Diffractive dijet production in ppbar collisions at 1.96 TeV

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The Rockefeller University
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GP meeting

documentation: CDF 7831 and CDF 7877

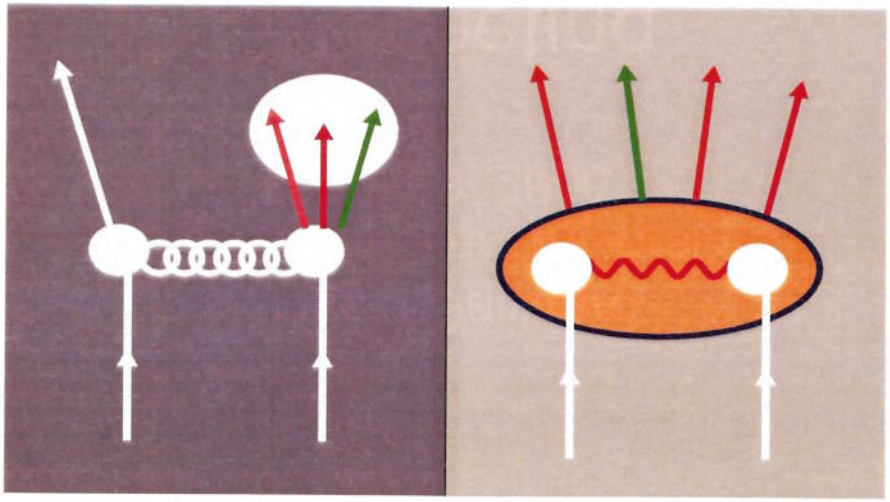
http://www-cdf.fnal.gov/internal/physics/godparents/diff_dijets/

Hadronic interactions

Diffractive

vacuum exchange

Protons retain their quantum numbers



Non-Diffractive

color exchange

Protons acquire color and break apart

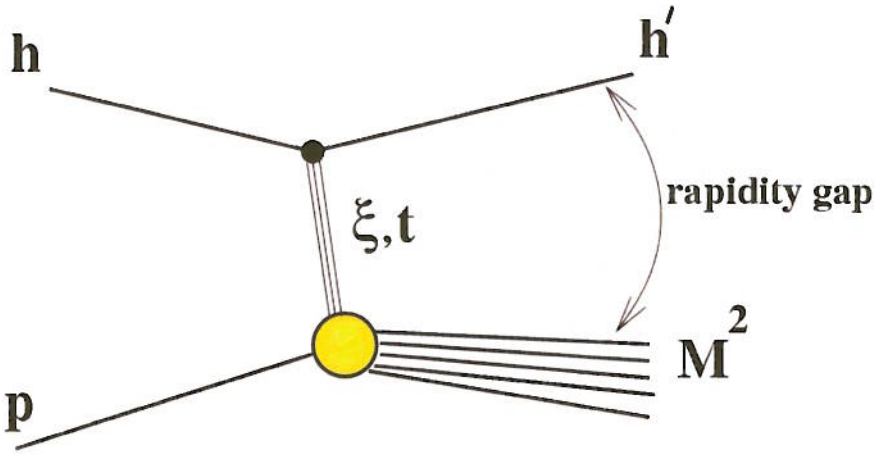
Goal: understand the nature of the colorless exchange

Hadronic diffraction

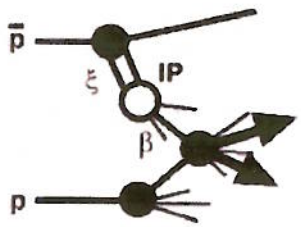
Small momentum transfer

Elastic and diffractive processes
⇨ leading hadron emitted at small angle

The exchange ("pomeron") is colorless
⇨ large rapidity gap



Introduction



ξ: fraction of anti-proton momentum loss

β: fraction of Pomeron momentum carried by parton

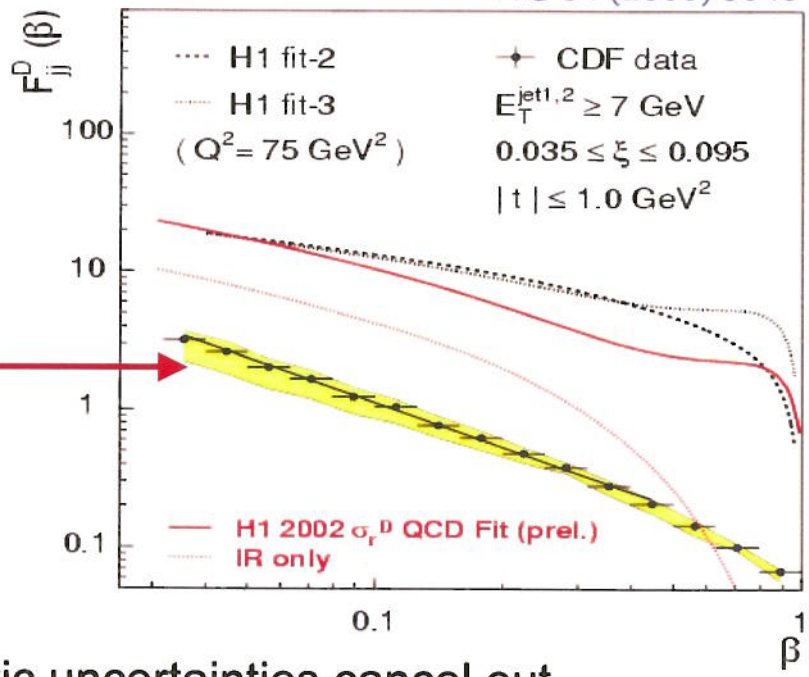
parton $x_{Bj} \equiv \beta \cdot \xi$

$$\frac{\sigma(SD_{jj})}{\sigma(ND_{jj})} = \frac{F_{jj}^{D}(x)}{F_{jj}(x)}$$ (LO QCD)

CDF Run I DSF suppressed
by a factor of ~10 relative to HERA

⇨breakdown of QCD factorization

PRL 84 (2000) 5043



in the ratio SD/ND many systematic uncertainties cancel out

Motivation

…or…what is the goal of the analysis?

Is the Pomeron a particle or made out of proton PDFs?

⇨understand Pomeron in terms of QCD

⇨characterize the exchange looking at Q^2 and t dependence

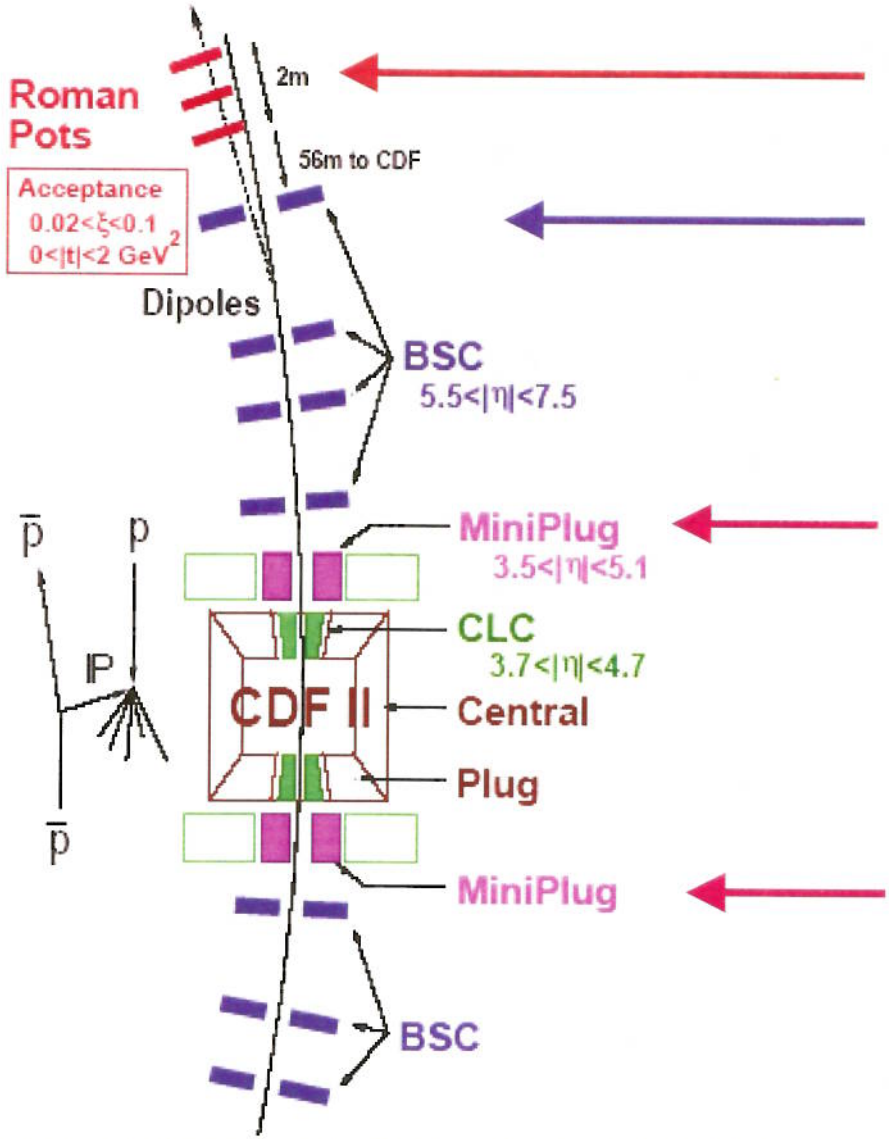
Measure:

1) DSF vs Q^2
2) t-distribution

From Run I to Run II

- improved detectors (BSC, MP)
- dedicated triggers
- more events at larger jet energies

