General aspects of QCD at future colliders

Gavin Salam (CERN)

SLAC Workshop on Physics at a 100 TeV Collider
23-25 April 2014

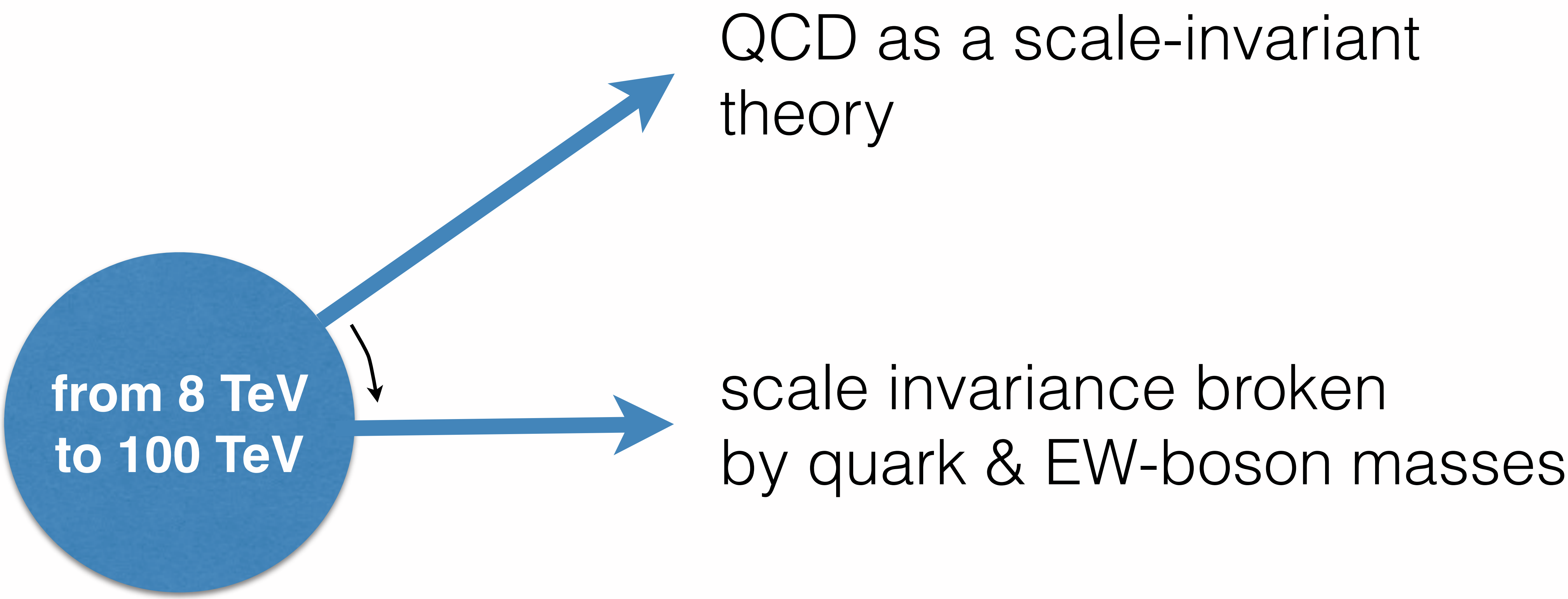
We have seen / will see talks on many of the key topics of QCD:

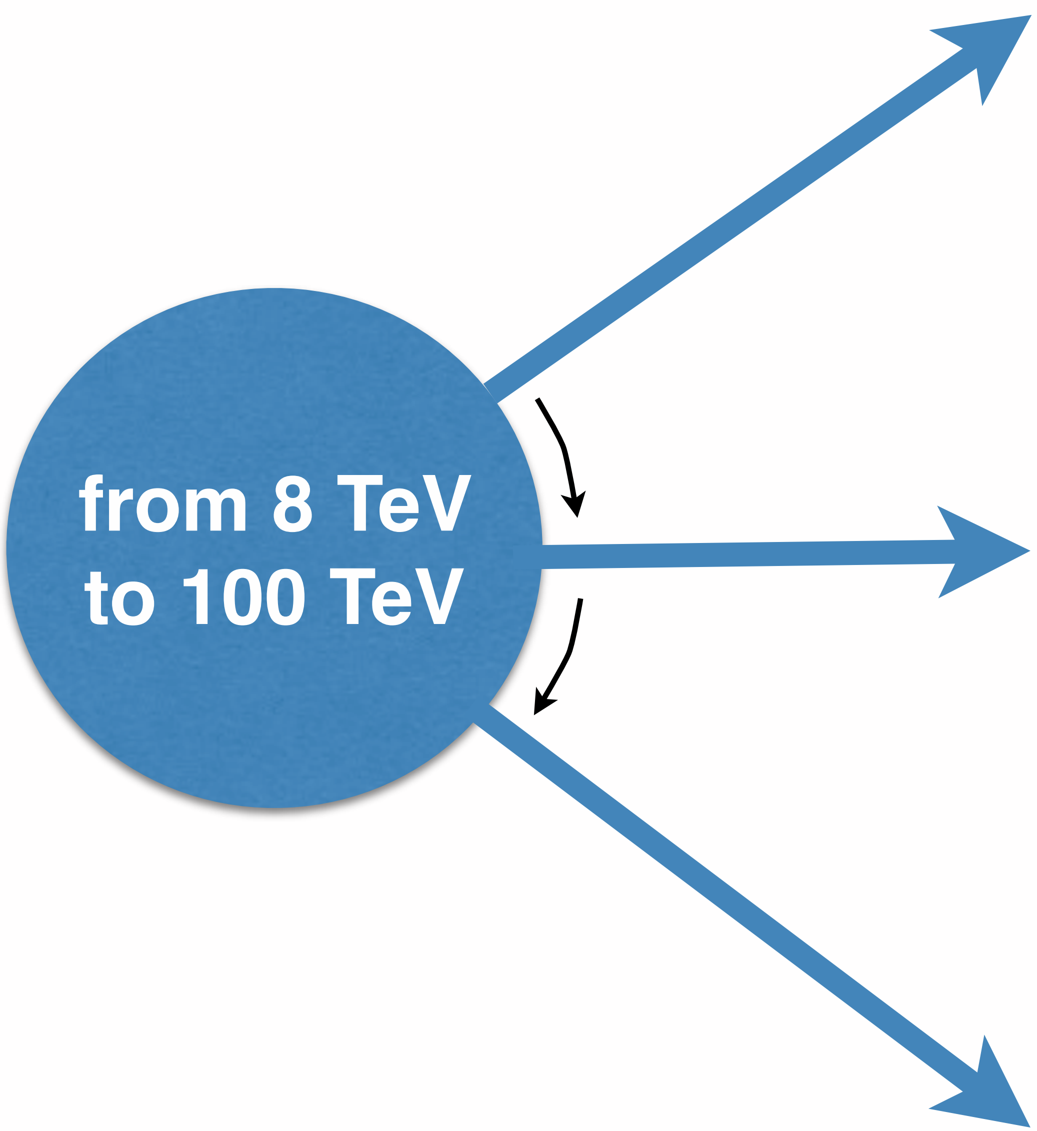
PDFs, MC matching, Jets

What is there left for me to tell you?

QCD as a scale-invariant theory

from 8 TeV to 100 TeV


from 8 TeV
to 100 TeV
QCD as a scale-invariant
theory
scale invariance broken
by quark & EW-boson masses

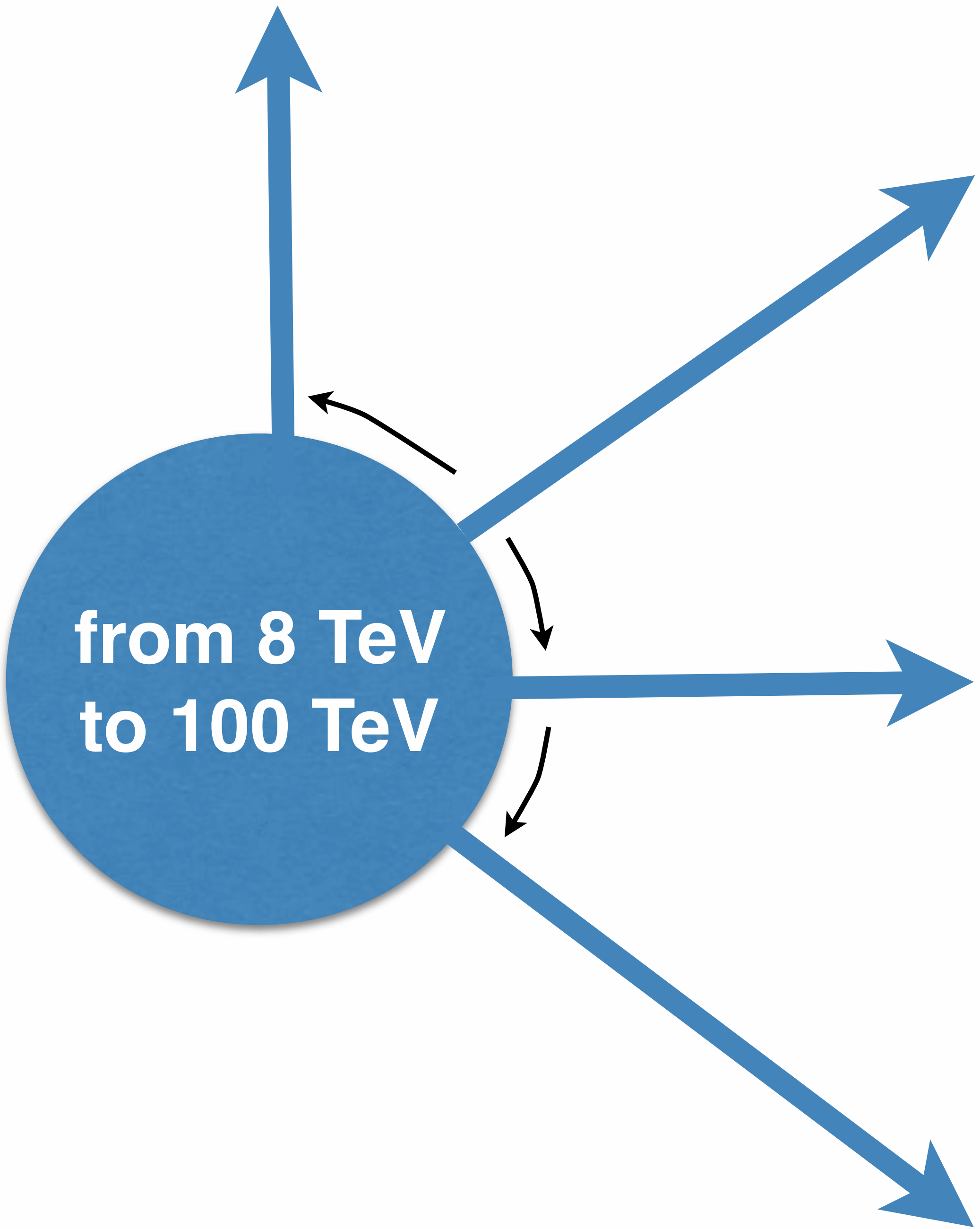


QCD as a scale-invariant theory

scale invariance broken
by quark & EW-boson masses

problems that need solving for LHC and for FHC

Collider Reach



QCD as a scale-invariant theory

scale invariance broken by quark & EW-boson masses

problems that need solving for LHC and for FHC

QCD as a scale-invariant theory

from 8 TeV to 100 TeV

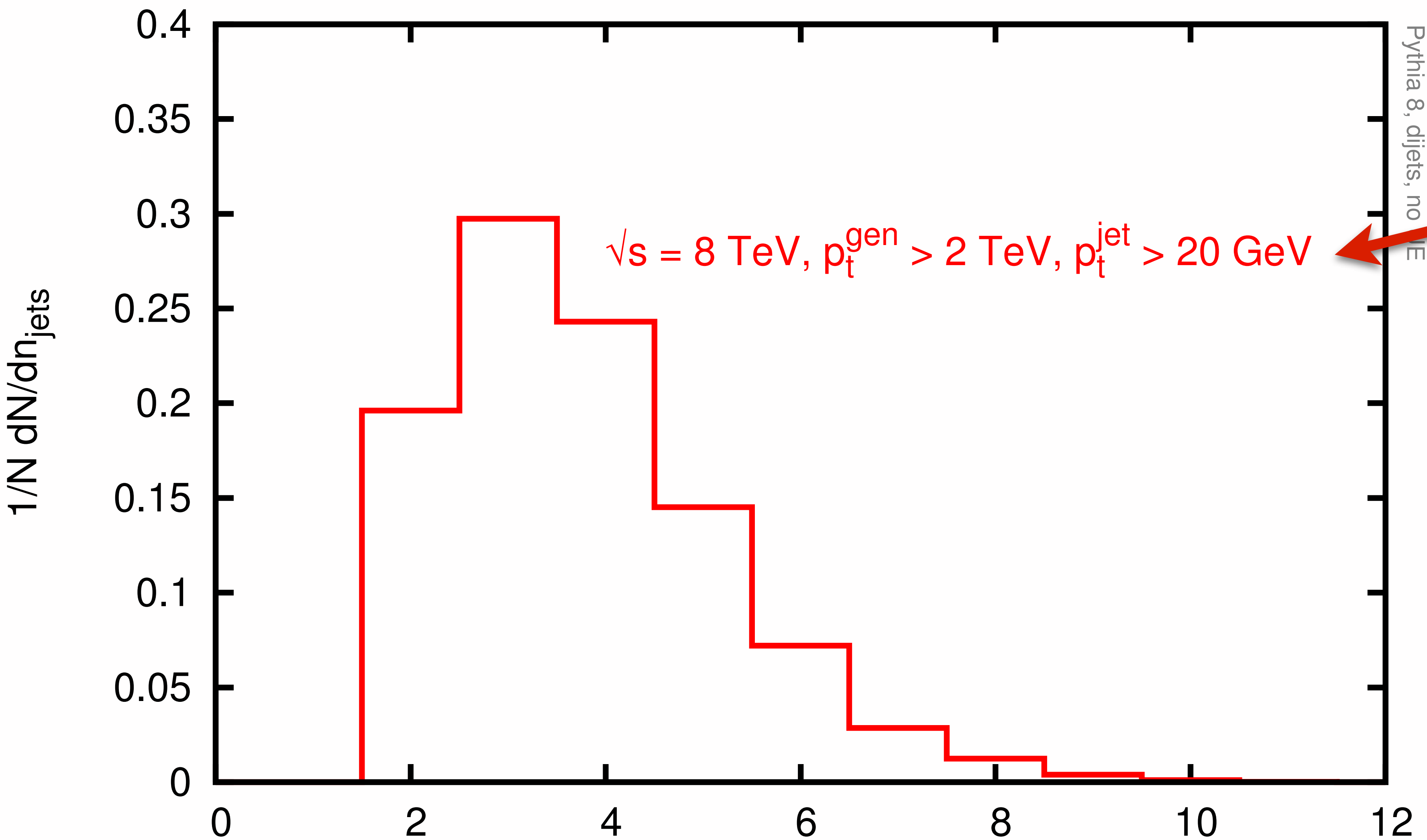
At high scales, α_s runs slowly, as do PDFs

Little difference between
2 TeV physics at an 8 TeV collider
and 25 TeV physics at a 100 TeV collider

α_s (2 TeV) = 0.083

α_s (25 TeV) = 0.067

Scale invariance holds if **all ratios of scales kept fixed**

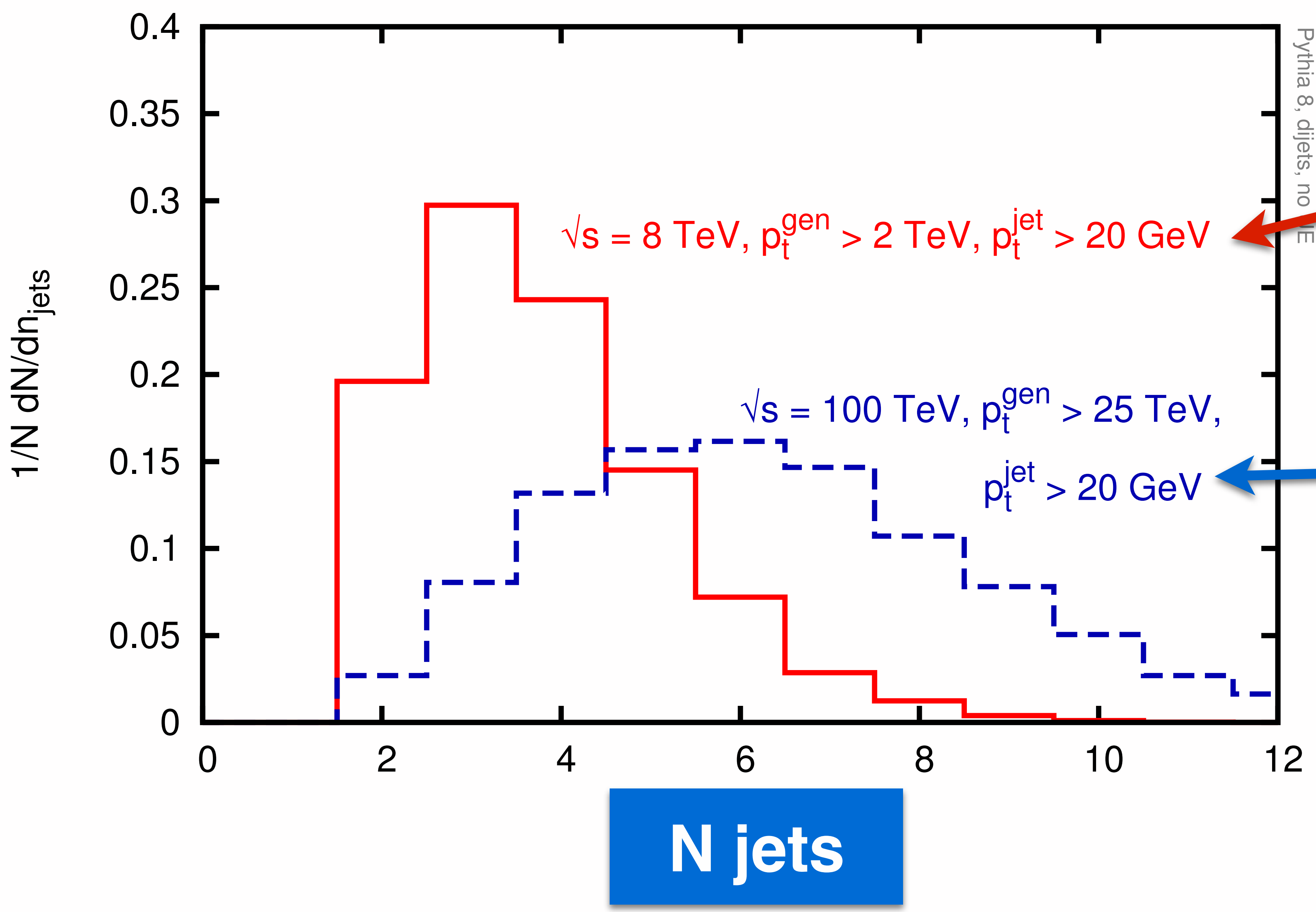


N jets

8 TeV analysis of QCD 2 → 2 scattering

Count the jets

Scale invariance holds if **all ratios of scales kept fixed**



8 TeV analysis of QCD 2 → 2 scattering

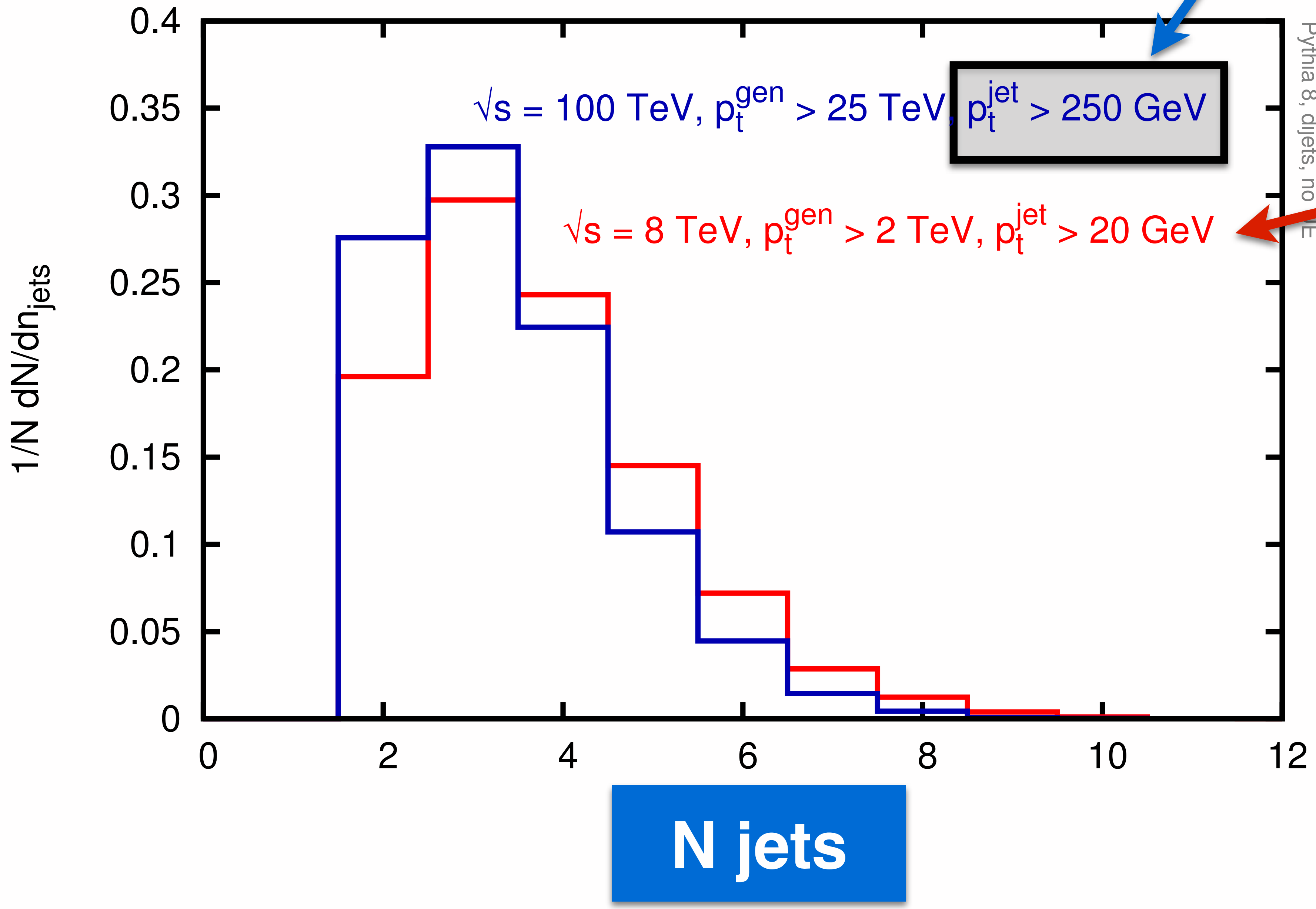
Extension to 100 TeV, jet p_t cut left unchanged @ 20 GeV

→ **many more jets**

Scale invariance holds if **all ratios of scales kept fixed**

100 TeV, scaling also the **jet cut → 250 GeV** gives a distribution much like the original

8 TeV analysis of QCD 2 → 2 scattering



from 8 TeV to 100 TeV → **scale invariance broken by quark & EW-boson masses**

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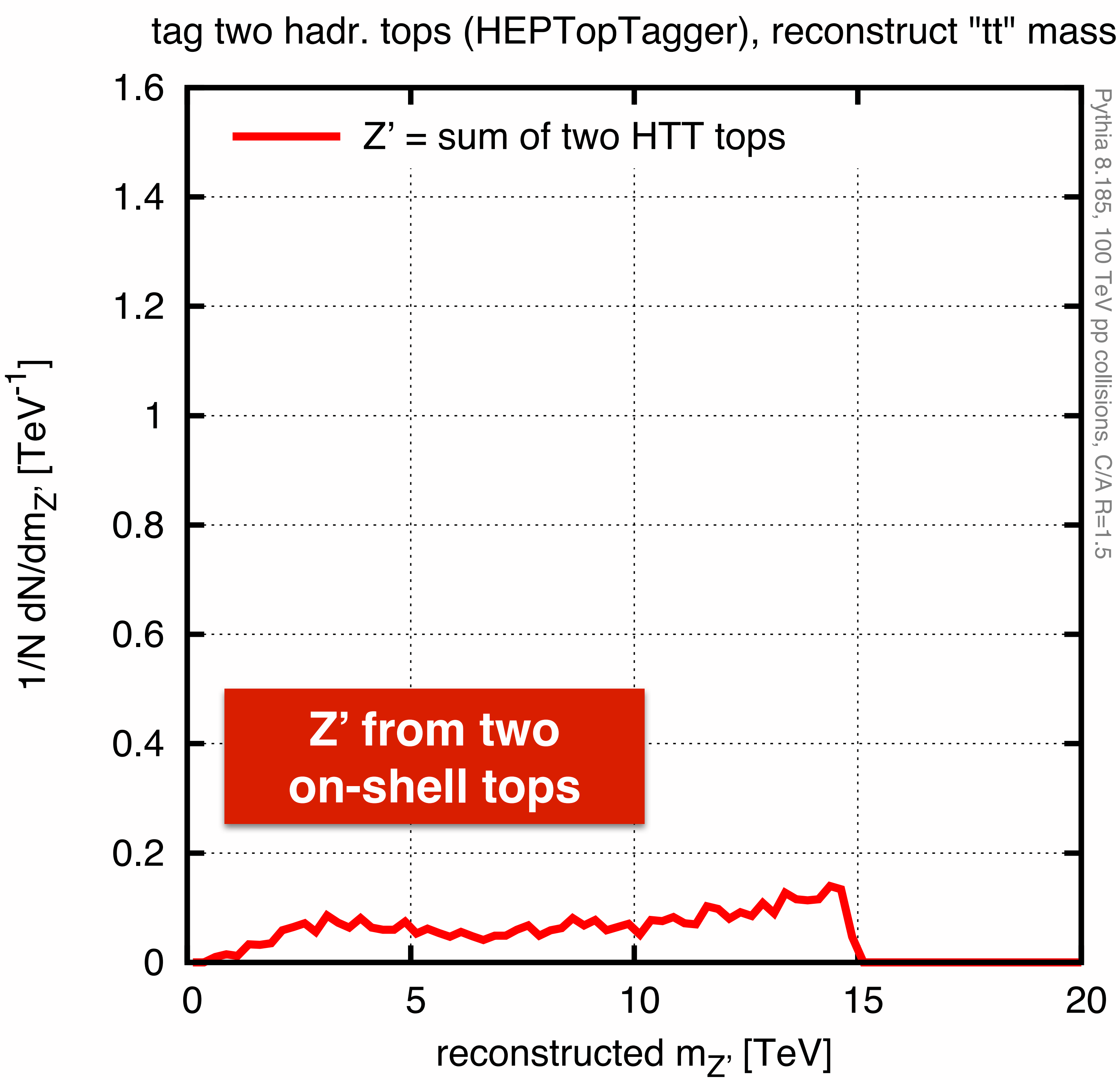
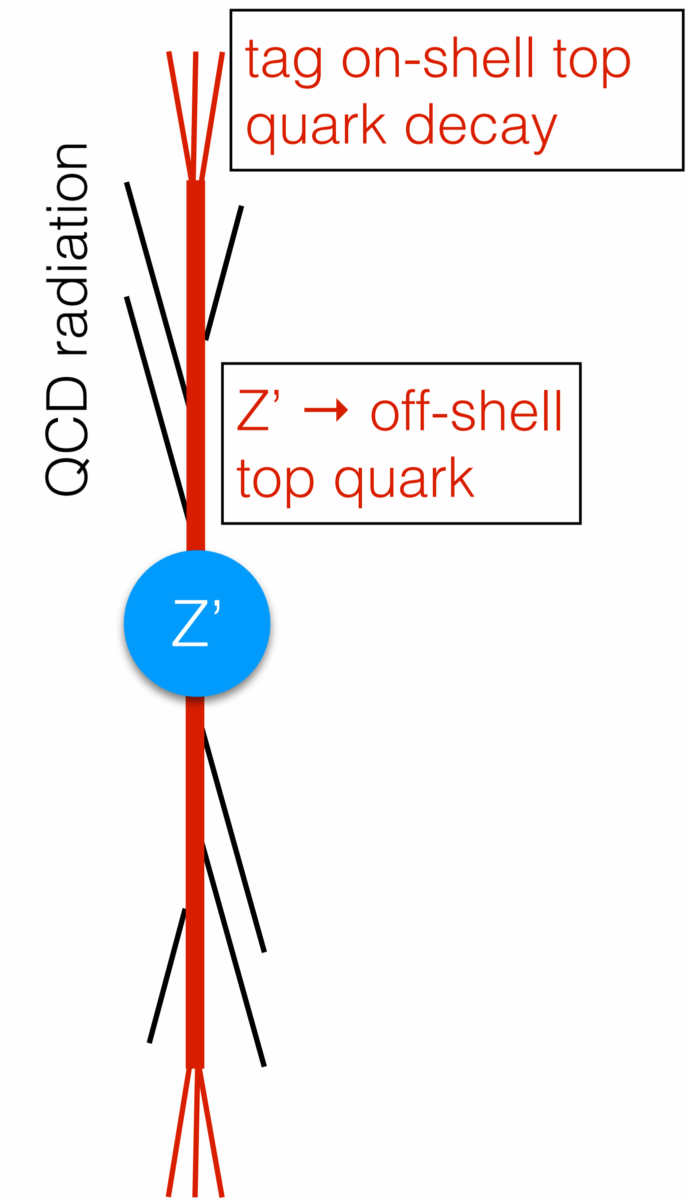
top quarks v. top jets

EW radiation in jets

The top quark as a light parton

[informal studies with Tilman Plehn]





