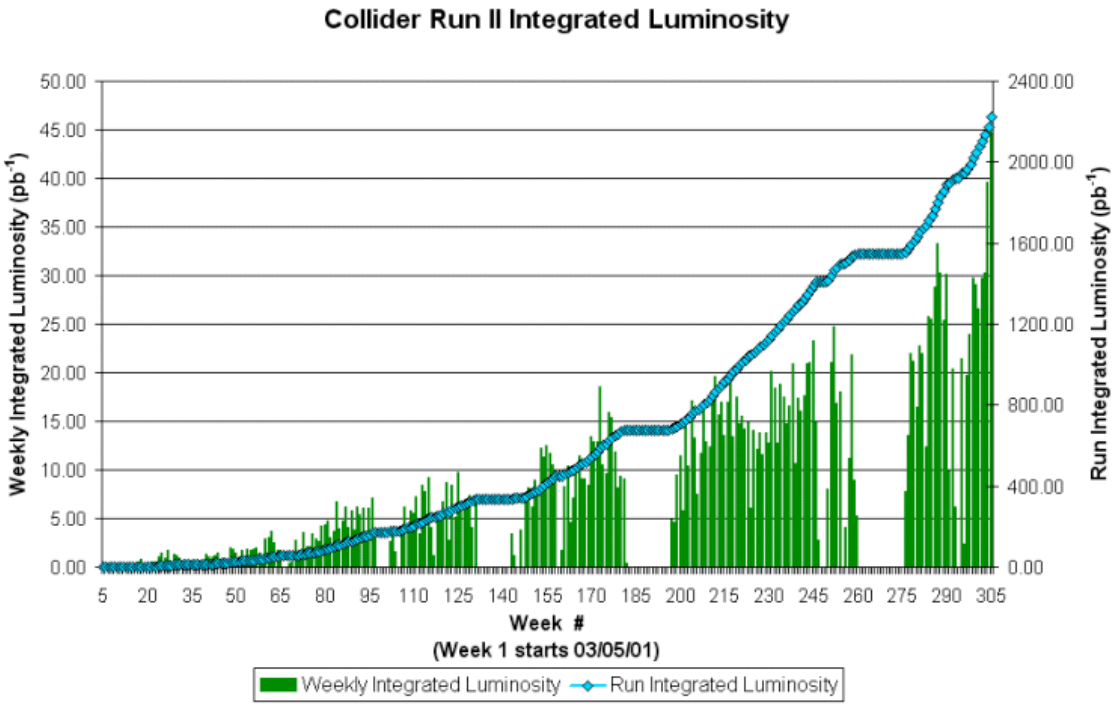
Overview of 'Photo-production' at CDF

ECT* Workshop on Photoproduction, Trento, Italy

Andrew Hamilton
Université de Genève
Jan. 15, 2007

Tevatron :: Introduction

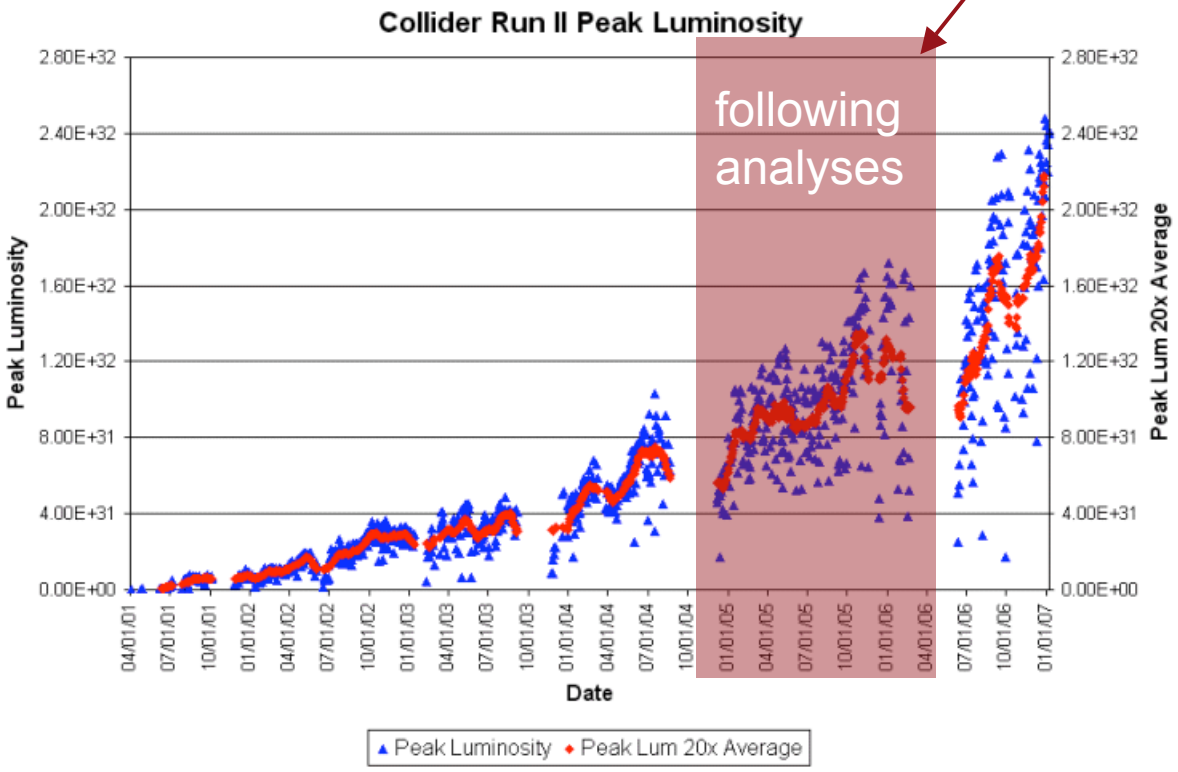
- $p\bar{p}$ collider
- $\sqrt{s} = 1.96$ TeV
- ~2.2 fb^{-1} delivered



