Top Mass at Tevatron

Deciding the fate of the universe....

Combination of the top-quark mass measurements from the Tevatron collider
arXiv:1207.1069v3

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On behalf of

AEPSHEP 2012 Group B

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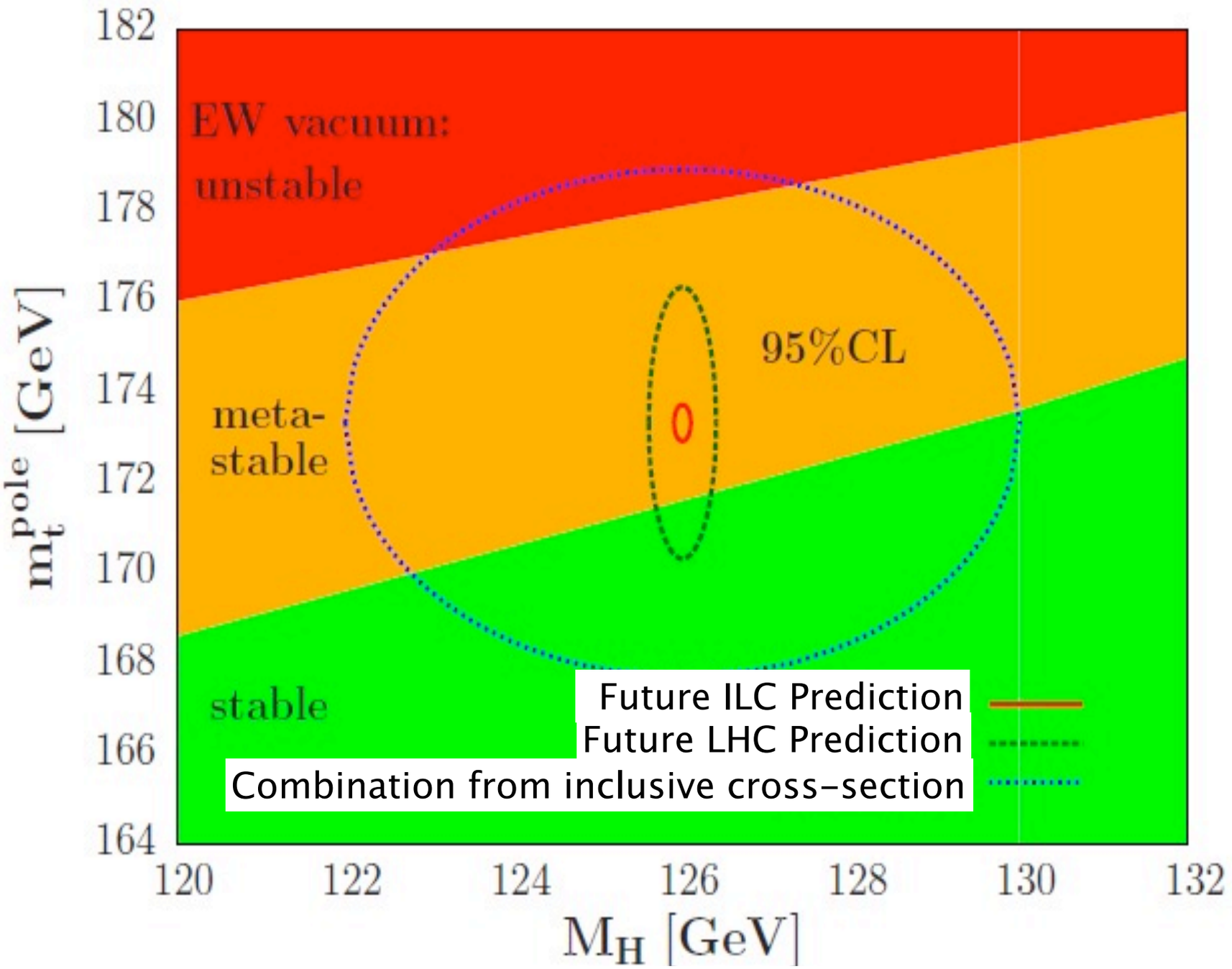
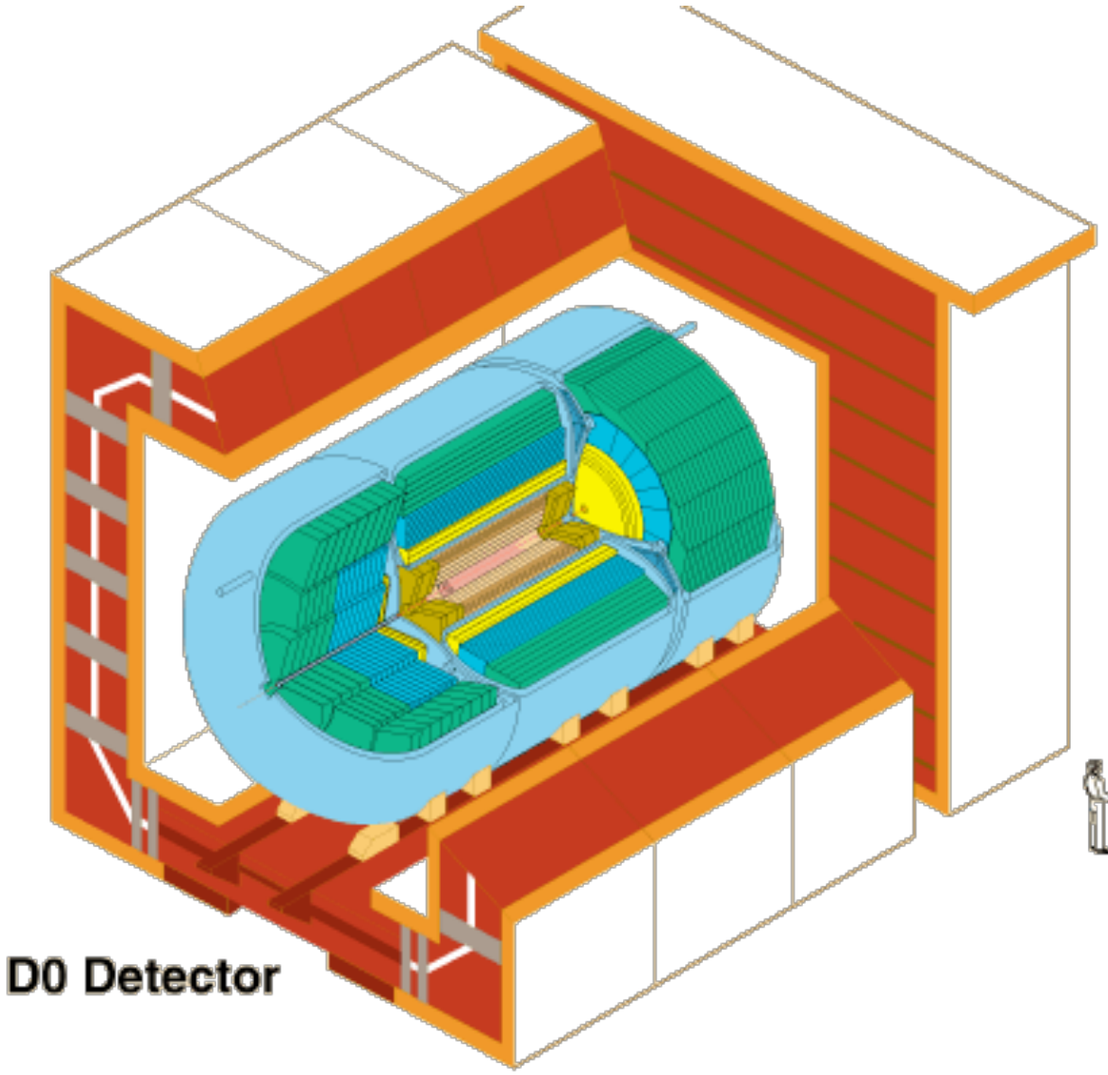
Why is top mass important?

