

# Latest QCD results from CDF

*Sofia Vallecorsa*  
for the CDF collaboration



UNIVERSITÉ DE GENÈVE



# Qcd @ CDF

- HIGH PT
  - INCLUSIVE JET CROSS SECTION
  - BOSONS + JETS
  - SEARCH FOR W/Z HADRONIC DECAYS IN  $\gamma$  EVENTS
- HEAVY FLAVOUR
  - INCLUSIVE b-JET CROSS SECTION
  - bb DI-JET CROSS SECTION
  - $\gamma$  + HEAVY FLAVOUR PRODUCTION
  - b-JET SHAPES
- UE, FRAGMENTATION
  - UNDERLYING EVENTS IN INCLUSIVE JET
  - TWO PARTICLE MOMENTUM CORRELATION IN JETS
  - $K_T$  DISTRIBUTION OF PARTICLE IN JETS
- DIFFRACTION
  - DIFFRACTIVE DI-JET PRODUCTION
  - EXCLUSIVE  $\gamma\gamma$

# Collider Detector at Fermilab

TEVATRON HAS DELIVERED  
MORE THAN  $2 \text{ fb}^{-1}$

CDF FULLY UPGRADED FOR RUN II:

- SI TRACKING
- EXTENDED CALORIMETERS RANGE
- L2 TRIGGER ON DISPLACED TRACKS
- HIGH RATE TRIGGER/DAQ



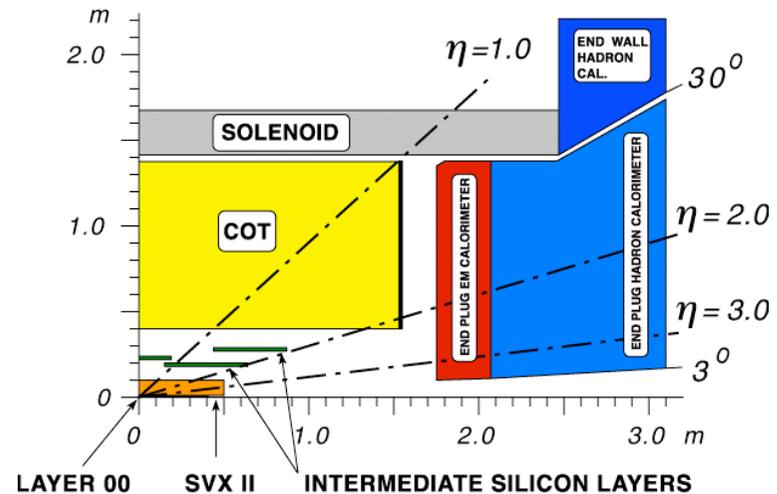
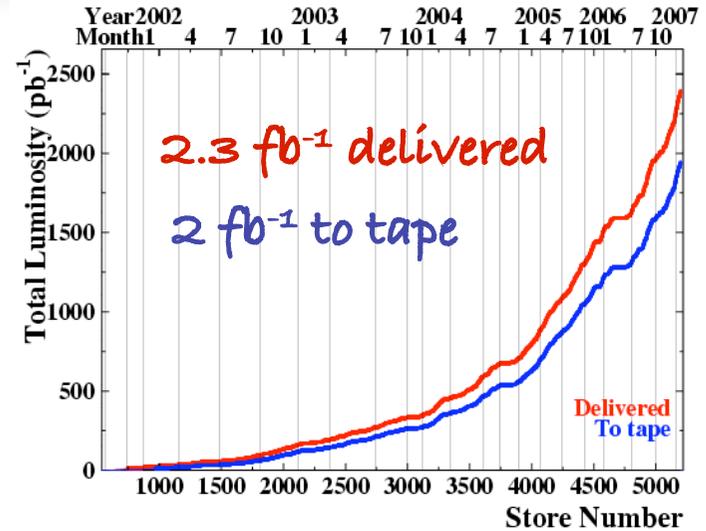
>80% DAQ EFFICIENCY

## CALORIMETER

- CEM LEAD + SCINT  $13.4\%/\sqrt{E_T} \oplus 2\%$
- CHA STEEL + SCINT  $7.5\%/\sqrt{E_T} \oplus 3\%$

## TRACKING

- $\sigma(d_0) = 40 \mu\text{m}$  (INCL.  $30 \mu\text{m}$  BEAM)
- $\sigma(P_T)/P_T = 0.15\% P_T$



# Inclusive jet cross section

ALREADY SHOWN @ LAKE LOUISE: MEASUREMENT @ 385 pb<sup>-1</sup>

- HIGHEST Q<sup>2</sup> SCALE CURRENTLY ACHIEVABLE
- WIDE PT RANGE
- 5 RAPIDITY REGIONS:
  - SENSITIVITY TO PDF OVER A BROAD KINEMATIC RANGE
  - MEASUREMENT AT LARGE X

