Preblessing: Study of ttbar Production Mechanisms

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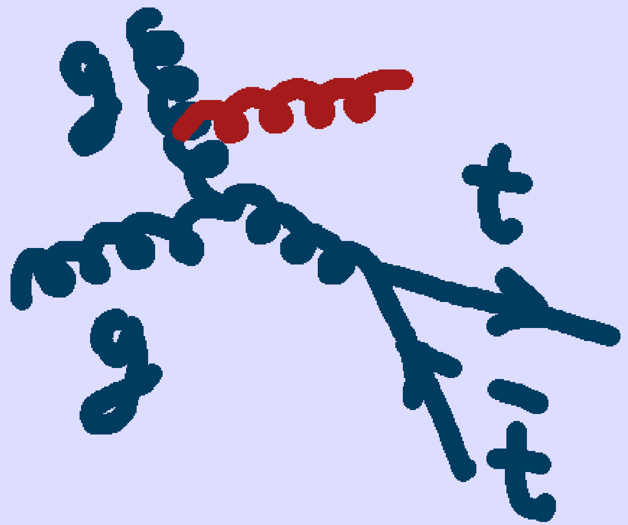
Outline

- Introduction
- Track multiplicity
- <Ng> and <Ntrk> correlation
- Gluon-rich fraction
- Extracting $\sigma(gg \rightarrow tt)/\sigma(ppbar \rightarrow tt)$
- Pseudo-experiments
- Systematics
- Results
- Summary/Outlook

Introduction - I

- According to SM, in $p\bar{p}$ collisions at $\sqrt{s} \sim 2$ TeV
  - ✓ $gg \rightarrow t\bar{t}$ ~ 15%
  - ✓ $q\bar{q} \rightarrow t\bar{t}$ ~ 85%
- Measure $\sigma_{(gg \rightarrow t\bar{t})} / \sigma_{(p\bar{p} \rightarrow t\bar{t})}$
  - ✓ Test of pQCD calculations
  - ✓ Non-SM mechanisms
- Processes differ in underlying activity
  - ✓ The difference comes from ISR



Introduction - II

- Can not rely on the modeling of gluon radiation
- Should calibrate using data
  - ✓ W + n jet events
    - W with no jet is mainly qq
    - As jet multiplicity increases, the gluon-content increases
  - ✓ Dijet events
    - Gluon-content decreases as the leading jet E_T increases

- Jet50 and Jet100 data
- High p_T electron and muon
- PYTHIA 40 and 90
- ALPGEN+PYTHIA
  $W \rightarrow l\nu$ + n parton, n=0,1,2,3 and 4 weighted to match the cross section

- Jet in W+ n jet categories:
  - ✓ $E_T \geq 20$ GeV
  - ✓ $|\eta| \leq 2$
- Leading jet in dijet categories:
  - ✓ starting from 80 GeV
  - ✓ bins of 20 GeV
  - ✓ up to 220 GeV or more
- All jets: cone 0.4, L5 corrected

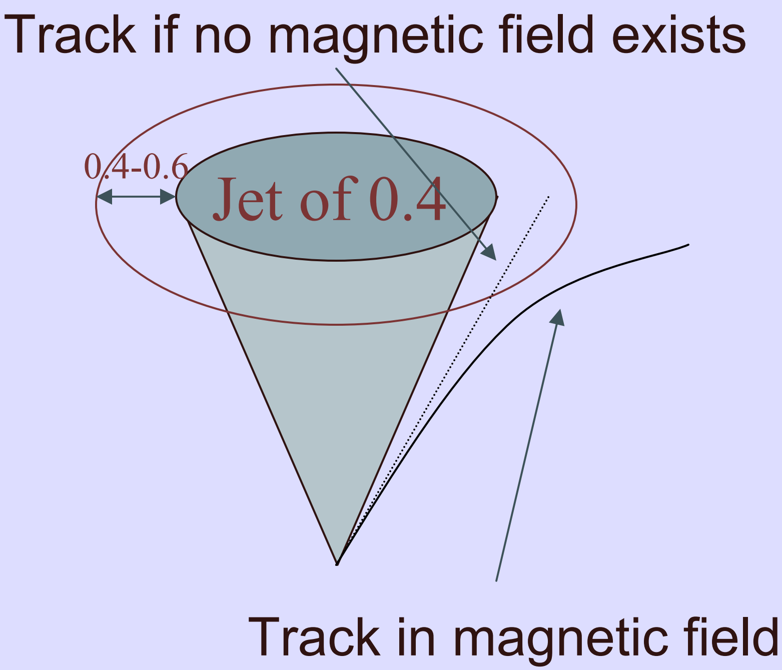
Event selection

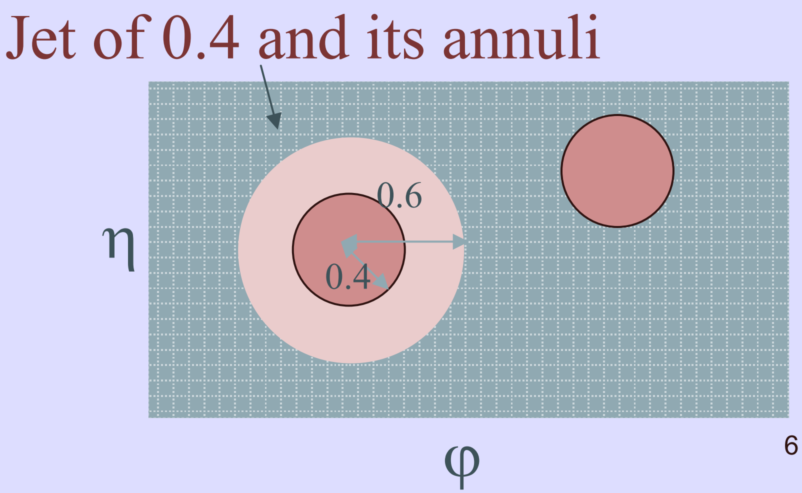
- W+n jet
  - ✓ One and only one tight lepton
  - ✓ Missing E_T of at least 20 GeV
    - If <30 GeV, $\Delta\varphi$ of 0.5-2.5
  - ✓ At least one good z vertex
  - ✓ Reject dilepton or Z
  - ✓ Veto cosmic or conversion
  - ✓ $|z| \leq 60$ cm and $|\Delta z| \leq 5$ cm
- ttbar
  - ✓ Exactly as the W+n jet
  - ✓ At least 4 jets
  - ✓ At least one positive tight b-tag
- dijet
  - ✓ An uncorrected E_T of at least 75 and 130 GeV for Jet50(Jet40) and Jet100(Jet90), respectively
  - ✓ No tight lepton present
  - ✓ Two and only two jets with E_T of at least 15 GeV, $|\eta| \leq 2$
  - ✓ 2 jets back-to-back in φ within 35^o
  - ✓ At least one good z vertex
  - ✓ $|z| \leq 60$ cm

Same cuts were used for data and MC

Track multiplicity

- Low p_T, 0.3 – 2.9 GeV/c^2
- $|\eta| \leq 1.1$
- Matched to the event vertex
  - ✓ 3cm
- Away from jets
  - ✓ ΔR=0.6, $E_T \geq$15 GeV
  - ✓ ΔR=0.4, 6 $\leq E_T <$ 15 GeV
- Correct for area differences
- Correct for remaining contribution of high E_T jets
  - ✓ 0d: 0.90 ± 0.03
  - ✓ 0h: 0.97 ± 0.04
  - ✓ 0i : 0.96 ± 0.04



