Diffractive physics at ATLAS and DØ

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Introduction

- Name: Arnab Kumar Pal
- Thesis topic: "Measurement of Single Diffractive differential cross section using the DØ Forward Proton Detectors."
- Experiment : **DØ**
- Was graduate student at UTA from 2005-2011.
  - Joined in ATLAS in 2005.
  - Went to CERN in 2007 for one year
  - Came back in 2008 and started work on thesis at Fermilab
  - Completed in Aug, 2011

Overview

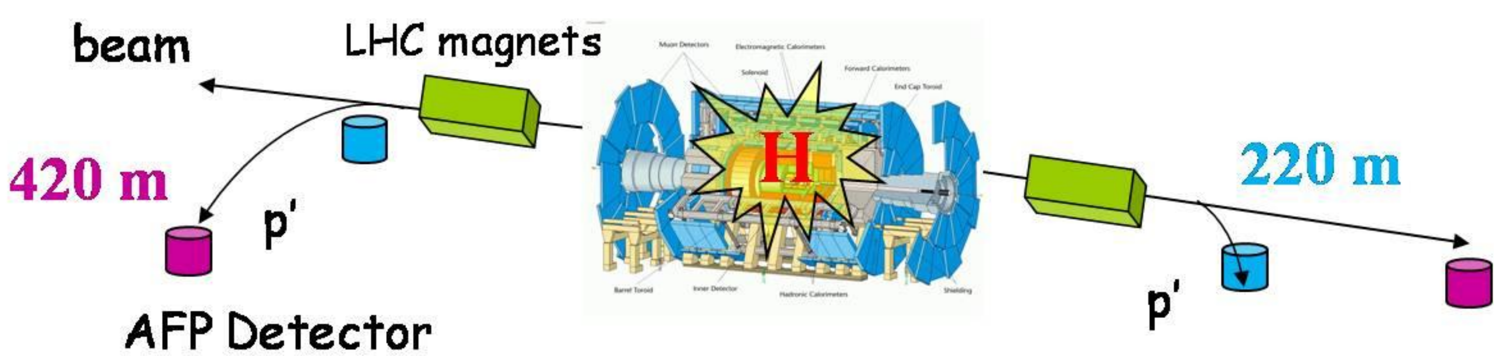
- Central exclusive processes.
- Standard model exclusive Higgs at ATLAS.
- ATLAS forward proton detectors.
- Single diffractive differential cross at the Tevatron.

Central exclusive production in pp collisions

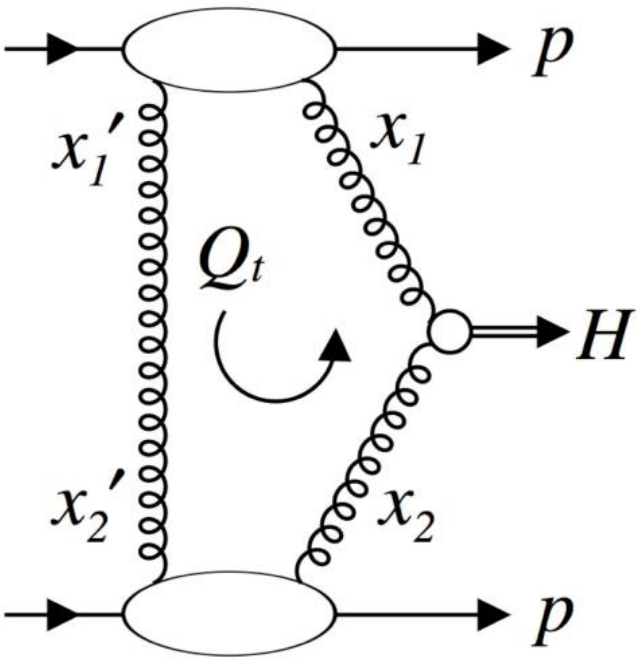
- Central exclusive processes refer to the processes like $pp \rightarrow p + \phi + p$, where '+' refers to the presence of large rapidity gaps.
- The final state contains the two outgoing protons and the decay products of the central system ϕ and nothing else.
- In the analysis the central decay product ϕ is detected using the central detector and the final state protons are detected using the forward detectors located at 220m and 420m on both sides of the IP.
- Rapidity gaps are not demanded because of the presence of large number of multiple interactions.
- The forward detectors allow the study of many other exclusive processes both within and beyond the standard model.

Benefits of forward detectors

- There is significant reduction in the cross section in the exclusive process, but since the final state protons remain intact and scatter through small angles it means that the primary systems in $J_z = 0, C - even$ and $P - even$ state. (J_z is the proton angular momentum along the beam axis).
- The discovery of a CEP Higgs would mean the measurement of its quantum number, which is 0^{++}.
- The mass of the central resonance can be precisely (with a resolution of 2 to 3 GeV) using momentum loss of the outgoing protons, irrespective of the decay channel of the central system.



Missing mass method



Production of Central Exclusive Higgs, Gluon is exchanged between the protons which conserves the color and the proton stays intact in the final state. The process can be written as

$$pp \rightarrow p + H^0 + p$$

- Missing mass method is used to reconstruct the mass of the central system.
- The proton with sufficient momentum loss are detected by the forward detectors located at 220m or 420m upstream and downstream of the ATLAS detector.
- Using the forward detectors calculate the fractional momentum loss
  - $\xi_1 = \frac{\Delta p_{1z}}{p_{1z}}$
  - $\xi_2 = \frac{\Delta p_{2z}}{p_{2z}}$
- Then the mass of the central system is
  - $\Delta M = \sqrt{\xi_1 \xi_2 s}$
- 1% loss in the fractional momentum of the protons gives a central system of 140 GeV.
- Mass resolution of the Higgs depends only of the resolution of ξ_1 and ξ_2, which is expected to be in the 2 to 3 GeV range, far superior to that Obtainable using central detector.

Scenarios of production of Higgs

- Looked into the production and detection of standard model Higg's boson of two different masses, 120GeV and 160GeV.
- M_H = 120 GeV, decay channel is
  - $H^0 \to b\bar{b}$.
- M_H = 160 GeV, decay channel is
  - $H^0 \to WW^* \to jjl\nu$.

$H^0 \to b\bar{b}$ decay channel

- The cross section times branching ratio for the Exclusive Higgs of mass 120 GeV was predicted to be $3.0 \times 0.6 = 1.86$ fb.
- The cut efficiencies must be included in order to get a correct estimate of the effective cross section.
- The main experimental signature in this decay channel are:
  - Two final state proton in the FP420 detector (note that a 120GeV particle is in the acceptance range of FP420 only).
  - Two b-Jets in the central detector, which are back to back.
  - Very little other activity outside the cone of the b-Jets.

$H^0 \to b\bar{b}$ Backgrounds

- The most serious background for this channel is inclusive $b\bar{b}$ production + two single diffractive protons from other pp interactions in the same bunch crossing.
- The cross section for $gg \to b\bar{b}$ is 500 μb.
- The effective pile-up cross section for the forward protons is given by

$$\sigma_{\text{eff}} = N(N-1)P_i^2 Q \sigma_{b\bar{b}}$$

Background

$$\sigma_{\text{eff}} = N(N-1)P_i^2 Q \sigma_{b\bar{b}}$$

- N = number of minimum bias events N ~ 35 at full luminosity.
- Q = rejection factor obtained using precision timing to reject events where the timing vertex is inconsistent with the central silicon vertex (Q=0.025).
- P_i = probability of an interaction giving a proton in the proton detector acceptance (P_i=0.012 for 420 m detectors)
- $\sigma_{b\bar{b}}$ is the input cross section for the hard scattering.

Exclusivity variables to beat down the background

- The background is extremely large as compared the signal cross section.
- Use the forward detectors in conjunction with the central detectors to maximize the signal.
- Based on the correlation of the forward track momentum and the central detector kinematics.
- There are four different variables: R_j, Δy, N_T and N_C.

Some of the physics quantities before the definition of the variables

- Fractional momentum loss of the protons, $\xi_1 = \frac{\triangle p_1}{p_1}$ and $\xi_2 = \frac{\triangle p_2}{p_2}$ can be measured at the FPD.$(0.002 < \xi < 0.015)$
- The mass of the central exclusive system is given by $\triangle M = \sqrt{\xi_1 \xi_2 s}$, where $\sqrt{s} = 14 GeV$. In the case of 1% fractional momentum loss the protons gives a central system of $140 GeV$.
- $M_{jj}^2 = \chi_1 \chi_2 s$ Invariant mass of the b jet where

$$\chi_1 = \frac{1}{\sqrt{s}} \sum_{i=1,2} P_T^i e^{\eta} \text{ and}$$

$$\chi_2 = \frac{1}{\sqrt{s}} \sum_{i=1,2} P_T^i e^{-\eta} \text{ S}$$

Definition of the variables

$$R_j = \frac{2}{\Delta M} p_T \cosh\left(\eta - y\right) \qquad y = 0.5 \ln\left(\frac{\xi_1}{\xi_2}\right)$$

$$\Delta y = 0.5 \ln\left(\frac{\xi_1}{\xi_2}\right) - 0.5\left(\eta_1 + \eta_2\right)$$

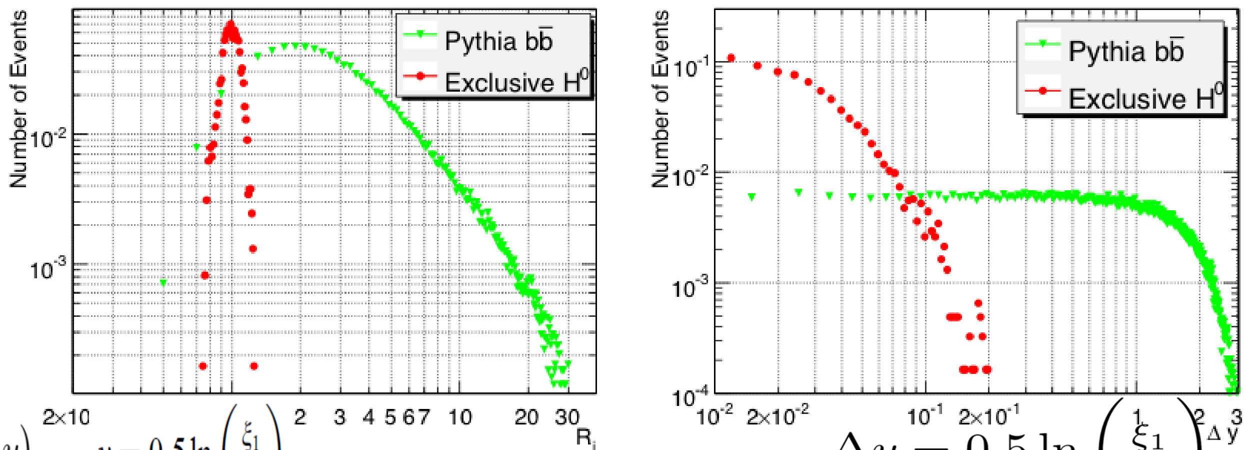
N_T is the number of tracks outside the cone of R = 0.7 of the b-jet

N_C is the number of tracks outside the cone of R = 0.7 of the b-jet 60° away from the jet in φ (Δφ > 60°)

Signal and background Monte Carlo

- The Signal processes were generated using EXHUME Monte Carlo generator.
- PYTHIA 6.3 was used to generate the background
- Kinematic cuts
  - Find the Combination of B-Jets Satisfying the Cuts.
    - Apply Cuts on P_t (Transverse Momentum).
      - ✓ $P_t^1 > 45.0$GeV and $P_t^2 > 30$GeV.
    - Apply Cuts on η (Pseudo Rapidity).
      - ✓ $2.5 > \eta > -2.5$
    - Cuts on Δη.
      - ✓ $1.0 > \Delta\eta > -1.0$
      - ✓ Make sure that the Jets central and Back to Back in η.
    - Cuts on Δφ.
      - ✓ $170 > \Delta\varphi > 190$ (deg)
      - ✓ Make sure that the Jets are Back to Back.
- In the Analysis a Gaussian error of 1GeV for ξ_1 and ξ_2 is introduced to approximately simulate the detector response.
- Calculate ΔM from the missing mass spectrum.
- Use Acceptance cuts such that $0.002 < (\xi_1, \xi_2) < 0.015$