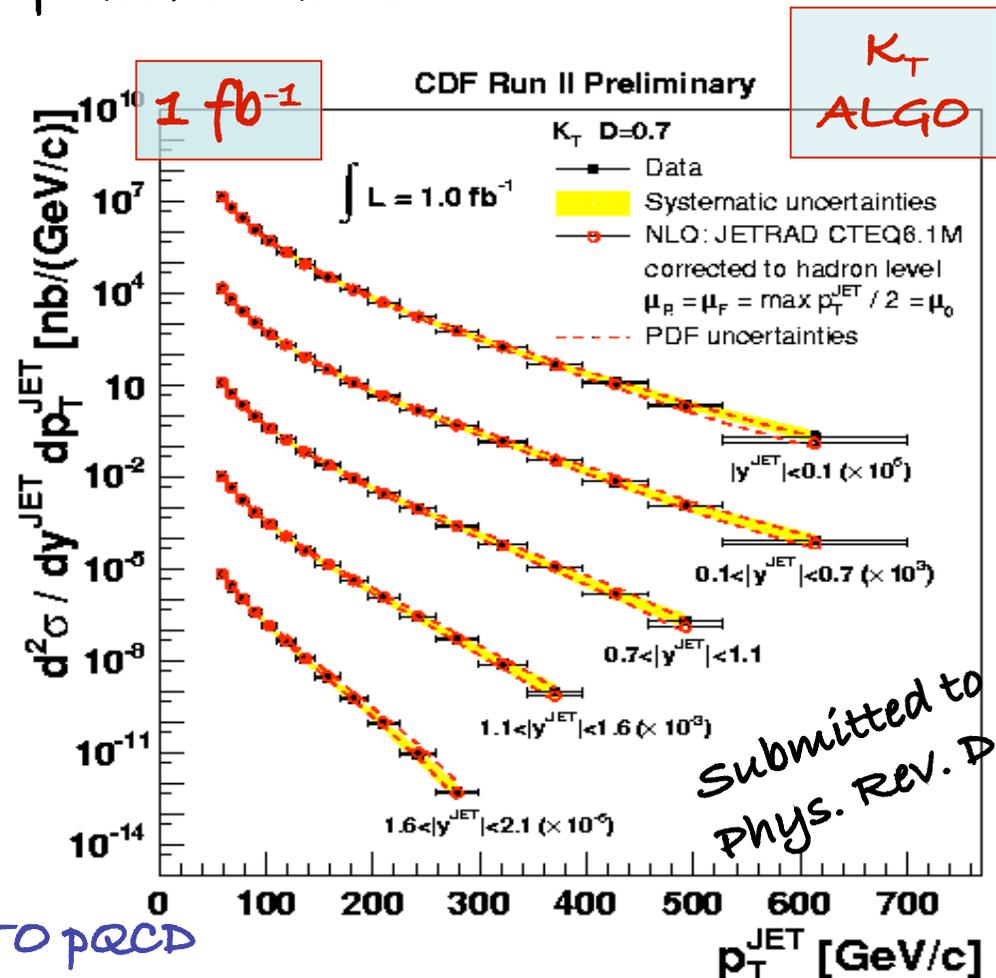


CONSTRAINTS GLUON PDFS

- TWO INDEPENDENT MEASUREMENTS:
  - CONE CLUSTERING ALG.
  - K<sub>T</sub> CLUSTERING ALG.



FUNDAMENTAL TEST TO pQCD



Heavy flavours

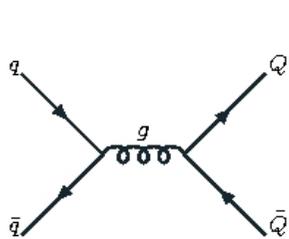
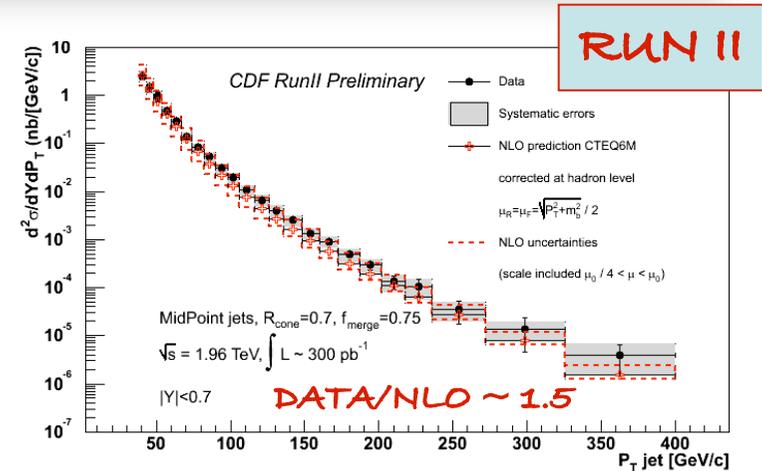
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# b quark production

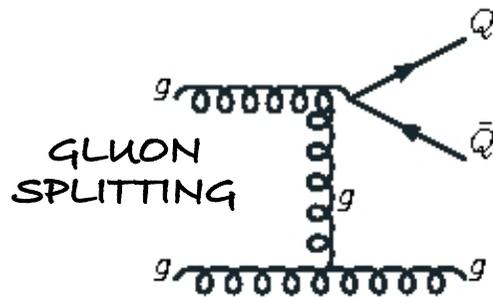
CDF HAS ALREADY MEASURED THE INCLUSIVE B-JET CROSS SECTION



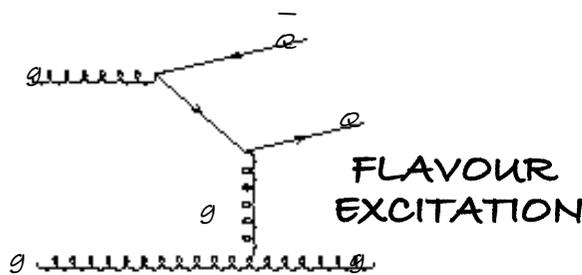
- **bb** CROSS SECTION AND CORRELATION GIVE A HINT ON B PRODUCTION MECHANISM
- GOOD TEST TO NLO VS LO PREDICTIONS