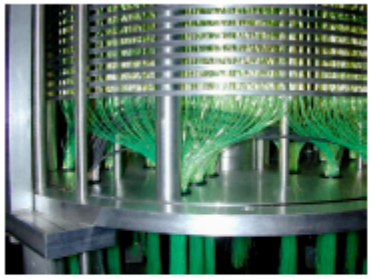
Tevatron :: Performance

- Tevatron performing very well
- Record breaking $\mathcal{L}_{\text{inst}}$

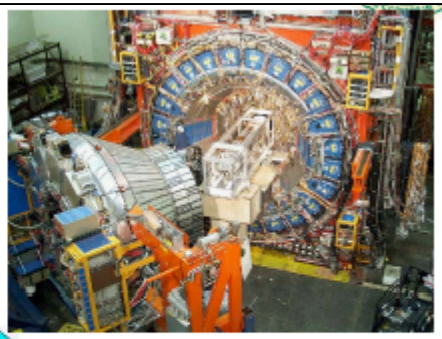
~ 1 - 6 interactions per beam crossing



CDF :: Introduction

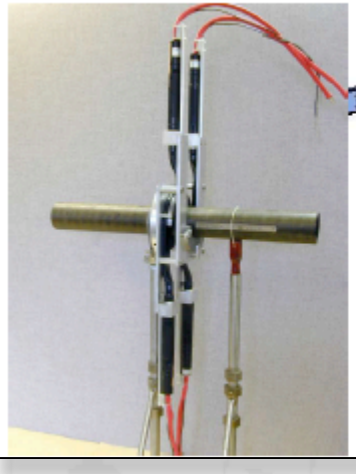


Plug and Central Calorimeters
$|\eta| < 3.5$



MiniPlug Calorimeter
$3.5 < |\eta| < 5.5$

Muon Chambers



COT Tracker
$|\eta| < 1$ (2)

Beam Shower Counter $5.5 < |\eta| < 6$

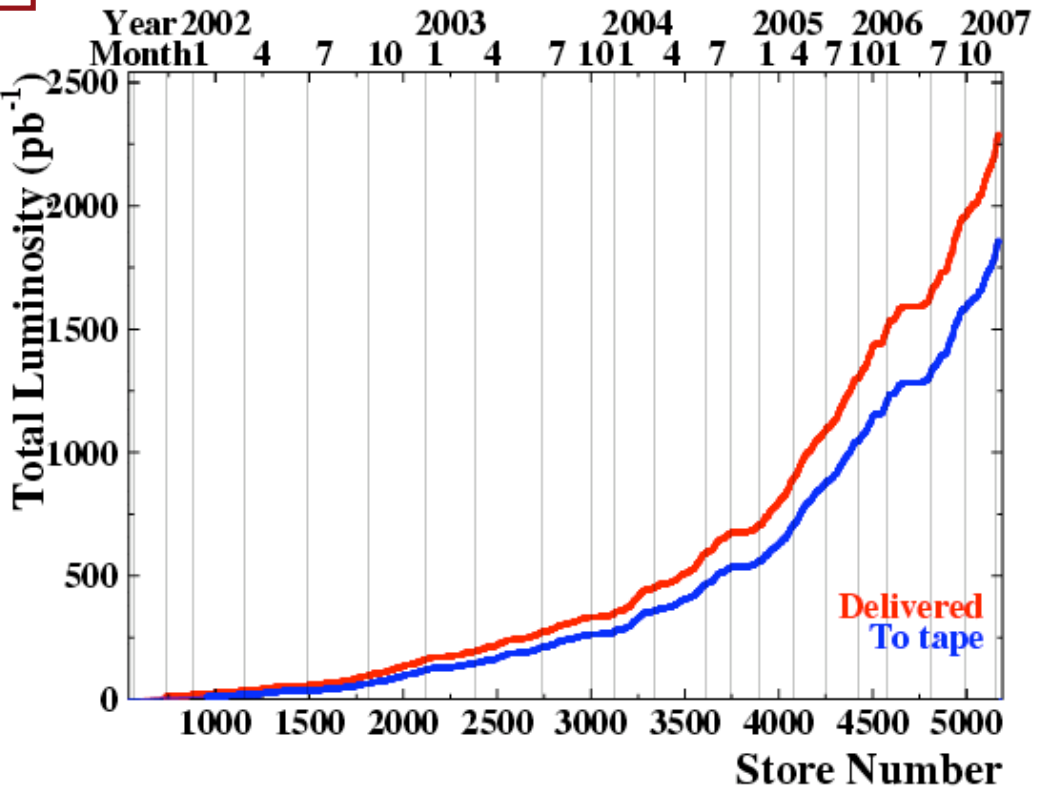
Roman Pots not used

CDF :: Performance

Recently made the World's best W mass measurement:

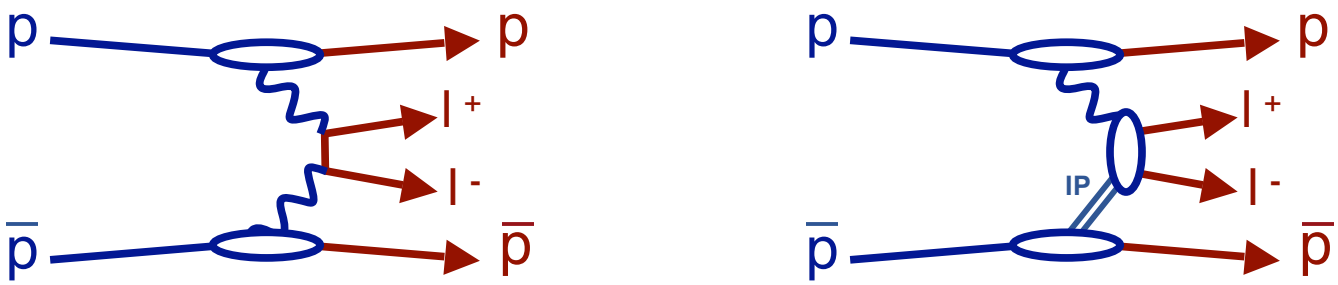
$M_W = 80{,}413 \pm 48\ \mathrm{MeV}/c^2$

- Well understood and
- performing very well
- almost 2 fb^{-1} written to tape



Motivation :: Introduction

Photoproduction at CDF:



We are looking at *exclusive* channels to test:

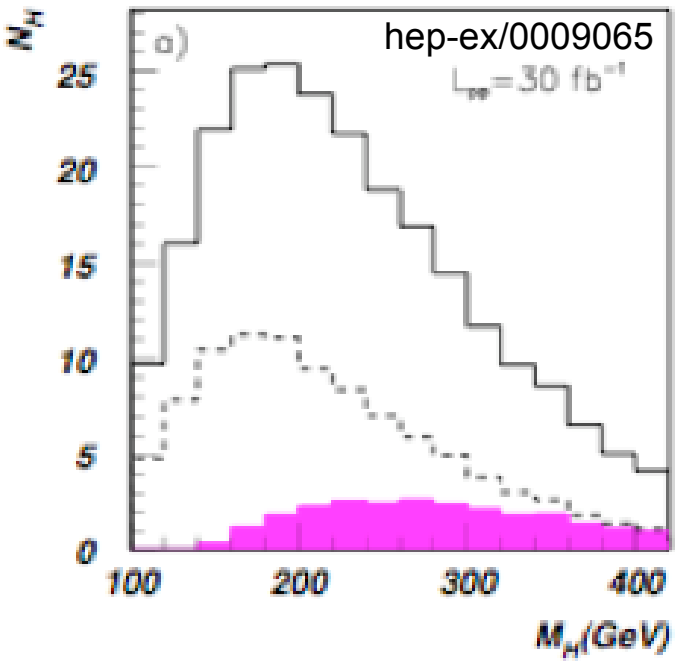
- exclusive production models for new physics at LHC
- experimental techniques to select exclusive events
- potential to measure luminosity and calibrate forward detectors (like FP420) at the LHC

