Double Pomeron Dijets in Run II

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Small-x and Diffraction 2003
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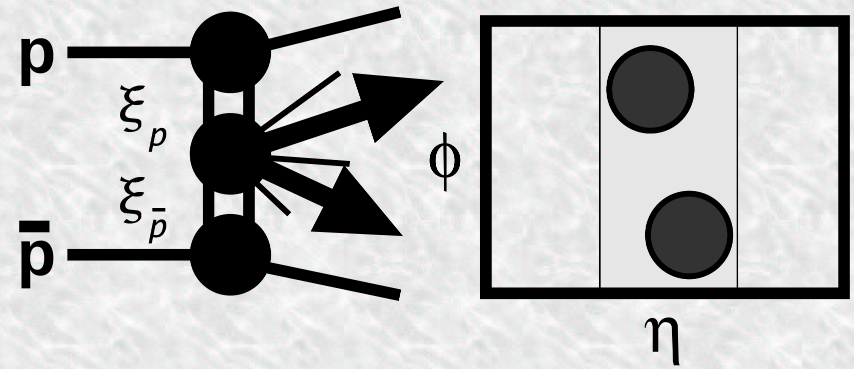
Double Pomeron Exchange

$p + \bar{p} \rightarrow p + X + \bar{p}$

✔ X = color-singlet system

✔ $\xi_{p/\bar{p}}$ = fractional momentum loss of $p/\bar{p}$

→ $M_x^2 = s \cdot \xi_p \cdot \xi_{\bar{p}}$



pp (CERN-ISR) @ $\sqrt{s}$ ~63GeV (1976-79)

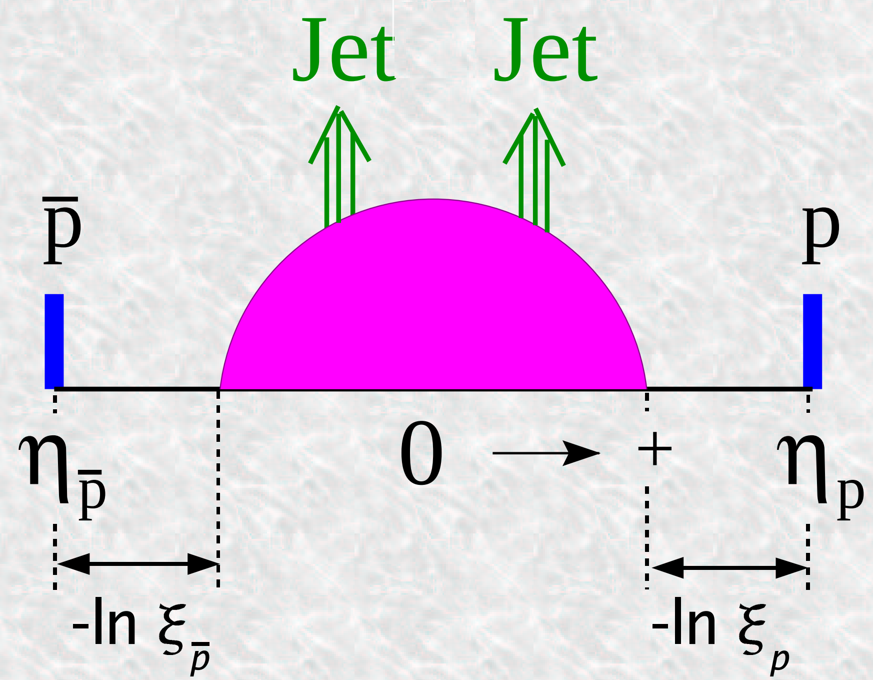
→ first experimental evidence for DPE

$p\bar{p}$ (CERN-S$p\bar{p}$S) @ $\sqrt{s}$ =630GeV (1993)

→ studied DPE dijets, but with trigger bias

$p\bar{p}$ (FNAL-Tevatron) @ $\sqrt{s}$ =1.8TeV (2000)

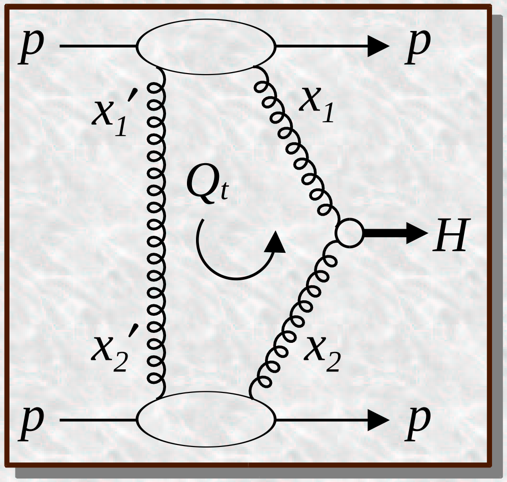
→ first conclusive observation of DPE dijets



DPE "Dijet" Production

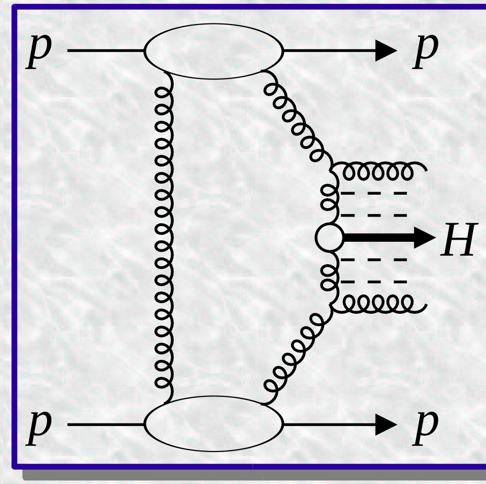
Diffractive Higgs in DPE?

Exclusive



Khoze, Martin, Ryskin
Eur. Phys. J. C23, 311 (2001), C26, 229 (2002)

Inclusive



SM light Higgs (M_H~120GeV) may be produced in DPE

- more interest on "exclusive" channel: $p + p \rightarrow p + H + p$
- M_H obtained from "missing mass" $M_H = M_{miss} = (s \cdot \xi_p \cdot \xi_p)^{1/2}$
- σ_H^{excl} ~ 3fb, signal/background ~ 3 @ LHC (if ΔM_{miss} = 1GeV)

➔ Attractive Higgs discovery channel at LHC !

Same mechanism for "exclusive" dijets

➔ Cross section or limit for exclusive dijets calibrates Higgs sentitivity at Tevatron/LHC

