Status of QCD, Charm and Bottom Physics at CDF

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On behalf of the CDF Collaboration

Fermilab Wine & Cheese, March 2004
In this talk...

A lot of analyses are in progress at CDF, here not at all exhaustive summary!

I will show mostly new results...

**QCD/Jets Physics Today’s Topics:**
- Inclusive jet cross-section
- Underlying event studies
- \( W + n \) jets
- Diphoton events
- \( \gamma + b/c \) cross-sections

**B/C Physics Today’s Topics:**
- \( B \) lifetimes in exclusive channels
- \( B_s \rightarrow \mu \mu \) search
- Semileptonic B decays
- CP asymmetries in \( D^0 \) decays
- Baryons and Pentaquark searches

**Not included:**
- Diffractive Physics
- Exclusive Diffractive production: \( \chi_c \rightarrow J/\psi + \gamma \)
- Jet algorithms
- ...

**Not included:**
- \( B, C, J/\psi \) cross-sections
- \( B \) Hadron masses
- Two body charmless decays
- Tagging studies
- \( X(3872) \rightarrow J/\psi \pi \pi \) state
- Branching ratio measurements
- …
• As you know the Tevatron is working very well this year

• Record Initial luminosity = $7.2 \times 10^{31} \text{ sec}^{-1} \text{ cm}^{-2}$

• Detector efficiency $\sim 85\%-90\%$

$\sim 300 \text{ pb}^{-1}$ on tape
$\sim 100\text{-}200 \text{ pb}^{-1}$ used for analysis so far
QCD and Jet Physics
Motivation

• Tevatron = Jet factory
• All production processes are “QCD related”:
  Optimal understanding is basic for all analyses
  – Main parameters (ex.: gluon PDFs in high x)
  – Non-perturbative regime (ex.: underlying event studies)
  – Studies of specific processes where QCD is important
    (ex.: diphotons, W+jets, γ+b/c)
• Probe higher energy scales:
  – Higher vs → higher s (factor 5 for $E_T > 600 \text{ GeV}$ w.r.t. run I)
  – Precise test of perturbative QCD at NLO
  – Look for deviations → new physics
• Other studies of interest:
  Diffraction, hadron spectroscopy…
Inclusive Jet Cross Section

- **Very challenging analysis:**
  - Theoretical computation is difficult (NNLO still going on...)
  - Uncertainties in PDFs
  - Cross-section varies with $E_t$ by 8 orders of magnitude (precise energy scale)

Run I vs Run II data

Leading diagrams for dijet events

Leading diagrams for $\gamma$-jet events

Jets with very high $E_t$ in Run II
Inclusive Jet Cross Section

- Theoretical error dominated by PDFs
- Experimental error dominated by energy scale

Better understanding of the calorimeter response \(\Rightarrow\) reduce the systematic uncertainty
Inclusive Jet Cross Section

- There was an apparent excess in Run I data
- SM explanation: gluon PDF was not well constrained at high x

Data currently agrees with NLO prediction within errors
High $E_T$ Jets

- Starting an era of QCD precision measurements at Hadron Colliders
- Studying “QCD backgrounds” in order to look for new Physics

Highest mass di-jet event so far
(Mass = 1364 GeV/c$^2$)

$E_T = 666$ GeV
$\eta = 0.43$

Calorimeter LEGO Plot

$E_T = 633$ GeV
$\eta = -0.19$
Energy flow inside jets

- Jet shape:
  fractional energy flow
  \( \Psi(r) = \frac{E_T(0:r)}{E_T(0:R)} \), where \( R=1 \)
- In central region, do it with
  - Calorimeter towers (?)
  - Charged tracks (?)
- Shapes are nearly identical
- Pythia and data agree very well in the central region
Underlying event studies

The **Underlying Event** is everything but the two outgoing **Jets**

- Whole event:
  - Hard scattered partons
  - Initial state radiation
  - Final state radiation
  - Multi-parton interactions
  - Proton remnants
  - ... everything is mixed with color reconnections

- Underlying event:
  ~(whole event)-(hard scatt)
  - ISR
  - A fraction of FSR
  - Multi-parton interactions
  - Proton remnants
  - ... but not completely independent from the hard scattering part
Underlying event studies

- Underlying event pollutes many analyses
- Basic in order to understand the jet fragmentation