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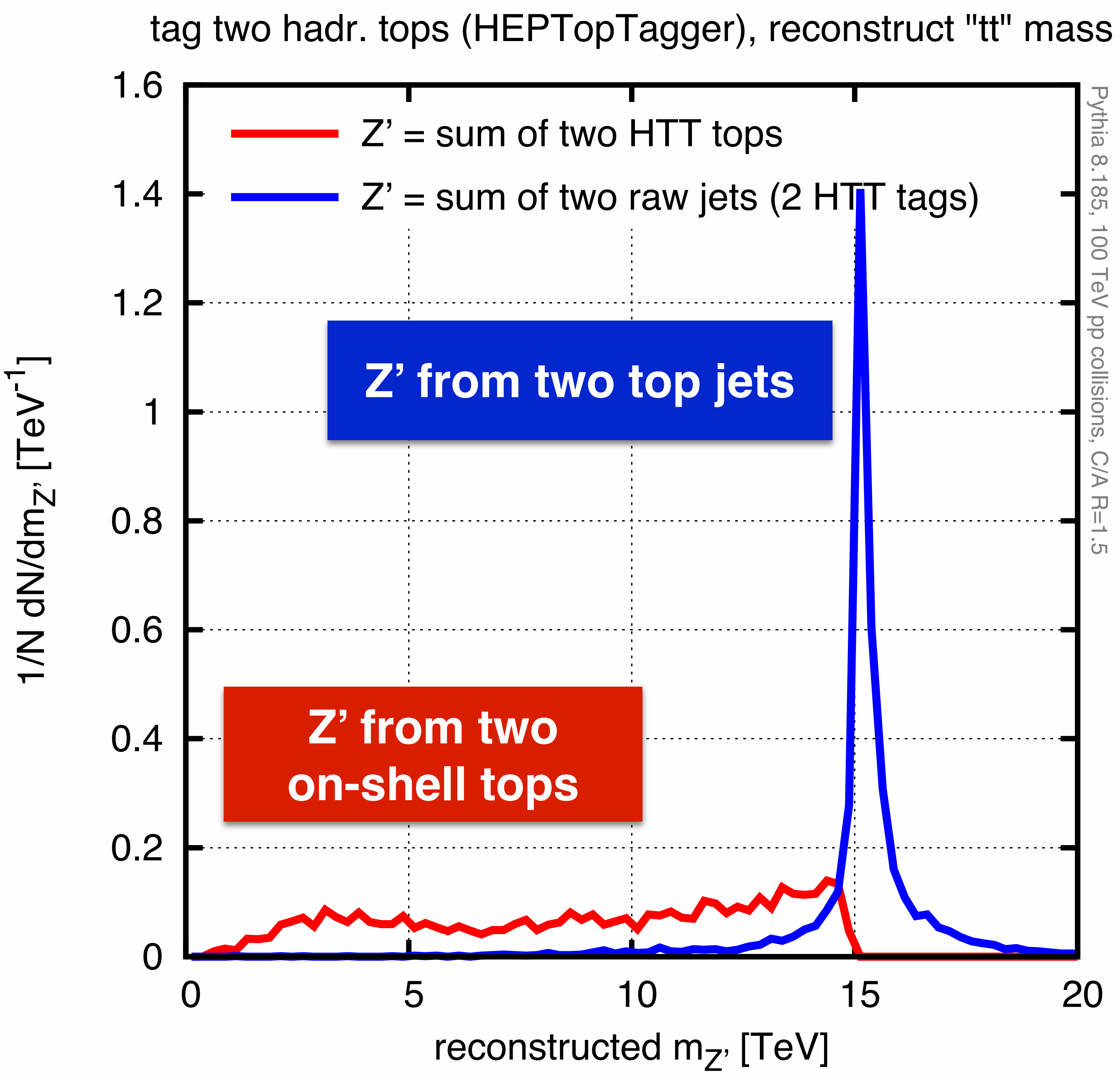
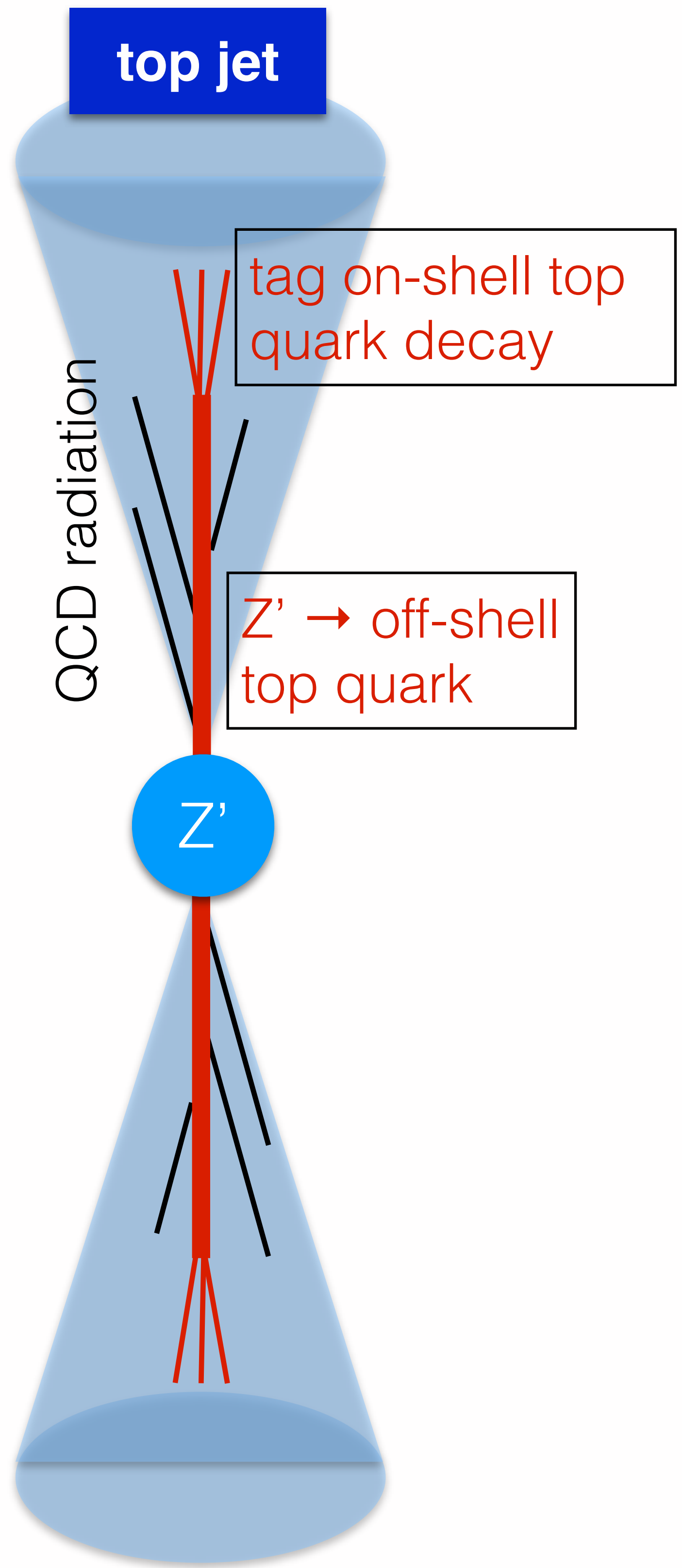
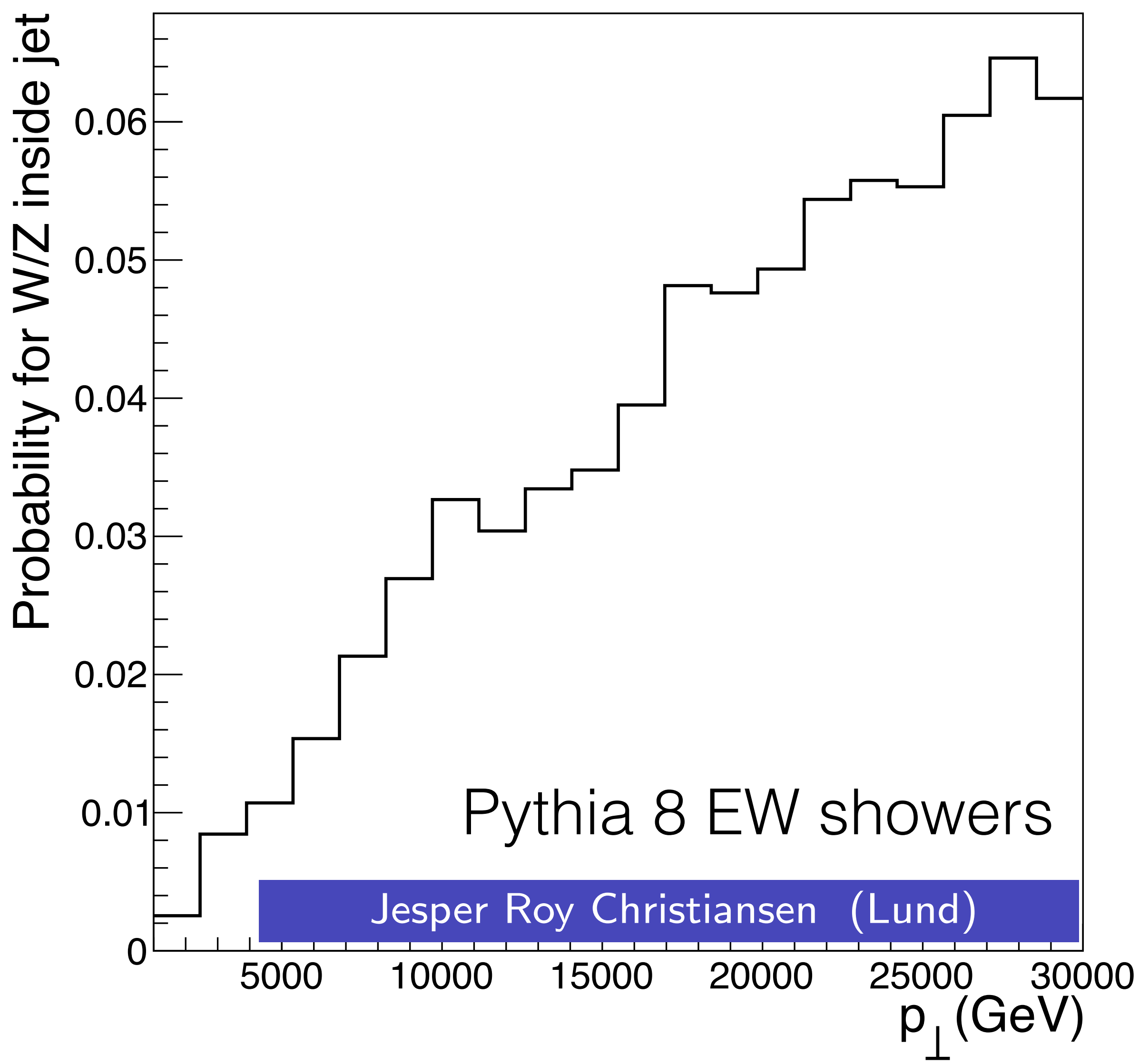




EW radiation in jets

Prob. of Z/W in jet v. jet p_t



+ analogous plots at fixed order from MLM

Significant enhancement of W's and Z's in jets:

$$\sim \alpha_{\mathrm{EW}} \ln^2 \frac{p_t}{M_W}$$

New, fun theory!

Experimentally, how different is this from bottom and charm in jet?

cf. 20% BR for b → c ν $l^\pm$ and O(10%) of 1 TeV gluon jets having b's inside

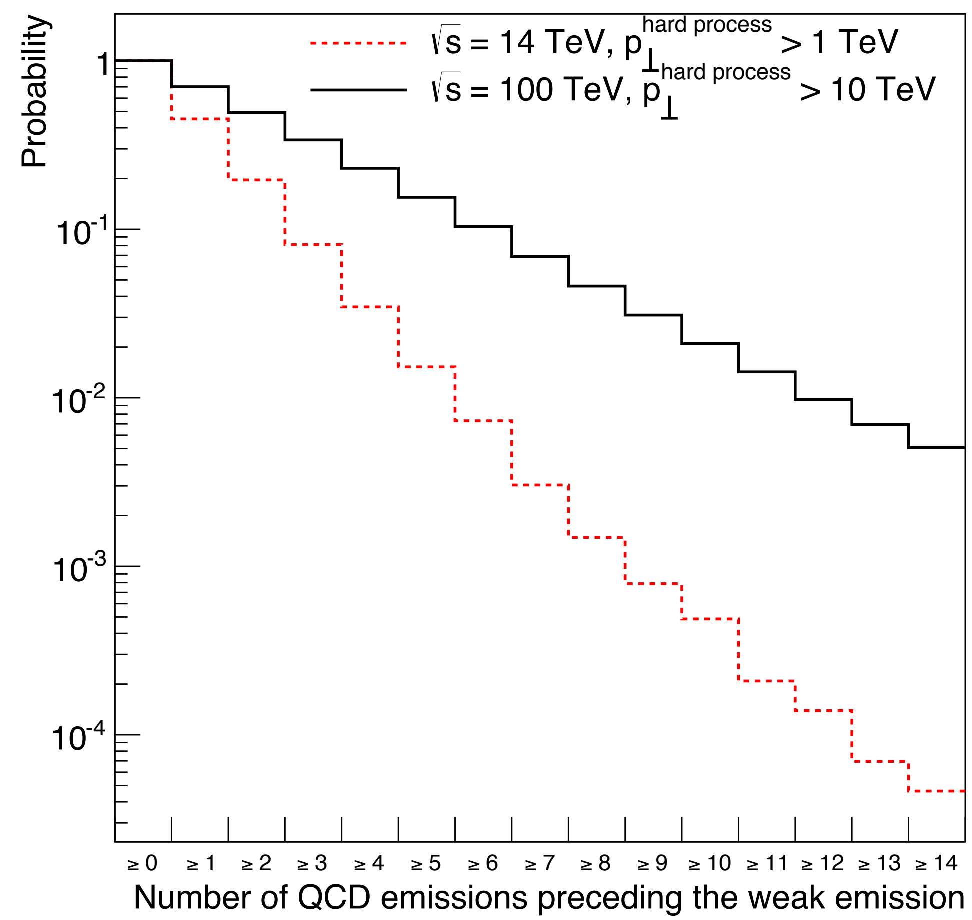
EW radiation in initial state

It polarizes the incoming partons
Can we make use of this?

How to simulate EW radiation correctly?

Competition between QCD and weak emissions

- Need to include up to 11 emissions, to only miss 1 % $\Rightarrow$ Does this become problematic for merging techniques?



Jesper Roy Christiansen (Lund) A weak parton shower April 17, 2014 12 / 14

Some long-standing problems:

Why is QCD so poorly convergent at hadron colliders?

How well do we know our fundamental constants?

from 8 TeV to 100 TeV

problems that need solving for LHC and for FHC

Radically worse perturbative series at hadron colliders:

e^+e^- collisions: $$R_{\text{hadrons}} \propto 1 + 0.32\alpha_s + 0.14\alpha_s^2 + \cdots$$

pp collisions: $$\sigma_{gg\to H} \propto 1 + 9.8\alpha_s + 33\alpha_s^2 + ?$$

C_A / C_F explains twice worse convergence

But convergence is 10–30 times worse

WHY?

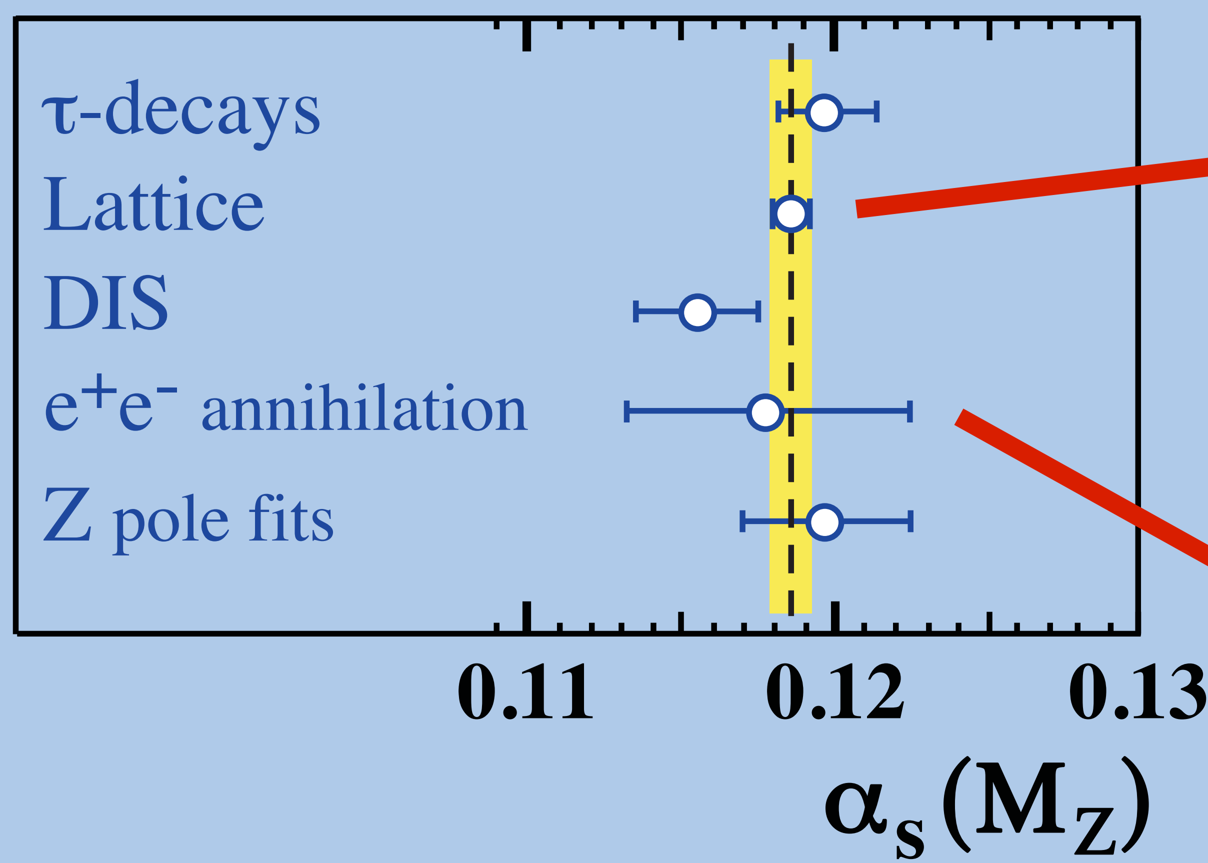
Strong Coupling Constant

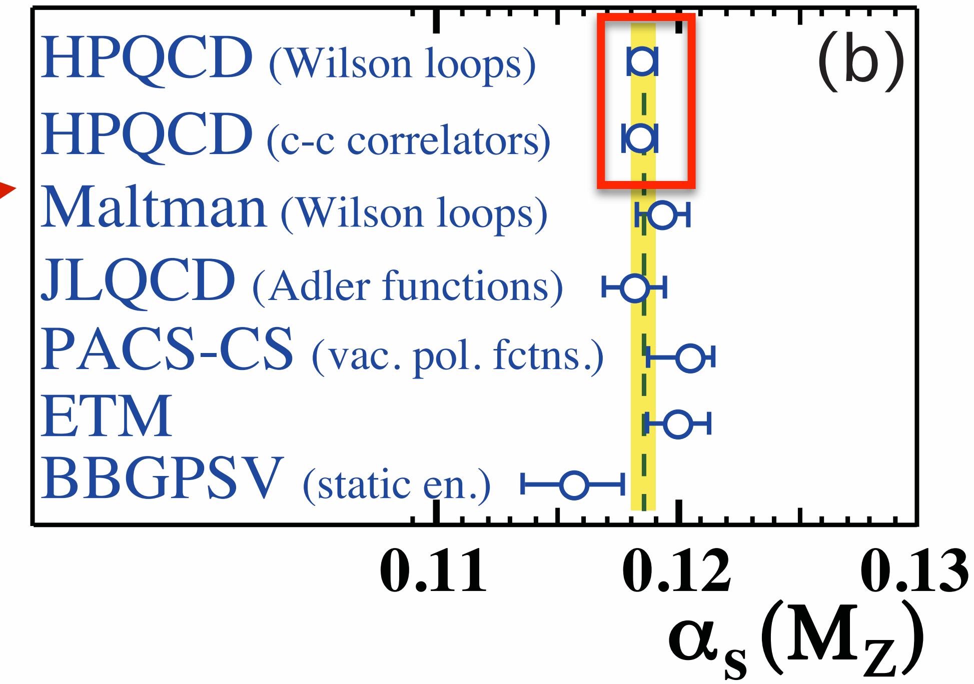
PDG world average: $\alpha_s(M_Z) = 0.1184 \pm 0.0006$

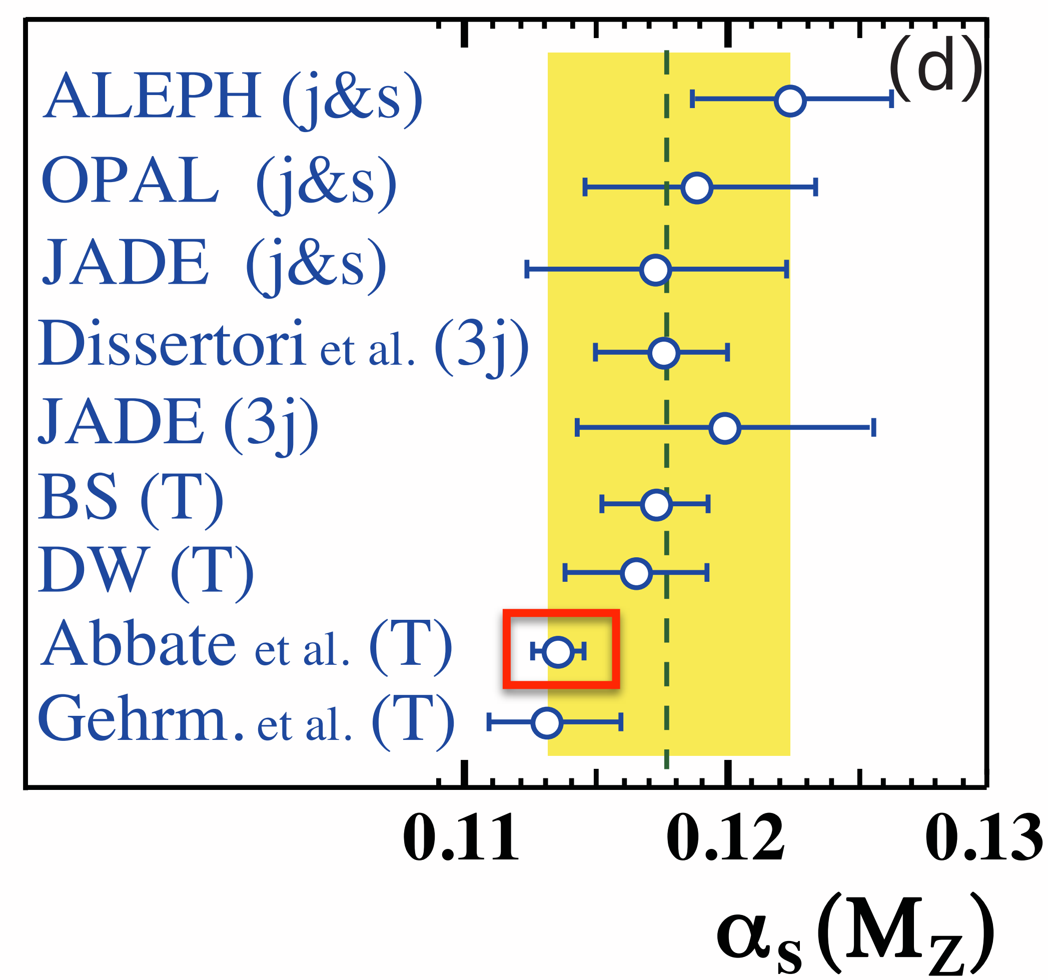
w/o lattice inputs: $\alpha_s(M_Z) = 0.1183 \pm 0.0012$
(~ choice by PDF4LHC)

Uncertainty gets amplified in cross sections, e.g. gg → H

$$\frac{\delta\sigma_{ggH}}{\sigma_{ggH}} \sim 3\frac{\delta\alpha_s}{\alpha_s}$$







Different extractions quoting small uncertainties are not consistent

Thrust + SCET: 0.1135 ± 0.0010

Wilson loops: 0.1184 ± 0.0006

Differ at 4σ — how do we resolve this?

Collider Reach

from 8 TeV to 100 TeV

Quick and dirty estimates of the reach of future colliders based on existing limits

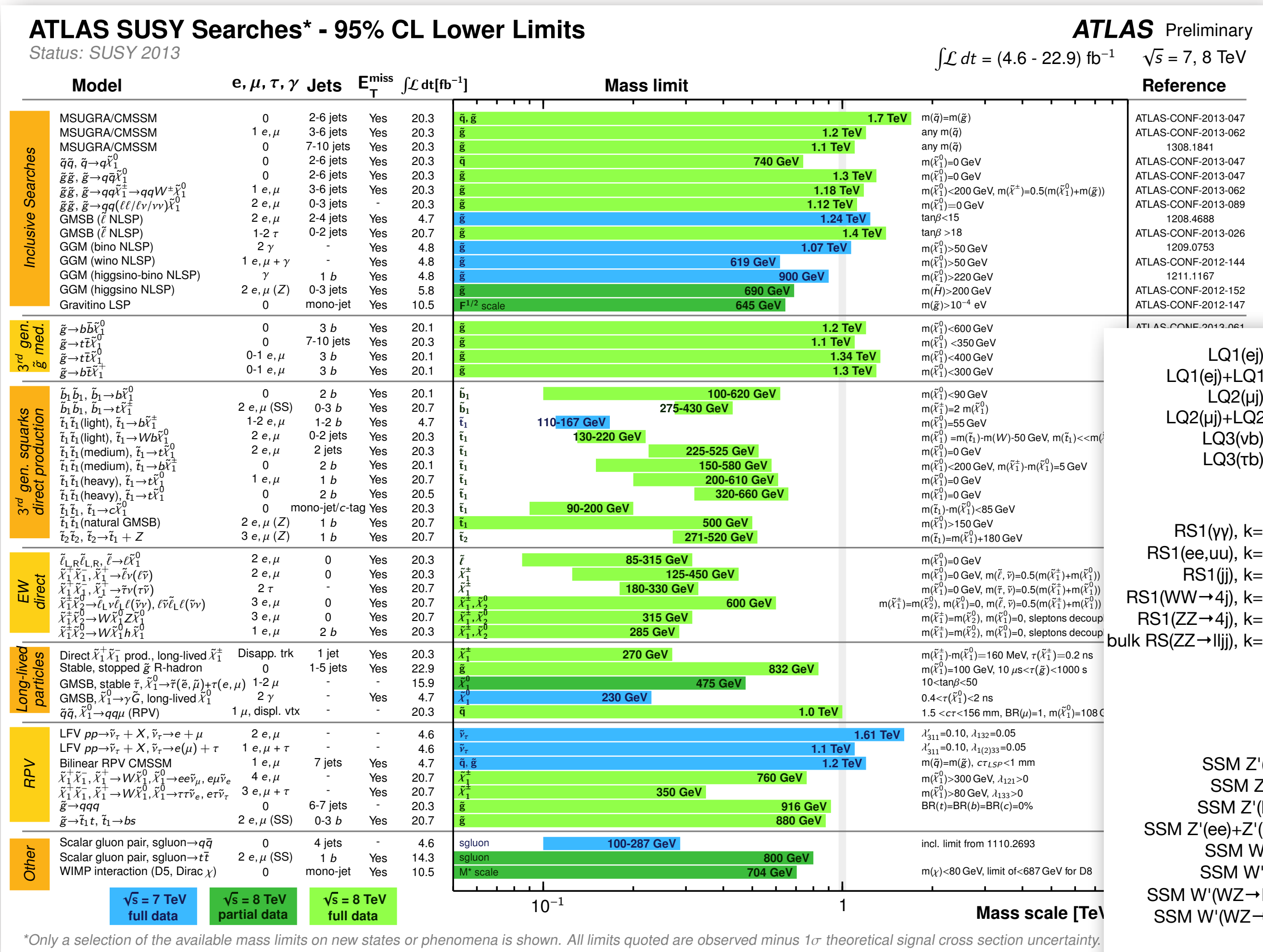
with Andi Weiler

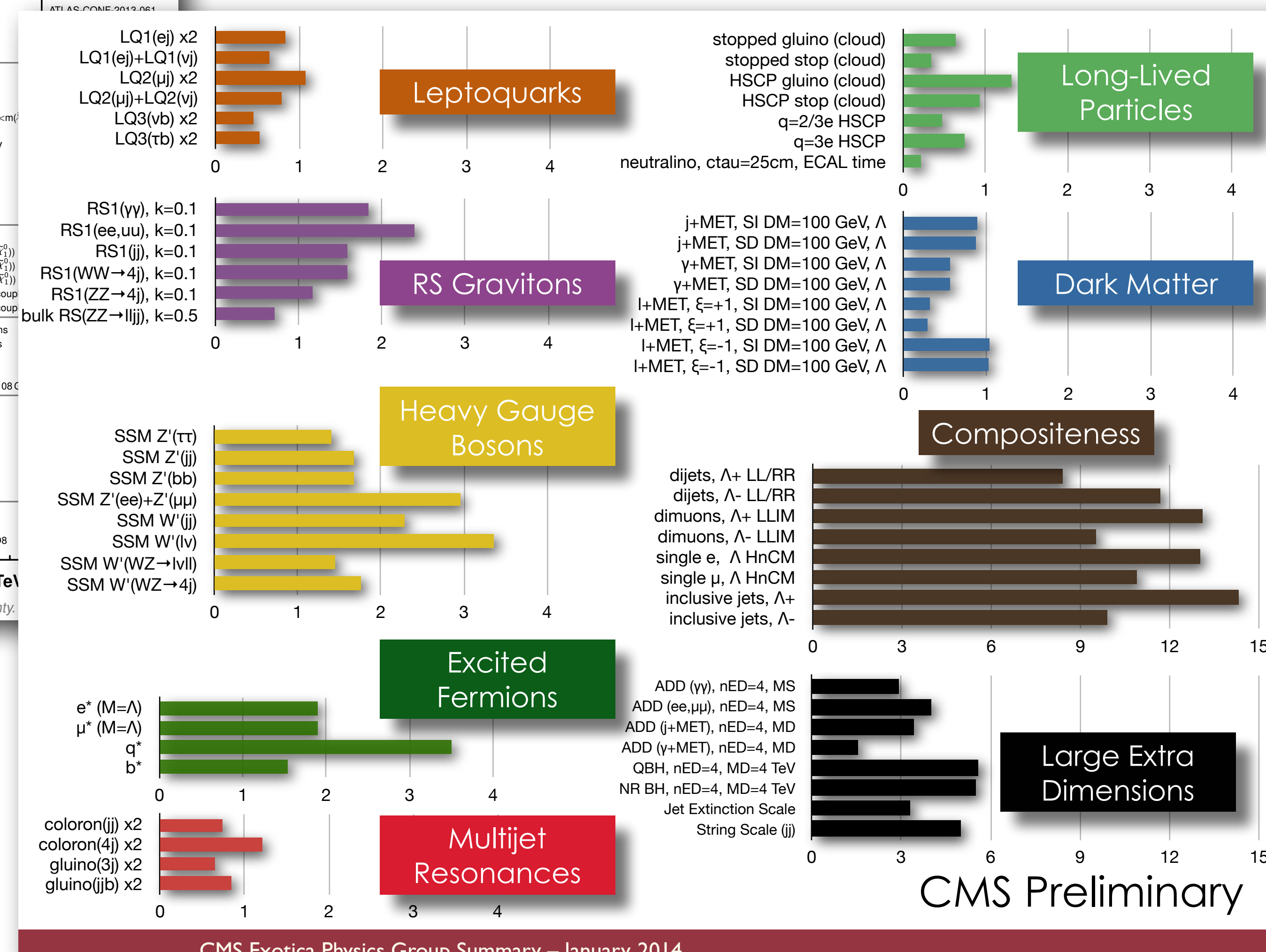
How soon will LHC@13TeV beat 8TeV searches?

What can high-lumi LHC (3000fb^{-1}) do compared to original LHC plan (300fb^{-1})?

What is the gain from a future 33/50/100/150 TeV collider?

There are already many well-designed searches





How do we leverage that experience to guesstimate future reaches?

A rough way of doing it

Suppose ATLAS/CMS are currently sensitive to gluinos of 1250 GeV (95% CL_S, 8 TeV, 20 fb^{-1})

↓

Work out how many signal events that corresponds to

↓

Find out for what gluino mass you would get the same number of signal events at 14 TeV with 300 fb^{-1} (assume # of background events scales same way)

What we're discussing is solution of the following equation for M_{high}

$$\frac{N_{\text{signal-events}}(M^2_{\text{high}}, 14\,\text{TeV}, \text{Lumi})}{N_{\text{signal-events}}(M^2_{\text{low}},\ 8\,\text{TeV},\ 19\text{fb}^{-1})} = 1$$

Many complications (e.g. coupling constants & other prefactors) mostly cancel in the ratio.

Dependence on *M* and on √s mostly comes about through parton distribution functions (PDFs) & simple dimensions.

Instead of cross section ratio, use **parton luminosity ratio**

Assume dominance of a single partonic scattering channel, ij (you have to know enough physics to figure out which is most appropriate).

