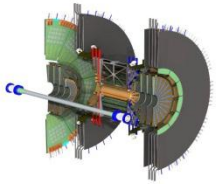

Reduction of background in observation of *W* – decay using FVTX tracker

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New Mexico State University

DNP2012 – Newport Beach, CA.
Oct 25, 2012

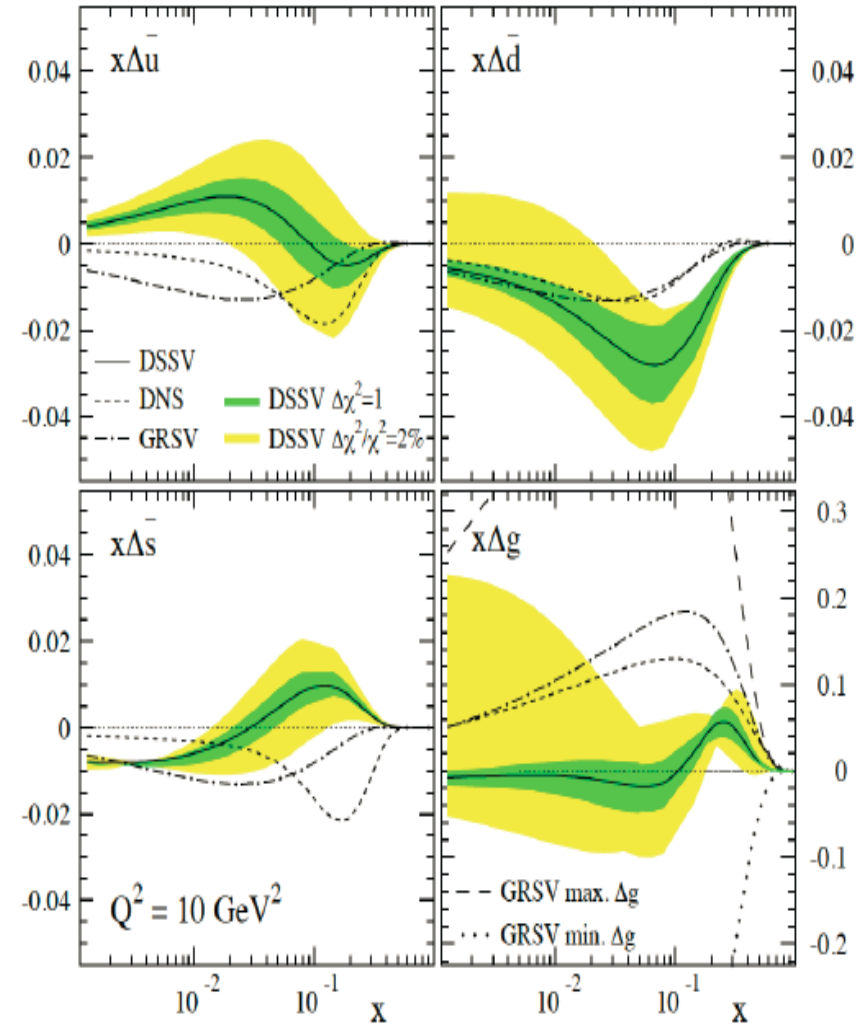
Outline

- Motivation
- Single Spin Asymmetry in *W* production.
- *W*-analysis at PHENIX .
- Forward Vertex Detector (FVTX)
- Backgrounds in *W* Production .
- Reducing backgrounds using FVTX.

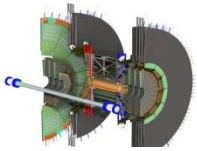
Motivation

DSSV Global Fit -- arXiv:1112.0904v1 [hep-ph] 5 Dec 2011

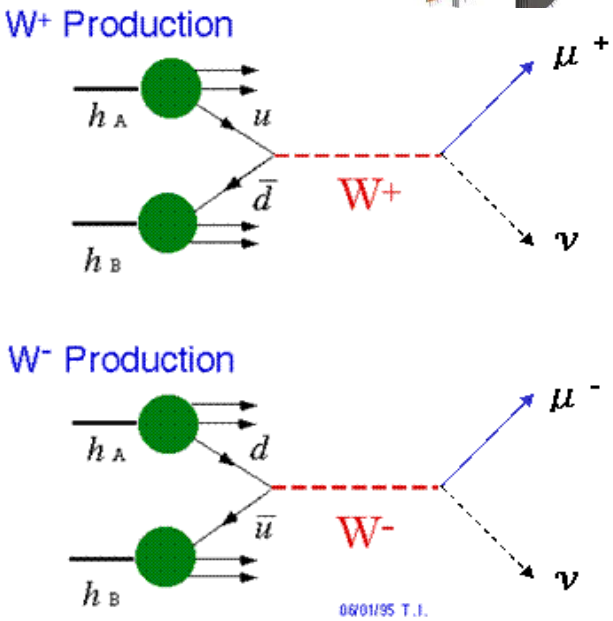
- The recent global fit by de Florian, Sassot, Stratmann and Vogelsang (experimental references therein) shows a clear determination of the polarized parton distribution function of $\Delta u(\mathrm{x})$ and $\Delta d(\mathrm{x})$.
- However, PDF for sea quarks ($\Delta\bar{u}, \Delta\bar{d}, \Delta s$ and $\Delta\bar{s}$) and gluons $\Delta\mathrm{g}$ have larger uncertainty.
- The Weak Interaction can be used to probe sea quark distribution.



W Single Spin Asymmetry



- **We can measure Parity-violating longitudinal single spin asymmetries (A_L) in $W \rightarrow \mu$ production during *pp* collisions.**
- **A_L's are sensitive to the polarized sea quark distribution of the proton spin**



$$A_L^{l^+} = \frac{\Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 - \Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}{\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 + u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}$$

$$A_L^{l^-} = \frac{\Delta\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 - \Delta d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}{\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 + d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}$$

where Θ is the lepton decay angle in the partonic center-of-mass system,

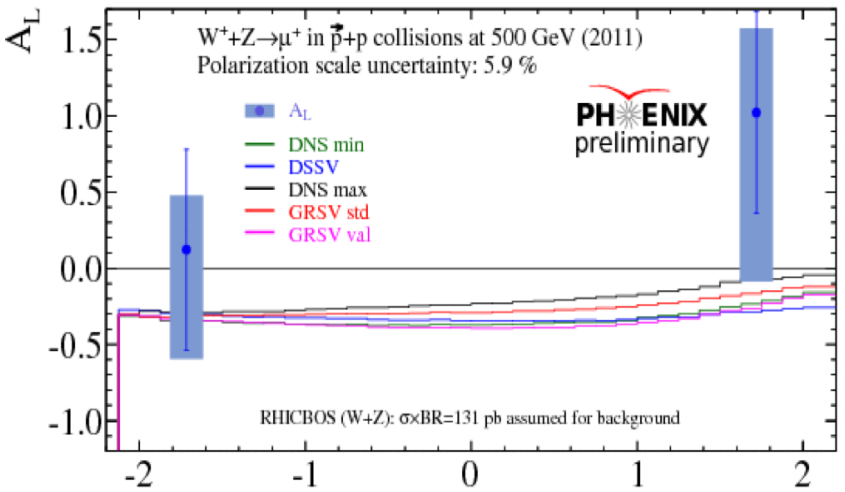
	Forward rapidity limit	Backward rapidity limit
W^+	$A_L^{\mu+} \approx \frac{\Delta\bar{d}}{\bar{d}}$	$A_L^{\mu+} \approx \frac{\Delta u}{u}$
W^-	$A_L^{\mu-} \approx \frac{\Delta d}{d}$	$A_L^{\mu-} \approx \frac{\Delta\bar{u}}{\bar{u}}$