- It must be tuned as well as possible
- Default Pythia does not describe well the CDF data → Pythia CDF tune A

- Look at charged particle correlations in the azimuthal angle $\Delta \phi$ relative to the leading calorimeter jet (JetClu $R = 0.7$, $|\eta| < 2$)
- Define $|\Delta \phi| < 60^\circ$ as “Toward”, $60^\circ < |\Delta \phi| < 120^\circ$ as “Transverse”, and $|\Delta \phi| > 120^\circ$ as “Away”
- All three regions have the same size in $\eta$-$\phi$ space, $\Delta \eta \times \Delta \phi = 2 \times 120^\circ = 4\pi/3$
Underlying event studies

- PYTHIA tune A (on Run I data) reproduces well Run II data
- HERWIG works only at high $E_{T1}$

Average charged particle density, $dN/d\eta d\phi$, in the “transverse” region versus $E_T(jet#1)$ for “Leading Jet” and “Back-to-Back” events compared with PYTHIA Tune A and HERWIG
The global comparison between data and QCD predictions is reasonable.

**We go to some specific channels now...**
$W \rightarrow e\nu + \text{jets cross section}$

- Test of QCD predictions at large $Q^2$, fundamental channel for Top/Higgs.
  Compared to LO ALPGEN + Herwig
- One energetic and isolated electron + high $E_T$ jets
- Backgrounds: Top dominates for 4-jet bin, QCD is an important fraction in all jet bins

Results agree with LO QCD predictions within the errors!

Systematic uncertainty (10% in $\sigma_1$ to 40% in $\sigma_4$) limits the measurement sensitivity
The ratio $R_{n/(n-1)}$ measures the decrease in the cross section with the addition of one jet. It depends on $\alpha_s$.

Highest ET jet in $W+\geq 1$ jet
Second highest ET jet in $W+\geq 2$ jet, etc…
W → ev + jets cross section

- Energy “out of cone” dominates the systematic uncertainty
- Data and simulation agreement is reasonable
Diphoton cross-section measurement

- Study of diphoton QCD production
  - Two isolated and energetic high $E_t$ photons in the central region

- Comparison with QCD predictions: DIPHOX and ResBos

Good agreement between data and QCD predictions!

$q\longrightarrow\gamma$

$q\longrightarrow\gamma$

$E_T^{\gamma_1} > 14 \text{ GeV}, E_T^{\gamma_2} > 13 \text{ GeV}$

$|\eta|^{\gamma_1,2} < 0.9$
\( \gamma + b/c \) cross-section

- It probes the heavy flavor content of the proton, sensitive to new Physics
- Basic requirements:
  - One isolated and High \( E_t \gamma \) (> 25 GeV)
  - One jet with a secondary vertex (b/c “like” jet)
- Fit on the secondary vertex mass distribution of the tagged jets to determine the number of events containing b, c and uds quarks in the data

\[ \int L = 66.7 \text{ pb}^{-1} \]

Cross-section measurements agree with the QCD predictions

\[ \sigma(b + \gamma) = 40.6 +/- 19.5 \text{ (stat.)} + 7.4 - 7.8 \text{ (sys.) pb} \]
\[ \sigma(c + \gamma) = 486.2 +/- 152.9 \text{ (stat.)} + 86.5 - 90.9 \text{ (sys.) pb} \]

Overall fit
QCD summary

- Measured inclusive cross-section agrees with NLO QCD
  Trying to reduce the systematic uncertainties

- Modeling the Underlying Event is important for precise Jet measurements
  A tuned PYTHIA version agrees well with CDF data

- Diphoton analysis and $\gamma +$ heavy quark production
  Results are found to be consistent with Pythia LO predictions
  No evidence so far of new physics production

- Study of $W+$jets is important to test QCD predictions at large $Q^2$
  It is a very important channel for Top/Higgs Physics
Charm and Bottom Physics
B Physics at CDF

BB production mechanics in hadron collider:

- Huge cross-section (~100 µb)
- All B species produced:
  \(-B_u, B_d, B_s, B_c, \Lambda_b, \ldots\)

BUT \(\sigma(bb) \ll \sigma(pp)\) \(\Rightarrow\) B events have to be selected with specific triggers...