Related measurements:

In pp Collisions:
D. Antreasyan et al., CERN-EP/80-82 (1980).
In ep Collisions:
…

In Heavy Ion Collisions:
A. Belkacem et al., Phys. Rev. A 56, 2806 (1997);
C. Vane et al., Phys. Rev. A 50, 2313 (1997);
R. Baur et al., Phys. Lett. B 332, 471 (1994);
J. Adams et al., Phys. Rev. C 70, 031902 (2004).

Motivation :: $\gamma\gamma$ Physics at LHC



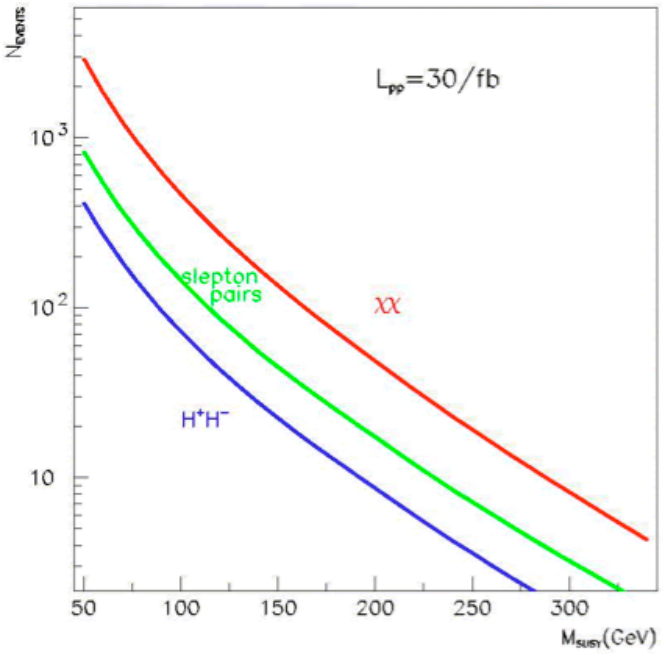
Standard Model:

- $\gamma\gamma \rightarrow W^+W^-$
- $\gamma\gamma \rightarrow tt$
- $\gamma\gamma \rightarrow H$

Beyond SM:

- $\gamma\gamma \rightarrow H^+H^-$
- $\gamma\gamma \rightarrow \chi\chi$
- $\gamma\gamma \rightarrow S^+S^-$

~1% of pp luminosity

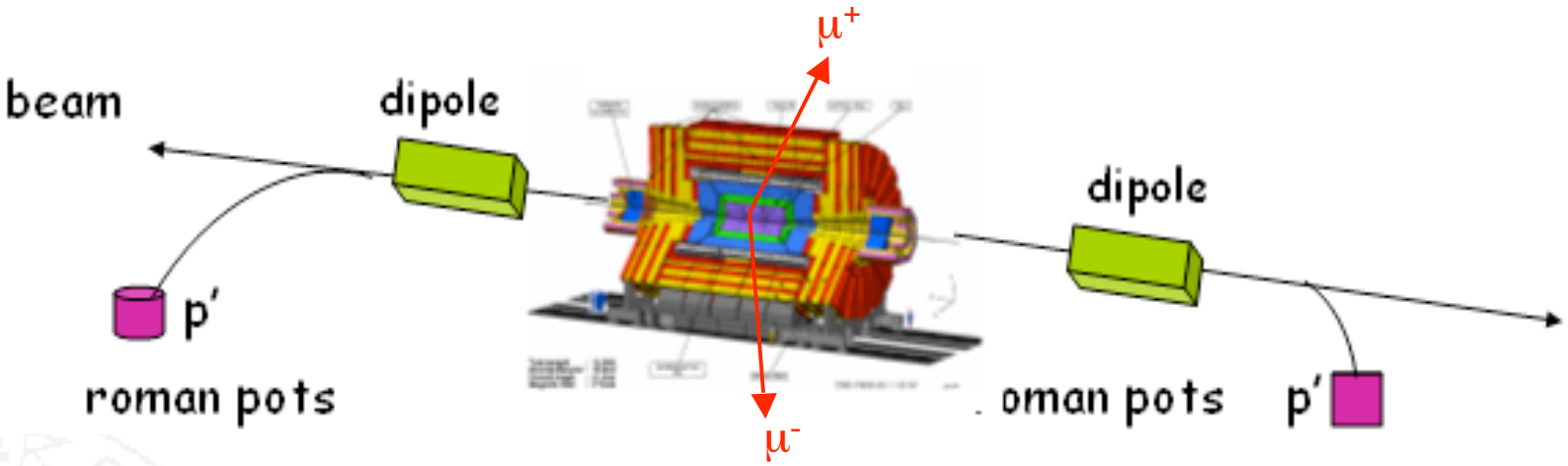


Advantages:

- 'clean' central state
- mass of central state known
  (if protons tagged)

Motivation :: FP420 Calibration

- Measure the $\mu^+\mu^-$ or e^+e^- with the central detector
- Compare with tags in the forward detectors

