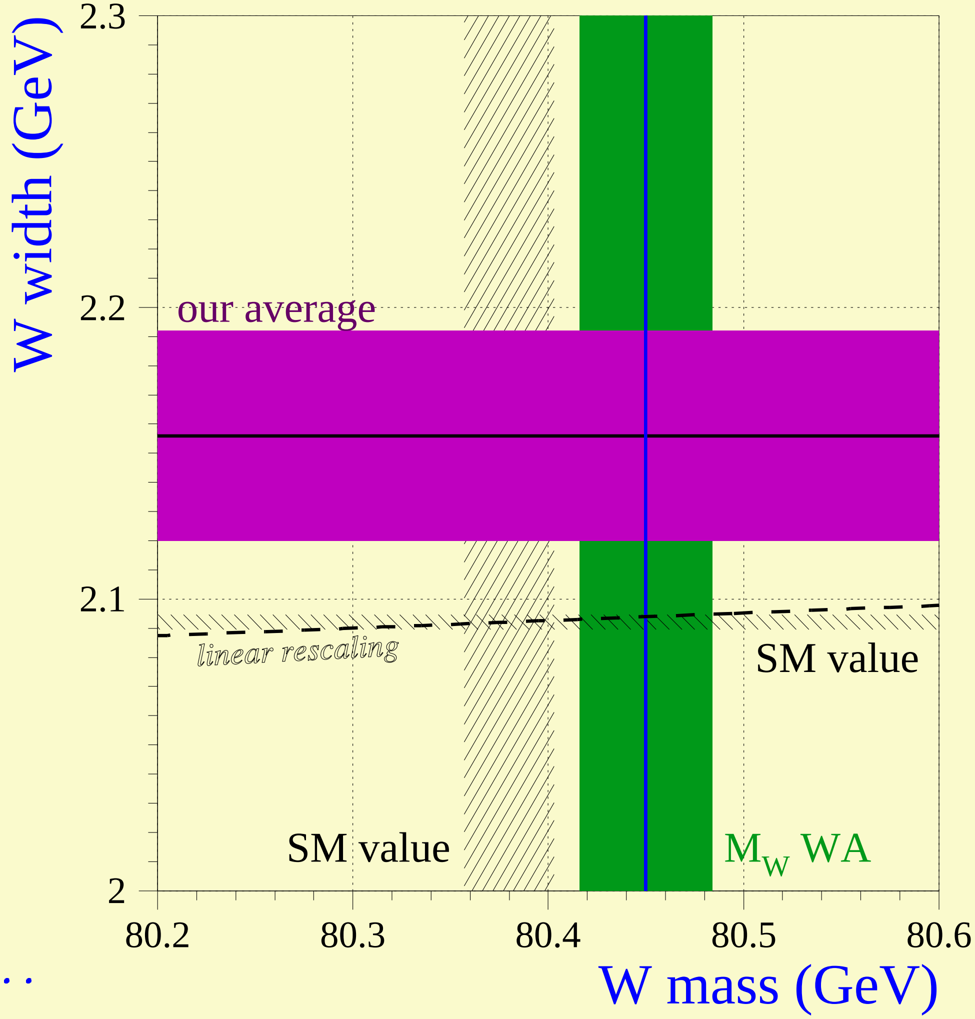
It is interesting that both Γ_W^{meas} and M_W^{meas} are 'high.'

Notice $\Gamma_W \sim g^2 M_W$. Linear rescaling does not bring Γ_W^{meas} into agreement with Γ_W^{SM}.

Suppose mixing of the W with a higher mass W' state increases the coupling of the W to SM fermions.

The increase in g would have to be around 1.5%. Is it possible to attain this while respecting the good agreement for Γ_Z?

$\longrightarrow$ *a challenge for model builders...*



Prospects for Better Measurements

- *Run II Indirect Method:*
  - ⋆ statistical uncertainty will decrease
  - ⋆ main systematic is recoil model $\rightarrow$
    presently conservatively estimated – will improve
  - ⋆ analysis could be optimized for Γ_W

$$\delta\Gamma_W^{\rm indir} \sim 40 \text{ MeV}$$

- *Run II Direct Method:*
  - ⋆ relatively weak measurement in Run 1
  - ⋆ requires high statistics & systematics are challenging
  - ⋆ WG on precision measurements estimated (`hep-ex/0011009`)

$$\delta\Gamma_W^{\rm dir} \sim 40 \text{ MeV for } 2\ \text{fb}^{-1}$$

- hope for WA $\delta\Gamma_W \sim 25$ MeV by end of Run IIa
- Giga-Z machine likely to make a much better measurement.

Summary and Conclusions

- Γ_W is almost 2σ above the SM expectation
  - $\star$ *all* measurements are high $\Rightarrow$ not a systematic effect?
  - $\rightarrow$ interesting but not yet exciting
- Measurements of Γ_W are rapidly improving.
  - $\star$ systematic uncertainties in latest preliminary results are conservatively estimated
  - $\star$ uncertainties will continue to decrease with luminosity
- **We welcome more input from our theorist friends!***

* Thanks for discussions with Heather Logan & Tim Tait.