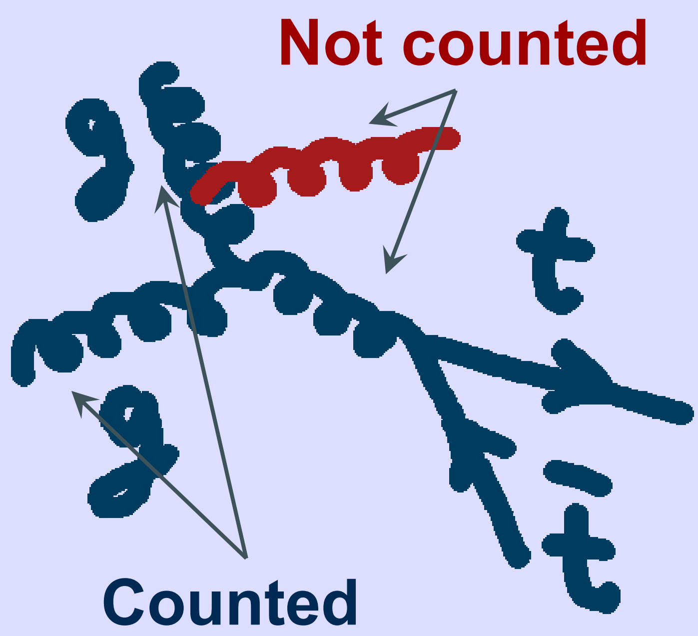


Comments

- We only use MC to predict the quark-gluon composition of a given data sample
  - ✓ MC calculations are reliable for predicting the process composition
- We combine 0d, 0h and 0i sample after all track selection and corrections
  - ✓ The differences between the data samples does not significantly affect the relative rate of gluon-rich and no-gluon processes
  - ✓ There is still a good separation between gluon-rich and no-gluon distribution
  - ✓ The method is statistically more robust

Counting gluons in a sample

- Count the number of gluons which are part of the Matrix Element
    - ✓ We distinguish between the “soft gluons” that are modeled using the splitting functions and the “hard gluons” that are part of the ME passed on to the MC generator



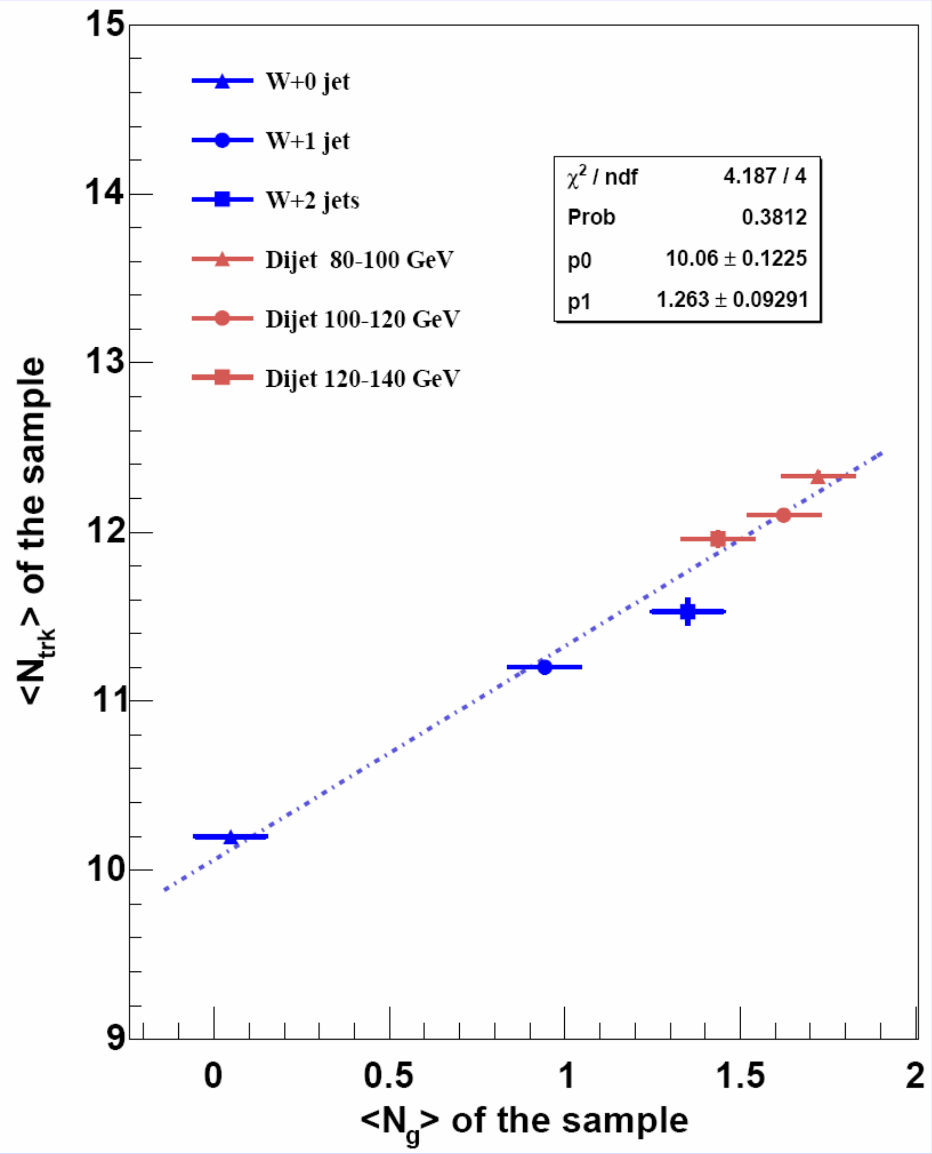
- Add the number for all the MC events
- Divide by the total number of MC events

$$\frac{\sum_{\text{events}} \text{number of gluons in the initial and final state of the process}}{\text{Total number of events}}$$

Correlation between $<N_g>$ and $<N_{trk}>$

Sample	MC $<N_g>$	Data $<N_{trk}>$
W+0 jet	0.04 ±0.10	10.20±0.01
W+1 jet	0.92 ±0.10	11.20 ±0.03
W+2 jets	1.33 ±0.10	11.53 ±0.07
80-100 GeV	1.72 ±0.10	12.33 ±0.02
100-120 GeV	1.62 ±0.10	12.10 ±0.02
120-140 GeV	1.44 ±0.10	11.96 ±0.04

In this table, MC uncertainties are systematic and data uncertainties are statistical



using the fit to find $\langle N_g \rangle$ for other samples $\langle N_{trk} \rangle$

Sample	MC prediction	Fit result
140-160 GeV	1.26 ±0.04	$1.38^{+0.06}_{-0.05}$
160-180 GeV	1.14 ±0.04	1.22 ±0.05
180-200 GeV	0.99 ±0.07	$1.08^{+0.05}_{-0.06}$
200-220 GeV	0.92 ±0.10	$0.87^{+0.05}_{-0.07}$
220+ GeV	0.67 ±0.10	0.64 ±0.05