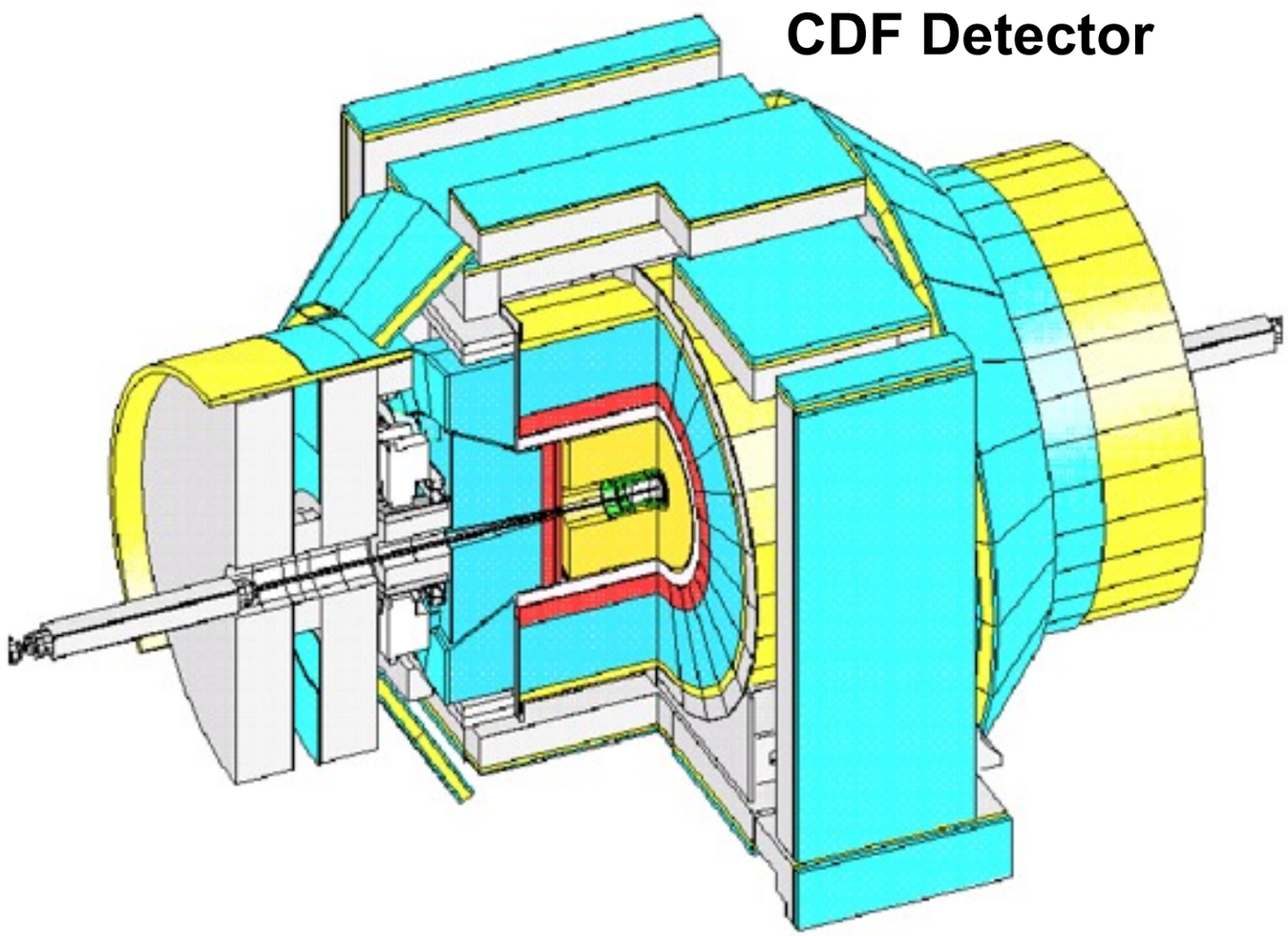


- Top has strongest coupling to EWSB sector.
- Vacuum stability depends on m_t (Nojiri's lecture)
- $m_H \sim 126$ GeV potentially observed
- $m_t = 173.2 \pm 0.9$ GeV @Tevatron most precise measurement

arXiv:1207.0980v2 [hep-ph]