Outline of the Talk

Overview of Run I DPE Dijet Results

Run II DPE Physics

DPE Dijet Analysis

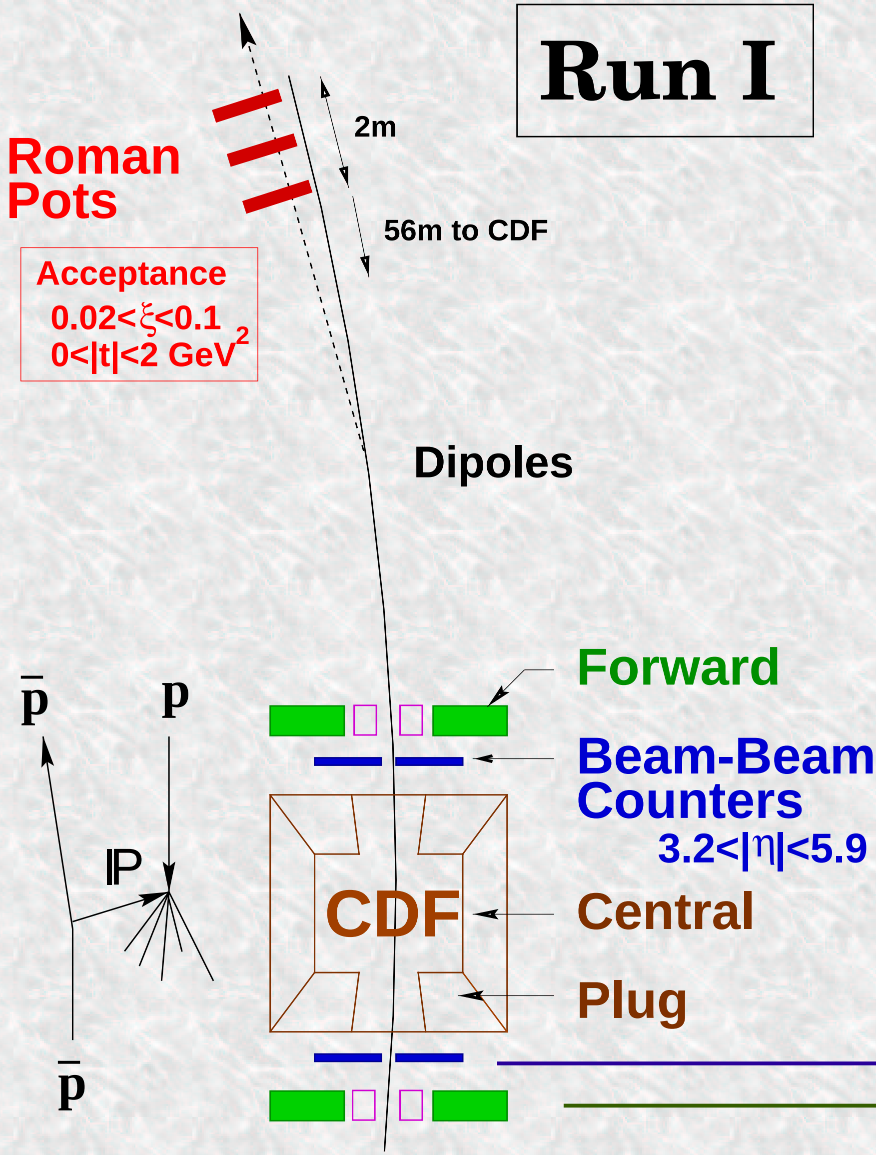
- Trigger
- Data Selection
- Results

Looking for $b\bar{b}$ Production

Summary

Run I DPE Dijets

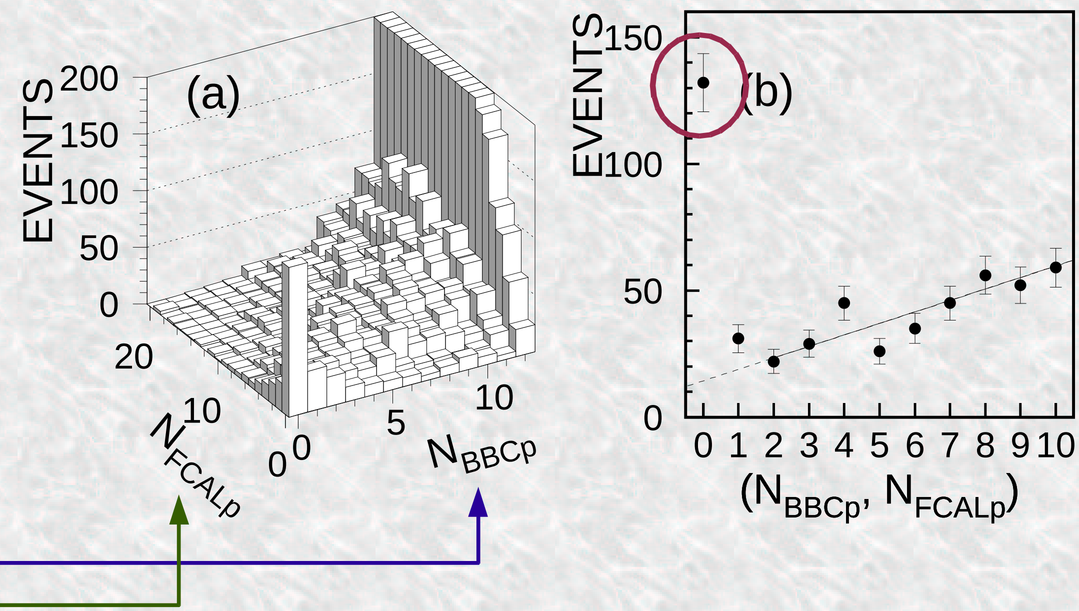
Phys. Rev. Lett. 85, 4215 (2000)



Leading antiproton in Roman Pot:

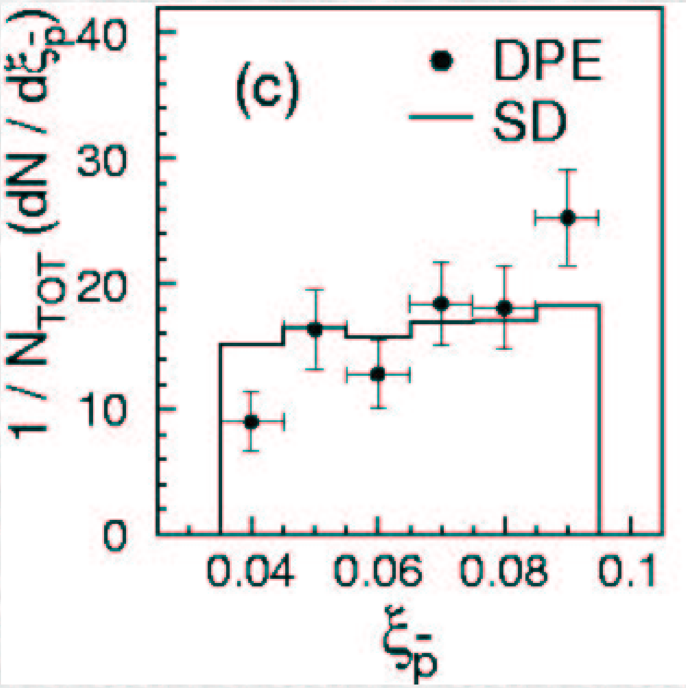
- $0.035 < \xi_{\bar{p}} < 0.095$
- $0 < |t_{\bar{p}}| < 1.0\ GeV^2$

Two jets with $E_T > 7$ GeV (parton level)



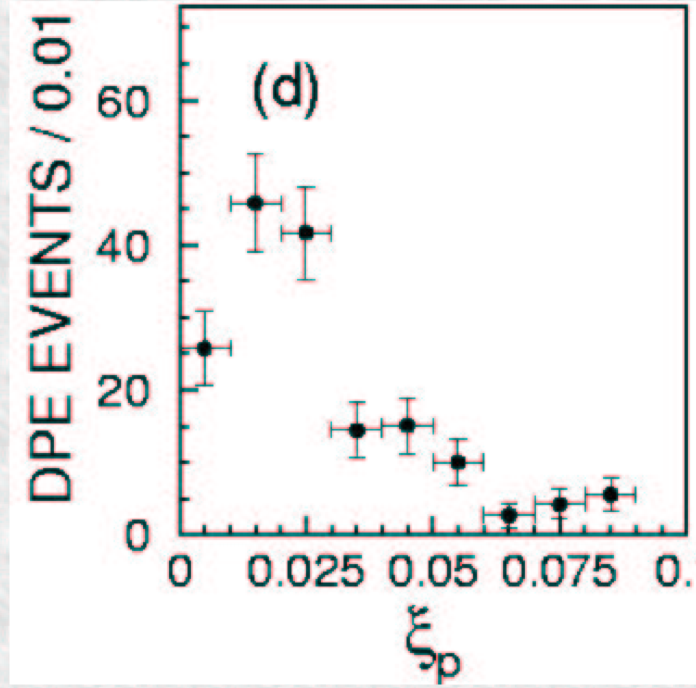
Clear gap signal ⟹ DPE dijets

Run I DPE Dijets



Antiproton Momentum Loss $\xi_{\bar{p}}$

- measured with RP
- corrected for RP acceptance



Proton Momentum Loss ξ_p

- calculated from particles in CAL/BBC

$$\Rightarrow \quad \xi_p^X = \frac{1}{\sqrt{s}} \sum_{i=1}^{all} E_T^i \cdot e^{+\eta_i}$$

- calibration factor applied

$$\xi_p = f_{calib} \times \xi_p^X \qquad f_{calib} \equiv \langle \xi_{\bar{p}}^{RP} / \xi_{\bar{p}}^X \rangle$$

Run I DPE Dijets

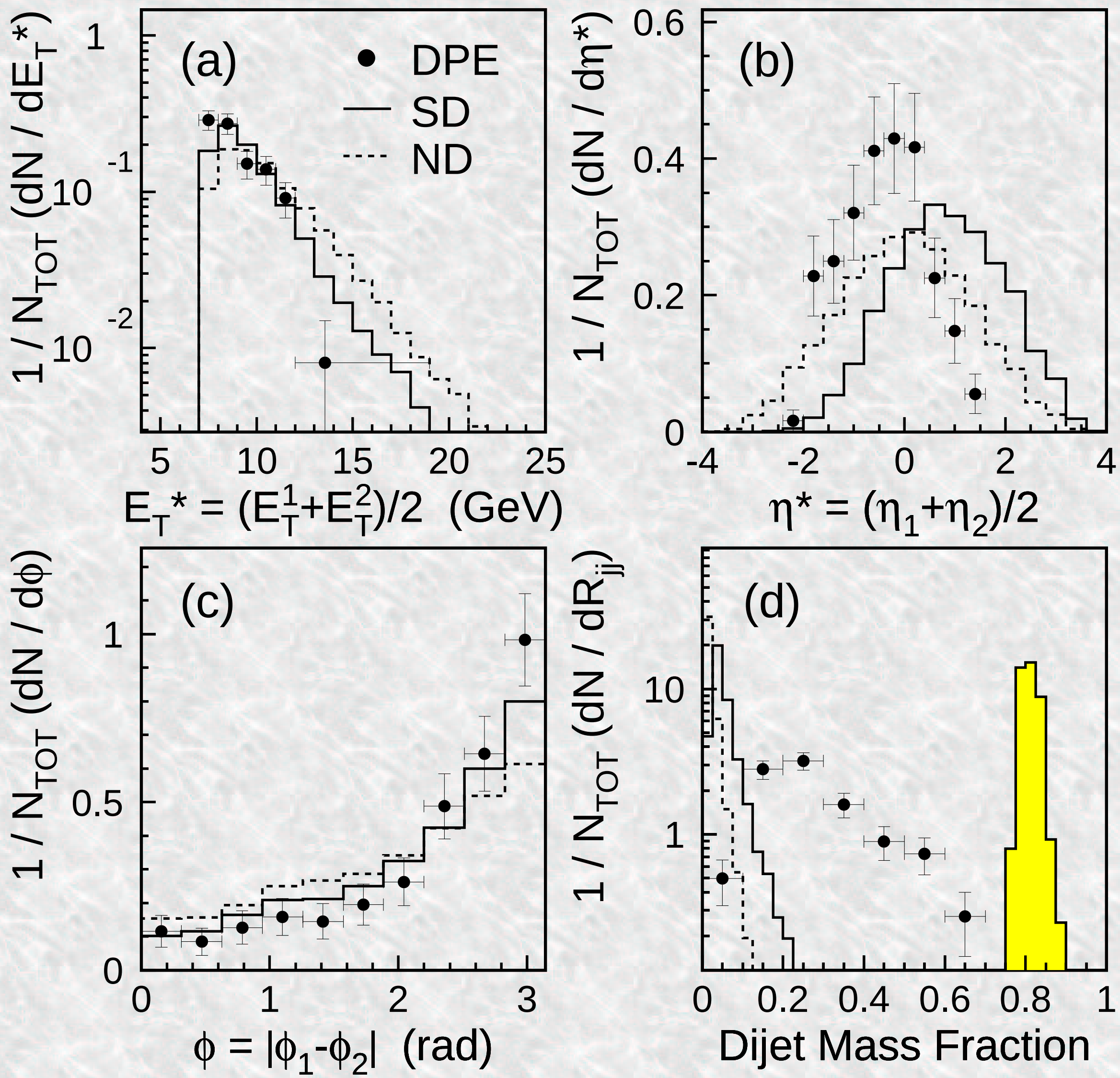
~130 DPE dijets observed

- $0.035 < \xi_{\bar{p}} < 0.095$
- $E_T^{jet} > 7$ GeV
- $2.4 < \eta_{gap} < 5.9$

Dijet Mass Fraction:

$$R_{jj} = \frac{M_{jj}^{cone}}{M_X}$$

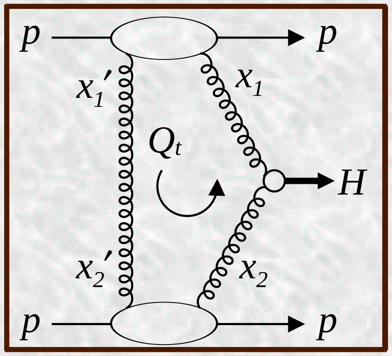
Look for exclusive dijets in $0.7 < R_{jj} < 0.9$



- Inclusive DPE dijets: $\sigma = 43.6 \pm 4.4(\text{stat}) \pm 21.6(\text{syst})$ nb
- Exclusive DPE dijets: $\sigma < 3.7$ nb (95% C.L.)