Equation we solve to find M_{high} is then

$$\frac{\mathcal{L}_{ij}(M^2_{\text{high}}, s_{\text{high}})}{\mathcal{L}_{ij}(M^2_{\text{low}}, s_{\text{low}})} \times \frac{\text{lumi}_{\text{high}}}{\text{lumi}_{\text{low}}} = \frac{M^2_{\text{high}}}{M^2_{\text{low}}}$$

The tools we use for this are
LHAPDF and HOPPET
most plots with MSTW2008 NNLO PDFs

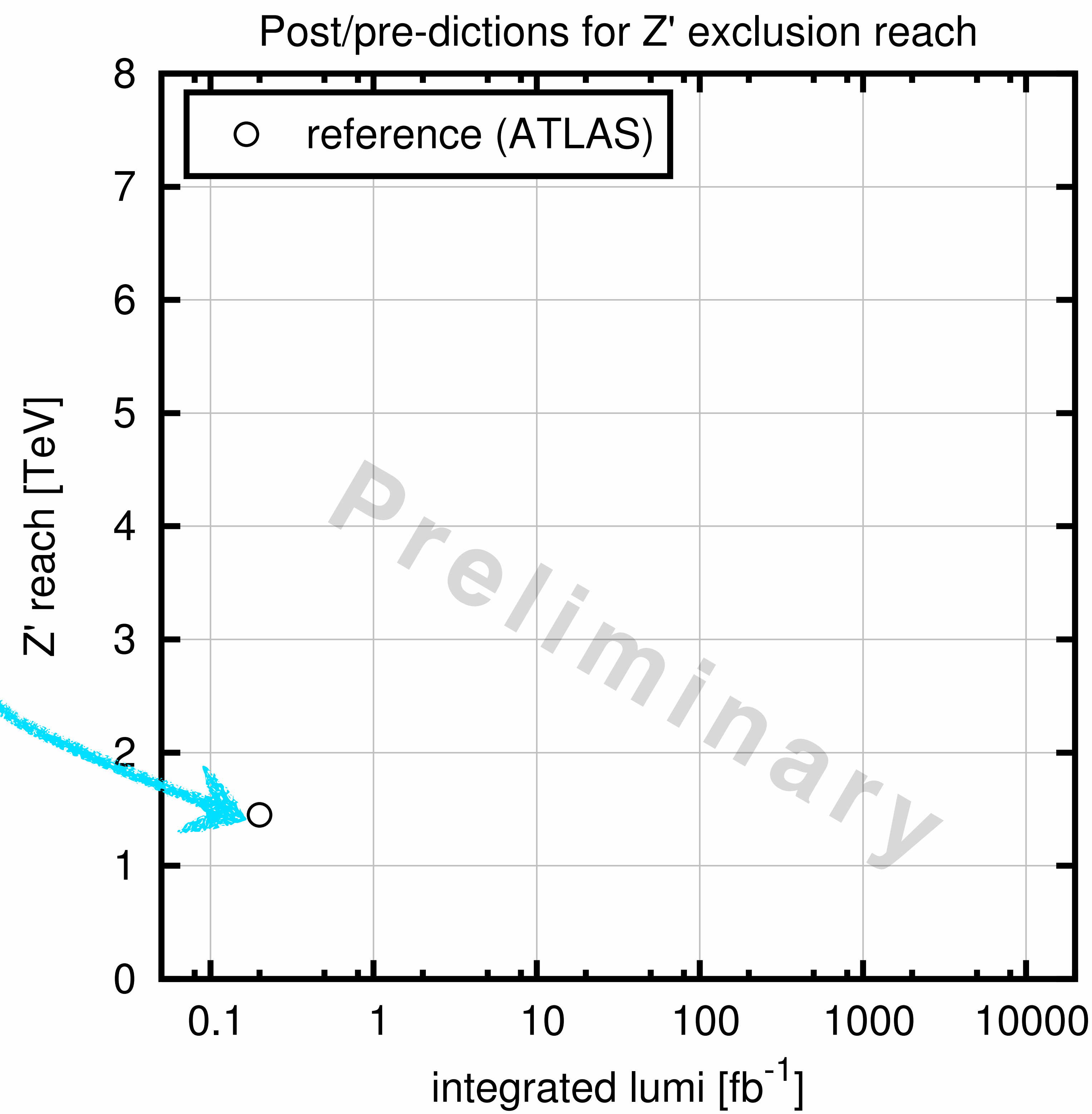
$$\mathcal{L}_{ij}(M^2, s) = \int_\tau^1 \frac{dx}{x} x f_i(x, M^2) \frac{\tau}{x} f_j\left(\frac{\tau}{x}, M^2\right) \qquad \tau \equiv \frac{M^2}{s}$$

i & j parton

Does it work?

Try a Z’ search. Take a baseline analysis:

ATLAS,
0.2 fb^{-1} @ 7 TeV
excludes M < 1450 GeV



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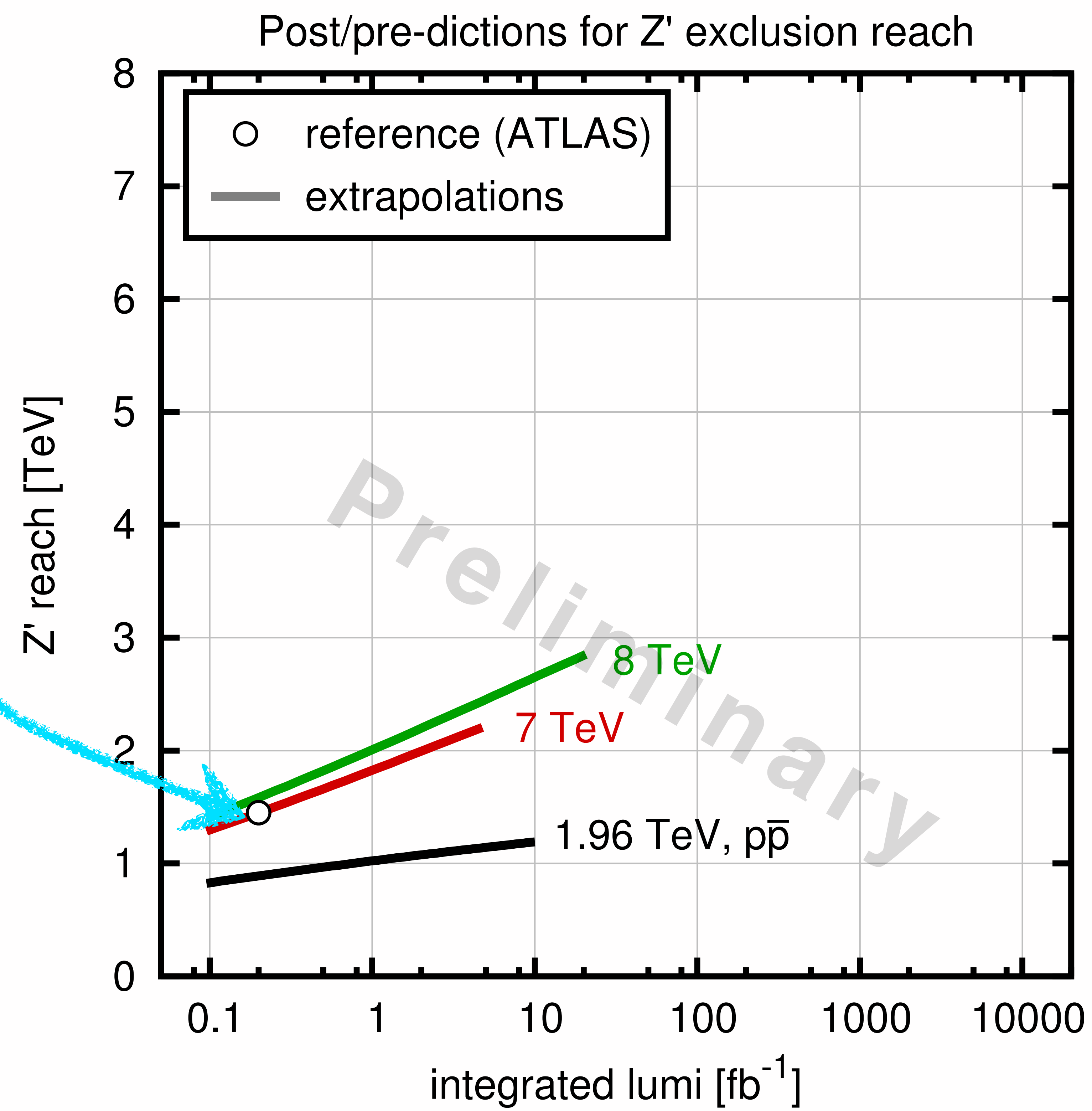
"Predict" exclusions at other lumis & energies (assume $q\bar{q}$)



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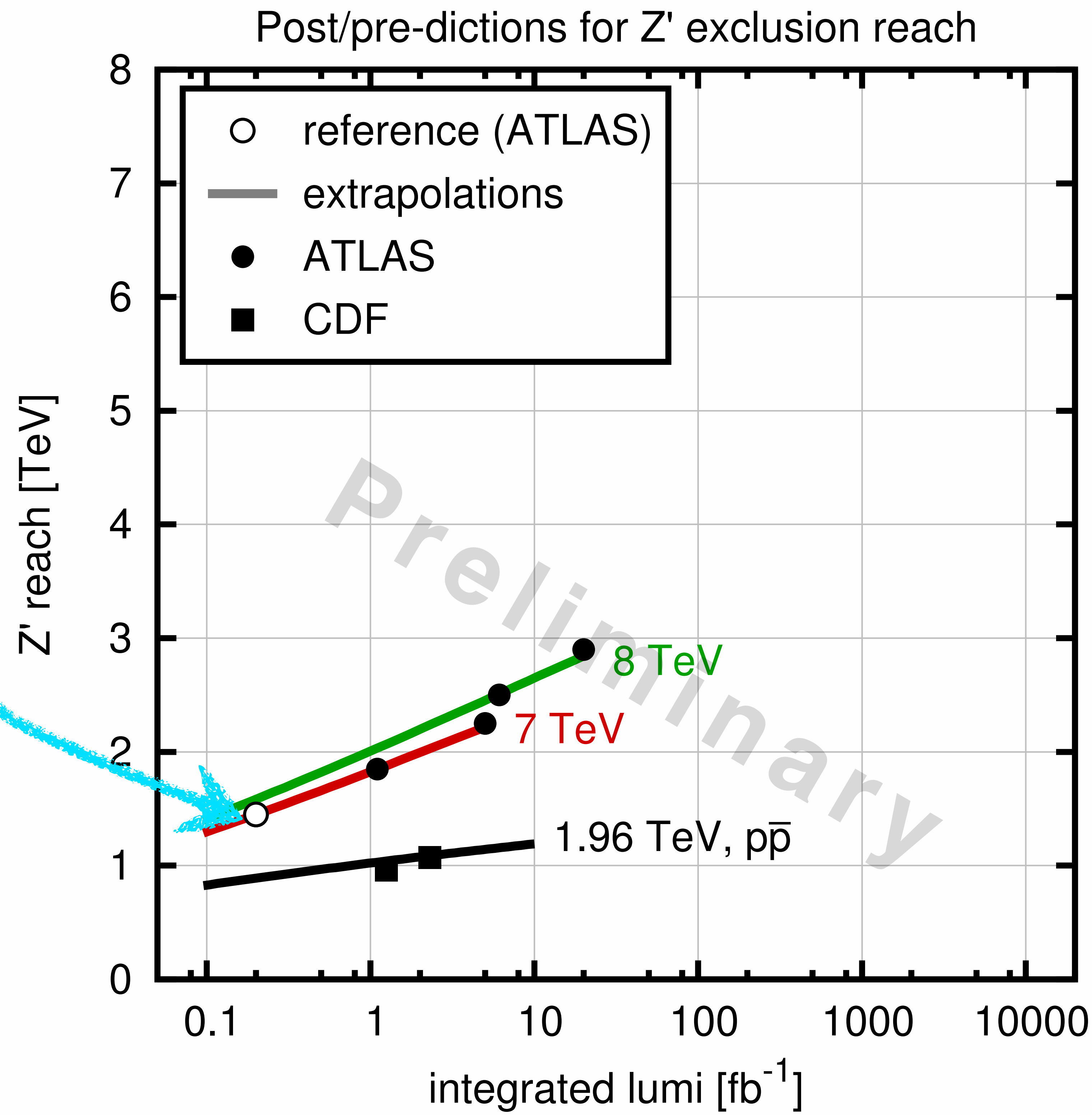
Compare to actual exclusions



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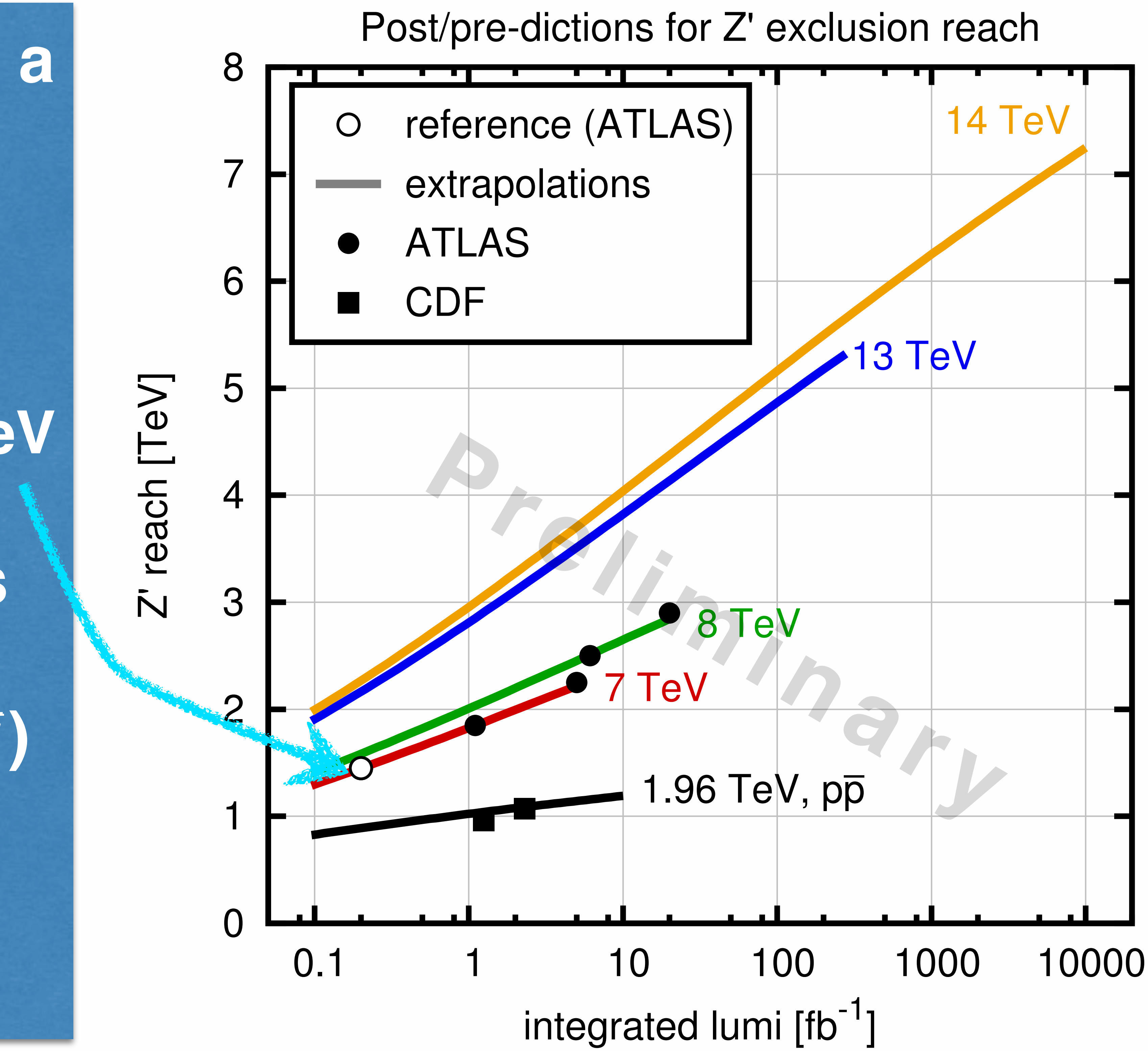
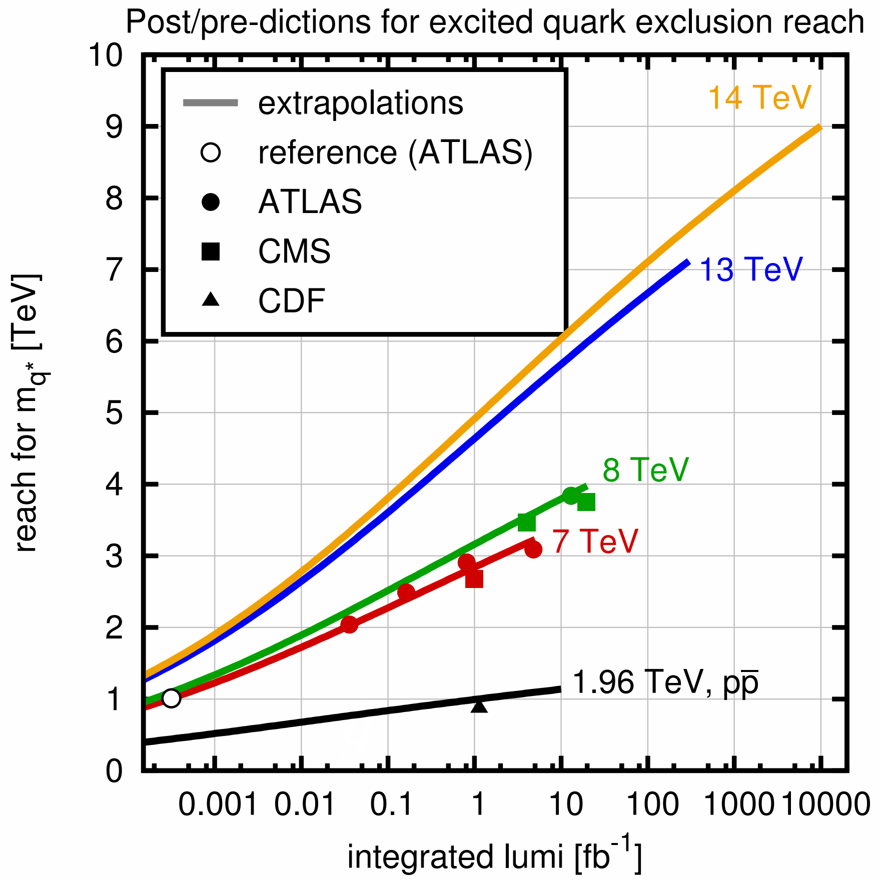
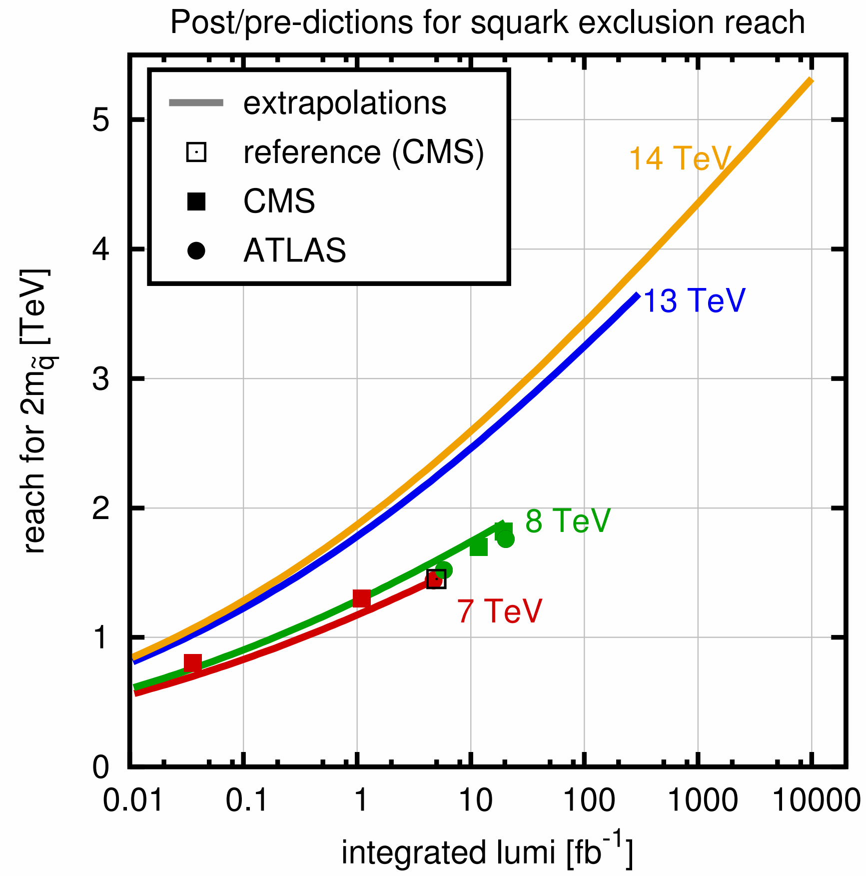
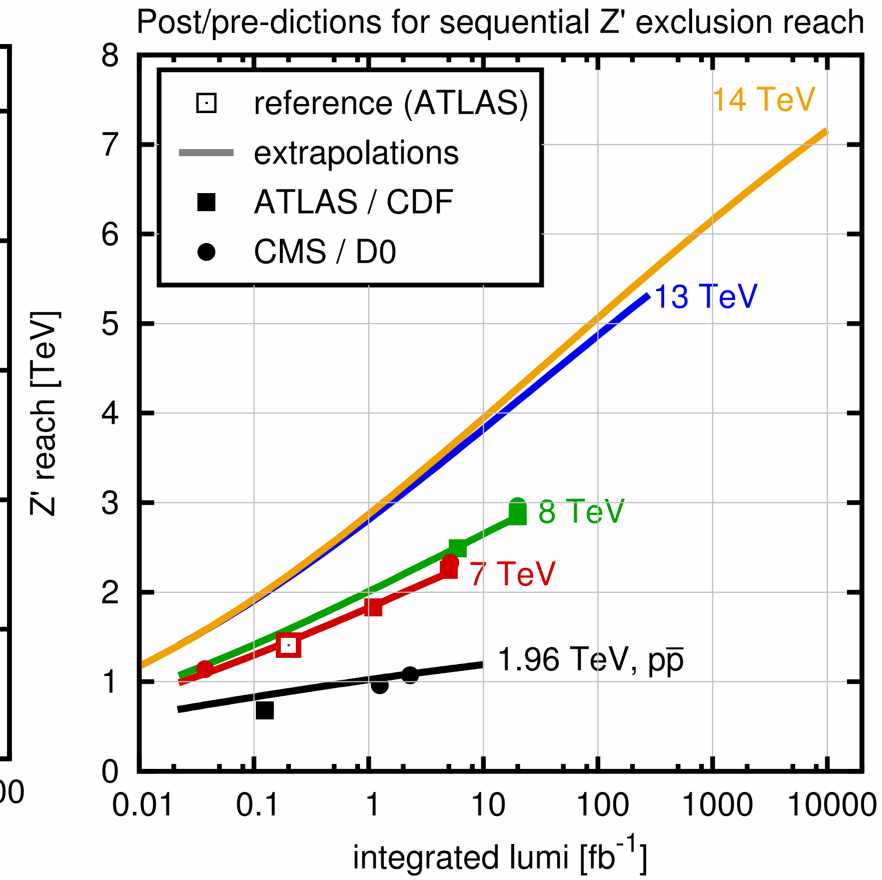
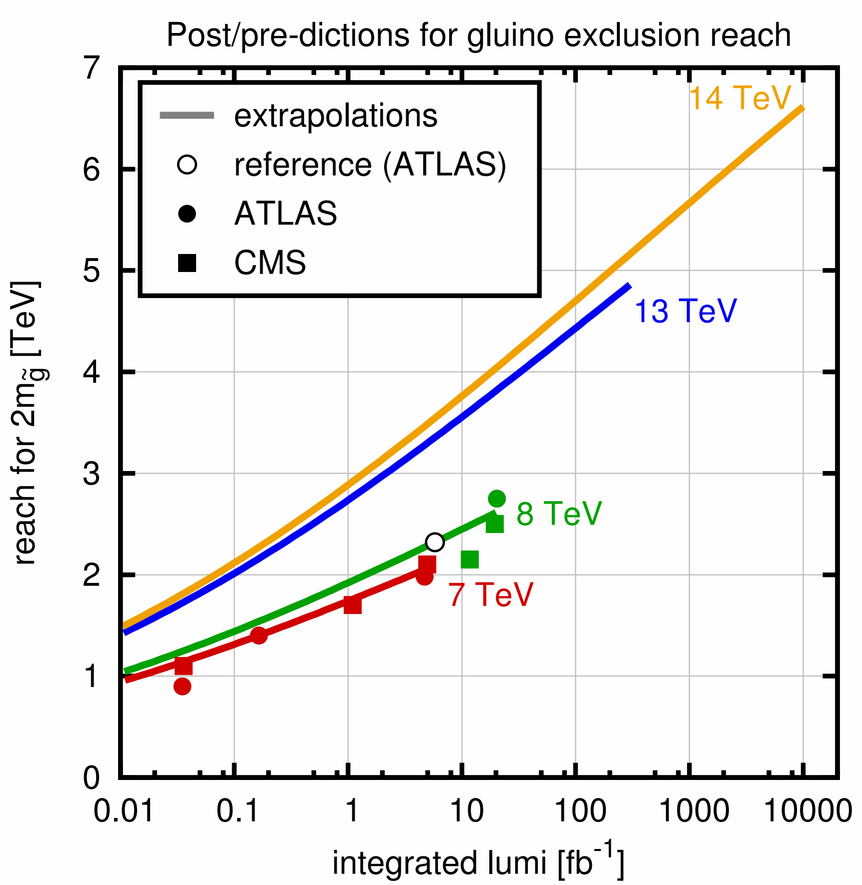


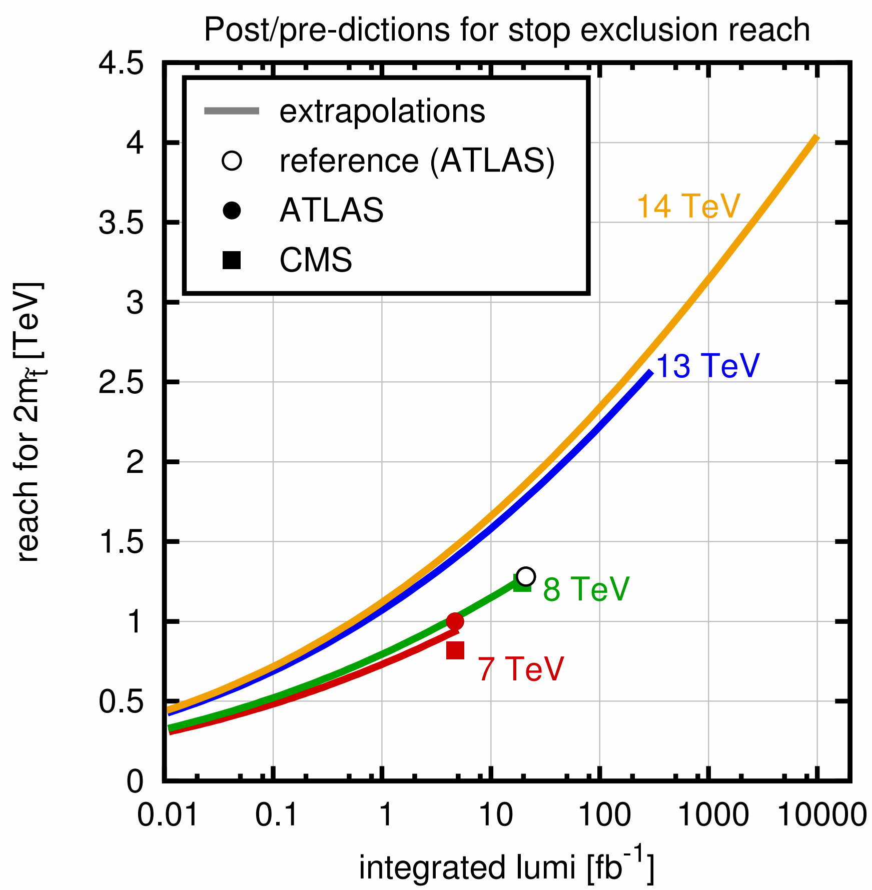
Maybe it only works so well because it's a simple search?
(Signal & Bkgd are both $q\bar{q}$ driven)

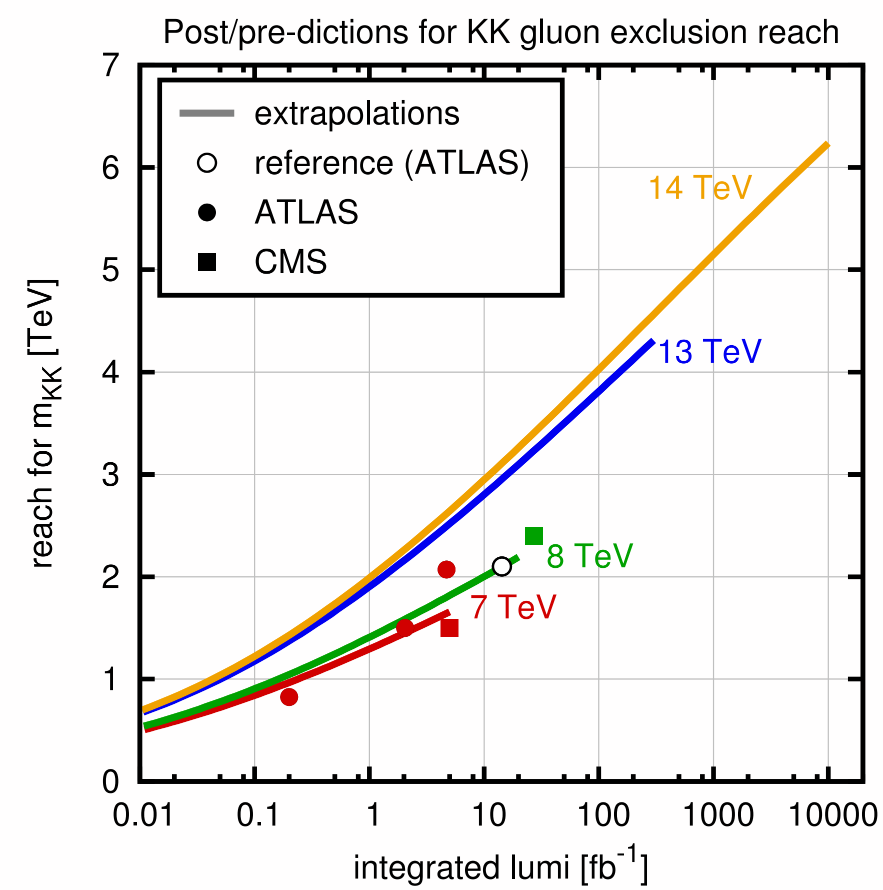

Post/pre-dictions for excited quark exclusion reach
extrapolations
reference (ATLAS)
ATLAS
CMS
CDF
14 TeV
13 TeV
8 TeV
7 TeV
1.96 TeV, pp̄
reach for m_{q^*} [TeV]
integrated lumi [fb^{-1}]


Post/pre-dictions for squark exclusion reach
extrapolations
reference (CMS)
CMS
ATLAS
14 TeV
13 TeV
8 TeV
7 TeV
reach for $2m_{\tilde{q}}$ [TeV]
integrated lumi [fb^{-1}]


Post/pre-dictions for sequential Z' exclusion reach
reference (ATLAS)
extrapolations
ATLAS / CDF
CMS / D0
14 TeV
13 TeV
8 TeV
7 TeV
1.96 TeV, pp̄
Z' reach [TeV]
integrated lumi [fb^{-1}]


Post/pre-dictions for gluino exclusion reach
extrapolations
reference (ATLAS)
ATLAS
CMS
14 TeV
13 TeV
8 TeV
7 TeV
reach for $2m_{\tilde{g}}$ [TeV]
integrated lumi [fb^{-1}]