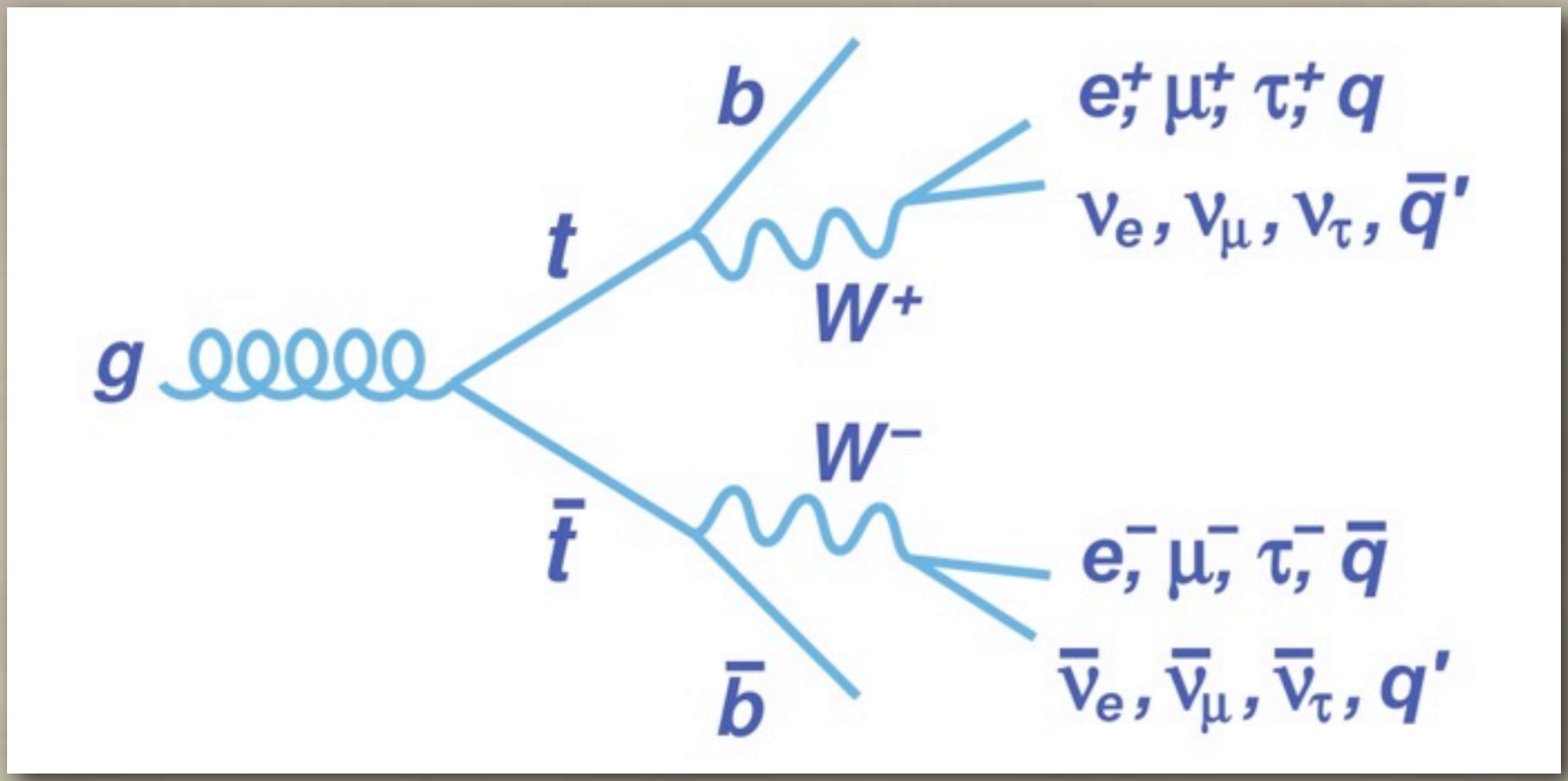
Tevatron





- $p\bar{p}$ collider, $\sqrt{s}$ = 1.96 TeV, $\int$ L dt = 8.7 fb^{-1}
- Hermetic, silicon trackers, calorimeter, muon trackers

ttbar at Tevatron



- Split to 4 main channels:
  - $t\bar{t} \rightarrow q\bar{q}'b\ \ l\bar{\nu}\bar{b}$ **(*l*+jets)**
  - $t\bar{t} \rightarrow q\bar{q}'b\ \ q\bar{q}'\bar{b}$ **(all had)**
  - $t\bar{t} \rightarrow l^{-}\bar{\nu}b\ \ l^{+}\nu\bar{b}$ **(dilepton)**
  - $t\bar{t} \rightarrow q\bar{q}'b\ \ \tau/l\,(\rightarrow jet)\bar{\nu}\bar{b}$ **(MET+jets)**

Analysis Channels

Channel	Lep+jets	All-had	Dilepton	MET+jets
Data	5.6 fb^{-1}	5.8 fb^{-1}	5.4 fb^{-1}	8.7 fb^{-1}
$N_{selected}$	~1.7k	~3.0k	~0.8k	~1.4k
Jets	4 jets 1+ b-tag	6+ jets 1+ b-tag	2+ jets 0/1 b-tag	4+ jets 1+ b-tag
Leptons	1 lepton Large MET	Small MET_{sig}: $\not\!\!E_T / \sqrt{\sum E_T^{jet}}$	2 lep (+/-) Large MET	No lepton Large MET_{sig}: $\not\!\!E_T / \sqrt{\sum E_T^{jet}}$
Main background	W+jets	QCD multijet	Z/γ^*+jets	QCD multijet

m_{top} extraction

Construct a likelihood trying various M_{top} and JES values for each channel:

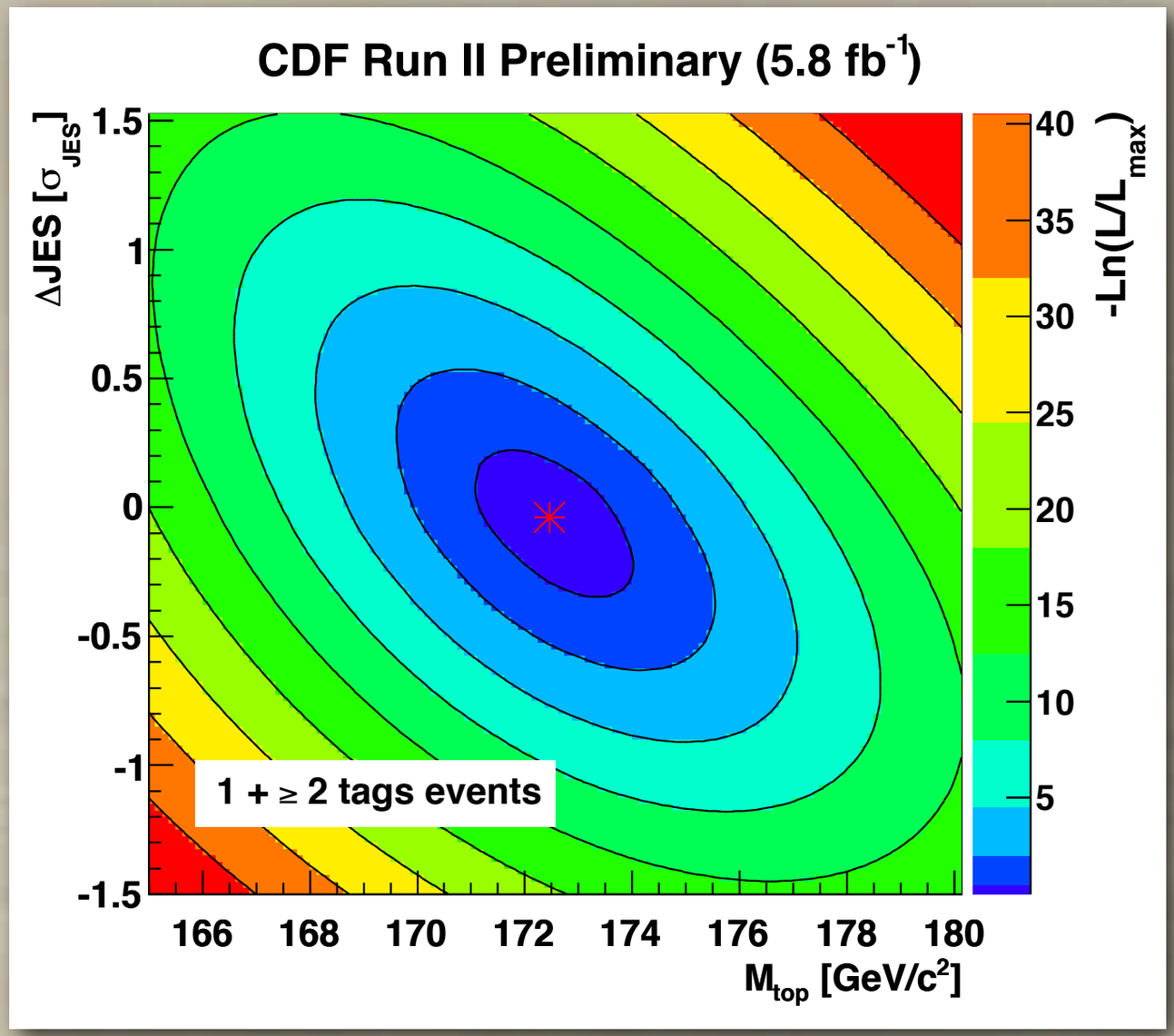
$$\mathcal{L}(M_{top}, \Delta_{JES})$$

M_{top} = MC top mass

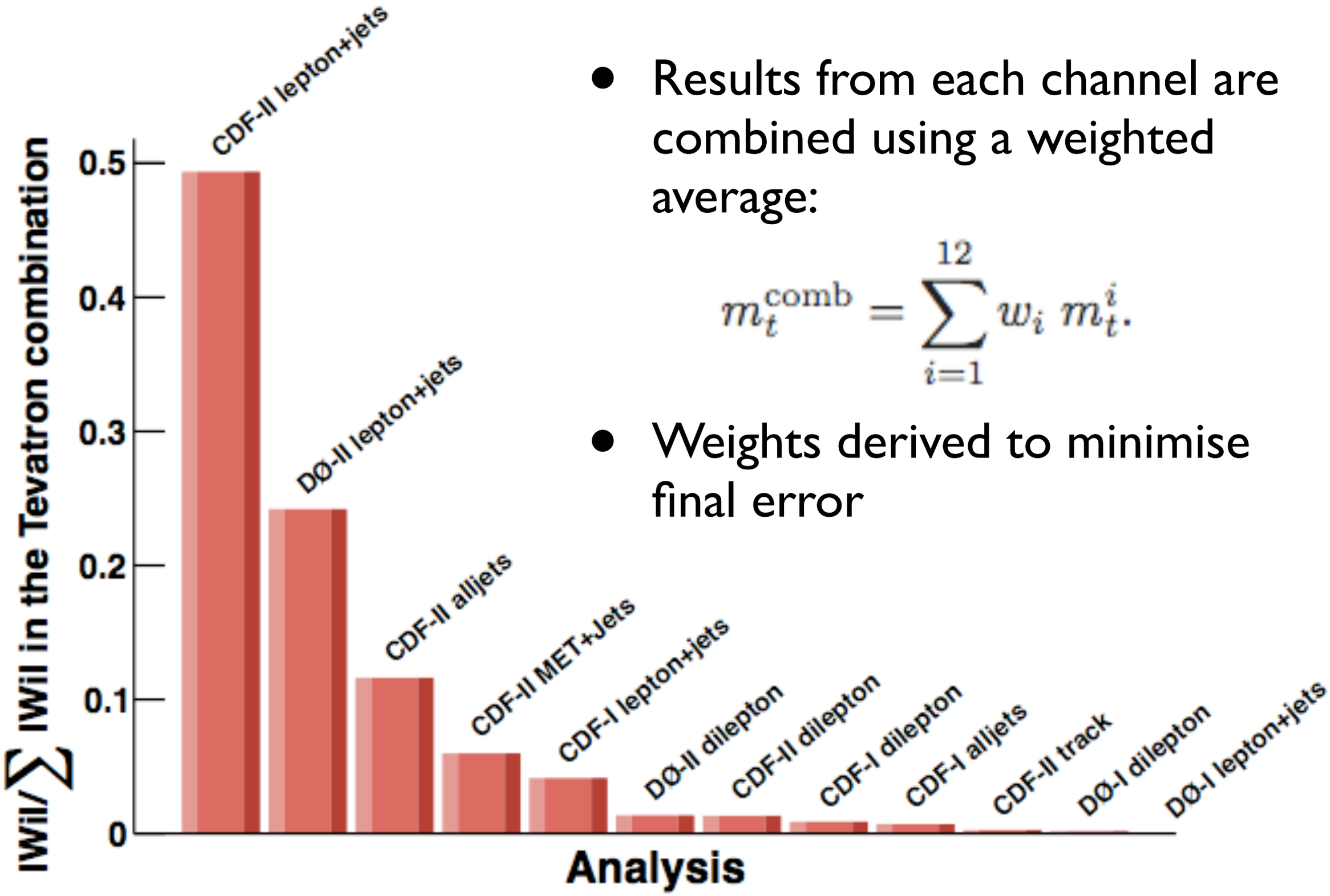
Δ_{JES} = jet energy scale correction factors