Run II diffractive program

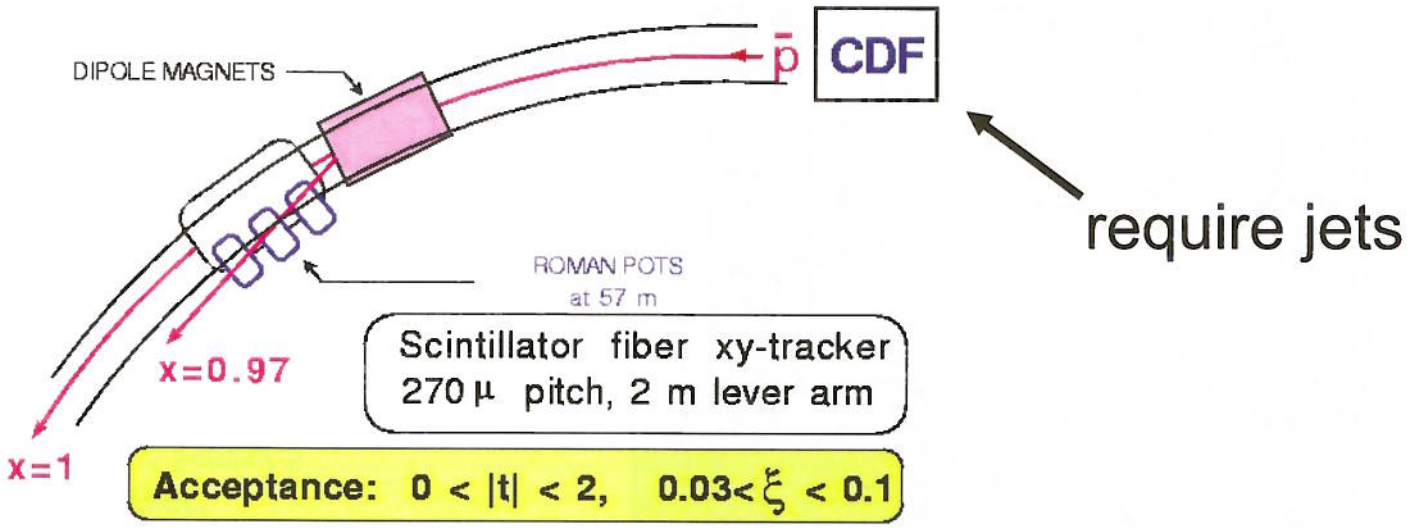


ROMAN POT DETECTORS

BEAM SHOWER COUNTERS: used to reject ND events

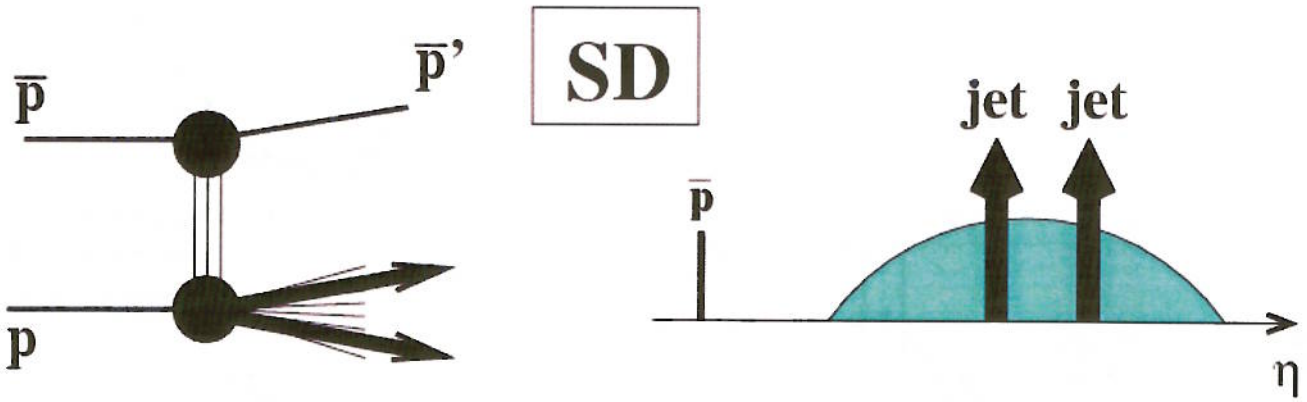


Data samples

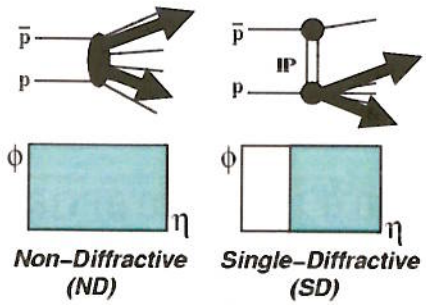


- RP is triggered on leading antiprotons
- use RP + jet triggers
- Run #151,683-168,889

Event selection



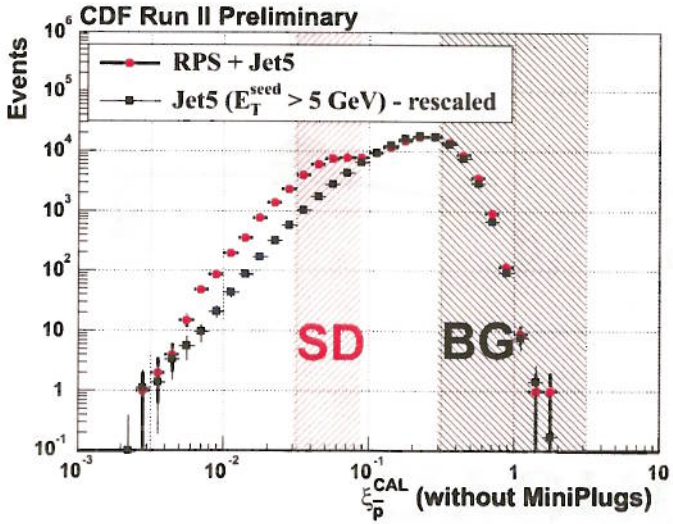
Selection cut	RP	RP+J5	RP+J20	RP+J50
Triggered events	1,634,723	1,124,243	1,693,644	757,731
Good run	1,431,460	955,006	1,421,350	561,878
$\not\!\!E_T$ significance $S_{\mathrm{MET}} < 2$	1,431,253	950,776	1,410,780	539,957
$N(jet) \geq 2$: $E_T^{1,2} > 5$ GeV, $\lvert\eta^{1,2}\rvert < 2.5$	59,157	557,615	1,168,881	521,645
"splash event" veto (SumRPT<5000 ADC counts)	27,686	259,186	541,031	215,975
RPS triple coincidence	27,680	259,169	541,003	215,974
SD ($0.03 < \xi_{\bar{p}} < 0.09$)	1,458	20,602	26,559	4,432

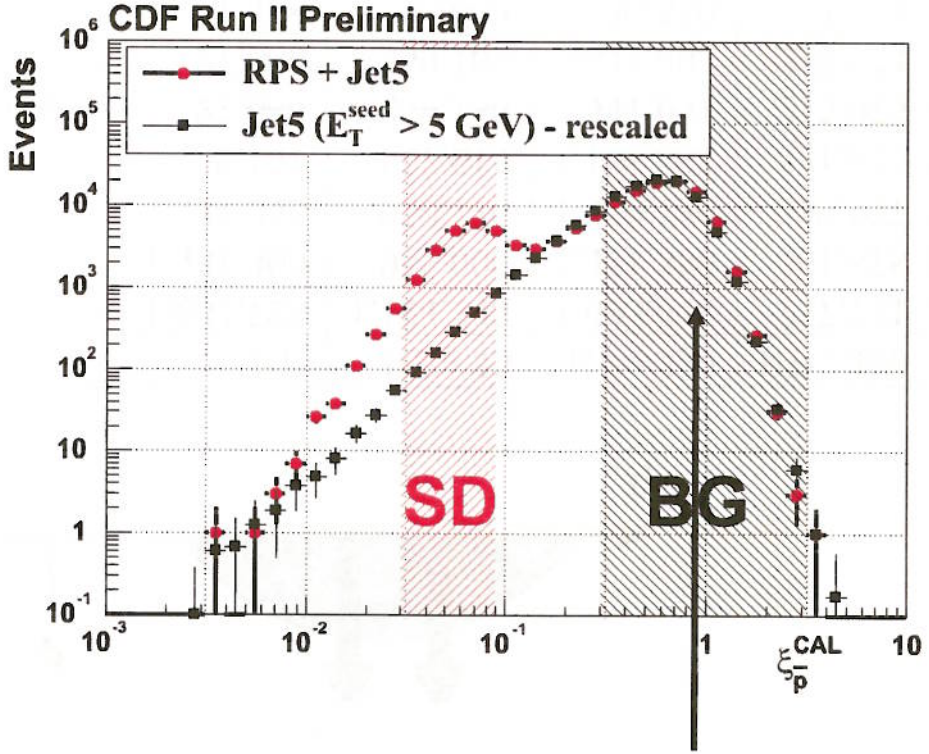


Diffractive dijets

ξ: momentum loss fraction of pbar

$$\xi = \frac{\Sigma_{\text{(all towers)}} E_T e^{-\eta}}{\sqrt{s}}$$

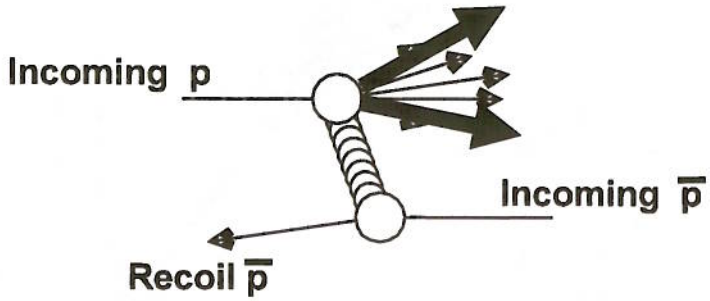




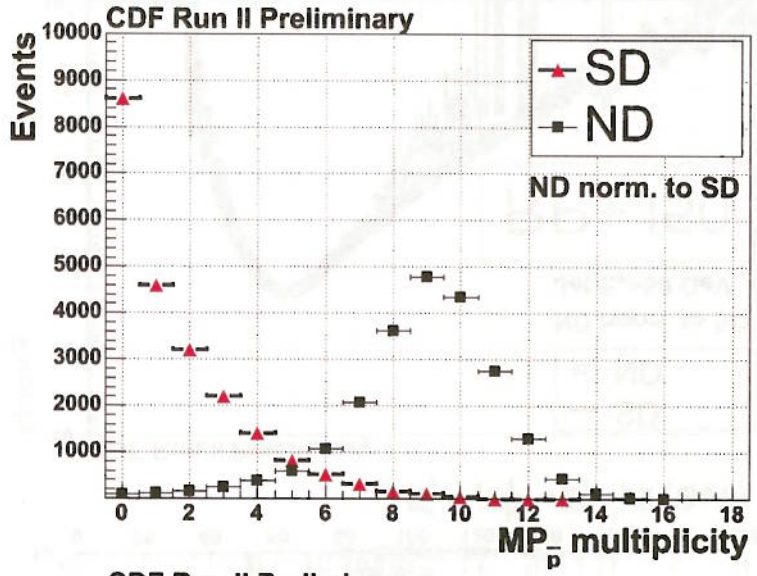
overlap events
(multiple $p\bar{p}$ interactions)

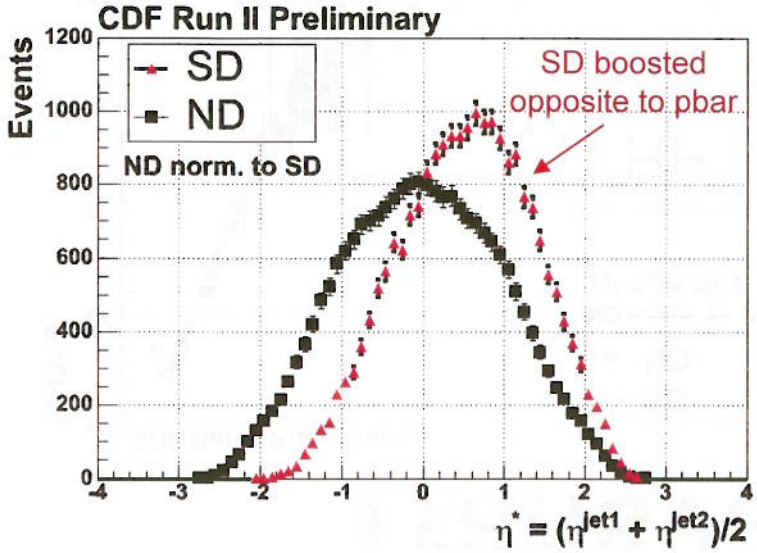
MP energy scale: ±30% →Δlogξ = ±0.1
RP acceptance (0.03<ξ< 0.09) ~ 80%