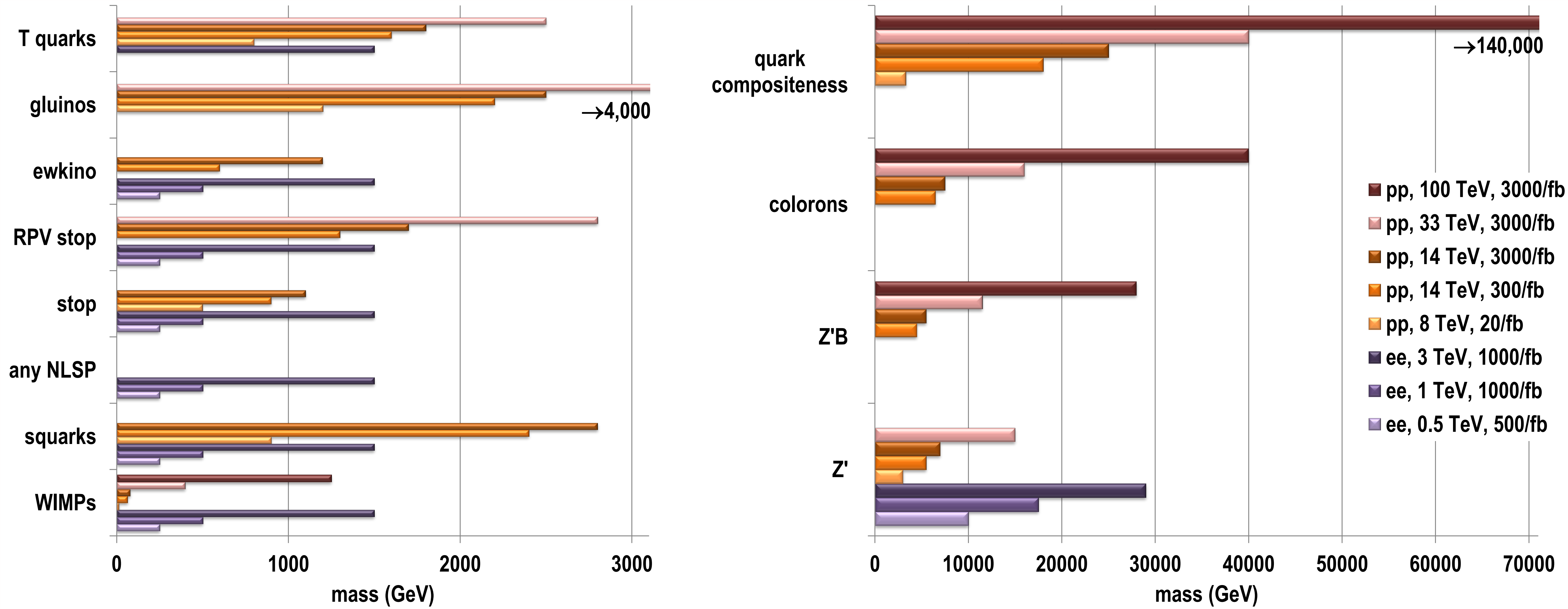

Post/pre-dictions for stop exclusion reach
extrapolations
reference (ATLAS)
ATLAS
CMS
14 TeV
13 TeV
8 TeV
7 TeV
reach for $2m_{\tilde{t}}$ [TeV]
integrated lumi [fb^{-1}]


Post/pre-dictions for KK gluon exclusion reach
extrapolations
reference (ATLAS)
ATLAS
CMS
14 TeV
13 TeV
8 TeV
7 TeV
reach for m_{KK} [TeV]
integrated lumi [fb^{-1}]

Future colliders

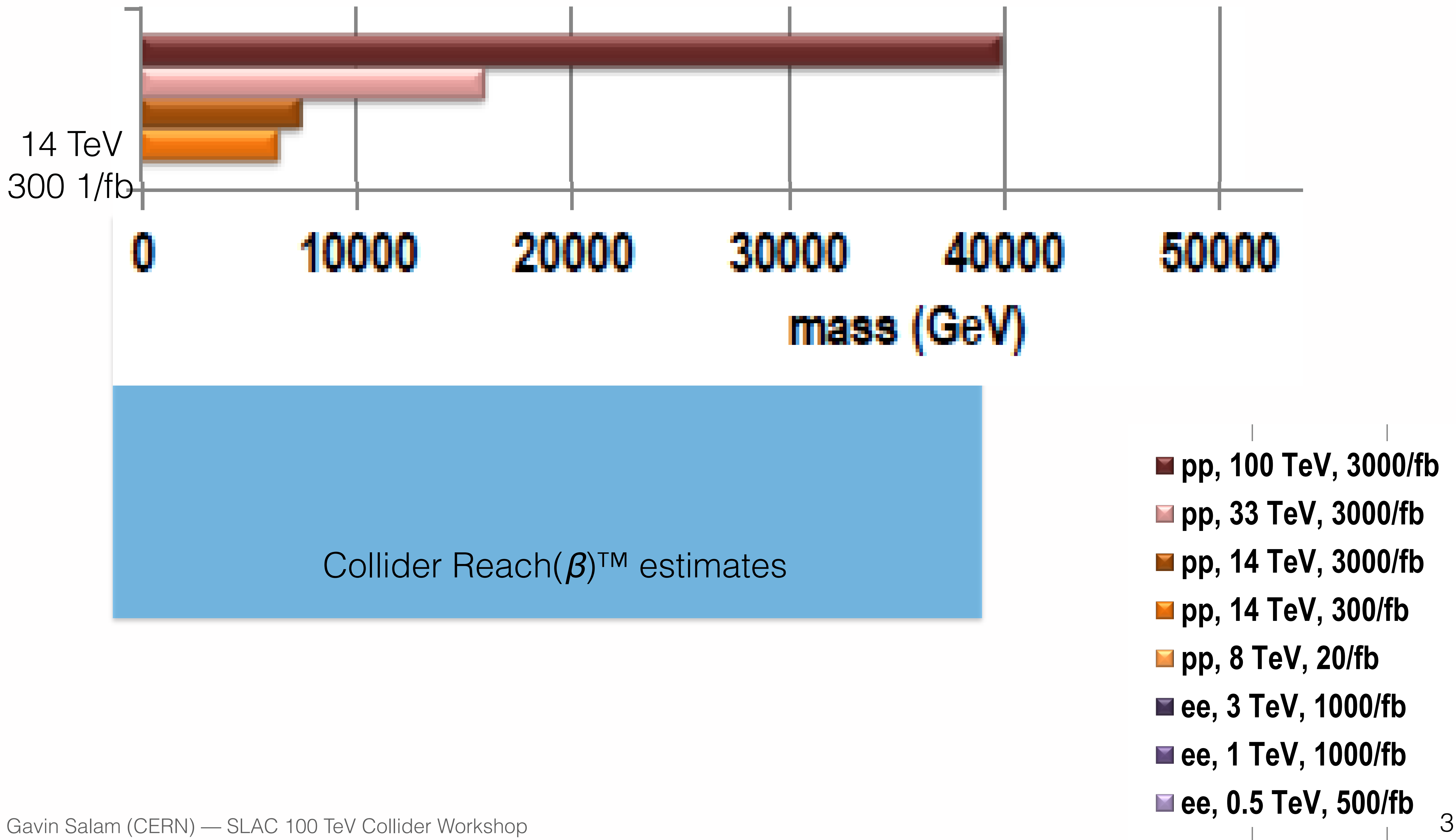
- We're ignoring all subtleties, just going for a base-line check
- If our estimate differs a lot from sophisticated simulations, something interesting has happened:
    - brick-wall (new irreducible backgrounds, granularity of assumed detectors, …)
    - overly conservative or non-optimal estimates

Future colliders comparison



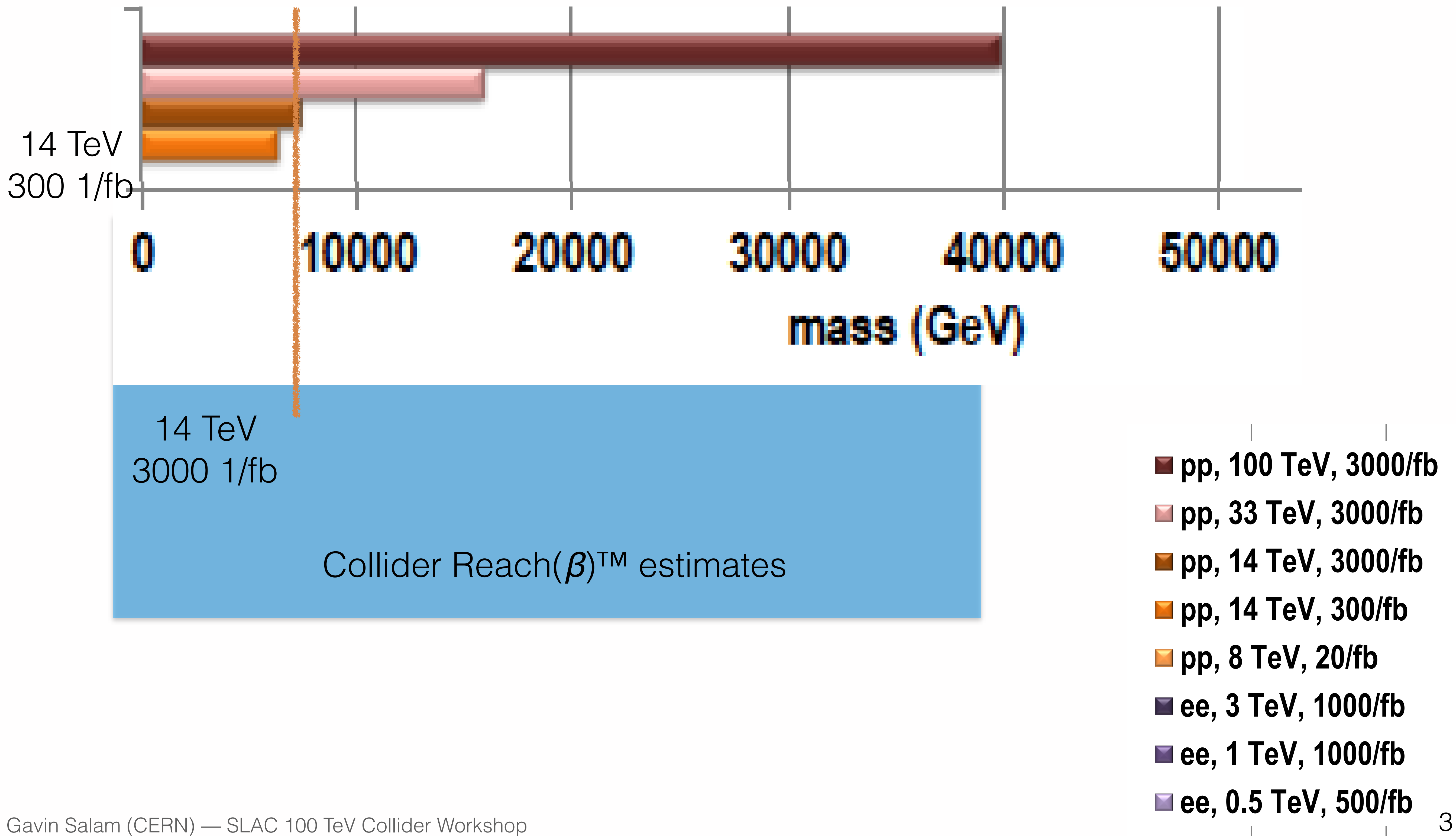
Energy Frontier Snowmass study (1311.0299)

Colorons

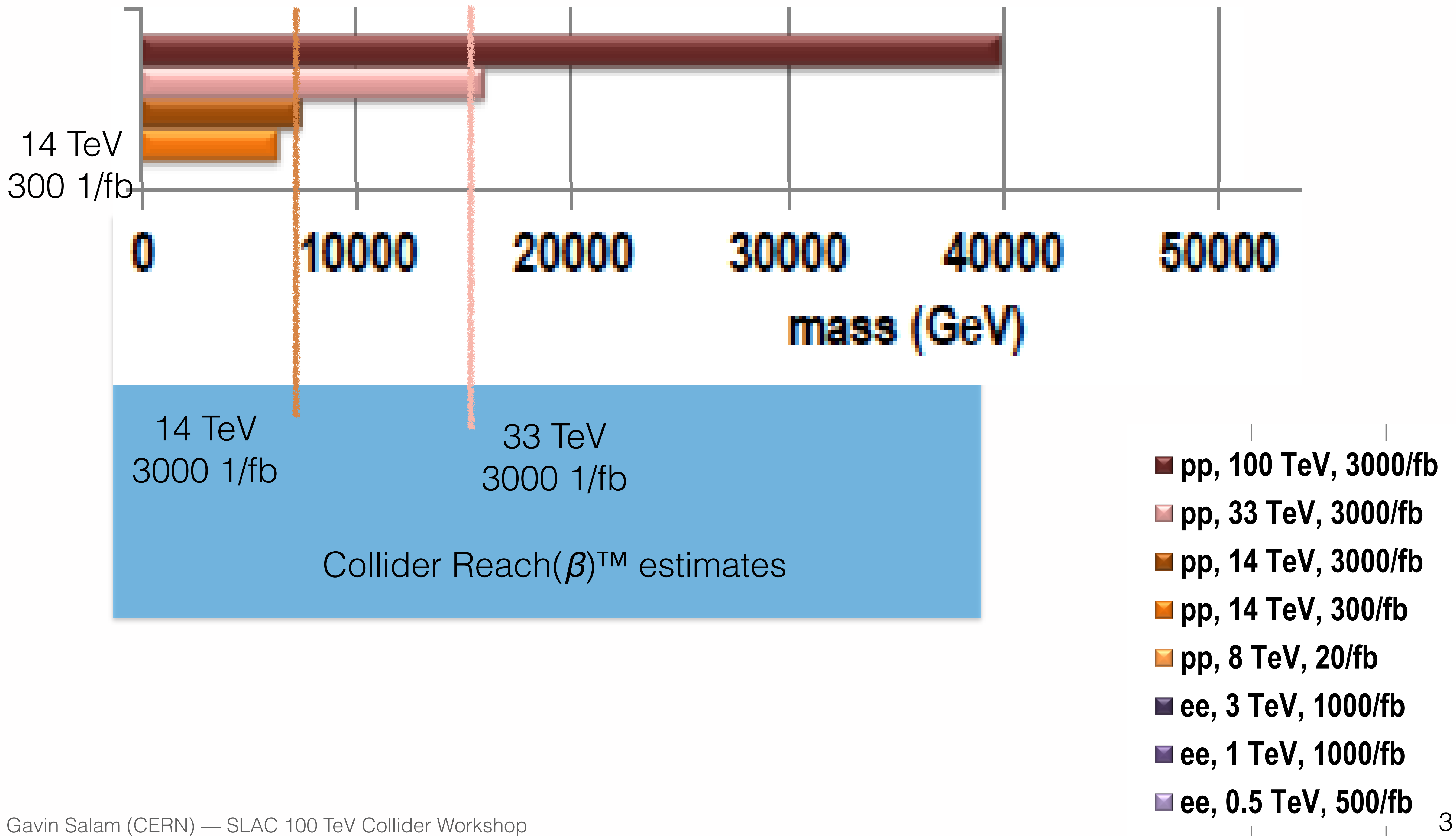


Collider Reach(β)™ estimates

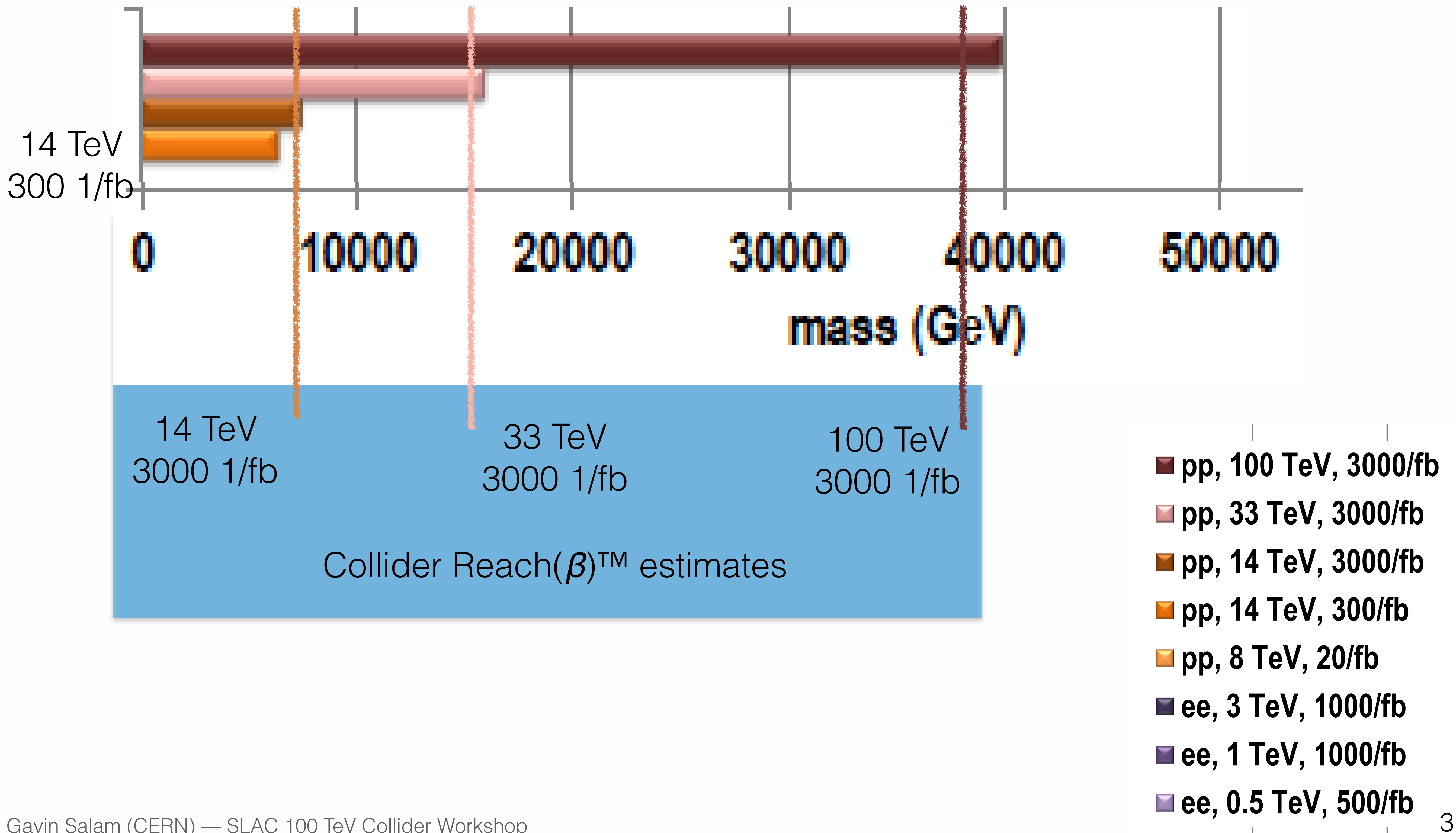
Colorons


14 TeV
300 1/fb
0
10000
20000
30000
40000
50000
mass (GeV)
14 TeV
3000 1/fb
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

Colorons

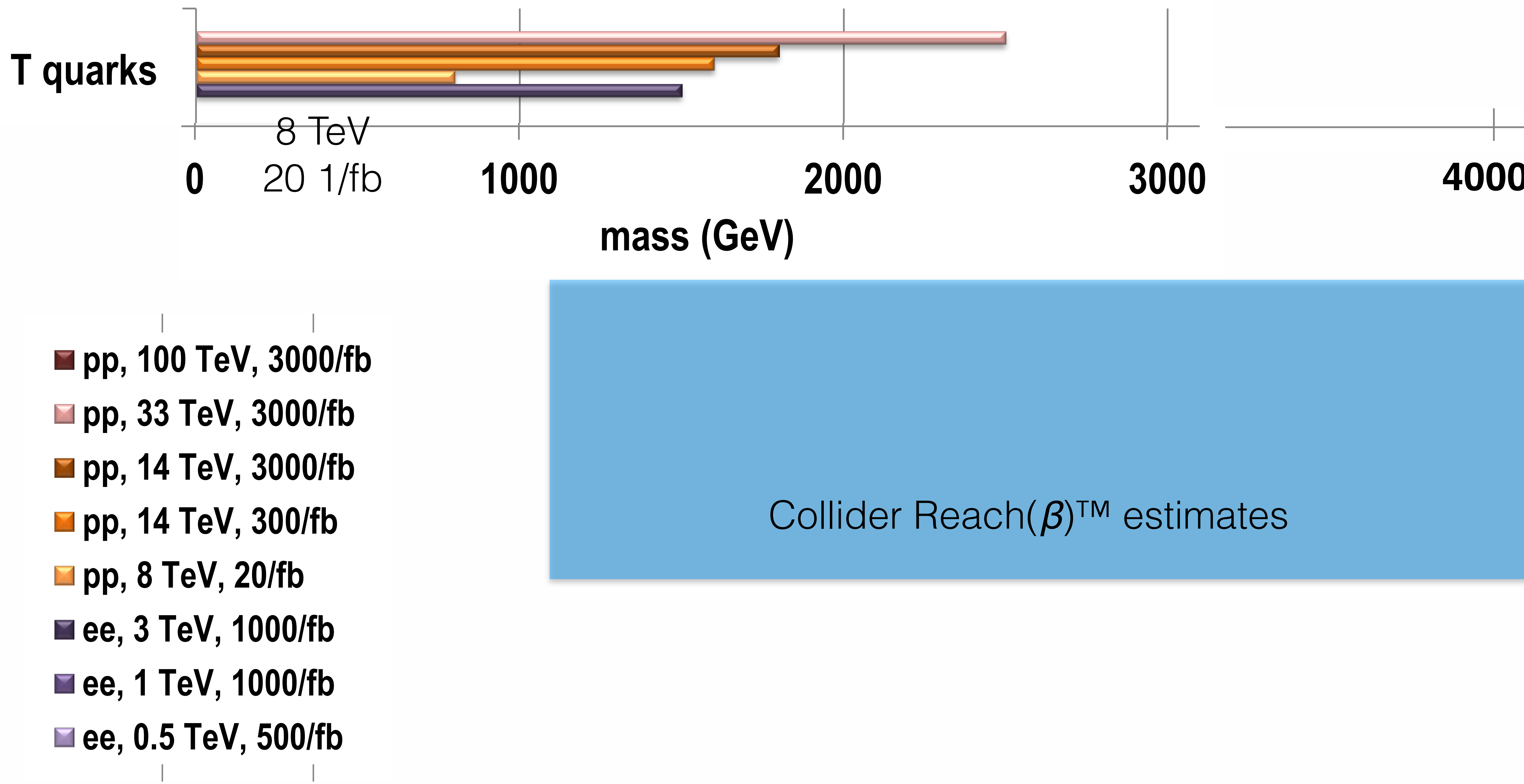

14 TeV
300 1/fb
0
10000
20000
30000
40000
50000
mass (GeV)
14 TeV
3000 1/fb
33 TeV
3000 1/fb
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

Colorons



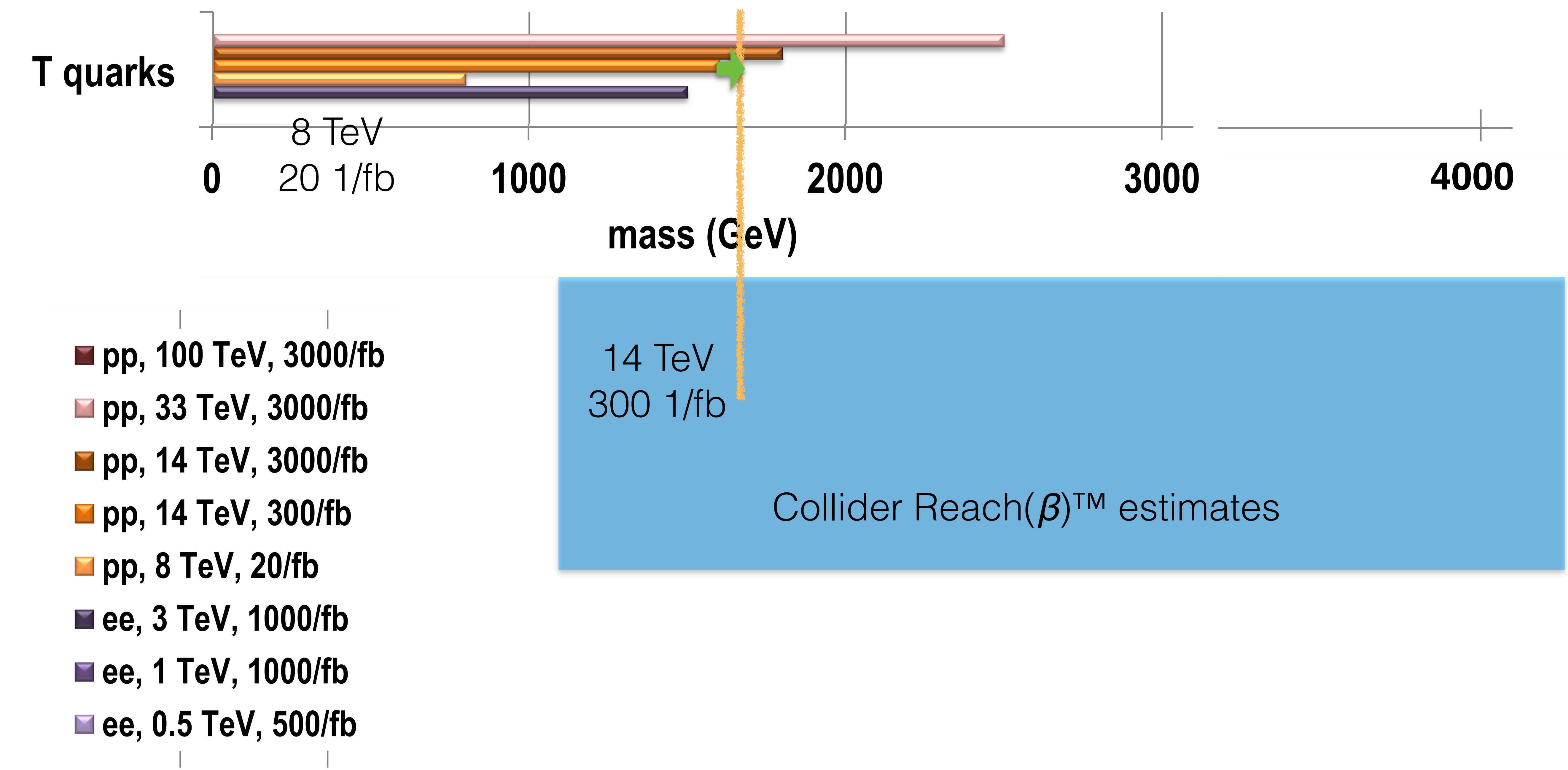
14 TeV
300 1/fb
0
10000
20000
30000
40000
50000
mass (GeV)
14 TeV
3000 1/fb
33 TeV
3000 1/fb
100 TeV
3000 1/fb
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

T Quarks

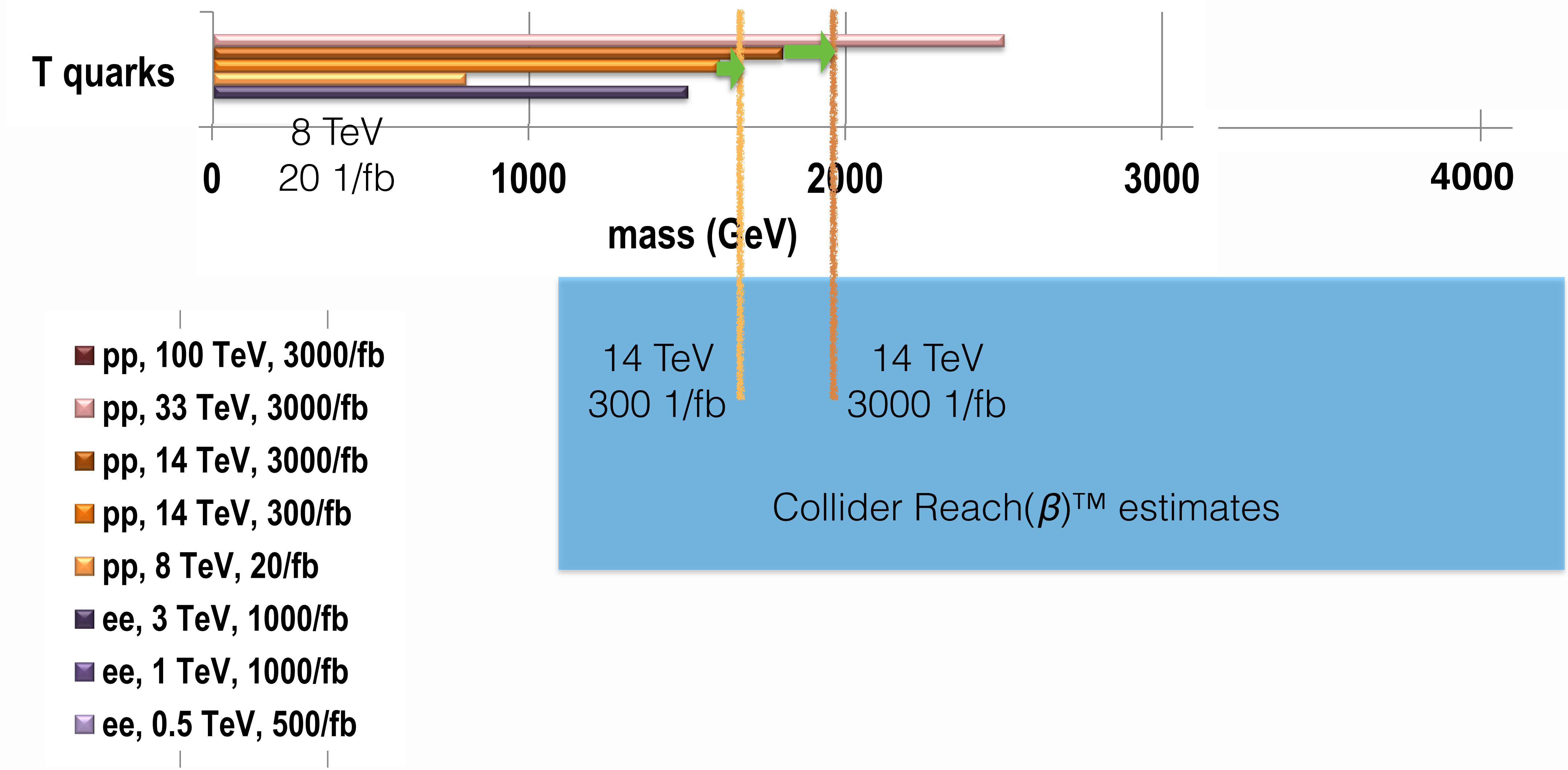


Collider Reach(β)™ estimates

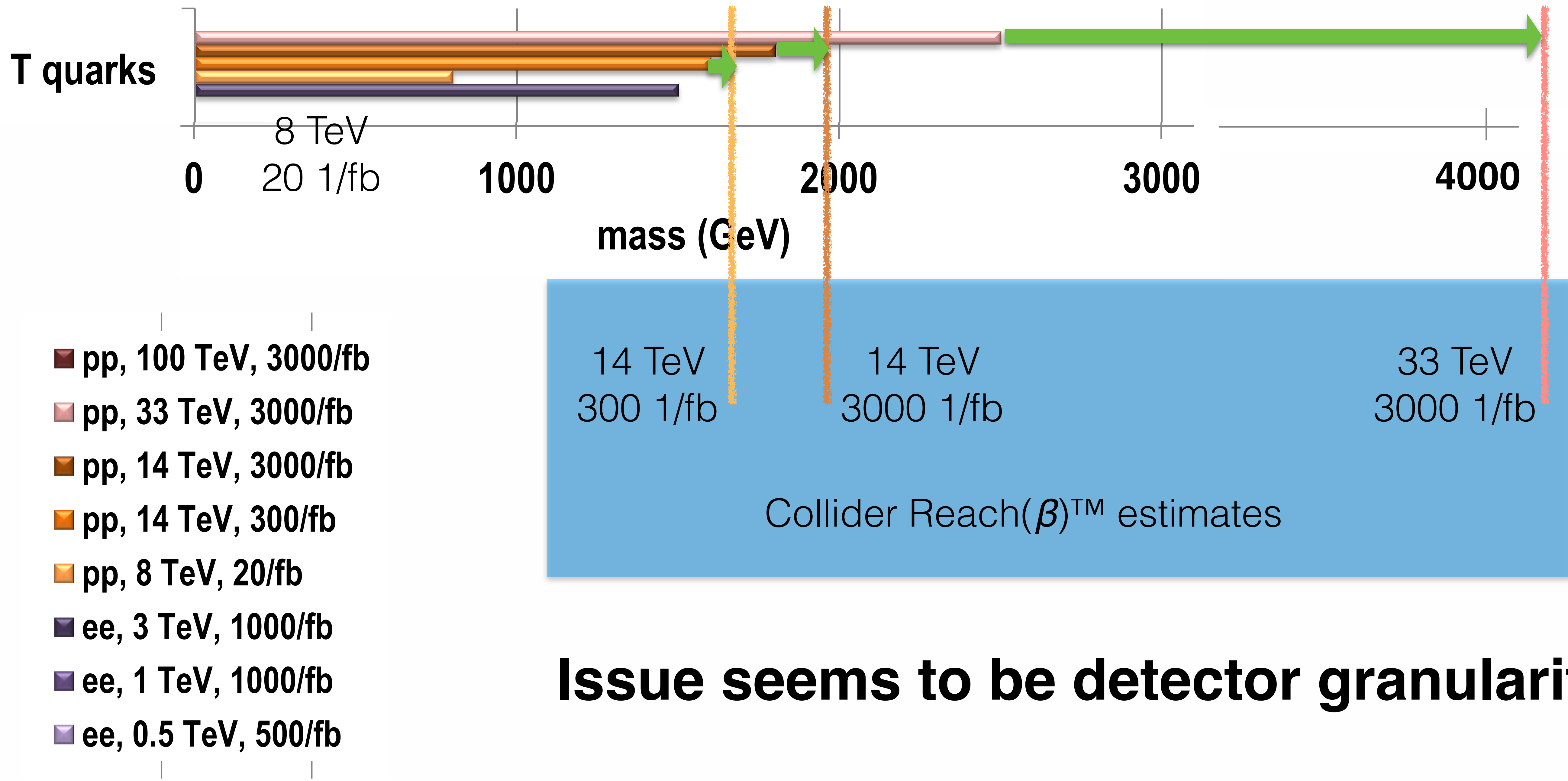
T Quarks


T quarks
8 TeV
20 1/fb
0
1000
2000
3000
4000
mass (GeV)
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb
14 TeV
300 1/fb
Collider Reach(β)™ estimates