The minimum $-Ln(L/L_{max})$ gives our M_{top}

e.g. All had channel



Combining Results

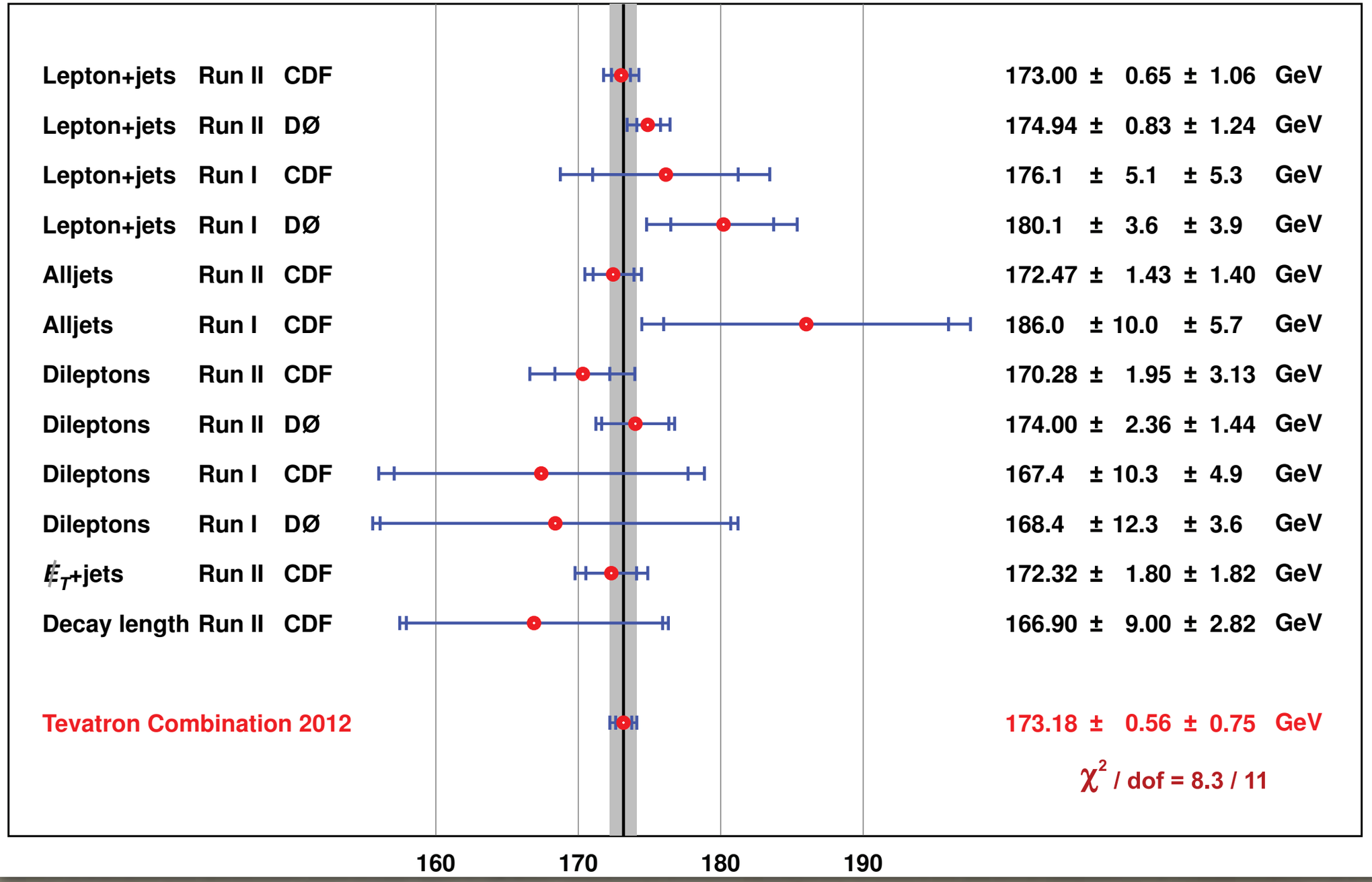


- Results from each channel are combined using a weighted average:

$$m_t^{\mathrm{comb}} = \sum_{i=1}^{12} w_i \, m_t^i.$$

- Weights derived to minimise final error

Results

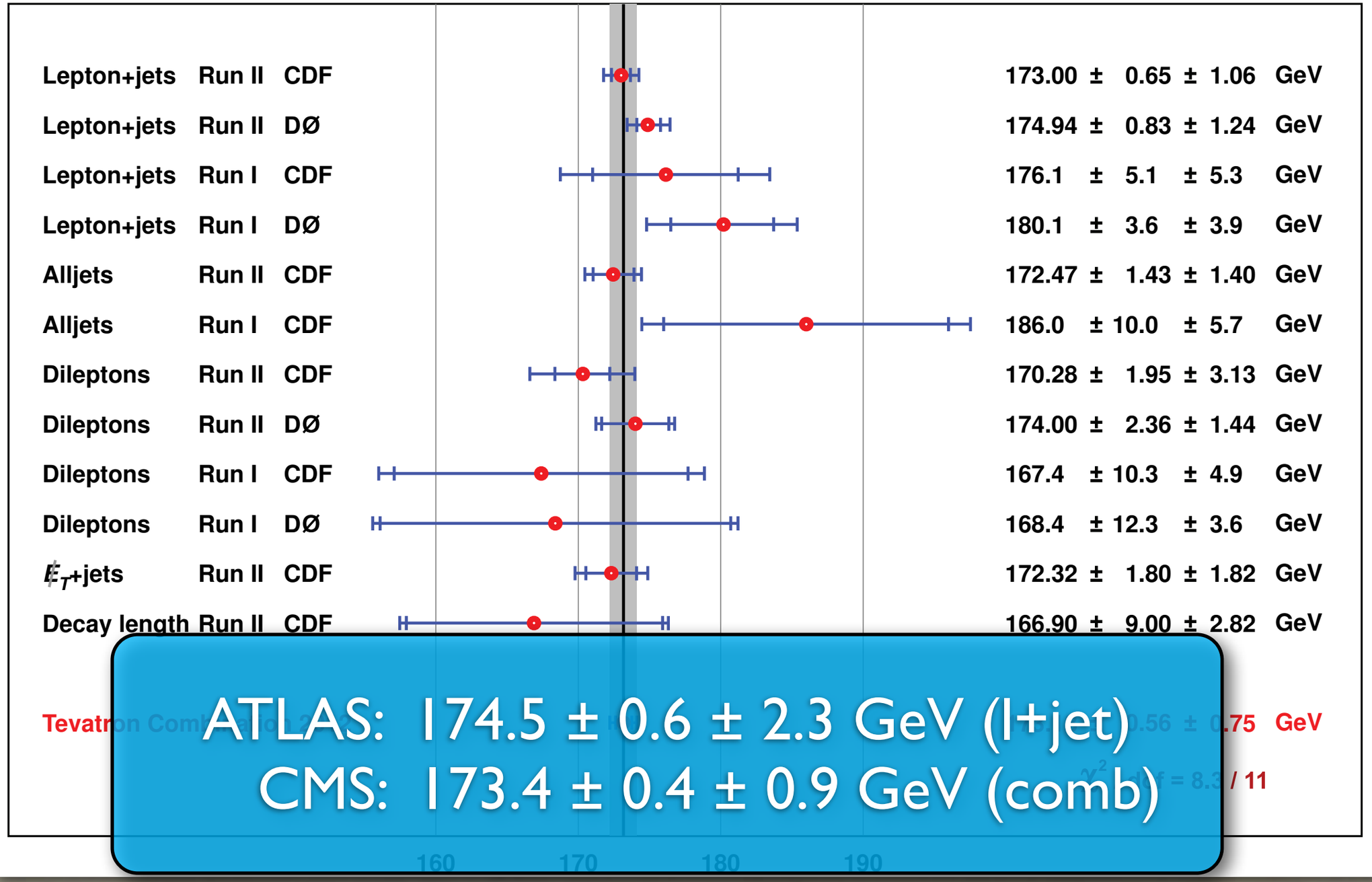


$$m_t^{comb} = 173.18 \pm 0.56\ (\text{stat}) \pm 0.75\ (\text{syst})\ \text{GeV}$$

WARNING

m_t^{comb} has no theoretically well-defined relationship to m_t^{pole}

Results



ATLAS: 174.5 ± 0.6 ± 2.3 GeV (l+jet)
CMS: 173.4 ± 0.4 ± 0.9 GeV (comb)

$$m_t^{comb} = 173.18 \pm 0.56\ (\text{stat}) \pm 0.75\ (\text{syst})\ \text{GeV}$$

WARNING

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Summary & Discussion

- Why is top mass important?
  - Fate of universe depends on it!
- How is top mass measured at Tevatron?
  - Mainly by l+jets and all-jets using likelihood methods
- Combination of Tevatron results gives
  - 173.2±0.9 GeV.
- Relation between m_t^{comb} and m_t^{pole} is still under debate
  - Measurement from inclusive cross-section is unambiguous
  - Best to measure at high energy e^+e^- (e.g. ILC)

Thank you for listening!

Thanks to all of members of Group B

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- Why is top mass important?
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- Combination of Tevatron results gives
  - **m_t = 173.2±0.9 GeV.**