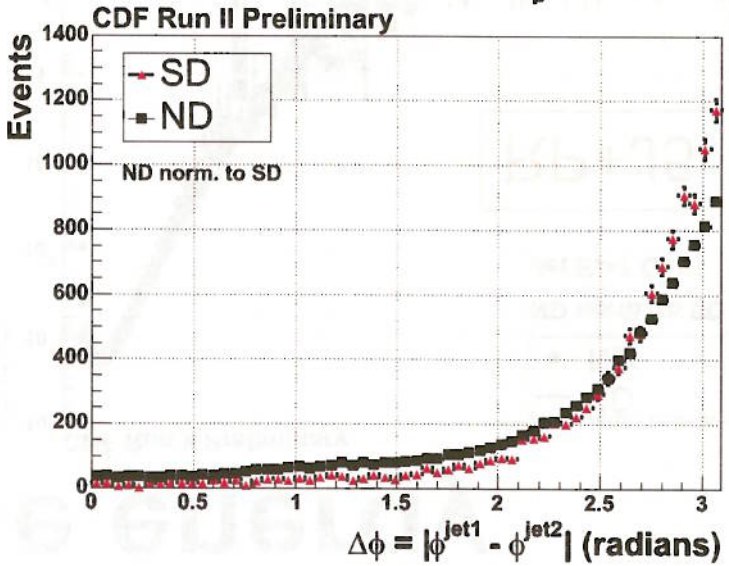
Kinematical Properties



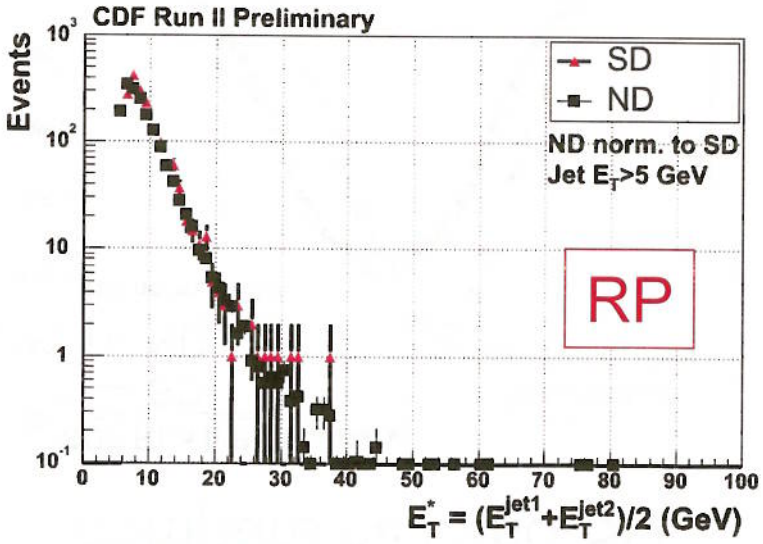
compare ND and SD

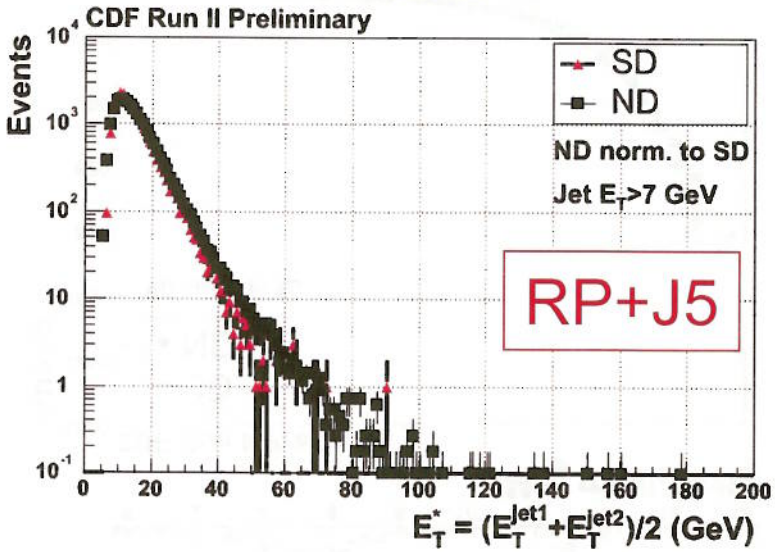


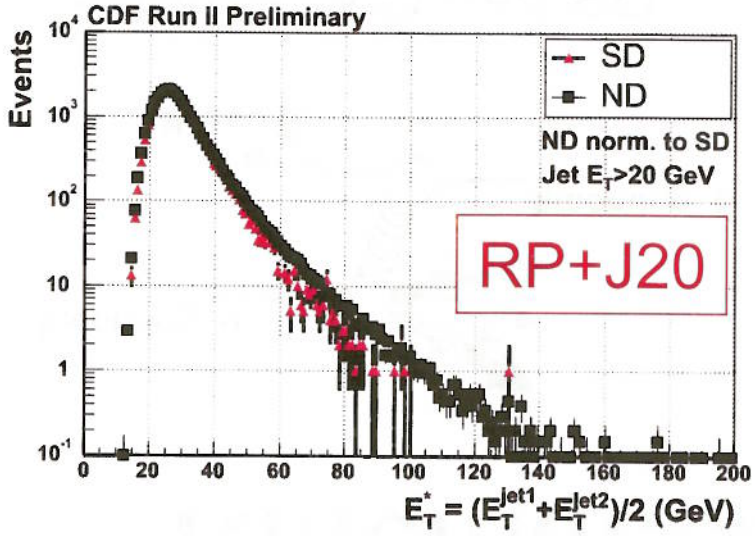


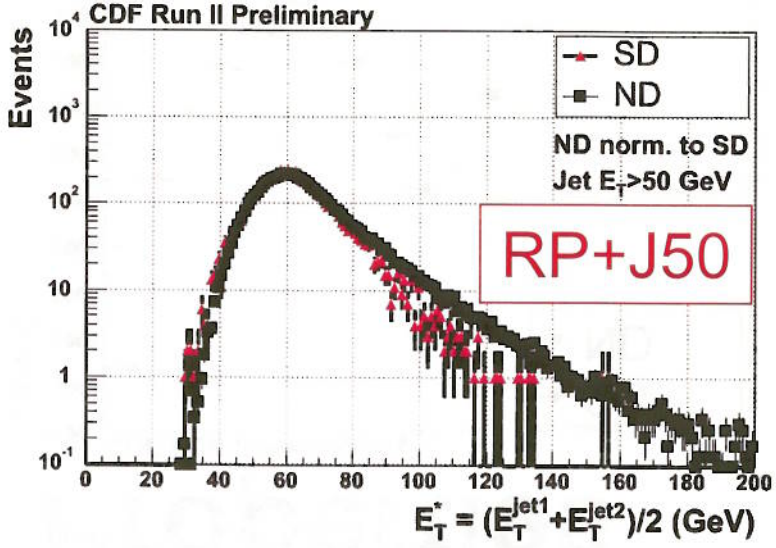


Transverse energy

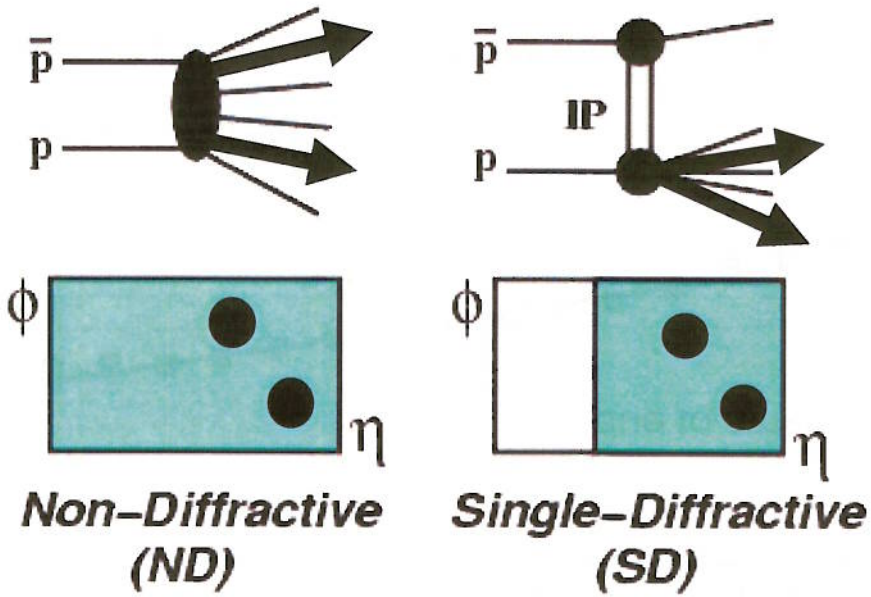








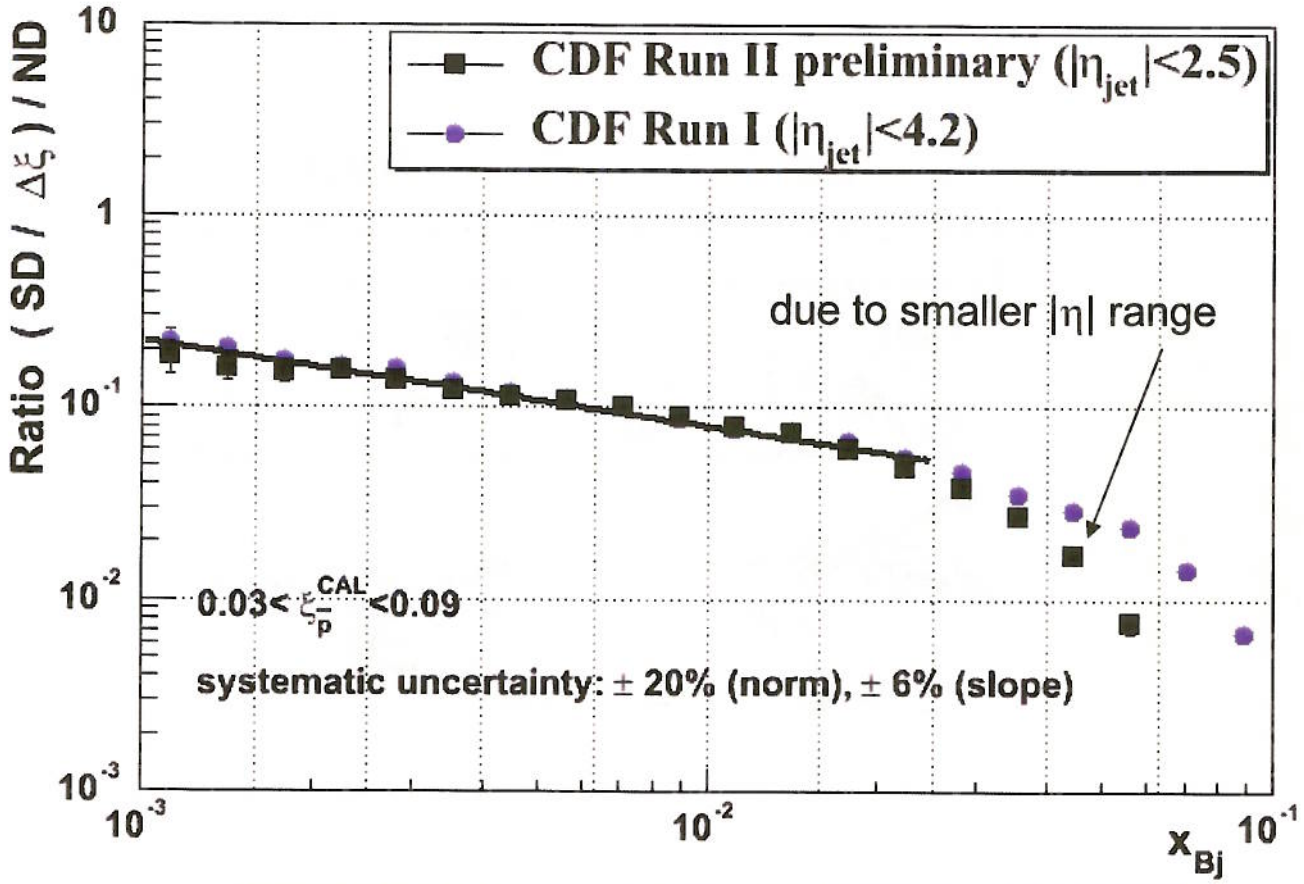
Diffractive structure function



$$R(x_{Bj}) \equiv \frac{\text{Rate}_{jj}^{SD}(x_{Bj})}{\text{Rate}_{jj}^{ND}(x_{Bj})}$$