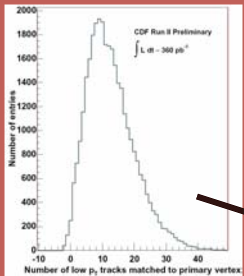
Fraction of gluon-rich events in calibration Samples

- Define and parameterize two distributions representing no-gluon and gluon-rich samples
  - ✓ F_q, W+0 jet which is almost purely qq→W
  - ✓ F_g, dijet sample with leading jet E_T of 80-100 GeV after we subtract the qq component from it, here we use PYTHIA dijet Monte Carlo calculations, an average of 2.37 gluons and 0.27 qq →qq
- Use the normalized parameterization of the two distributions in a fit to the low p_T track multiplicity distribution in any other sample

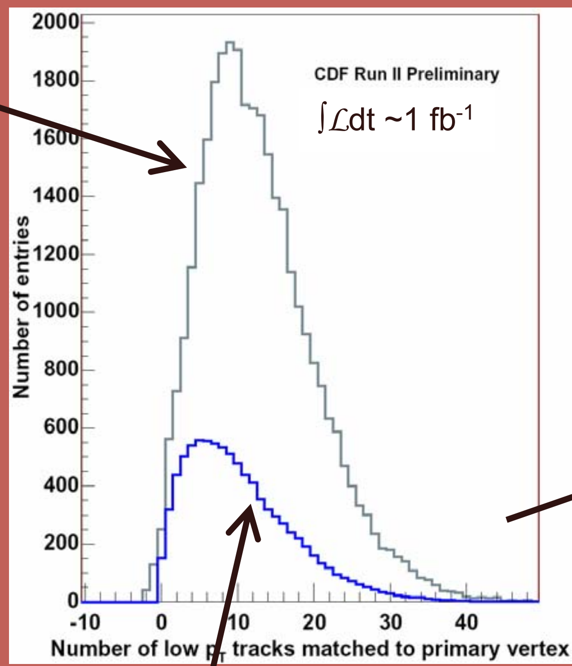
$$N[\, f_g F_g^{norm} + (1 - f_g) F_q^{norm} \,]$$