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Backups

m_{top} extraction

$\mathcal{L}(M_{top}, \Delta_{JES})$ → all others → **Template fitting**

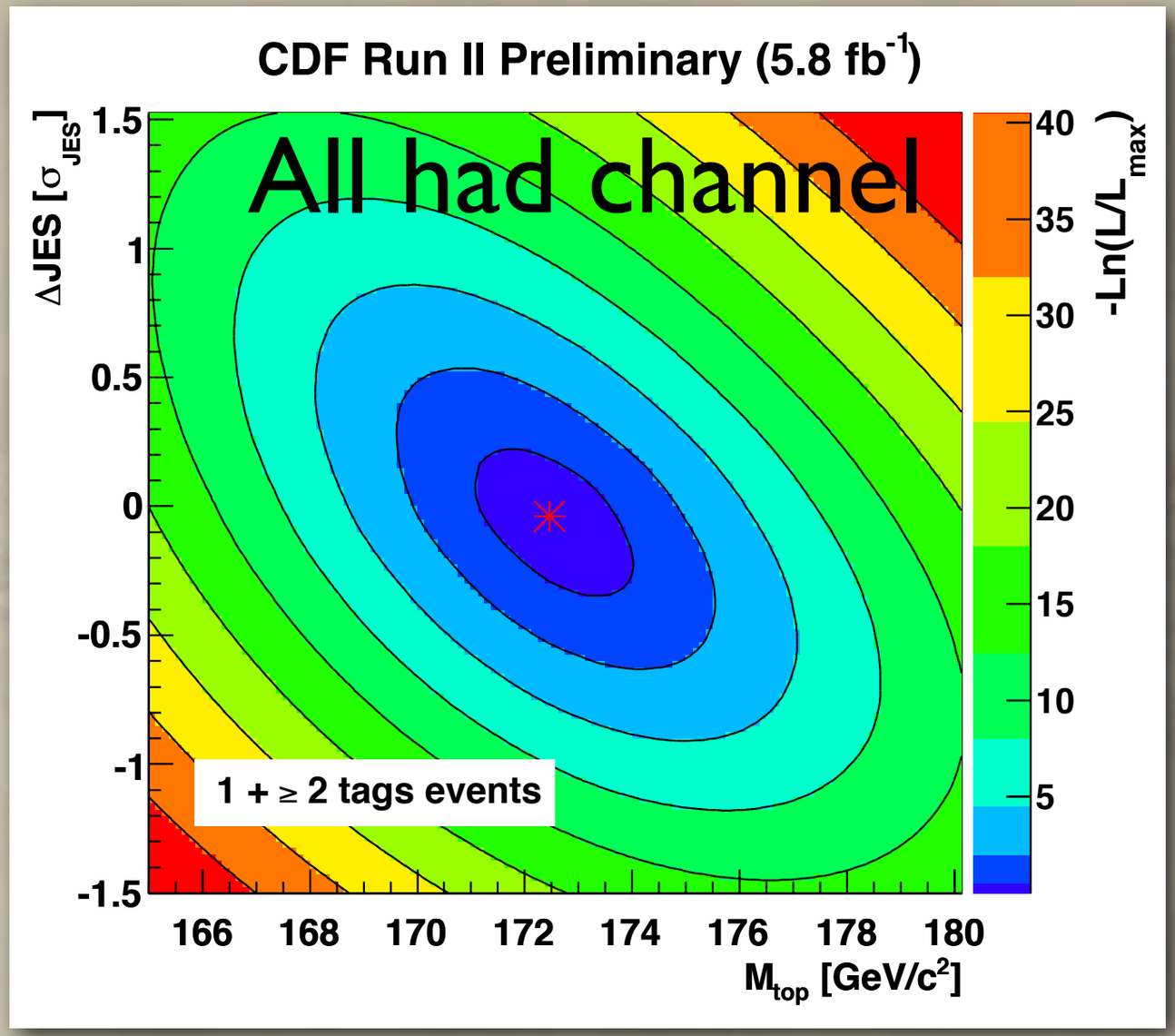
PDF derived by fitting Monte Carlo samples with a given m_{top} and Δ_{JES}

lep+jets ↓

Matrix element

- PDF derived from:

1. LO S-matrix element for given M_{top}
2. Transfer function which maps given Δ_{JES}



BLUE

- Best Linear Unbiased Estimator
- Weighted average with correlated input values
- Features:
  1. Linear combination of individual estimates
  2. unbiased estimate
  3. minimum possible variance sigma^2

$$\mathbf{E} = \begin{bmatrix} var(X_1) & cov(X_1, X_2) & \cdots & cov(X_1, X_n) \\ cov(X_2, X_1) & var(X_2) & \cdots & cov(X_2, X_n) \\ \vdots & \vdots & \ddots & \vdots \\ cov(X_n, X_1) & cov(X_n, X_2) & \cdots & var(X_n) \end{bmatrix}$$

$$\hat{y} = \sum \alpha_i \; y_i$$

$$\sum \alpha_i = 1$$

$$\sigma^2 = \alpha^T \; \mathbf{E} \; \alpha$$

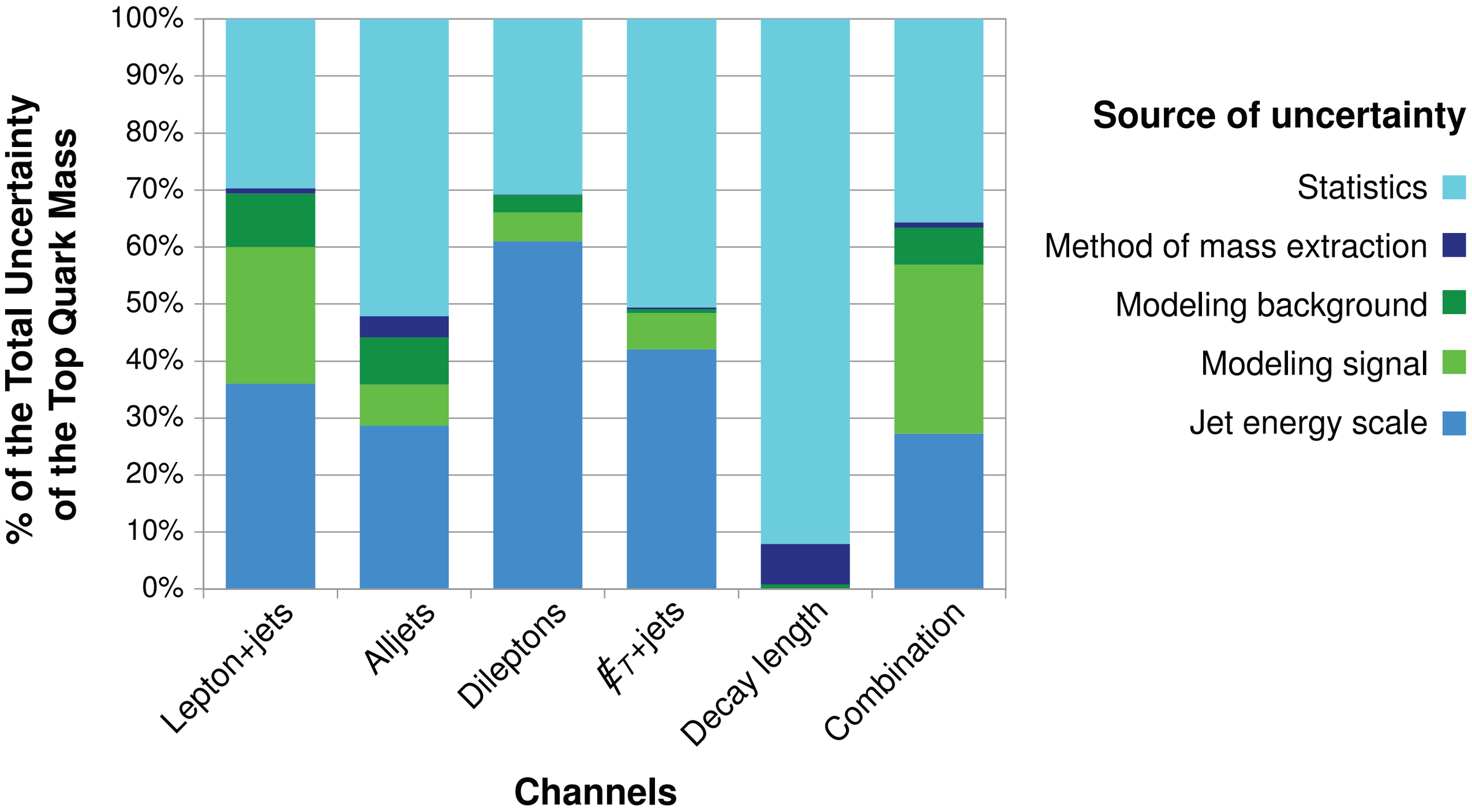
$$\alpha = \mathbf{E^{-1}} \mathrm{U} / (\mathrm{U}^{\mathrm{T}} \; \mathbf{E^{-1}} \; \mathrm{U})$$