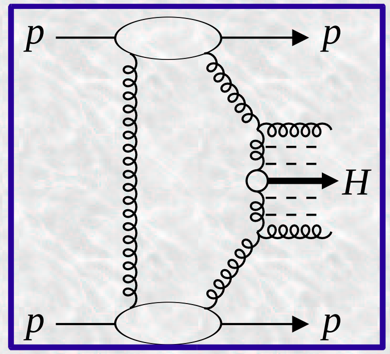
Inclusive/Exclusive Dijets in DPE

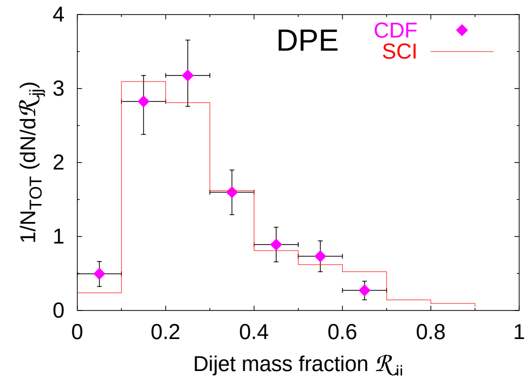
Exclusive



Khoze, Martin, Ryskin
Eur. Phys. J.
C23, 311 (2001),
C26, 229 (2002)

Inclusive





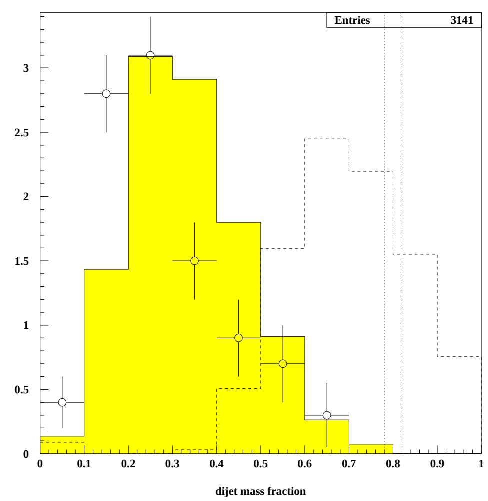
Enberg, Ingelman, Timneanu
Phys. Rev. D67, 011301 (2003)

Exclusive Dijet Cross Section

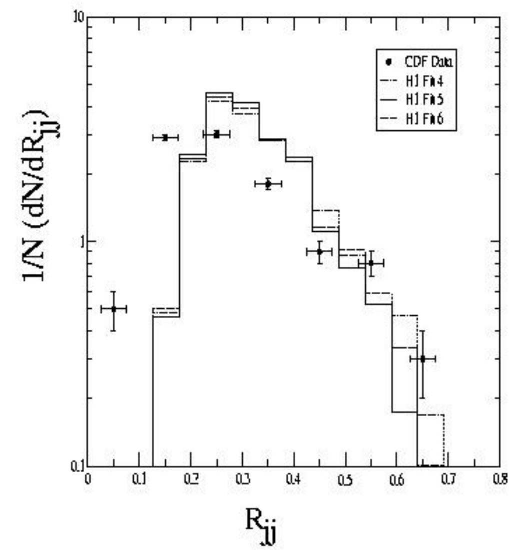
~ 1nb @ Run I CDF kinematics

~ 60pb @ $25 < E_T^{jet} < 35$ GeV, $|\eta^{jet1} - \eta^{jet2}| < 2$

(factor 2 uncertainty on both)



Boonekamp, Peschanski, Royon
Phys. Rev. Lett. 87, 251806 (2001)



Appleby, Forshaw
Phys. Lett. B541, 108 (2002)

Run I DPE Dijets

<u>LO QCD</u>

$R_{SD}^{DPE} = F_{jj}^{D}/F_{jj}$ (proton)

$R_{ND}^{SD} = F_{jj}^{D}/F_{jj}$ (antiproton)

Factorization:

$R_{SD}^{DPE} = R_{ND}^{SD}$

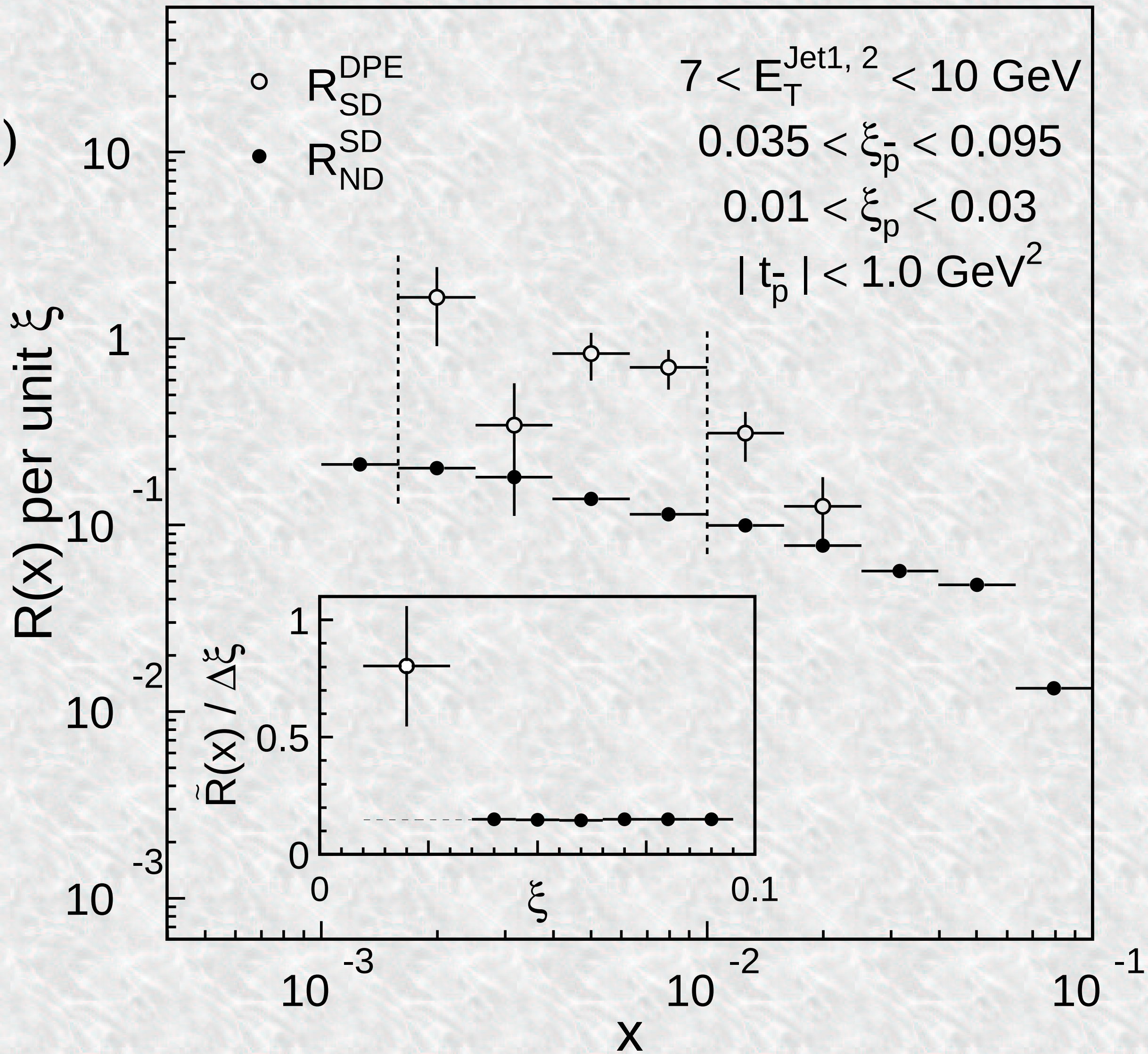
at same ξ, Q^2 and x_{BJ}

$\tilde{R}_{SD}^{DPE} = 0.80 \pm 0.26$

$\tilde{R}_{ND}^{SD} = 0.15 \pm 0.02$

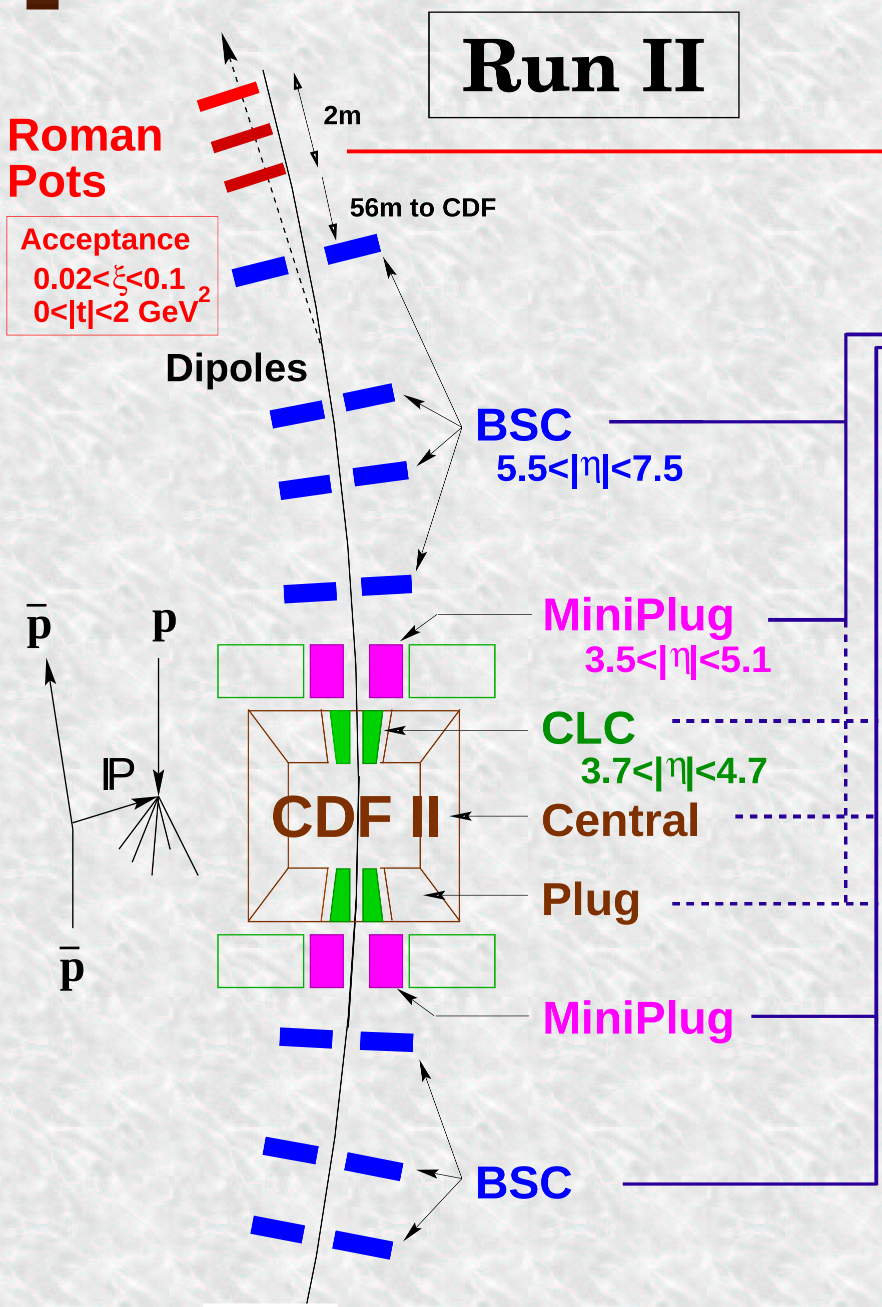
$D \equiv \tilde{R}_{ND}^{SD} / \tilde{R}_{SD}^{DPE}$

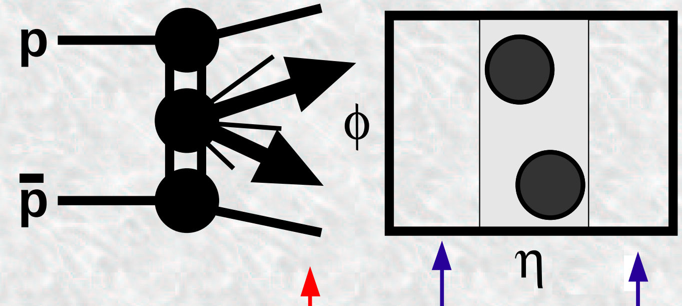
$= 0.19 \pm 0.07$



➡ Breakdown of QCD Factorization

Run II DPE Physics





High *Et* Jet Production

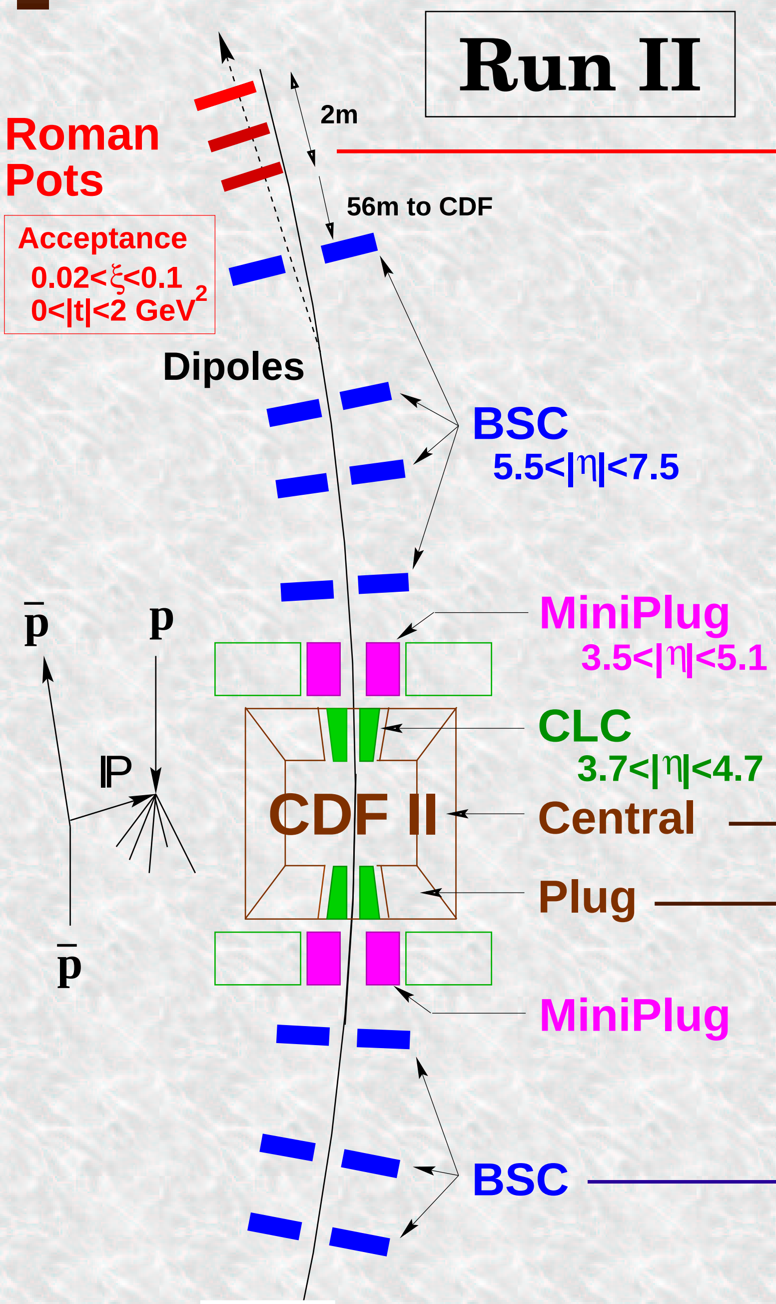
- ✔ hard subprocess ($Q^2 \gtrsim 100$ GeV^2)
- ✔ tag $\bar{p}$\GAP$_{\bar{p}}$ and GAP$_p$
  - ➢ F_{jj}^D from R_{SD}^{DPE} vs GAP$_{\bar{p}}$ width
  - ➢ Exclusive dijet\\$b\bar{b}$ production

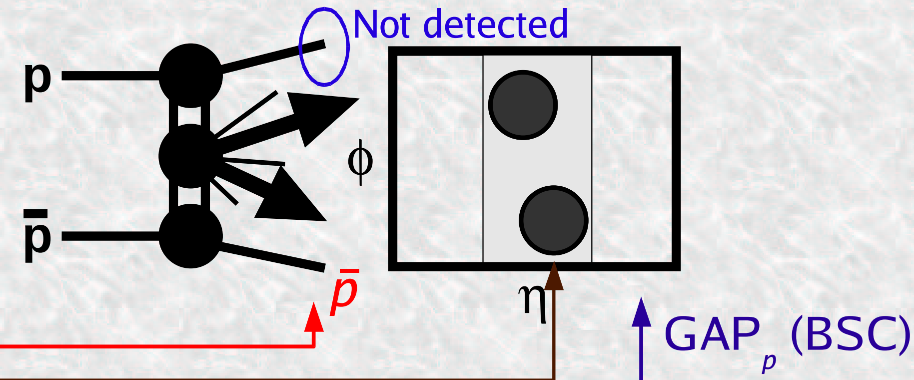
Exclusive Low Mass States

- ✔ very wide gaps on both side
- ✔ require low mass states in central

→ see talks by Albrow/Hamilton/Wyatt

Run II DPE Dijet Trigger





Dedicated DPE Trigger (PS5):

- RP + SingleTower 5 GeV + GAP$_p$(BSC)
  - ✔ implemented in April 2002
  - ✔ MiniPlug instrumented in Sep 2002
  - ✔ >100 pb^{-1} data collected by Sep 2003
  - ✔ 26pb^{-1} data analyzed (Sep-Dec 2002)

Control Sample:

- SD = RP + SingleTower 5 GeV (PS280)
- ND = SingleTower 5 GeV (PS6000)