- f_g, fraction of gluon-rich events with $<N_g>$ ~ 2

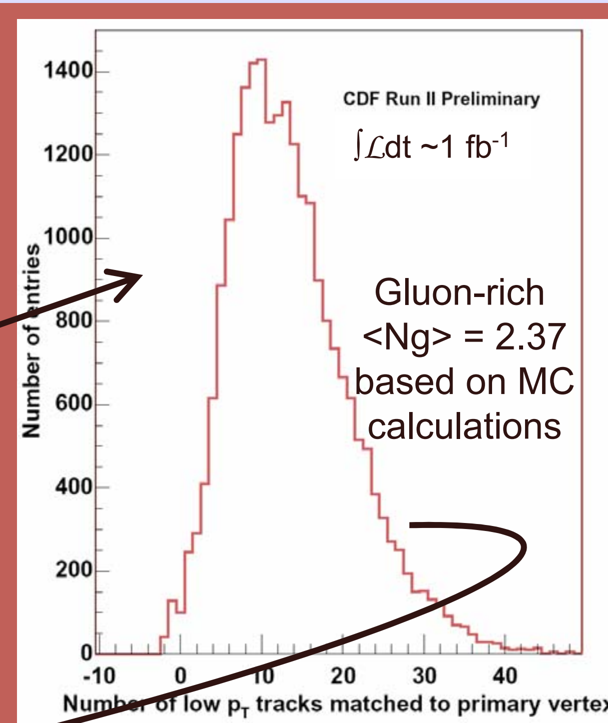
Gluon-rich and no-gluon distributions



DATA
dijet 80-100 GeV
Based on MC
27% qq → qq
<Ng> = 2.37
for the rest

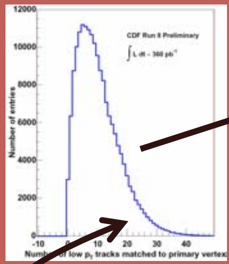


Subtract



Gluon-rich
<Ng> = 2.37
based on MC
calculations

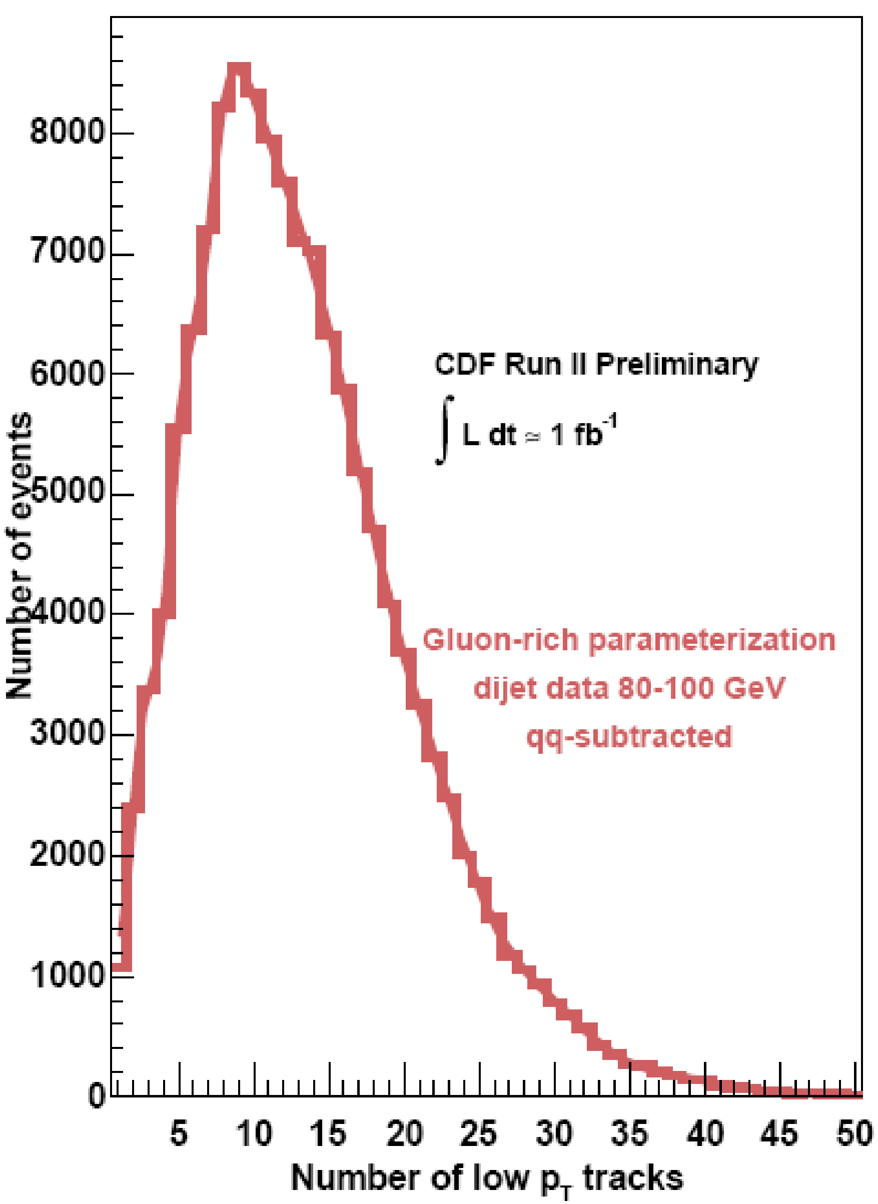
DATA
W+0 jet
Similar to
qq → qq

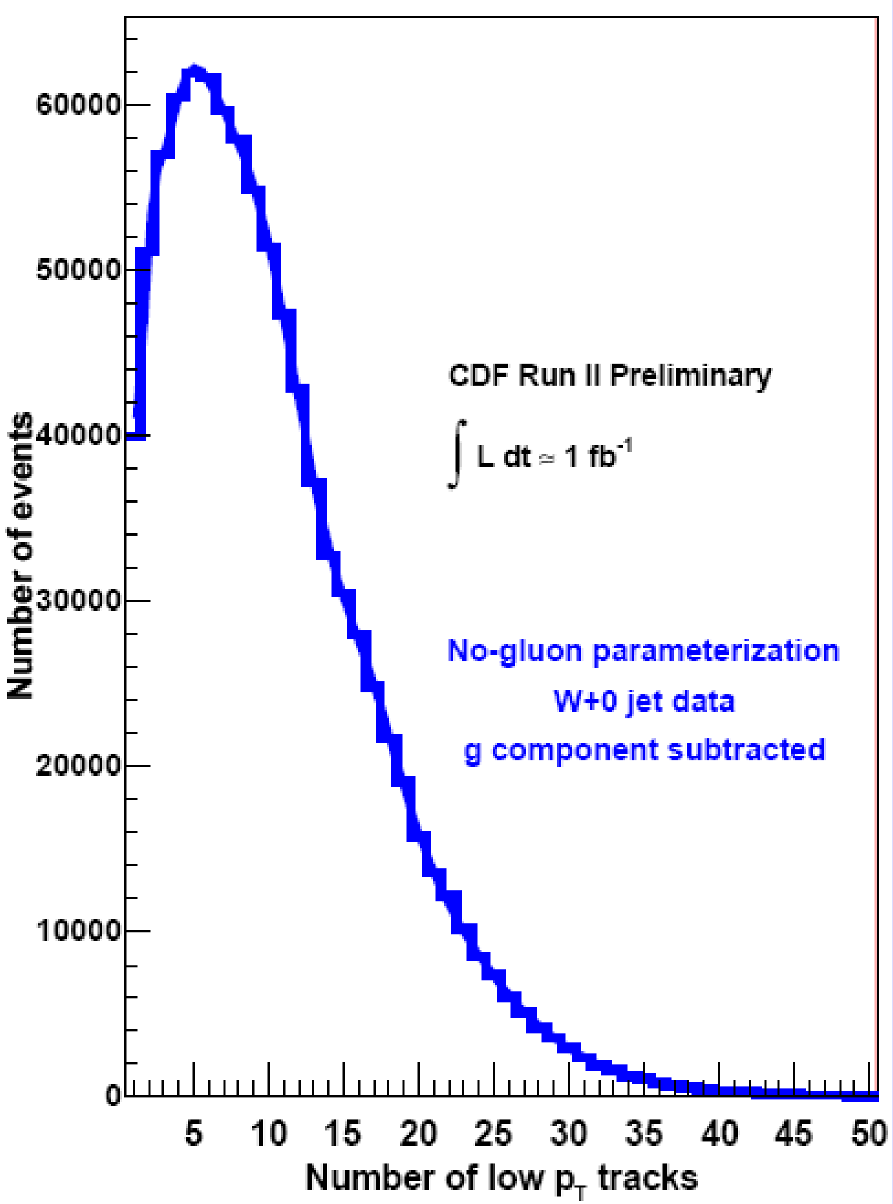


Normalized to dijet
80-100 GeV
Scaled by 0.27 to
represent qq → qq

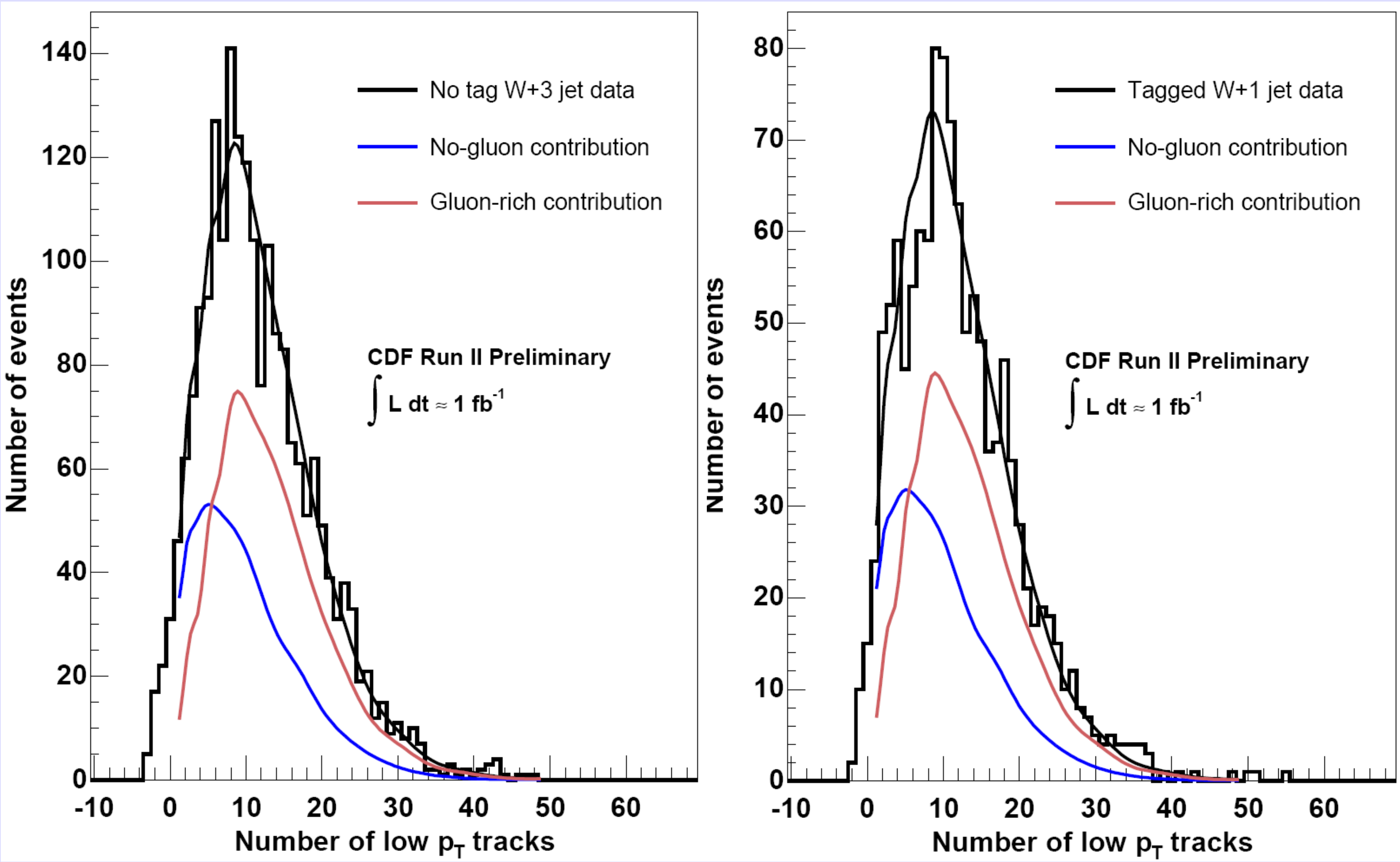
Iterate to subtract gluon contributions
from W+0 jet data distribution