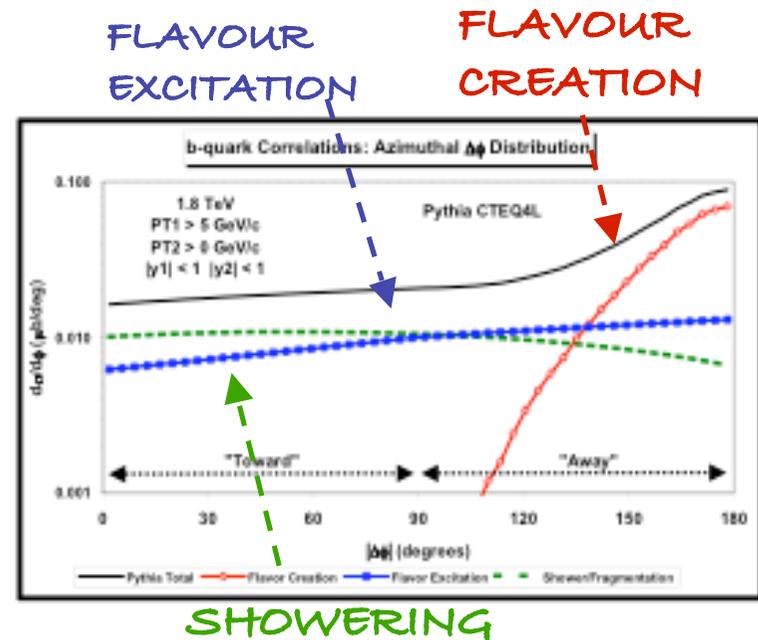
FLAVOUR CREATION



GLUON SPLITTING



FLAVOUR EXCITATION

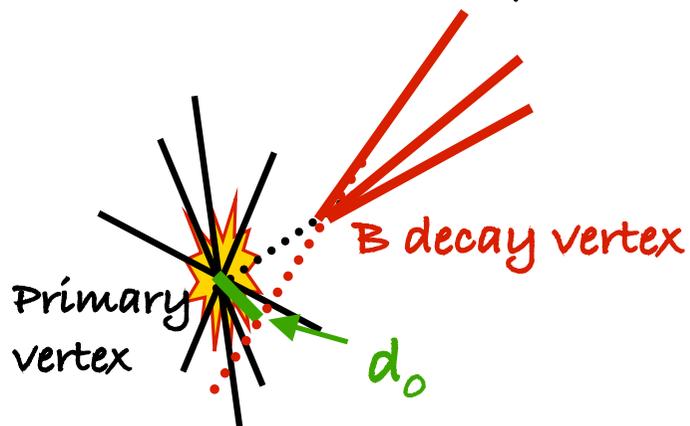


# Silicon Vertex Trigger

$\sigma(bb) \sim 50 \mu\text{b}$  @ 1.96 TeV

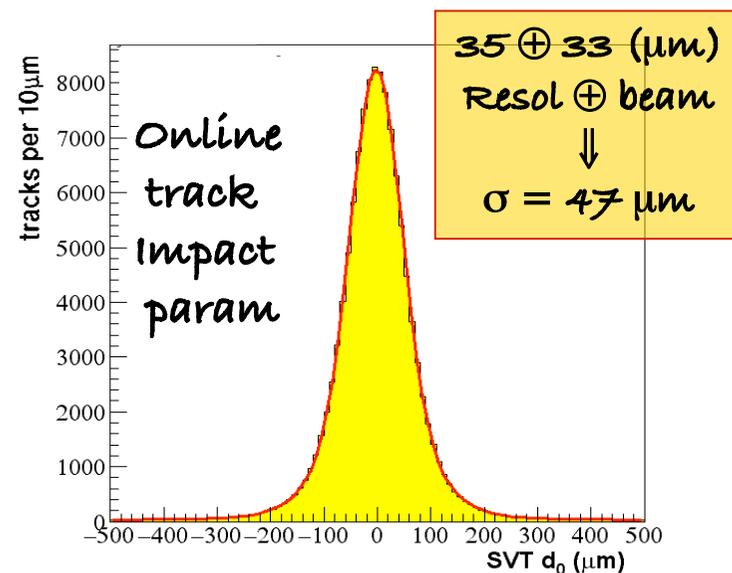
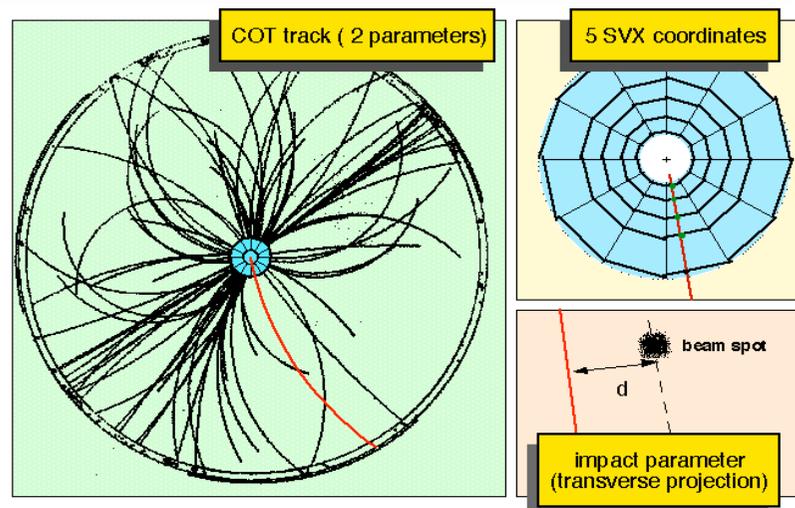
-> RATE OF FEW KHZ

BUT 3-4 TIMES LOWER GENERIC QCD



DEDICATED **IMPACT PARAMETER TRIGGER**  
LONG LIFETIME ( $\sim 1.5$  PS) OF B-HADRON  
BASED ON SILICON DETECTOR HITS  
AND L1 FAST TRACKING INFO