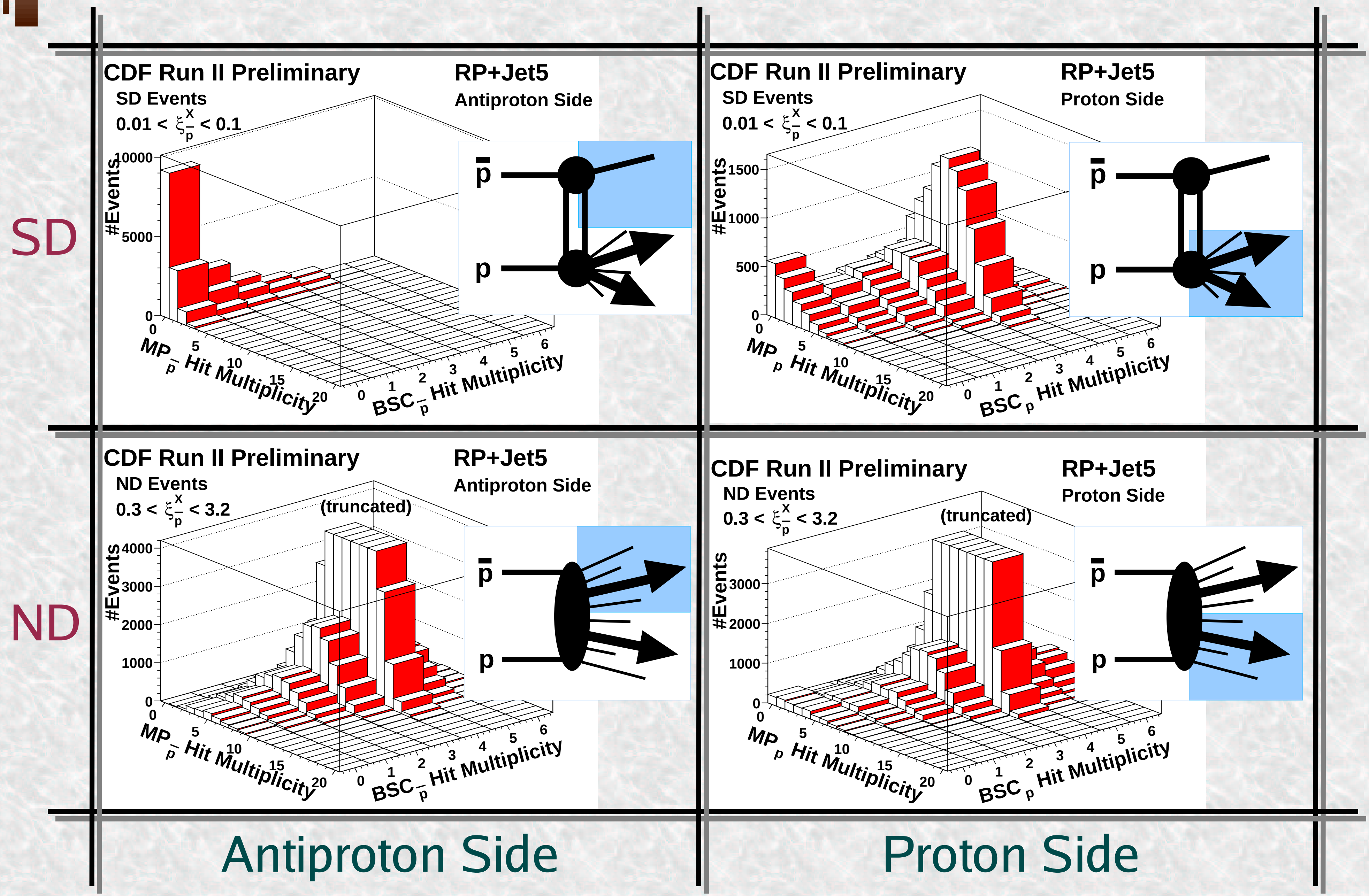
Data Selection

Cuts	DPE PS5/26pb^{-1}	SD PS280/26pb^{-1}	ND PS6K/6pb^{-1}
Triggered Events	397K	356K	278K
Single Vertex	365K	205K	196K
$\|Z_{vertex}\| < 60$cm	347K	195K	186K
#Jets (R=0.7) ≥ 2	204K	158K	160K
$\|$detector $\eta^{jet1,2}\| < 2.5$	163K	122K	123K
corrected* $E_T^{jet1,2} > 10$ GeV	116,473	93,567	85,038
$0.01 < \xi_{\bar{p}}^{X} < 0.1$	54,552	14,956	N/A
GAP$_p$ (MiniPlug)	17,101	N/A	N/A

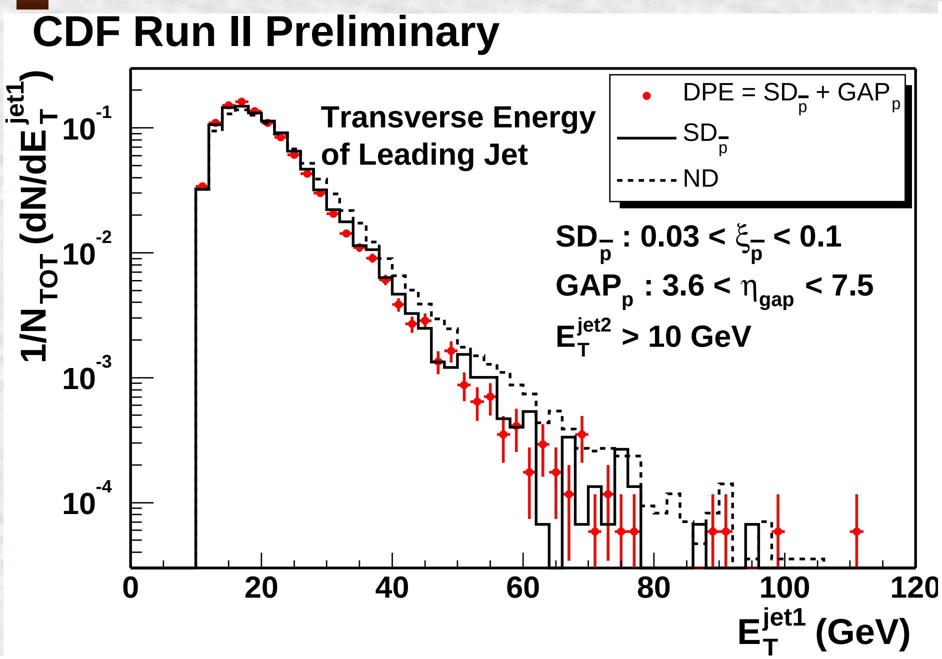
*Jet energy: corrected to "parton level" using Run I absolute correction

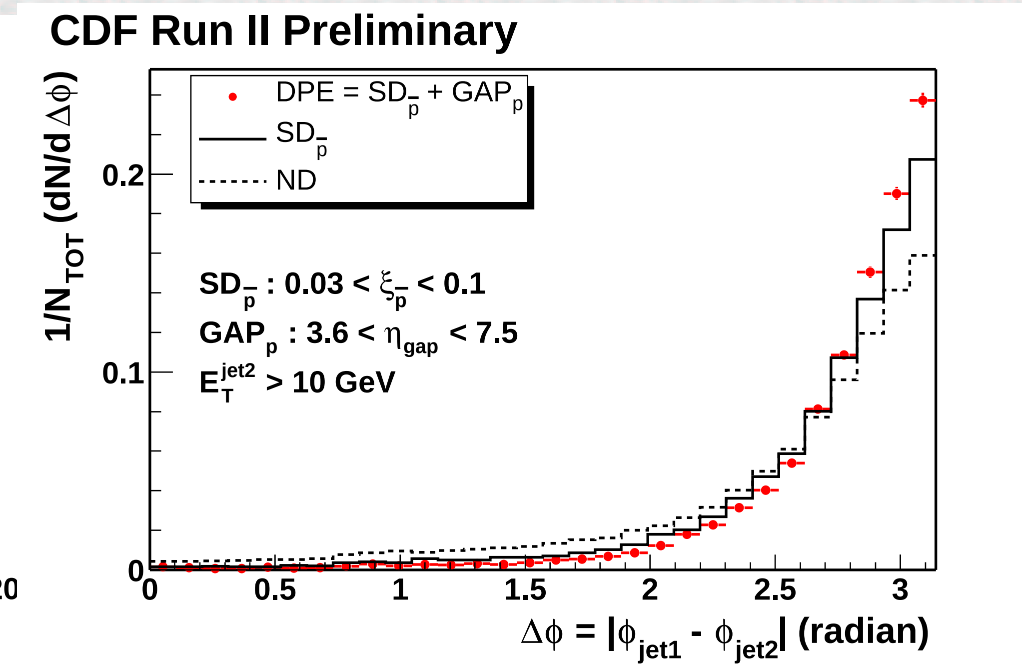
: underlying event energy measured in Run I subtracted