Parameterization

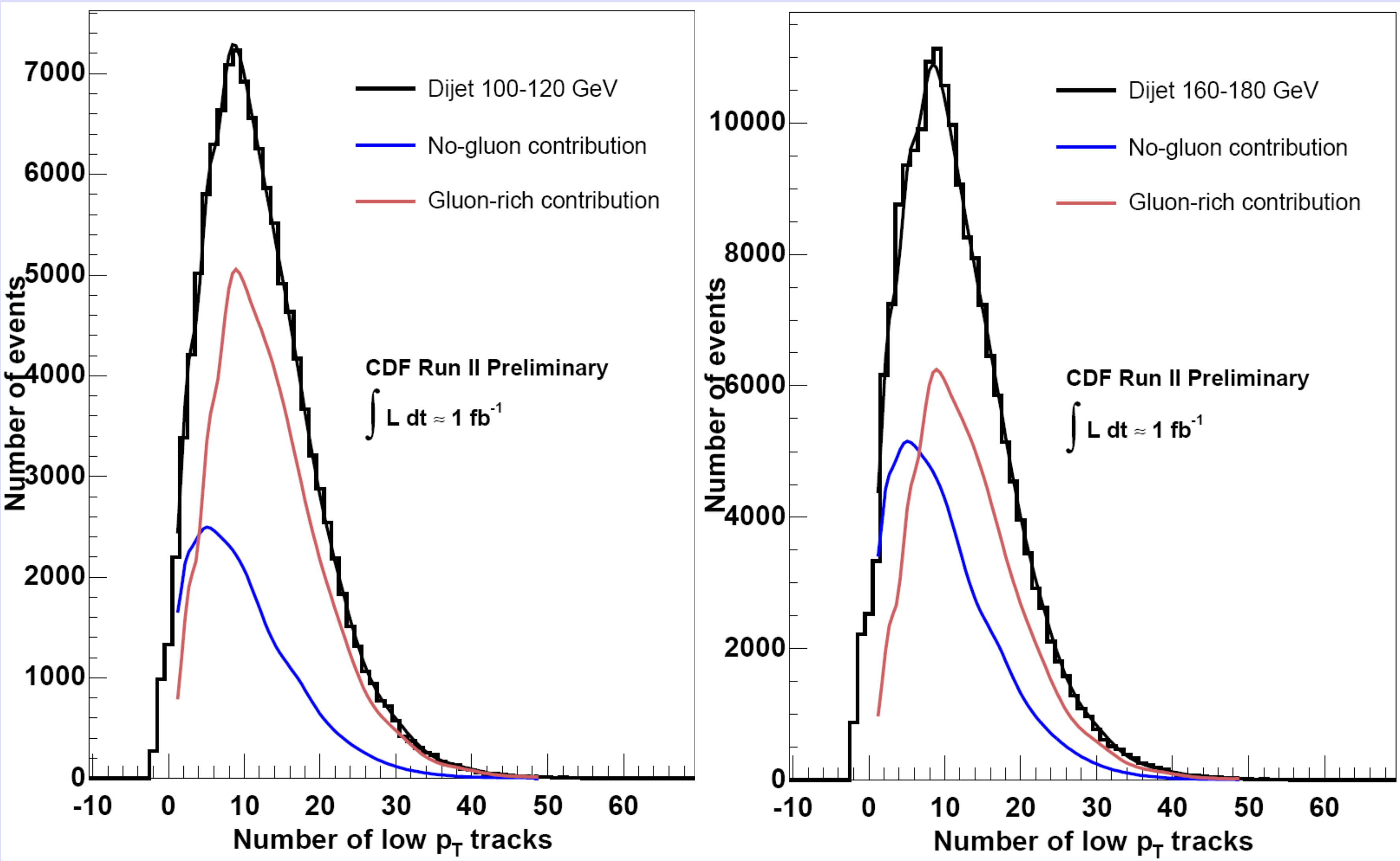




Sample fits – W+jet



Sample fits - dijet



Fit and MC values for different dijet calibration samples

Sample	f_g from fit	f_g MC
80-100 GeV	0.733 ± 0.004	0.73 ± 0.02
100-120 GeV	0.685 ± 0.006	0.69 ± 0.02
120-140 GeV	0.66 ± 0.01	0.63 ± 0.03
140-160 GeV	0.621 ± 0.005	0.57 ± 0.03
160-180 GeV	0.565 ± 0.005	0.52 ± 0.03
180+ GeV	0.481 ± 0.005	0.42 ± 0.05

- Uncertainties from fit are only statistical
- Uncertainties on MC predictions are both statistical and systematics

Fraction of gg → ttbar events

- f_g in W+≥4 jet tagged sample can be written as

$$f_g = f_{bkg} f_g^{bkg} + (1 - f_{bkg}) f_g^{tt}$$

where f_{bkg} is fraction of background in the sample, f_g^{bkg} is the gluon-rich fraction in the background and f_g^{tt} is the fraction of gluon-rich events in the ttbar signal that can be found as

$$f_g^{tt} = \frac{f_g - f_{bkg} f_g^{bkg}}{1 - f_{bkg}}$$

Extracting relative cross section

- From f_g^{tt} , we can get the relative cross section of gg→tt

$$f_{gg}^{true} = \frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = f_g^{tt} \frac{A_{p\bar{p}\to t\bar{t}}}{A_{gg\to t\bar{t}}}$$

- To reduce the theoretical uncertainties in the estimate of acceptance for pp→tt, using

$$A_{p\bar{p}\to t\bar{t}} = f_{gg}^{true} A_{gg\to t\bar{t}} + (1 - f_{gg}^{true}) A_{q\bar{q}\to t\bar{t}}$$

- We measure the fractional cross section as

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = \frac{1}{1 - (A_{gg\to t\bar{t}} / A_{q\bar{q}\to t\bar{t}}) + (A_{gg\to t\bar{t}} / A_{q\bar{q}\to t\bar{t}})(1 / f_g^{tt})}$$

Estimating gluon-rich fraction in background - I

- For both tagged and no-tag
  - ✓ Extrapolate from W+1, 2 and 3 jet gluon-rich fraction
  - ✓ Average the estimates for the 4 and 5 jet bins
  - ✓ No-tag sample represents LF background
  - ✓ Tagged sample represents HF background
- Add the averaged extrapolated gluon-rich fractions weighted by the relative size of HF and LF background
- Given the low contribution of background, specially HF portion, we do not correct for ttbar events present in W+2 and W+3 jet tagged sample, as this requires an assumption of the gg$\rightarrow$ttbar fraction.