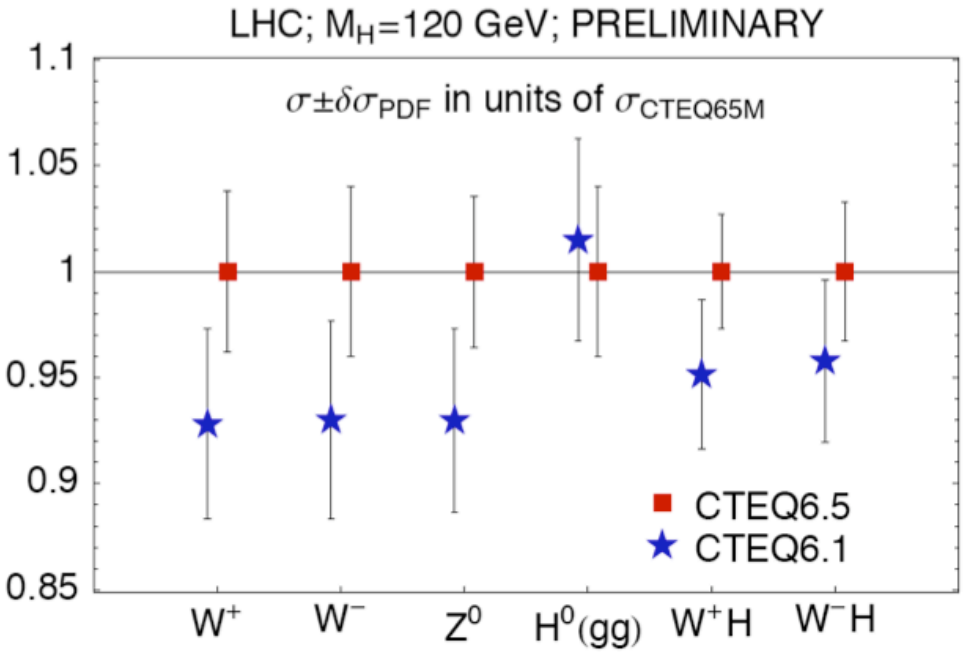


- Low lepton trigger thresholds is desirable
- CMS ~ 5 GeV, ATLAS ~ 3 GeV

Motivation :: Luminosity at LHC

Luminosity monitoring at ATLAS based on:

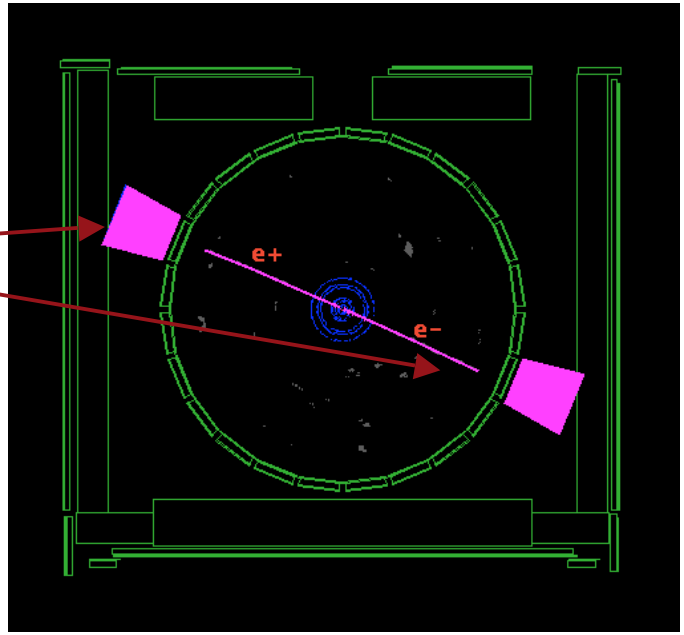
- Coulomb scattering using forward pots ➡ *needs special runs*
- Minimum bias detector LUCID ➡ *a relative measurement*
- W and Z cross section ➡ *hello PDF uncertainty!*
- $\gamma\gamma \to \mu^+\mu^-$ ➡ *~1% theoretical uncertainty, but how efficiently can you pick it out of 20 pp interactions? (no proton tagging)*

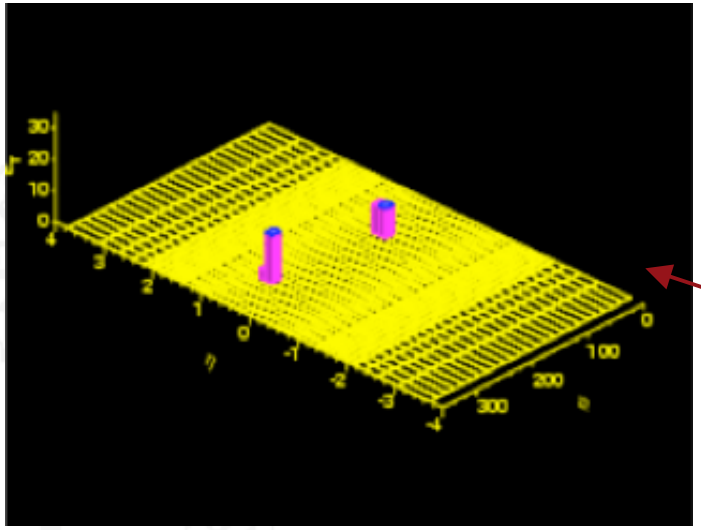


Exclusive e^+e^- :: Introduction

Events selected with:

e^+e^- pair: $E_T > 5$ GeV/c, $|\eta|<2.0$



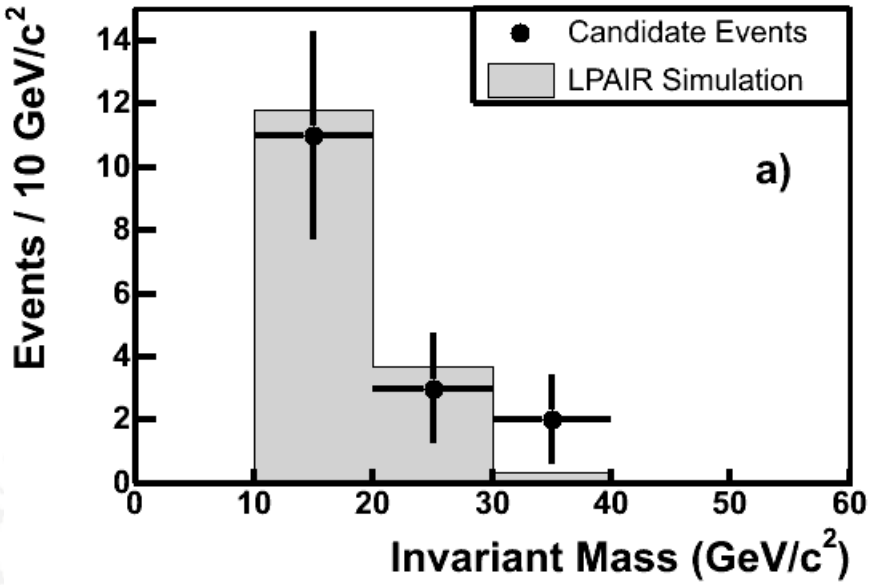


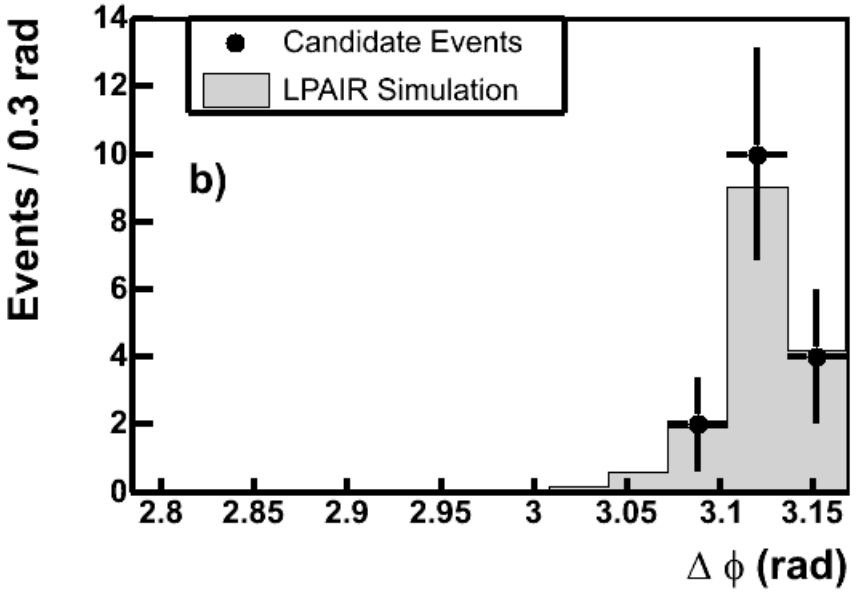
No other calorimeter activity: $|\eta|<7.4$
(this eliminates "pile-up" events!)

pile-up ≡ bunch crossing with more than one pp interaction

Exclusive e^+e^- :: Candidate Sample

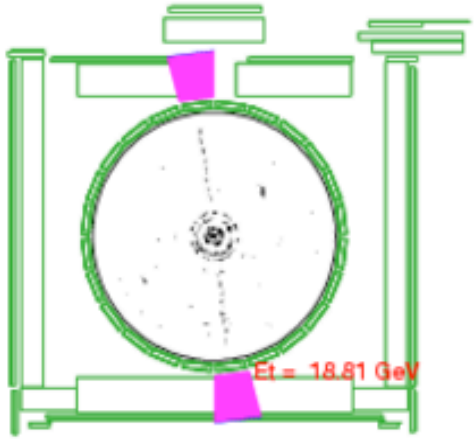
***16** candidate events* found in 532±22 pb^{-1}

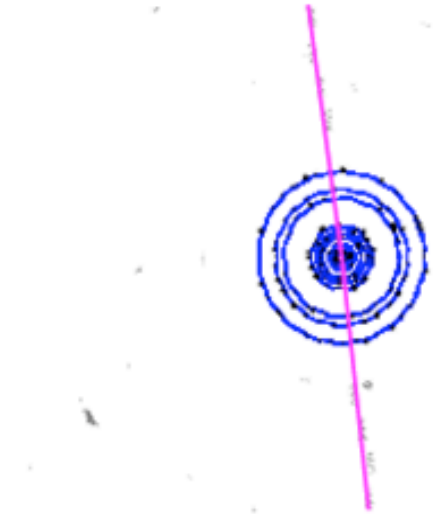




Events' kinematics shows good agreement when compared to LPAIR MC

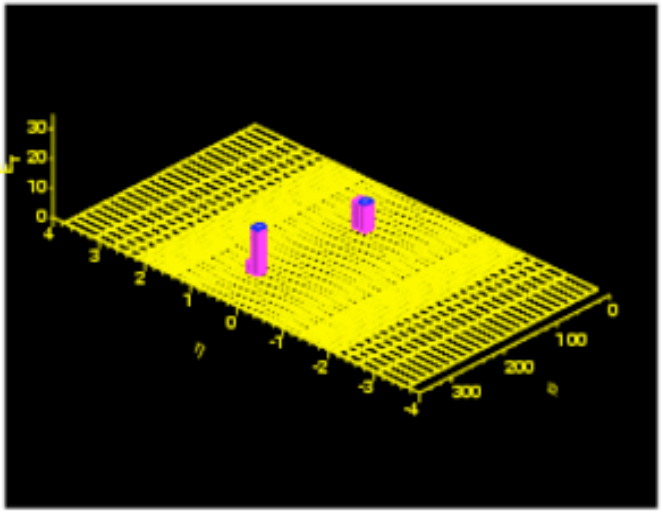
Exclusive e^+e^- :: Event Display

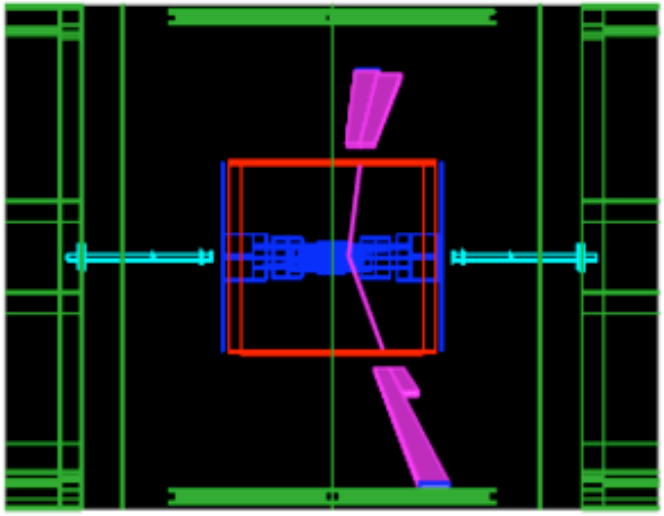




Run: 201155
Event: 151042

m_{ee} = 38.4 GeV/c^2
E_T(e+) = 18.8 GeV
E_T(e-) = 19.3 GeV
$\Delta\phi$ = 179.6°