Signal and background separation



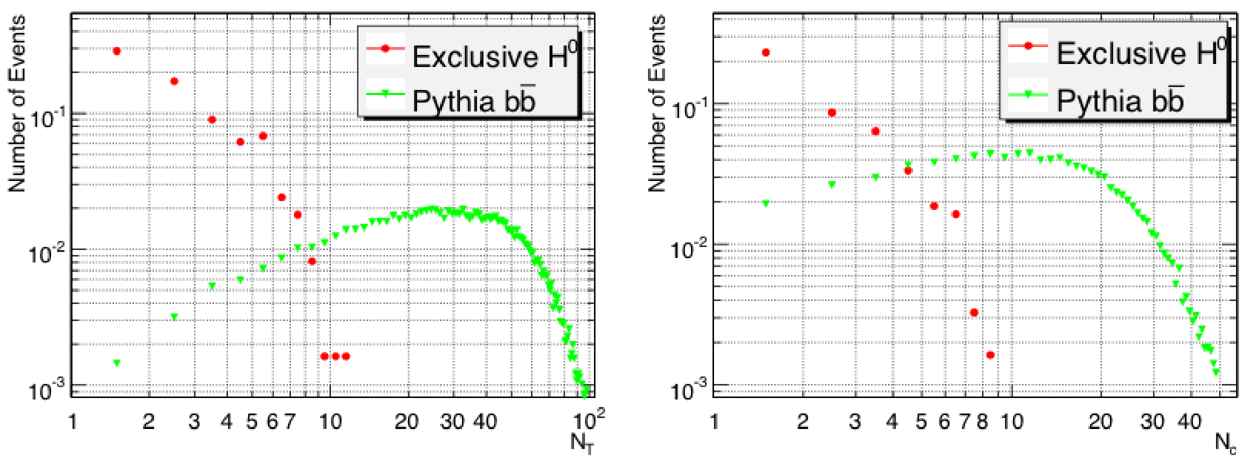
$$R_j = \frac{2}{\Delta M} p_T \cosh(\eta - y)$$

$$y = 0.5 \ln\left(\frac{\xi_1}{\xi_2}\right)$$

(a)

$$\Delta y = 0.5 \ln\left(\frac{\xi_1}{\xi_2}\right) - 0.5(\eta_1 + \eta_2)$$

(b)



(c)

(d)

Efficiencies of Cuts

Variable	Cuts	H^0	$b\bar{b}$
Kinematic Cuts	(see text)	0.061	0.062
R_j	0.85 to 1.15	0.925	0.038
Δy	< 0.1	0.905	0.060
N_c	< 2	0.777	0.031
N_T	< 4	0.810	0.010
N_c and N_T	2 and 4	0.734	0.008
$\Delta M_{420+420}$	118.3, 121.7 GeV	0.723	0.014

- The cuts have been optimized manually.
- The correlation was removed by applying the cuts in different order

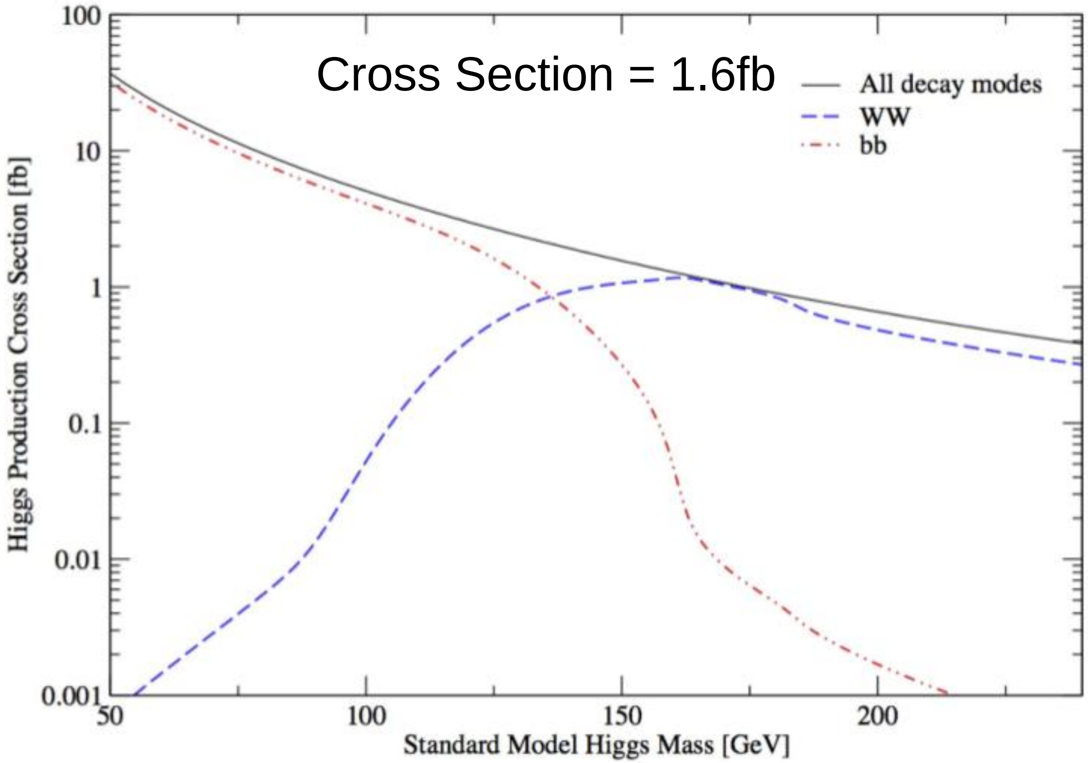
Results

$\mathscr{L}\,(\mathrm{fb}^{-1})$	H^0 (Signal)	N	$b\bar{b}$	Significance
30	2.3	3.5	1.12	2.15
60	4.5	3.5	2.24	3.0
60	4.5	7	10.8	1.35
150	11	18	184	0.85
300	23	35	1520	0.6

- Very few signal events
- But the background is low as well!

$H^0 \rightarrow WW^* \rightarrow jjl\nu$ decay channel

- For H^0 of Mass 160GeV we have acceptance in Forward proton detector at 420m as well as 220m.



The main Decay channels

Decay	Branching Ratio
$\mu\nu jj$	10.27%
$e\nu jj$	10.27%
$\tau\nu jj$	10.27%
$jjjj$	58.94%
$\ell\nu\ell\nu$	10.27%

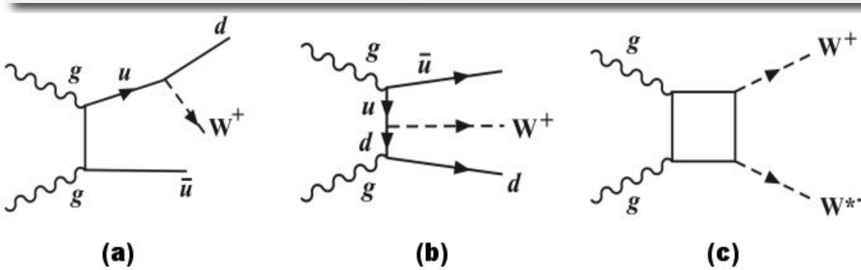
Cross Sec × BR for this channel = 0.17fb

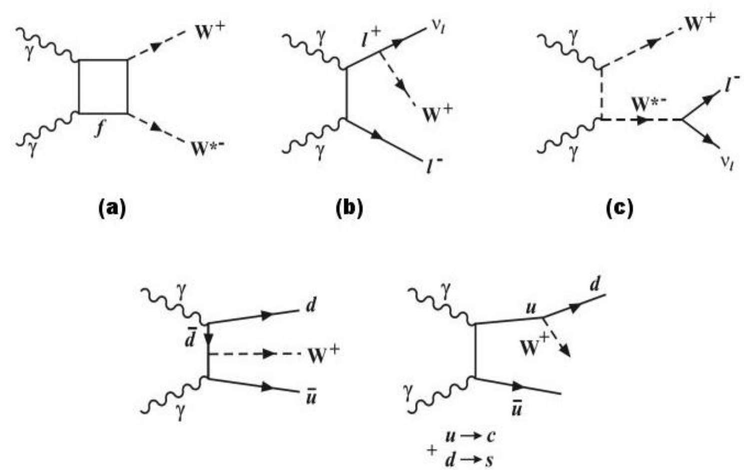
Signal Events were generated using EXHUME

$H^0 \to WW^* \to jjl\nu$ backgrounds

- $W + 2j$ production with one of the W's decaying in the semi-leptonic mode along with 2 pile up protons at the forward detectors. (2.5 nb)
- Continuum production of WW^*, in which the W's decay in semi-leptonic channel. (181 pb)

Gluon Induced Background + pileup





Photon Induced Background + pileup

Preselection (Kinematic cuts)

- Jets
  - PT of jet1 & jet2 > 25 GeV.
  - $|\eta|$ of jet1 & jet2 < 3.2.
- Muon
  - $P_T > 20$ GeV.
  - $|\eta| < 2.5$.
- Missing E_T
  - $E_T > 25$ GeV.
- Select Events with at least 2 jets, 1 Muon and Missing E_T

Exclusivity variables

- Ignore the rapidity of the leptonic W, and use the rapidity of the hadronic W as an estimate of the Higgs rapidity, rather than trying to account for the neutrino ambiguity.
- New variable ΔY_M which takes into account both the mass difference and the rapidity difference

Ratio of cluster mass and missing mass, r_{cm}

$$r_{cm} = \frac{m_c}{\Delta M}$$

Where $m_c = \sqrt{p_T^2(jj\ell) + m_{jj\ell}^2} + \not{E}_T$, ΔM is the missing mass measured at the FPDs and is given by $\Delta M = \sqrt{\xi_1 \xi_2 s}$ and $m_{jj\ell}^2$ is invariant mass of the di-jets and the lepton.

Difference in the rapidity and pseudorapidity, Δy_{jj}

$$\Delta y_{jj} = \left| \frac{1}{2}(\eta_{j1} + \eta_{j2}) - \frac{1}{2} \log \left\{ \frac{\xi_1}{\xi_2} \right\} \right|$$

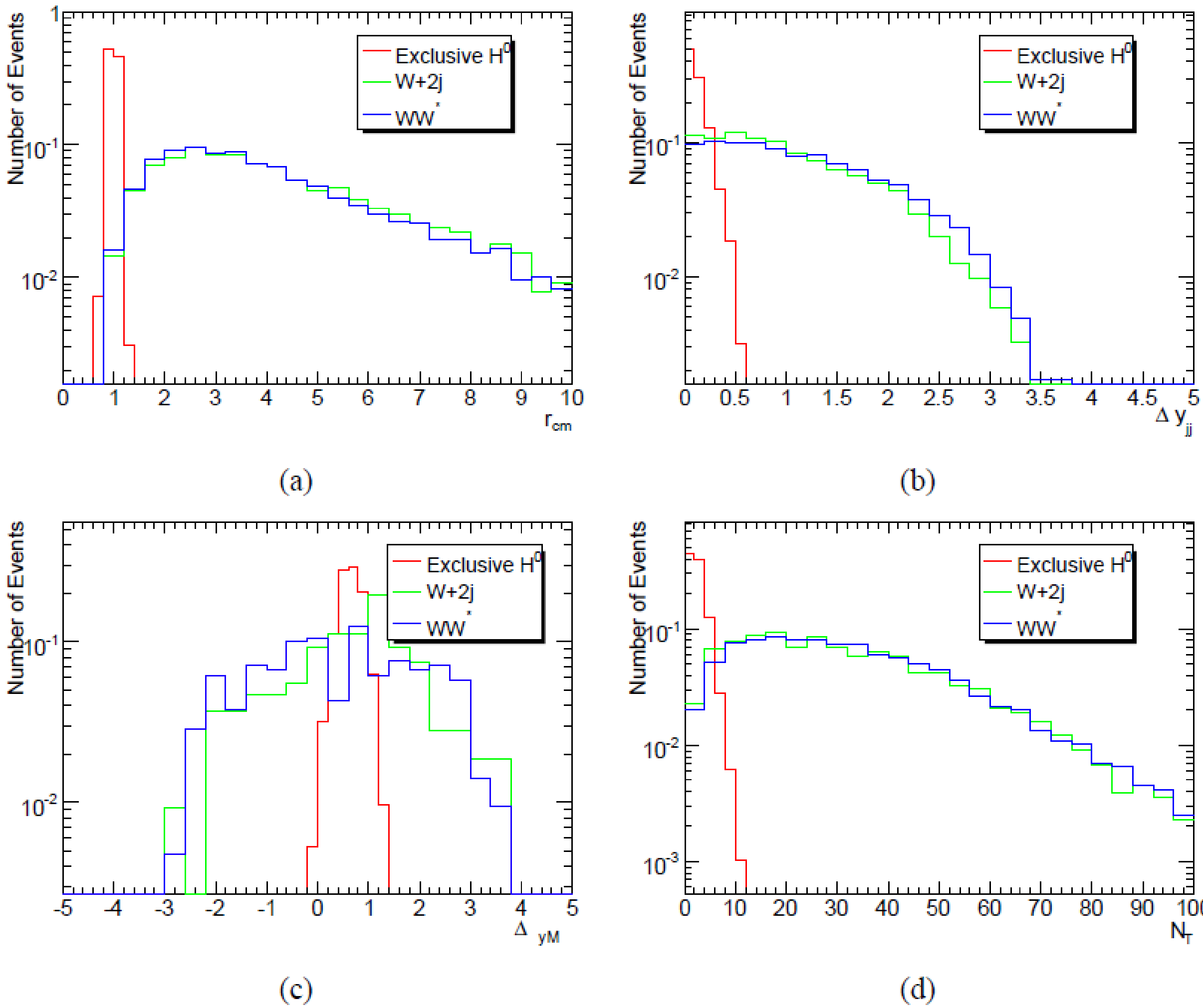
where $\frac{1}{2} \log \left\{ \frac{\xi_1}{\xi_2} \right\}$ is the rapidity measured by the proton detectors