W-analysis at PHENIX

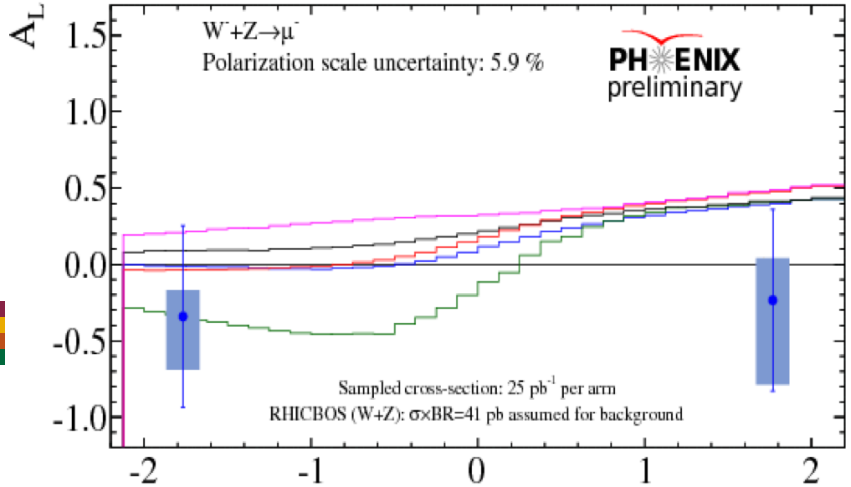
- During 2009 run, non-zero parity violating asymmetries were observed at the *central arms* (mid rapidity) from $W \rightarrow e$ decay at 500 GeV polarized *pp* collisions. PRL 106, 062001 (2011).

2011, L = 25.5pb^{-1}, P =50%

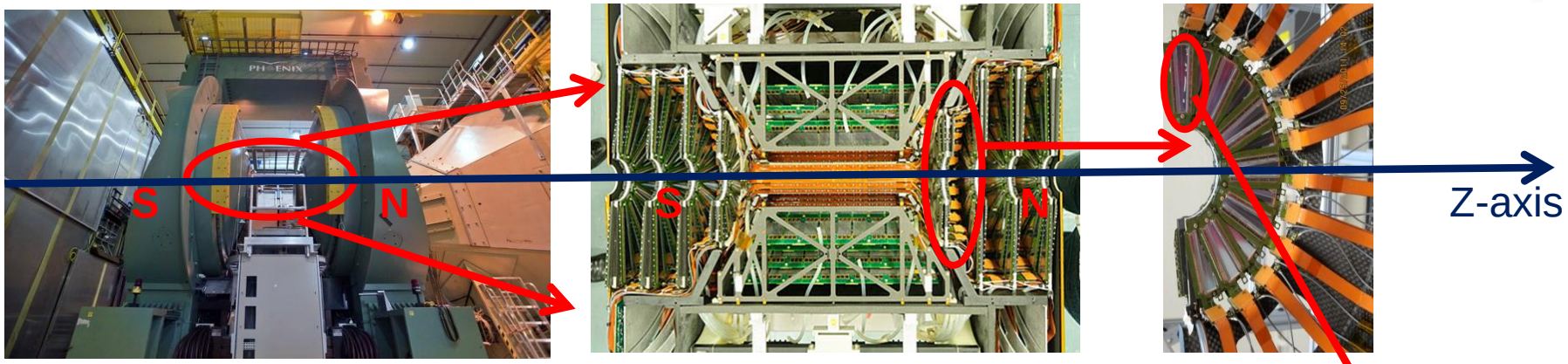
- 2011run, *forward arms* of PHENIX observed μ from *W* decay at 500 Gev polarized pp collision. (RPC's upgrade, MuTrigger Upgrade and fast read-out electronics added).



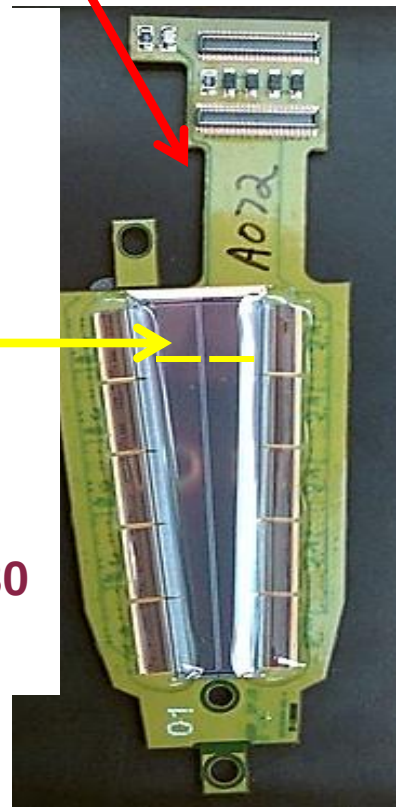
- However, still more luminosity and background reduction is required to improve the significance of the result.
- **Forward Vertex Detector (FVTX) is installed in 2012. Expected to improve tracking for Muon-Arms.**



FVTX- General Info



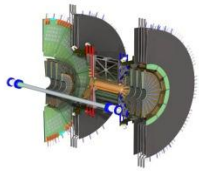
PHENIX F/VTX Half disc Wedge



- FVTX has N and S arms. Each arm contains 4 discs perpendicular to the beam axis. Each disc contains 48-"wedges" made of Silicon mini-strips.

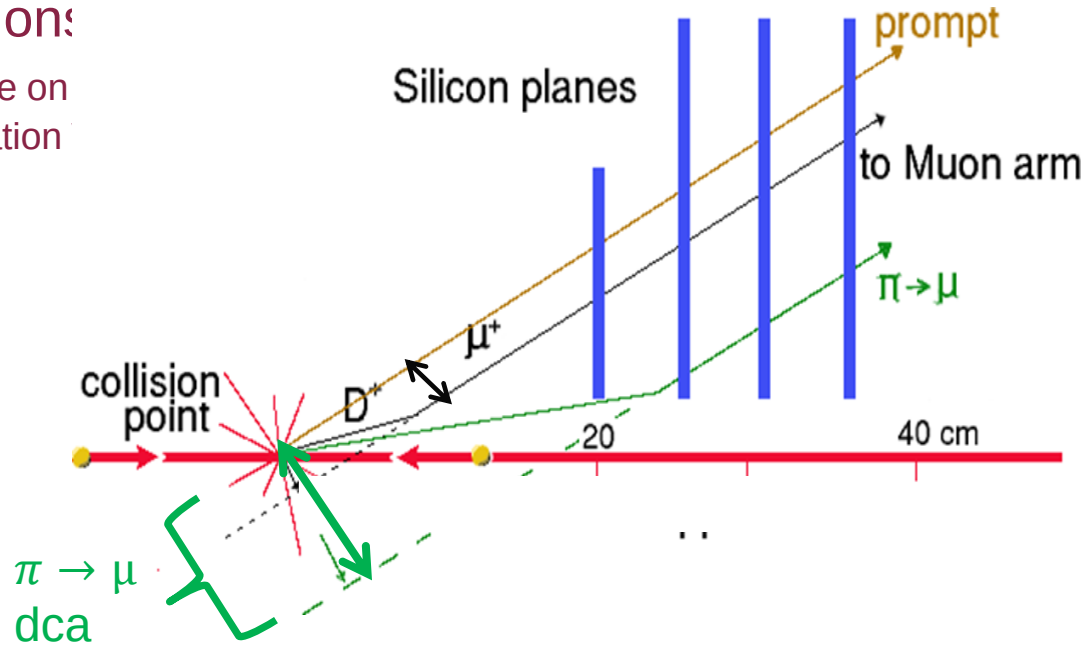
- 1.1 Million strips (each 75 μm radial, 3.75 in φ).
- FVTX covers $1.2 < |\eta| < 2.4$, 2π in φ
- Fully operational in 2012 (*p-p, Cu-Au*)
- During 510 GeV *p-p*, FVTX recorded integrated luminosity of 30 $(pb)^{-1}$ for $z < |30|$ cm vertex.