$$\Rightarrow \frac{F_{jj}^{SD}(x_{Bj})}{F_{jj}^{ND}(x_{Bj})}$$

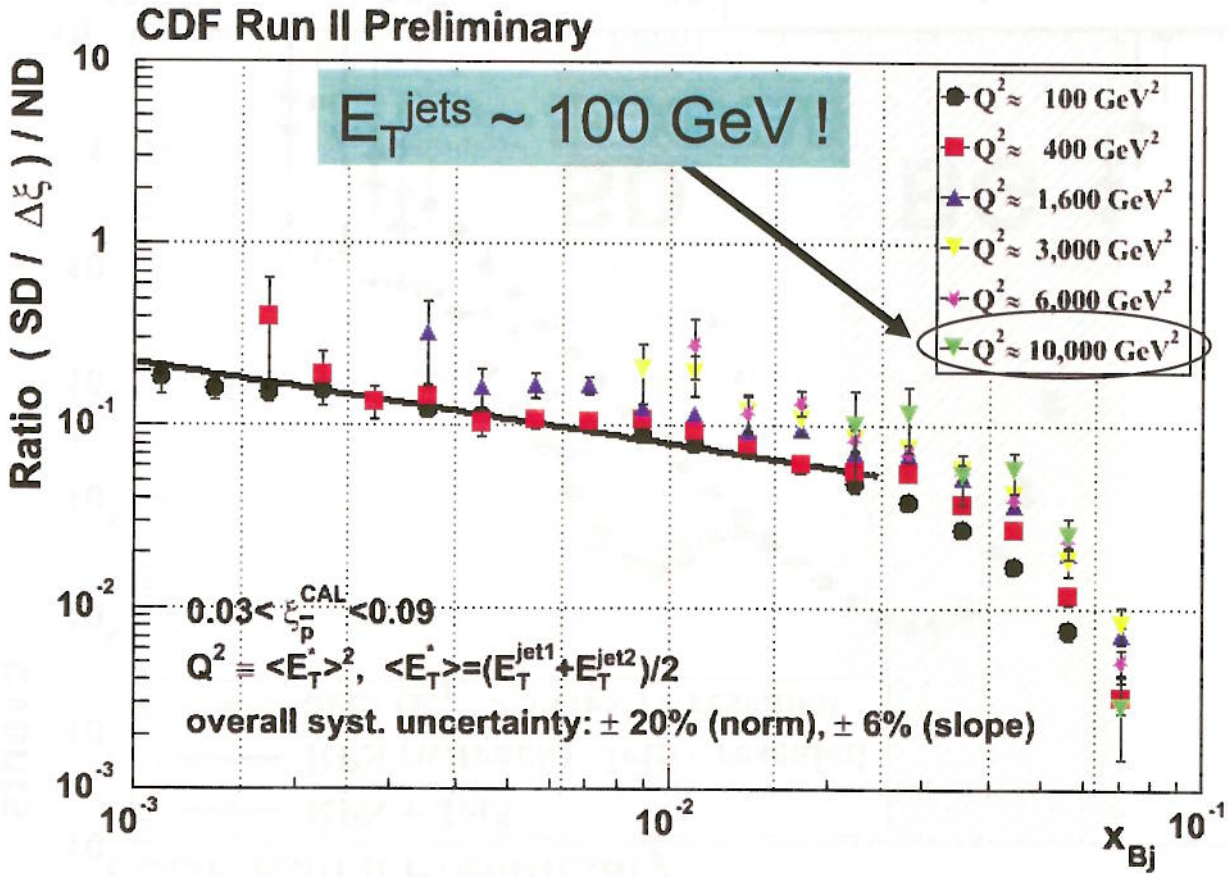
SD/ND ratio



ratio of SD/ND dijet event rates

⇨ confirms Run I results

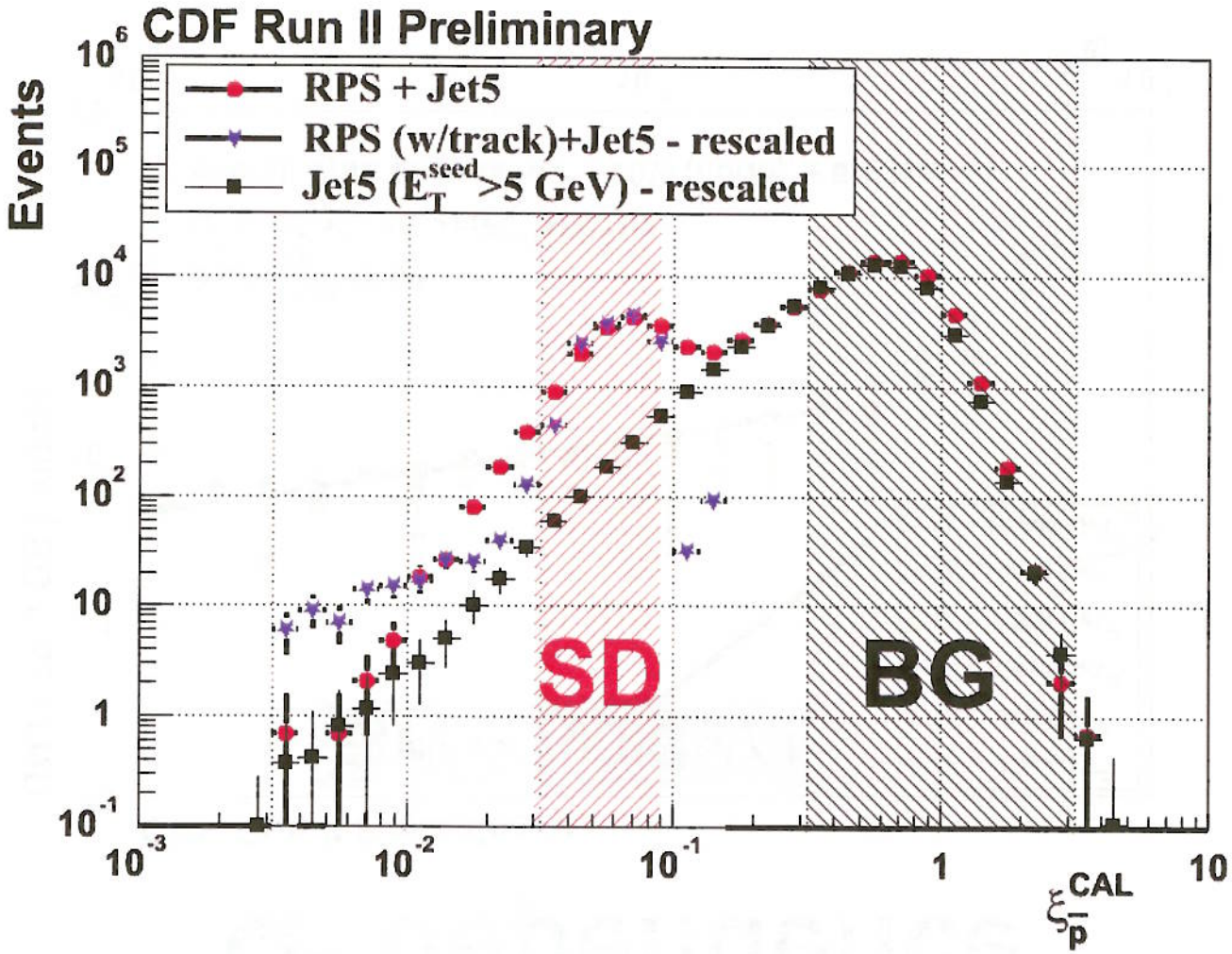
Q^2 dependence



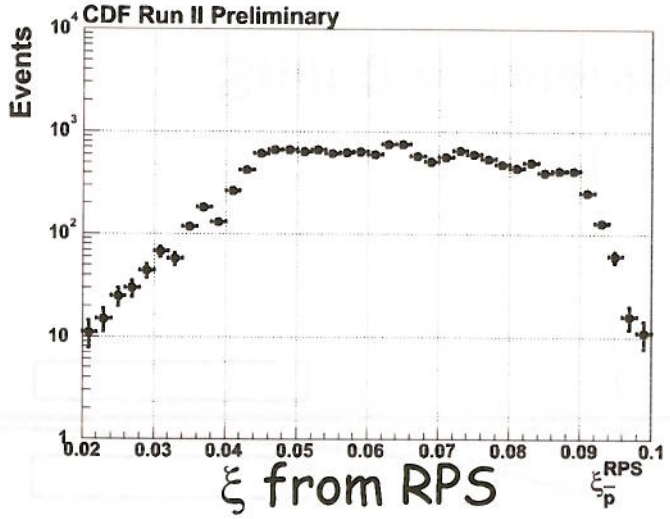
small Q^2 dependence for $100 < Q^2 < 10{,}000$ GeV^2