Combined variable of rapidity and mass difference, ΔyM

$$\Delta yM = \cosh^{-1} \left\{ \frac{\Delta M}{2\left(p_T^1 + p_T^2\right)} \right\} - 0.5(\eta^1 + \eta^2) + 0.5 log \left\{ \frac{\xi_1}{\xi_2} \right\}$$

N_T is the number of tracks outside the cone of R = 0.7 of the b-jet

Signal and background separation



(a) (b)

(c) (d)

Cut efficiencies

Variable	Cuts	H^0	$W+2j$	WW^*
R_{cm}	0.6 to 1.3	1.0	0.020	0.025
Δy_{jj}	< 0.4	0.98	0.0045	0.0041
ΔyM	0 to 1.3	0.95	0.0032	0.0026
N_T	8	0.94	0.0003	0.0002
$\Delta M_{420+420}$	156.5 to 163.5 GeV	0.68	2.9×10^{-5}	1.5×10^{-5}
$\Delta M_{420+220}$	154.5 to 165.5 GeV	0.81	4.6×10^{-5}	2.5×10^{-5}
RP Acc.(420+420)	0.002 to 0.015	0.12	-	-
RP Acc. (220 + 420)	-	0.57	-	-

Cuts	H^0	$W+2j$	WW^*
kinematical cuts + BR	0.01924	0.0313	0.1421
Exclusivity Cuts + $\Delta M(420+420)$	0.00175	8.92×10^{-7}	2.06×10^{-6}
Exclusivity Cuts + $\Delta M(420+220)$	0.0062	1.43×10^{-6}	3.59×10^{-6}

Results

$\mathscr{L}(\text{fb}^{-1})$	H^0 (Signal)	N	$W+2j$	WW^*	Total BG	Significance
30	0.061	3.5	2.8×10^{-3}	3.5×10^{-4}	3.15×10^{-3}	1.23
60	0.122	7	2.0×10^{-2}	3.4×10^{-3}	2.34×10^{-2}	0.78
150	0.306	17.5	0.348	0.060	0.408	0.48
300	0.611	35	2.864	3.344	6.208	0.33

420m + 420m

$\mathscr{L}(\text{fb}^{-1})$	H^0 (Signal)	N	$W+2j$	WW^*	Total BG	Significance
30	0.217	3.5	0.160	0.028	0.188	0.498
60	0.433	7	1.536	0.280	1.816	0.321
150	1.083	17.5	26.44	4.820	31.26	0.193
300	2.165	35	217.936	39.73	257.67	0.134

420m + 220m

Things related to exclusive Higgs

- The pile up with one forward proton is single diffraction which is the main source of background for the exclusive Higgs
  - Studies of the single diffraction was required on real data
  - Tevatron (D0) had forward detector data, next step was to study the single diffraction and possible “Double-pomeron” exchange
- Worked on forward jet triggers needed to isolate the single diffraction.
- Worked on Soft QCD studies e.g. color singlet exchange.
- Working on b-Jet studies at D0.

DØ

Measurement of Single Diffractive differential cross section using the DØ Forward Proton Detectors.

Definition of variables used in the analysis

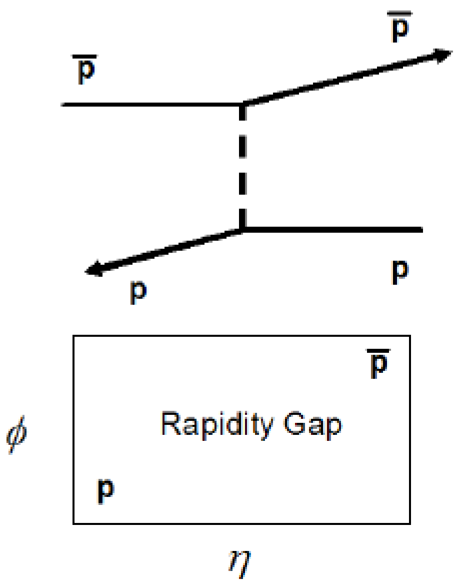
- $\sqrt{s}$: Total center of mass energy of the collision.
  - For the Run II this is 1.96 TeV.
- $|t|$: Standard four momentum transfer.
  - This is defined as : $|t| = (p_f - p_i)^2 = 2K^2(1 - \cos\theta)$.
  - $|t| = \theta^2$ (For small angles).
- ξ : Fractional momentum loss.
  - $\xi = 1 - x_f = 1 - \frac{p_f}{p_i}$
- M_X : Maximum Diffractive Mass
  - $M_X = \sqrt{\xi . s} \sim 400\ GeV$

FPD Gives us access to these variables

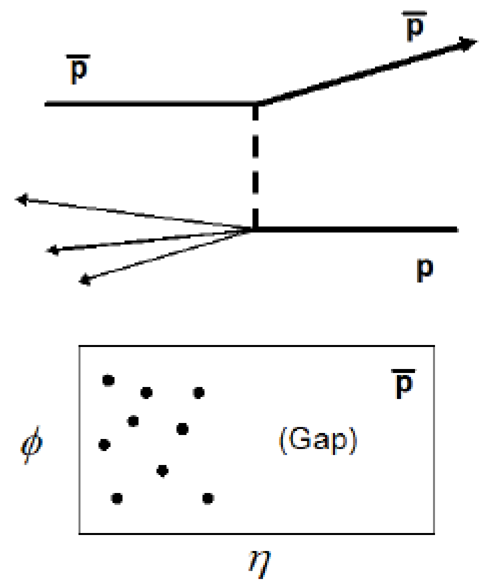
Diffractive cross sections are defined as $\frac{d\sigma}{dt\, dM_X}$, we integrate over the mass dM_X to get $\frac{d\sigma}{dt}$

Experimental Signatures of Diffraction

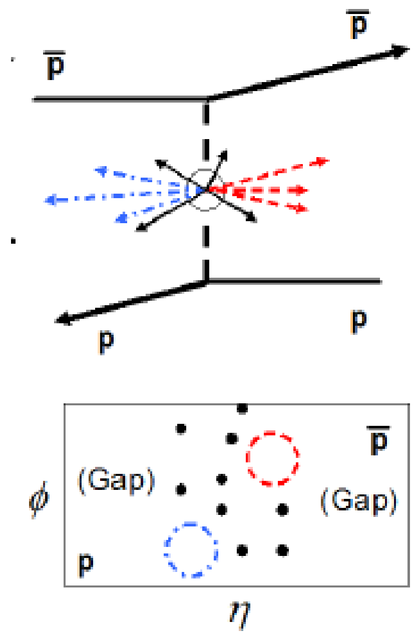
- A diffractive reaction is characterized by the presence of a large rapidity gap in the final state and a leading beam particle carrying most of the beam momentum



Elastic Scattering

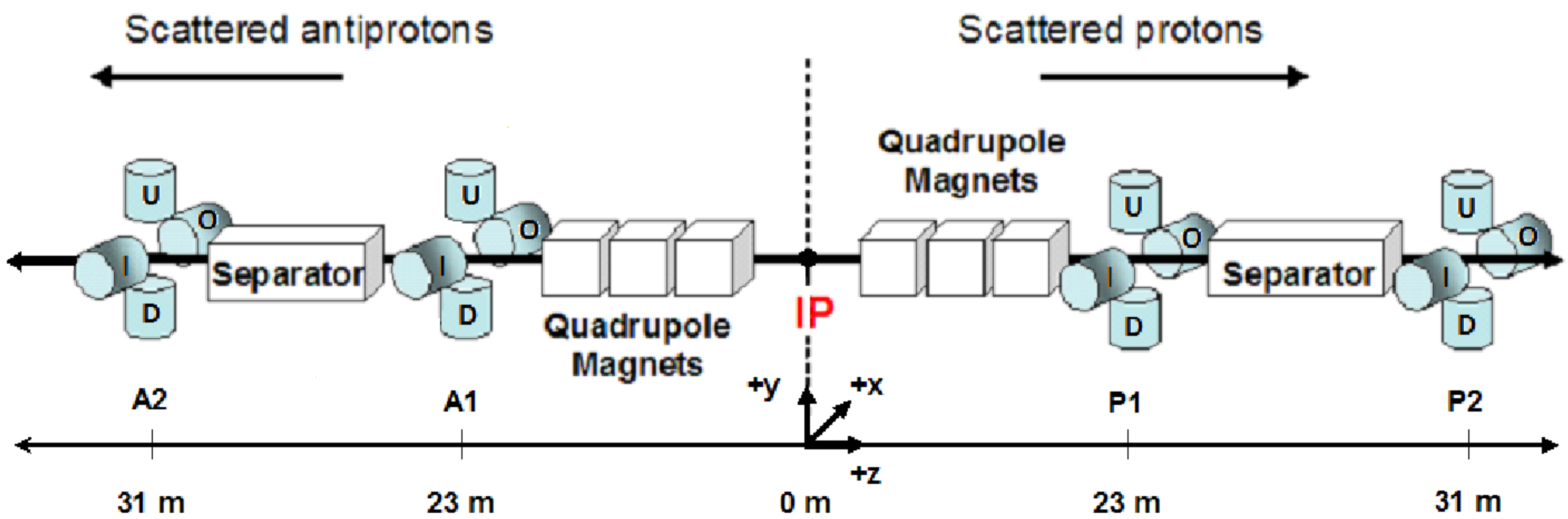


Single Diffractive



Double Pomeron Exchange

DØ Forward Proton Detector



⇨**There are eight quadrupole spectrometers (Up, Down, In, Out) on the outgoing proton (P) and anti-proton (A) sides each comprised of two detectors (1, 2)**

⇨**Use Tevatron lattice and scintillating fiber hits to reconstruct ξ and |t| of scattered protons (anti-protons)**

⇨**The acceptance for $|t|>|t_{min}|$ where t_{min} is a function of pot position:**
for standard operating conditions $|t| > 0.8$ GeV^2

Goals of analysis

Measure the differential cross section, $\frac{d\sigma}{dt}$ of single diffractive scattering over a large |t| range.

Previously there have been measurements of the single diffractive cross section

- UA4, $\sqrt{s}$ = 546 GeV, : low and intermediate |t|. **Phys.Lett.B186:227,1987**
- UA8, $\sqrt{s}$ = , 630 GeV : high |t|. **: Phys.Lett.B297 (1992) 417**
- CDF, $\sqrt{s}$ = 1.8 TeV : low |t|, high ξ>0,035. **Phys. Rev.Lett.78 (1997) 2698**

- **The DØ measurement**

- Consists of multiple independent measurements of protons and anti-protons, allowing reduction of systematic errors
- Is unique in that it covers a large |t| range (0.2 to 1.2 GeV^2) and ξ range (0 to 0.1).
- At $\sqrt{s}$ = 1.96 TeV (UA4 and UA8 covered parts only low |t| and high |t|, respectively, while CDF only measured large ξ anti-protons