Estimating gluon-rich fraction in background - II

Sample	f_{g} - no tag	f_{g} - tagged
W+1 jet	0.38 ± 0.01	0.60 ± 0.06
W+2 jet	0.51 ± 0.02	0.36 ± 0.08
W+3 jet	0.60 ± 0.04	0.34 ± 0.13
Extrapolated W+4^{+} jet, (f_g^{LF}) (f_g^{HF})	0.80 ± 0.05	0.02 ± 0.22
LF fraction in background (f_b^{LF})	-	0.65 ± 0.17
HF fraction in background (f_b^{HF})	-	0.35 ± 0.11

- We calculate f_g^{bkg} assuming Gaussian distributions for the variables used in the following equation using the above values

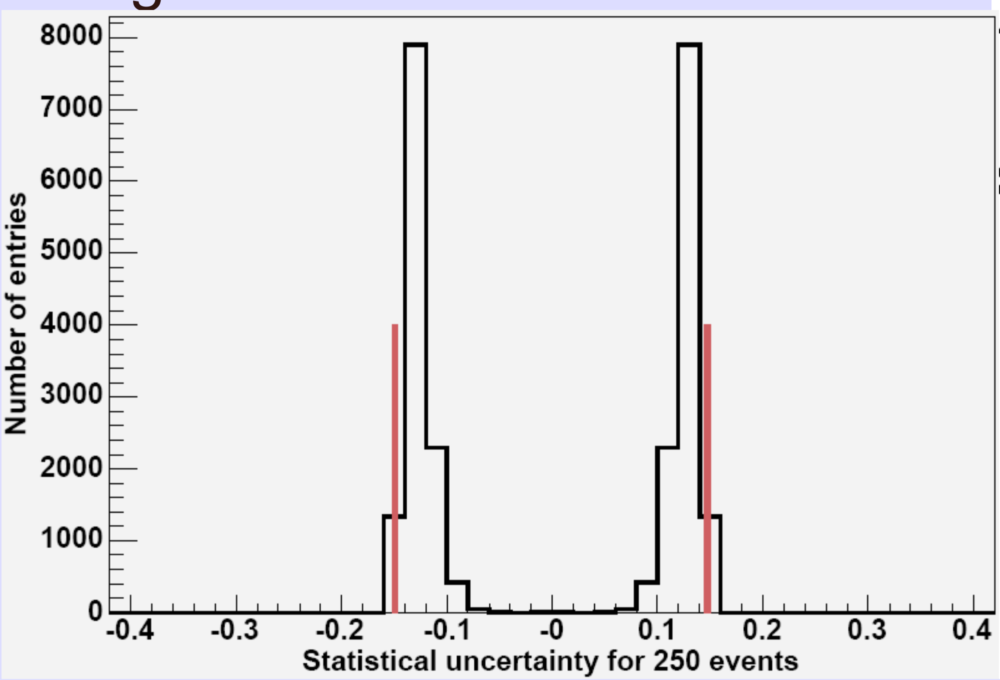
$$f_g^{bkg} = f_b^{LF} f_g^{LF} + f_b^{HF} f_g^{HF}$$

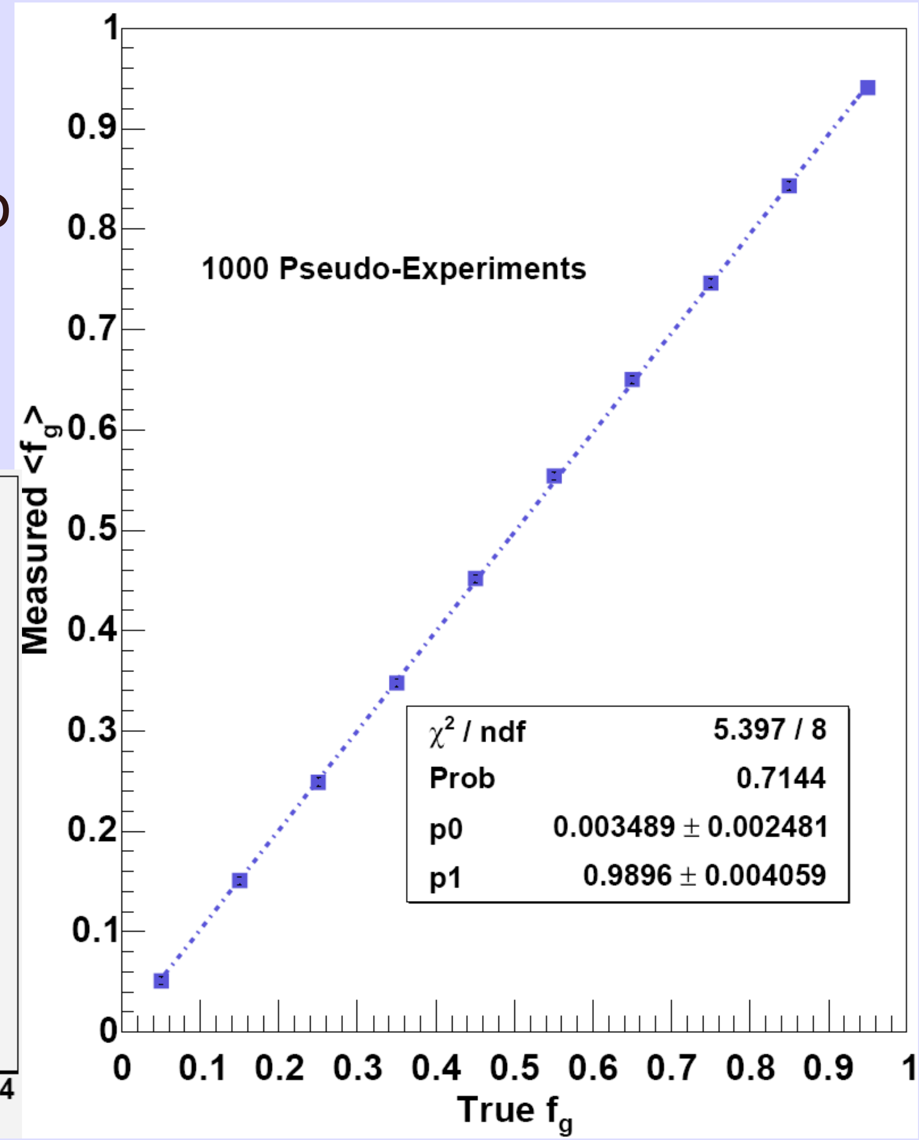
- We find $f_g^{bkg} = 0.58 \pm 0.08$

- HF background is anything that can have a real tag (Wc, Wcc, Wbb, Single Top) and the rest is what we consider LF

Pseudo-experiments

- Perform 1000 pseudo-experiments with 250 events, using the parameterizations to generate the track multiplicity distributions for different true gluon-rich fractions





Systematic uncertainties-I

- Uncertainties affecting track multiplicity
  - ✓ Change the central values and observe the changes in relevant variables

	f_g	f_g^{bkg}
Track/jet correction	±0.052	±0.015
Low jet E_T cut	±0.012	±0.034
Dijet qq→qq fraction	±0.004	±0.025
W+0 jet f_g	±0.034	±0.005
Total	±0.06	±0.042*

*This should be combined with ±0.08 uncertainty from f_g^{bkg} calculation described on slide 20

Systematic uncertainties-II

- Uncertainties due to f_g, f_g^{bkg} and f_b

	f_g^{tt}
f_g	±0.07
f_g^{bkg}	±0.01
f_b	±0.01
Total	±0.07

Systematic uncertainties-III

- Uncertainties due to f_g^{tt} and acceptances

	$\sigma(gg \to tt)/\sigma(pp \to tt)$
f_g^{tt}	± 0.06
$\mathcal{A}_{gg \to tt}$	± 0.002
$\mathcal{A}_{qq \to tt}$	± 0.002
Total	± 0.06