How Does FVTX Help?



- Different distributions of Distance of Closest Approach (dca) for Muons from *D,B,K, π* and prompt. (More on Jeongsu Bok' s Talk, Sat – PC Instrumentation

- ***dca_r* = impact parameter in the r direction *(Better measurement in radial)***

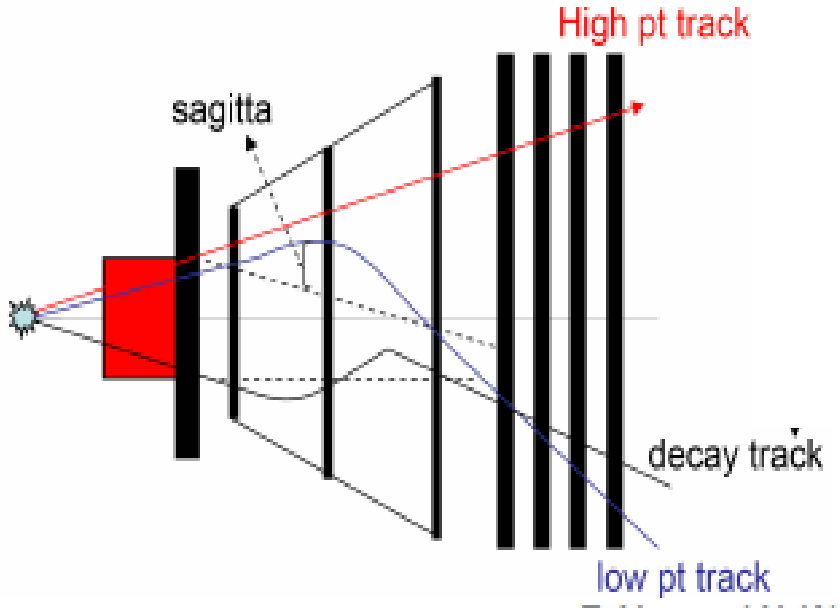


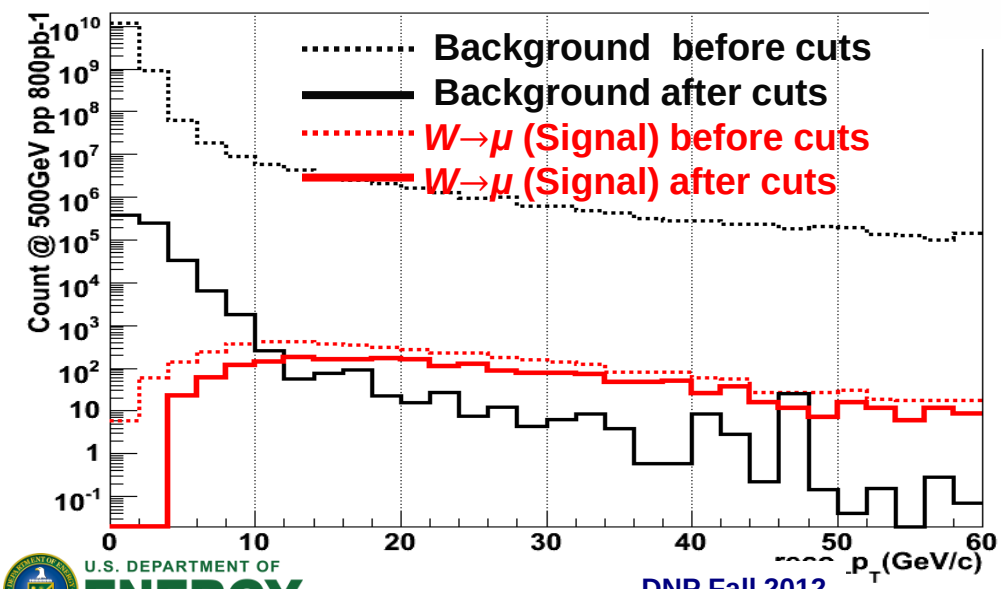
FVTX Provides;

- **Better dca measurement,**
- **Combined FVTX+MuTr track fit (chi2) helps reject decay-in flight hadrons,(next slide)**
- **isolation cut helps reduce hadronic background.**

Dominant background: from low p_T hadrons

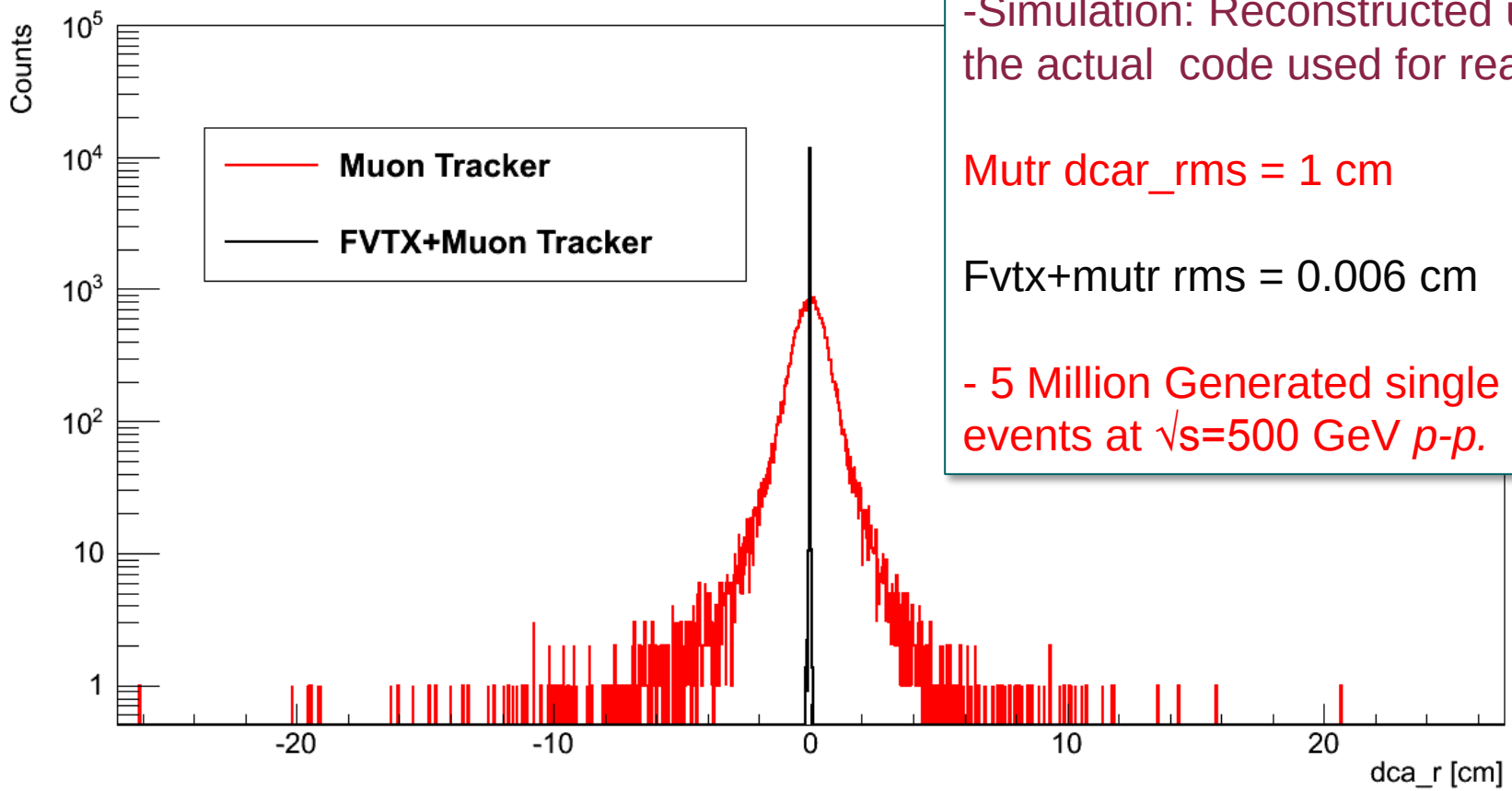
Muons from hadrons decays in Mutr could be (mis)reconstructed to higher momentum, because of their kink trajectory accidentally matching to straight hit points in the MuTr. (fake high p_T muons).