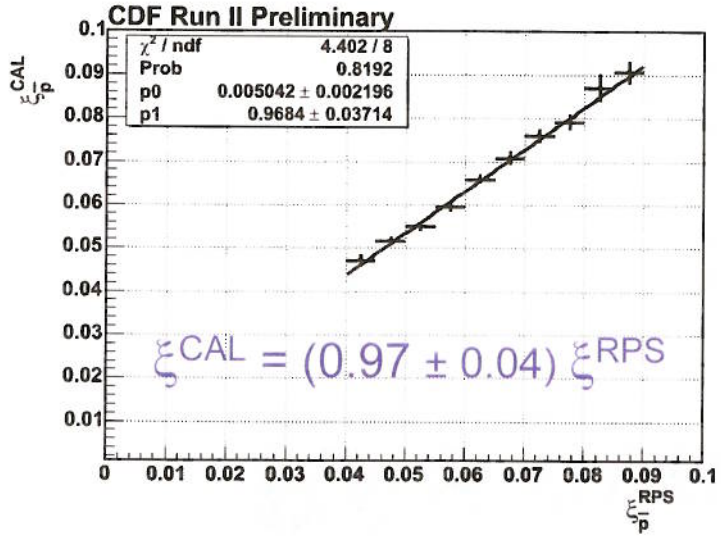
⇨ Pomeron evolves as proton

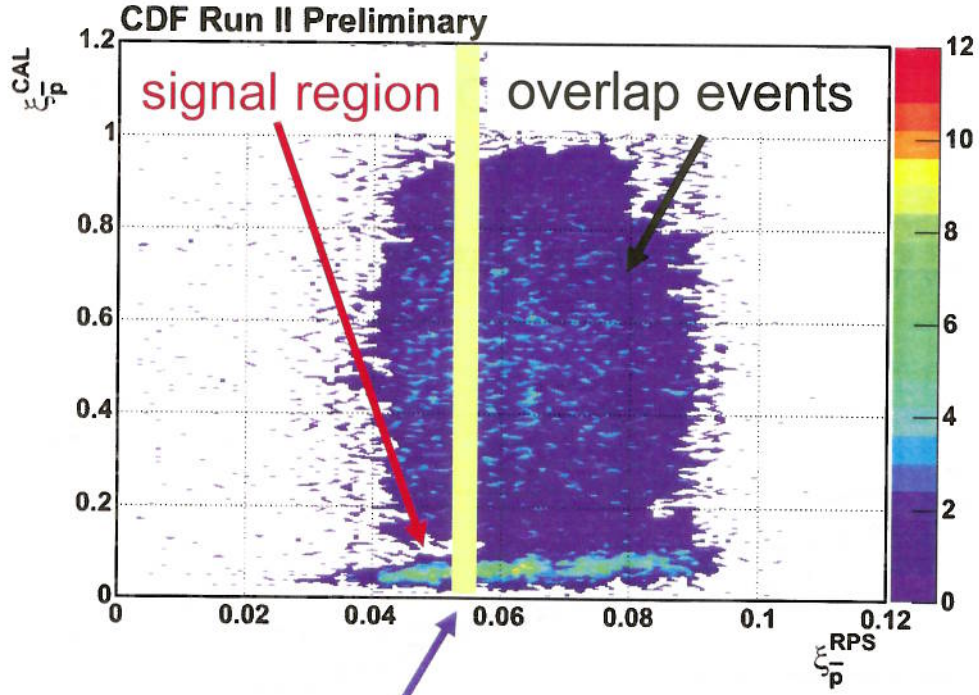
RPS tracking

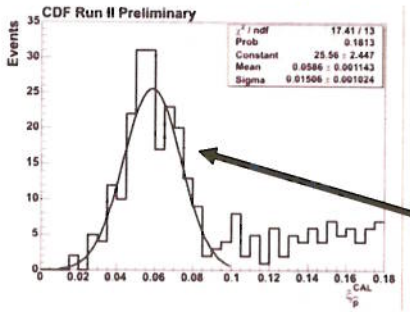


ξ: RPS vs calorimeter





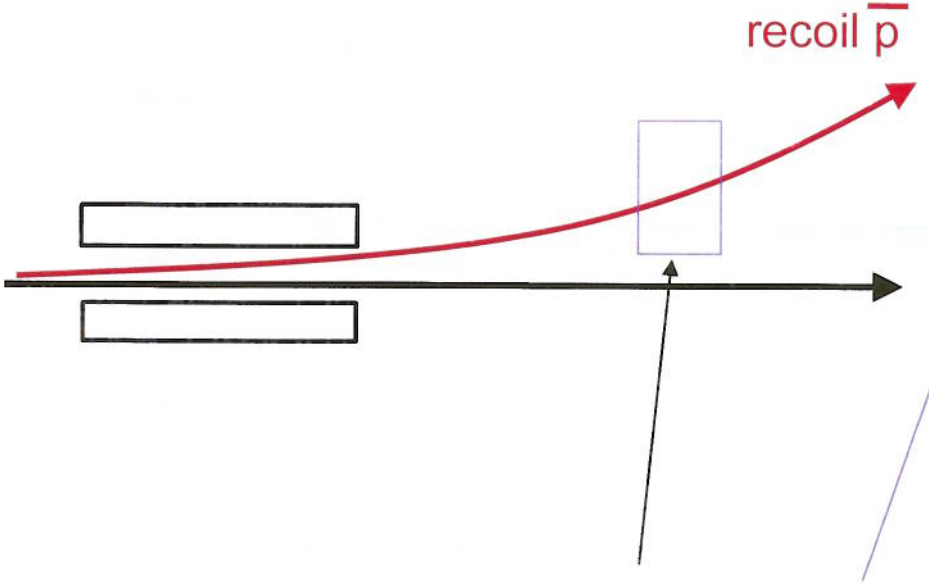


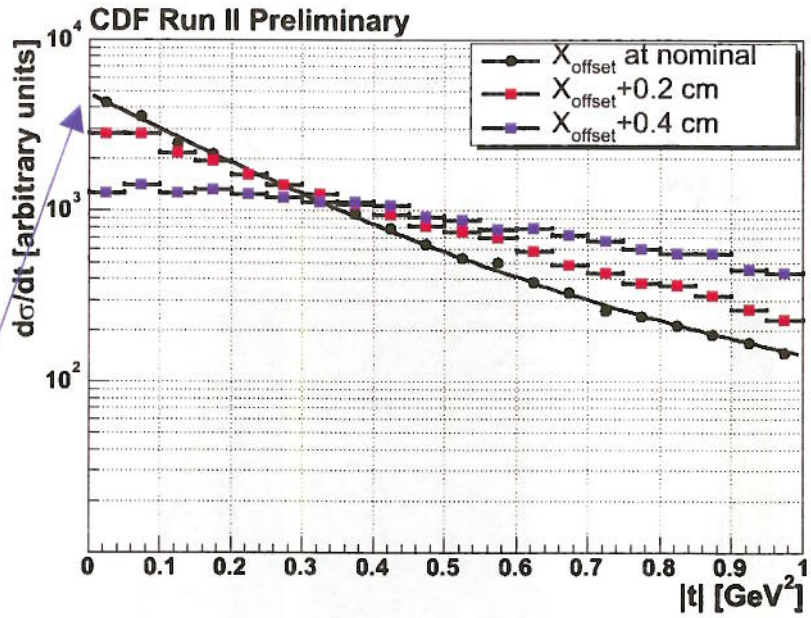


ξ^{cal} distribution for slice of ξ^{RPS}

σ / mean ~ 30%

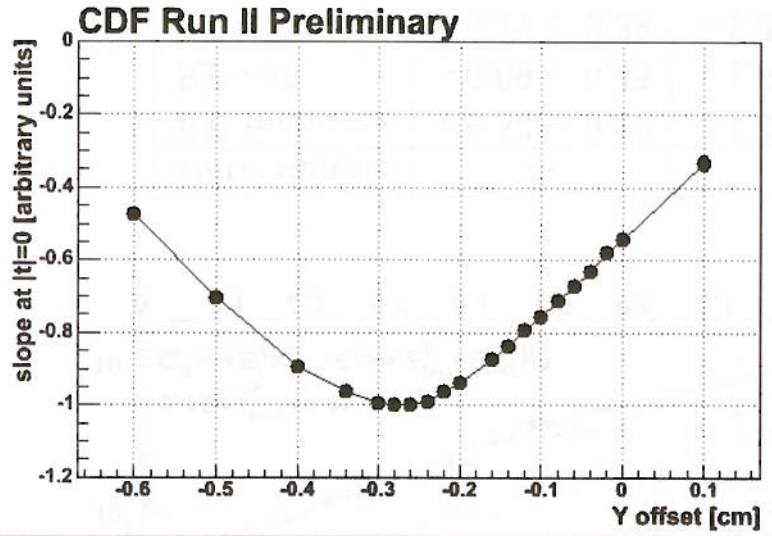
RPS dynamic alignment

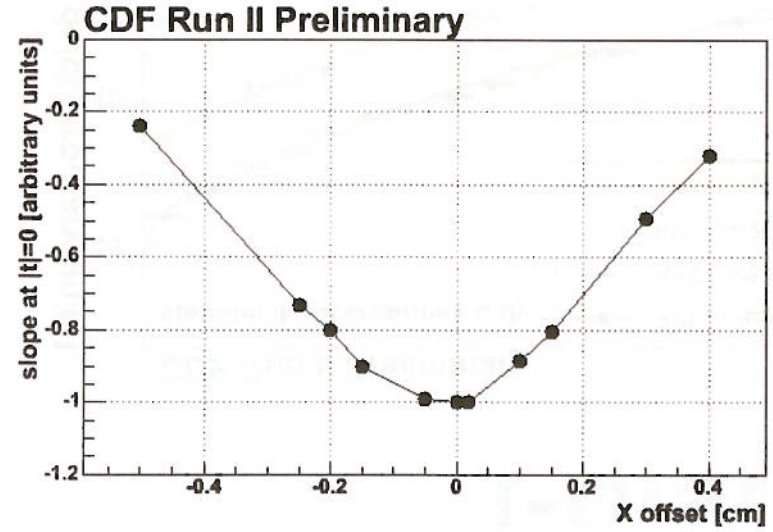




Shift the detector to maximize the slope

RPS dynamic alignment

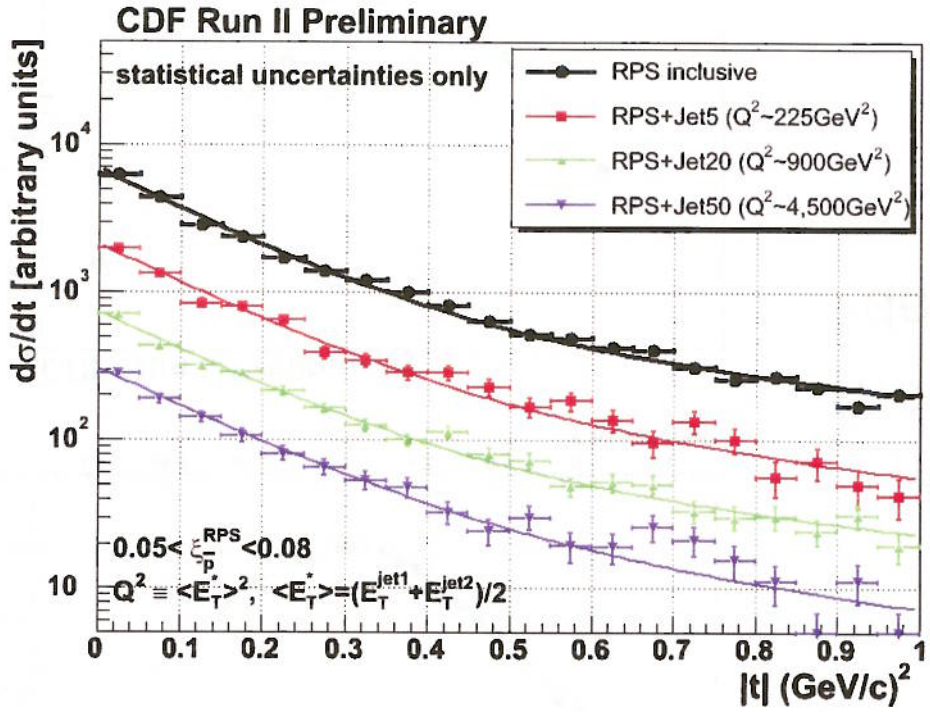




maximize the |t|-slope
(normalized to max slope)