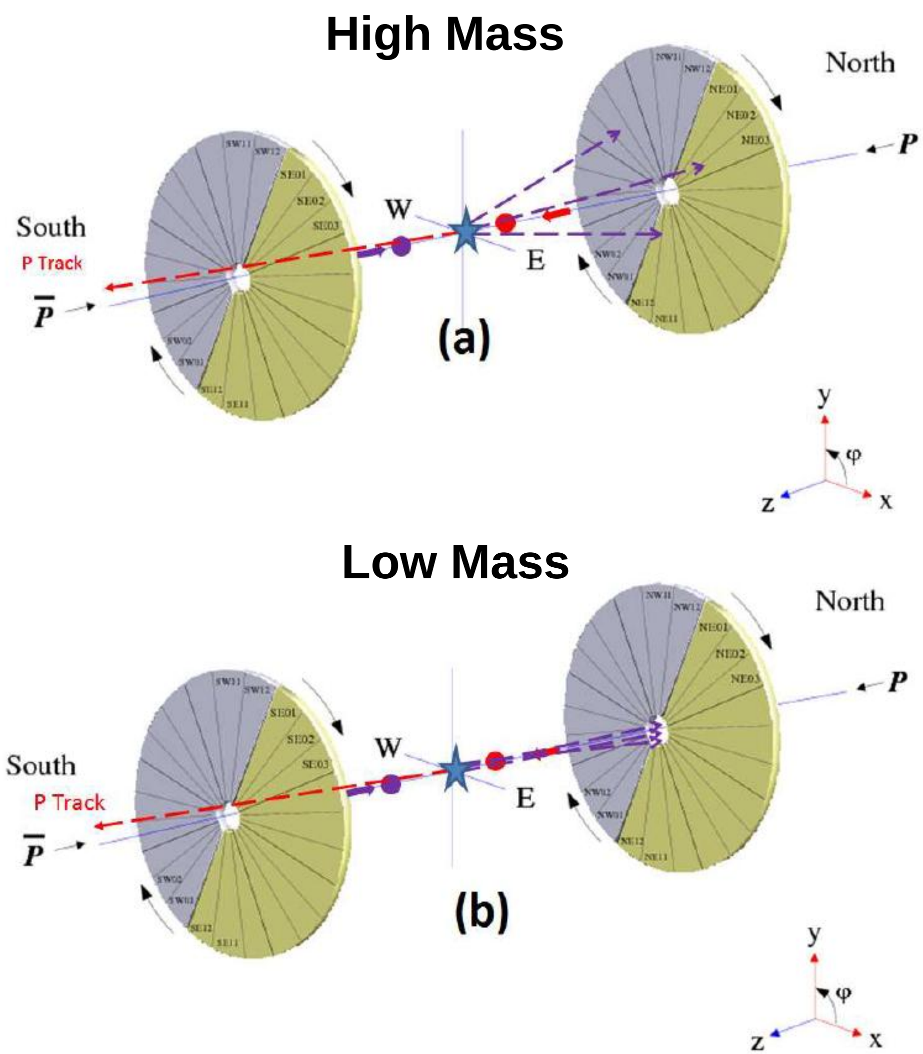
Dataset

- Data used in this analysis is taken in a special high β^* (1.6 m, the injection tune) in February 2006.
- Optimized for alignment and physics of the DØ FPD
- The beam consisted of only one proton and anti-proton bunch (electrostatic separators were off), and extra scraping was done so that the FPD detectors could be positioned closer to the beam axis than during the normal running of the experiment.
- Initial instantaneous luminosity was 0.5×10^{30} cm^{-2} s^{-1}
- 20 Million triggers/integrated luminosity 30 nb^{-1}

Event selection

- Select events with SD_PRO or SD_PBAR triggers.
- Choose hits based on the single diffractive track trajectory (detector correlation cuts)
- Demand a valid track in the FPD spectrometer.
- Select high mass single diffractive events demanding a hit in opposite side luminosity monitor.
- Choose events that have tracks inside the good fiducial region of the spectrometers.
- Reject halo tracks

High and low mass diffraction



- Low mass SD will have a large halo contamination
- We can select high mass SD by demanding hits in the opposite side luminosity monitors.
- Analysis is on high mass SD

Corrections for single diffractive cross section

We want to go from : $\frac{dN}{dt} \rightarrow \frac{d\sigma}{dt}$

Need to calculate the following:

- Efficiency (Trigger and Track reconstruction efficiency)
- Acceptance (Due to the incomplete coverage and the alignment of the detector)
- Background subtraction (Due to residual halo and overlap events)

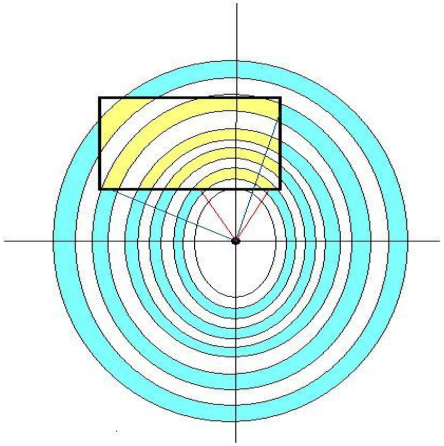
$$\frac{d\sigma}{dt} = \left(\frac{1}{\varepsilon \times A \times \mathcal{L}}\right)\frac{dN}{dt}$$

Efficiency Acceptance Luminosity

Acceptance

- Since the detectors don't cover the whole φ region, the data has to be corrected for the geometrical acceptance.
- The acceptance is a function of the detector position with respect to the beam and their alignment only.
- To calculate the acceptances of the detector we perform the following steps.

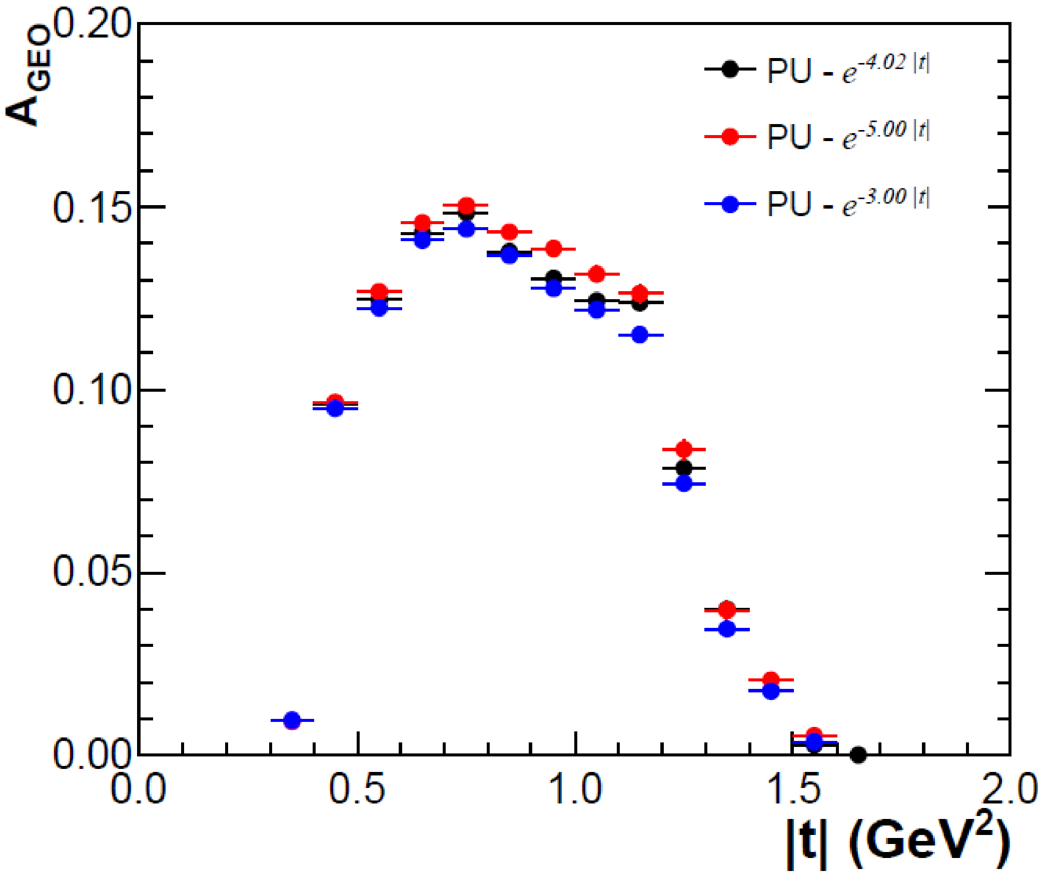
  - Generate uniform random distributions of |t|, ξ and φ for the proton and anti-proton.
  - This gives us the values at the collision point, then use the tevatron transport matrix to get the positions of the protons and anti-proton at the detector positions. (x and y)
  - Then use the FPD reconstruction program to find if there is a track and calculate the |t|, ξ and φ variables at the detector.



ϕ **acceptance:**

Only a fraction of each t bin is accepted by the detector

Acceptance functions

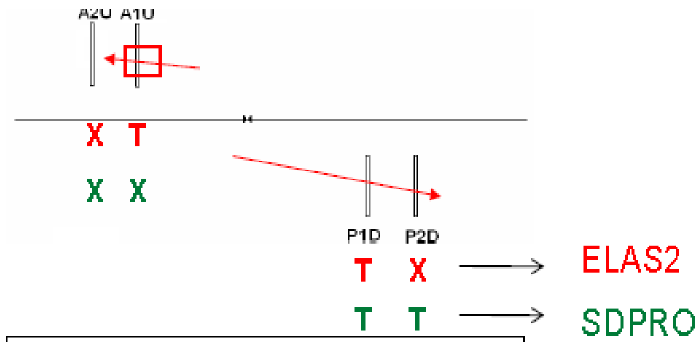


$$A_{GEO} = \frac{N(Reconstructed)}{N(Generated)}$$

- Acceptance calculation using single diffractive Monte Carlo.
- $p(|t|) \sim e^{(-4.02\,|t|)}$.
- $p(\xi) \sim \xi^{-1.11}$.
- φ distributed uniformly
- Corrected for the beam smearing and detector resolution effects.
- Used three functions to calculate acceptances
  - $e^{(-4.02\,|t|)}$
  - $e^{(-3.00\,|t|)}$
  - $e^{(-5.00\,|t|)}$
- A_{GEO} also accounts for the bin smearing correction

Detector efficiency calculation

HIT EFFICIENCIES



$$\varepsilon^{HIT}_{A2U} = \frac{Hit_{A2U}\ \&\&HIT_{A1U}\ \&\&HIT_{PD}}{Hit_{A1U}\ \&\&HIT_{PD}}$$

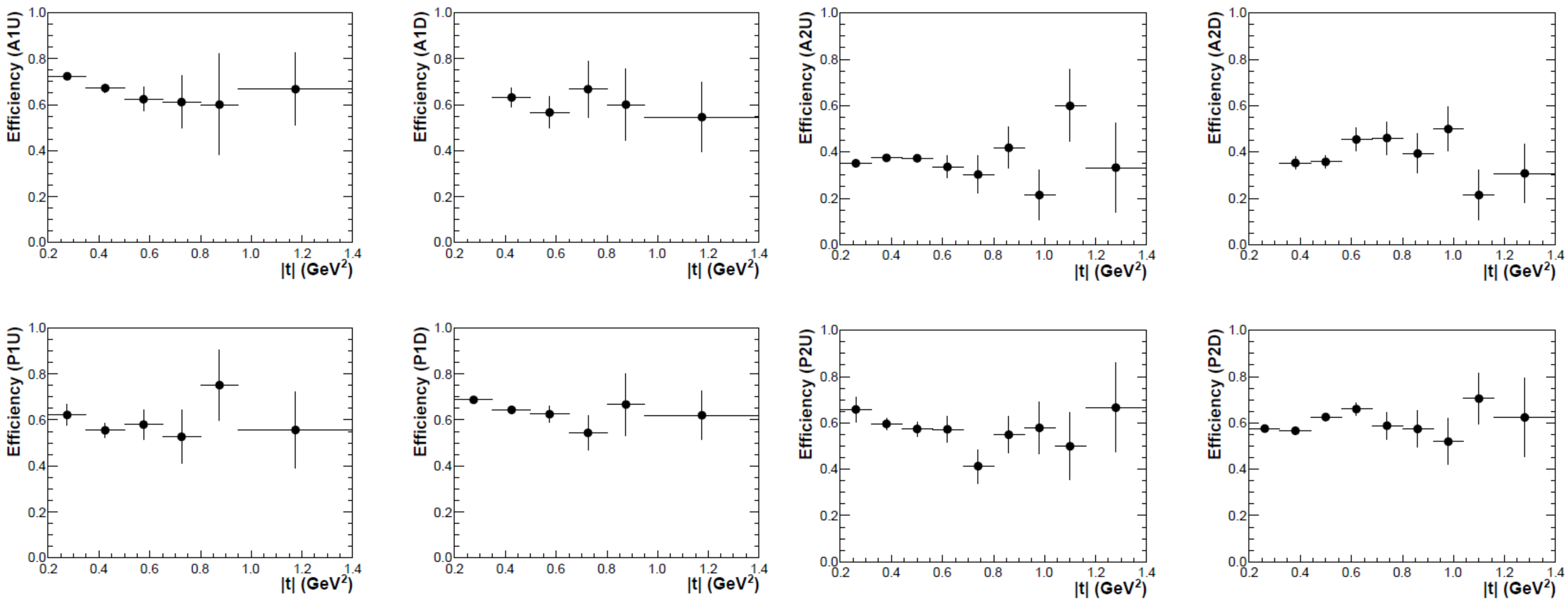
TRIGGER EFFICIENCIES

$$\varepsilon^{T}_{A2U} = \frac{Hit_{A2U}Hit_{A1U}Hit_{PD}\ \&\&T_{A2U}}{Hit_{A2U}Hit_{A1U}Hit_{PD}}$$

We emulate Trigger condition

- Use ELAS2 (XTXT or TXTX) triggers to calculate trigger efficiencies.
- Demand a track on opposite side, now have 3 hits and sample is dominated by elastic events
- The efficiency of the detector in question is the ratio of 4-detector hit to 3-detector hit
- Use the opposite side track to look at t dependence of efficiencies .
- Gives combined hit, trigger and selection efficiencies.
- Increased statistics in the efficiency calculation method by requiring a looser opposite side track and verifying that this yielded consistent results

Detector efficiencies



Detector	Efficiencies
A1U	0.704 ± 0.009
A1D	0.615 ± 0.032
P1U	0.572 ± 0.023
P1D	0.683 ± 0.004
A2U	0.366 ± 0.004
A2D	0.377 ± 0.016
P2U	0.571 ± 0.016
P2D	0.579 ± 0.004

- Efficiency does not show |t| dependence.
- At high |t| fluctuation due to low statistics.
- Use single values as efficiencies as in table.
- Efficiencies are higher than what is calculated in elastic analysis because of different hit finding and selection.

