Fermilab

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Evidence for Low p_T D^+ Production in the 900 GeV Run of CDF

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Training Program

“ The intern will be conducting CDF data analysis aimed at the measurement of the production cross section of the D+ meson a the Tevatron energy. The intern will review the existing D+ cross section analysis and be introduced to charmed meson reconstruction and identification. Reproducing the analysis will develop CDF analysis software and Root skills. Updating and enhancing the analysis will impart C++ programming and Root macro writing skills and help the intern become familiar with Grid computing.

Major Equipment to be used: C++ programming language, CDF software environment.

Major Computer Software to be used: C++ Compiler, Root analysis software, PowerPoint, LateX ”

My goal

My goal was to search for D+ production in the data from the special 900 GeV run for the first time and explore the possibility of extending to that energy the cross section analysis, already in an advanced state, for the 2 TeV data.

Outline

- Motivations
- The Tevatron and CDF
- Description of the analysis
- 900 GeV vs. 2 TeV comparisons
- Results
- Conclusions

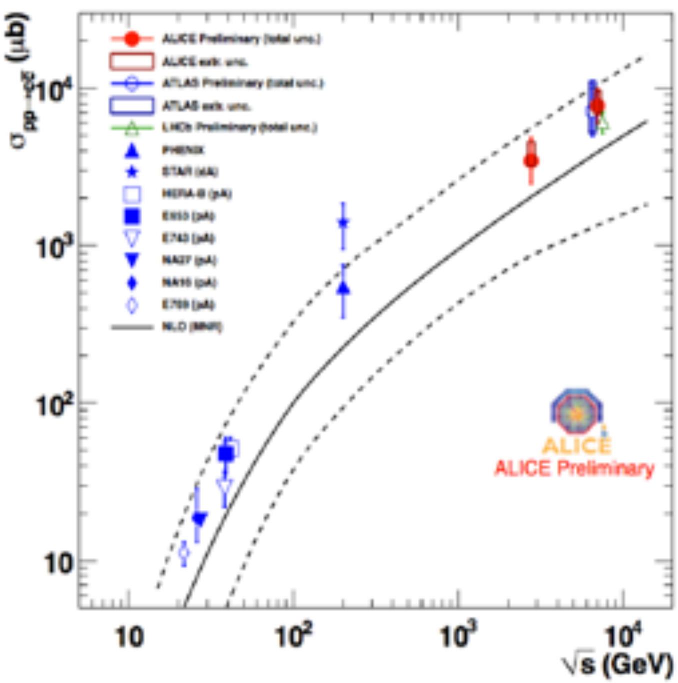
Motivations

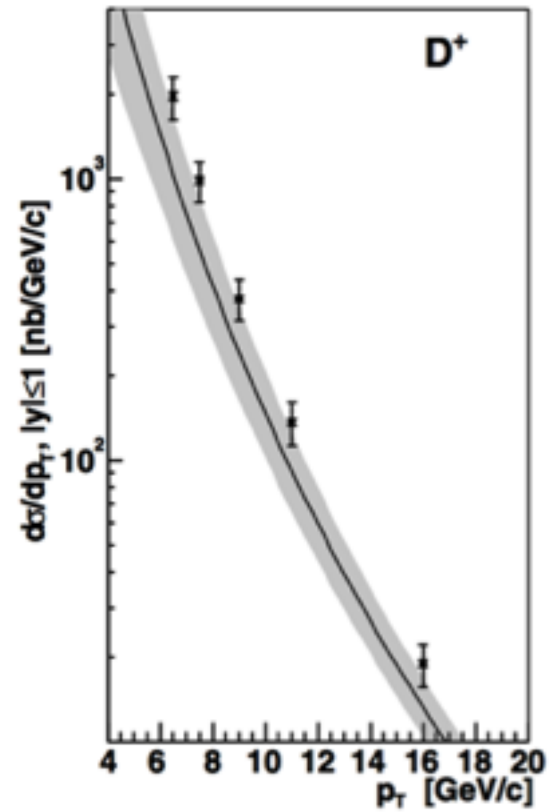
- QCD at Low Energies

$$\alpha_s(|q^2|) = \frac{\alpha_s(\mu^2)}{1 + \left(\frac{33-2N_f}{12\pi}\right)\alpha_s(\mu^2)\ln\left(\frac{|q^2|}{\mu^2}\right)}$$