@ HIGH PT:  
SEARCH FOR NEW PHYSICS  
NEW FOR QCD STUDIES

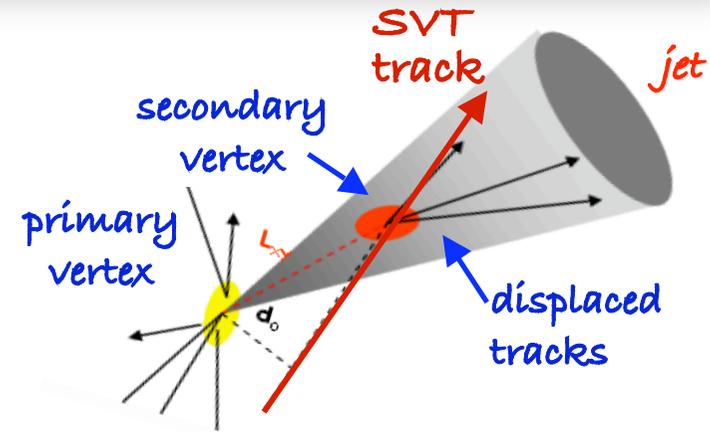
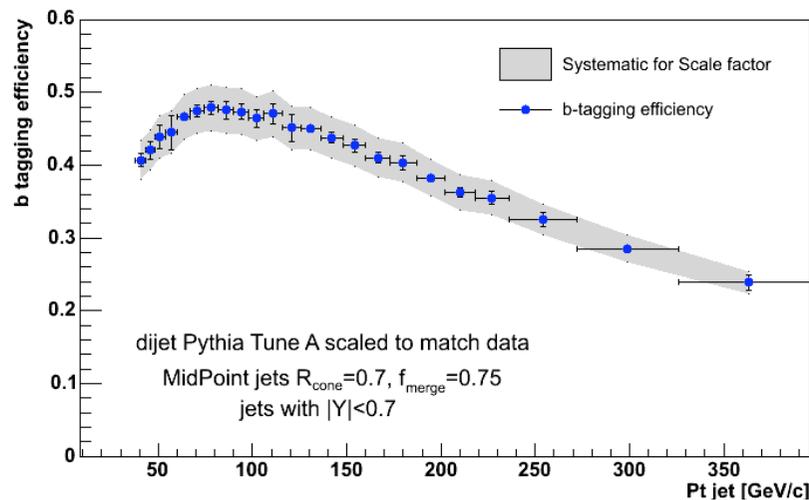


# Identifying b-jets

## 1. B-TAGGING:

### SEARCHING FOR THE B DECAY VERTEX

- RECONSTRUCTING THE SECONDARY VERTEX
- CUT ON  $L_{xy}$  SIGNIFICANCE  
(DISTANCE PRIMARY-SECONDARY VERTEX)



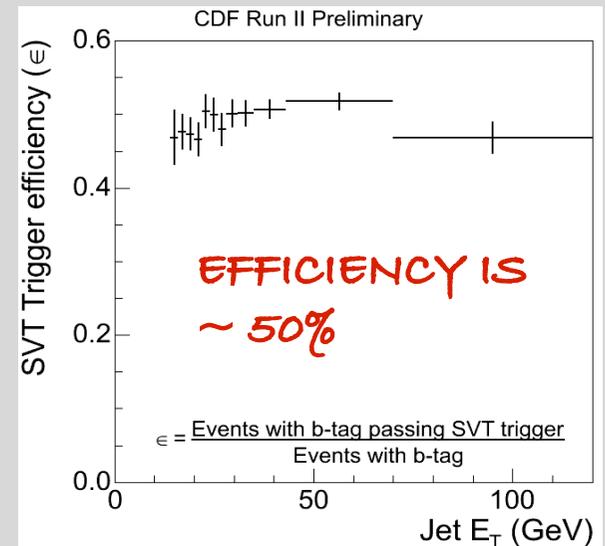
## 2. B-PURITY OF TAGGED JETS:

INVARIANT MASS OF THE SECONDARY VERTEX IS DIFFERENT IF B/C/LIGHT



**BUILT TEMPLATES IN MC  
FIT THE SHAPE**

## SVT TRIGGER EFF. FOR B-TAGGED JETS



SVT-TRIGGERED  
260 pb<sup>-1</sup>

# $b\bar{b}$ di-jet cross section

2 SVT TRACKS AT TRIGGER LEVEL

SELECT EVENTS WITH:

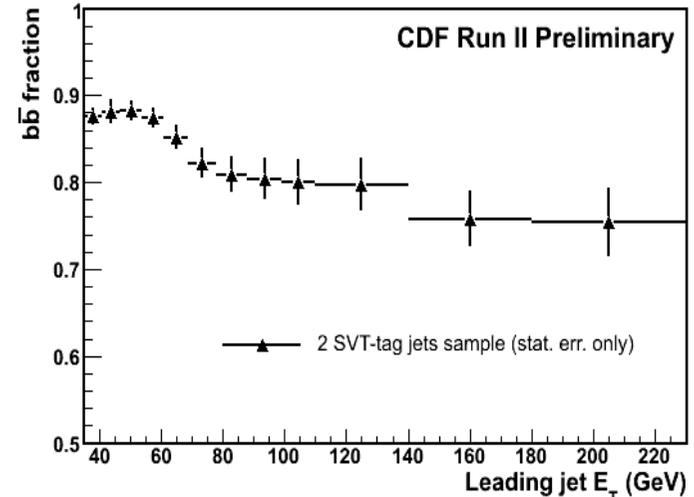
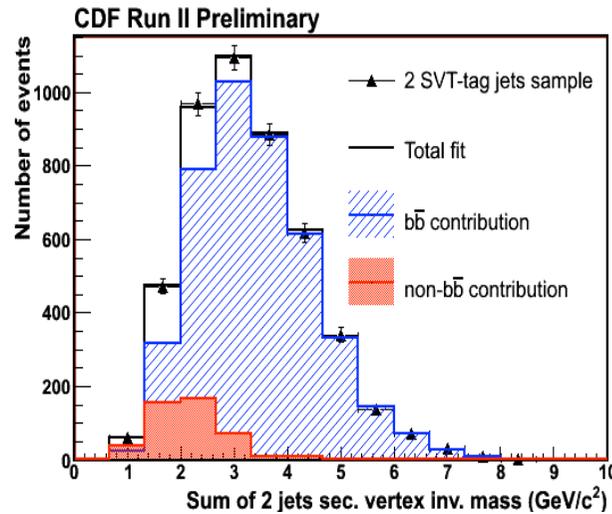
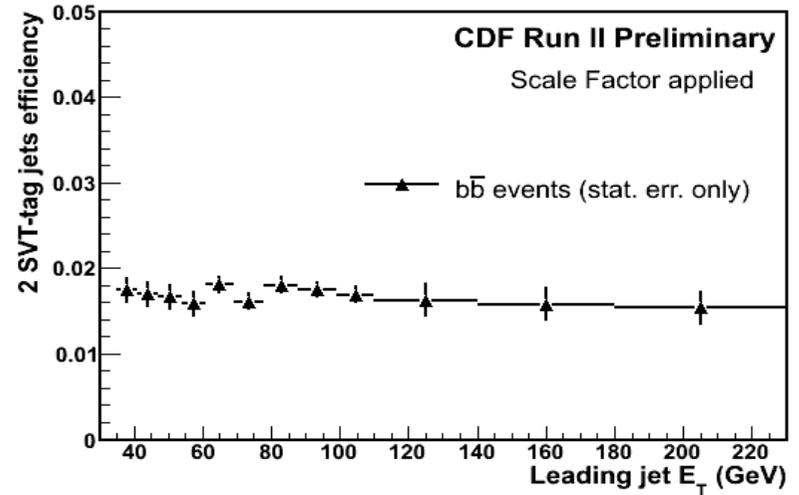
- 2 SVT TRACKS  $|d_o| > 120 \mu\text{m}$
- 2 B-TAGGED JET (CONE 0.4)  
 $E_T > 35, 32 \text{ GeV}, |\eta| < 1.2$
- TRACK - JET MATCHING