T Quarks


T quarks
8 TeV
20 1/fb
0
1000
2000
3000
4000
mass (GeV)
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb
14 TeV
300 1/fb
14 TeV
3000 1/fb
Collider Reach(β)™ estimates

T Quarks



Issue seems to be detector granularity

From your iPhone

(or a generic browser)

cern.ch/collider-reach

From your Android Phone

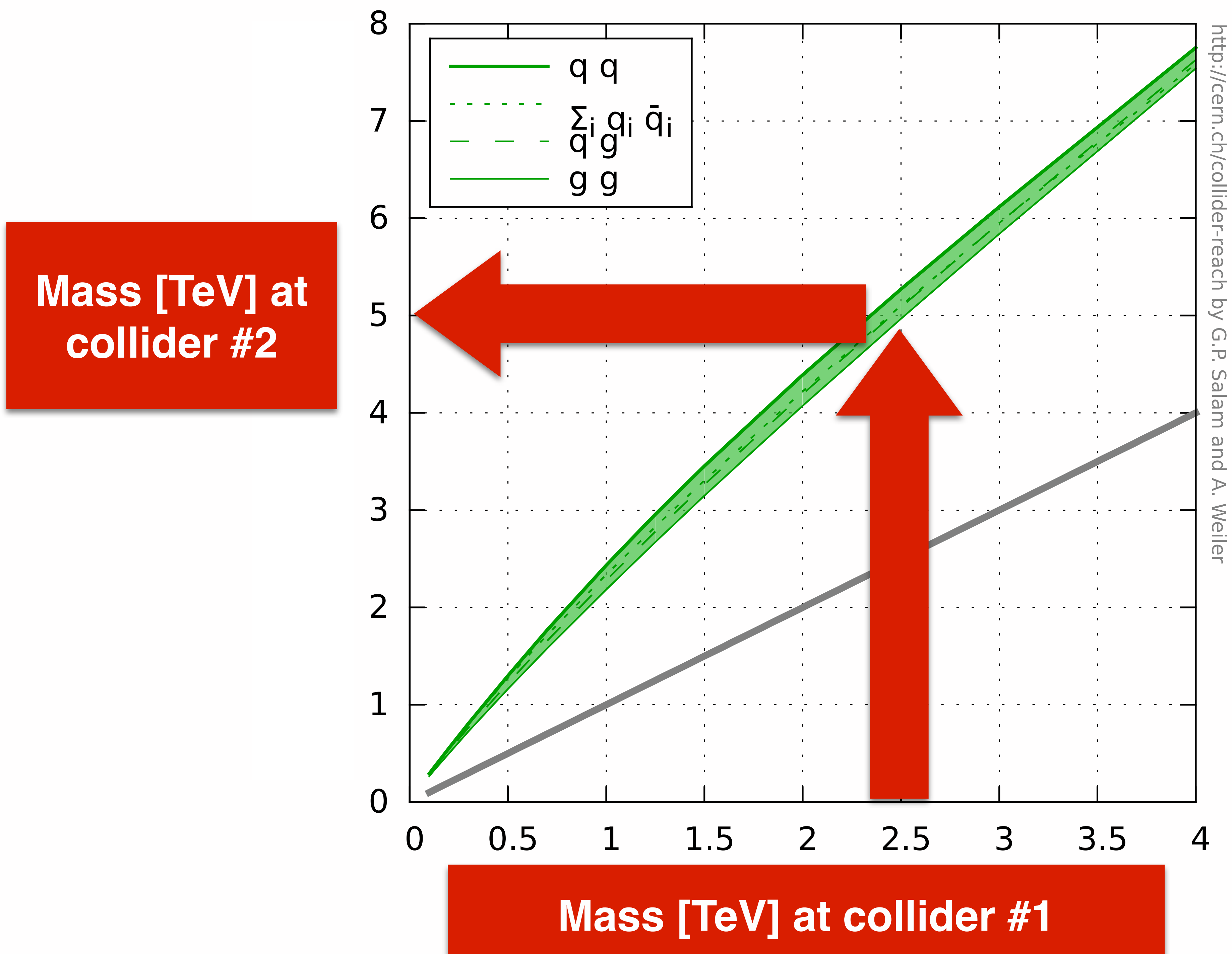
(or a generic browser)

cern.ch/collider-reach

Collider 1: CoM energy 8 TeV, integrated luminosity 20 fb^{-1}

Collider 2: CoM energy 14 TeV, integrated luminosity 300 fb^{-1}

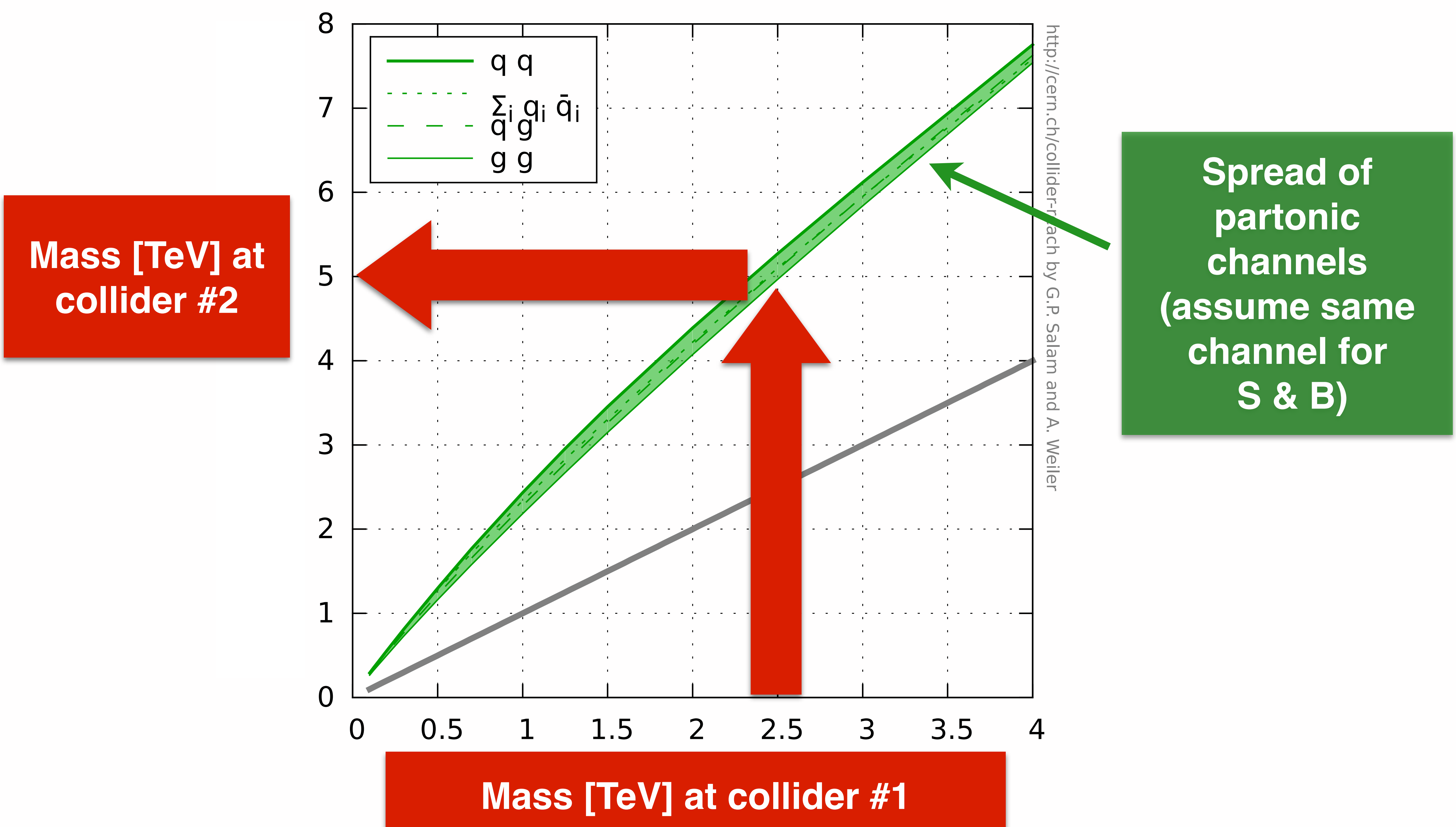
PDF: MSTW2008nnlo68cl



Collider 1: CoM energy 8 TeV, integrated luminosity 20 fb^{-1}

Collider 2: CoM energy 14 TeV, integrated luminosity 300 fb^{-1}

PDF: MSTW2008nnlo68cl



Collider Reach (β) Home Plots About

cern.ch/collider-reach

The Collider Reach tool gives you a quick (and dirty) estimate of the relation between the mass reaches of different proton-proton collider setups.

Collider 1: CoM energy 14 TeV, integrated luminosity 300 fb^{-1}

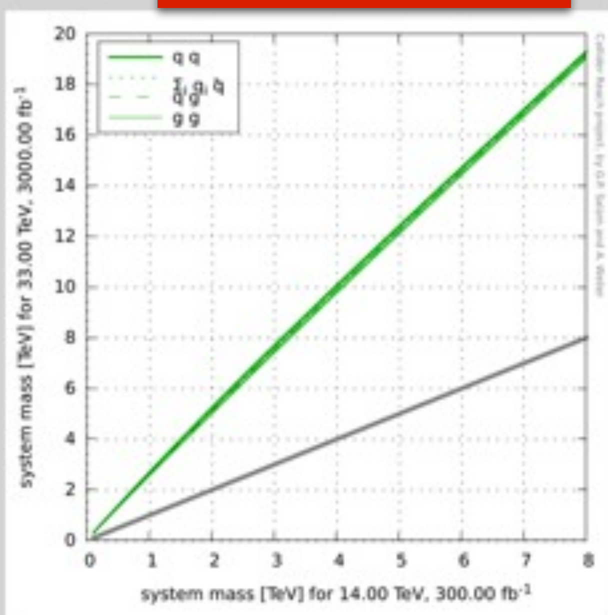
Collider 2: CoM energy 33 TeV, integrated luminosity 3000 fb^{-1}

PDF: CT10nlo

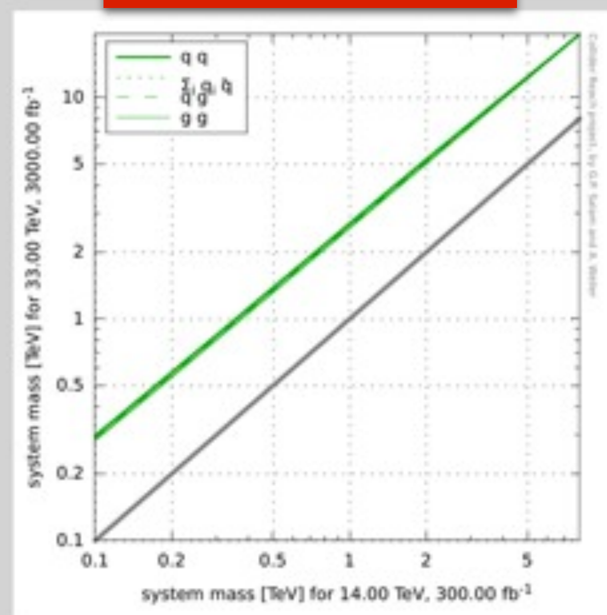
Submit

Plots

linear plot



log-log plot

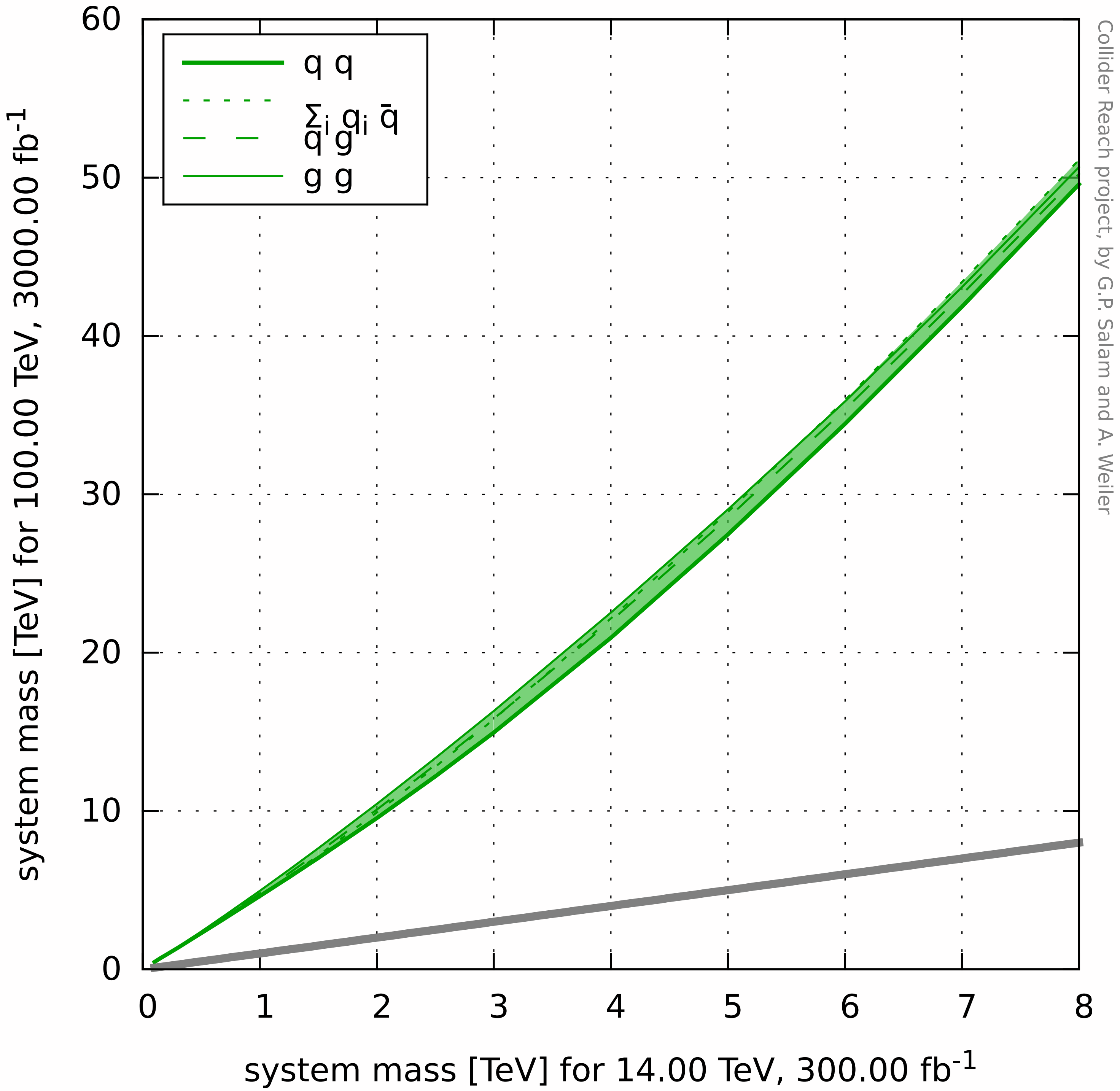


Download: collider.pdf, colliderloglog.pdf, plot generation log file

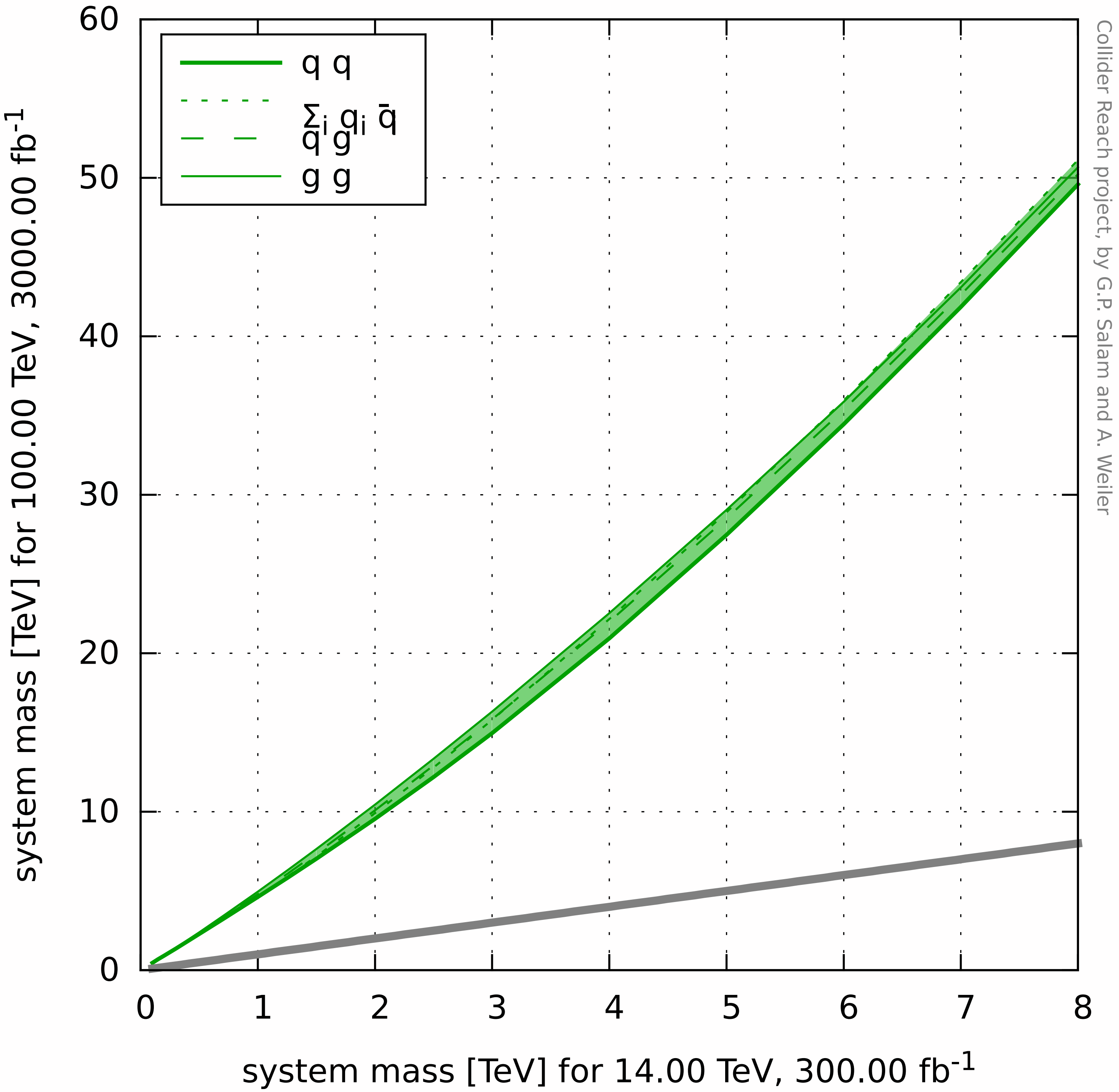
The PDF choice was CT10nlo.LHgrid

Original mass	gg	qg	allqq	qqbar
100.	283.	291.	298.	297.
125.	350.	359.	368.	367.
150.	416.	427.	438.	437.
200.	547.	562.	576.	575.
300.	806.	827.	848.	847.
500.	1317.	1350.	1386.	1382.
700.	1822.	1866.	1916.	1907.
1000.	2570.	2628.	2702.	2680.
1250.	3188.	3256.	3349.	3314.
1500.	3802.	3879.	3990.	3939.
2000.	5018.	5110.	5251.	5169.
2500.	6223.	6327.	6488.	6380.
3000.	7417.	7530.	7703.	7578.
4000.	9782.	9904.	10082.	9945.
5000.	12120.	12246.	12417.	12284.
6000.	14439.	14565.	14726.	14601.
7000.	16748.	16871.	17021.	16905.
8000.	19053.	19169.	19310.	19206.

14 TeV$_{300\ fb^{-1}}$ → 100 TeV$_{3\ ab^{-1}}$



14 TeV$_{300\ fb^{-1}}$ → 100 TeV$_{3\ ab^{-1}}$



The PDF choice was CT10nlo.LHgrid

Original mass	gg	qg	allqq	qqbar
100.	469.	465.	462.	457.
125.	585.	579.	575.	568.
150.	702.	693.	687.	679.
200.	937.	923.	912.	902.
300.	1414.	1386.	1365.	1350.
500.	2394.	2332.	2279.	2261.
700.	3401.	3300.	3206.	3194.
1000.	4956.	4793.	4619.	4640.
1250.	6287.	6072.	5818.	5892.
1500.	7647.	7382.	7038.	7187.
2000.	10444.	10090.	9552.	9905.
2500.	13337.	12908.	12185.	12781.
3000.	16319.	15833.	14954.	15795.
4000.	22531.	21986.	20933.	22162.
5000.	29050.	28508.	27467.	28894.
6000.	35863.	35366.	34451.	35960.
7000.	43079.	42620.	41854.	43411.
8000.	50671.	50230.	49590.	51132.

When you’ve lost your XPhone

Rule of Thumb #1

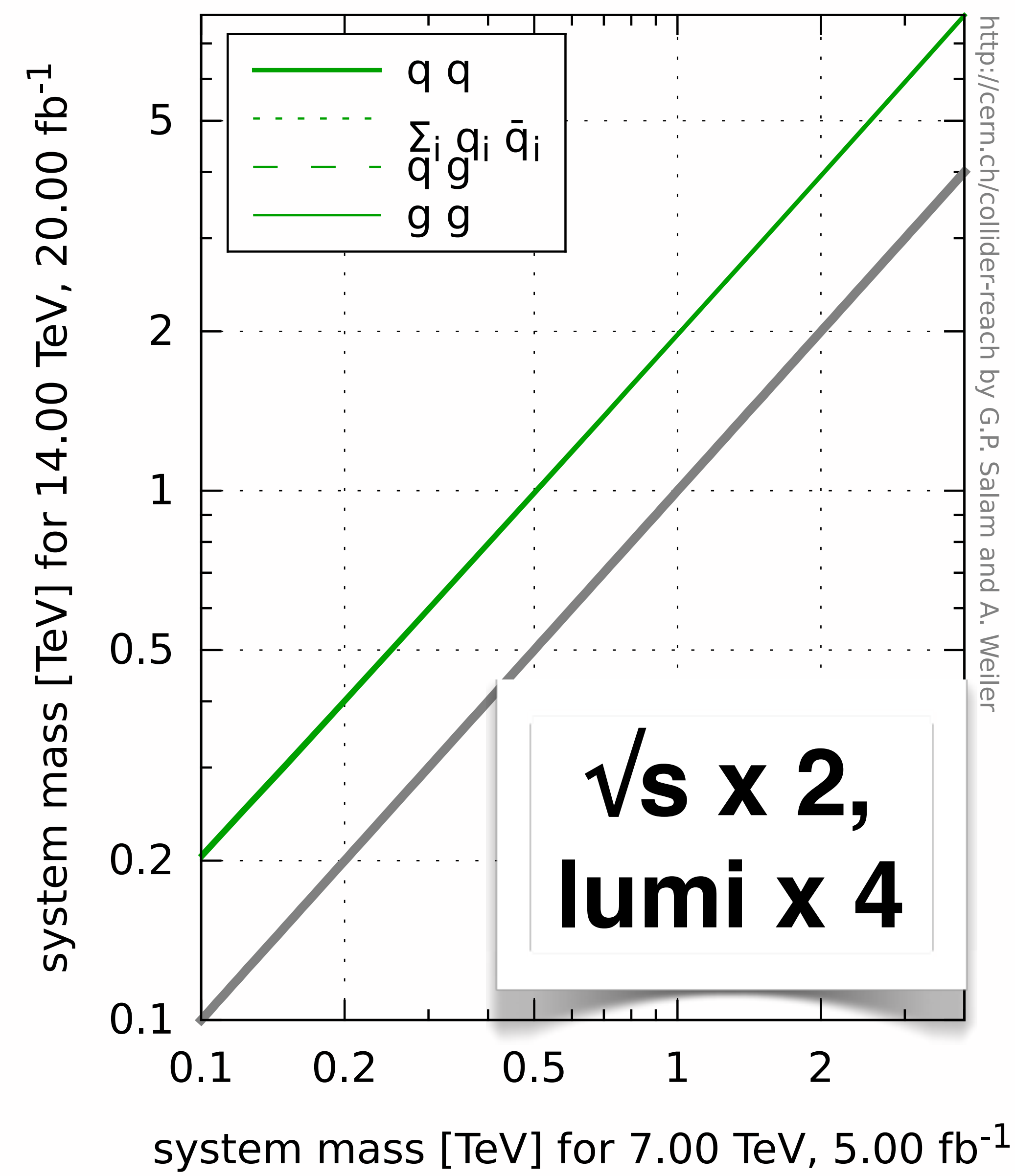
(well known among practitioners)

Increase collider energy by factor X
& increase luminosity by a factor X^2

→ **reach goes up by a factor X**

[Because you keep same Bjorken-x & luminosity increase compensates for $1/\text{mass}^2$ scaling of cross sections]

PDF scaling variations are small effect



Rule of Thumb #2

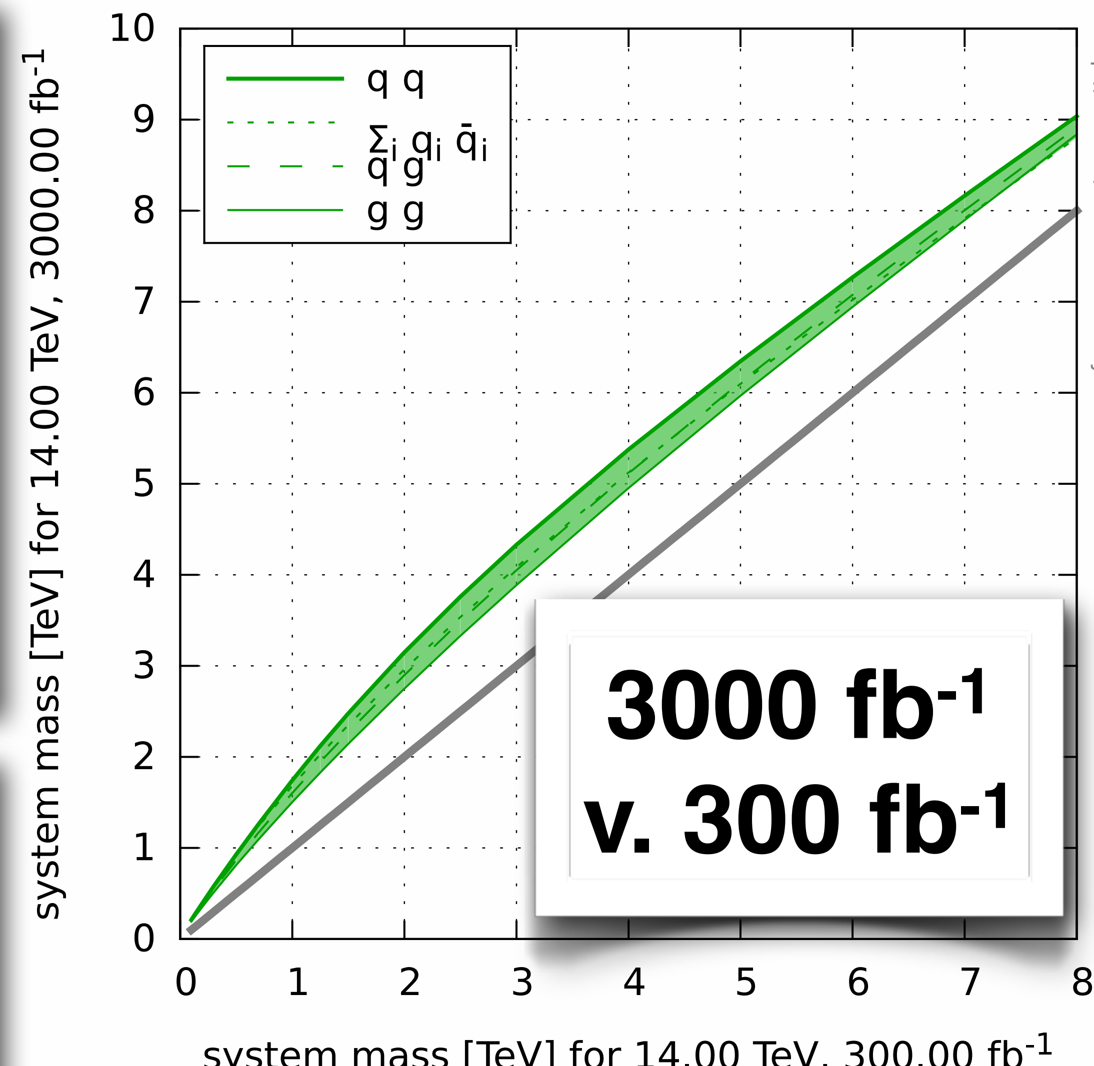
(apparently not widely known previously)

Increase luminosity by factor 10

→ reach increases by constant
$\Delta m \simeq 0.07\sqrt{s}$

i.e. for $\sqrt{s}$=14 TeV, reach goes by up 1 TeV

No deep reason — a somewhat random characteristic of large-x PDFs.
Only holds for $0.15 \lesssim M/\sqrt{s} \lesssim 0.6$



Consequence of rule #2

(may be a bit fragile & only for S ≲ B)

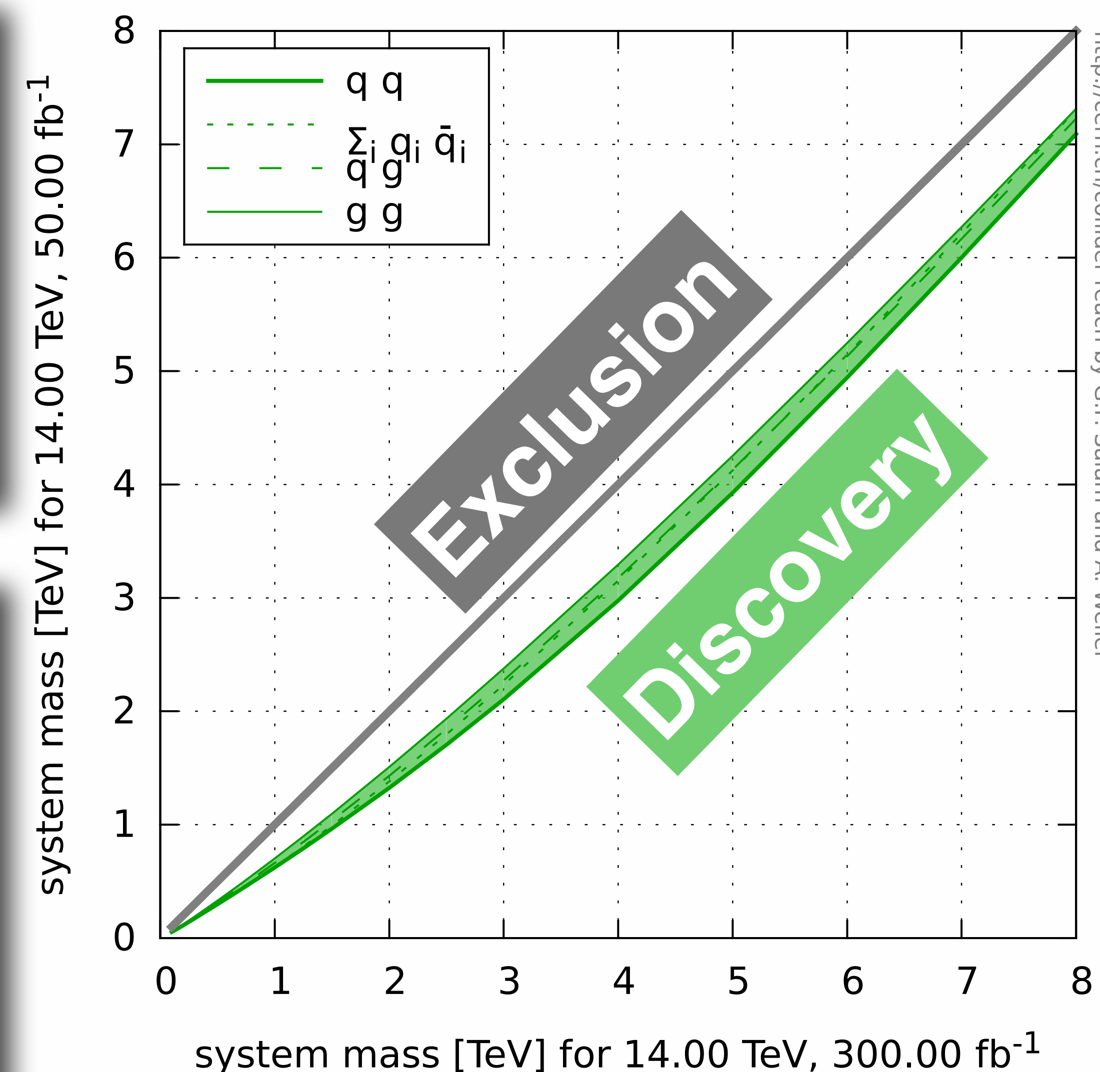
Exclusion is 2-**σ**
Discovery is 5-**σ**

Need $(5/2)^2$ = 6.25 increase in lumi to go from one to the other.