Trigger requirements: large bandwidth, background suppression, deadtimeless
B Triggers at CDF Run II

• Di-lepton - dilepton sample
  – $p_T(\mu/e) > 1.5/4.0$ GeV/c
  – J/$\psi$ modes, masses, lifetime, x-section
  – Yield 2x Run I (low Pt threshold, increased acceptance)

• Lepton + displaced track - semileptonic sample
  – $p_T(e/\mu) > 4$ GeV/c, 120 $\mu$m < $d0(Trk)$ < 1mm, $pT(Trk) > 2$ GeV/c
  – Semileptonic decays, Lifetimes, flavor tagging
  – B Yields 3x Run I

• Two displaced vertex tracks - hadronic sample
  – $p_T(Trk) >2$ GeV/c, 120 $\mu$m < $d0(Trk)$ < 1mm, $\Sigma p_T > 5.5$ GeV/c
  – Branching ratios, $B_S$ mixing...

![Diagram of primary and secondary vertex with impact parameter and b, c decays]
B/C analyses in this talk vs. Trigger

- **Dilepton Trigger:**
  - $B$ hadron lifetimes with exclusive modes
  - $B_{s(d)} \rightarrow \mu\mu$ search

- **Lepton + Displaced Track Trigger:**
  - Yields in Semileptonic $B$ decays

- **Two Displaced Tracks Trigger:**
  - CP Asymmetries and Decay Rate ratios in $D^0$ decays
  - Search for Pentaquarks
B hadron Lifetimes

- **Test of Heavy Quark Expansion** predictions of the lifetimes for different B hadron species:
  \[ \tau(B^+) > \tau(B^0) \sim \tau(B_s) > \tau(\Lambda_b) \gg \tau(B_c) \]

- CDF can be competitive in all B hadron lifetimes measurements (better momentum and vertex resolution than any other current experiment)

- \(B^0\) and \(B^+\) can be used as control samples

<table>
<thead>
<tr>
<th>B hadron</th>
<th>Lifetime (ps)</th>
<th>(c\tau (\mu m))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B^+)</td>
<td>1.674 +/- 0.018</td>
<td>502</td>
</tr>
<tr>
<td>(B^0)</td>
<td>1.542 +/- 0.016</td>
<td>462</td>
</tr>
<tr>
<td>(B_s)</td>
<td>1.461 +/- 0.057</td>
<td>438</td>
</tr>
<tr>
<td>(B_c)</td>
<td>0.460 +/- 0.180</td>
<td>138</td>
</tr>
<tr>
<td>(\Lambda_b)</td>
<td>1.229 +/- 0.080</td>
<td>368</td>
</tr>
</tbody>
</table>
B hadron Lifetimes in exclusive decays

**J/ψ trigger**
- Clean
- Fully reconstructed
- Lifetime unbiased
- “Low statistics”

\[ \begin{align*}
B^+ &\rightarrow J/\psi \ K^+ \\
&\rightarrow J/\psi \ K^{*+} \\
B^0 &\rightarrow J/\psi \ K^{0*} \\
&\rightarrow J/\psi \ K_s \\
\Lambda_b &\rightarrow J/\psi \ \Lambda_c \\
B^0_s &\rightarrow J/\psi \ \phi
\end{align*} \]

Lifetime measurement:
- Reconstruct decay length
- Measure \( p_T \) of decay products

\[ c\tau = \frac{L_{xy}}{\beta \gamma} = \frac{L_{xy} \ m(B)}{P_T(B)} \]
Exclusive $B^+ \rightarrow J/\psi X$ Lifetimes

Simultaneous fit of Mass and $c\tau$ distributions
Exclusive $B^0 \rightarrow J/\psi K^0 X$ Lifetimes

CDF Run II Preliminary

$B^0 \rightarrow J/\psi K^0$

966 ± 39 signal candidates
Fit Prob: 20%

CDF Run II Preliminary

$B^0 \rightarrow J/\psi K_s^0$

603 ± 35 signal candidates
Fit Prob: 19%
$\Lambda_b \rightarrow J/\psi \Lambda$ Lifetime