NEED A TIGHT SELECTION TO  
ACCOUNT FOR EVENT SHAPING BY  
THE TRIGGER

$b\bar{b}$  PURITY:  
SUM  
OF 2 JETS  
SEC. VTX  
INVARIANT MASS

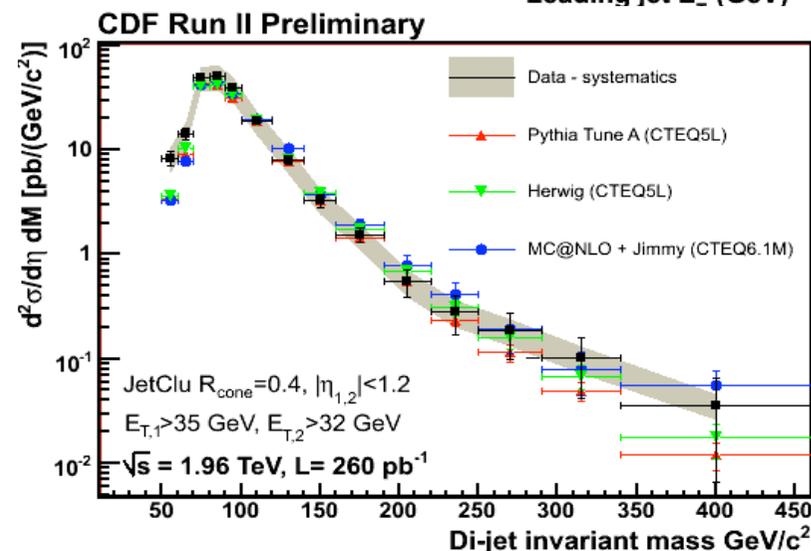
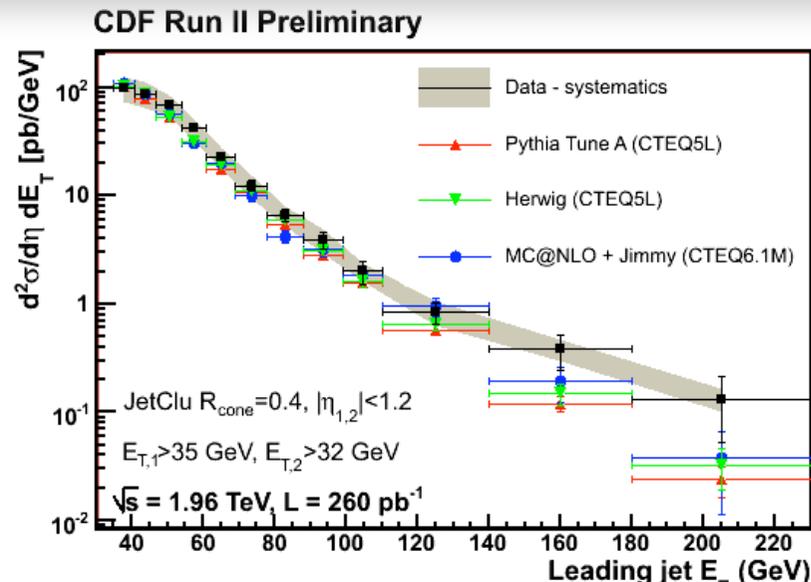
FIT DATA