Using rule #2:

discovery reach is about 0.05√s below exclusion reach

~ 0.8 TeV at 14 TeV



Conclusions

Amazing recent progress on MC merging/matching, NLO automation, high precision (N)NNLO calculations — hard to imagine how much further we will get by 100 TeV era

FHC as scaled-up LHC is probably not too bad an approx if cuts & analyses are adapted appropriately

→ part of assumption of http://cern.ch/collider-reach

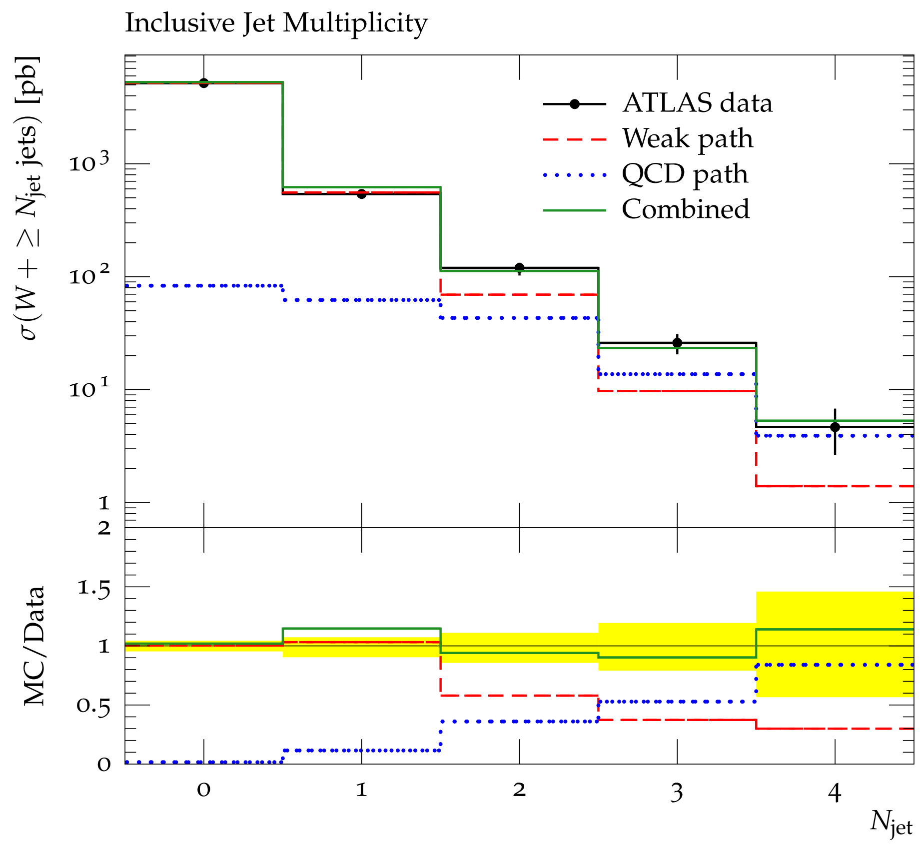
We've maybe only touched the surface on potential from $\sqrt{s} \gg m_{EW}$ — e.g. incoming parton polarization

Hard (= interesting!) problems remain in collider QCD...

BACKUP SLIDES

W + jets

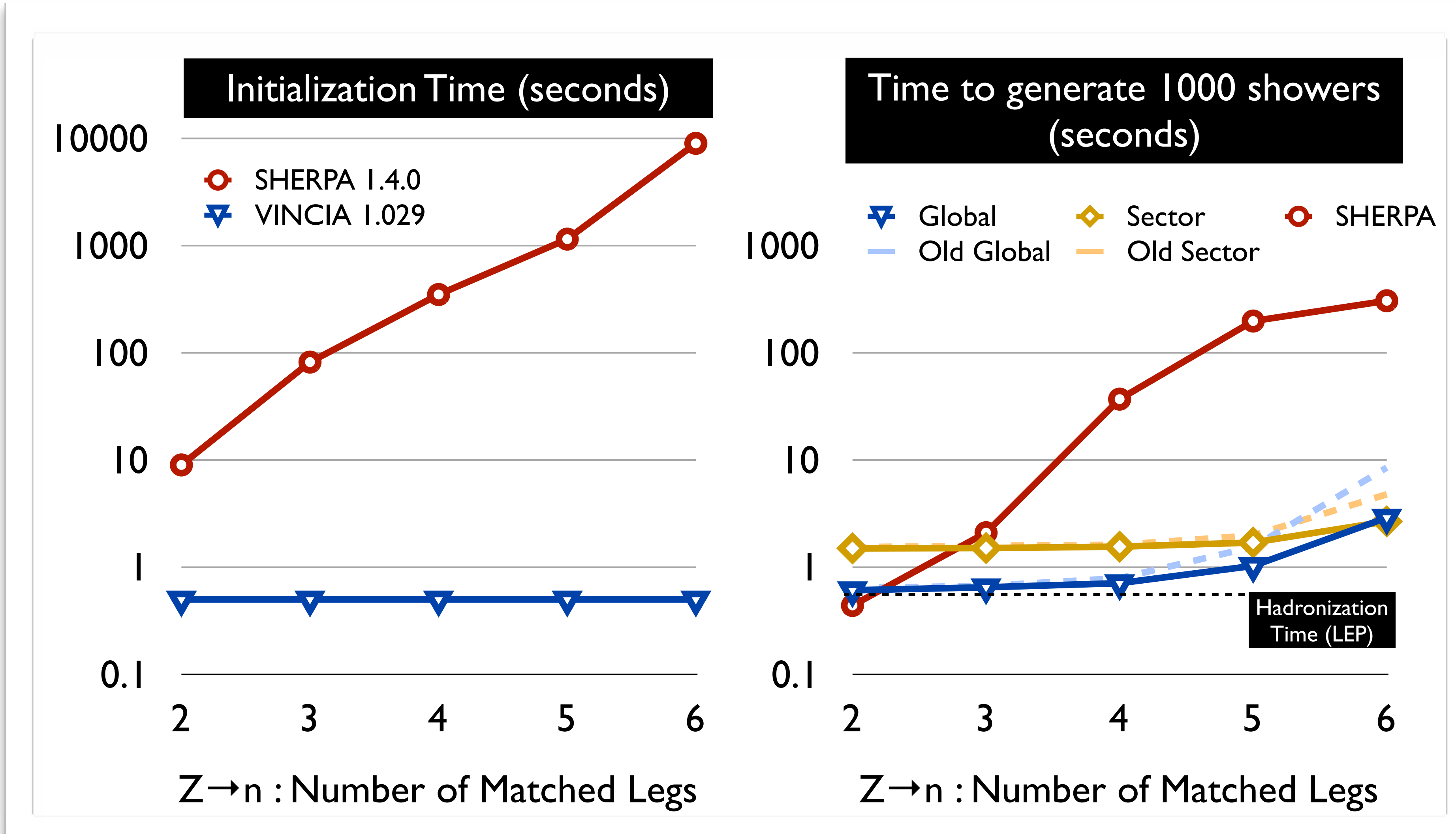
- W + jets is notoriously known for PS not describing data well
- Combine Drell-Yan W production with QCD radiation and $2 \to 2$ hard QCD processes with weak shower
- Double counting avoided by applying cuts in the spirit of the $k_\perp$ jet algorithm
- k-factor applied (normalized to fit first bin)



Some Higgs reference numbers

√s [TeV]	σ [pb]
8	18.4
14	47.6
100	718

large m_{top}, NNLO, MSTW2008 (α_s = 0.117)



1301.0933

Can this gain be replicated for pp collisions?

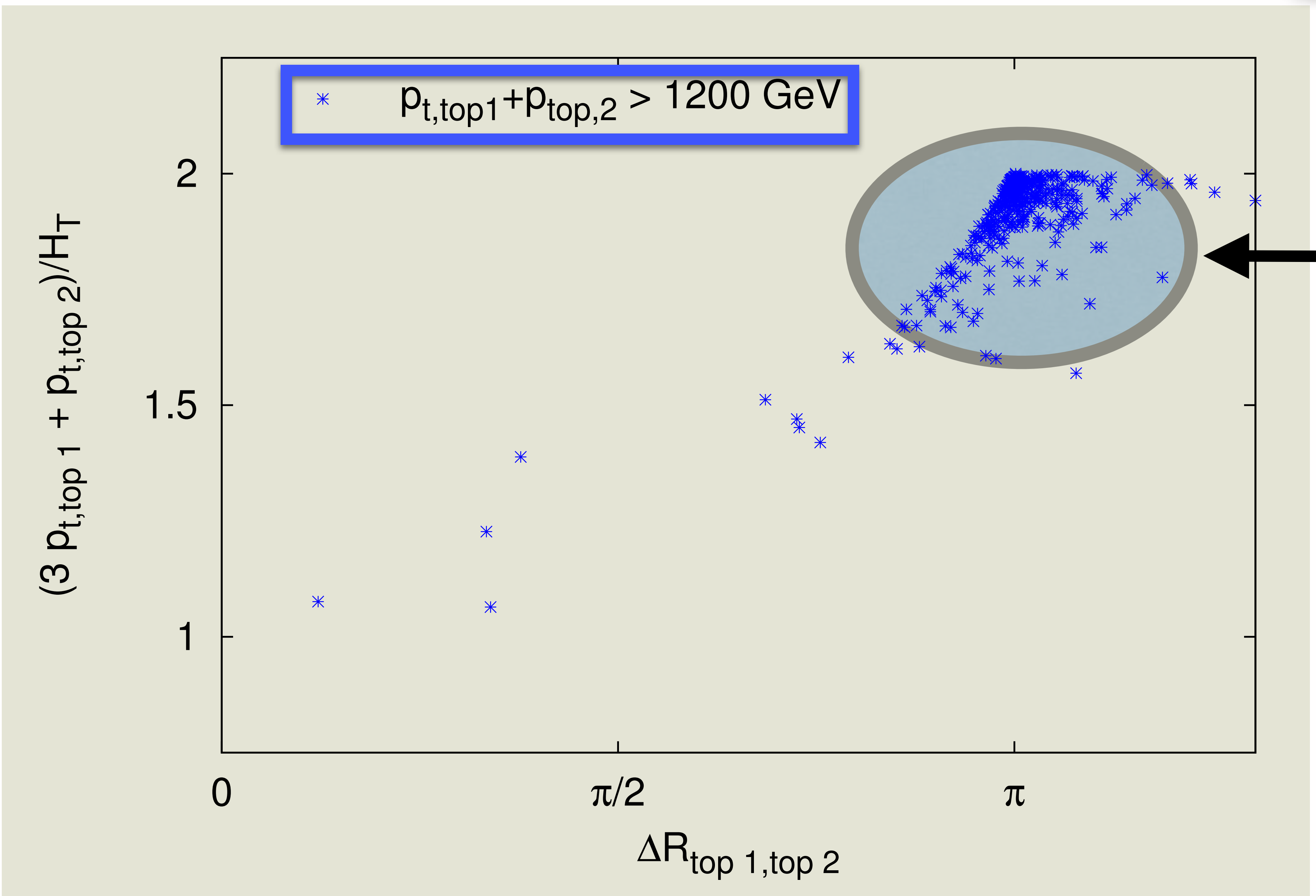
Are top pairs in high-p_t events always back-to-back?

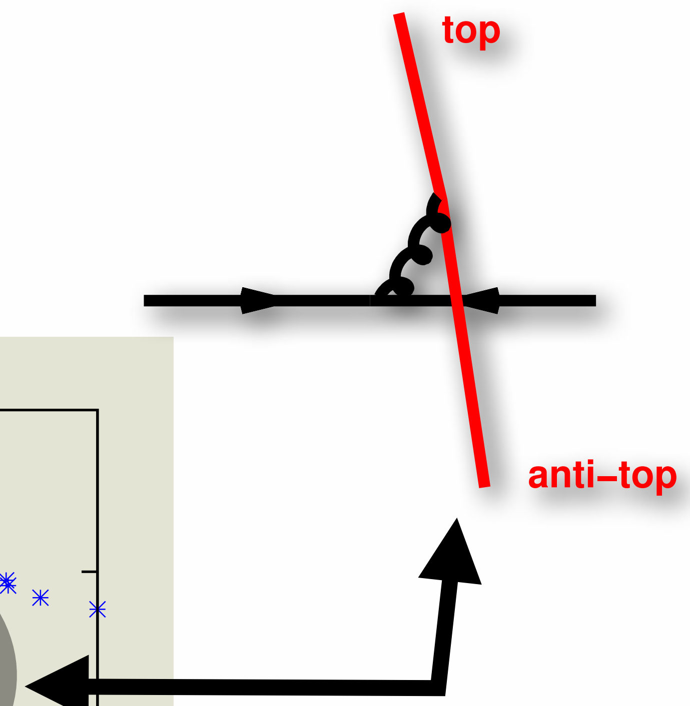
A reminder that top-quarks at LHC are almost "light"

An 8 TeV study with POWHEG, top-pair production, no decay and no parton showering (to keep things simple)

top topology v. cuts

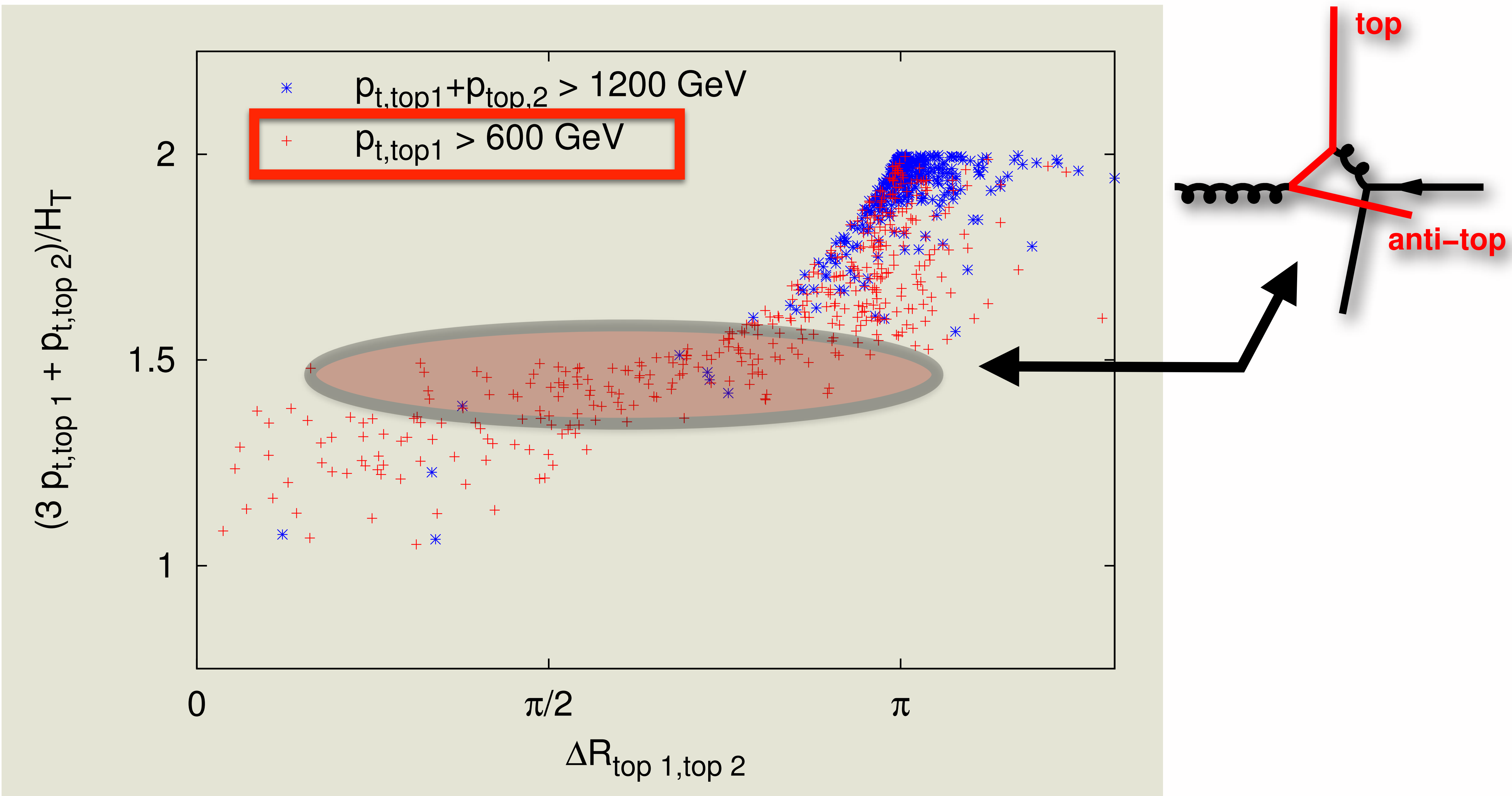
Flavour Creation





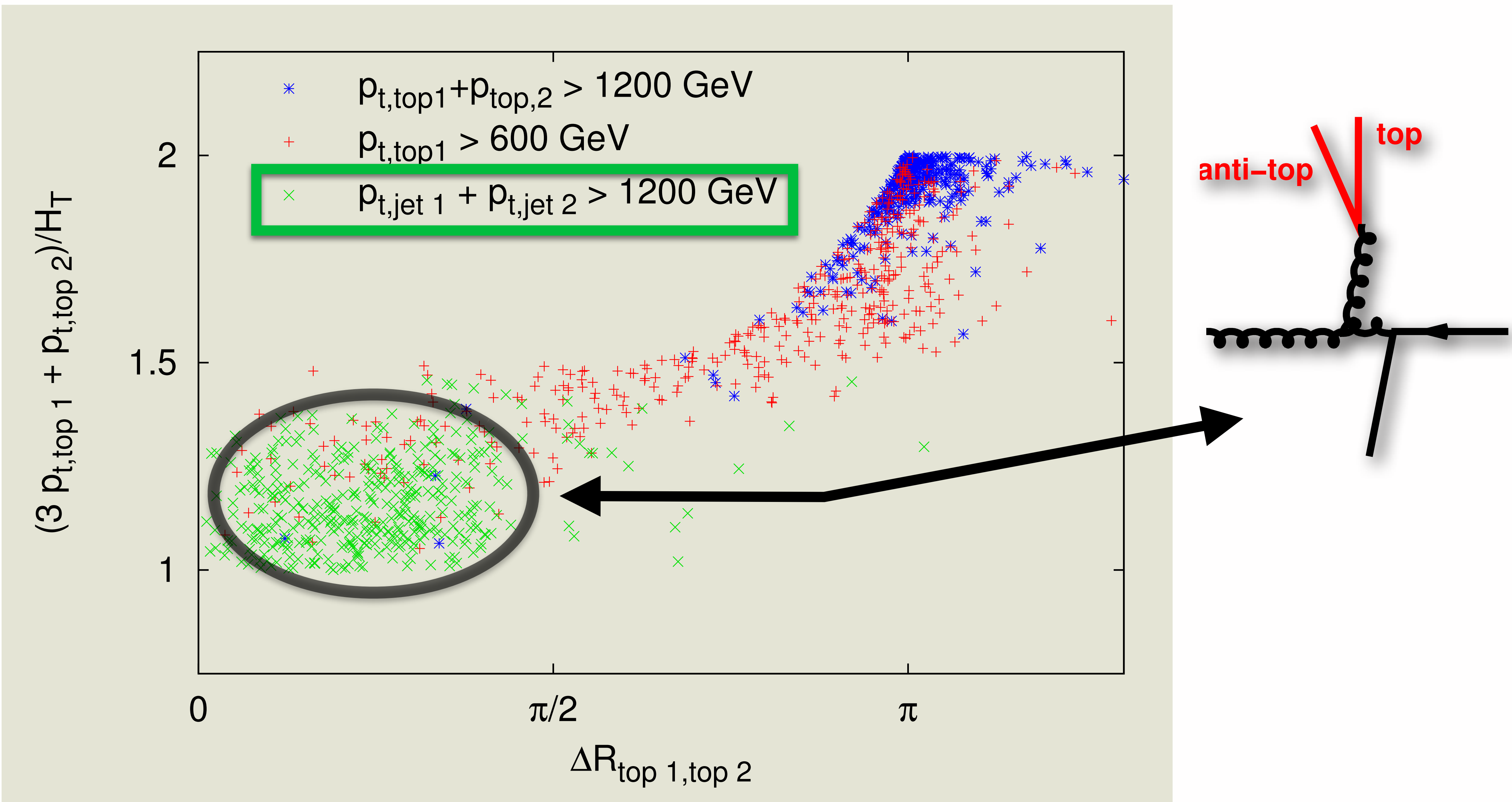
top topology v. cuts

Flavour Excitation – tops inside your PDFs



top topology v. cuts

Gluon Splitting



Assumptions

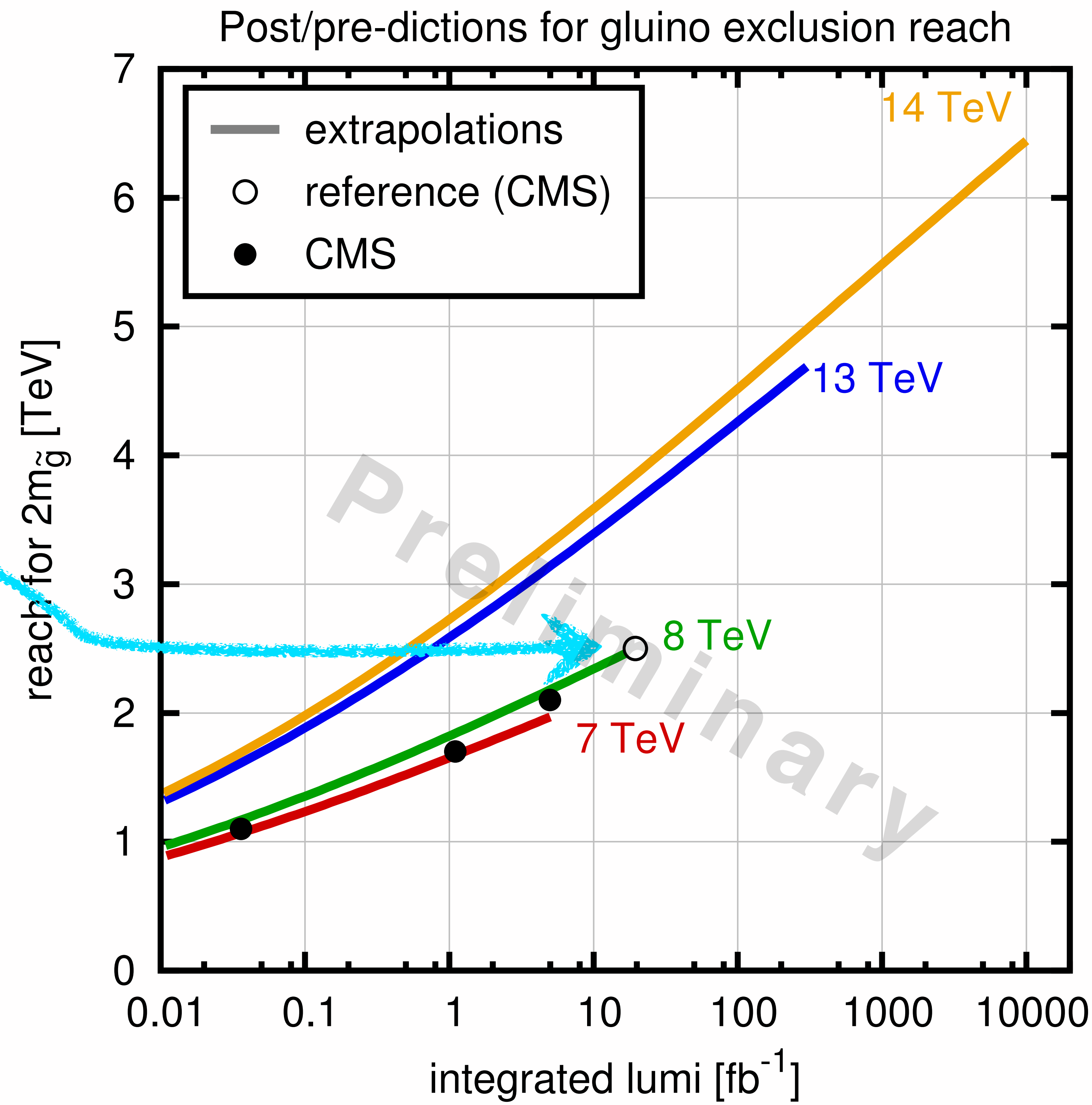
- We don't need to worry about scaling of background vs. signal
- Reconstruction efficiencies, background rejection, etc all stay reasonably constant

Try a SUSY example, gluinos. Baseline:

CMS, 20 fb^{-1} @ 8 TeV excludes $M_{\tilde{g}}$<1250 GeV i.e. $2M_{\tilde{g}}$ < 2.5 TeV

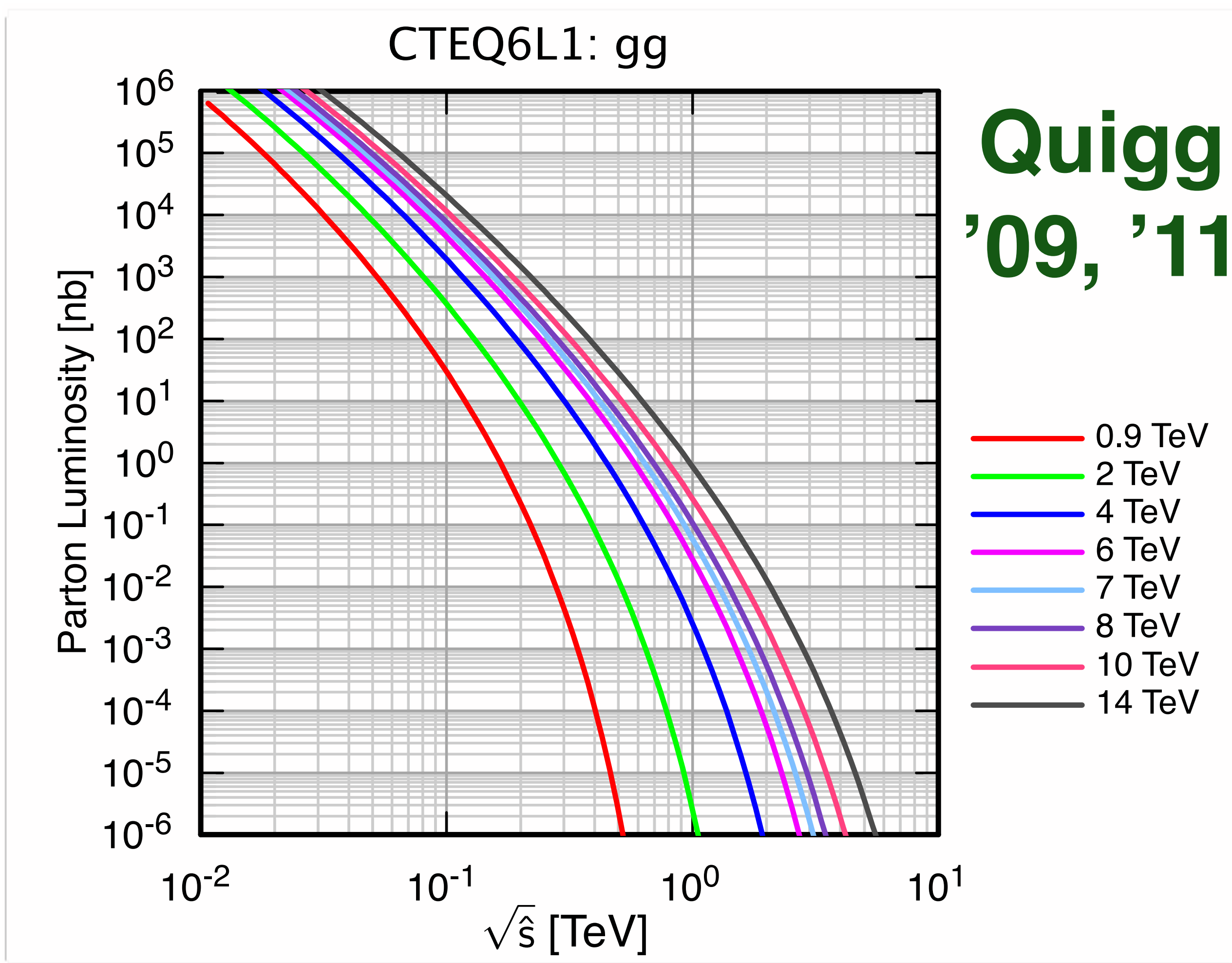
"Predict" exclusions at other lumis & energies (assume *gg*)