⇨determine X and Y offsets

t-distribution



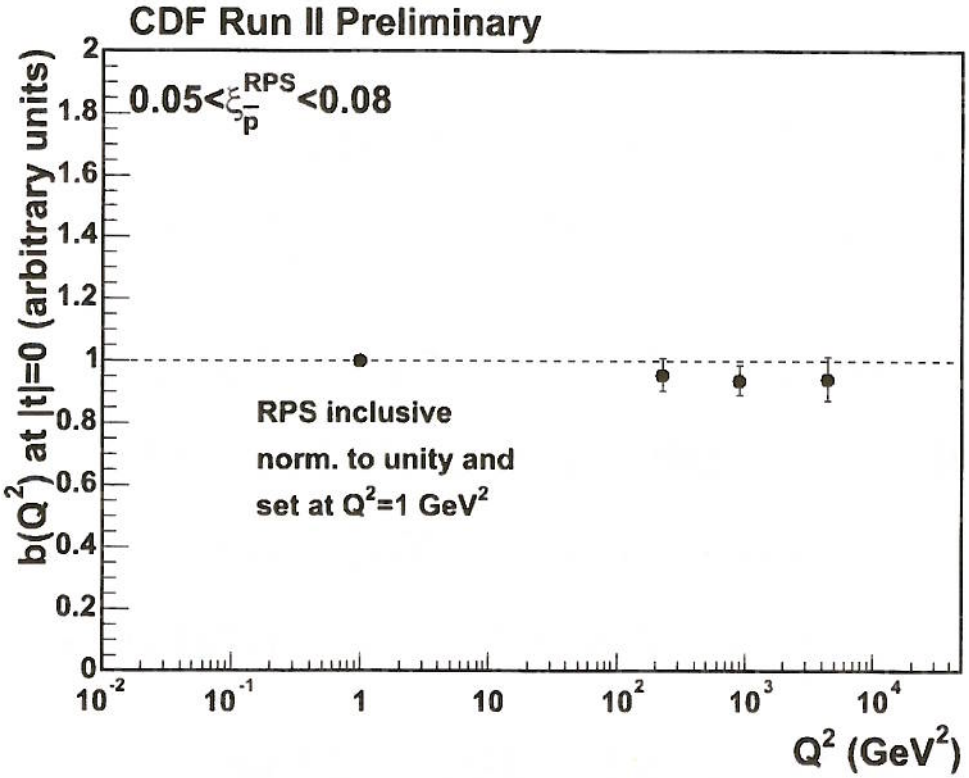
fit t-distribution to a double exponential using:

$$F = 0.9 \cdot e^{b_1 \cdot t} + 0.1 \cdot e^{b_2 \cdot t}$$

⇨ no diffraction 'dips' observed for |t|<1

Data sample	b_1	b_2	$< E_T >$ (GeV)	Q^2 (GeV^2)
RP inclusive	-6.56 ± 0.12	-1.46 ± 0.04	small	≈ 1
RP+J5	-6.09 ± 0.45	-1.57 ± 0.18	15	225
RP+J20	-6.17 ± 0.38	-1.38 ± 0.13	30	900
RP+J50	-6.80 ± 0.57	-1.27 ± 0.17	67	4,500
mean value	-6.41 ± 0.41	-1.42 ± 0.14	N/A	N/A

t-slope vs Q^2



⇨ same slope over the region $0 < Q^2 < 4{,}500$ GeV^2

Data sample	b_1	b_2	$< E_T >$ (GeV)	Q^2 (GeV^2)
RP inclusive	1.00 ± 0.02	1.00 ± 0.02	small	≈ 1
RP+J5	0.97 ± 0.05	0.97 ± 0.07	15	225
RP+J20	0.96 ± 0.04	0.97 ± 0.06	30	900
RP+J50	1.02 ± 0.06	0.93 ± 0.08	67	4,500

2002-2003 data

Alignment method works well but…

- different runs/stores (used beam position at B0)

  ⇨ alignment should be done run-by-run, but runs too short to do single run-calibration

  ⇨could broaden resolution

- uncertainty of background at large |t|

  ⇨ not enough events at large |t| values to estimate shape

Low luminosity run

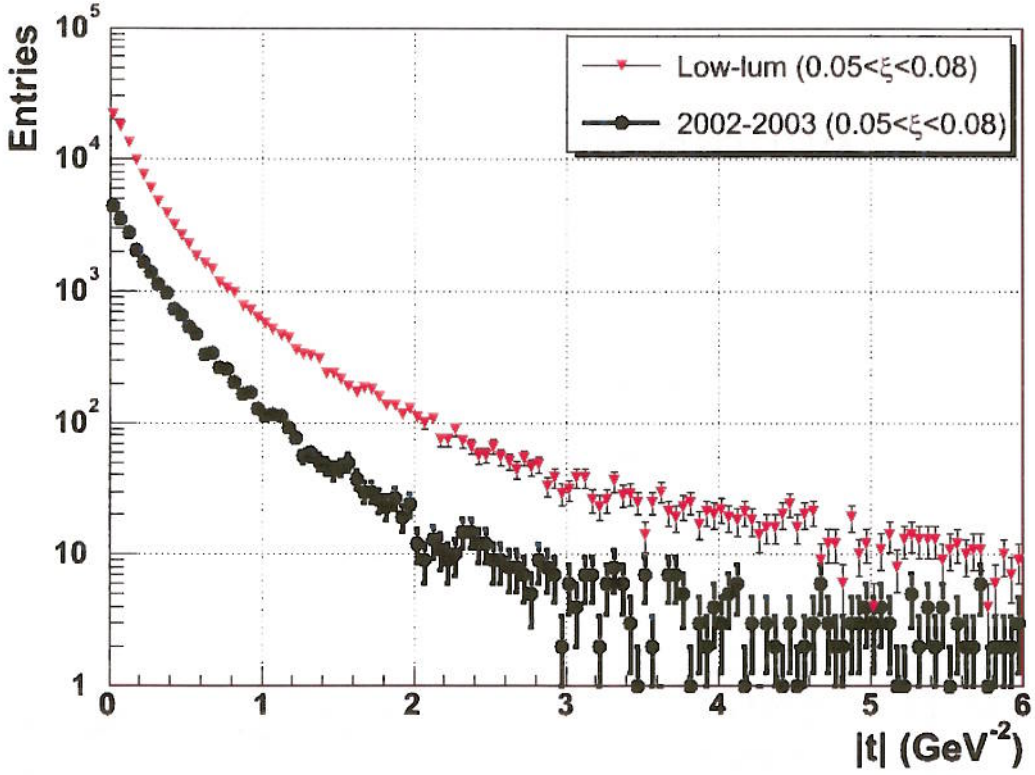
Taken in Jan 2006:
Runs: 211,058 to 211,079

Run	Integr. Lum	Inst Lum
211058	18 nb^{-1}	0.5-0.6
211073	11 nb^{-1}	0.5-0.5
211079	13 nb^{-1}	0.4-0.5

E30

- a single store/few runs
  - ⇨ alignment works well
- more events
  - ⇨ can study background
- low luminosity
  - ⇨ less overlap/background

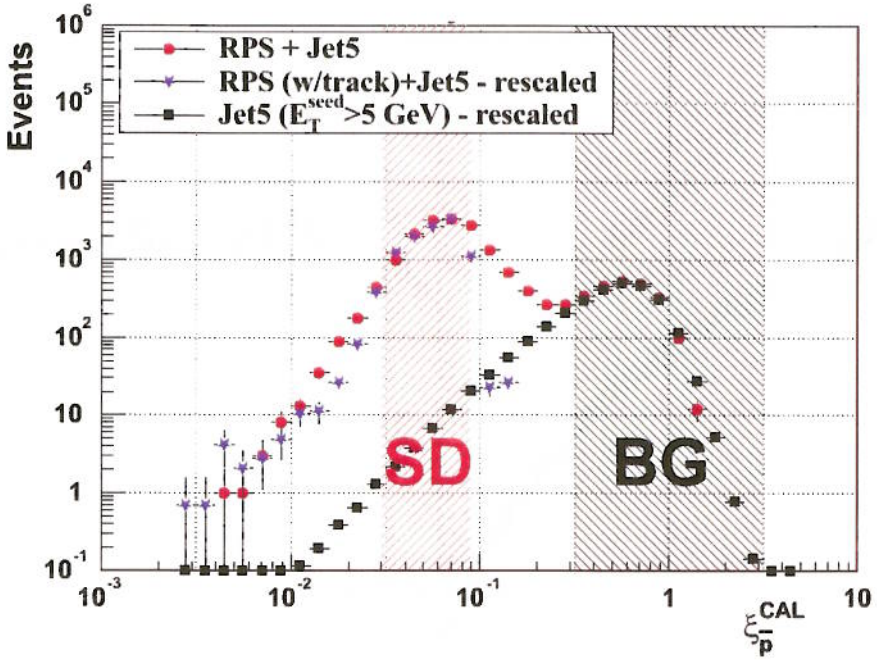
t-distribution



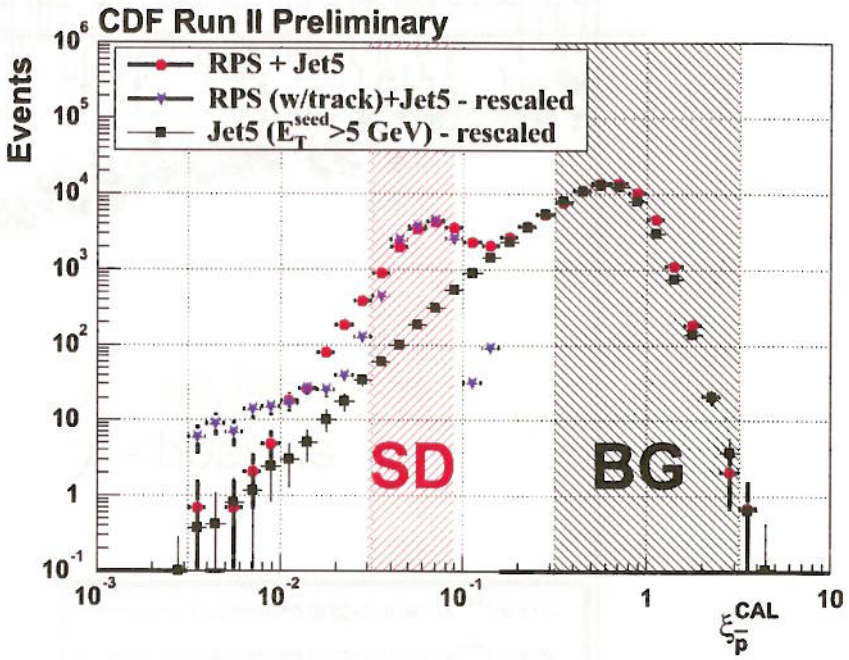
⇨ same slope over the region 0< |t| <5 GeV^{-2}

⇨ no diffraction 'dips' observed for |t|<5

Low-luminosity run (ξ-dist)