Background estimation

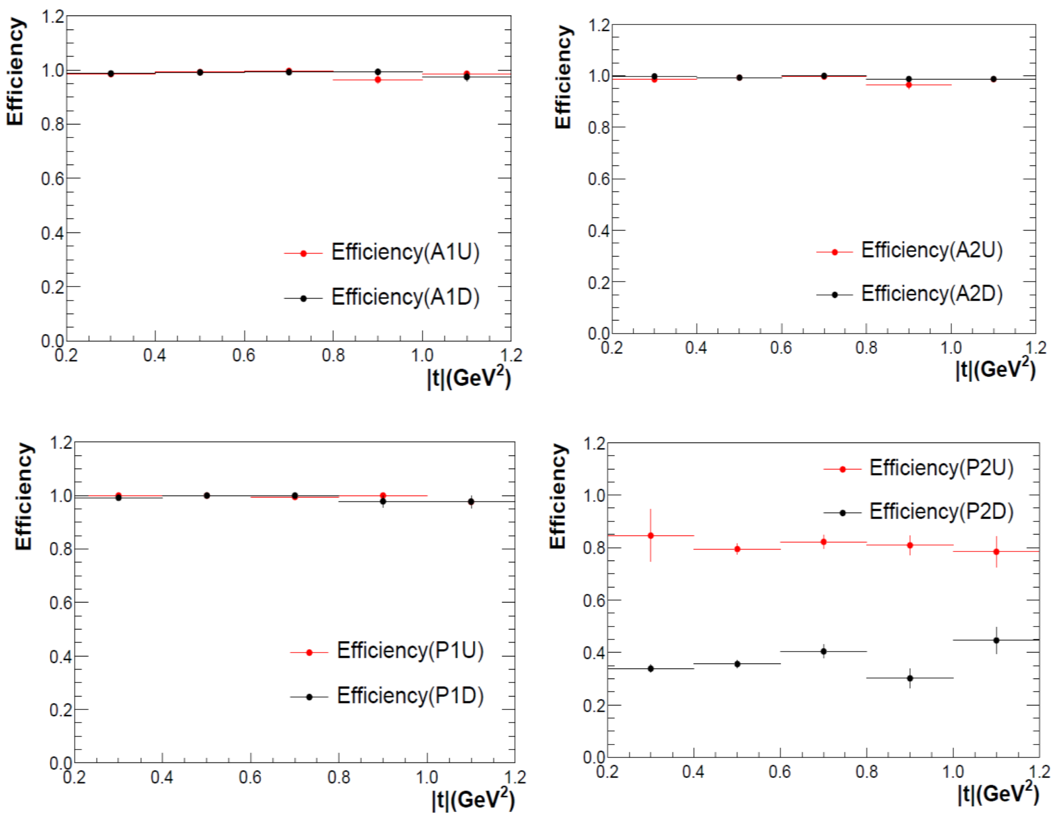
- Main background in untagged halo events.
- Due to efficiency of the trigger scintillators in the diagonally opposite side detectors.
- Efficiency of tagging halo is given by the logical OR of the scintillator efficiency of two detectors :

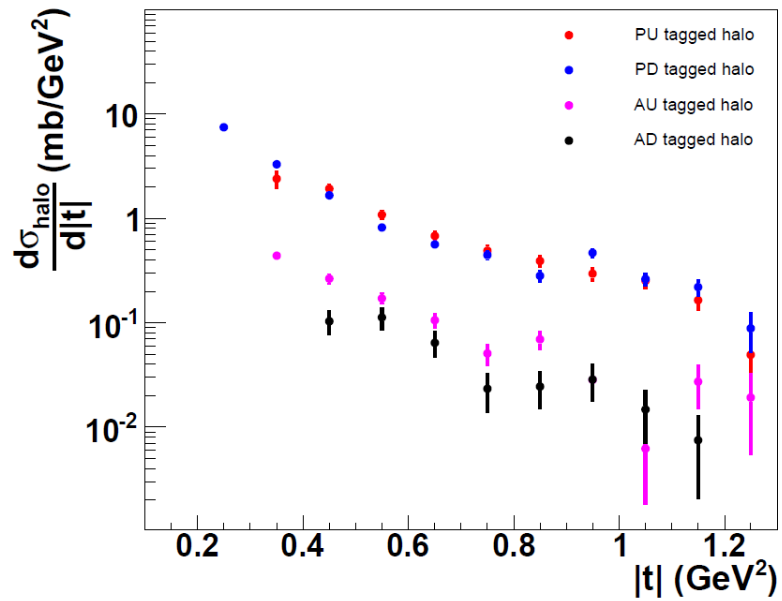
$$\epsilon(A1U) \text{ OR } \epsilon(A2U) = \epsilon(A1U) + \epsilon(A2U) - \epsilon(A1U) \cdot \epsilon(A2U)$$

- The inefficiency of tagging halo is: 1 – Efficiency(Halo).
- Untagged halo background is given by:

$$\sigma_{bg} = (1 - \mathcal{E}_{Halo}) \cdot \sigma_{halo}$$

Background



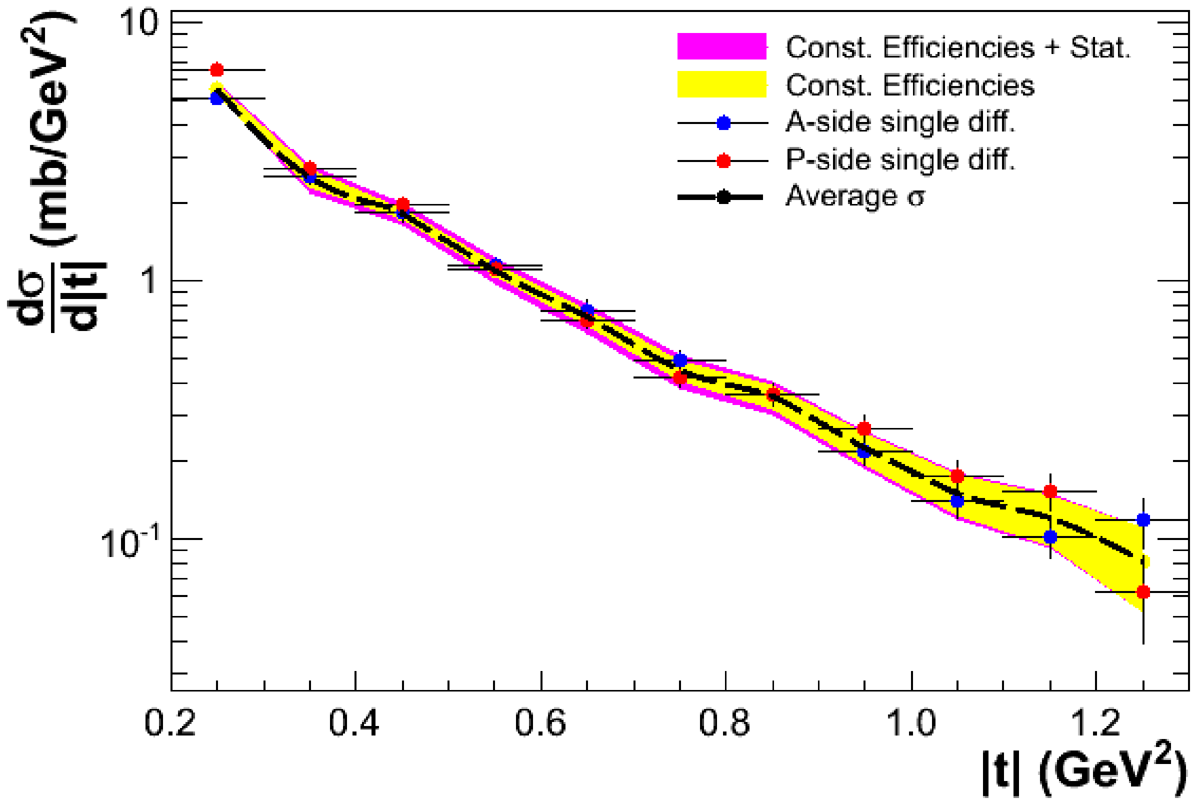


- ❑ High efficiencies for the scintillators.
- ❑ P2D has very low efficiency.
- ❑ This is well known

- Cross section distribution of tagged halo events.
- The effective background is a fraction of this distribution given by(~ 1% and 0.1% P and A -side:

$$\sigma_{bg} = (1 - \mathcal{E}_{Halo}) \cdot \sigma_{halo}$$

Single diffractive differential cross section



- Single diffractive differential cross section obtained for protons and anti-protons after applying the correction factors.
- The signal is weighted according to the acceptance and the efficiencies.
- The dashed line shows the average of the proton and anti-proton cross section

Sources of systematic uncertainty

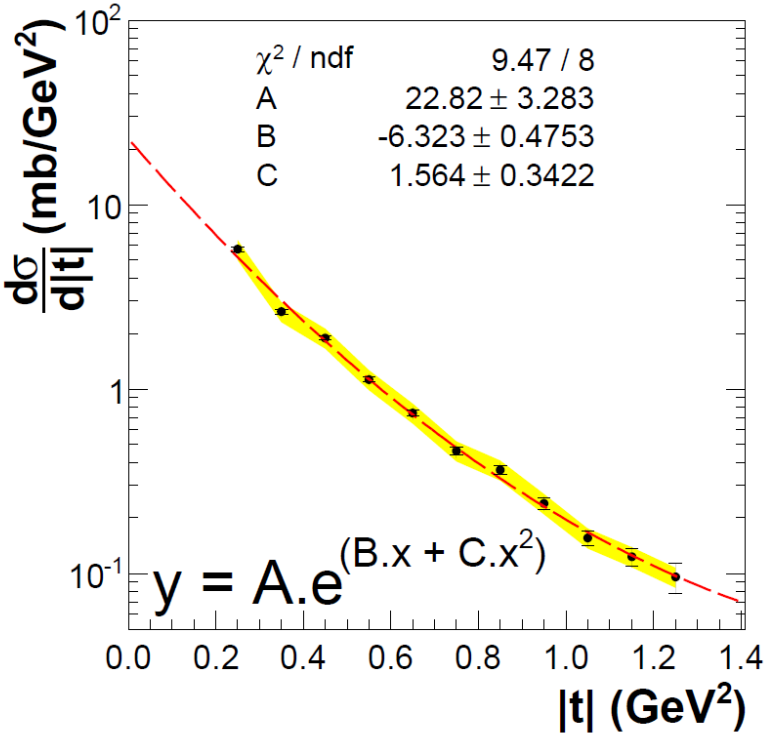
- Luminosity measurement.
- Detector efficiency measurement.
- Luminosity monitor efficiency.
- Luminosity monitor acceptance.
- Choice of ansatz function in acceptance calculation.
- Beam smearing
- Pot position uncertainty

Total systematic errors

- The main sources of systematic are Luminosity and detector efficiencies.
- Rest of them are negligible.