Low efficiency  
BUT very high purity > 80%



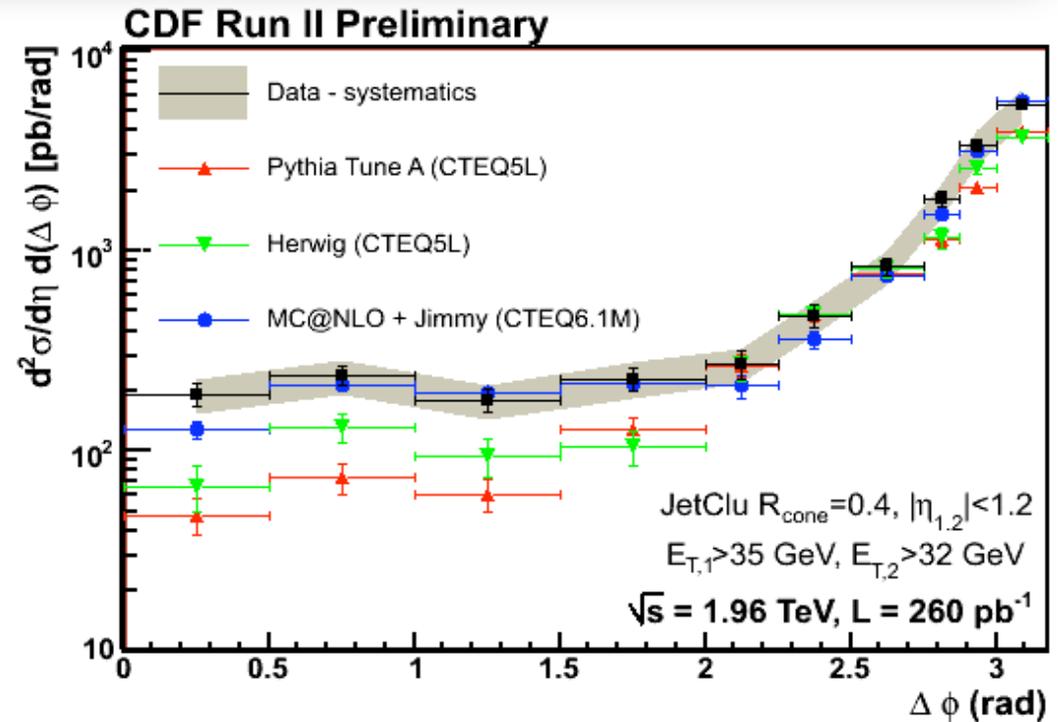
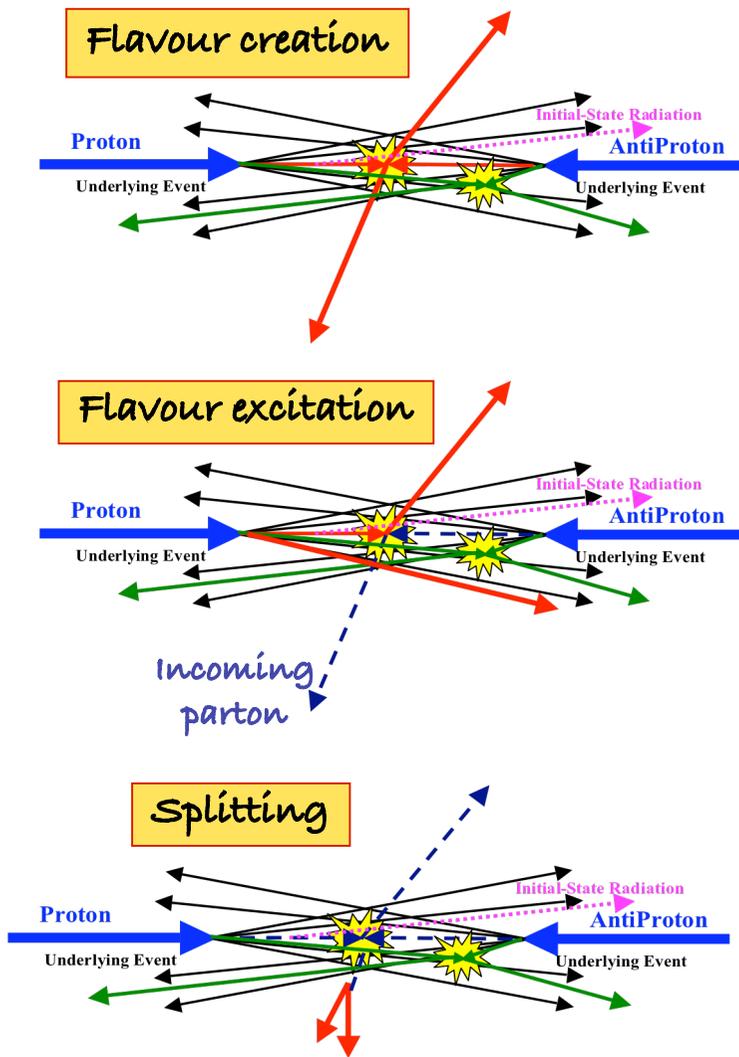
# $b\bar{b}$ di-jet cross section

- SPECIFIC  $b$ -JET CORRECTIONS:
  - HARDER FRAGMENTATION
  - $B$ -HADRON DECAYS
- DATA IS UNFOLDED TO MC HADRON LEVEL
- SYSTEMATICS:
  - JES (15%-20%),
  - $B$ -JET PURITY (7%)
  - TAGGING EFFICIENCY (5%)
- COMPARISON TO MC (PRELIMINARY):
  - LO PYTHIA (TUNE A)\*
  - AND HERWIG
  - NLO MC@NLO + JIMMY (UE)



\* tuned on Run I data for UE

# $b\bar{b}$ di-jet cross section



MC@NLO IS CLOSER TO DATA THAN PYTHIA OR HERWIG:

- NLO CALCULATION
- DIFFERENT UE MODELING (MULTIPLE INTERACTION - JIMMY)

WHAT IS THE AGREEMENT DUE TO ?