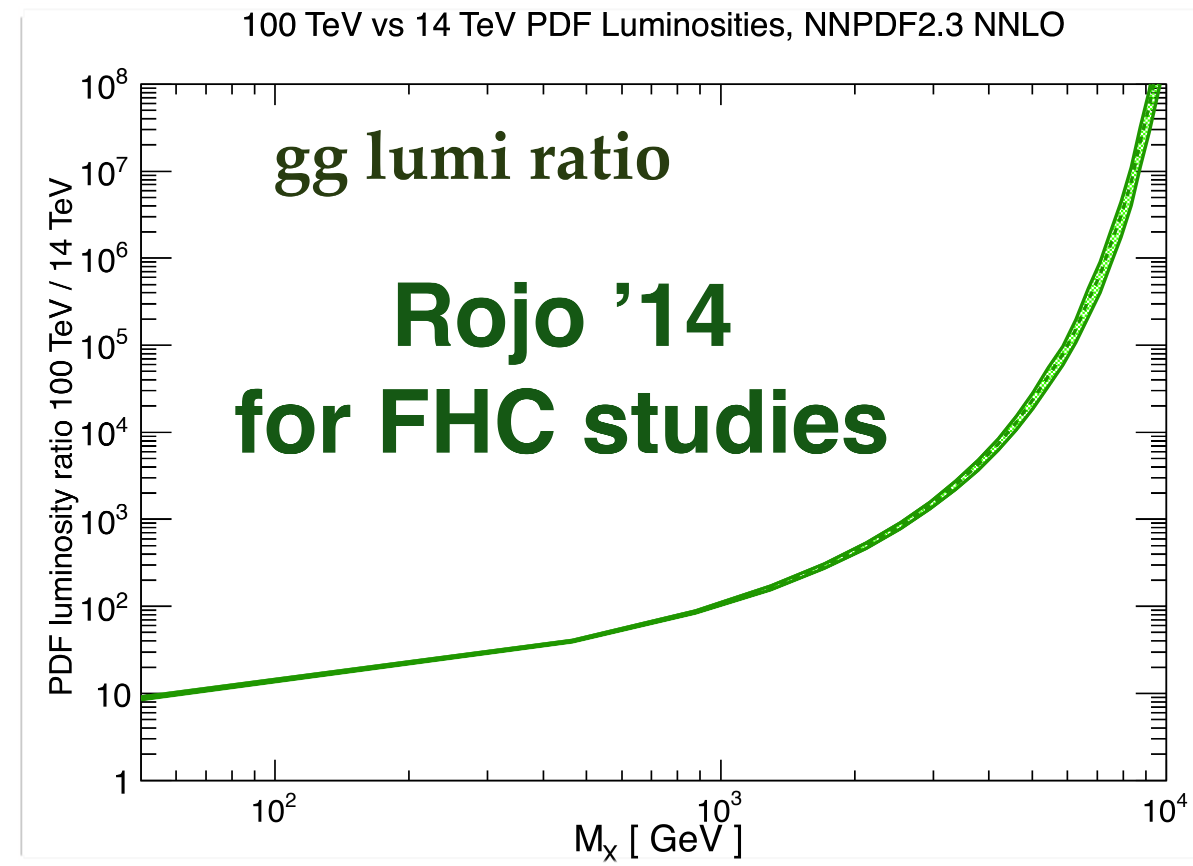
Compare to actual exclusions



Still works OK, despite (poor) assumption of same signal and background channels *[see also later]*

A side remark:
Studying partonic luminosities is a standard technique



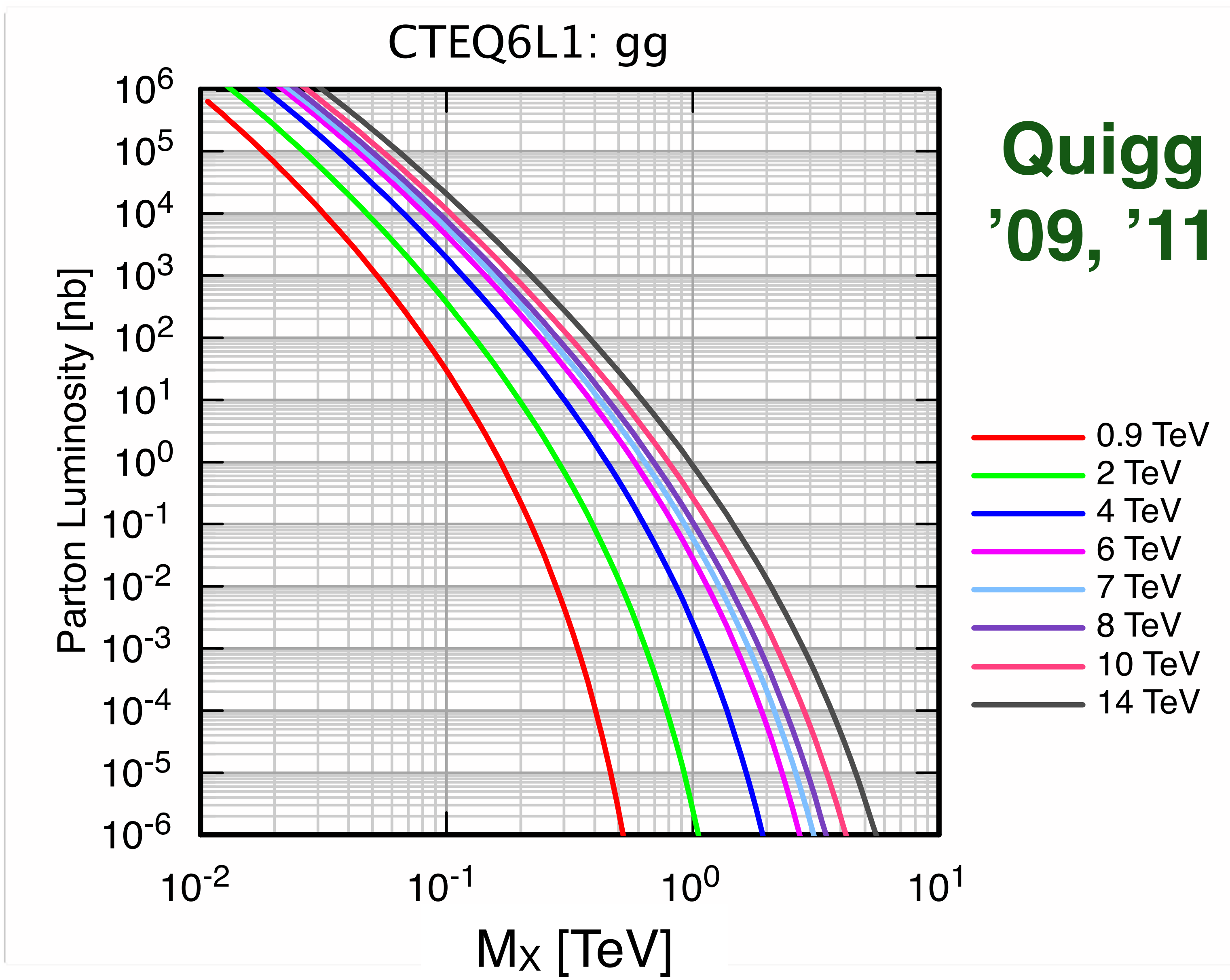


How do we differ?

Study one key question: **relate reaches [TeV]** of different colliders

Validate the approach **by postdicting** LHC and Tevatron results

Why does it work?



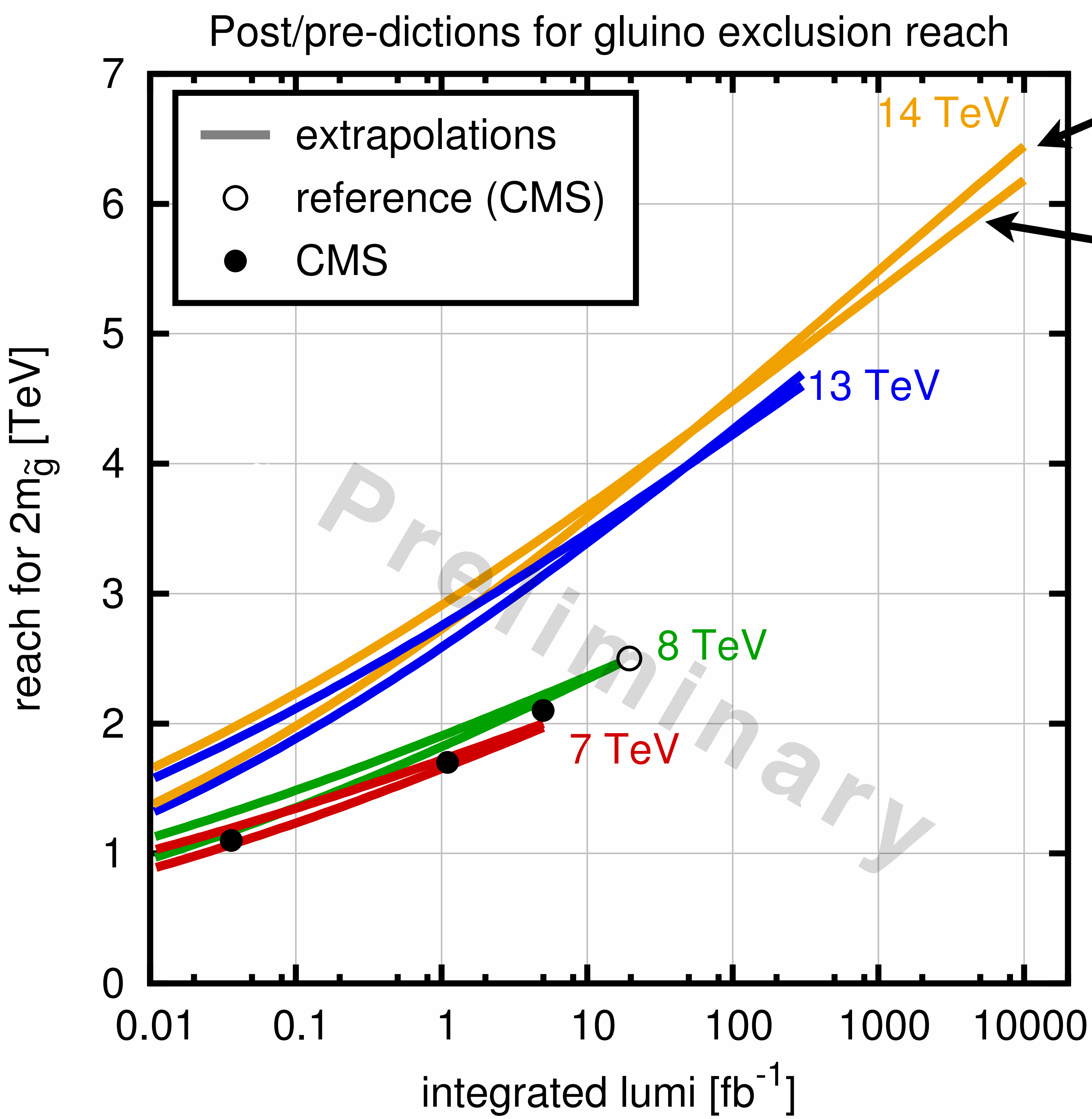
Parton luminosities fall off very fast with increasing M_X

Even when you make a mistake (e.g. wrong partonic channel) the impact on estimated M_X reach is modest

x2 in lumi ~ 10% in M_X

ATLAS						
Search	Signal	Bgd	E_{CM}[TeV]	$\mathcal{L}_{int}$[fb^{-1}]	Expected [GeV]	`collider-reach` [GeV]
Sequential Z'	$\sum \bar{q}_i q_i$	$\sum \bar{q}_i q_i$	7	0.2	1450 [?]	(base-line)
			7	1.1	1850 [?]	1849
			7	5	2200 [?]	2219
			8	6.1	2550 [?]	2510
			8	20	2900 [?]	2844
Stop ($m_{LSP} = 0$ GeV)	gg	gg	7	4.7	500 [?]	(base-line)
			8	20.5	650 [?]	675
Excited quark	gq	gg	7	$315 \cdot 10^{-6}$	1010 [?]	(base-line)
			7	$36 \cdot 10^{-3}$	2040 [?]	2026 (gq)
			7	$163 \cdot 10^{-3}$	2490 [?]	2395 (gq)
			7	0.81	2910 [?]	2790 (gq)
			7	4.8	3090 [?]	3220 (gq)
			8	13	3840 [?]	3865 (gq)

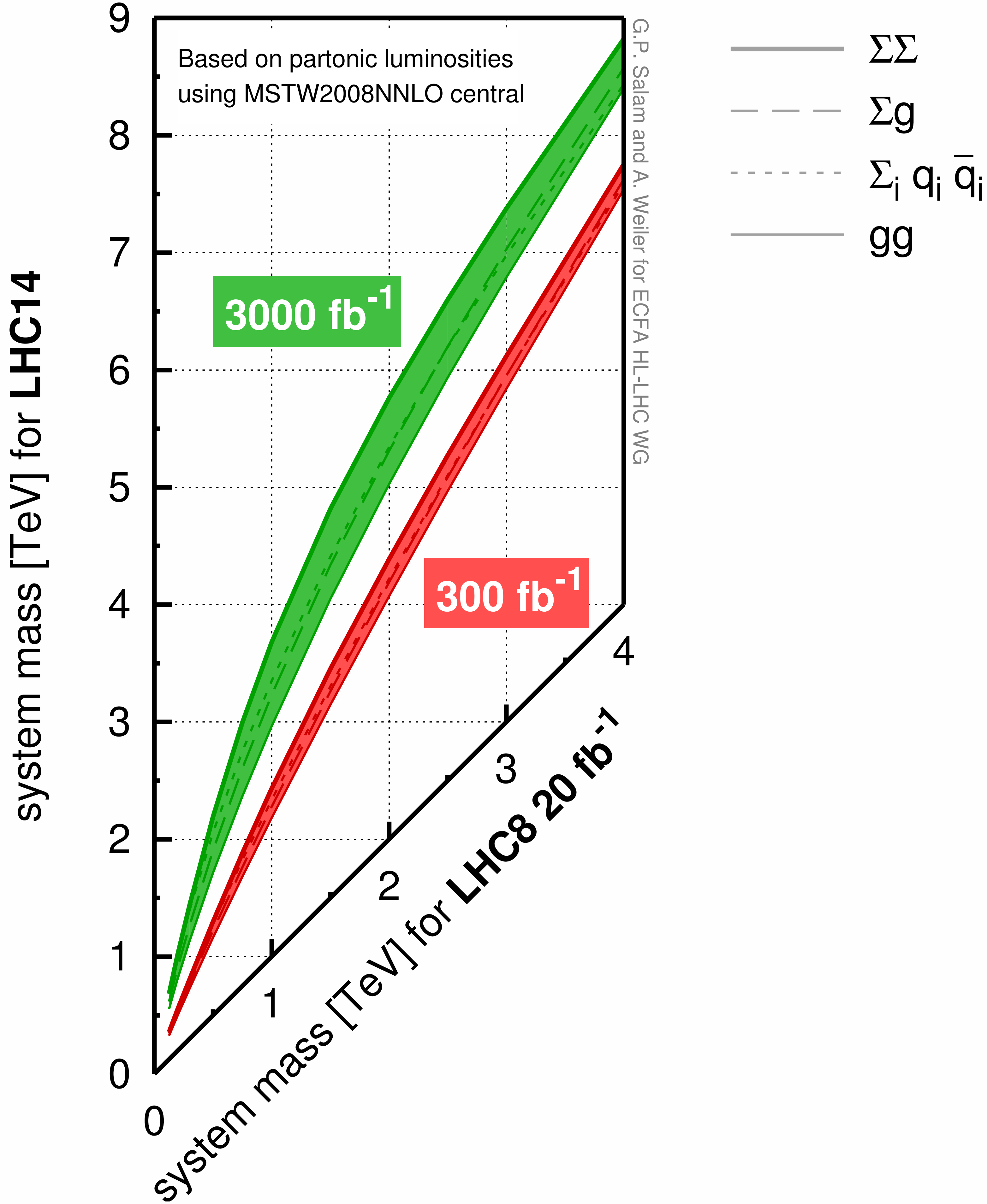
CMS						
Search	Signal	Bgd	E_{CM}[TeV]	$\mathcal{L}_{int}$[fb^{-1}]	Expected [GeV]	`collider-reach` [GeV]
gluinos ($m_{LSP} = 100$ GeV)	gg	$gg/gq/qq$	7	0.036	550 [?]	(base-line)
			7	1.1	850 [?]	855
			7	4.98	1050 [?]	1005
			8	19.5	1250 [?]	1275
squarks ($m_{LSP} = 100$ GeV)	gg	$gg/gq/qq$	7	0.036	400 [?]	(base-line)
			7	1.1	650 [?]	663
			7	4.98	725 [?]	801
			8	19.5	910 [?]	1033
T-quarks (Br($T \to tZ$) = 1)	gg	$gg/gq/qq$	7	1.14	510 [?]	(base-line)
			7	5	550 [?]	629
			8	19.6	813 [?]	827



Signal gg; bkgd: gg

Signal gg; bkgd: qg

Scattering channel matters, but not too much


Based on partonic luminosities
using MSTW2008NNLO central
3000 fb^{-1}
300 fb^{-1}
G.P. Salam and A. Weiler for ECFA HL-LHC WG
system mass [TeV] for **LHC14**
system mass [TeV] for **LHC8 20 fb^{-1}**
0
1
2
3
4
5
6
7
8
9
ΣΣ
Σg
$\Sigma_i\, q_i\, \bar{q}_i$
gg

G. Salam/AW

LHC comparison

1208.1447
ATLAS-CONF-2013-024

```
gg
   stop limits          [expected]   (lsp = 0gev)
      7TeV, 4.7 ifb        500 gev
      8TeV, 20.5 ifb       650 gev          ---> 675 GeV
```

ATLAS EXOT-2011-06
ATLAS-CONF-2012-129
ATLAS-CONF-2013-017

```
qqbar

      sequential z-prime [expected]
      7TeV, 1.1 ifb        1800 gev
      8TeV, 6 ifb,         2550 gev     ---> 2450 GeV
      8TeV, 20 ifb        2800 gee     ---> 2790 GeV
```

EXOT-2011-07
ATLAS-CONF-2012-088
ATLAS-CONF-2012-148

```
qg
      excited quark q*  [expected]   (NB,sig ≠ bgd scaling )
      7 TeV, 1 ifb          2900 gev
      8 TeV, 5.8 ifb       3500 gev     ---> 3700 GeV
      8 TeV, 13 ifb         3700 gev     ---> 3900 GeV
```

LHC comparison

1208.1447
ATLAS-CONF-2013-024

```
gg
  stop limits       [expected]   (lsp = 0gev)
    7TeV, 4.7 ifb       500 gev
    8TeV, 20.5 ifb      650 gev        ---> 675 GeV
```

Baseline

```
qqbar
```

ATLAS EXOT-2011-06
ATLAS-CONF-2012-129
ATLAS-CONF-2013-017

```
    sequential z-prime [expected]
    7TeV, 1.1 ifb       1800 gev
    8TeV, 6 ifb,        2550 gev    ---> 2450 GeV
    8TeV, 20 ifb       2800 gee    ---> 2790 GeV
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EXOT-2011-07
ATLAS-CONF-2012-088
ATLAS-CONF-2012-148

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qg
    excited quark q*  [expected]   (NB,sig ≠ bgd scaling )
    7 TeV, 1 ifb         2900 gev
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    8 TeV, 13 ifb        3700 gev    ---> 3900 GeV
```

LHC comparison

1208.1447
ATLAS-CONF-2013-024

gg

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7TeV, 4.7 ifb 500 gev

8TeV, 20.5 ifb 650 gev ---> 675 GeV

qqbar

ATLAS EXOT-2011-06
ATLAS-CONF-2012-129
ATLAS-CONF-2013-017

sequential z-prime [expected]

7TeV, 1.1 ifb 1800 gev

8TeV, 6 ifb, 2550 gev ---> 2450 GeV

8TeV, 20 ifb 2800 gee ---> 2790 GeV

EXOT-2011-07
ATLAS-CONF-2012-088
ATLAS-CONF-2012-148

qg

excited quark q* [expected] (NB, sig ≠ bgd scaling)