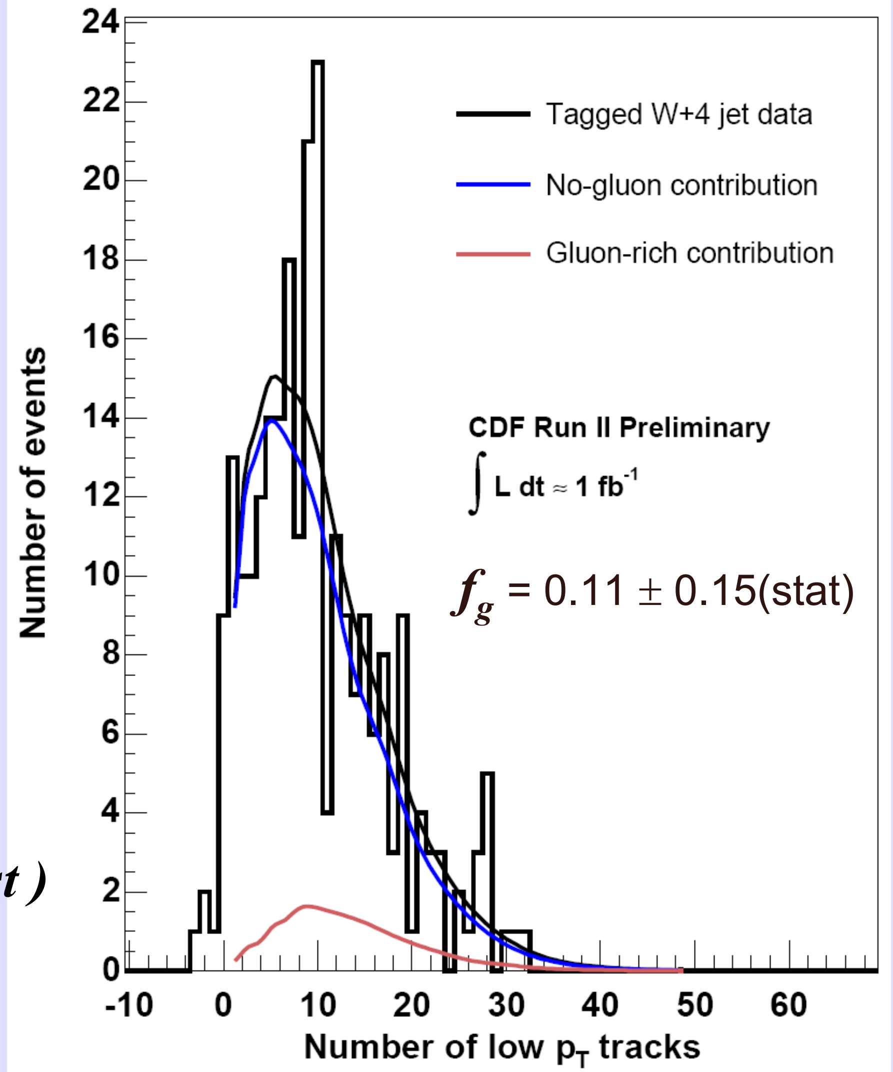
Result

- Using the values we found, and a background fraction of (10 ± 2)%, we get

$$f_g^{tt} = 0.06 \pm 0.15(stat) \pm 0.07(syst)$$

- And using a ttbar acceptance of 0.060 ± 0.002 and 0.052 ± 0.002 for gg fusion and qqbar respectively, we find

$$\frac{\sigma(gg \to t\bar{t})}{\sigma(p\bar{p} \to t\bar{t})} = 0.05 \pm 0.14(stat) \pm 0.06(syst)$$