SVT-TRIGGERED  
208 pb<sup>-1</sup>

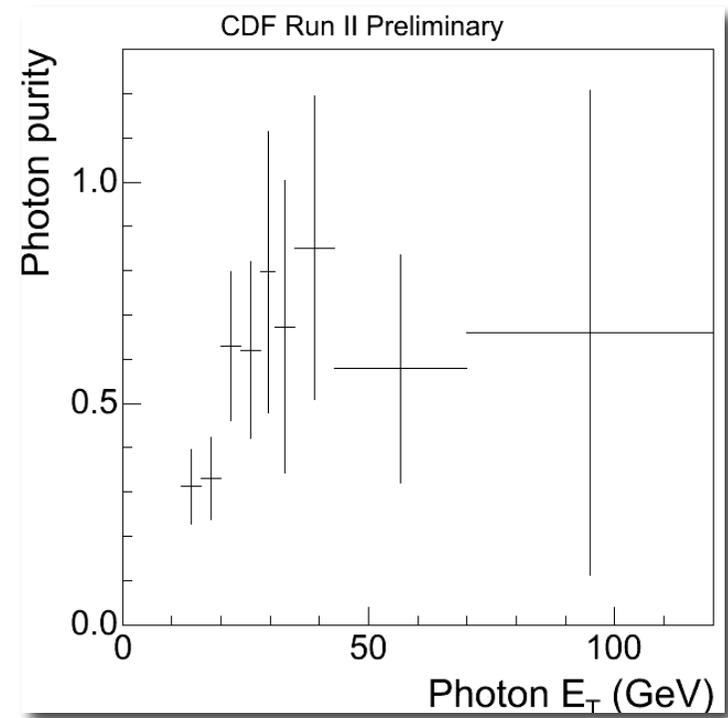
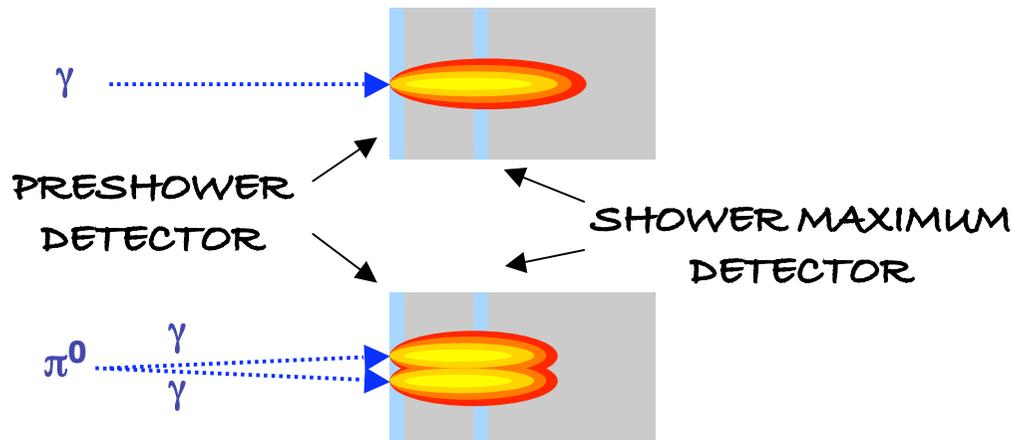
# Photon + b-jet production

SVT TRACK + PHOTON AT TRIGGER LEVEL

PROMISING CHANNEL TO LOOK FOR DEVIATION FROM SM (NEW PHYS.)  
SENSITIVE TO  $b$  CONTENT IN THE  $p$  → PDF (QCD)

PHOTON SELECTION:

- $E_T > 12$  GEV,  $|\eta| < 1.1$
- $\gamma/\pi^0$  BAKGD is STATISTICALLY SEPARATED USING SHOWER SHAPE IN CPR & CMX



SVT-TRIGGERED  
208 pb<sup>-1</sup>

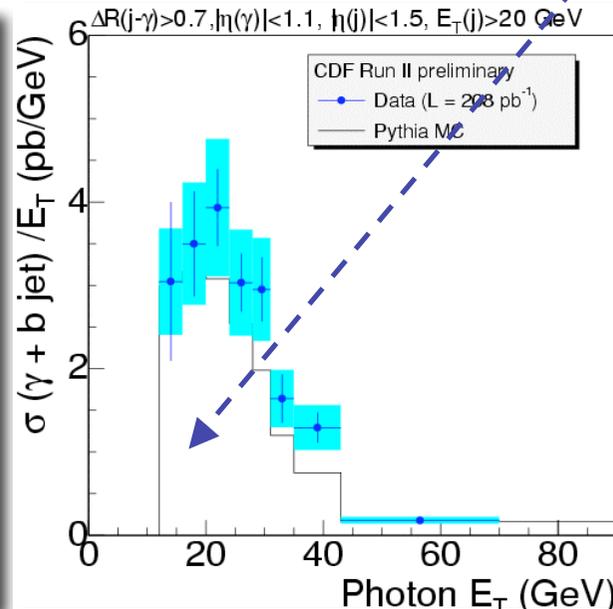
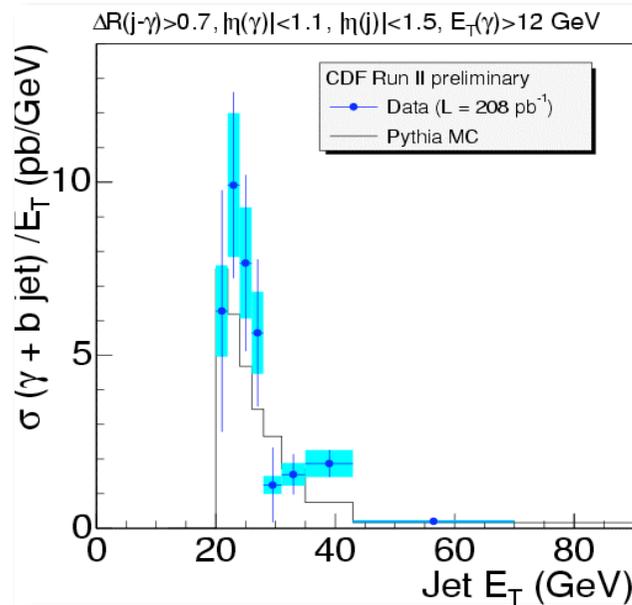
# Photon + b-jet production