The background in *W* production is dominated by the misreconstructed low p_T light hadrons (pion and kaon)

Improved *W* signal *dca_r (FVTX+Mutr)*



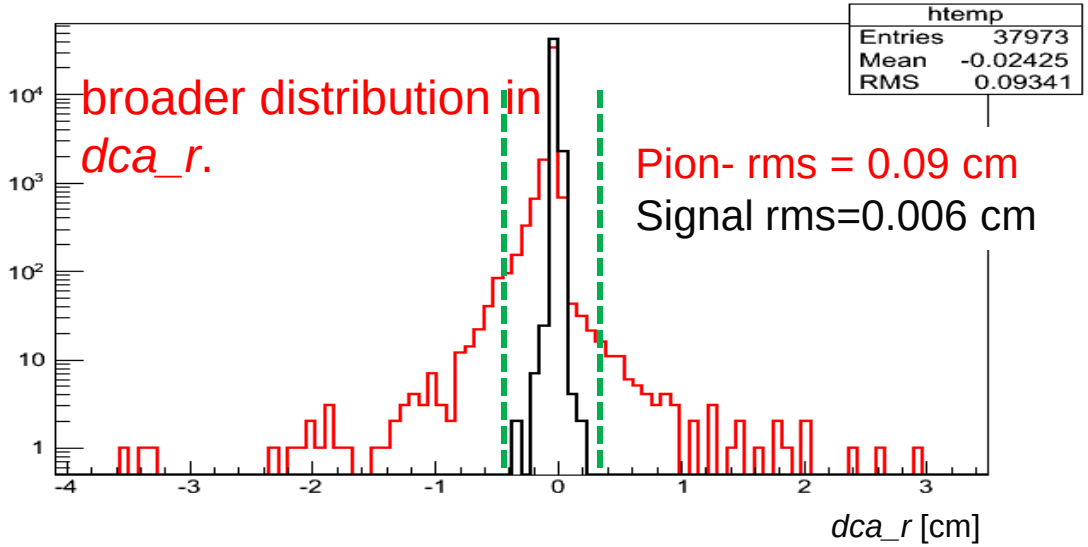
-Simulation: Reconstructed using the actual code used for real data.

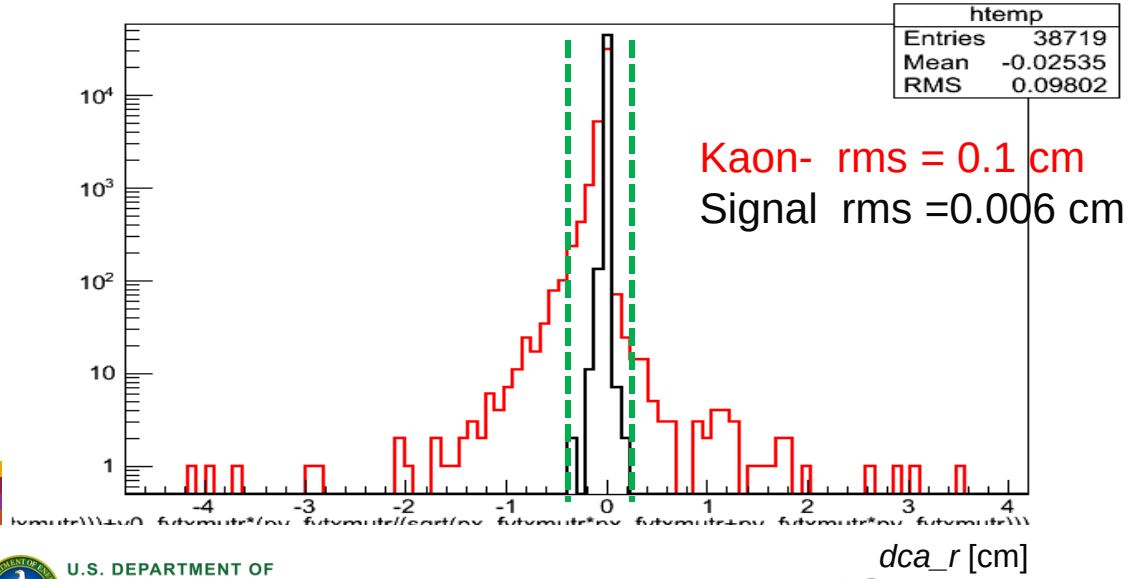
Mutr dcar_rms = 1 cm

Fvtx+mutr rms = 0.006 cm

- 5 Million Generated single muon events at √s=500 GeV *p-p.*

Comparing dca_r of Hadron and *W* Signals





Method

- **By applying cuts on the upper limit of |*dca_r*|, we can reject some hadrons while preserving *W* signals.**
- **Rejection with dca_r is just ONE of the cuts that are planned to be applied (chi2, isolation cut …).**

In progress;