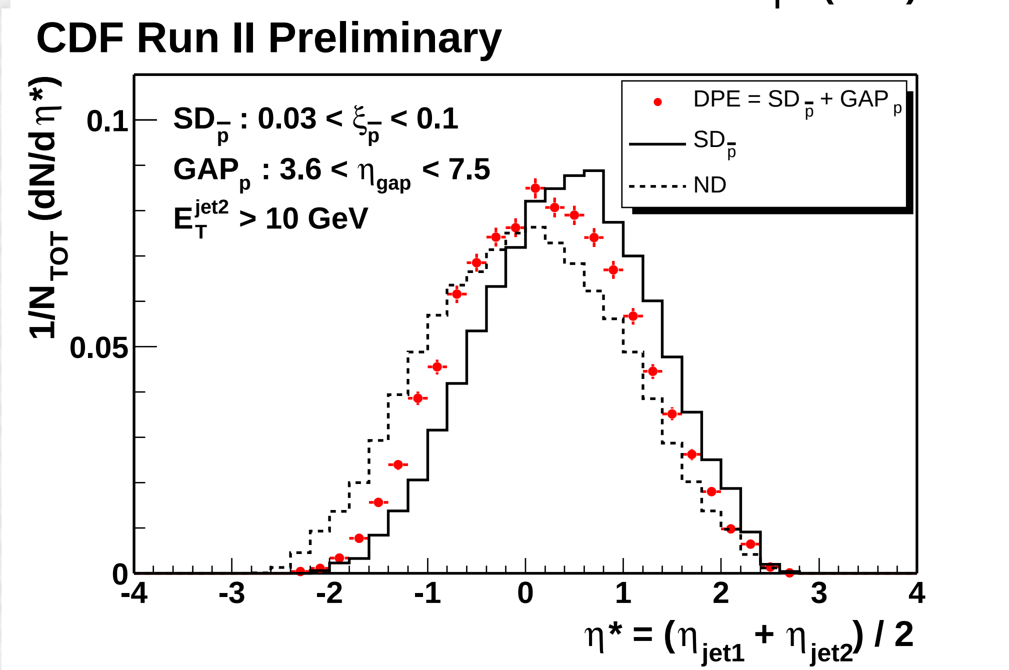
DPE Signal in SD Trigger Data



Kinematic Distributions

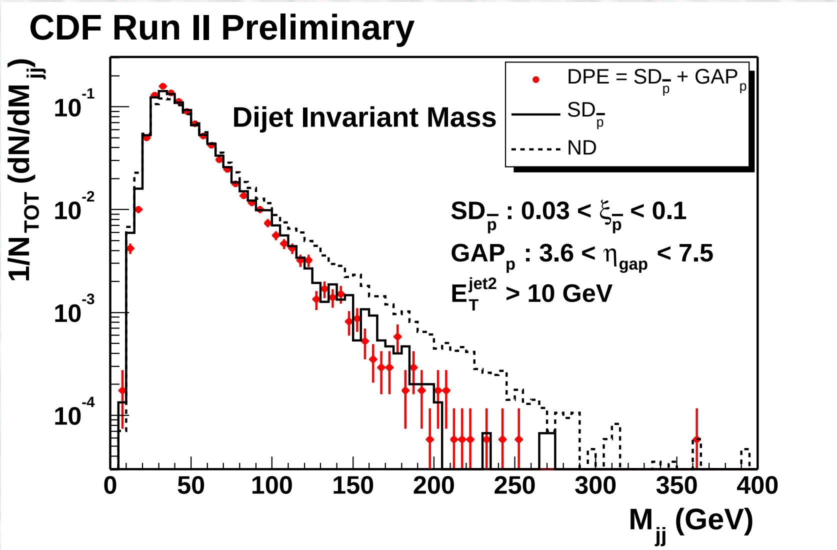


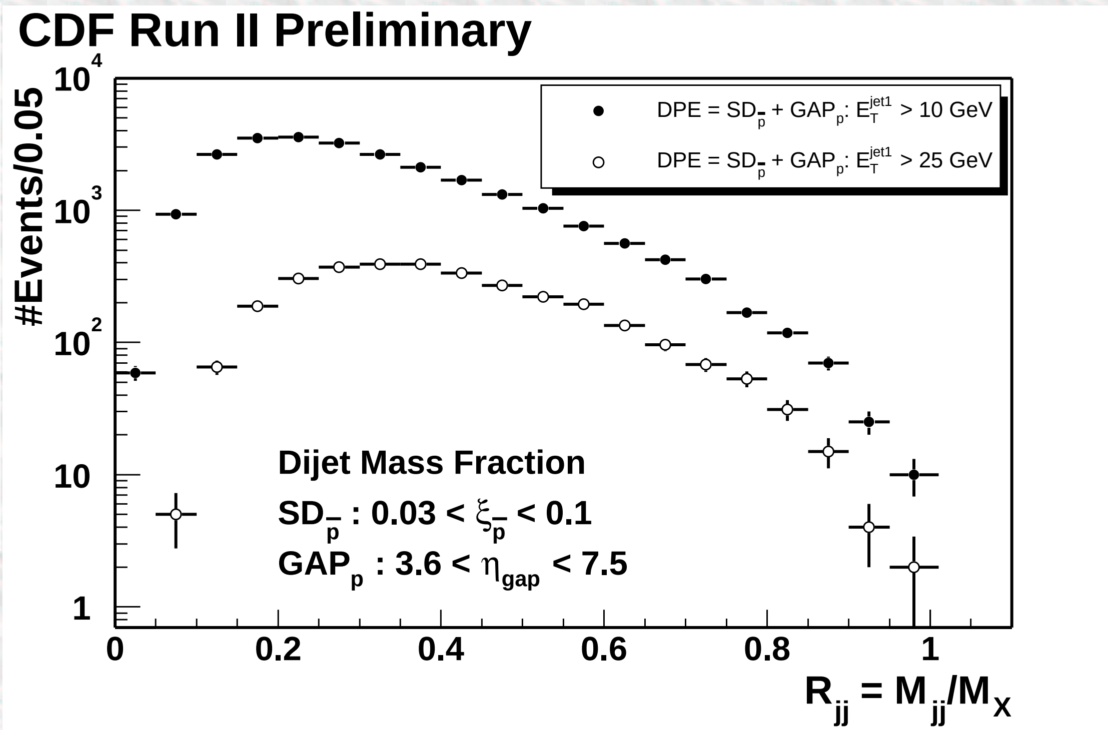




- DPE\SD jet E_T steeper than ND
- SD jets boosted away from $\bar{p}$
- $\overline{\Delta\Phi}_{DPE} > \overline{\Delta\Phi}_{SD} > \overline{\Delta\Phi}_{ND}$

Dijet Mass and Mass Fraction





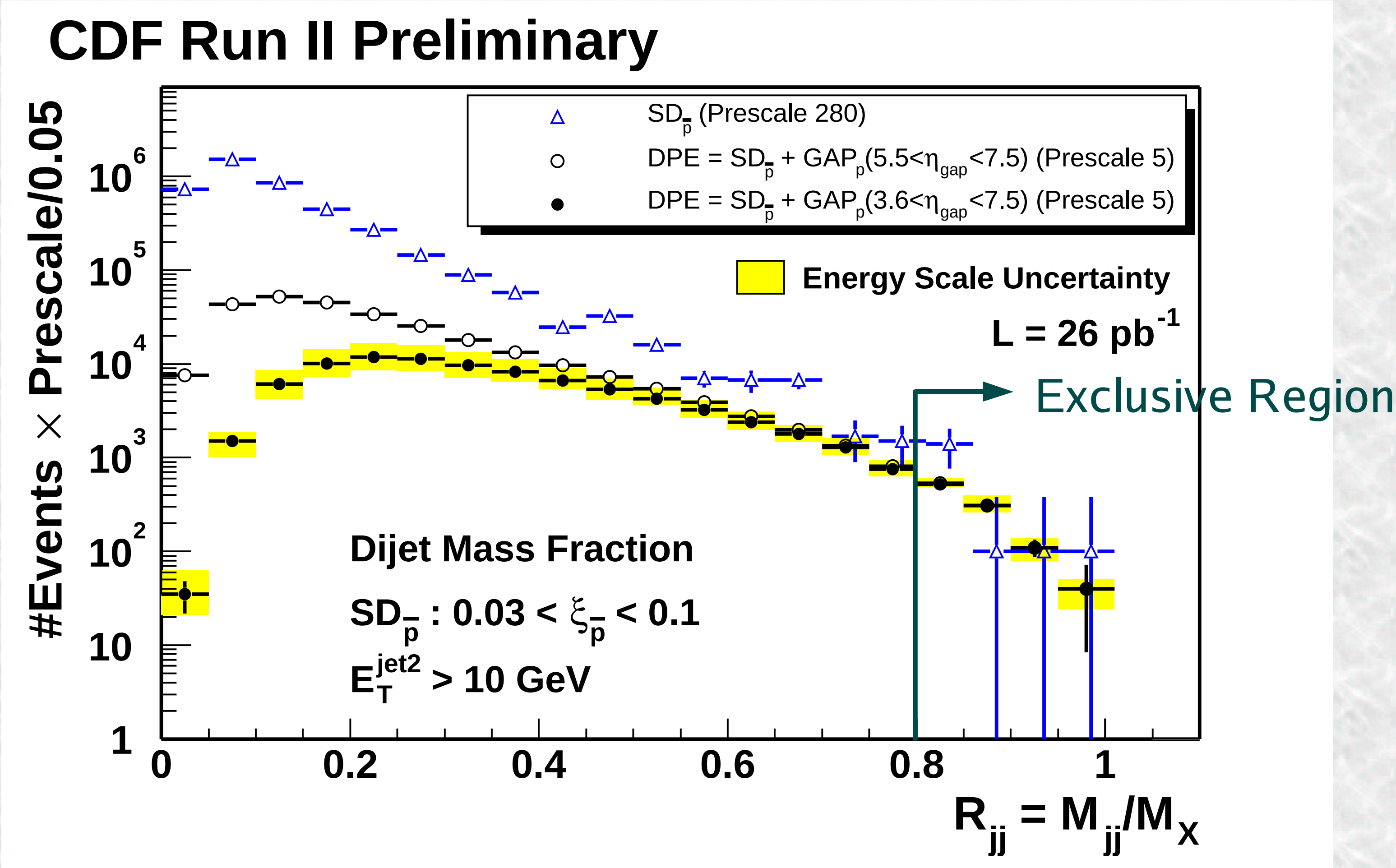
Dijet Mass Fraction:

$$R_{jj} = \frac{M_{jj}^{cone}}{M_X}$$

$$M_X = \sqrt{\xi_p \cdot \xi_{\bar{p}} \cdot s} = \sqrt{\left(\sum_i E_T^i e^{+\eta_i}\right)\cdot\left(\sum_i E_T^i e^{-\eta_i}\right)}$$

- R_{jj} falls smoothly as $R_{jj} \to 1$
- No significant excess due to exclusive dijets seen at high R_{jj}

Dijet Mass Fraction



- Dijets with R_{jj} > 0.8 : Independent of GAP$_p$ size (0<$\Delta\eta_{gap}$<3.9)

  ➡ qualitatively consistent with "exclusive" dijets, but also consistent with inclusive dijet background

- No significant excess seen over continuous curves

Cross Section for R_{jj} > 0.8

Systematic Uncertainties on $\sigma_{DPE}(R_{jj}>0.8)$ (percent)