Syst. source	Value(X)	$\frac{\delta X}{X}$
Luminosity	12.6 ± 1.6 nb^{-1}	0.126
LM efficiency(N)	0.968	0.004
LM efficiency(S)	0.935	0.004
LM acceptance	0.218	0.006
Trigger efficiencies (syst.)		0.050
Trigger efficiencies (stat.)		bin-wise

Single diffractive differential cross section

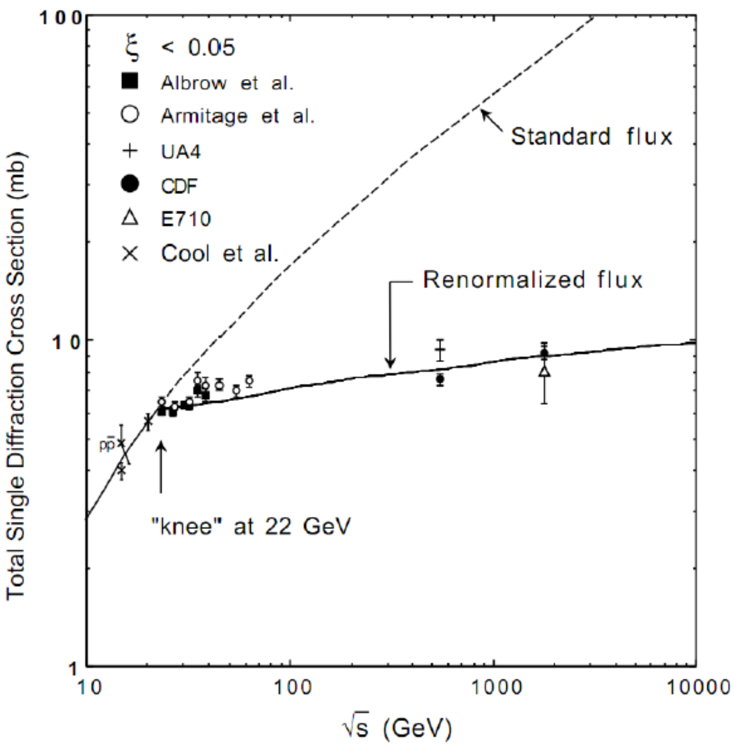


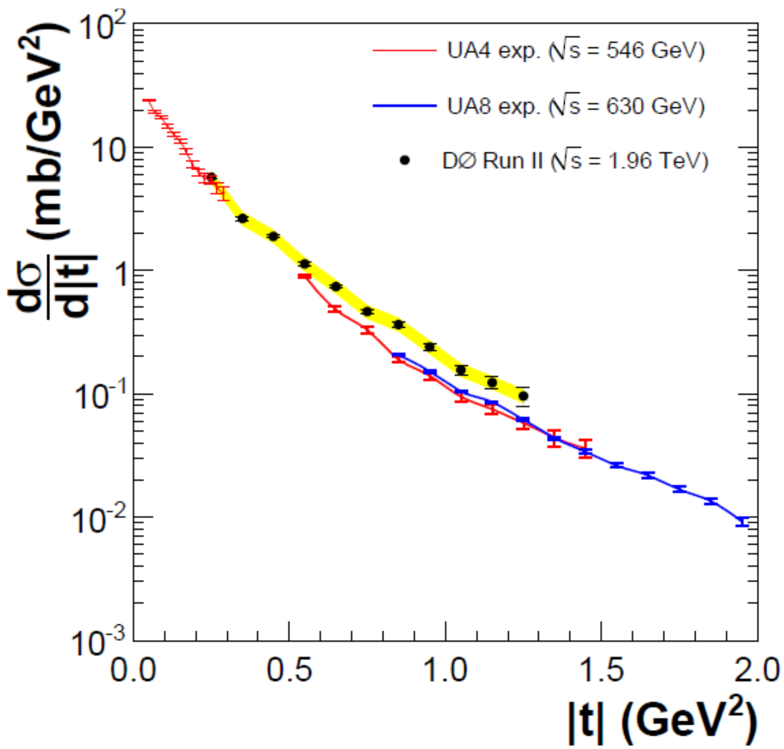
$\lvert t\rvert$(GeV^2)	σ(mb/GeV)	Error (stat.)	Error (syst.)
0.25	5.721	0.174	0.310
0.35	2.628	0.081	0.165
0.45	1.890	0.045	0.122
0.55	1.127	0.033	0.075
0.65	0.741	0.027	0.053
0.75	0.463	0.021	0.033
0.85	0.365	0.020	0.025
0.95	0.239	0.017	0.015
1.05	0.156	0.014	0.011
1.15	0.123	0.014	0.008
1.25	0.096	0.018	0.006

- Single diffractive differential cross section in bins of |t|.
- Fitted to polynomial function.
- Includes statistical and systematic errors.
- Shaded region shows uncertainty in normalization (12.6%)

Comparison with theory and experiments

Experiment	$\sqrt{s}$	σ_{sd}
UA4	546 GeV	9.4 ± 0.7 mb
CDF	546 GeV	7.89 ± 0.33 mb
E710	1.8 TeV	8.1 ± 1.7 mb
CDF	1.8 TeV	9.46 ± 0.44 mb
DØ Data fit + extrapolation	1.96 TeV	7.950 ± 0.324 (stat.) ± 1.007 (syst.) mb
DØ + UA4	1.96 TeV	9.681 ± 0.048 (stat.) ± 1.219 (syst.) mb





Conclusions

- Measurement of single diffractive differential cross section at = 1.96 TeV.
- Data can be fitted with a equation of the form:

$$A \cdot e^{(B \cdot |t| + C \cdot |t|^2)}$$

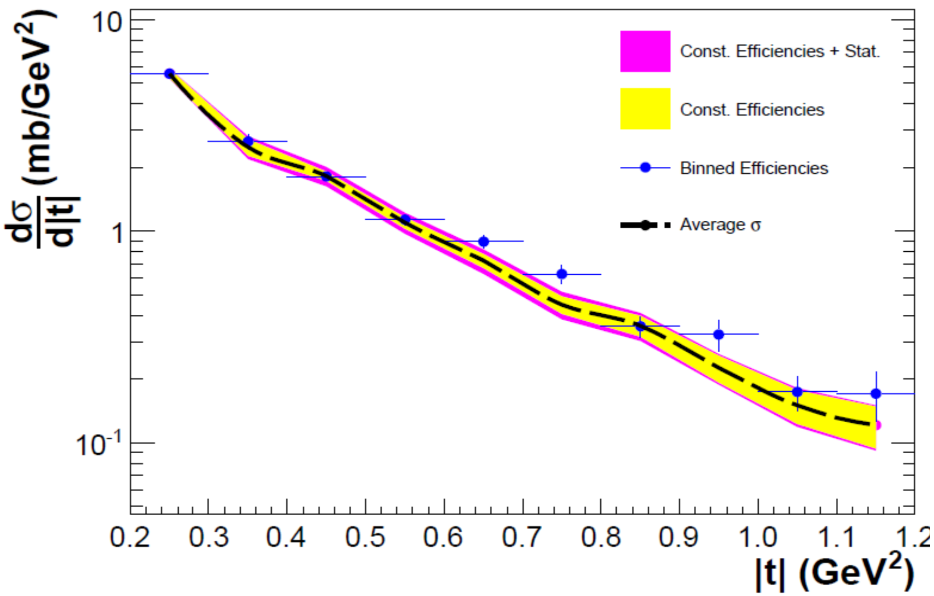
χ^2 / ndf	9.47 / 8
A	22.82 ± 3.283
B	-6.323 ± 0.4753
C	1.564 ± 0.3422

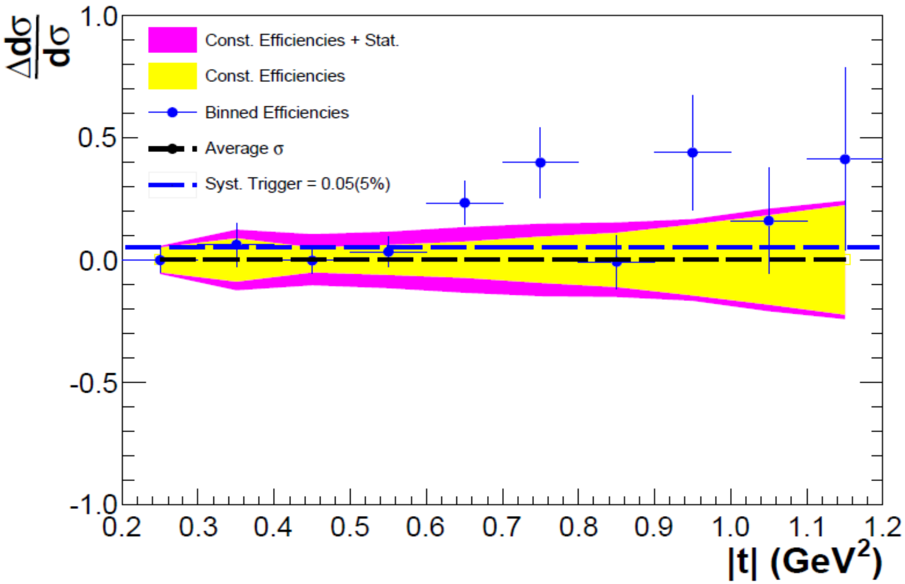
- Total single diffractive cross section using low \|t\| UA4 data and a PYTHIA normalization is found to be
  - 9.682 ± 0.048(stat.) ± 1.219(syst.) mb.
  - In addition to it there is Monte Carlo uncertainty of 10%, difference between PYTHIA and PHOJET
- Cross section is in good agreement with other experiments

Backup

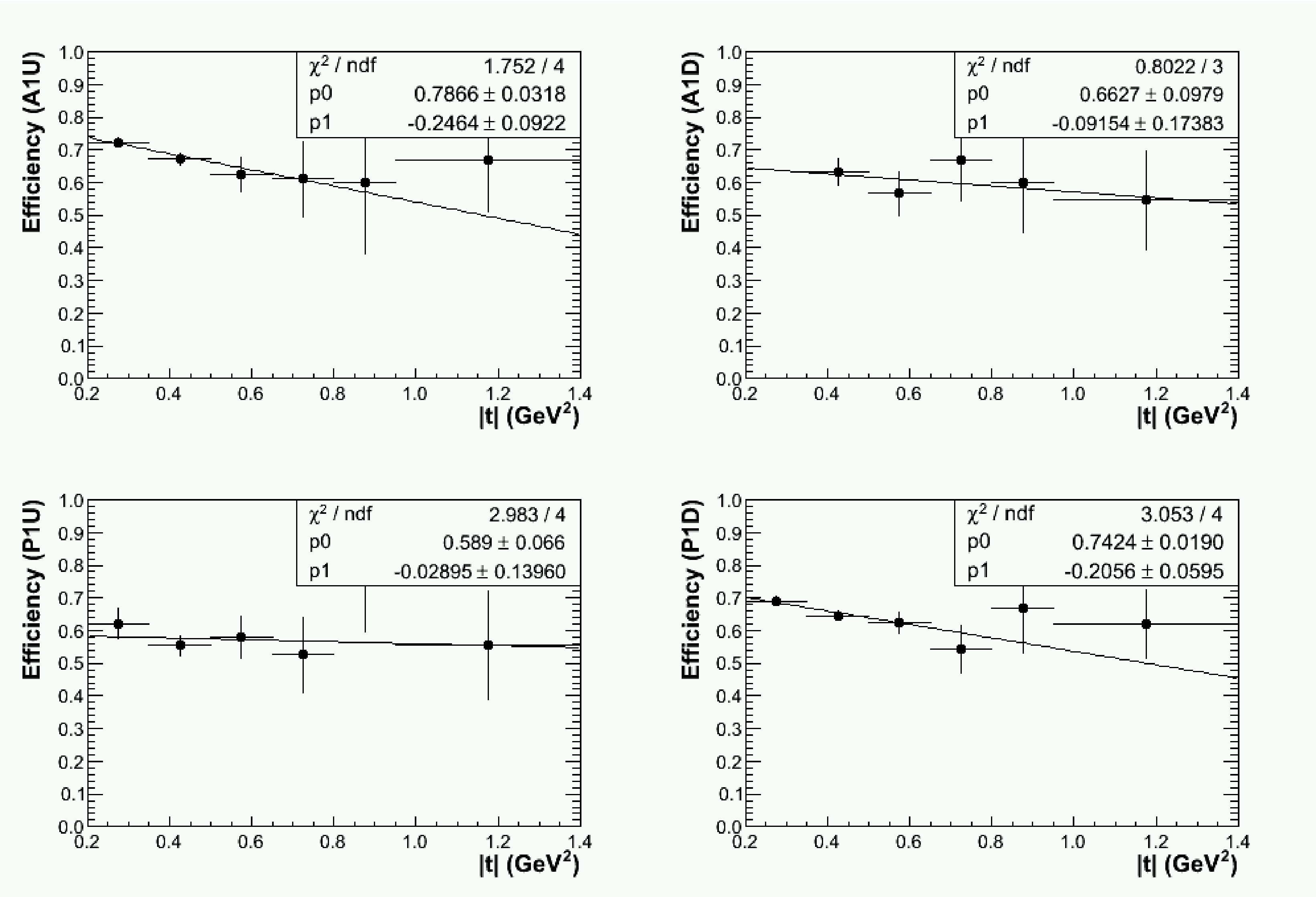
Systematic due to trigger efficiencies

- Use the bin by bin efficiency values to calculate the cross section.
- There is systematic shift of 5% form the cross section calculated by using const efficiency