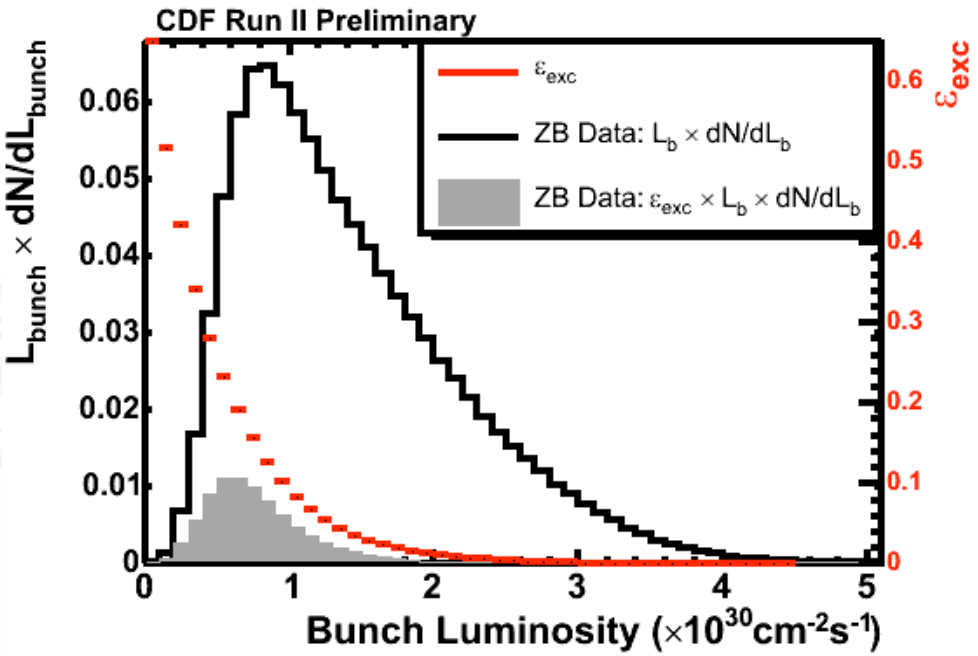


Exclusive e^+e^- :: Efficiencies

Efficiency

- Electron ID: (26 ± 3) %
- Cosmic Rejection: (93 ± 3) %
- Final State Radiation: (79 ± 5) %
- Exclusive Cuts: 8.6 %

(1.6 ± 0.2) %

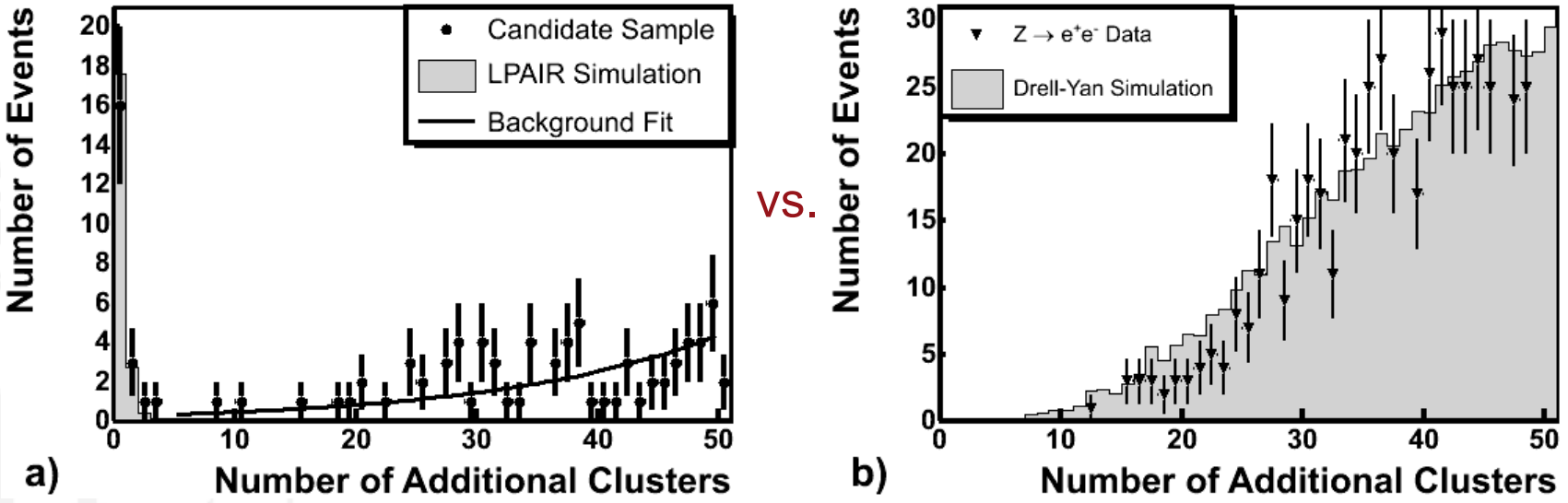


Efficiency is dominated by requiring events with no pile-up.

Exclusive e^+e^- :: Backgrounds

4 backgrounds are considered:

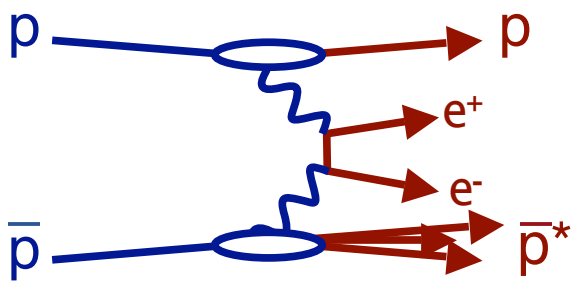
- Jet Fakes: $0.0^{+0.1}_{-0.0}$ events
- Cosmics: negligible
- Inclusive (QCD) events: 0.3 ± 0.1 events
- Dissociation events: 1.6 ± 0.3 events (next slide)



Exclusive e^+e^- :: Dissociation

Proton Dissociation Events:

- Photoproduction events where the proton(s) dissociate



- While this is still photoproduction, *it does not satify the motivation of our study* - the protons must stay in tact.
- This background is studied by simulating the proton dissociation using LPAIR (with MBR) and GRAPE-DILEPTION

Exclusive e^+e^- :: Conclusions

$$\sigma_{Measured} = 1.6^{+0.5}_{-0.3} \text{ (stat)} \pm 0.3 \text{ (sys) pb}$$

Agrees with LPAIR theory: $\sigma_{LPAIR} = 1.71 \pm 0.01$ pb

Probability of 1.9 → 16 = 1.3×10^{-9}
Corresponds to 5.5σ "observation"

Submitted to PRL (hep-ex/0611040)

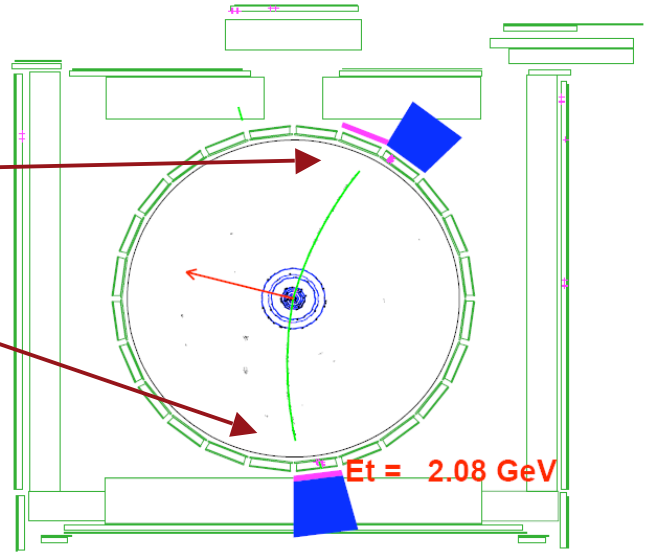
We present the first observation of exclusive e^+e^- production in hadron-hadron collisions, using $p\bar{p}$ collision data at $\sqrt{s} = 1.96$ TeV taken by the Run II Collider Detector at Fermilab, and corresponding to an integrated luminosity of 532 pb^{-1}. We require the absence of any particle signatures in the detector except for an electron and a positron candidate, each with transverse energy $E_T > 5$ GeV and pseudorapidity $|\eta| < 2$. With these criteria, 16 events are observed compared to a background expectation of 1.9 ± 0.3 events. These events are consistent in cross section and properties with the QED process $p\bar{p} \to p + e^+e^- + \bar{p}$ through two-photon exchange. The measured cross section is $1.6^{+0.5}_{-0.3}(\text{stat}) \pm 0.3(\text{syst})$ pb. This agrees with the theoretical prediction of 1.71 ± 0.01 pb.