- Previous CDF cross section measurements at $p_T > 6$ GeV/c

- Extending measurements to $p_T < 6$ GeV/c

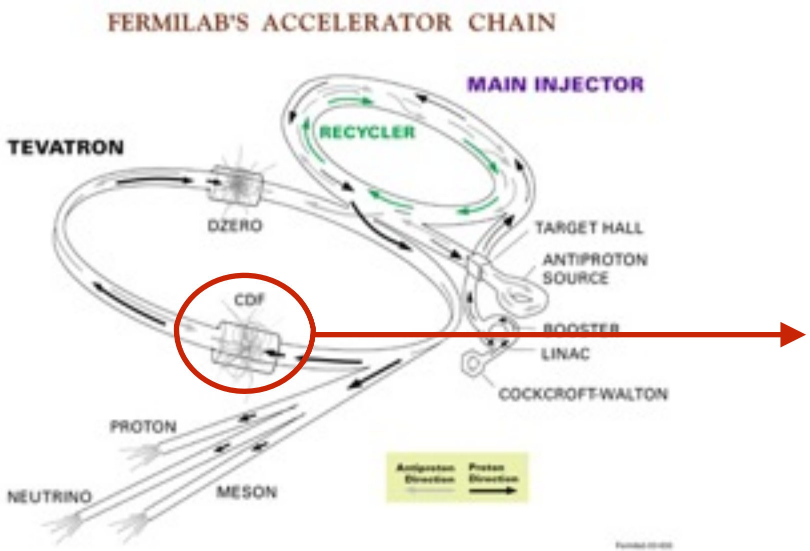


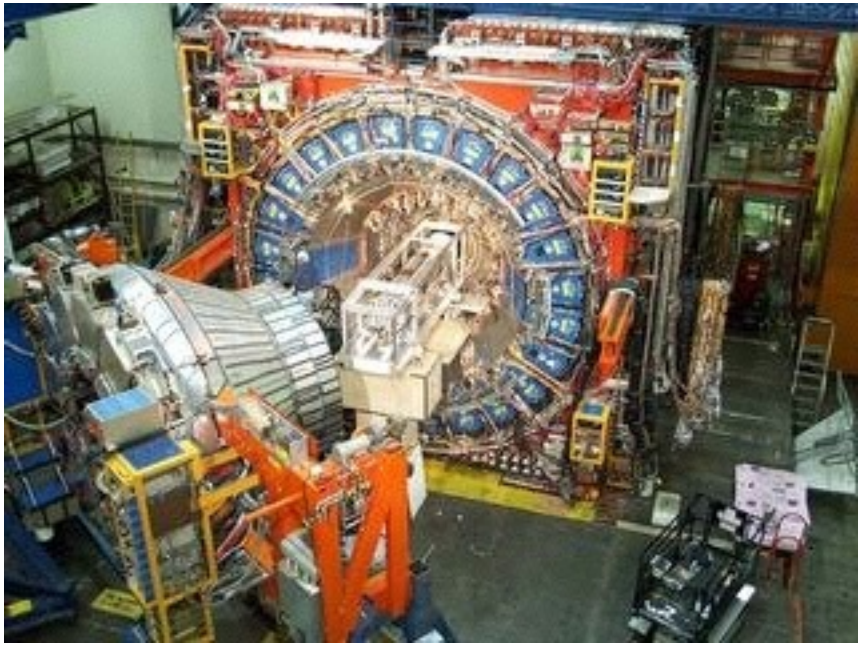


Tevatron

- Ring Interaction points: CDF & D0

Run	***Luminosity***
1.96 TeV	≈10
900 GeV	≈1

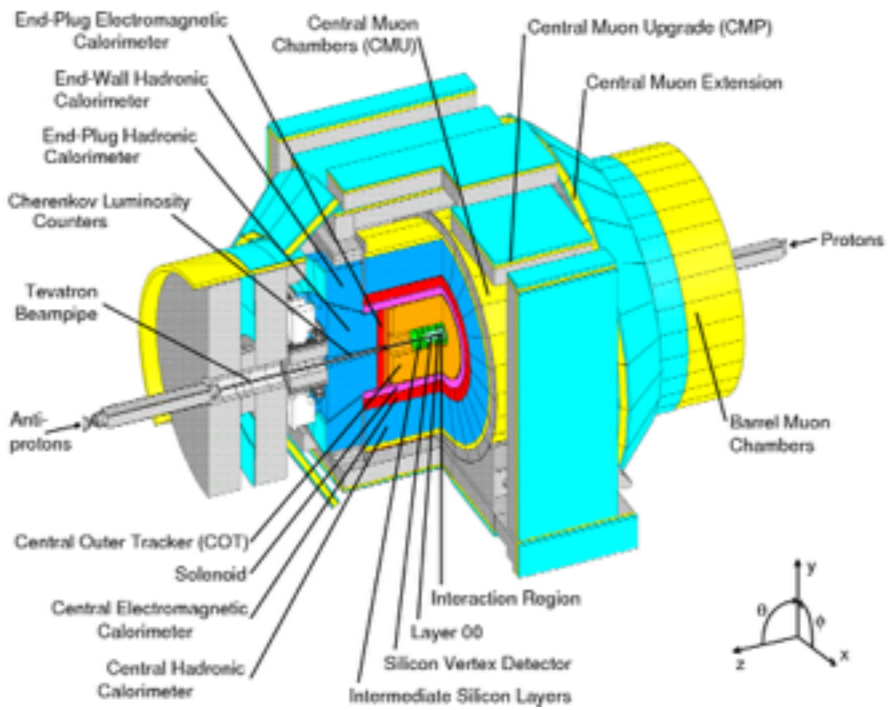




CDF

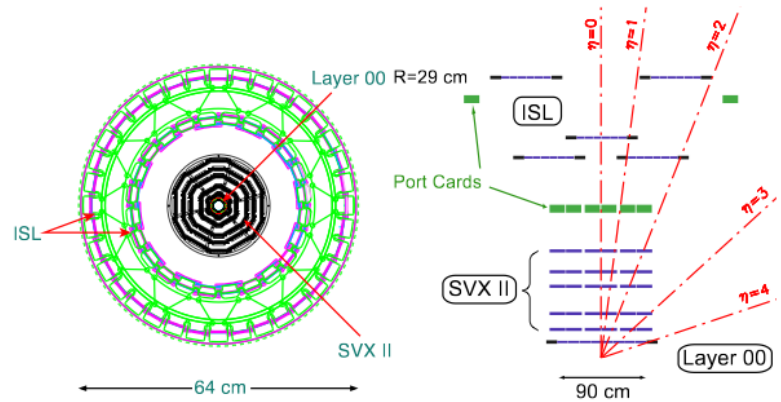
- CDF = Collider Detector at Fermilab

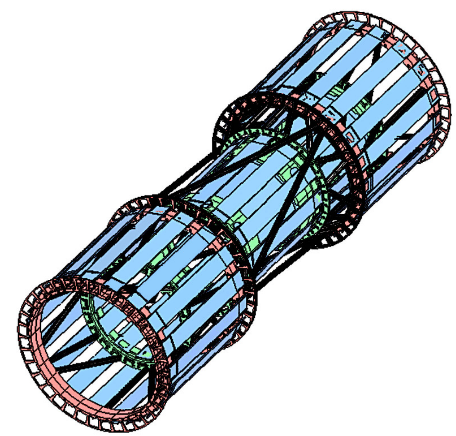
- CDF II detector was a large multi purpose solenoidal magnetic spectrometer surrounded by 4π, fast, projective calorimeters and fine-grained muon detectors



Silicon Detector

- Components: L00, SVX II, ISL (going from the center to the outside)
- SVX II active surface → Double-sided silicon sensors
- Three different strips orientations for each sensor → Axial / Small Angle Stereo (SAS) / 90º Stereo





- Crucial for D+ decay vertex reconstruction

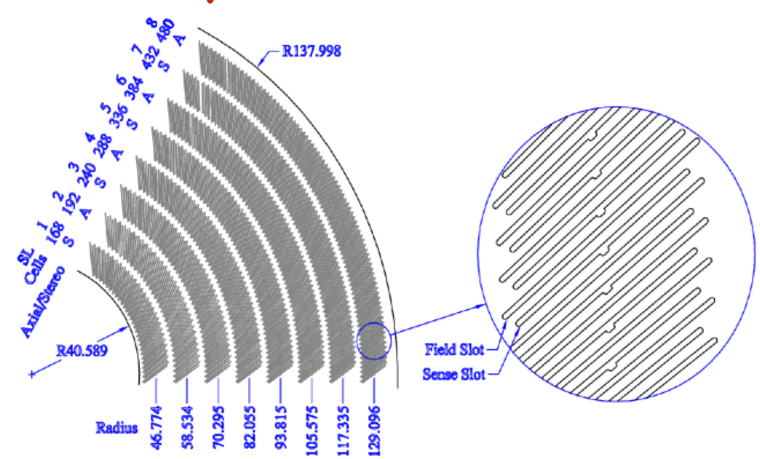
COT

Central Outer Tracker → coaxial cylindrical detector

between the radius of 40 cm and 138 cm

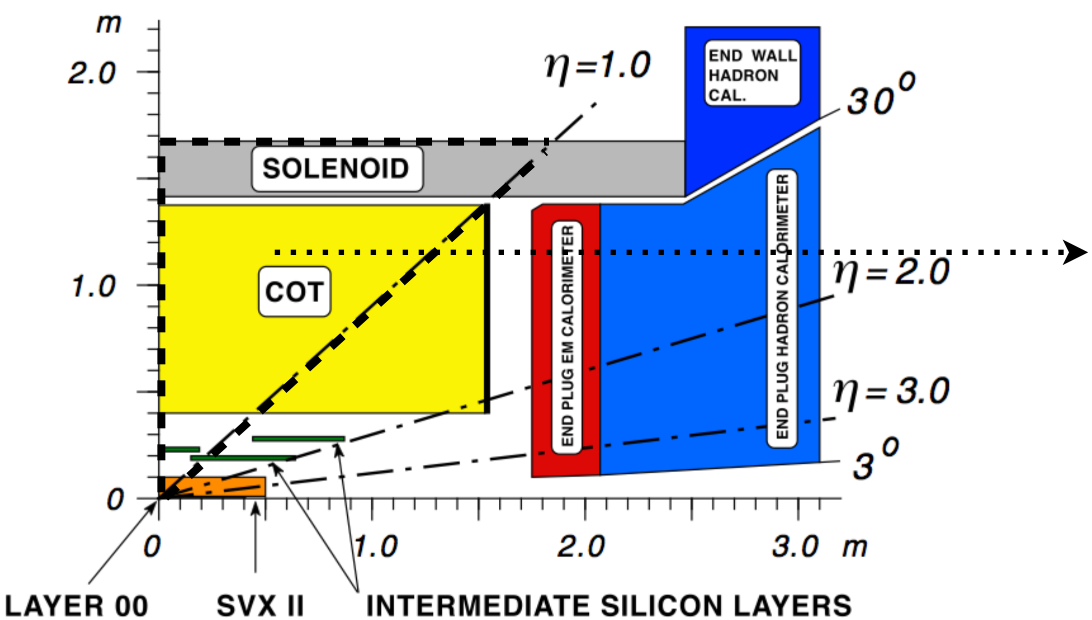
96 radial layers arranged into 8 *superlayers*

Gas Mixture	Ar(50%)/Ethane(35%)/CF_4(15%)
Electron drift speed	about 100 μm/ns
Maximum drift time	about 100 ns
Track efficiency	99%
Single hit resolution	$\sigma_{\text{hit}} \simeq 140\ \mu$m
p_t resolution	$\sigma_{p_T}/p_T^2 \simeq 0.0015$ c/GeV
Mass	$0.016 \cdot X_0$ for normally incident particle



Tracker

Tracker characteristics	
σ	*$σ_{d0}$*
1.5 10	*30 μm*



Pseudorapidity range

-1< η <1

Low p_T D^+ production analysis

- Data collected by CDF

- Special run at 900 GeV performed on September 2011 (just before Tevatron shut down)

- Low p_T → Zero and Minimum bias triggers

- 2 TeV D^0 and D^+ productions analyses are already in an advanced state

$D^0 \to K^- \pi^+$ $D^+ \to K^- \pi^+ \pi^+$

- My goal is to find D^+ signal at 900 GeV

↓

Is it possible to do a similar analysis as for the 2 TeV sample?