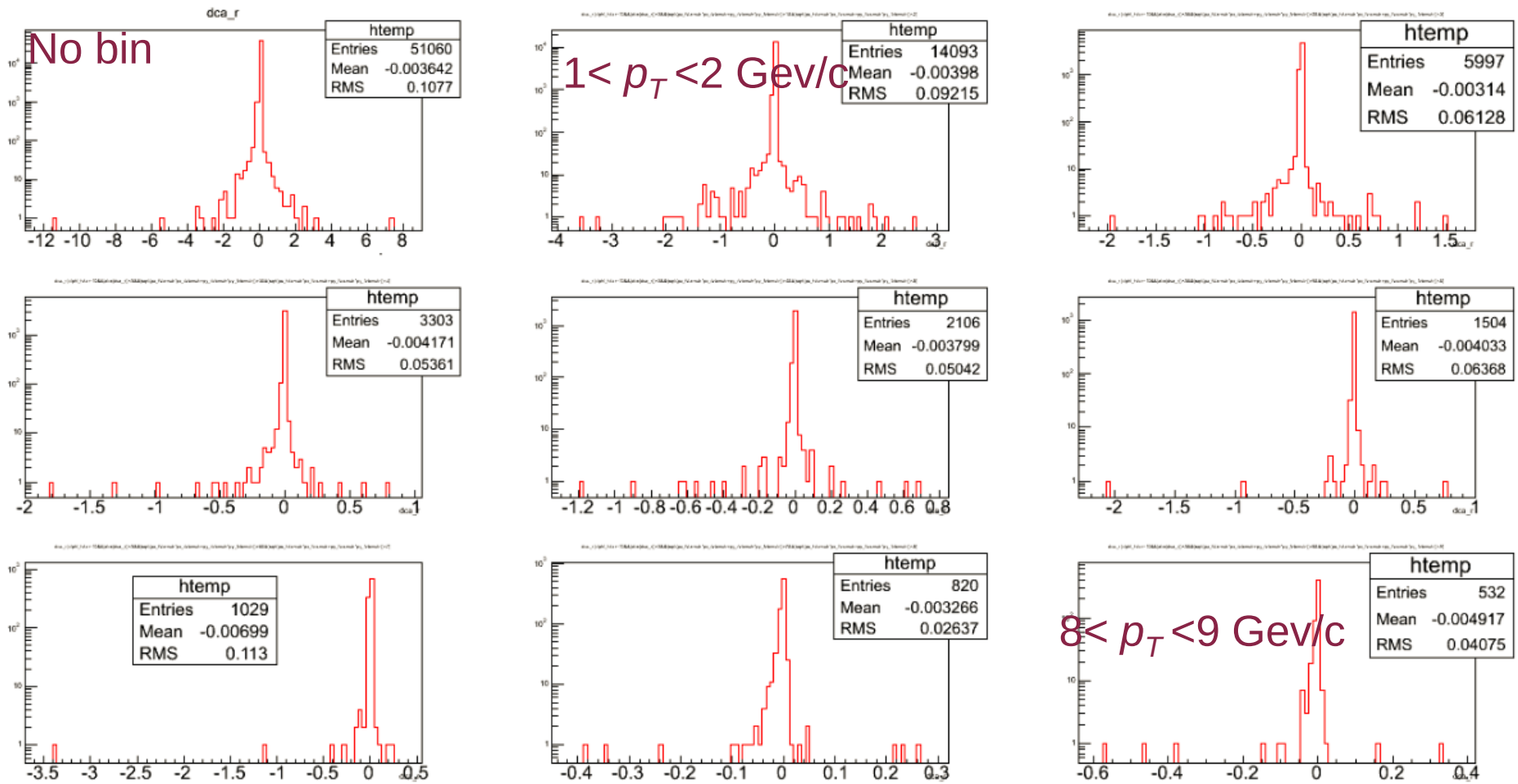
- ***The plot shows contribution from all pions/kaons.***
- ***Need to identify those hadrons with low p_T and misreconstructed as high p_T.***

Summary

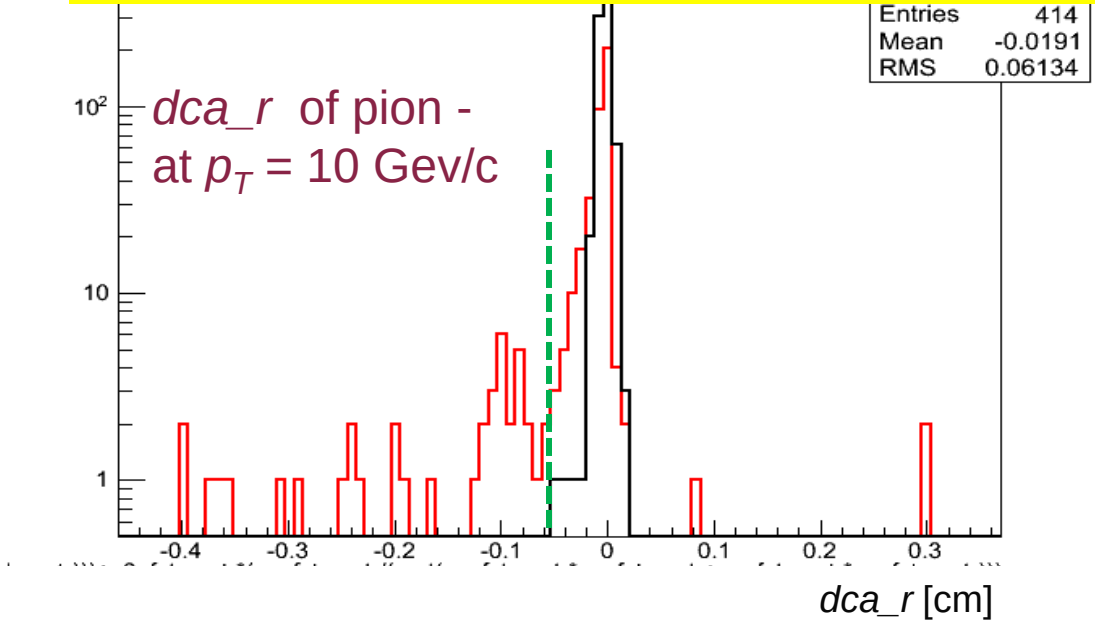
- Sea-quark polarized distribution can be studied using *W* Production Asymmetry.
- 2012 – FVTX collected its first commissioning and physics data - analysis in progress.
- FVTX upgrade will add more tracking information reduce backgrounds while having high efficiency on the signals.
- Run 2013 is expected to bring us enough data to finalize our W measurements