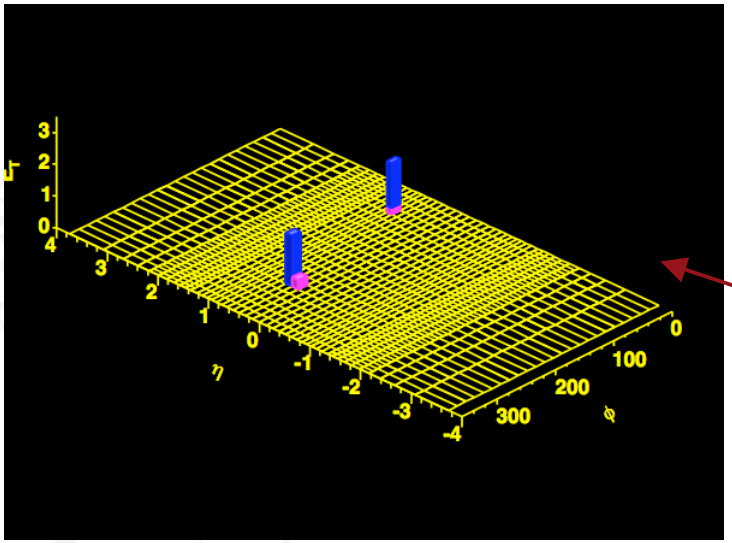
Exclusive $\mu^+\mu^-$ :: Introduction

Events selected with:

$\mu^+\mu^-$ pair:

- $P_T > 1.3$ GeV/c
- $|\eta|<1.2$
- $2.7 < M_{\mu\mu} < 4.0$ GeV/c^2 (trigger rate)



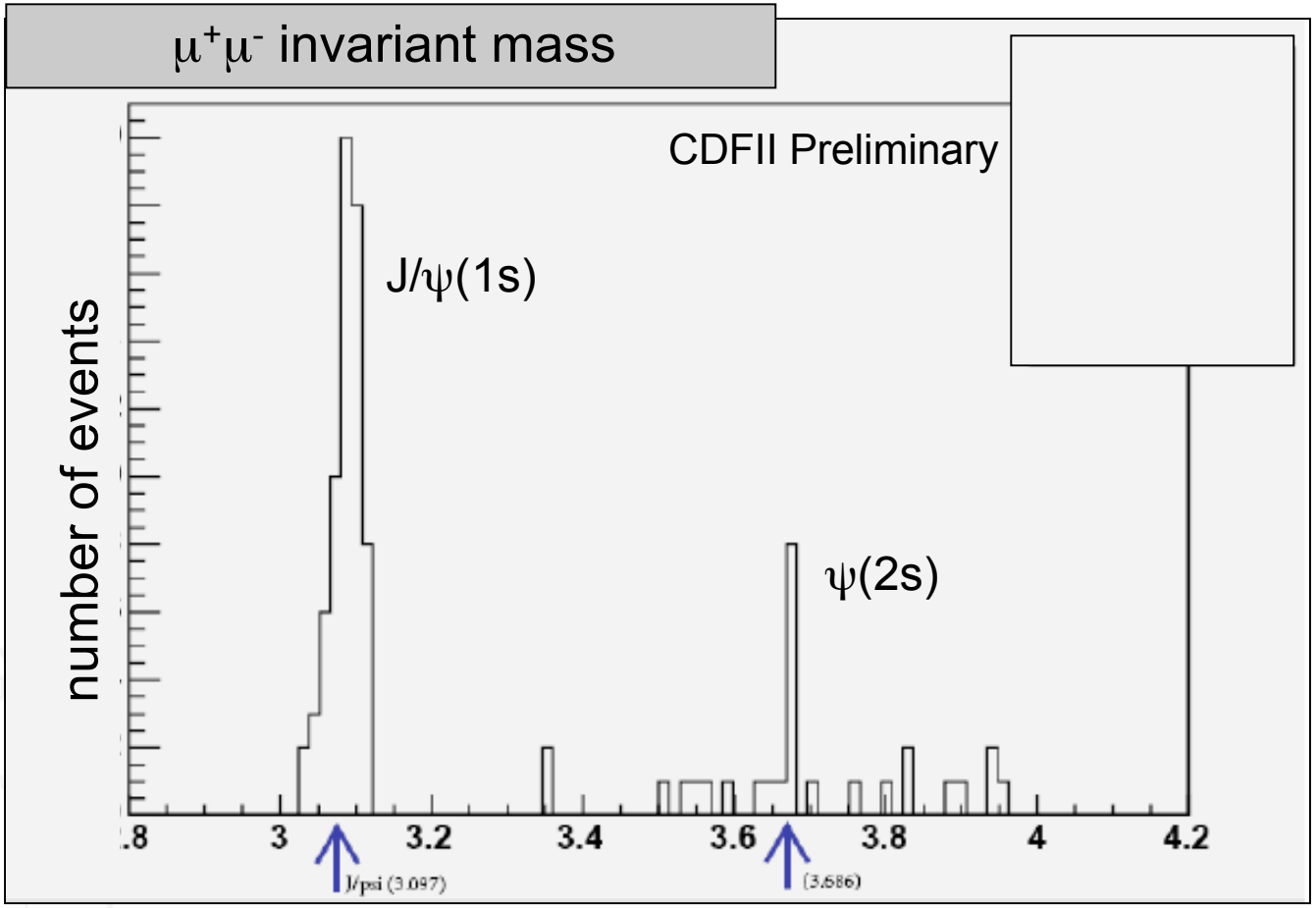


No other calorimeter activity:

- $|\eta|<7.4$

Exclusive $\mu^+\mu^-$ :: Candidate Sample

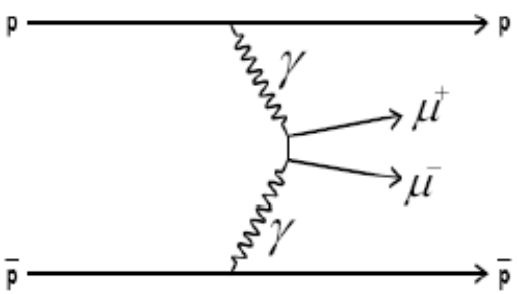
candidate events have been found.