CDF Run II Preliminary  65pb$^{-1}$

**$\Lambda_B$ Lifetime Control Sample: $B^0 \rightarrow J/\psi K^0_s$**

$ct = 414 \pm 31 \mu m$

- signal region fit
- background fit

CDF Run II Preliminary  65pb$^{-1}$

**Unbinned Likelihood Fit To $\Lambda_B$ Lifetime**

$ct = 374 \pm 78 \text{(stat)} \pm 29 \text{(syst)} \mu m$

- signal region fit
- background fit

$B^0 \rightarrow J/\psi K^0_s$

$\Lambda_B \rightarrow J/\psi \Lambda$
Exclusive $B_s \rightarrow J/\psi \phi$ Lifetimes

CDF Run II preliminary results (in ps)

<table>
<thead>
<tr>
<th>$B$ hadron</th>
<th>CDF measurement</th>
<th>PDG value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^+$</td>
<td>$1.66 \pm 0.04 \pm 0.02$</td>
<td>$1.674 \pm 0.018$</td>
</tr>
<tr>
<td>$B^0$</td>
<td>$1.49 \pm 0.05 \pm 0.03$</td>
<td>$1.542 \pm 0.016$</td>
</tr>
<tr>
<td>$\Lambda_b$</td>
<td>$1.25 \pm 0.26 \pm 0.10$</td>
<td>$1.229 \pm 0.080$</td>
</tr>
<tr>
<td>$B_s$</td>
<td>$1.33 \pm 0.14 \pm 0.02$</td>
<td>$1.461 \pm 0.057$</td>
</tr>
</tbody>
</table>

$R(B^+/B^0) = 1.119 \pm 0.046$ (stat.) $\pm 0.014$ (syst.) (PDG: $1.073 \pm 0.014$)
Rare B decays: $B_{s(d)} \to \mu^+ \mu^-$

- SM prediction: $BR(B_{s} \to \mu^+ \mu^-) = (3.8 \pm 1.0) \times 10^{-9}$
- Several extensions to the SM predict an enhancement of this branching ratio by 1 to 3 orders of magnitude
- If there is not excess we can already constrain several SUSY models!

**Discriminating variables**

- **CDF II**
  - $M(\mu^+ \mu^-)$ vs. entries
  - $c\tau$ vs. entries
- **Background (data)**
  - $\Delta \phi$ vs. entries
  - Isolation ratio vs. entries

**Final mass distribution**

- **CDF II**
  - $B_{s(d)} \to \mu^+ \mu^-$
  - 171 pb⁻¹
  - $M(\mu^+ \mu^-)$ vs. entries / 20 MeV/c²

"Blind" analysis: cuts were optimized before looking at the signal mass region
Rare B decays: $B_{s(d)} \rightarrow \mu^+\mu^-$

- No excess has been found unfortunately
- Limits on the Branching fractions have been set

(Expected/Observed) **BR limits vs. luminosity**

**Already Submitted to PRL!**

<table>
<thead>
<tr>
<th></th>
<th>$B_s \rightarrow \mu^+\mu^-$</th>
<th>$B_d \rightarrow \mu^+\mu^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>1.05 +/- 0.30</td>
<td>1.07 +/- 0.31</td>
</tr>
<tr>
<td>Data</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BR limit @95% C.L.</td>
<td>7.5 X 10^{-7}</td>
<td>1.9 X 10^{-7}</td>
</tr>
<tr>
<td>BR limit @90% C.L.</td>
<td><strong>5.8 X 10^{-7}</strong></td>
<td><strong>1.5 X 10^{-7}</strong></td>
</tr>
</tbody>
</table>

*Best world result*

**Slightly better results than Belle and BaBar**

- BR limit @95% C.L.: $1.6 \times 10^{-7}$
- BR limit @90% C.L.: $2.0 \times 10^{-7}$
Semileptonic B samples

lepton + displaced vertex track trigger collects a lot of Semileptonic B decays!

- It provides:
  - High statistics
  - “Clean” environment
  - Good control sample
- But:
  - Lifetime bias
  - Sample composition \( B^0 \leftrightarrow B^+ \)

- Work in progress:
  - Understand lifetime measurements in this sample
  - \( B_{s(d)} \) mixing might be done in Semileptonic B decays

> 40000 \( B \rightarrow l D^0 X \) decays!
Semileptonic $B_s$ samples

$B_s \rightarrow l D_s X$

Only yields and mass plots today
CP Asymmetries and Decay Rate ratios

• The huge amount data collected by the Two Track Trigger have been used for this analysis