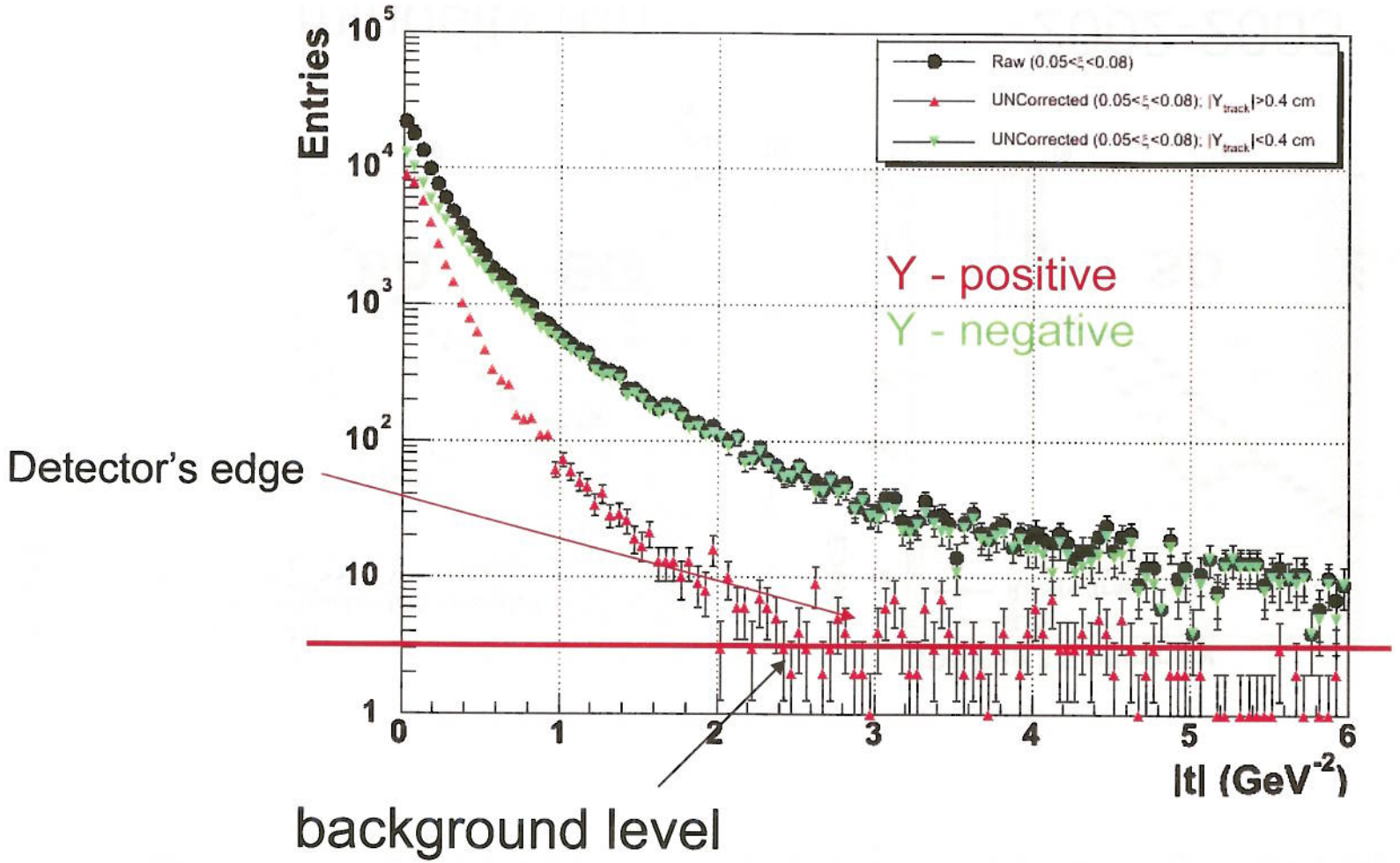


Low-luminosity run

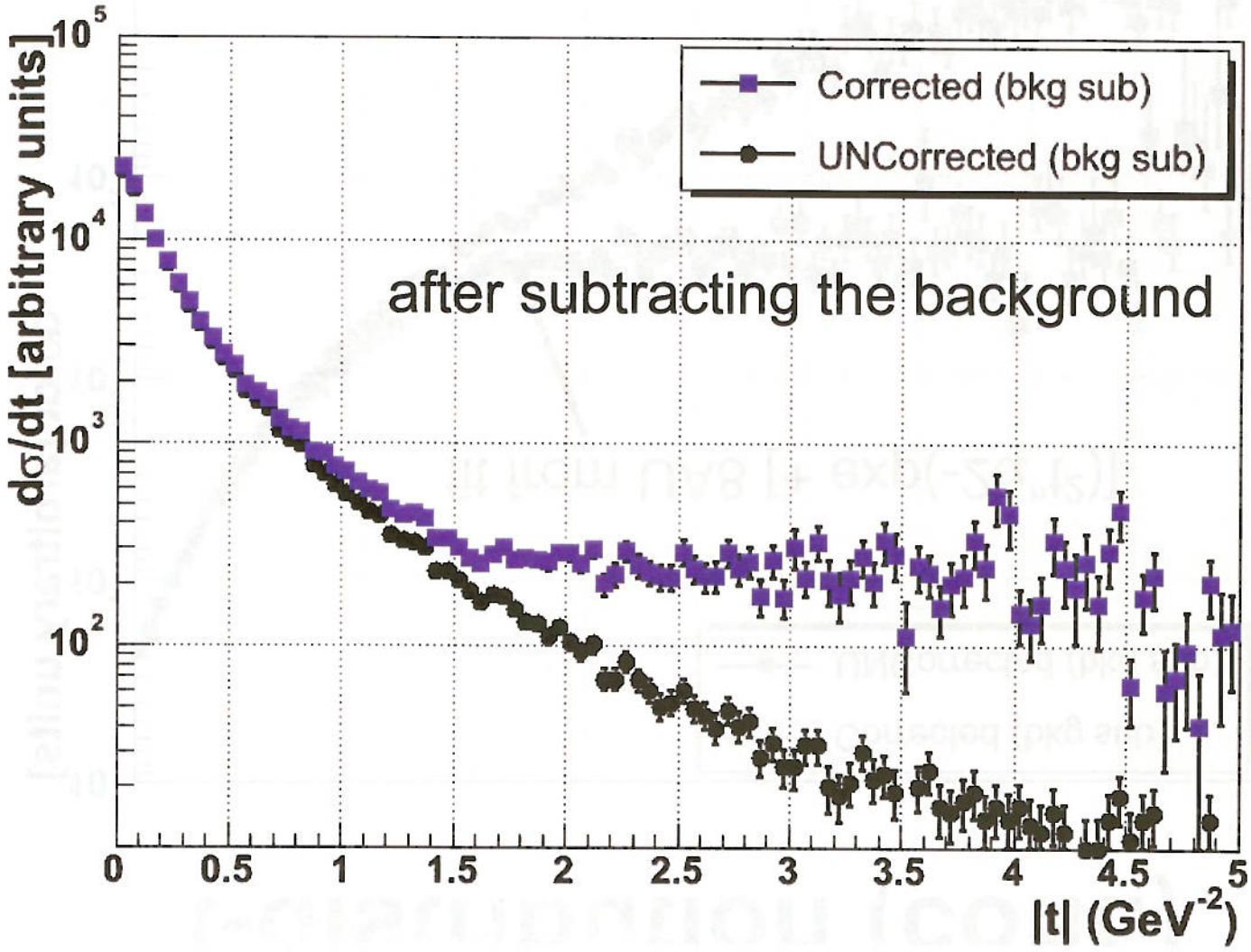


2002-2003 data

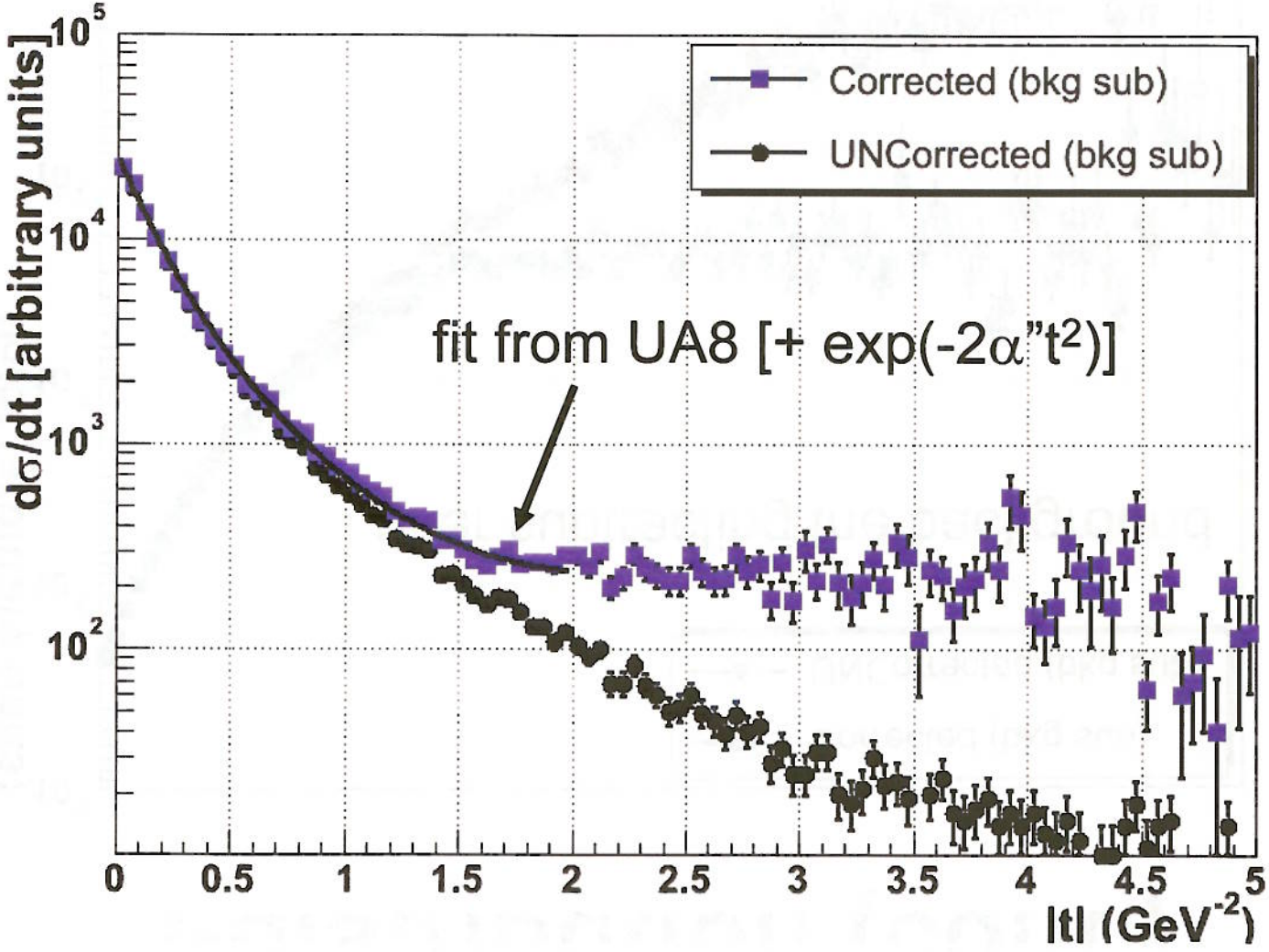
t-distribution (cont.)



t-distribution (cont.)



t-distribution (cont.)