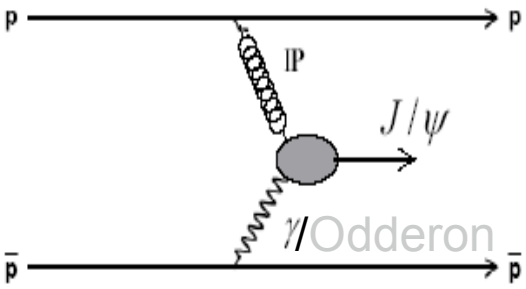


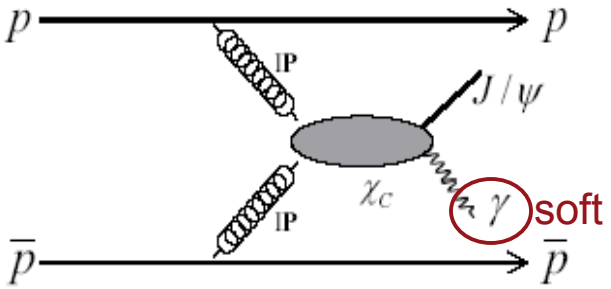
Exclusive $\mu^+\mu^-$ :: Lots to do…

Not yet complete:

- acceptance & efficiency
- deconvolution of signal events
- background estimates



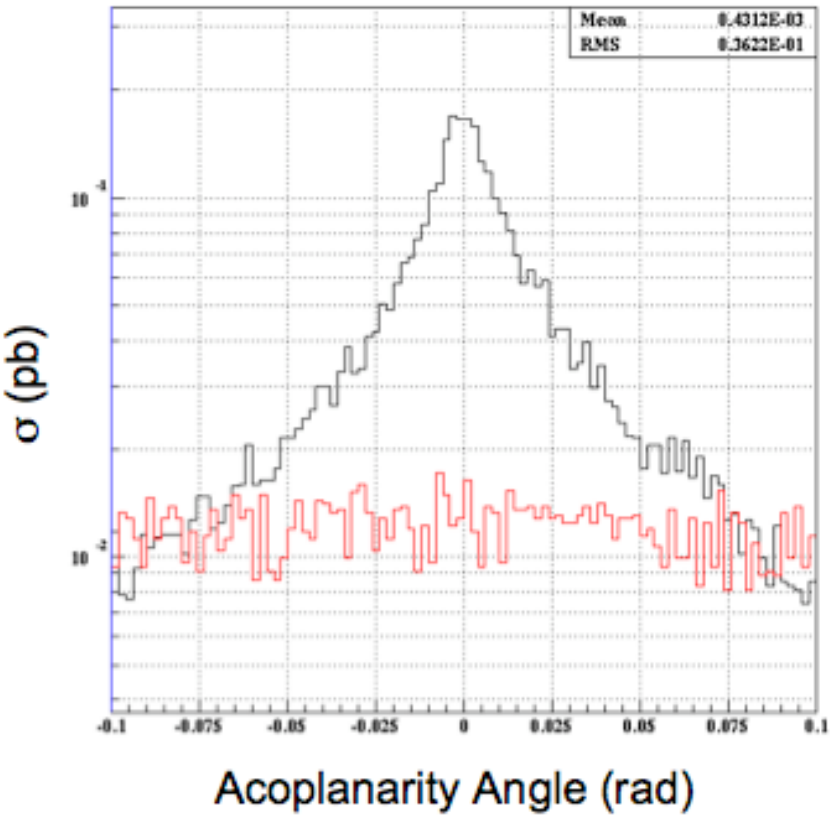




Exclusive $\mu^+\mu^-$ :: Next Steps

Look for signal in presence of pile-up at CDF

- Replace empty calorimeter cut with $\Delta\varphi$ and Δp_T cuts on $\mu^+\mu^-$



$\mu^+\mu^-$ exclusive

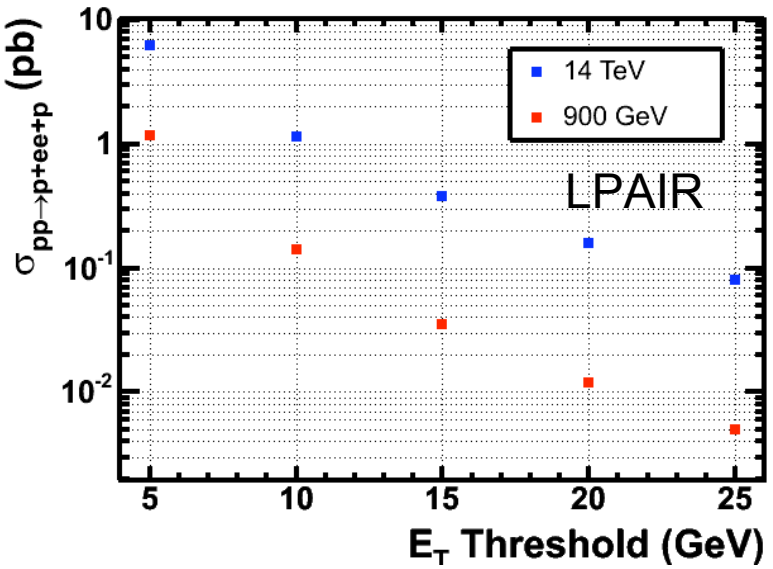
$\mu^+\mu^-$ with pp dissociation

Measuring exclusive signal in presence of pile-up is essential for luminosity monitoring at LHC

Outlook for LHC

Luminosity

- luminosity monitoring potential depends highly on trigger thresholds
- $\gamma\gamma \to \mu^+\mu^-$ will be much easier than $\gamma\gamma \to e^+e^-$



New Physics

- Advantages of $\gamma\gamma$ collisions in new physics searches depend entirely on tagging forward protons
- Anyone interested in searching for new physics in $\gamma\gamma$ collisions should be a member of the FP420 collaboration (*www.fp420.com*)

Conclusions

- $p\bar{p} \rightarrow p + e^+e^- + \bar{p}$ has been observed at CDF.
- $p\bar{p} \rightarrow p + \mu^+\mu^- + \bar{p}$ is expected soon.
- We are working towards an understanding of exclusive processes in ~TeV proton collisions to be sure we can exploit all possible physics processes at the LHC to calibrate the detectors and search for new physics.