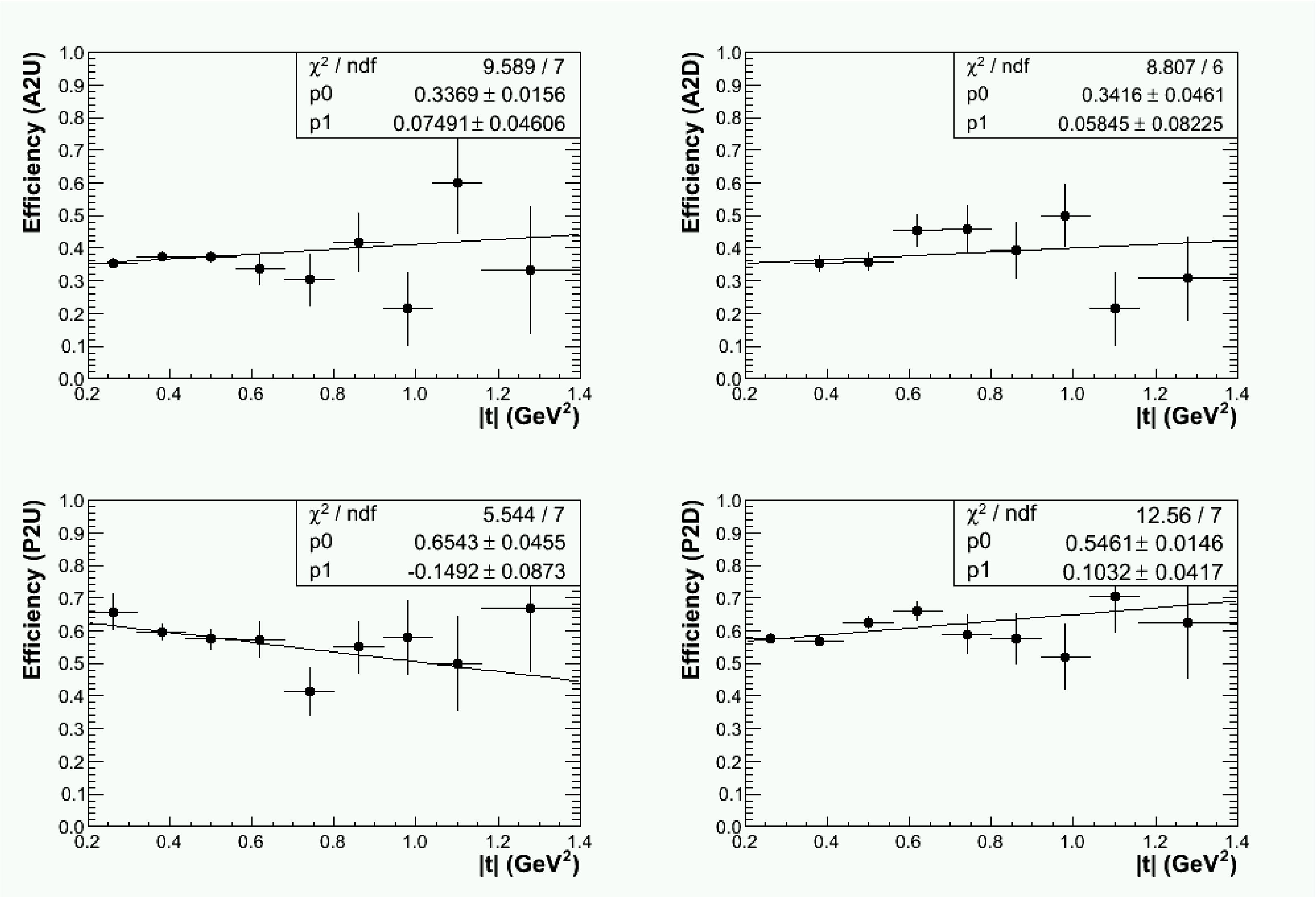




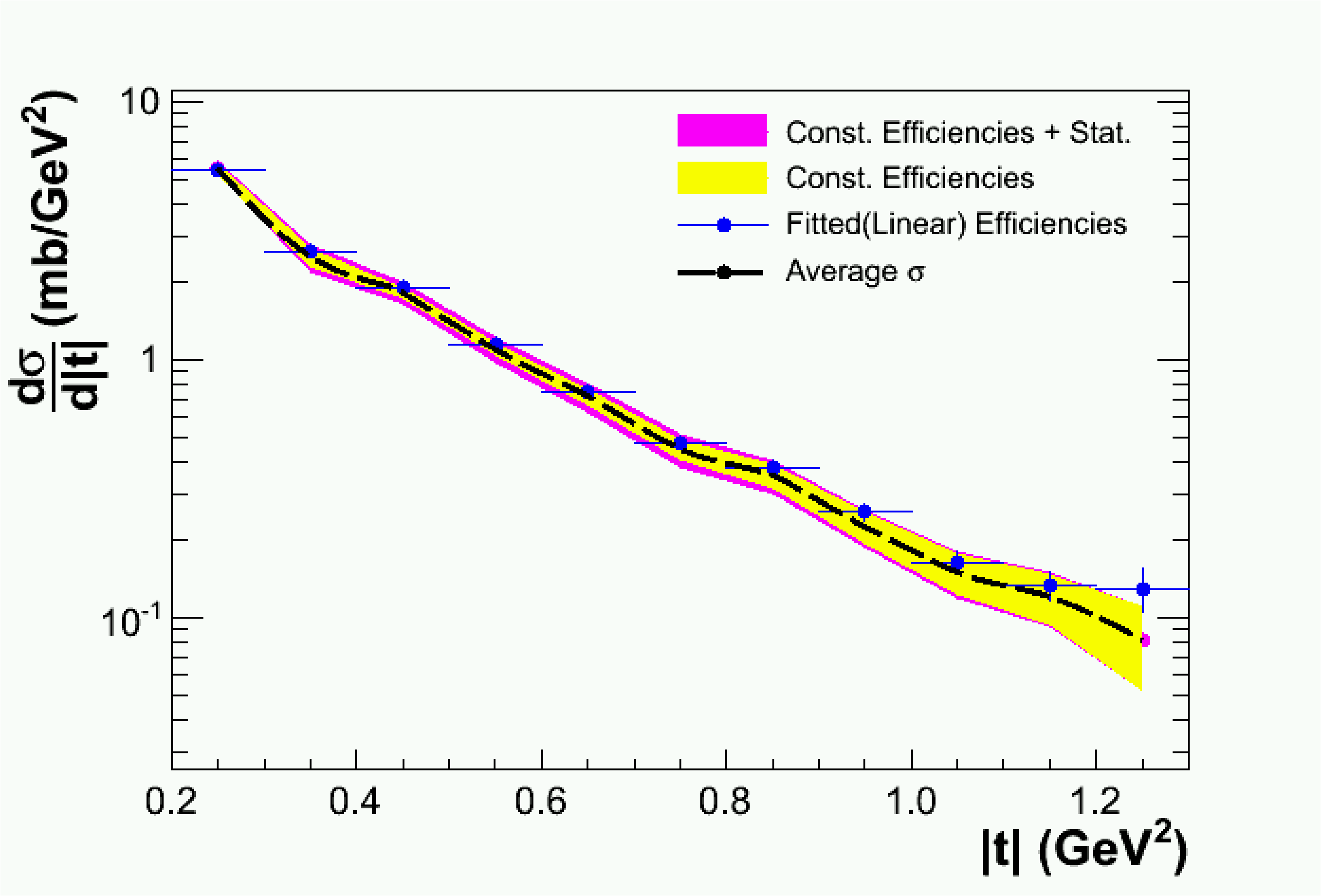
Fits 1st Detectors



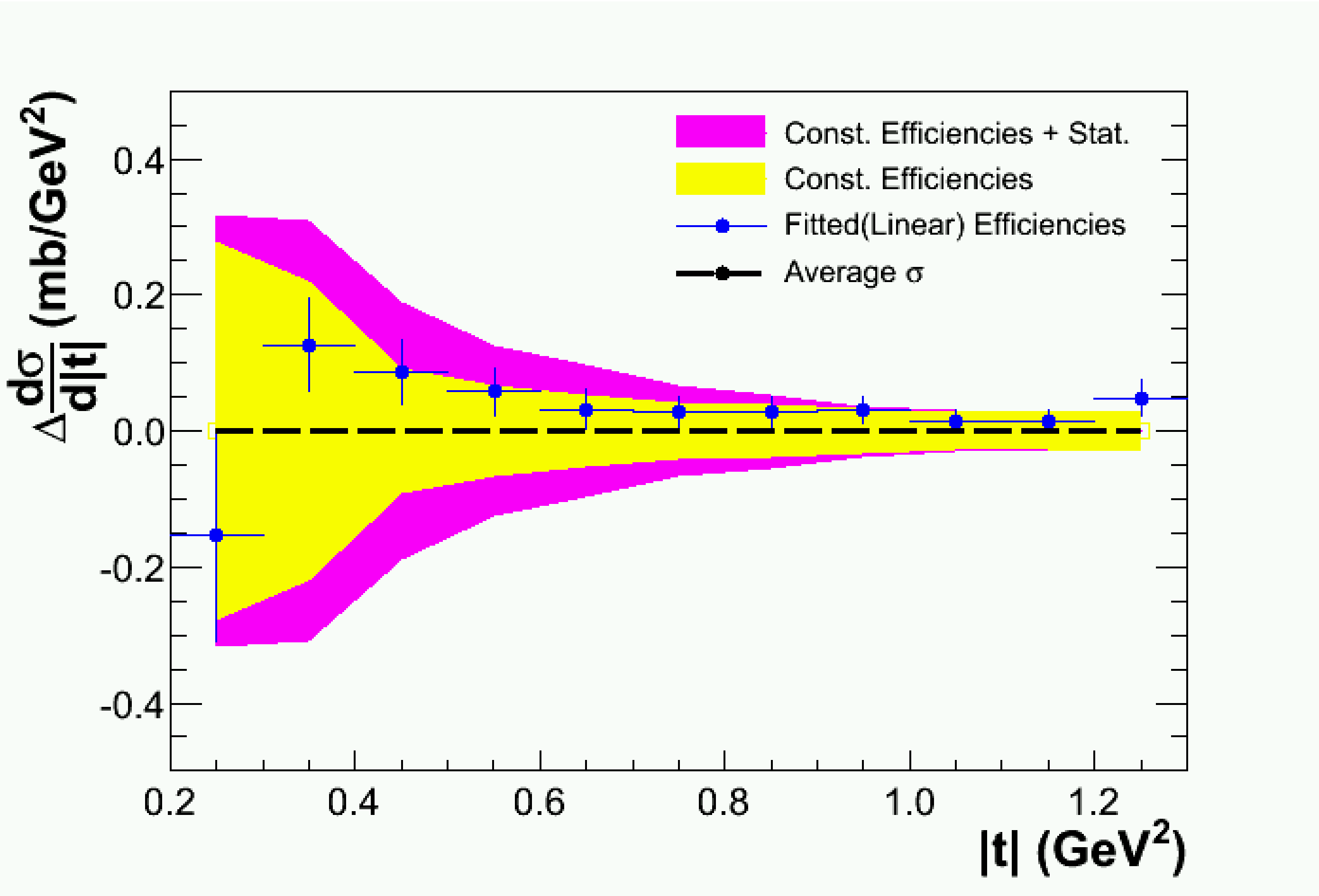
Fits 2nd Detector



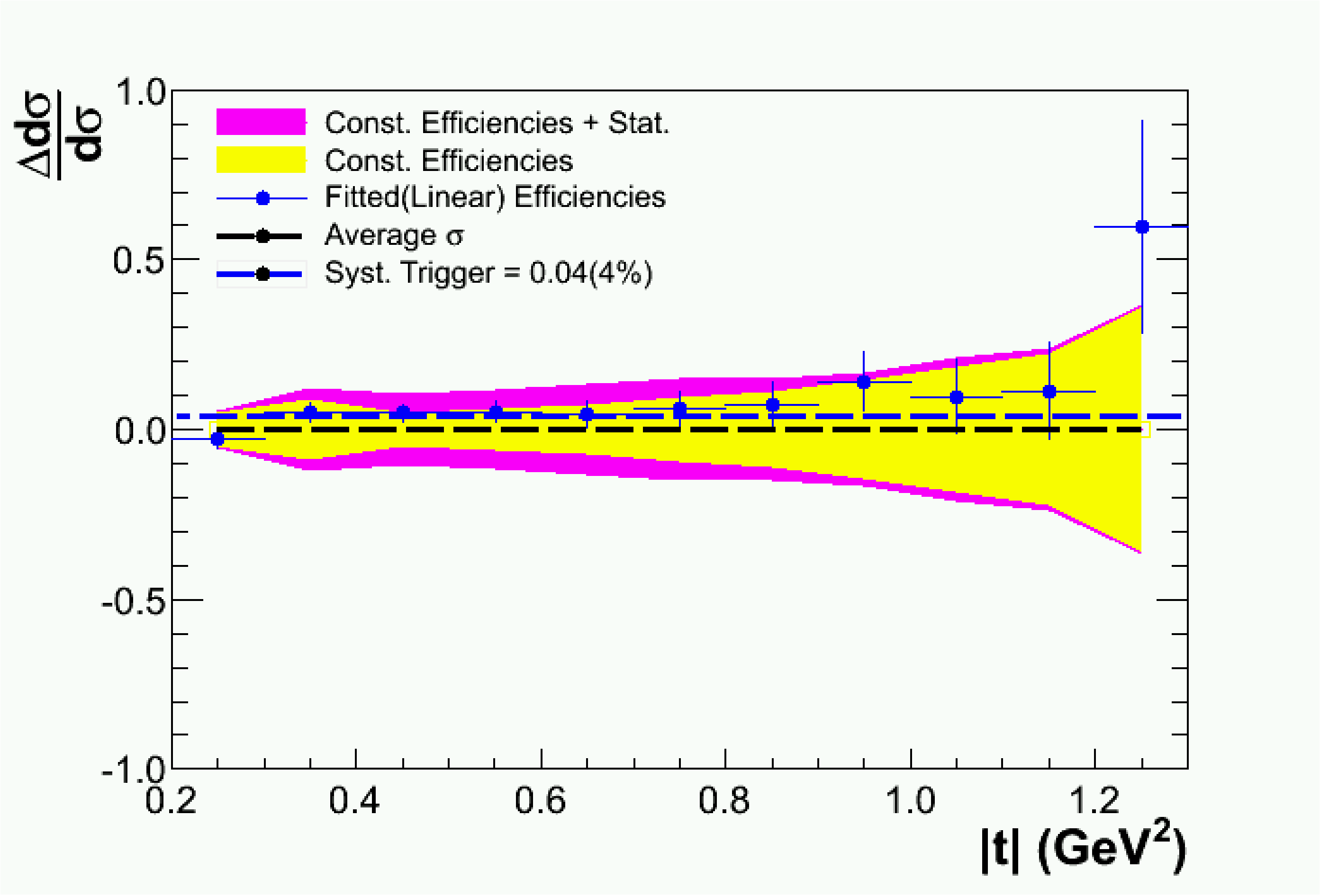
Cross section using efficiency fits



Cross section using efficiency fits

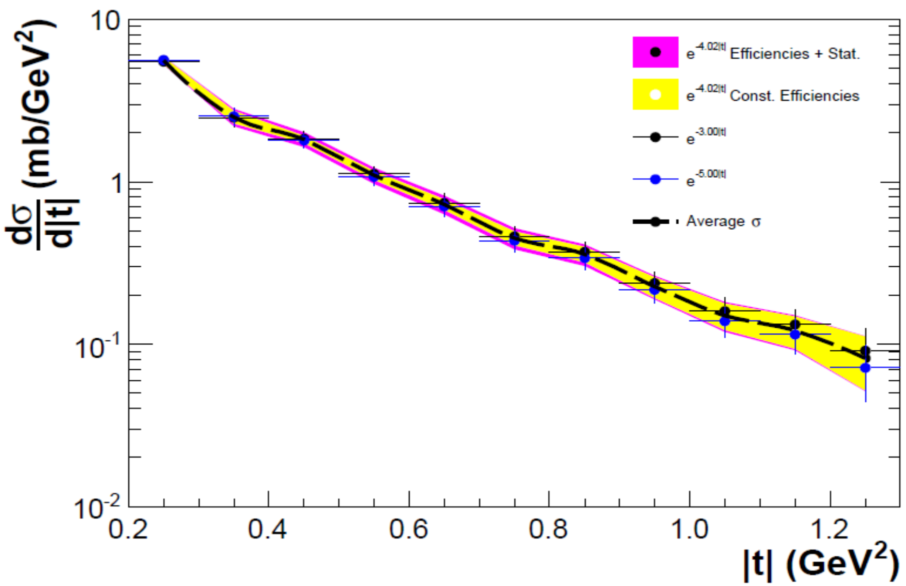


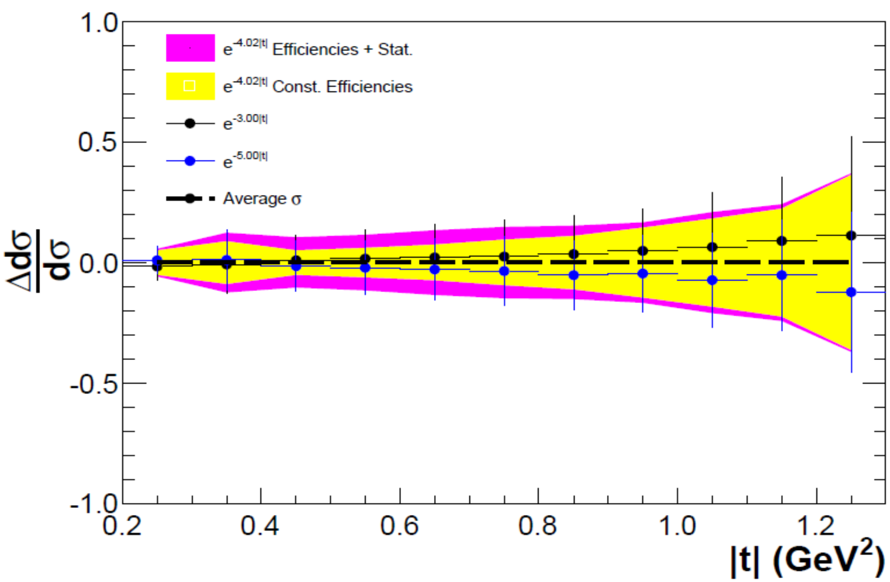
Cross section using efficiency fits



Systematic due to choice of ansatz function

- Take three ansatz function to calculate acceptances and evaluate cross sections using them.
- Difference of 1 GeV in slope of the ansatz function is overestimate.
- Still there is no need to add extra systematic from the choice of ansatz function

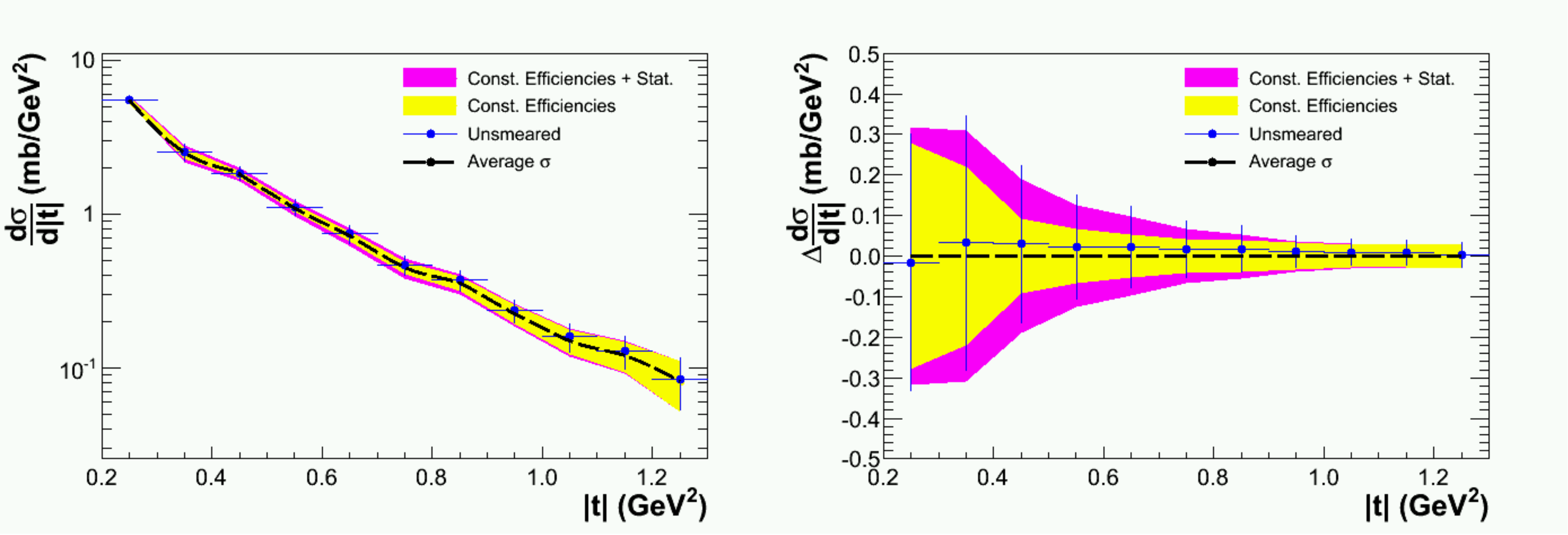




Shows the combined effect of ansatz function and bin smearing

Systematic due to beam smearing