Summary

measured DSF at different Q^2 values

SD/ND ratio is consistent with Run I and it is slightly increasing (same within unc.) with Q^2 (100-10000 GeV^2)

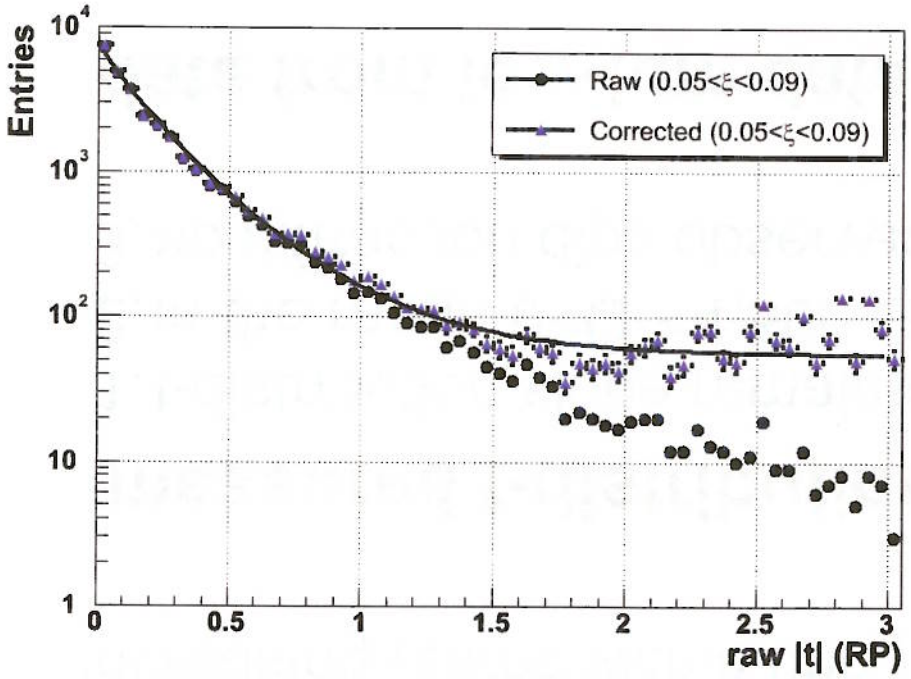
measured t-distribution in diffractive events

1. t-distribution slope remains constant
2. in the range $0<Q^2<4{,}500$ GeV^2
3. no diffraction dips observed for $|t|<3$ GeV^2

data from low-lum data yields similar results

single store/few runs and large statistics
results consistent with UA8 data

t-distribution (cont)



- Correct for acceptance
- Use 1-parameter fit

A. Donnachie and P. Landshoff, PLB 518 (2001) 63

$$F_1(t) = \frac{4m_p^2 - 2.8t}{4m_p^2 - t} \cdot \left(\frac{1}{(1-t)/0.71}\right)^2$$

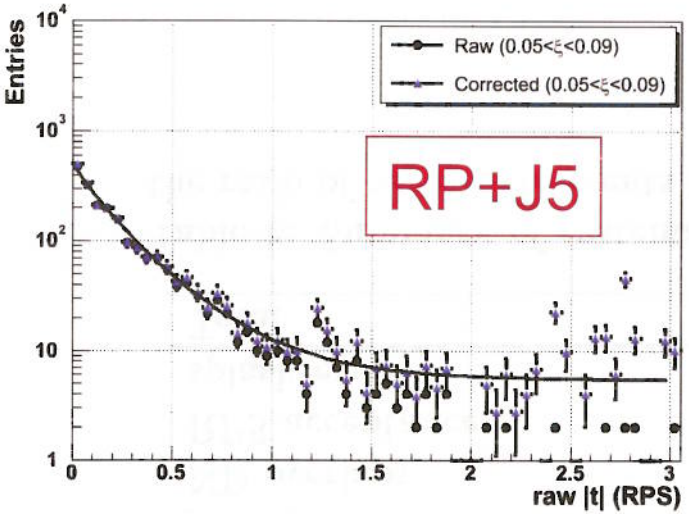
$$\frac{d\sigma}{dt} = N_0 \cdot F_1(t)^2 \cdot exp[2\alpha' \cdot \ln(s/M_X^2)] + constant$$

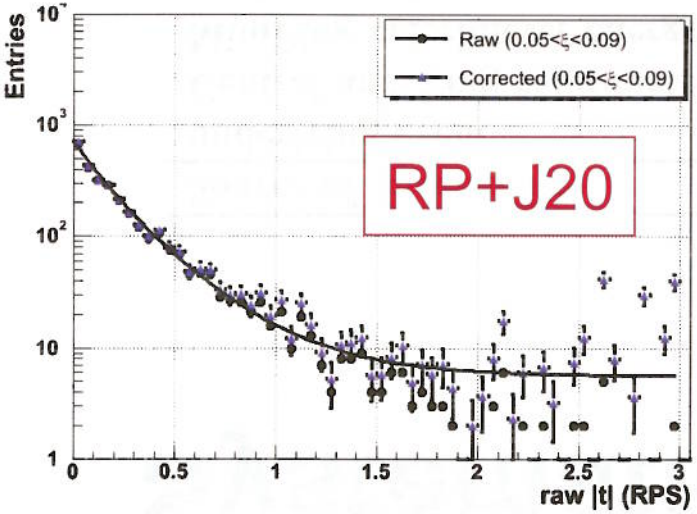
free parameter

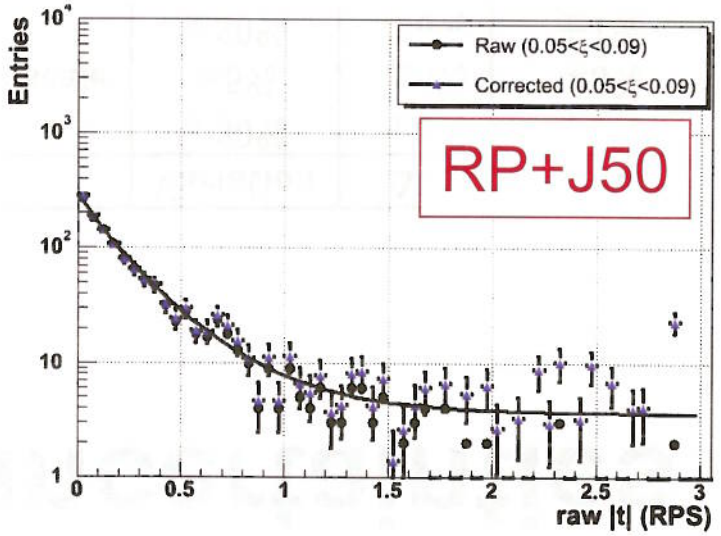
⇨ same slope over the region $0 < Q^2 < 4500$ GeV^2

⇨ no diffraction 'dips' observed for $|t| < 3$

t-distribution @ different Q^2





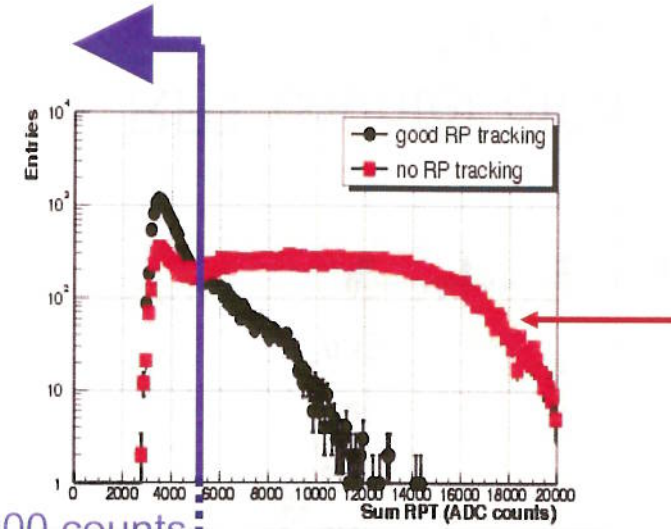


Systematic uncertainties

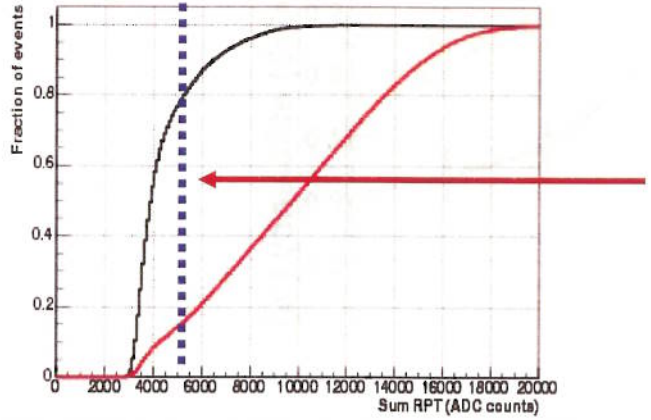
Source of uncertainty	Variation	$\Delta\mathcal{R}_\circ$	Δb
underlying event	$\pm 30\%$	$\pm 3\%$	$\mp 5\%$
Central and Plug calorimeter energy scale	$\pm 5\%$	$\pm 8\%$	$\mp 3\%$
MiniPlug calorimeter energy scale	$\pm 30\%$	$\mp 6\%$	$\pm 1\%$
jet E_T threshold	$\pm 10\%$	$\pm 1\%$	$\pm 1\%$
ND overlaps	$\pm 20\%$	$\pm 8\%$	$< \pm 1\%$
RPS acceptance	N/A	$\pm 10\%$	N/A
splash events	N/A	$\pm 6\%$	N/A
Total		$\pm 18\%$	$\pm 6\%$

Table 8: Summary of systematic uncertainties contributing to $\mathcal{R}_\circ$ and b in the ratio of SD to ND events $\mathcal{R} = \mathcal{R}_\circ \cdot x_{Bj}^b$.

Splash events



<6000 counts

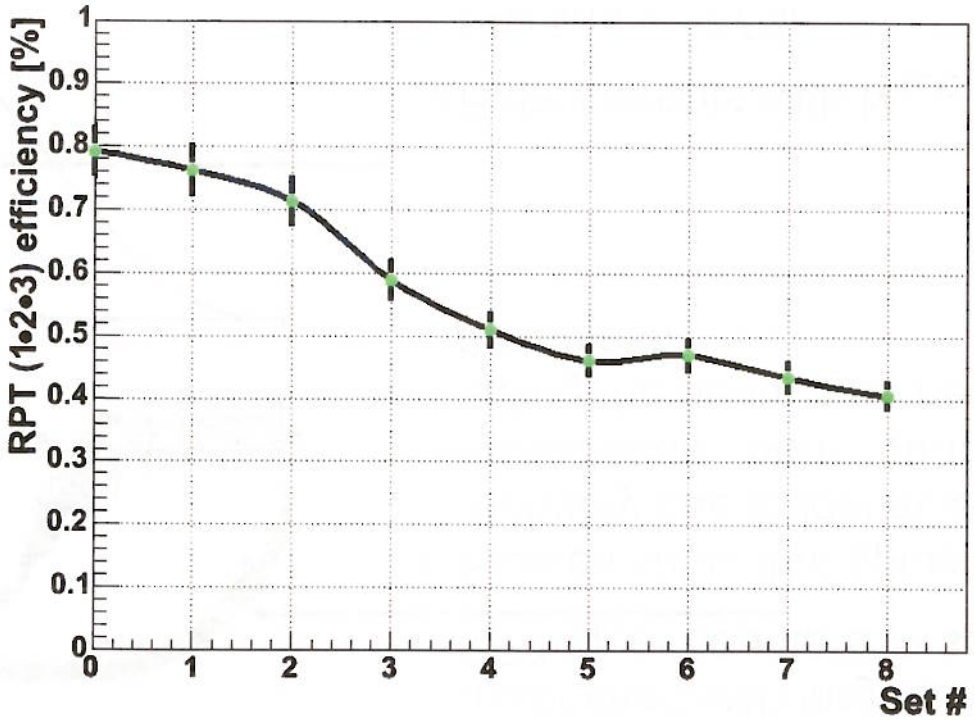


- About 50% of the RP triggered data yield splashes in the RP tracking detectors associated with large pulse heights in the RP trigger counters ⇨ splash events.
- Studies show that splash events are probably due to low mass pbar dissociation, pbar→pbar'+X, with the pbar' hitting the beam pipe near the RPs causing the splash

⇨ Reject events with N_{ADC} >5000

Efficiency ~77%

RPT efficiency



RPT counter efficiency degrades with integrated luminosity due to radiation

⇨ apply integrated luminosity dependent correction