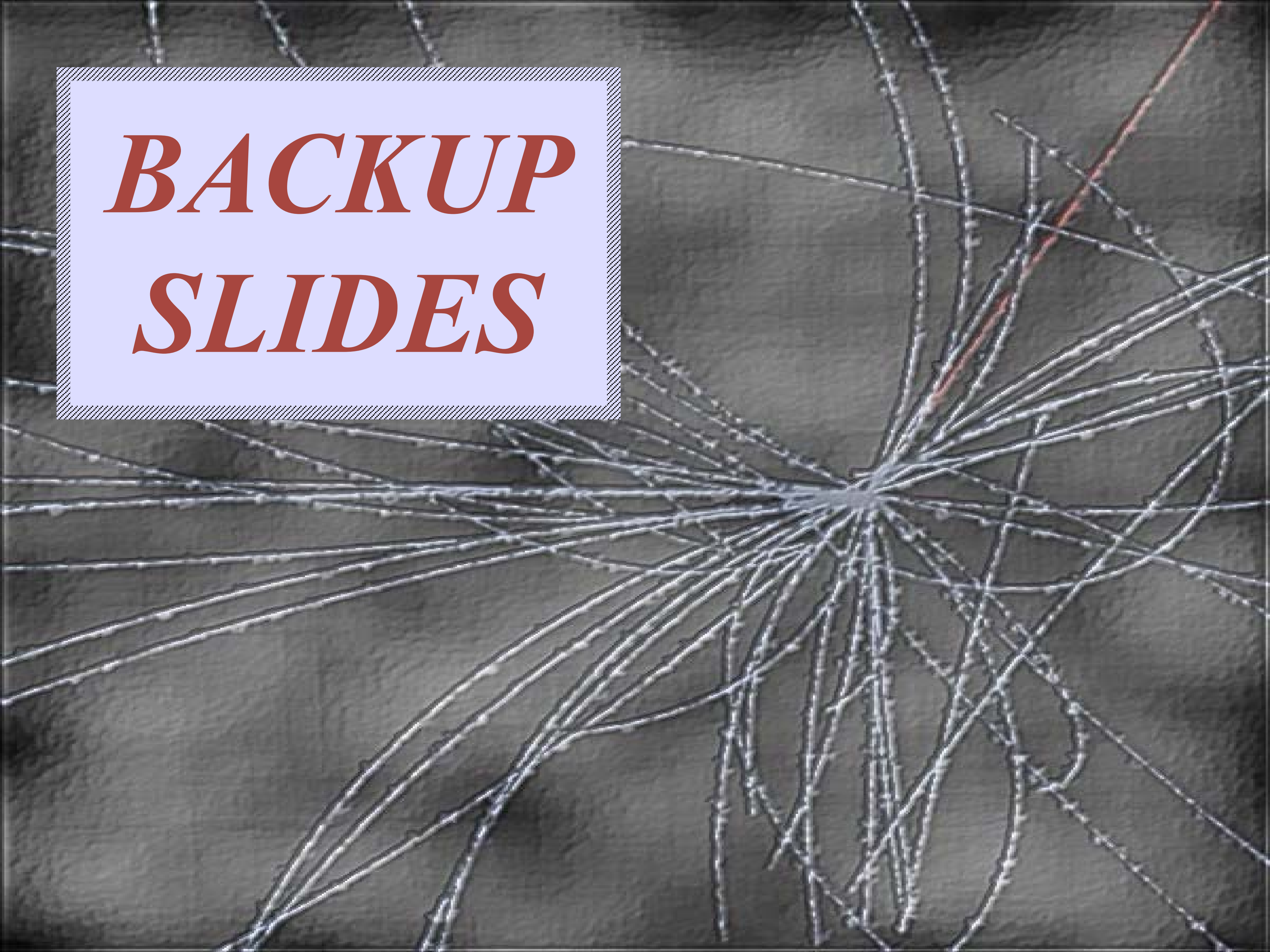
Summary/Outlook

- We have used 1 fb^{-1} of data and measured

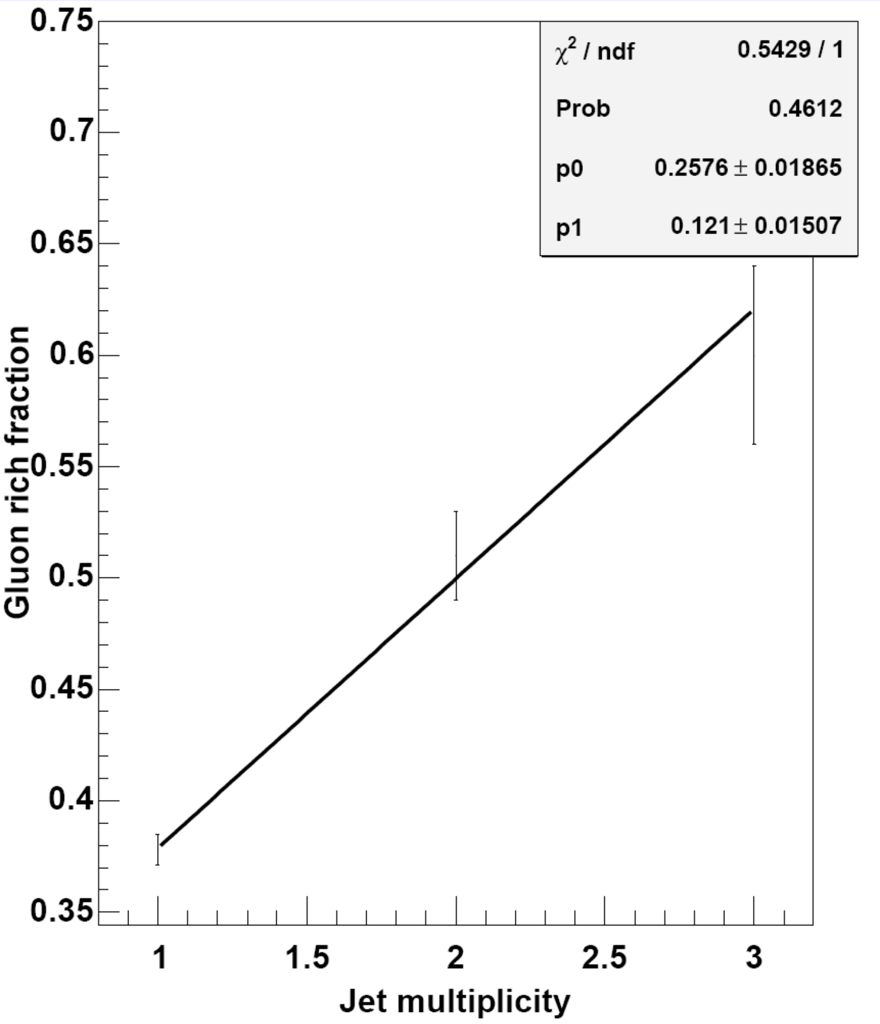
$$\frac{\sigma(gg \rightarrow t\bar{t})}{\sigma(p\bar{p} \rightarrow t\bar{t})} = 0.05 \pm 0.14(stat) \pm 0.06(syst)$$

- We showed the measurement method and sources for systematic uncertainties (6%)
- The plan is to BLESS on January 31st

BACKUP SLIDES



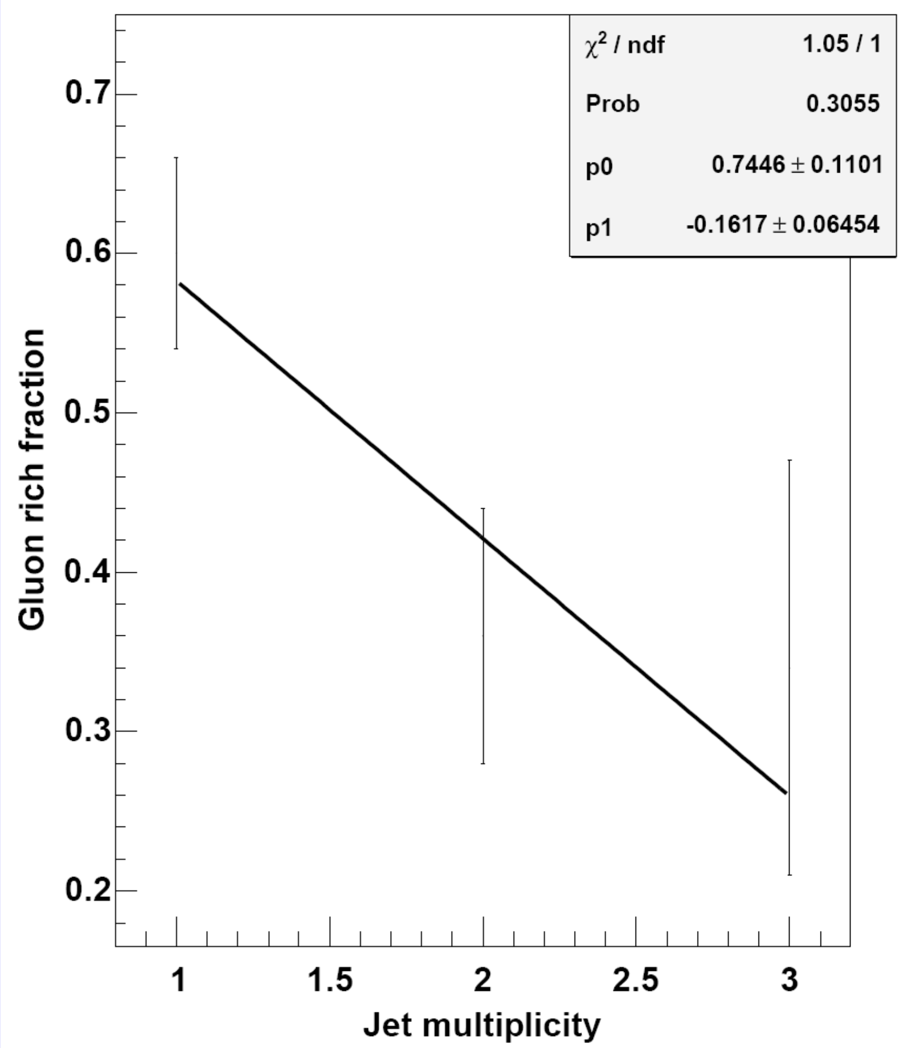
gluon-rich fraction in bkg, no tag samples



- 4 jet: 0.74 ± 0.06
- 5 jet: 0.86 ± 0.08

- Estimated LF gluon-rich fraction:
  - ✓ 0.80 ± 0.05

gluon-rich fraction in bkg, tagged samples



- 4 jet: 0.10 ± 0.28
- 5 jet: -0.06 ± 0.34

- Estimated HF gluon-rich fraction:
  - ✓ 0.02 ± 0.22

Gluon-rich fraction of background