Backup

dca_r at different p_T bins

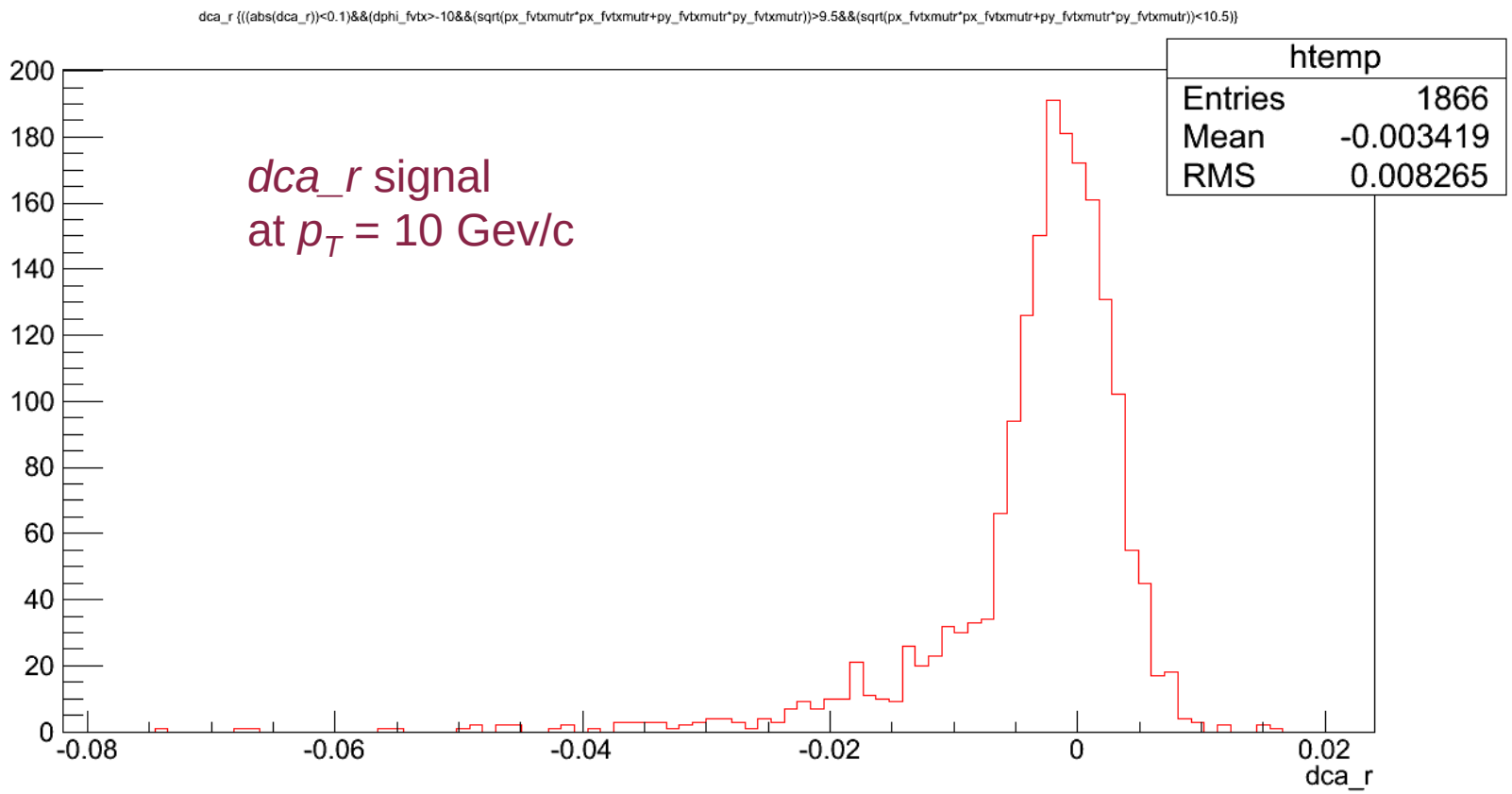


Tight *dca_r* cuts

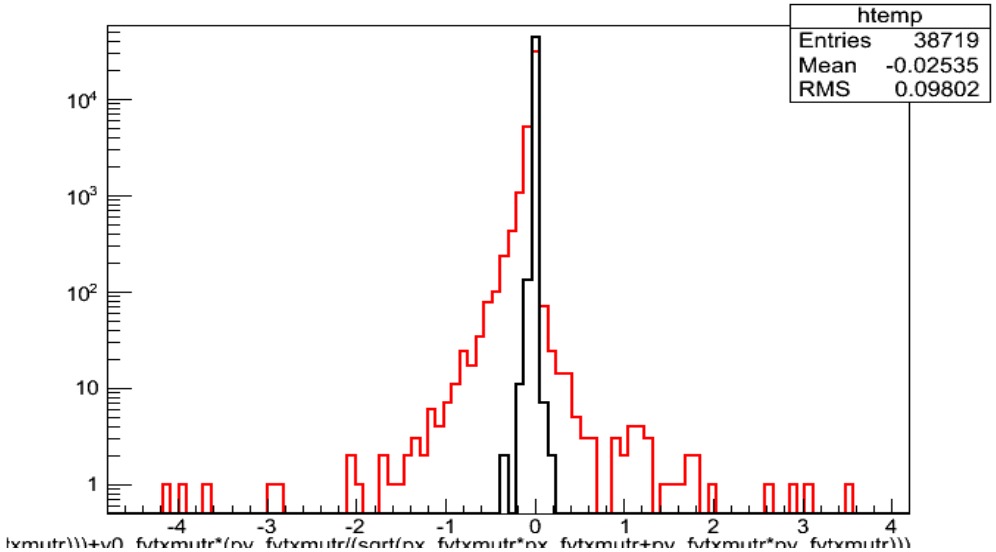


	Signal	Background rejected
Cut at 0.06 cm	100%	9.5%
Cut at 0.012	90%	27%

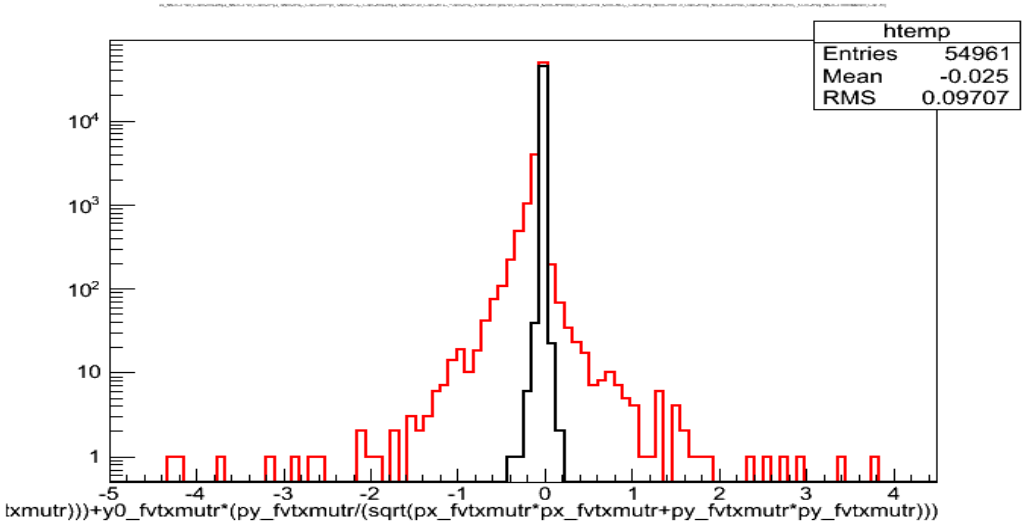
Backup


dca_r {((abs(dca_r))<0.1)&&(dphi_fvtx>-10&&(sqrt(px_fvtxmutr*px_fvtxmutr+py_fvtxmutr*py_fvtxmutr))>9.5&&(sqrt(px_fvtxmutr*px_fvtxmutr+py_fvtxmutr*py_fvtxmutr))<10.5)}
htemp
Entries 1866
Mean -0.003419
RMS 0.008265
dca_r signal
at p_T = 10 Gev/c
200
180
160
140
120
100
80
60
40
20
0
-0.08
-0.06
-0.04
-0.02
0
0.02
dca_r