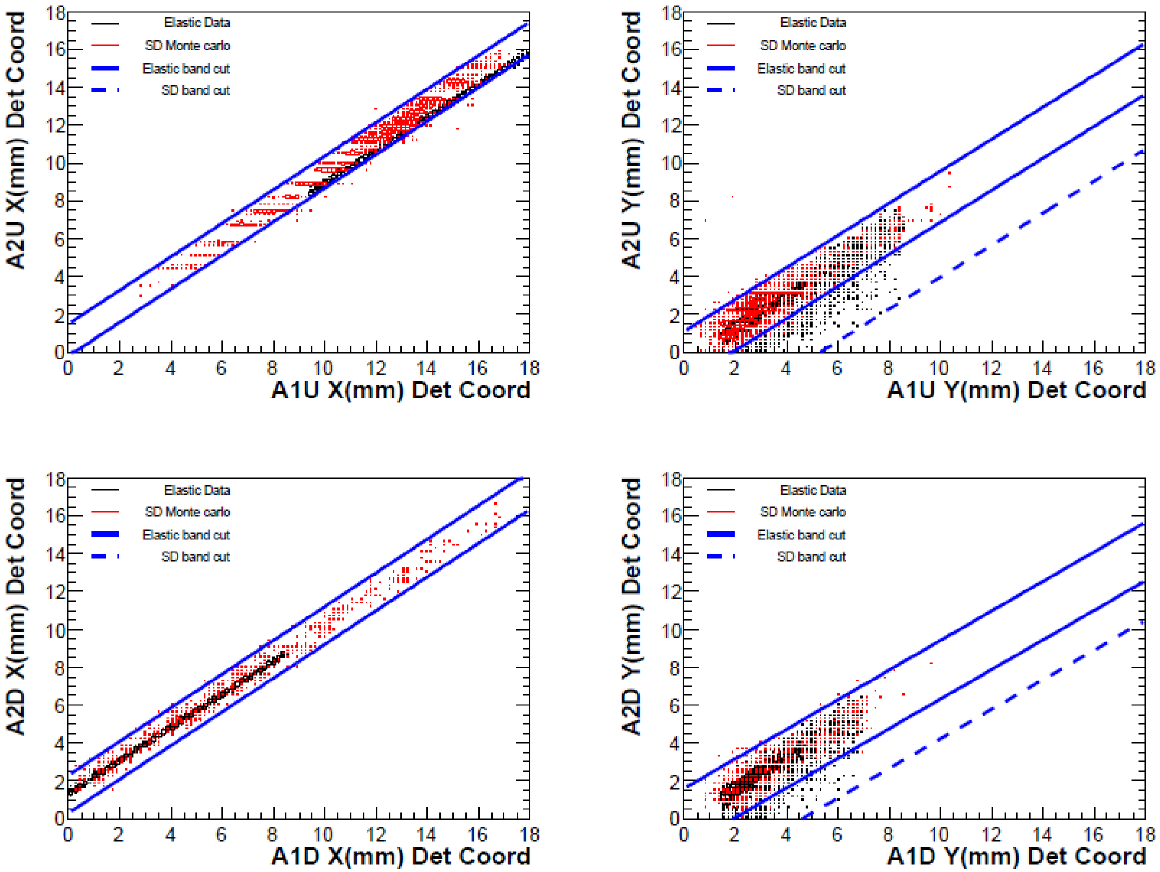
- Use the smeared and un-smeared acceptances to calculate the cross section.
- There is no need to add extra systematic due to beam smearing



Detector correlation

- Evaluate the single diffractive band cuts based on generic single diffractive Monte Carlo.
- The proton ξ and t are selected according to POMWIG parameterization function.
- The interaction point value is smeared by a Gaussian distribution to account for z-vertex distribution
- The generated protons and anti-proton are propagated to forward detectors using the Tevatron transport matrix.
- The location of the hits from the detectors are passed to track reconstruction program.

Detector correlation cuts



- The black points are SD Monte Carlo and red points are elastic data.
- The band cut equation are evaluated using the SD Monte Carlo.