## JET SELECTION:

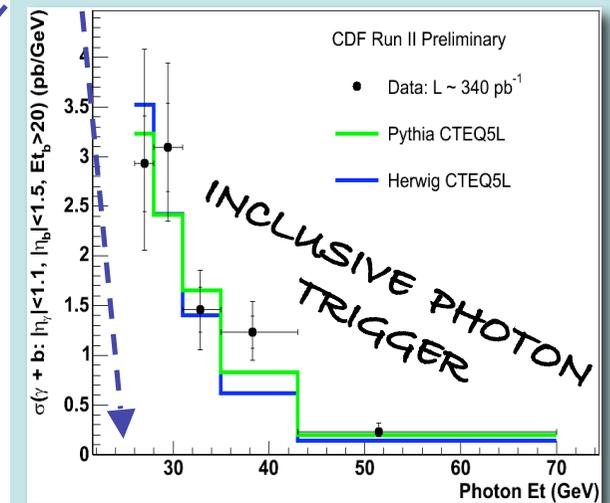
- B-TAG. JET  $E_T > 20$  GeV  $|\eta| < 1.5$
- BJET PURITY FROM SEC. VERTEX MASS

## MAIN SYSTEMATICS:

- TRIGGER EFFICIENCY 10%
- TAGGING PURITY 10-20%
- PHOTON BKGD 6%



LOWER THRESHOLD ON  $\gamma$   $E_T$  THAN PREVIOUS MEASUREMENT

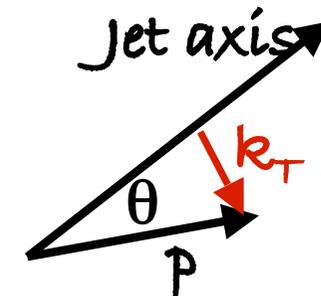


# Jet fragmentation

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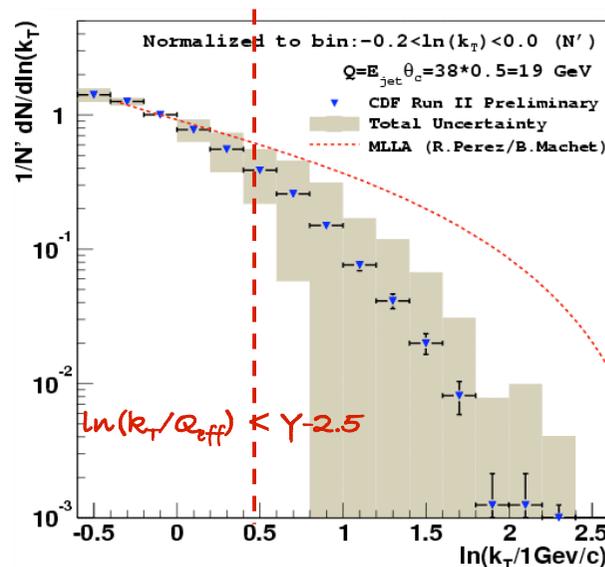
# Particle $k_T$ inside the jet

- PROBES REGION THE BOUNDARY BETWEEN:
  - PERTURBATIVE PARTON SHOWER
  - NON-PERTURBATIVE HADRONIZATION
- FIRST COMPARISON TO  
Modified Leading Log Approximation CALCULATION\*
- PROBE SOFT PARTICLE SPECTRUM,  $P/E_{JET} \sim 0.1$
- CENTRAL DIJET EVENTS
- 8  $M_{jj}$  BINS
- JET  $\Delta R = 1.0$
- TRACKS IN  $\Delta R < 0.5$

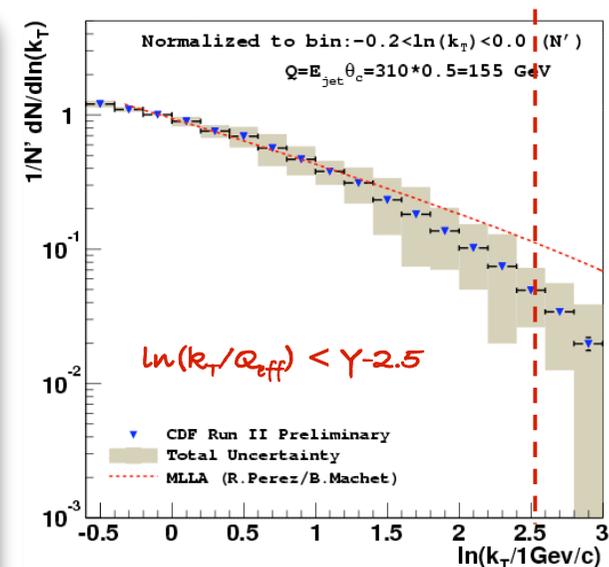


DATA SHOWS FEWER PARTICLES AT LARGE  $k_T$

BETTER AGREEMENT AT LARGE ENERGY SCALE  $Q$



$\langle M_{jj} \rangle = 76 \text{ GeV}/c^2$



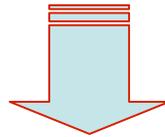
$\langle M_{jj} \rangle = 620 \text{ GeV}/c^2$

\*Perez-Ramos & Machet, JHEP 04 (2006) 043

# Summary

## JUST A GLIMPSE TO THE WIDE QCD PROGRAM @CDF

- INCLUSIVE JET CROSS SECTION
- FIRST USE OF THE SVT TRIGGER TO STUDY HEAVY FLAVOUR IN QCD PROCESSES:
  - $b\bar{b}$  CROSS SECTION
  - $b + \gamma$  PRODUCTION
- FIRST COMPARISON MLLA TO KT DISTRIBUTION IN THE JET



TEST pQCD AND CONSTRAIN PDFs OVER A WIDE KINEMATIC RANGE

TEST THEORETICAL APPROX. AND TUNE MCs  
HELP UNDERSTAND HADRON COLLIDER ENVIRONMENT AND  
BACKGROUND TO « GOLDEN ANALYSES »