Minimum E_T^{jet1}	10 GeV	25 GeV
Central/Plug energy scale	20	22
MiniPlug energy scale	14	19
Roman Pot acceptance	10	10
Trigger efficiency	5	5
Multiple interaction correction	6	6
Luminosity	6	6
TOTAL	**28%**	**32%**

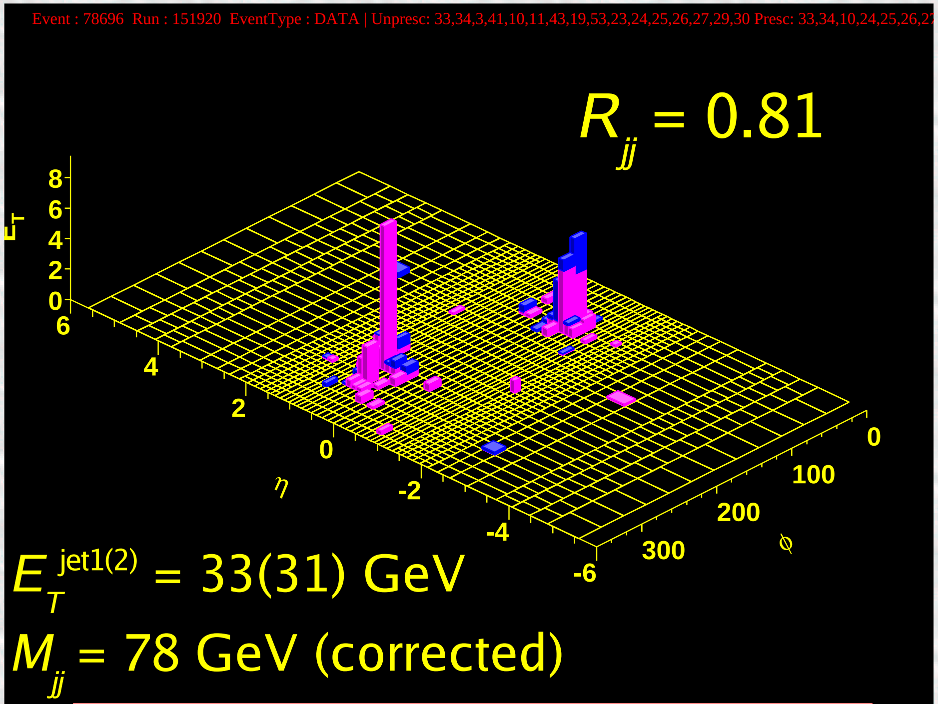
$|\eta^{jet1,2}|<2.5$, $0.03<\xi_{\bar{p}}<0.1$, $3.6<\eta_{gap}<7.5$, $R_{cone}=0.7$

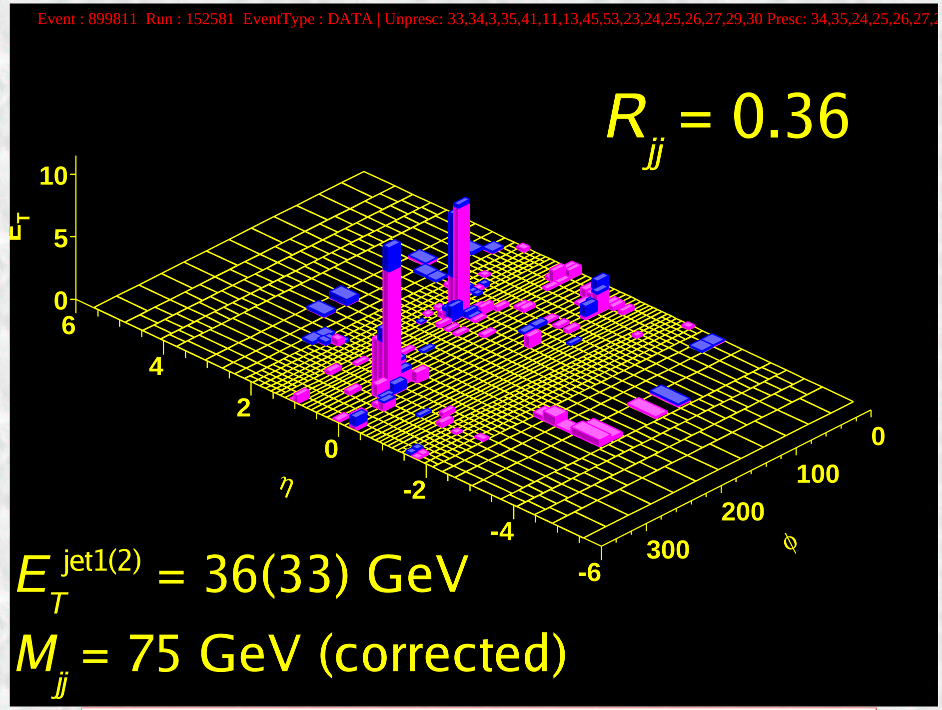
$\sigma_{DPE}(R_{jj}>0.8)$ = 970 ± 65(stat) ± 272(syst) pb (E_T^{jet1} > 10 GeV)

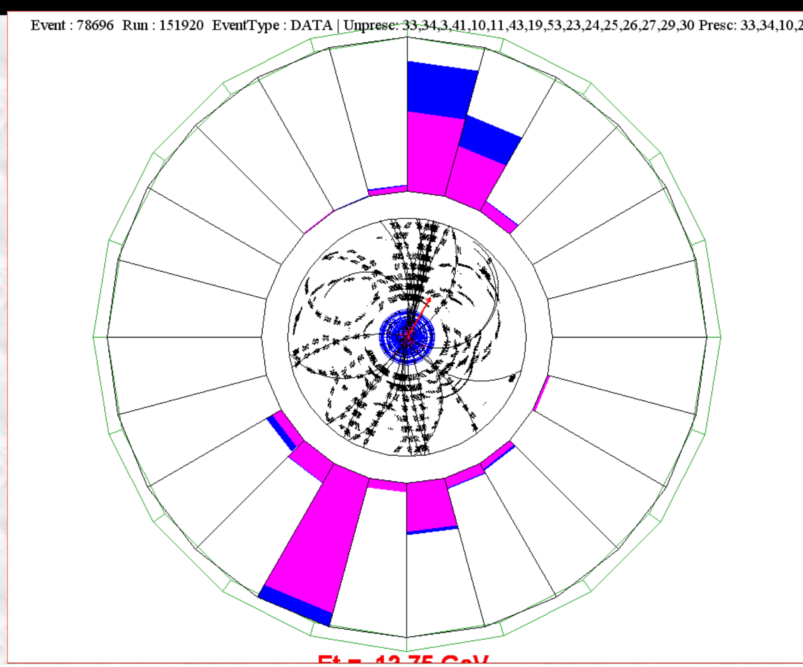
34 ± 5(stat) ± 10(syst) pb (E_T^{jet1} > 25 GeV)

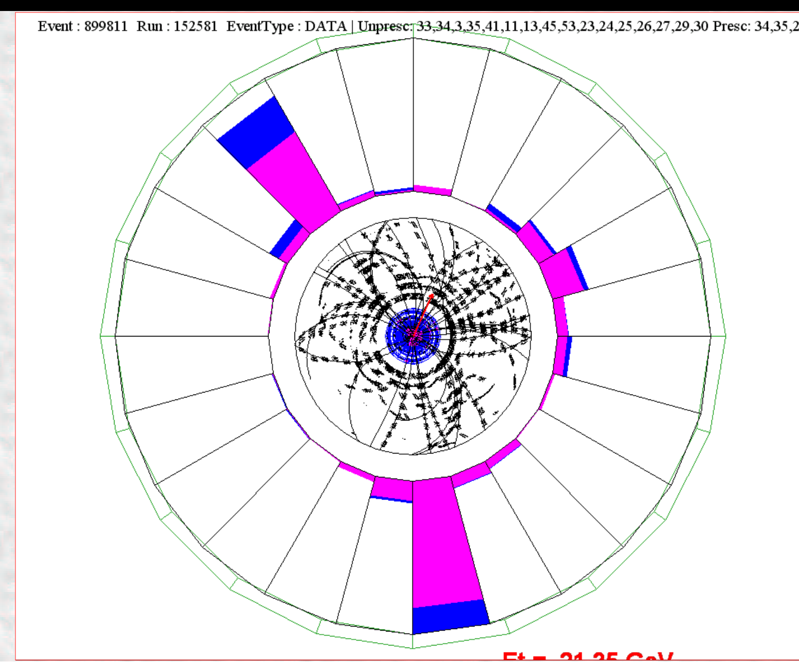
➡ "Upper Limit" on exclusive dijet cross section

DPE Dijet Event Displays







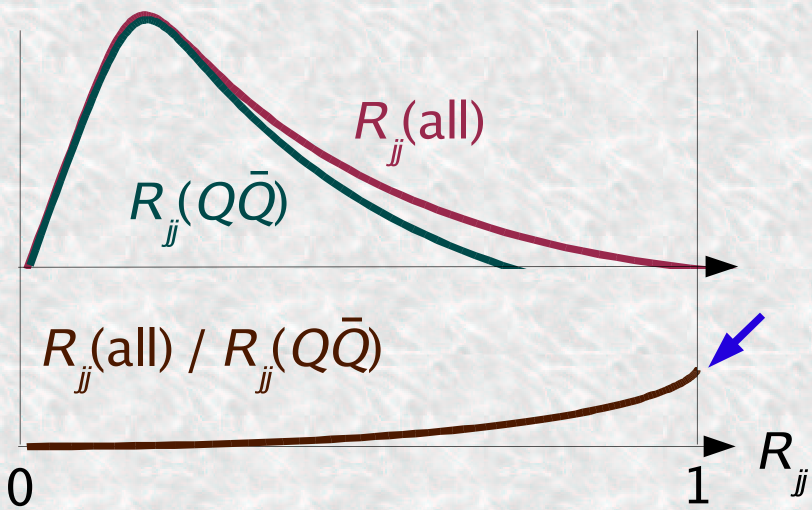


Looking for $b\bar{b}$ Production in DPE

Theory

Khoze, Martin, Ryskin
Eur. Phys. J. C23, 311 (2001)
$\sigma^{excl}(gg^{PP} \to q\bar{q})$
$\propto (m_q^2/M_{JJ}^2)(1 - 4m_q^2/M_{JJ}^2) \to 0$
at $M_{JJ} \gg m_q$
*no such term for $\sigma^{excl}(gg^{PP} \to gg)$