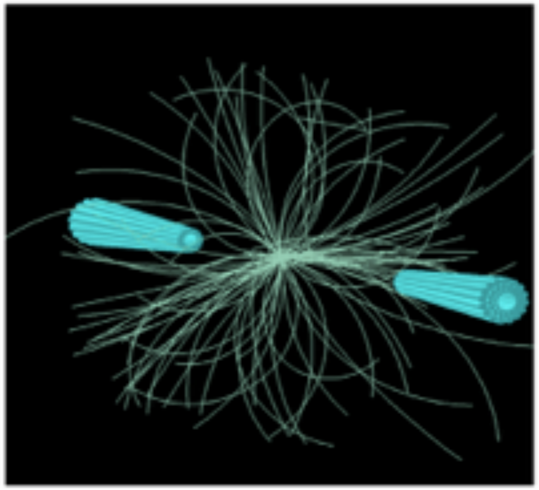
Triggers used for this analysis

Zero Bias

- Any bunch crossing
- No trigger request

Minimum Bias

- Any bunch crossing
- CLC signals coincidence

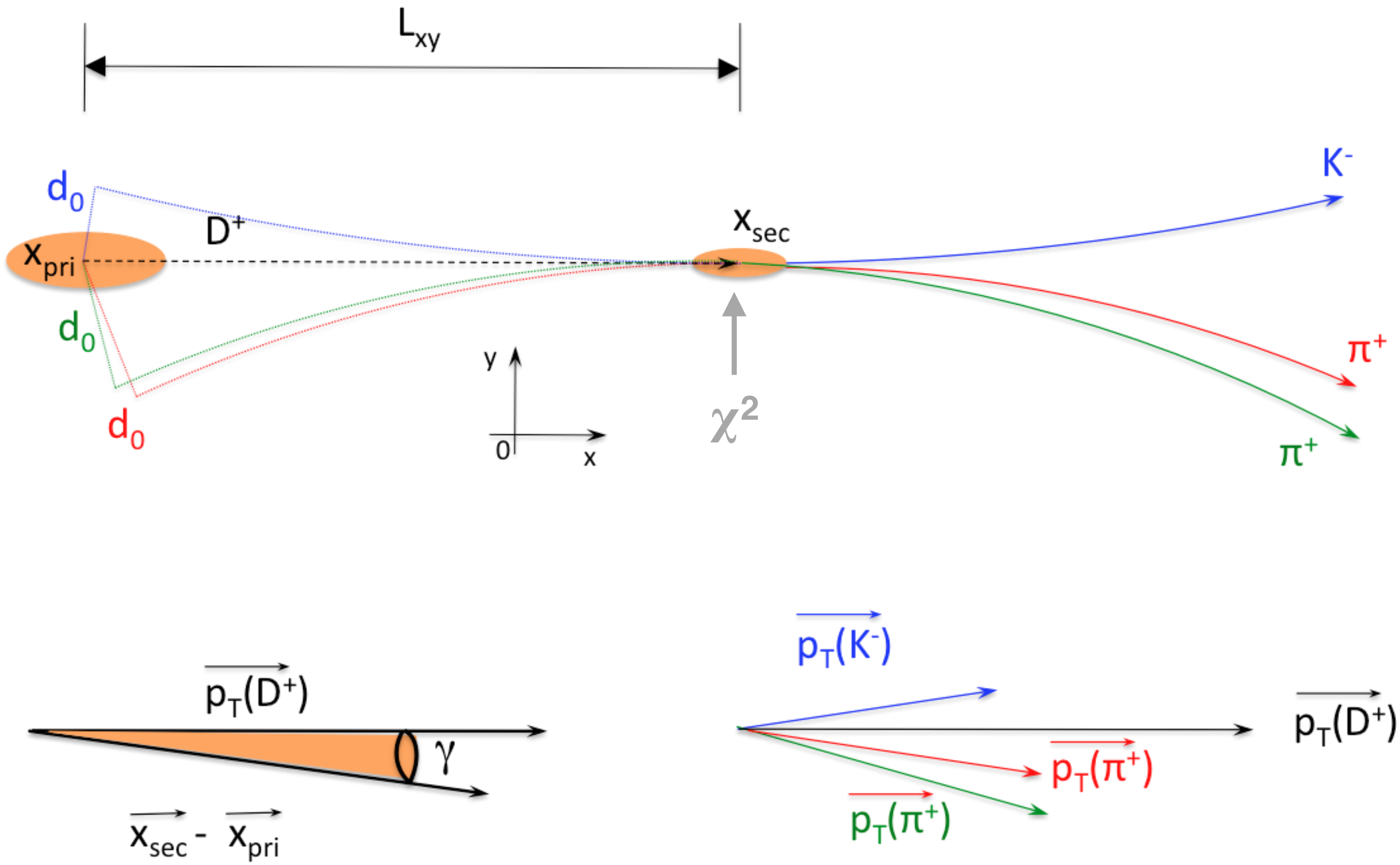


Signal & Background

- Studied decay $D^+ \to K^-\pi^+\pi^+$ (+ c.c.)

- Background → B decay
  → Combinatorics

Kinematical Variables



D+ Candidate Construction

- Construct D+ candidates with all possible combinations of three tracks
  - Charge combinations: (+ + -) (- - +)
  - $L_{xy} > 0$
  - Track $d_0 < 1$mm
  - Vertex χ^2 / NDF < 10

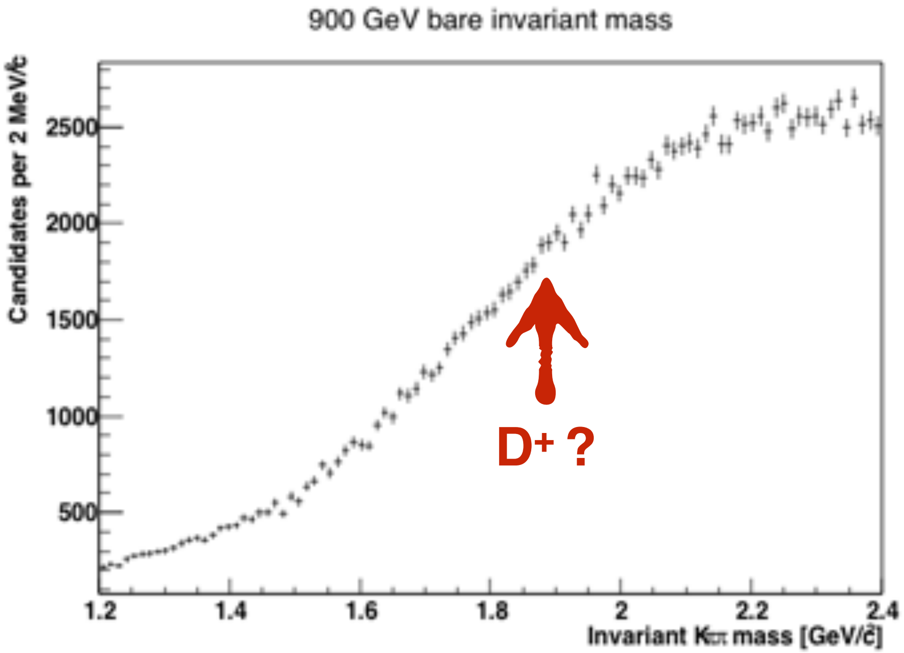
- Pion mass assigned to tracks with equal sign

- Kaon mass assigned to track with different sign

No-cut plot

- No signal is visible
- Need to apply cuts on kinematical variables
- Is it possible to apply the same cuts as for 2 TeV?