http://www.sciencedirect.com/science/article/pii/016890028890186

Combining Results

			Lepton+jets Run II CDF	Lepton+jets Run II D0	Lepton+jets Run I CDF	Lepton+jets Run I D0	Alljets Run II CDF	Alljets Run I CDF	Dileptons Run II CDF	Dileptons Run II D0	Dileptons Run I CDF	Dileptons Run I D0	$\not\!\!E_T$+jets Run II CDF	Decay length Run II CDF	Weight
Lepton+jets	Run II	CDF	100	27	45	25	25	26	44	12	26	11	24	8	55.50
Lepton+jets	Run II	D0	27	100	21	14	16	9	11	39	13	7	15	6	26.66
Lepton+jets	Run I	CDF	45	21	100	26	25	32	54	12	29	11	22	7	-4.72
Lepton+jets	Run I	D0	25	14	26	100	12	14	27	7	15	16	10	5	-0.06
Alljets	Run II	CDF	25	16	25	12	100	15	25	10	15	7	14	4	13.99
Alljets	Run I	CDF	26	9	32	14	15	100	38	6	19	7	14	4	-0.80
Dileptons	Run II	CDF	44	11	54	27	25	38	100	7	32	13	22	6	1.41
Dileptons	Run II	D0	12	39	12	7	10	6	7	100	8	5	10	3	2.28
Dileptons	Run I	CDF	26	13	29	15	15	19	32	8	100	8	14	4	-1.05
Dileptons	Run I	D0	11	7	11	16	7	7	13	5	8	100	6	2	-0.15
$\not\!\!E_T$+jets	Run II	CDF	24	15	22	10	14	14	22	10	14	6	100	4	6.65
Decay length	Run II	CDF	8	6	7	5	4	4	6	3	4	2	4	100	0.29

Relative Uncertainties



Systematics Summary

Channel	Run	Exp.	Light-jet response (1)	Light-jet response (2)	Out-of-cone correction	Offset	Model for b jets	Response to $b/q/g$ jets	*In-situ* light-jet calibration	Jet modeling	Lepton modeling	Signal modeling	Multiple interactions model	Background from theory	Background based on data	Calibration method	**Statistical uncertainty**	**Total JES uncertainty**	**Other systematic uncertainty**	**Total uncertainty**
			Jet energy scale systematics							Other systematics										
Lepton+jets	II	CDF	0.41	0.01	0.27	n/a	0.23	0.13	0.58	0.00	0.14	0.56	0.10	0.27	0.06	0.10	0.65	0.80	0.67	1.23
Lepton+jets	II	D0	n/a	0.63	n/a	n/a	0.07	0.26	0.46	0.36	0.18	0.77	0.05	0.19	0.23	0.16	0.83	0.83	0.94	1.50
Lepton+jets	I	CDF	3.4	0.7	2.7	n/a	0.6	n/e	n/a	n/e	n/e	2.7	n/e	1.3	n/e	0.0	5.1	4.4	2.8	7.3
Lepton+jets	I	D0	n/a	2.5	2.0	1.3	0.7	n/e	n/a	n/e	n/e	1.3	n/e	1.0	n/e	0.6	3.6	3.5	1.6	5.3
Alljets	II	CDF	0.38	0.04	0.24	n/a	0.15	0.03	0.95	0.00	n/a	0.64	0.08	0.00	0.56	0.38	1.43	1.06	0.91	2.00
Alljets	I	CDF	4.0	0.3	3.0	n/a	0.6	n/e	n/a	n/e	n/a	2.1	n/e	1.7	n/e	0.6	10.0	5.0	2.6	11.5
Dileptons	II	CDF	2.01	0.58	2.13	n/a	0.33	0.14	n/a	0.00	0.27	0.80	0.23	0.24	0.14	0.12	1.95	3.01	0.88	3.69
Dileptons	II	D0	n/a	0.56	n/a	n/a	0.20	0.40	0.55	0.50	0.35	0.86	0.00	0.00	0.20	0.51	2.36	0.90	1.11	2.76
Dileptons	I	CDF	2.7	0.6	2.6	n/a	0.8	n/e	n/a	n/e	n/e	3.0	n/e	0.3	n/e	0.7	10.3	3.9	3.0	11.4
Dileptons	I	D0	n/a	1.1	2.0	1.3	0.7	n/e	n/a	n/e	n/e	1.9	n/e	1.1	n/e	1.1	12.3	2.7	2.3	12.8
$\not\!\!E_T$+jets	II	CDF	0.45	0.05	0.20	n/a	0.00	0.12	1.54	0.00	n/a	0.78	0.16	0.00	0.12	0.14	1.80	1.64	0.78	2.56
Decay length	II	CDF	0.24	0.06	n/a	n/a	0.15	n/e	n/a	0.00	n/a	0.90	0.00	0.80	0.20	2.50	9.00	0.25	2.80	9.43
Tevatron Combination			0.12	0.19	0.04	0.00	0.15	0.12	0.39	0.11	0.10	0.51	0.00	0.14	0.11	0.09	0.56	0.49	0.57	0.94