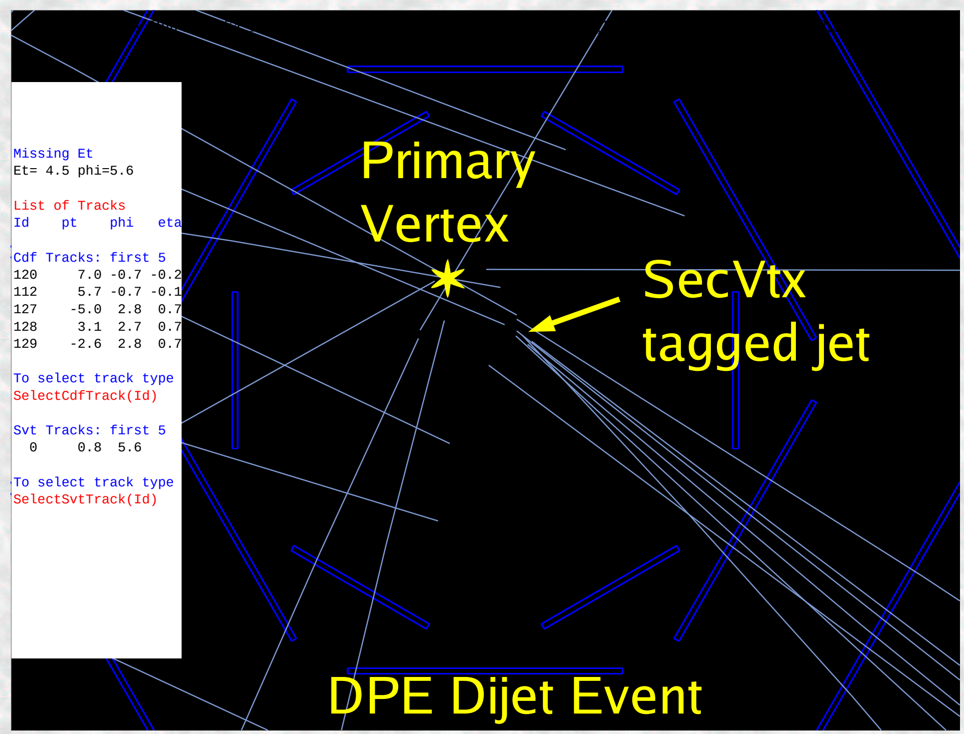
b/c quarks can be identified by standard *b*-tagging algorisms (SecVtx, JetProb)



Experiment

- DPE *b/c*-jet production is interesting in itself
- Extract exclusive dijet:
  - normalize R_{jj} for all jets to R_{jj} for $b\bar{b}$ jets
  - look for excess as $R_{jj} \to 1$

Pros: many systematic effects cancel out
Cons: limited statistics



Summary

Significant increase in data sample in Run II allows detailed studies of DPE dijet production

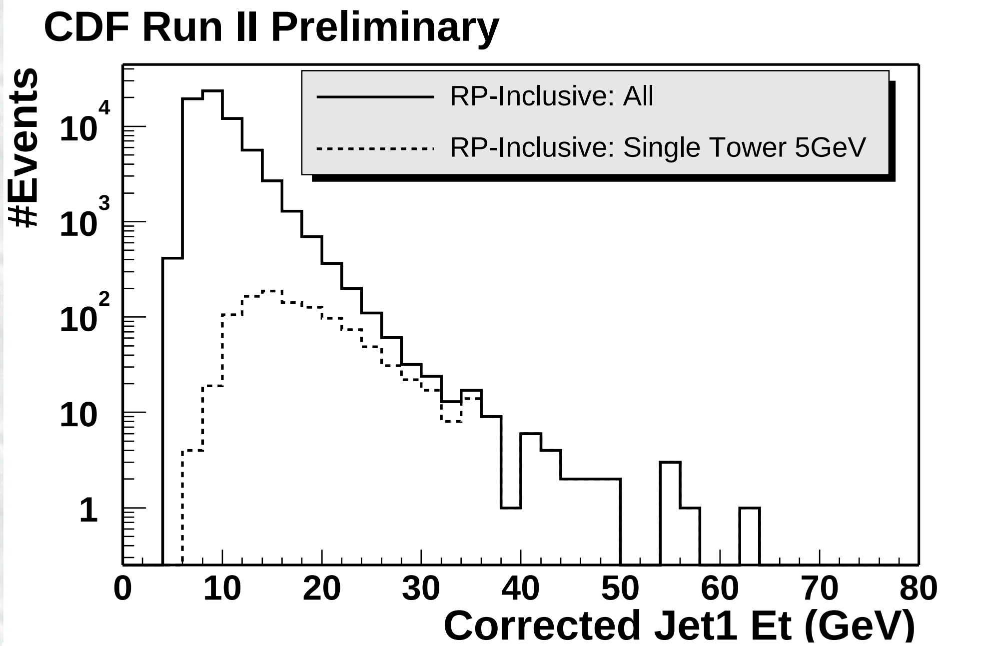
- so far, x100 more DPE events analyzed than in Run I
- 4-fold increase is expected when all available data are included

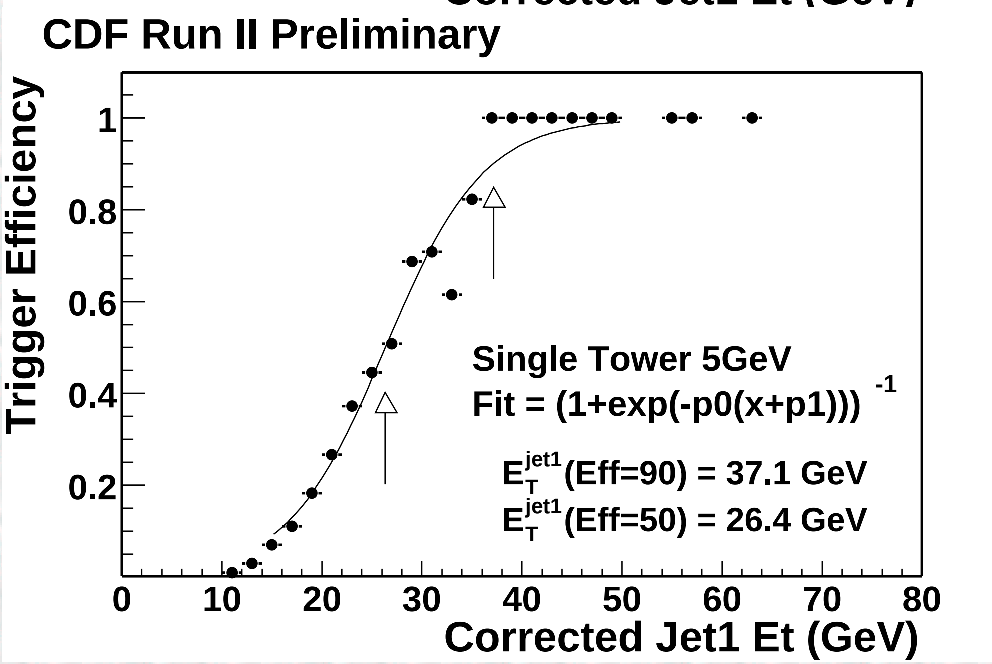
Obtained “upper limit” on exclusive dijet production

- no significant excess due to exclusive dijets seen in high R_{jj}
- limits can be used to calibrate diffractive higgs production in DPE

More exciting results will appear soon...

Jet Trigger Efficiency





Trigger Efficiency vs Leading Jet E_T intervals

E_{T1}^{min}	E_{T1}^{max}	$\epsilon(\Delta E_{T1})$
10	15	5.77±0.29%
15	20	14.4±0.7%
20	25	31.6±1.6%
25	35	66.6±3.3%
35	50	95.1±4.8%
50	110	100^{+0}_{-5}%

(±5% error assigned)

Systematic Effects

Calorimeter Energy Scale:

±10% change of Central/Plug scale ⟶ $\Delta\sigma_{\mathrm{DPE}}(R_{jj}>0.8)$ = 20-26%

±25% change of MiniPlug scale ⟶ $\Delta\sigma_{\mathrm{DPE}}(R_{jj}>0.8)$ = 14-26%

Multiple Interaction Correction:

- multiple interactions (soft collisions) would kill gap signal on the proton side, even though single vertex is required
- corrected for this by giving every event a weight of $P_{\bar{n}_i}(0)^{-1} = e^{\bar{n}_i}$

  where $\bar{n}_i = L_i \cdot \sigma_{inel} / f_{TeV}$ (average # of interactions per bunch crossing)

  ±10% change of $L_i \cdot \sigma_{inel}$ ⟶ $\Delta\sigma_{\mathrm{DPE}}(R_{jj}>0.8)$ = 6%

Hadronization Effect:

- R_{jj} depends on cone size (unless no out-of-cone and no underlying energy)
- R_{jj} of exclusive dijets (no UE) depends on cone size
- checked R_{jj} and $\sigma(R_{jj}>0.8)$ for R_{cone}=0.4, 0.7 and 1.0

  R_{cone}=0.4 shows non-negligible OOC energy: $\sigma_{Rjj>0.8}(R_{cone}=0.7)>\sigma_{Rjj>0.8}(R_{cone}=0.4+E_{\mathrm{UE}}(0.7-0.4))$

  R_{cone}=1.0 well approximated by $R_{cone}=0.7+E_{\mathrm{UE}}(1.0-0.7)$

Our $\sigma_{\mathrm{DPE}}(R_{jj}>0.8)$ depends on R_{cone}, and should be quoted with "R_{cone}=0.7"