- L_{xy}
- χ^2
- Track d_0
- Track p_T
- Pointing Angle

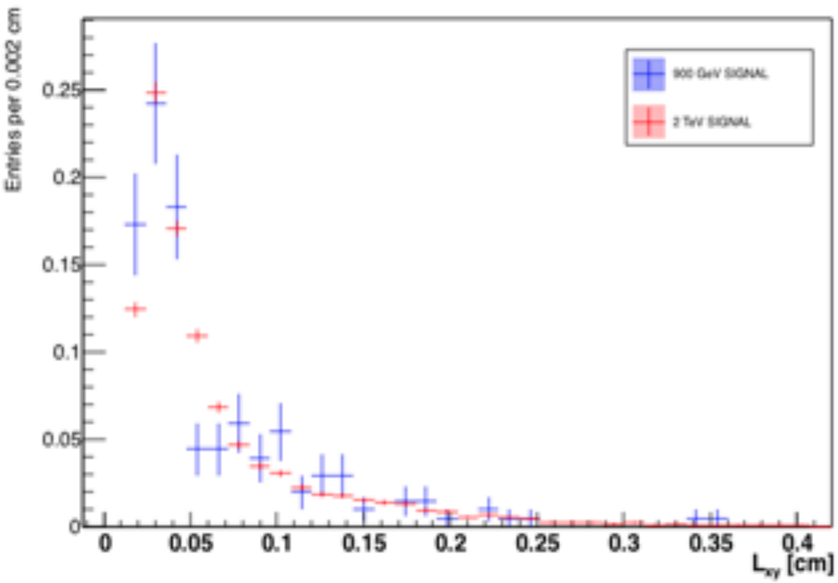


Candidate raw mass distribution

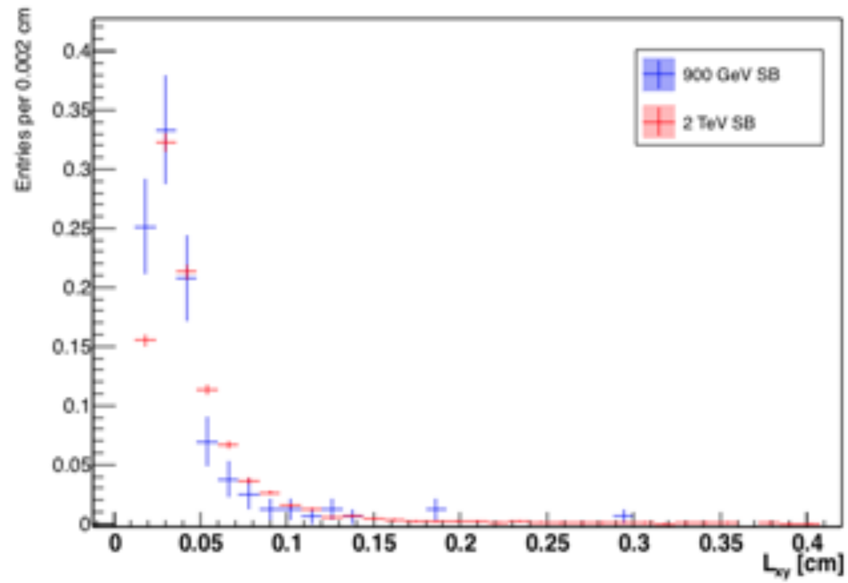
900 GeV vs. 2 TeV comparisons

L_{xy}

Signal [-2σ,+2σ]



Sideband [-7σ,-5σ] [+5σ,+7σ]



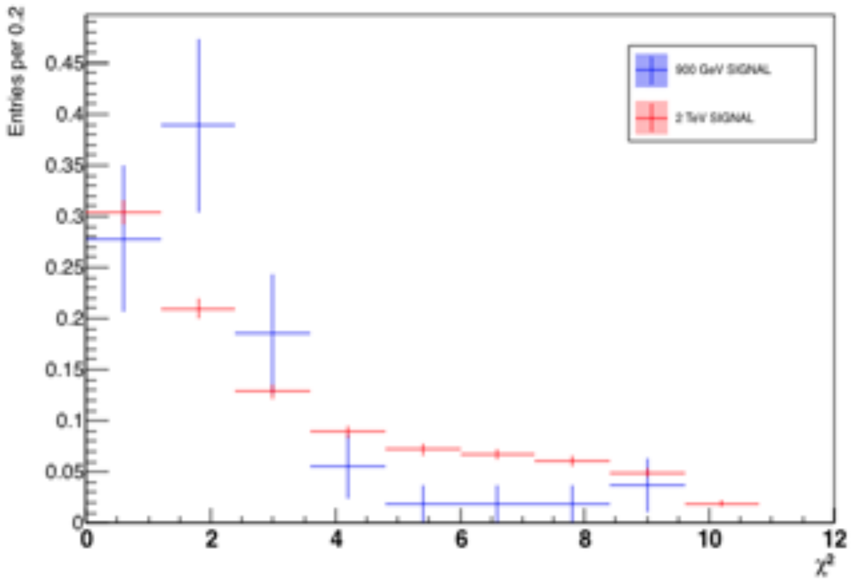
KS pValue: 0.21

KS pValue: 0.019

900 GeV vs. 2 TeV comparisons

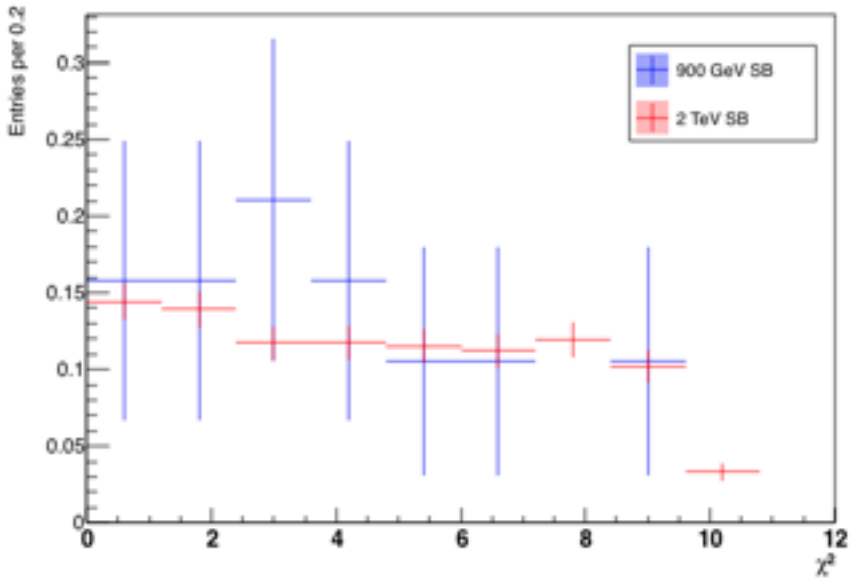
χ^2

Signal [-2σ,+2σ]



KS pValue: 0.013**

Sideband [-7σ,-5σ] [+5σ,+7σ]

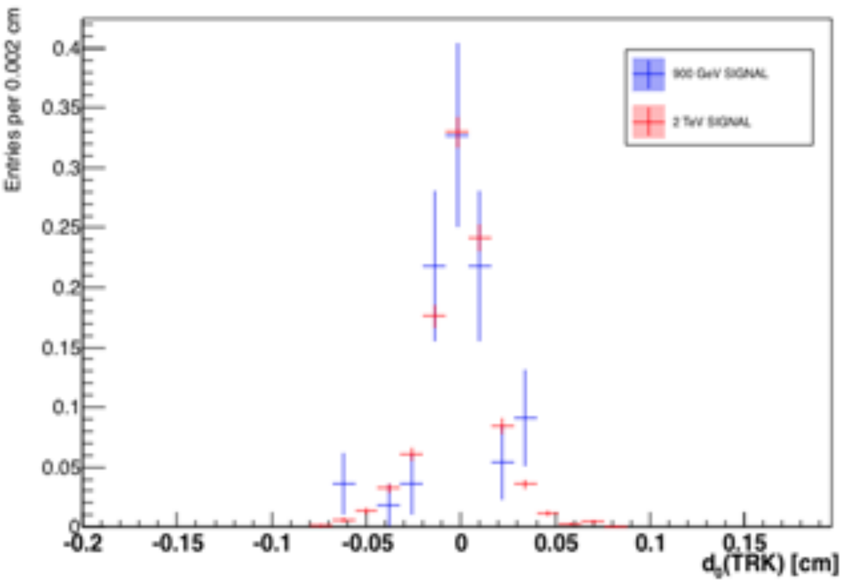


KS pValue: 0.28

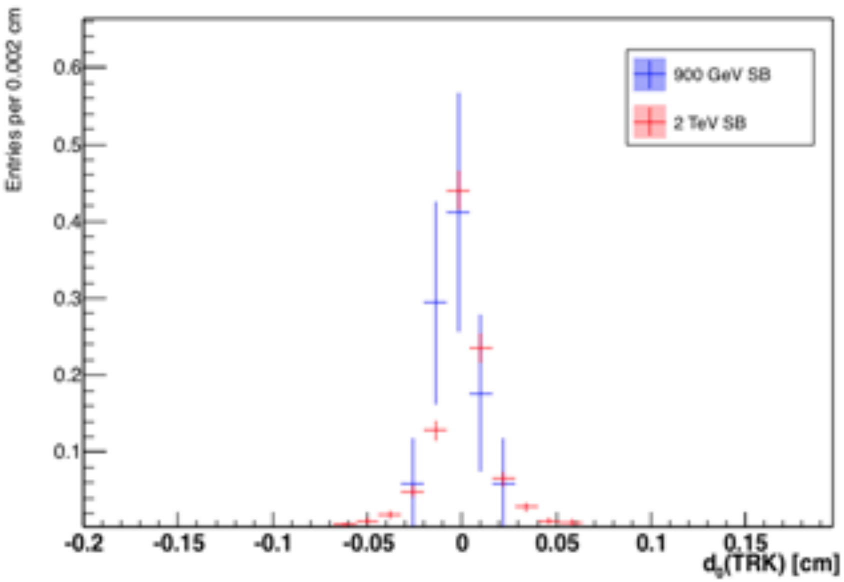
900 GeV vs. 2 TeV comparisons

d_0

Signal [-2σ,+2σ]