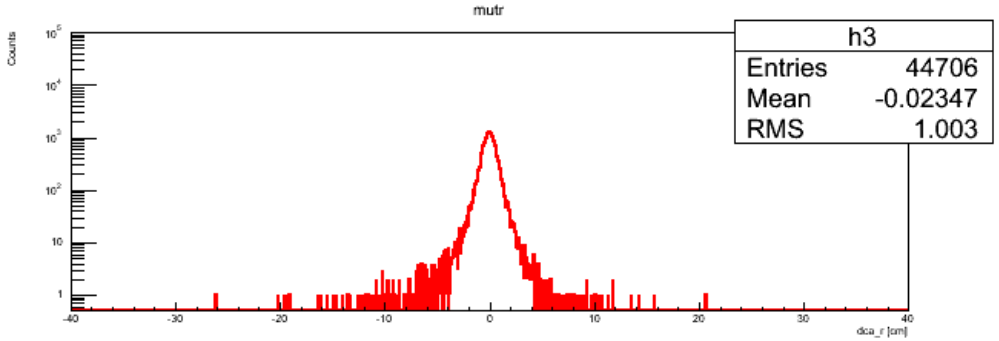
dca r of hadrons vs Signals

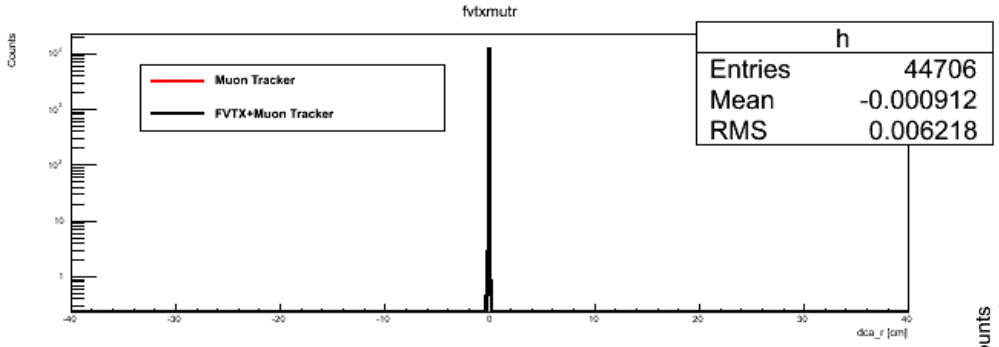


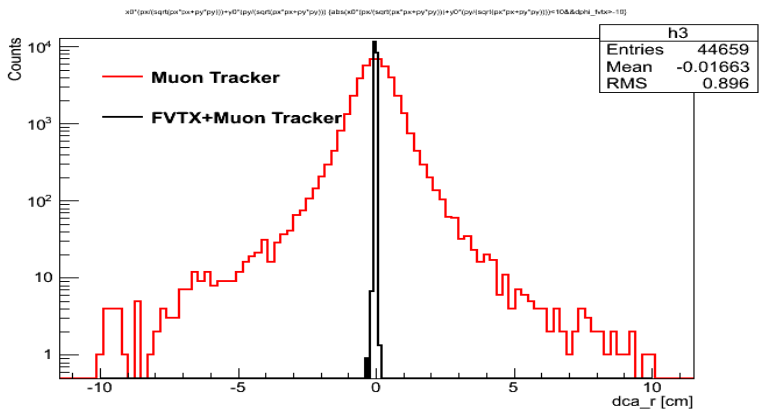
Pion+ rms=0.1 cm
Signal rms=0.006 cm

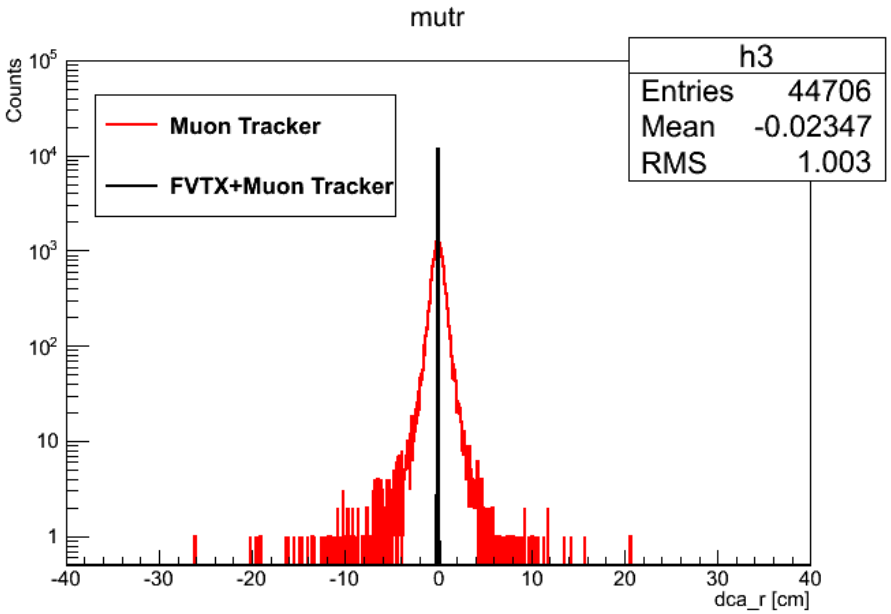


kaon+ rms 0.1 cm
Signal rms 0.006 cm


mutr
h3
Entries 44706
Mean -0.02347
RMS 1.003
Counts
dca_r [cm]


fvtxmutr
h
Entries 44706
Mean -0.000912
RMS 0.006218
Muon Tracker
FVTX+Muon Tracker
Counts
dca_r [cm]

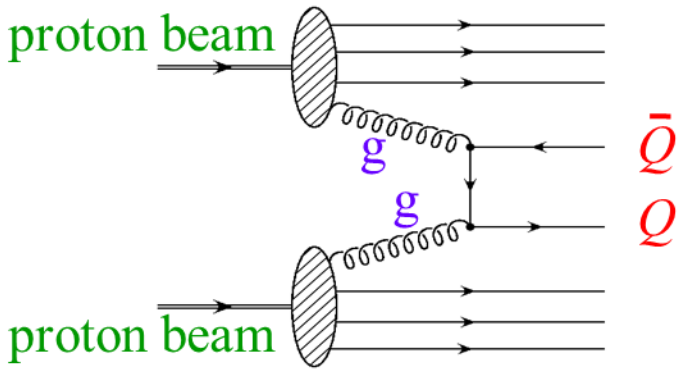

h3
Entries 44659
Mean -0.01663
RMS 0.896
Muon Tracker
FVTX+Muon Tracker
Counts
dca_r [cm]


mutr
h3
Entries 44706
Mean -0.02347
RMS 1.003
Muon Tracker
FVTX+Muon Tracker
Counts
dca_r [cm]

- W bosons only couple to the left-handed fermions and right-handed anti-fermions,

Observing Heavy Quarks Production.

The most common mechanism is "gluon-gluon fusion" -- a gluon from each proton contributes to an "open box" diagram involving a quark and an anti-quark.



Heavy quark pair ($Q = c$ or b)

Then, there are two possible general outcomes:

(1) The quark pair combines to form a single meson. "Closed heavy flavor"

E.g. $c + \bar{c} \rightarrow J/\psi \rightarrow \mu + \bar{\mu}$

This meson decay is electromagnetic and so is very fast. $\tau \approx 10^{-20}$ s $\quad c\tau \approx 10^{-10}$ cm

(2) The individual quarks fragment to form heavy mesons. "Open heavy flavor"

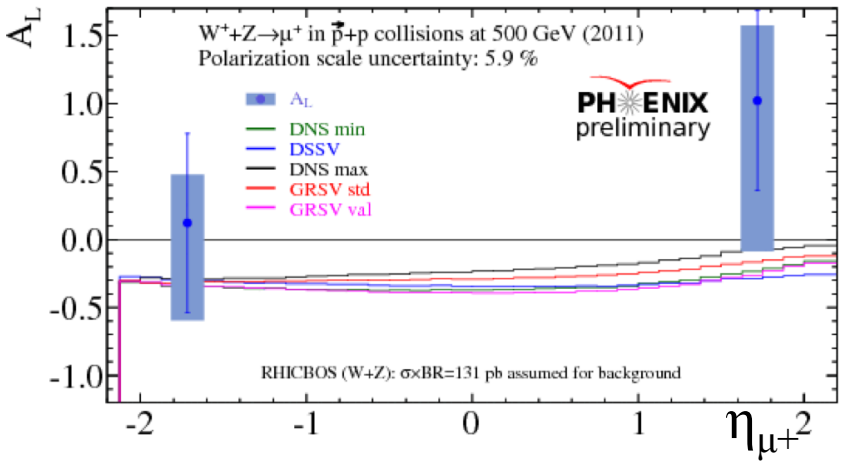
E.g. $c \rightarrow D \rightarrow \mu + X$

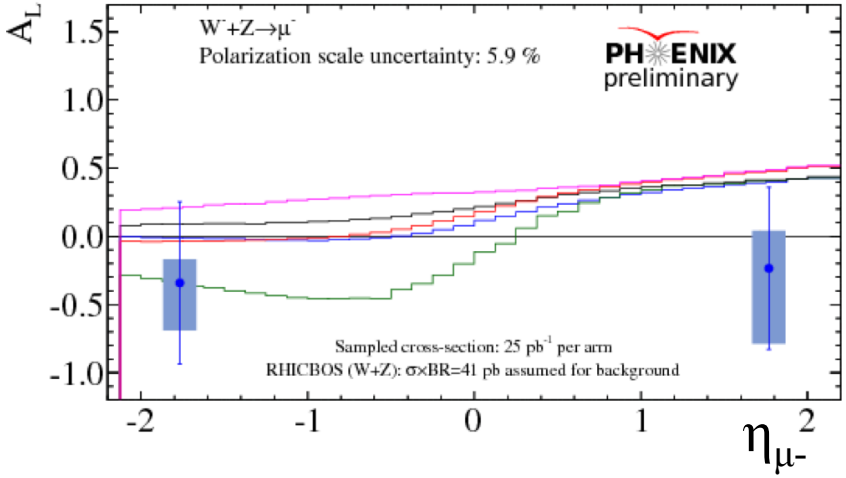
This is a weak meson decay and so is slow. $\tau \approx 10^{-12}$ s $\quad c\tau \approx 10^{-2}$ cm