Relative branching ratios:
\[ \frac{\Gamma(D^0 \to K^+K^-)}{\Gamma(D^0 \to K\pi)} \]
\[ \frac{\Gamma(D^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to K\pi)} \]
\[ \frac{\Gamma(D^0 \to KK)}{\Gamma(D^0 \to \pi\pi)} \sim 2.8 \ (SM) \]

Direct CP-violating decay rate asymmetries:
\[ A_{CP} = \frac{\Gamma(D^0 \to f) - \Gamma(\bar{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\bar{D}^0 \to f)} \approx 0 \ (SM) \]

• Candidates selected as: \( D^{*+/-} \to D^0 \pi \)
(unchiased tag of the \( D^0 \) flavor)

\[ \sim 2 \times 90000 \ \text{D}^{*+/-}!!! \]
CP Asymmetries and Decay Rate ratios
CP Asymmetries and Decay Rate ratios

Very important to understand the asymmetry of the CDF detector!!!

Results are computed after applying a correction for the intrinsic charge asymmetry of the detector response and tracking algorithms.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>CDF</th>
<th>FOCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Gamma(D^0 \rightarrow KK) / \Gamma(D^0 \rightarrow K\pi)$</td>
<td>(9.96 +/- 0.11 +/- 0.12)%</td>
<td>(9.93 +/- 0.14 +/- 0.14)%</td>
</tr>
<tr>
<td>$\Gamma(D^0 \rightarrow \pi\pi) / \Gamma(D^0 \rightarrow K\pi)$</td>
<td>(3.608 +/- 0.054 +/- 0.040)%</td>
<td>(3.53 +/- 0.12 +/- 0.06)%</td>
</tr>
<tr>
<td>$\Gamma(D^0 \rightarrow KK) / \Gamma(D^0 \rightarrow \pi\pi)$</td>
<td>(2.762 +/- 0.040 +/- 0.034)%</td>
<td>(2.81 +/- 0.10 +/- 0.06)%</td>
</tr>
</tbody>
</table>

$A(D^0 \rightarrow KK) = (2.0 +/- 1.2 \text{ (stat.)} +/- 0.6 \text{ (syst.)})\%$

$A(D^0 \rightarrow \pi\pi) = (1.0 +/- 1.3 \text{ (stat.)} +/- 0.6 \text{ (syst.)})\%$

$A(D^0 \rightarrow KK) = (0.0 +/- 2.2 \text{ (stat.)} +/- 0.8 \text{ (syst.)})\%$

$A(D^0 \rightarrow \pi\pi) = (1.9 +/- 3.2 \text{ (stat.)} +/- 0.8 \text{ (syst.)})\%$
Pentaquarks searches

• The beginning: Announcements from several experiments around the world provide evidence for the existence of an exotic baryon, a *Pentaquark* with strangeness $S=+1$

• What are Pentaquarks?
  • Minimum content: 4 quarks and 1 antiquark $(q_1 q_2 q_3 q_4 \bar{Q})$
  • “Exotic” Pentaquarks if the antiquark has a different flavor than the other 4 quarks
  • Quantum numbers can not be defined by 3 quarks alone
Summary of experiments

$\Theta^+, M \sim 1.53 \text{ GeV/c}^2, \Gamma \ll 15 \text{ MeV/c}^2$)
- LEPS, $\gamma n \rightarrow K^-\Theta^+ \rightarrow K^-K^+n$, $4.6 \sigma$, $M = 1540 \text{ MeV/c}^2$
- DIANA at ITEP, $K^+\text{Xe} \rightarrow \Theta^+n \rightarrow K_s p n$, $4.5 \sigma$, $M = 1539 \text{ MeV/c}^2$
- CLAS, $\gamma d \rightarrow \Theta^+pK^- \rightarrow nK^+pK^-$, $5.3 \sigma$, $M = 1542 \text{ MeV/c}^2$
- SAPHIR, $\gamma p \rightarrow K_s \Theta^+$, $4.8 \sigma$, $M = 1540 \text{ MeV/c}^2$
- $\nu$s WA21, E180... $\Theta^+ \rightarrow K_s p$ spectrum, $6.7 \sigma$, $M = 1533 \text{ MeV/c}^2$
- CLAS, $\gamma p \rightarrow p^+\Theta^+K^- \rightarrow p^+K^+nK^-$, $5.3 \sigma$, $M = 1555 \text{ MeV/c}^2$
- HERMES, $\gamma n \rightarrow K^-\Theta^+ \rightarrow K^-K^+n\pi^+$, $5 \sigma$, $M = 1527 \text{ MeV/c}^2$
- ZEUS, $ep \rightarrow \Theta^+X \rightarrow K_spX\pi^+$, $5 \sigma$, $M = 1525 \text{ MeV/c}^2$