Sideband [-7σ,-5σ] [+5σ,+7σ]



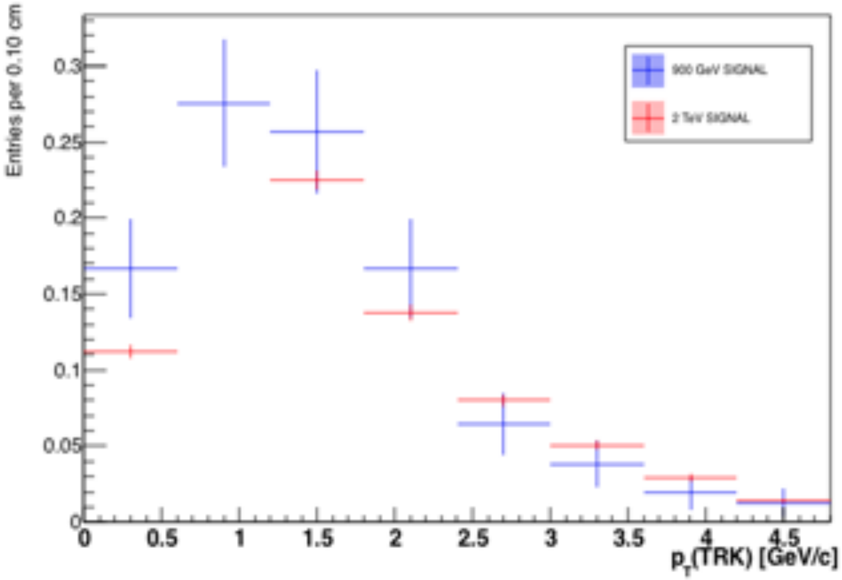
KS pValue: 0.98

KS pValue: 0.70

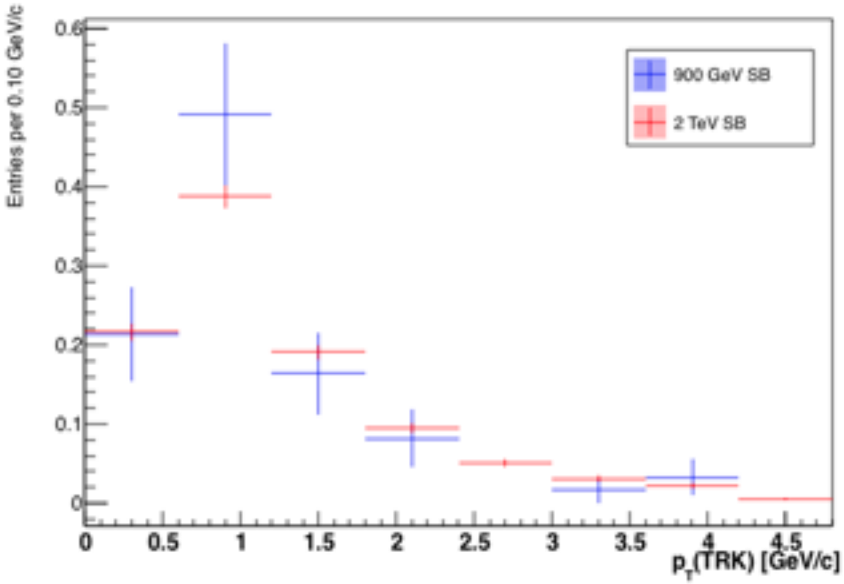
900 GeV vs. 2 TeV comparisons

Track p_T

Signal [-2σ,+2σ]



Sideband [-7σ,-5σ] [+5σ,+7σ]



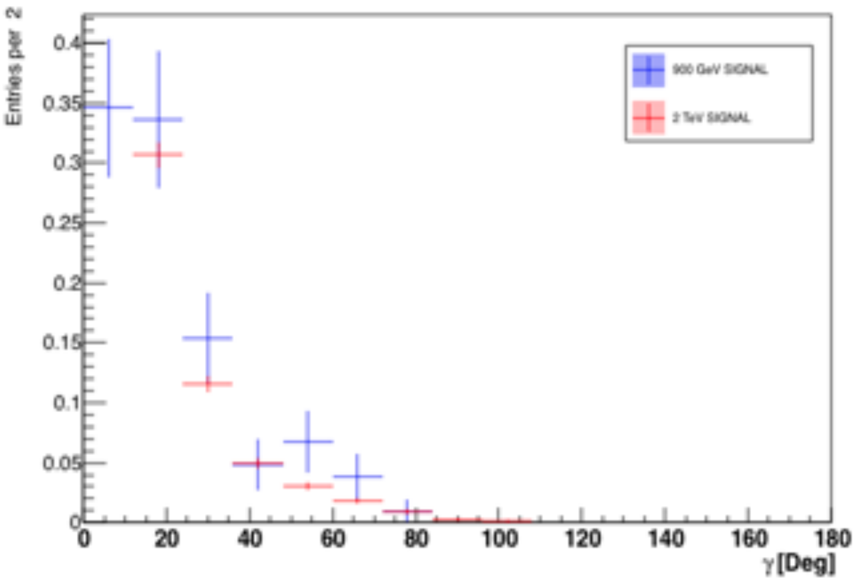
KS pValue: 0.59

KS pValue: 0.12

900 GeV vs. 2 TeV comparisons

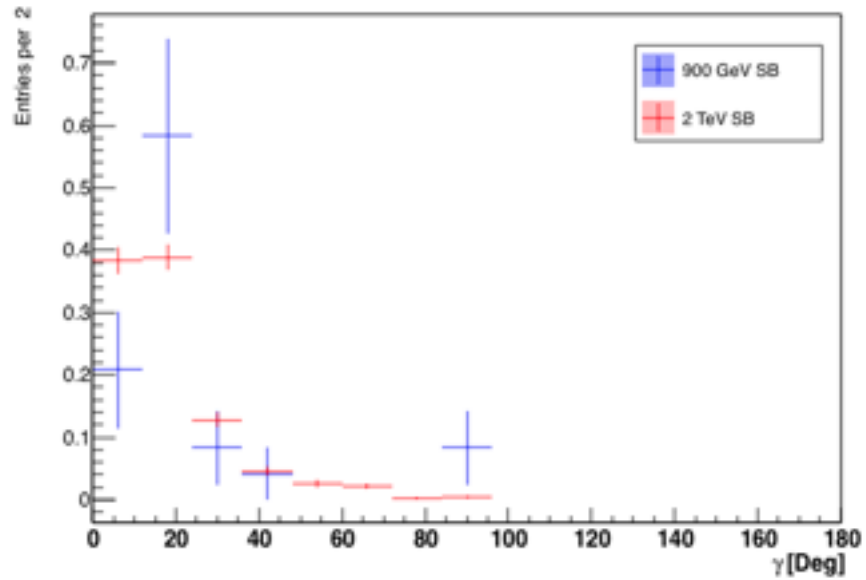
Pointing Angle

Signal [-2σ,+2σ]