7 TeV, 1 ifb 2900 gev

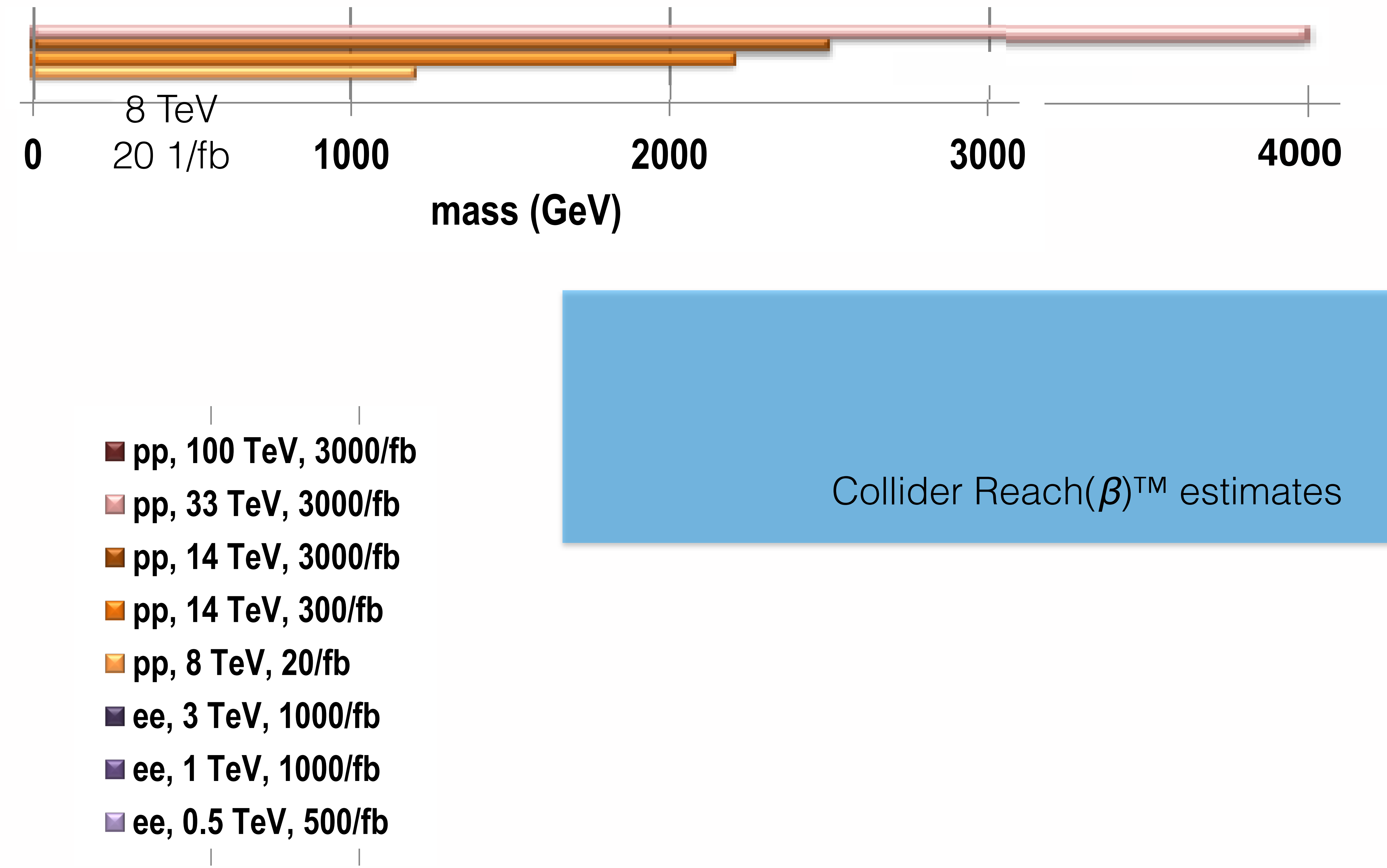
8 TeV, 5.8 ifb 3500 gev ---> 3700 GeV

8 TeV, 13 ifb 3700 gev ---> 3900 GeV

Baseline

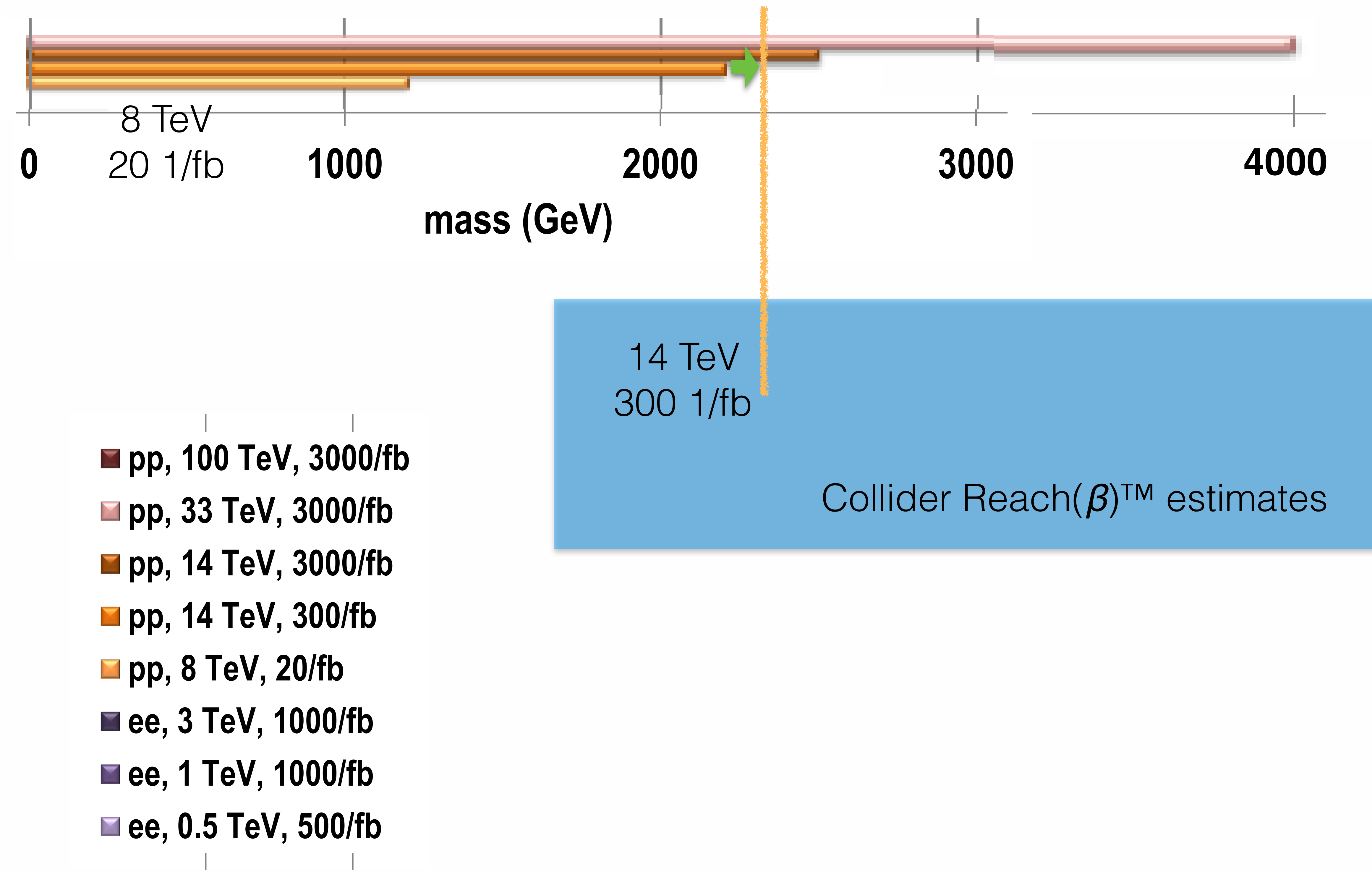
Lumi method

Gluinos



Collider Reach(β)™ estimates

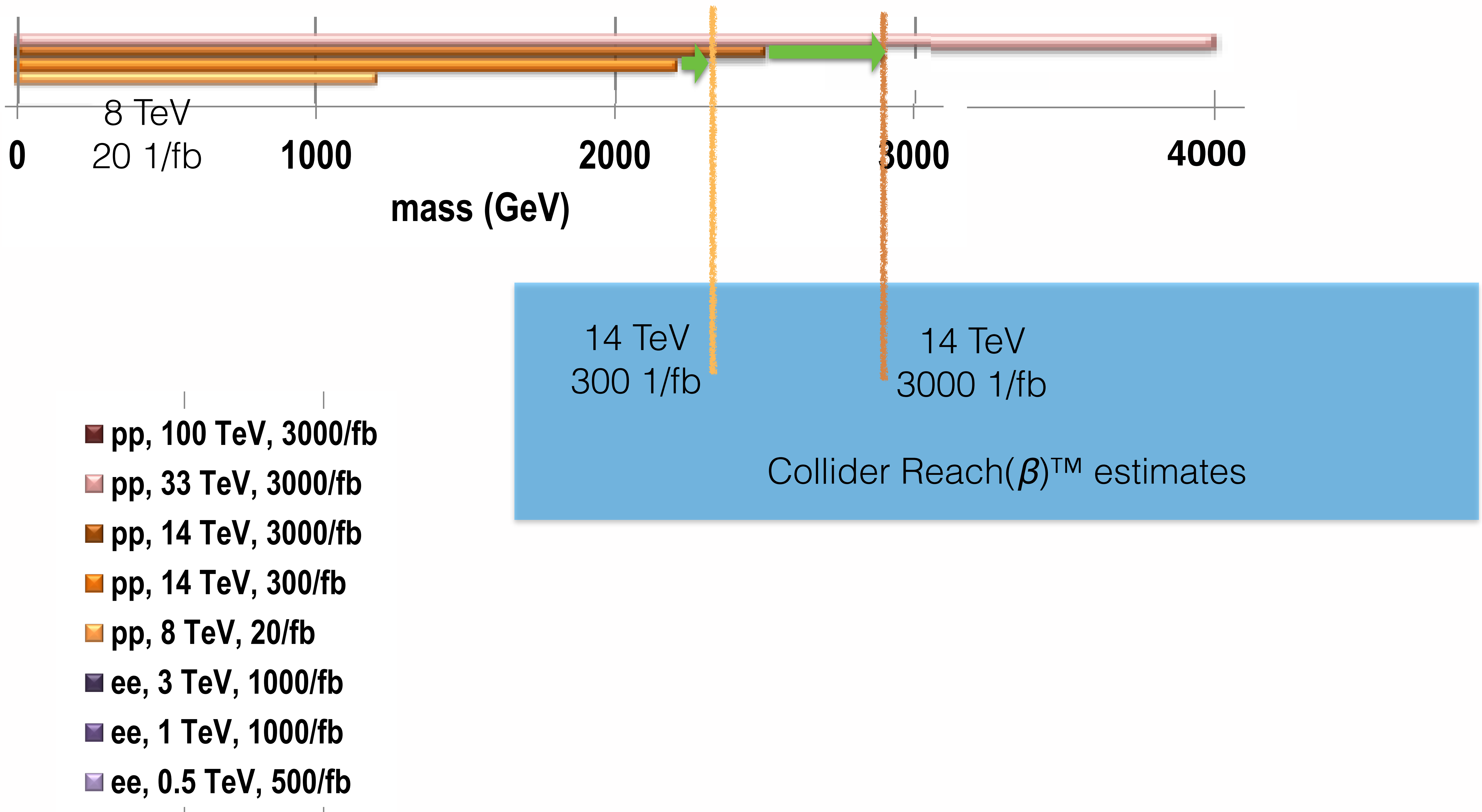
Gluinos



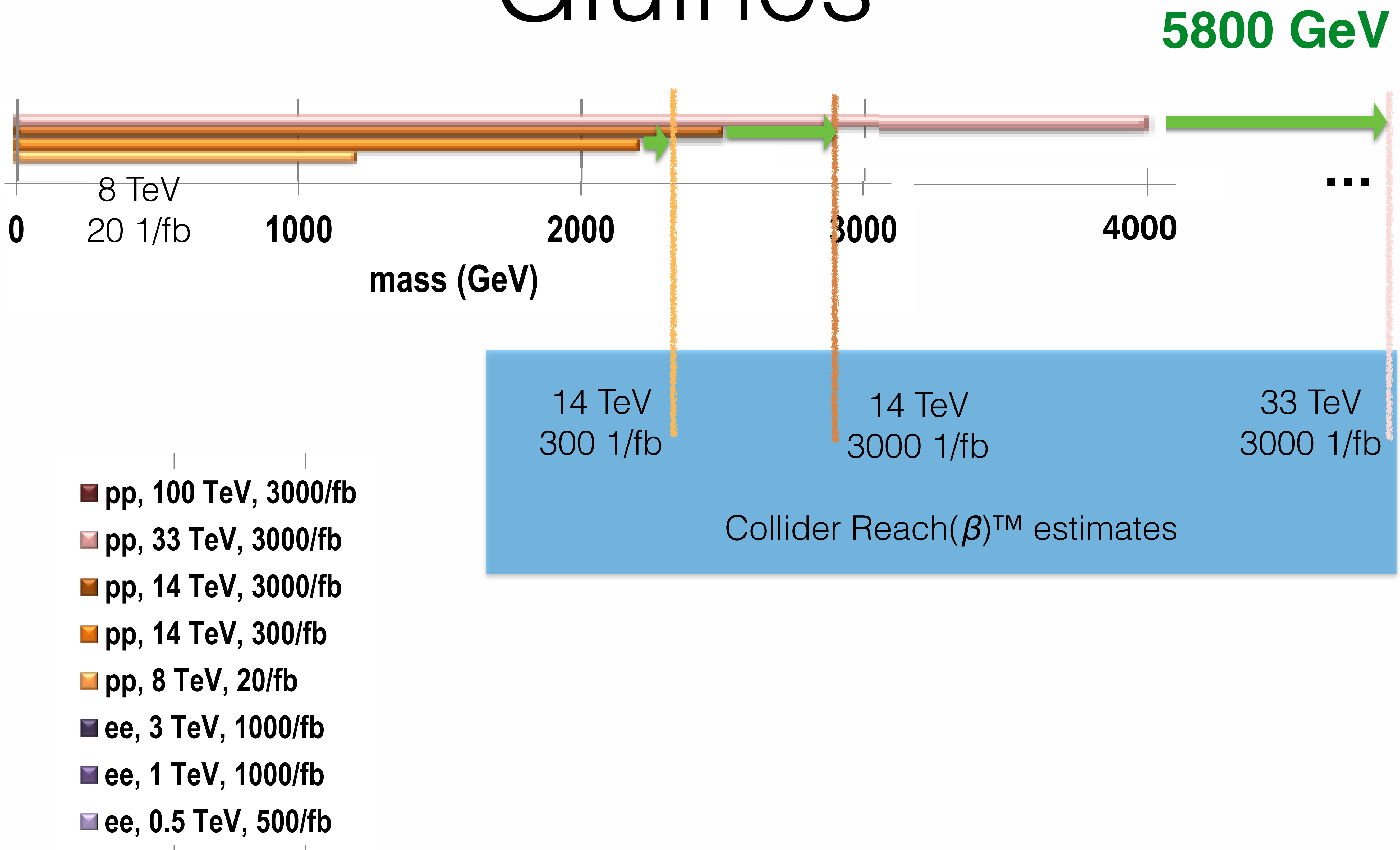
14 TeV
300 1/fb

Collider Reach(β)™ estimates

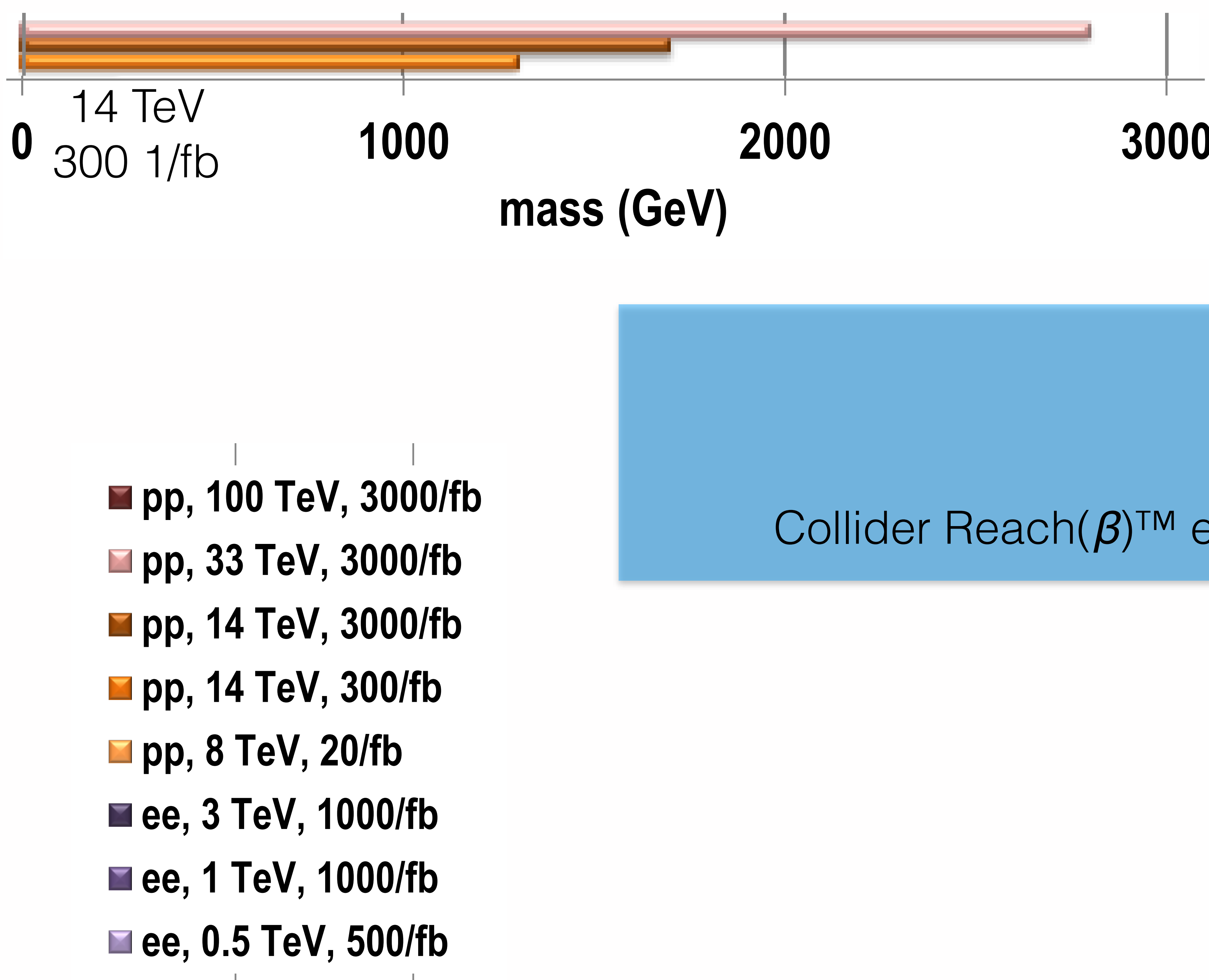
Gluinos


8 TeV
20 1/fb
0
1000
2000
3000
4000
mass (GeV)
14 TeV
300 1/fb
14 TeV
3000 1/fb
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

Gluinos

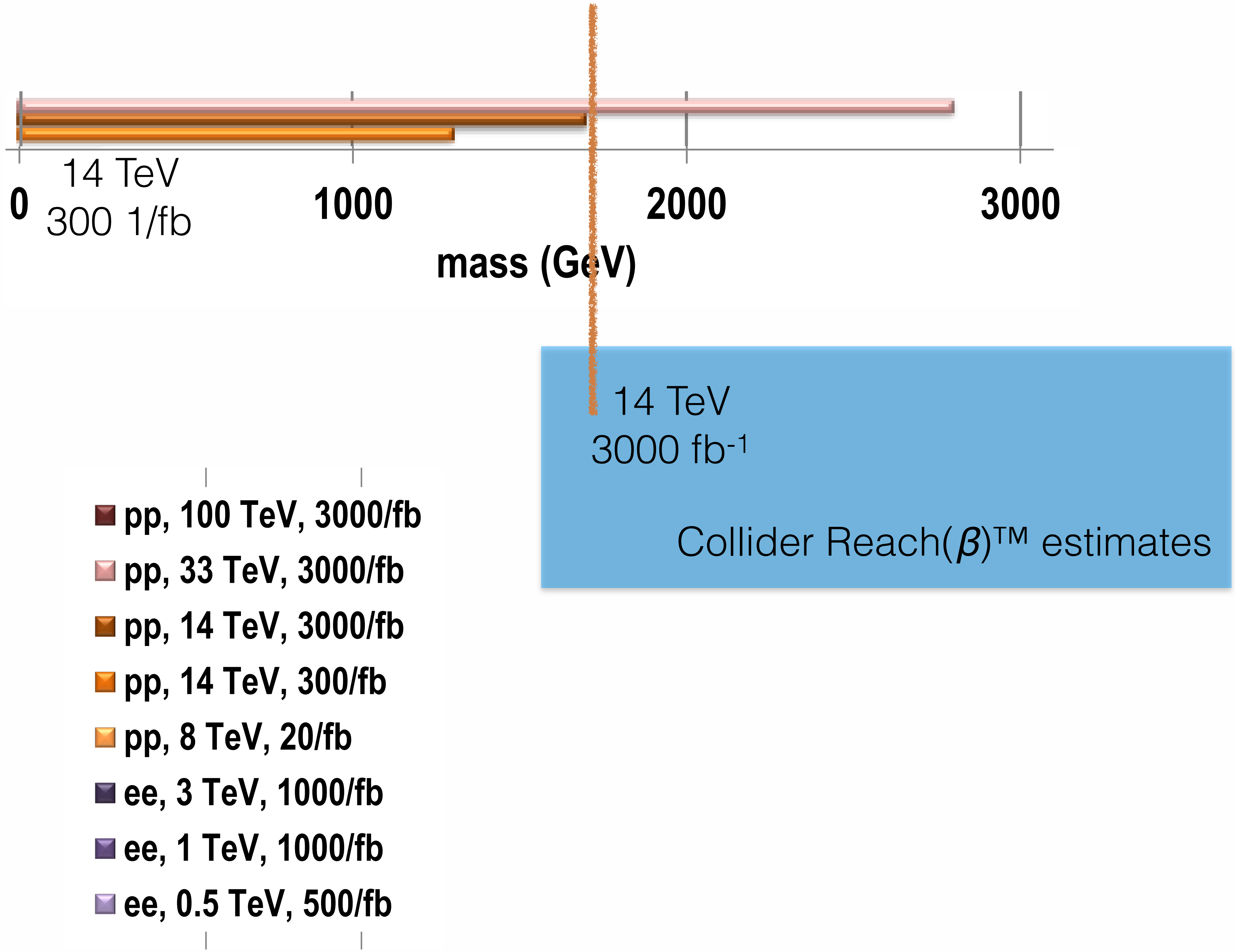

5800 GeV
8 TeV
20 1/fb
0
1000
2000
3000
4000
...
mass (GeV)
14 TeV
300 1/fb
14 TeV
3000 1/fb
33 TeV
3000 1/fb
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

RPV stops



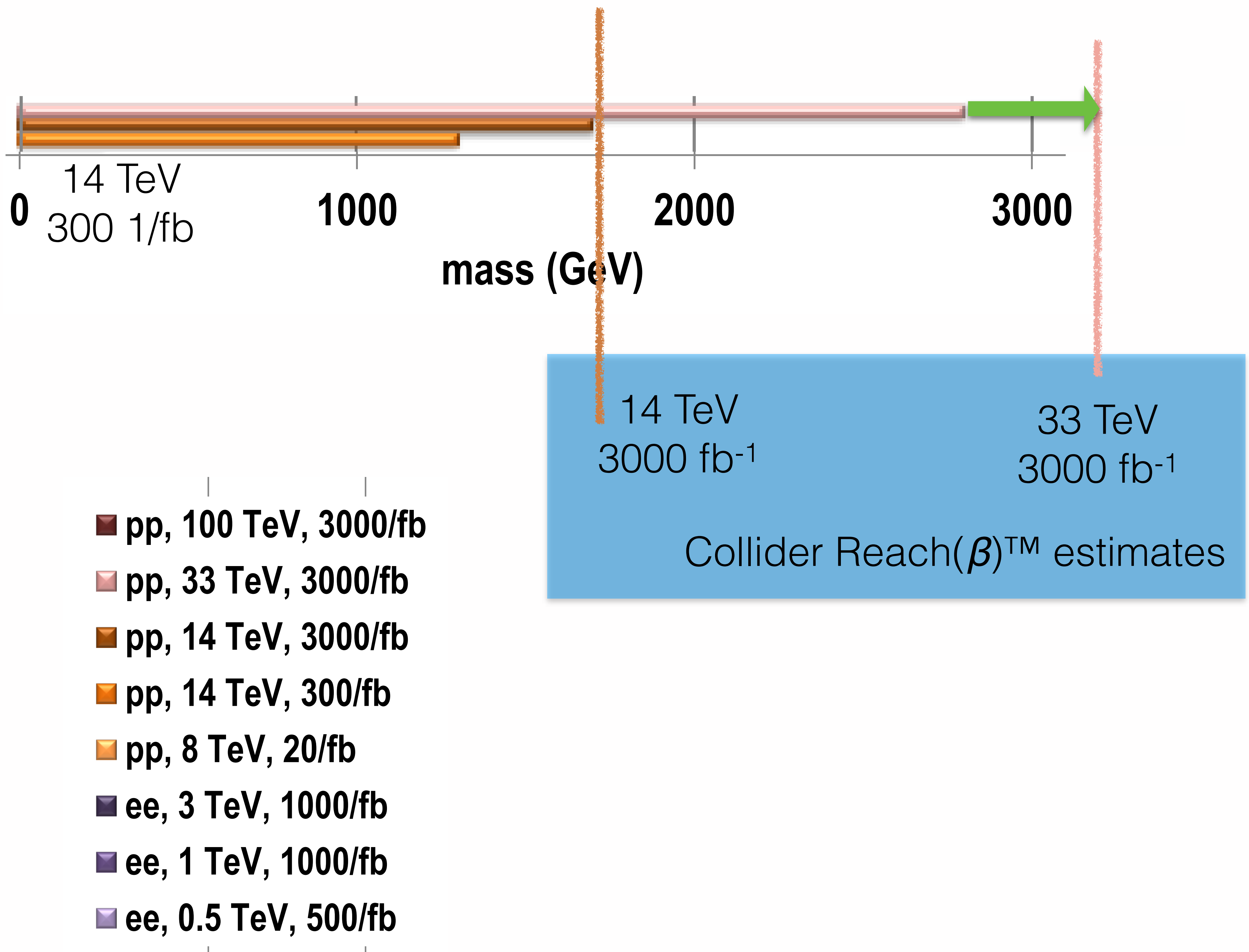
Collider Reach(β)™ estimates

RPV stops



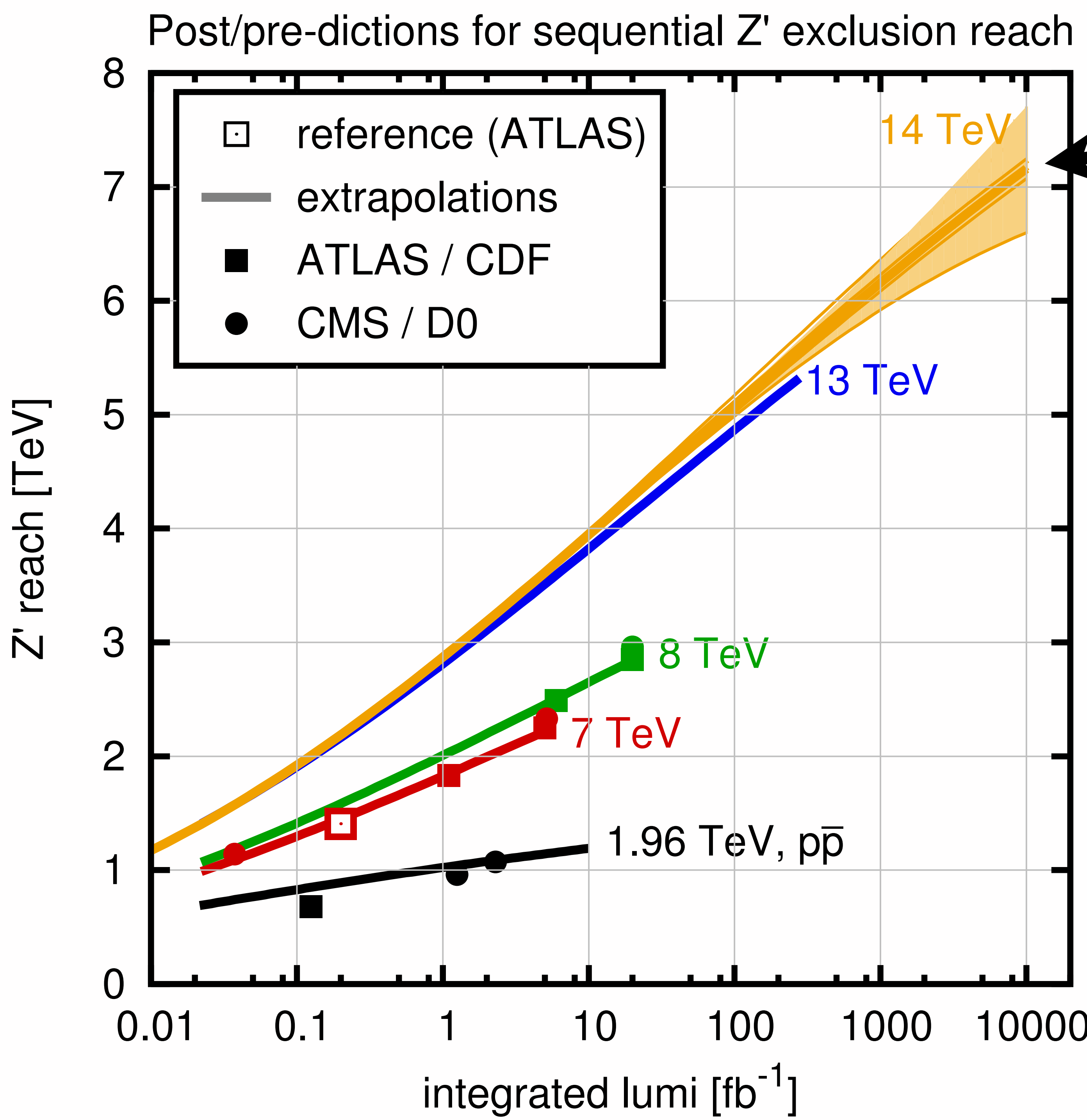
14 TeV
300 1/fb
0
1000
2000
3000
mass (GeV)
14 TeV
3000 fb-1
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

RPV stops

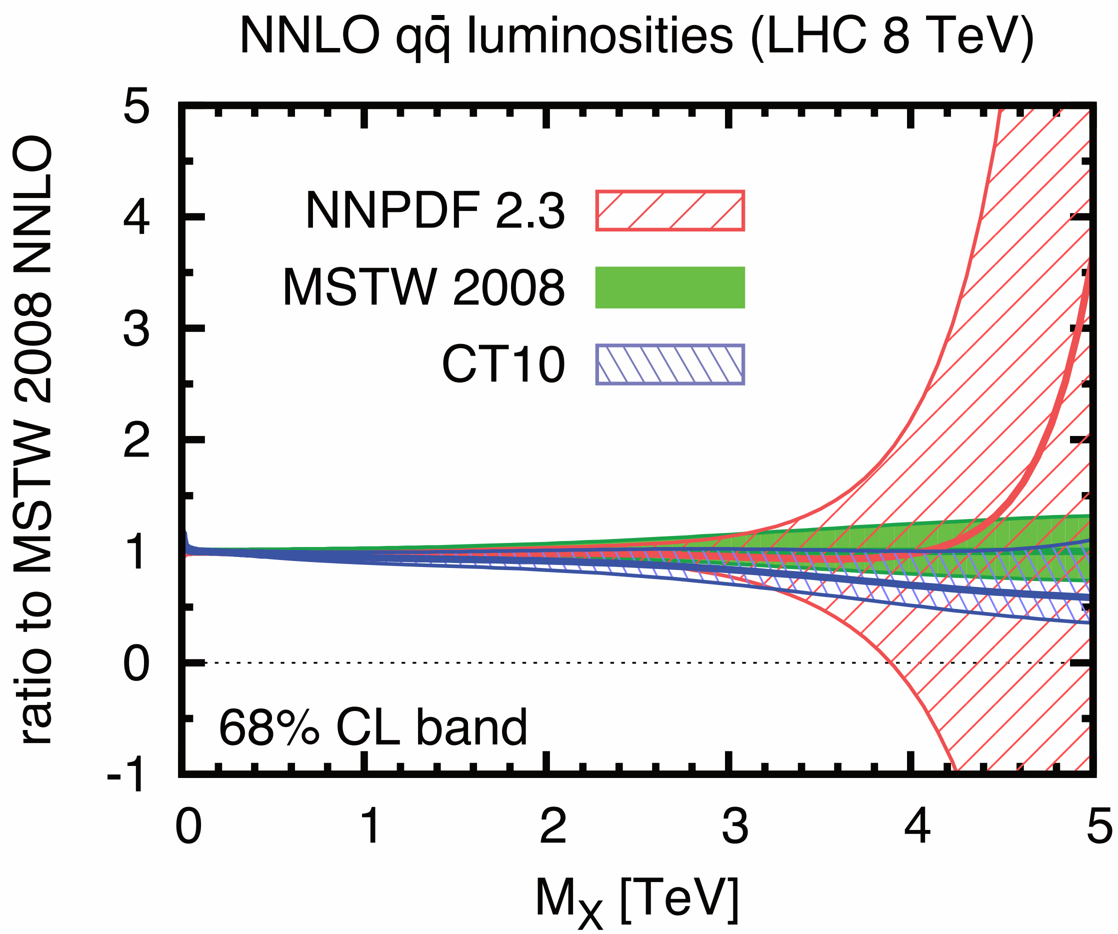


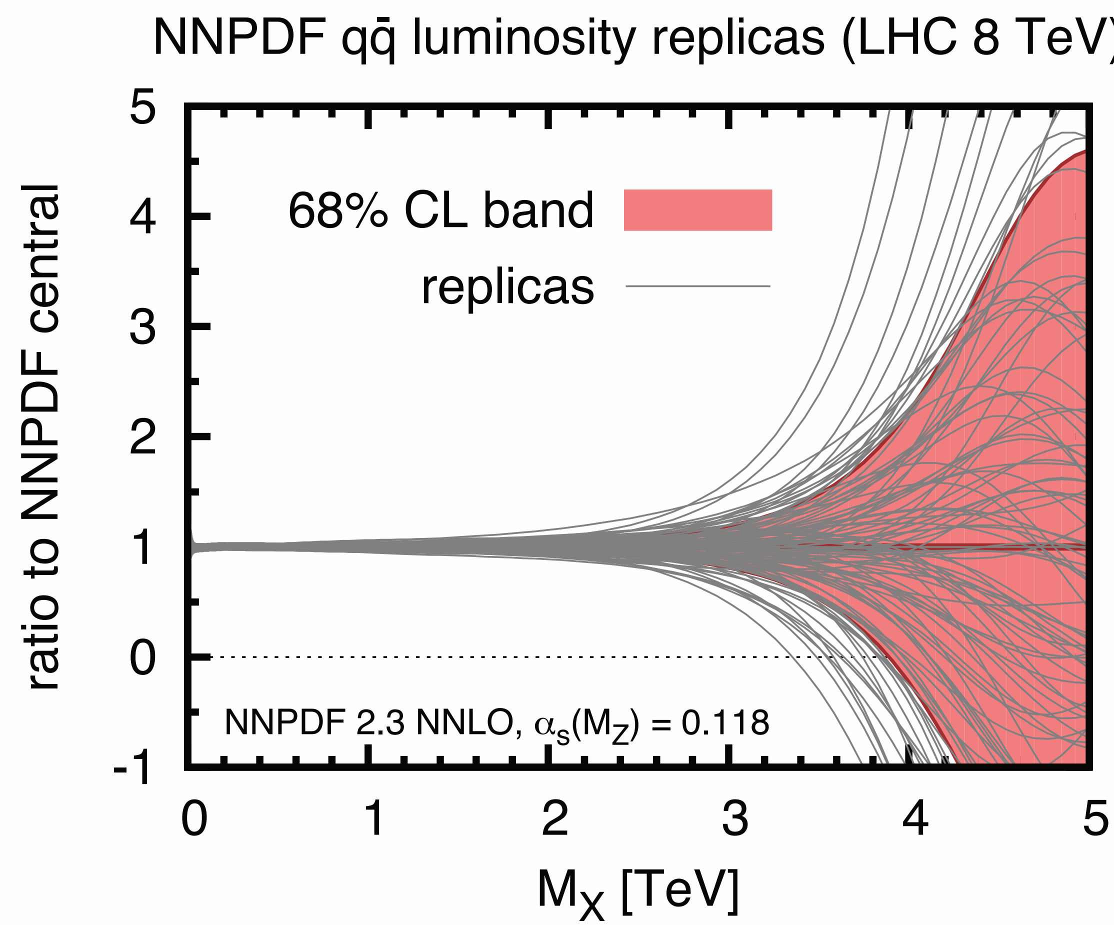
14 TeV
300 1/fb
0
1000
2000
3000
mass (GeV)
14 TeV
3000 fb-1
33 TeV
3000 fb-1
Collider Reach(β)™ estimates
pp, 100 TeV, 3000/fb
pp, 33 TeV, 3000/fb
pp, 14 TeV, 3000/fb
pp, 14 TeV, 300/fb
pp, 8 TeV, 20/fb
ee, 3 TeV, 1000/fb
ee, 1 TeV, 1000/fb
ee, 0.5 TeV, 500/fb

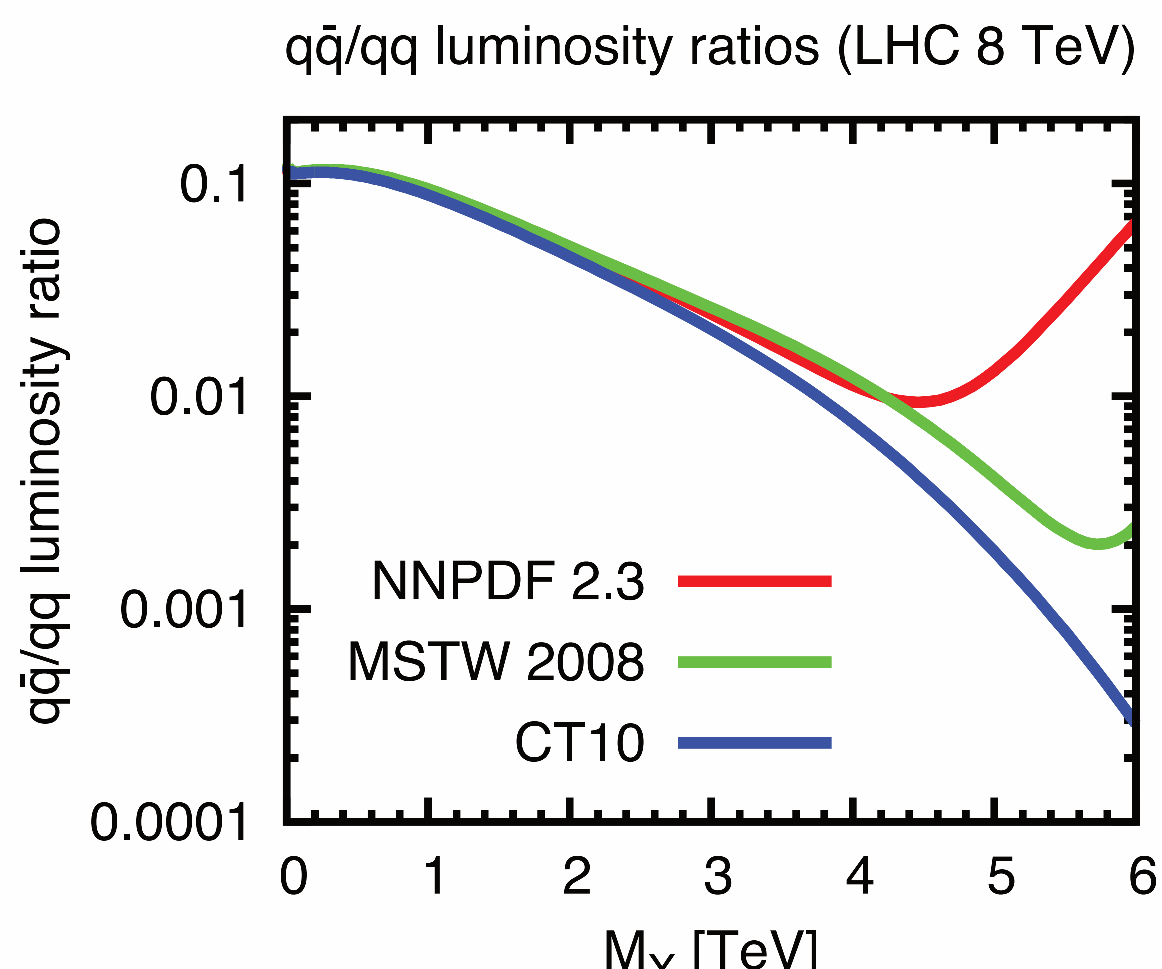
Impact of PDF uncertainties



Envelope of CTEQ10 MSTW2008 & NNPDF23 results


NNLO qq̄ luminosities (LHC 8 TeV)
NNPDF 2.3
MSTW 2008
CT10
68% CL band
ratio to MSTW 2008 NNLO
M_X [TeV]


NNPDF qq̄ luminosity replicas (LHC 8 TeV)
68% CL band
replicas
NNPDF 2.3 NNLO, $\alpha_s(M_Z)$ = 0.118
ratio to NNPDF central
M_X [TeV]


qq̄/qq luminosity ratios (LHC 8 TeV)
NNPDF 2.3
MSTW 2008
CT10
qq̄/qq luminosity ratio
M_X [TeV]