$\Xi^{3/2}: \{\Xi^0, \Xi^-, \Xi^--\}$, $M \sim 1862 \text{ MeV/c}^2$
- NA49 at SPS/CERN (pp collider at $E_{cm} = 17.2 \text{ GeV}$)

\[
\Xi^{3/2} \rightarrow \Xi^{+/-}\pi^{+/-}, \Xi^{+/-} \rightarrow \Lambda \pi^{+/-}
\]

Last week!: New state $\rightarrow D^+p$

- H1, $ep \rightarrow D^+pX$, $M = 3099 \text{ MeV/c}^2$

BUT:
- all results are obtained with relatively low statistics, 20-100 events in peaks, $S/B \sim 1-0.3$, $S/\sqrt{S+B} \sim 3-6$
- some other experiments are seeing “nothing” in similar searches (BES, Hera-B this week...)

Are they Pentaquarks?
The new cousin of $\Theta^+$: $\Xi^{--}$

$M = 1.862 \pm 0.002$ GeV

NA49 CERN SPS hep-ex/0310014
Pentaquarks searches

- CDF has developed tracking of long lived hyperons ($\Xi$ and $\Omega$) in the SVX detector
- Silicon tracking of hyperons improves momentum and impact parameter resolution as well as background reduction

Analysis has been performed using two different triggers

$N_{TTT} \sim 18$ times larger than NA49 data
$N_{Jet20} \sim 2$ times larger than NA49 data
Pentaquarks searches

But... No excess is observed in the CDF data
Pentaquarks searches

- No signals have been found
- Upper limits have been set
- Results confirmed using two different triggers

<table>
<thead>
<tr>
<th>Channel (TTT)</th>
<th># of events</th>
<th>$R(\Xi_{1860}/\Xi_{1530})$ U. L. 95% C.L.</th>
<th>$R(\Xi_{1860}/\Xi_{1530})$ NA49</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi^-\pi^+$</td>
<td>57 +/- 51</td>
<td>0.07</td>
<td>~0.21</td>
</tr>
<tr>
<td>$\Xi^-\pi^-$</td>
<td>-54 +/- 47</td>
<td>0.04</td>
<td>~0.24</td>
</tr>
<tr>
<td>$\Xi^-\pi^+/-$</td>
<td>47 +/- 70</td>
<td>0.08</td>
<td>~0.45</td>
</tr>
</tbody>
</table>

Other Pentaquarks searches are in progress at CDF, to be continued...
This is the first observation of charmed-strange isodoublet \( \{ \Xi_c^0, \Xi_c^+ \} \) in hadron collider
Charm/Bottom summary

- Measured Hadron B lifetimes using fully reconstructed modes: precision at the level of 3% for $B^0$ and $B^+$ hadrons

- Limits on $\text{BR}(B_{s(d)} \rightarrow \mu\mu)$ of the order of $10^{-7}$: best world limits

- Large Semileptonic B sample collected by the lepton + Displaced Track Trigger

- Studies on CP Asymmetries and Decay Rate Ratios of Cabibbo supressed $D^0$ decays

- Pentaquarks searches: no excess found yet
Conclusions

- Starting an era of QCD precision measurements, Jets with $E_t$ up to 600 GeV
- Pythia for Underlying Event well tuned at CDF
- **World best $B_s \rightarrow \mu\mu$ limit, $BR(B_s \rightarrow \mu\mu) < 5.8 \times 10^{-7}$ at 90% C.L.**
- **Precision charm Physics**
  - $A(D^0 \rightarrow KK) = (2.0 +/- 1.2 \text{ (stat.)} +/- 0.6 \text{ (syst.)})%$
  - $A(D^0 \rightarrow \pi\pi) = (1.0 +/- 1.3 \text{ (stat.)} +/- 0.6 \text{ (syst.)})%$
- We can not confirm $\Xi_{2/3}^-$ from NA49

*(hard) work in progress, stay tuned!*