KS pValue: 0.019

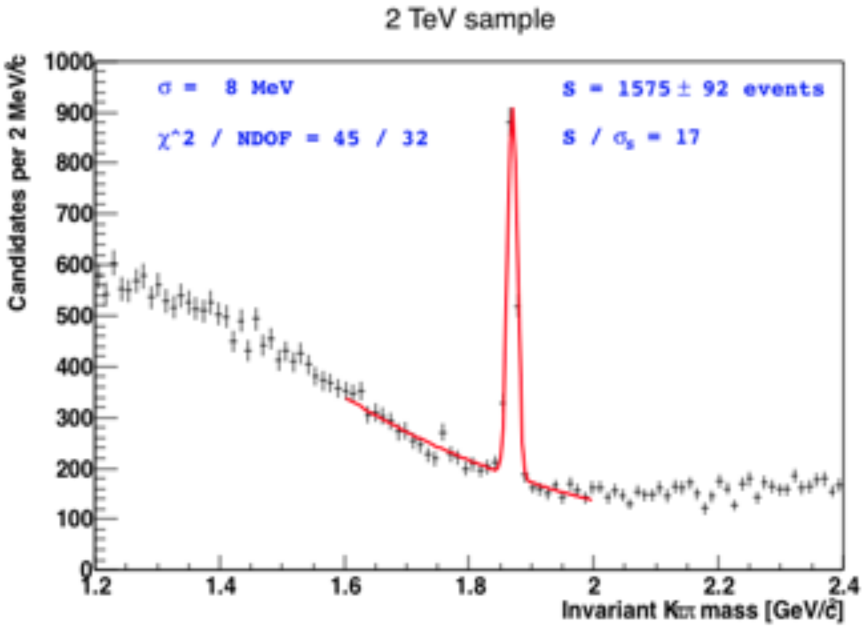
Sideband [-7σ,-5σ] [+5σ,+7σ]

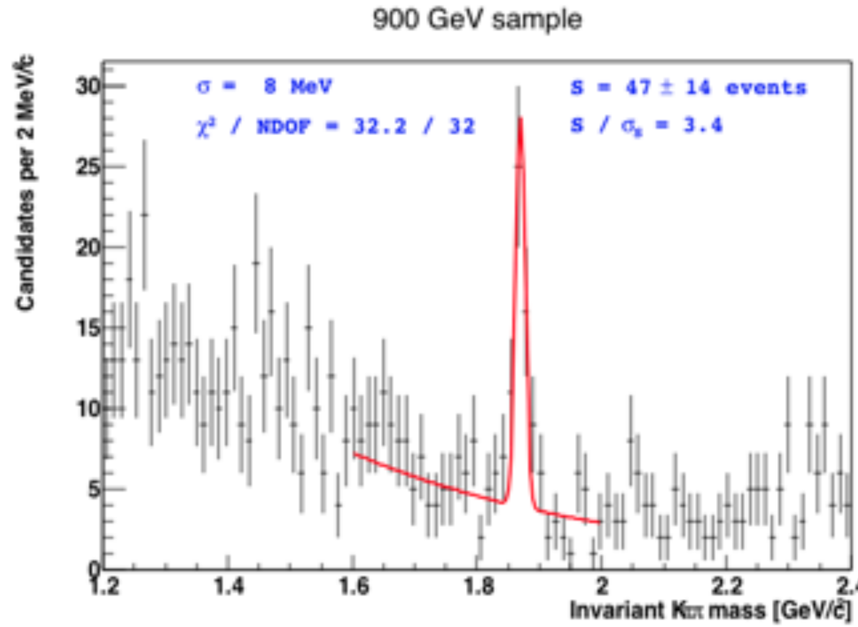


KS pValue: 0.43

Results

Since all distributions appear to be reasonably similar, we apply the same cuts as optimized for the 2 TeV data



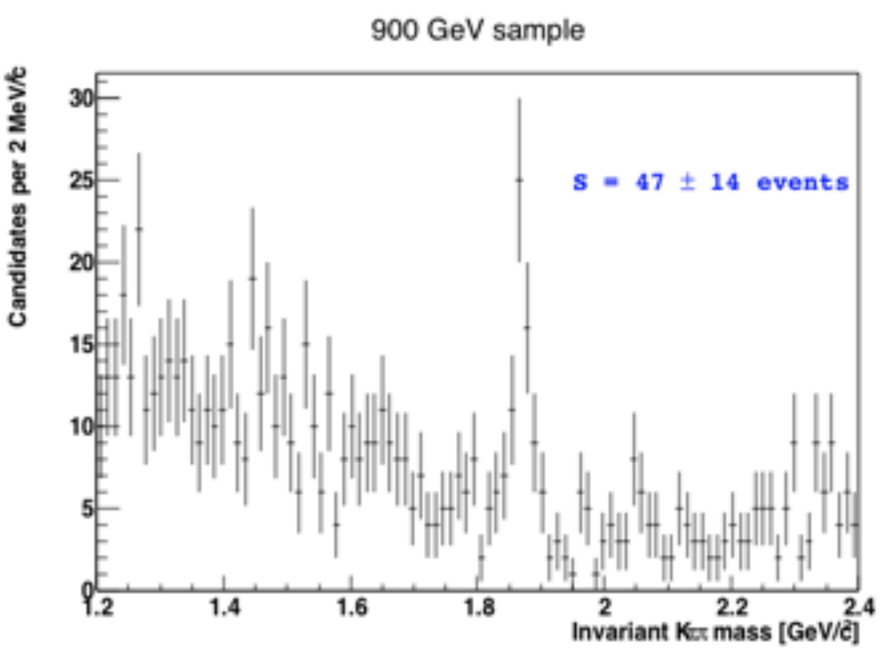


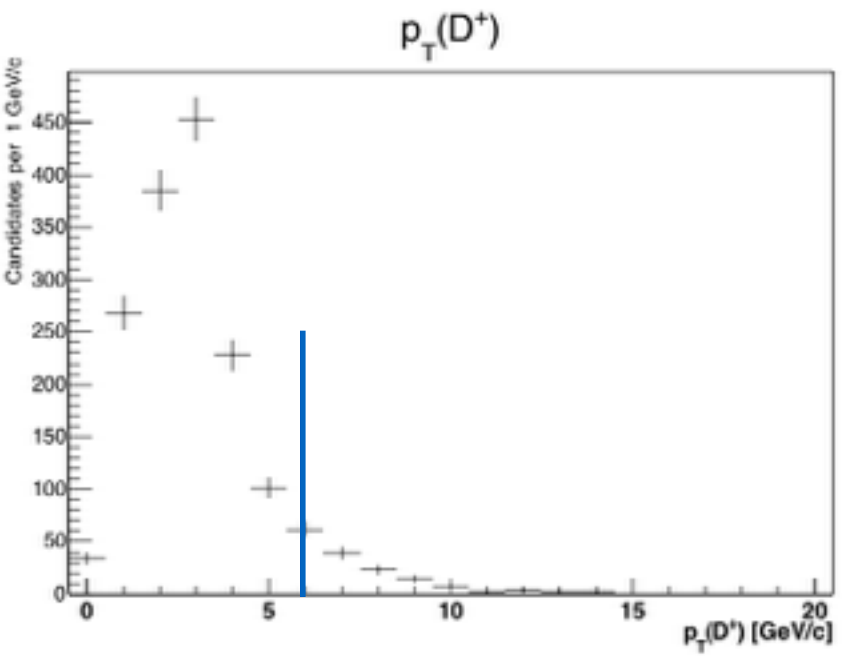
Number of D^+ = 47 ± 14

Conclusions

- Despite the low statistics the invariant mass spectrum shows a > 3 (sigma) excess at the D^+ mass

- A measurement of the production cross section might be possible at the (circa) 30% percent level although subtraction of secondaries might be problematic