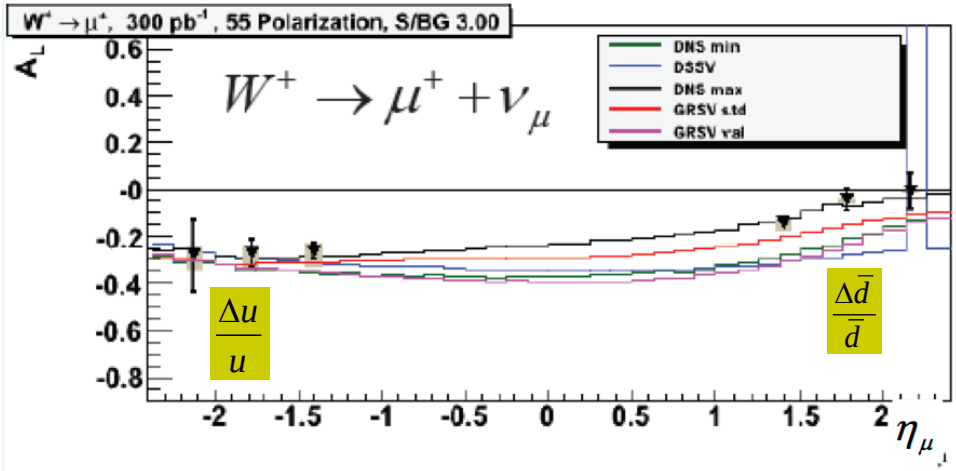
First $W^{\pm} \rightarrow \mu^{\pm}$ Single Spin Asymmetry at Forward Rapidity

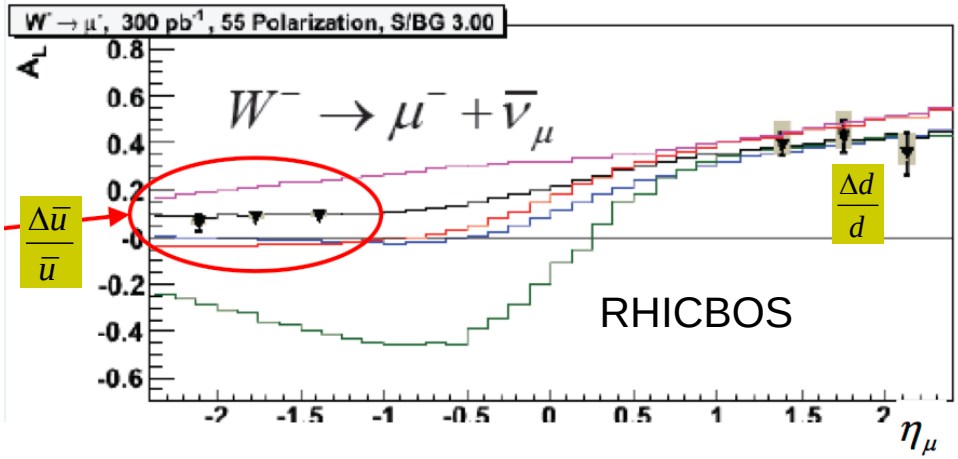
2011, L = 25.5pb^{-1}, P =50%

L = 300pb^{-1}, P =55%, S/B =3.0



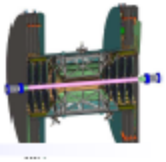




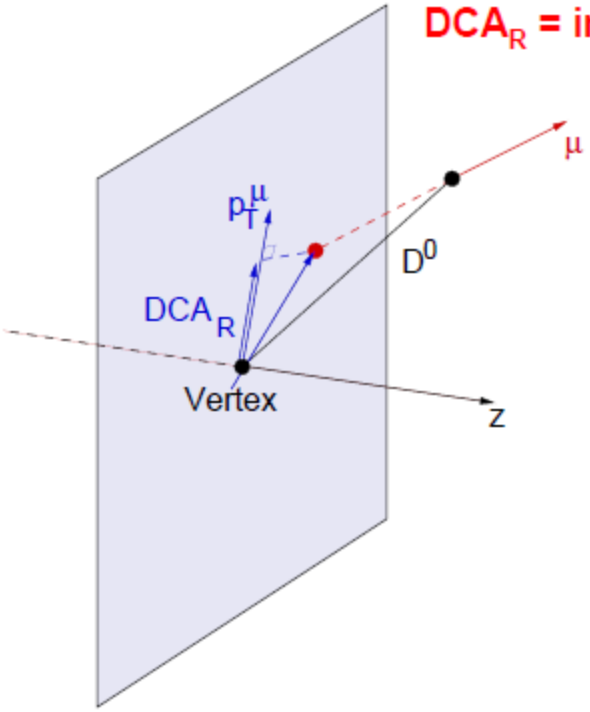


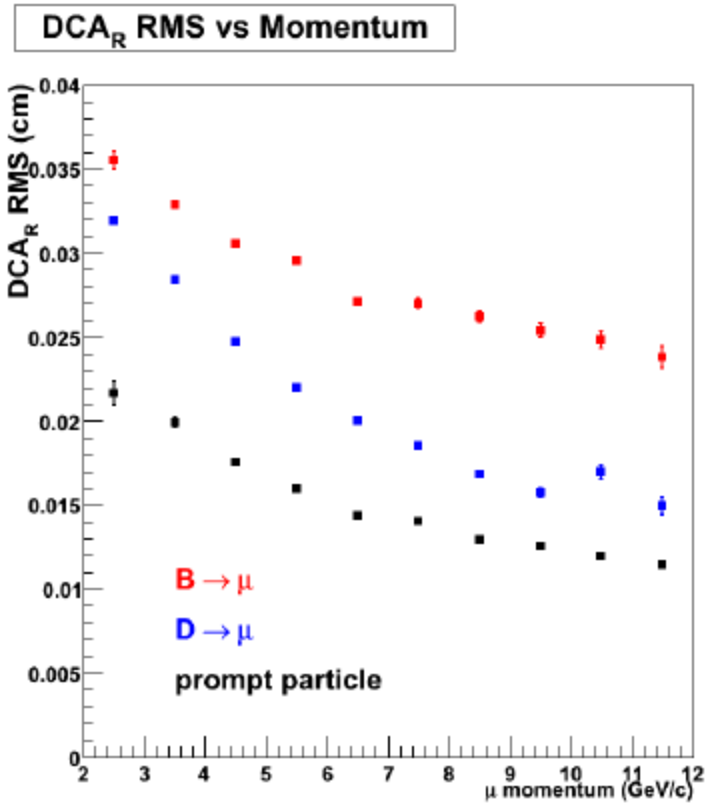
FVTX will make big contribution on background reduction for |z| <10cm!

DCA_R



DCA_R = impact parameter projected onto μ p_T.





$$DCA_R = x0reco * \left(\frac{px0reco}{\sqrt{px0reco^2 + py0reco^2}}\right) + y0reco * \left(\frac{py0reco}{\sqrt{px0reco^2 + py0reco^2}}\right);$$