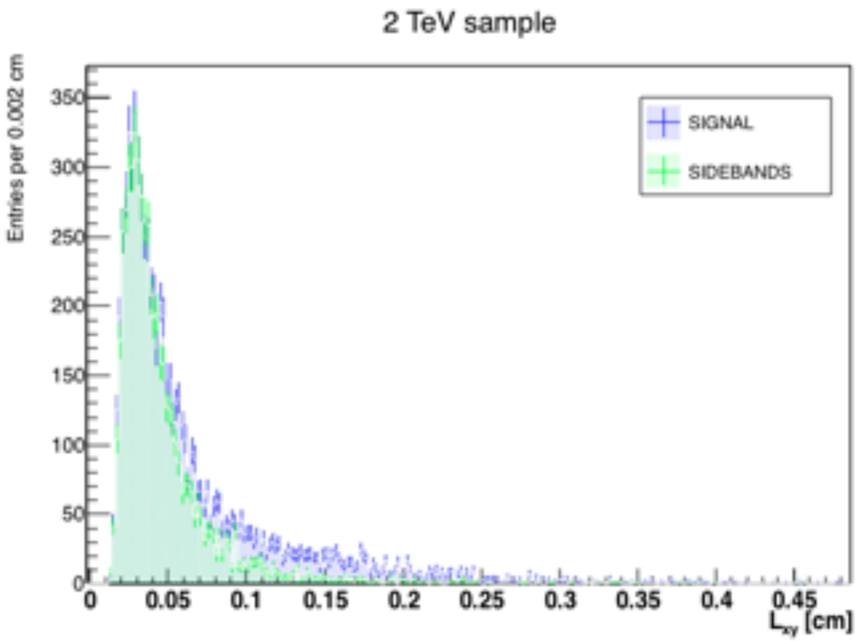


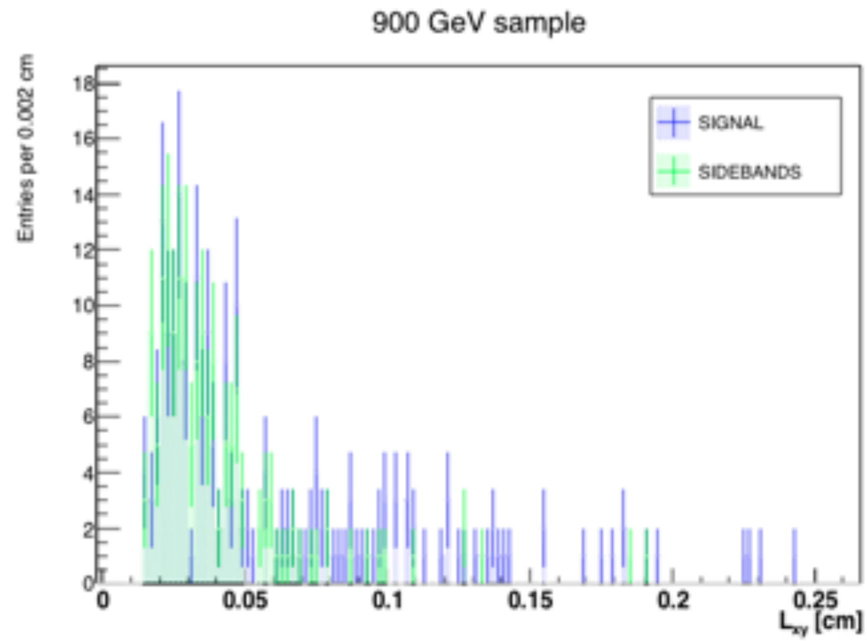
Backup

Cuts

- $L_{xy} > 900\ \mu m$
- $\chi^2/NDF < 4$
- $D_0 < 110\ \mu m$
- At least two Track $p_T > 0.8$ GeV/c
- $\gamma < 15$ deg

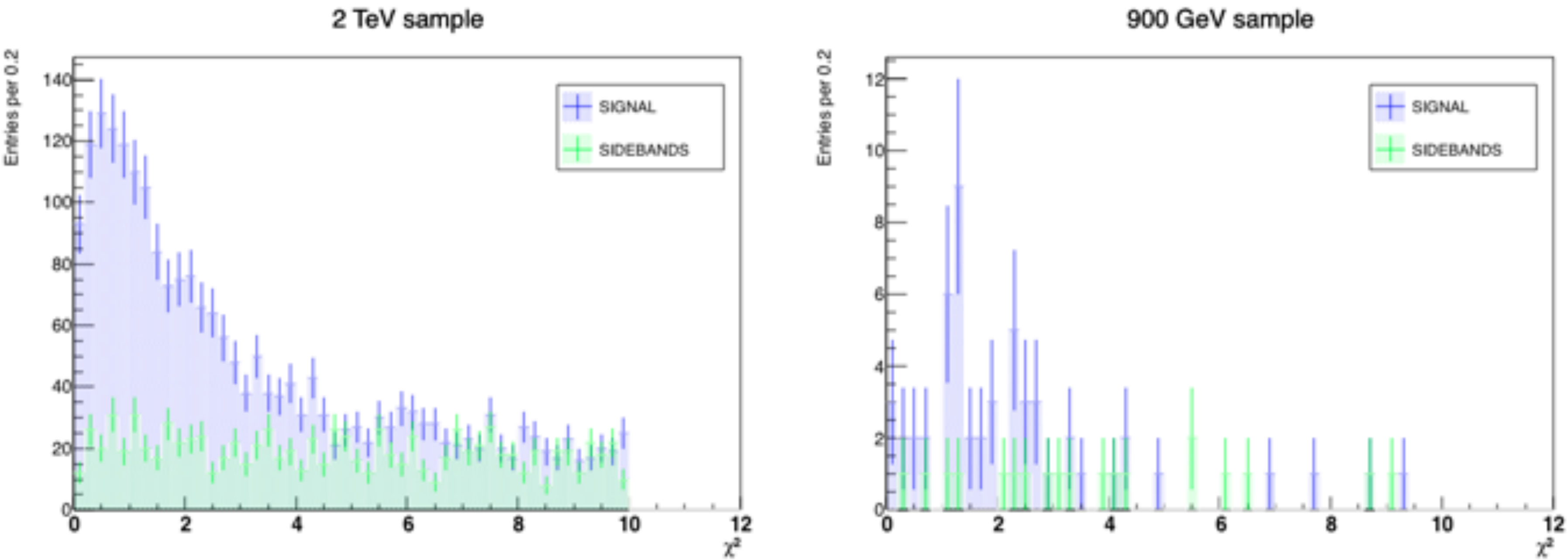
L_{xy}





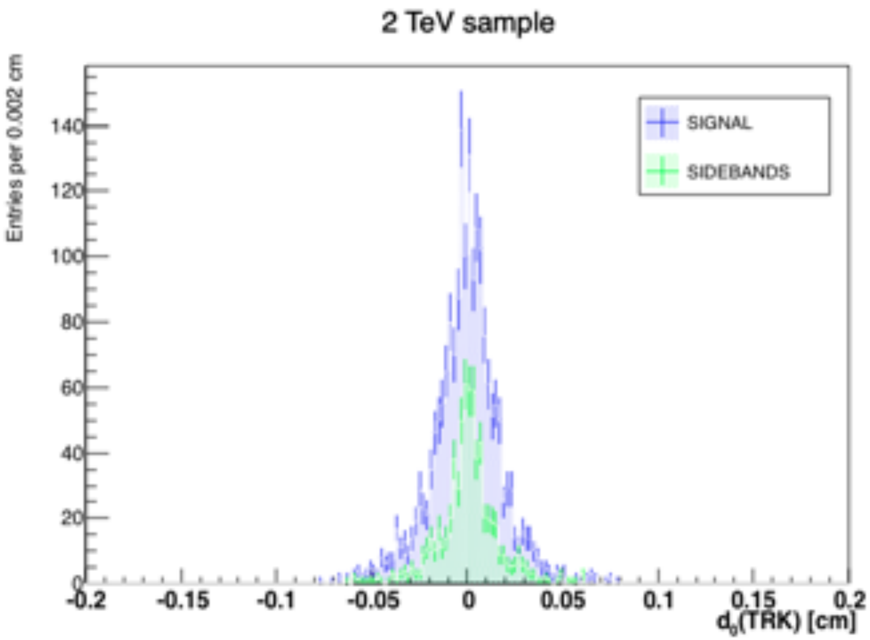
Fermilab

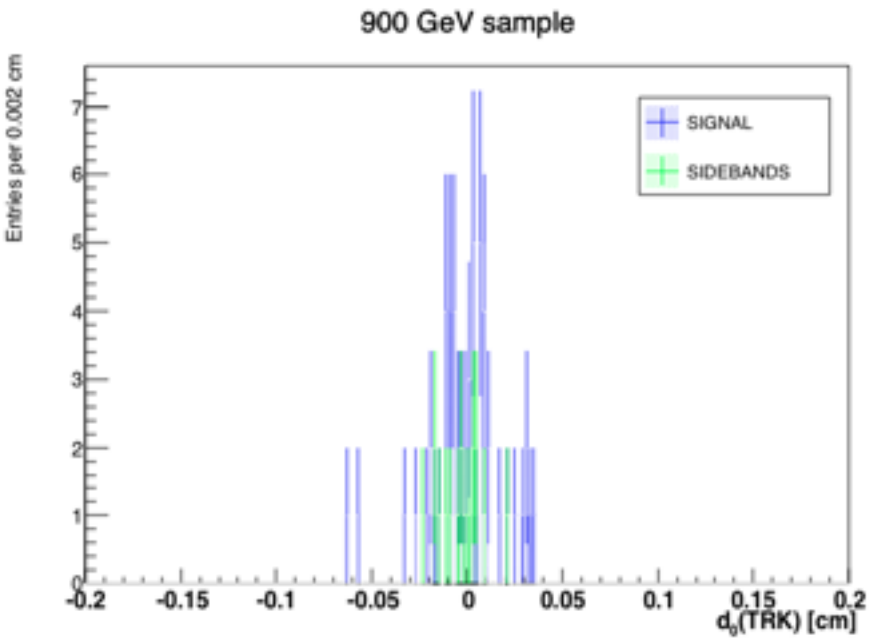
χ^2



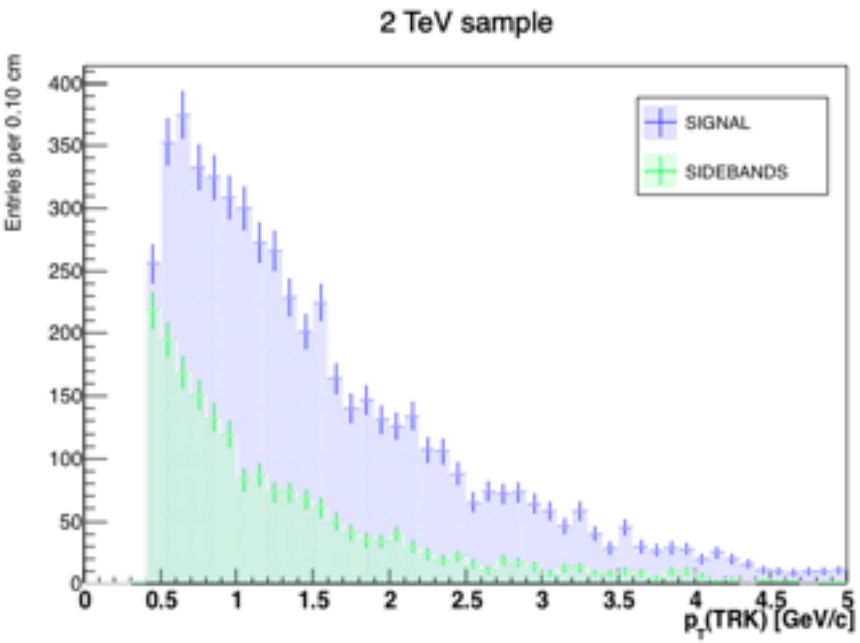
Fermilab

d_0

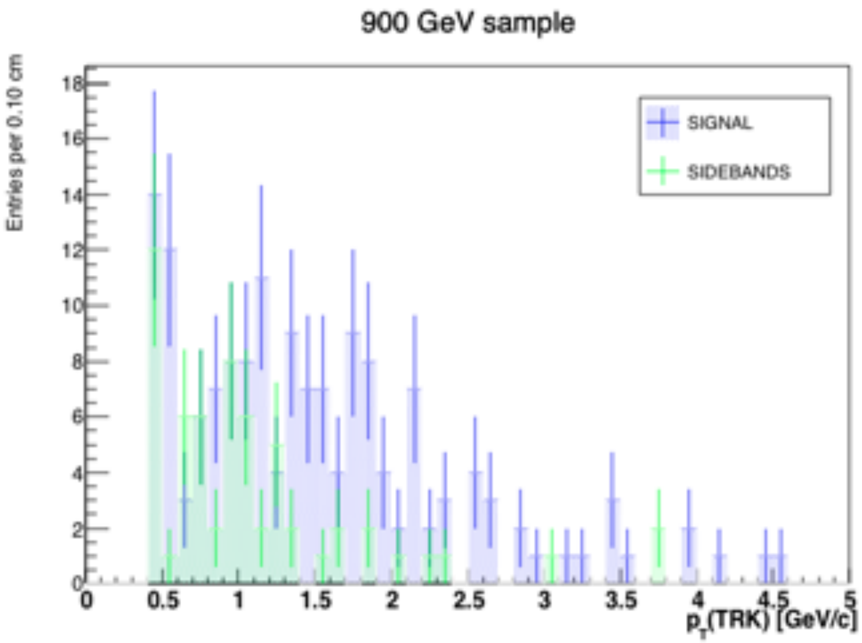

2 TeV sample
Entries per 0.002 cm
SIGNAL
SIDEBANDS
0
20
40
60
80
100
120
140
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
d0(TRK) [cm]


900 GeV sample
Entries per 0.002 cm
SIGNAL
SIDEBANDS
0
1
2
3
4
5
6
7
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
d0(TRK) [cm]

Tracks p_T

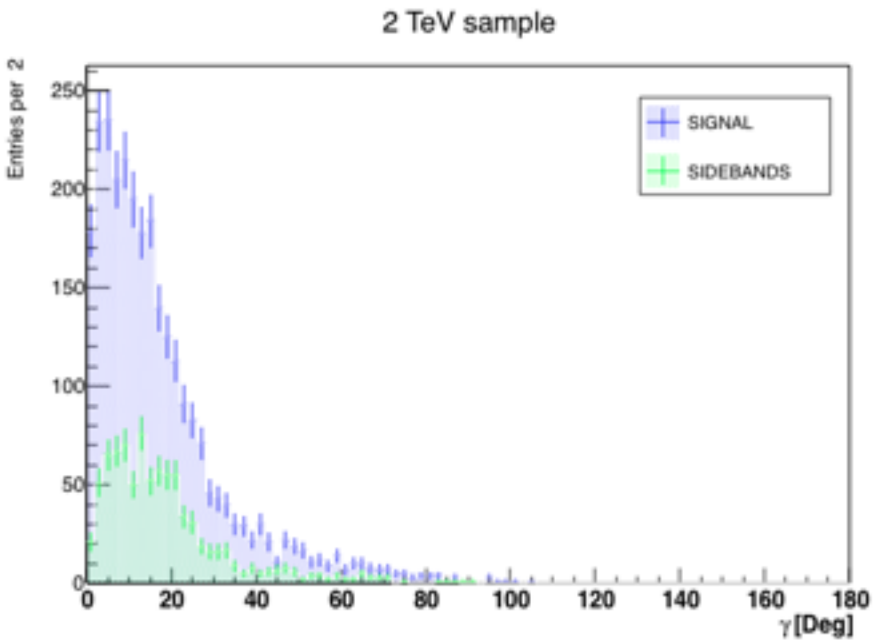


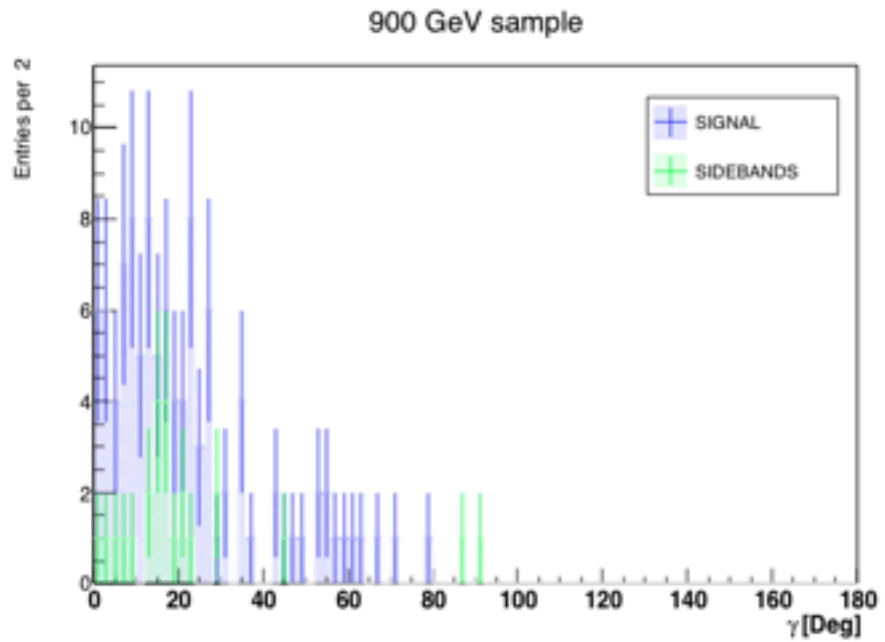
2 TeV sample
Entries per 0.10 cm
SIGNAL
SIDEBANDS
p_T(TRK) [GeV/c]



900 GeV sample
Entries per 0.10 cm
SIGNAL
SIDEBANDS
p_T(TRK) [GeV/c]

γ


2 TeV sample
Entries per 2
SIGNAL
SIDEBANDS
γ [Deg]


900 GeV sample
Entries per 2
SIGNAL
SIDEBANDS
γ [Deg]