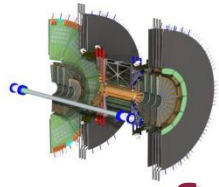
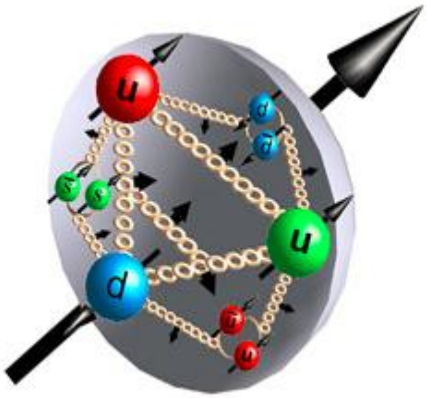
PHENIX



Reduction of Background in Observation of *W* Decay Using the Forward Vertex (FVTX) detector at PHENIX

Abraham Meles
New Mexico State University
APS April Meeting 2013 • April 13 - April 16 • Denver, CO



April meeting 2013

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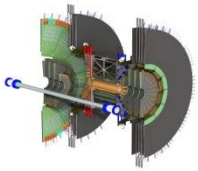
Motivation



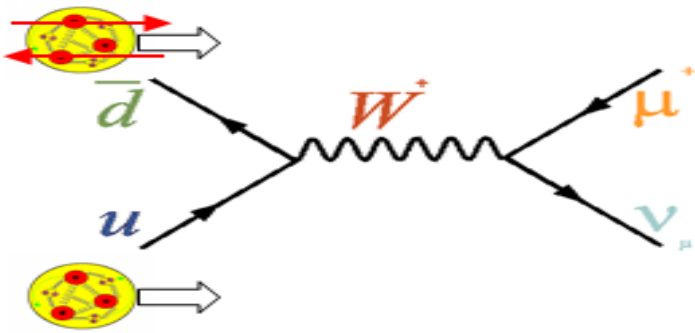
Spin dependent quark distribution
➔by the QCD analysis of (SI)DIS data

Polarized Parton distribution function (pPDF)

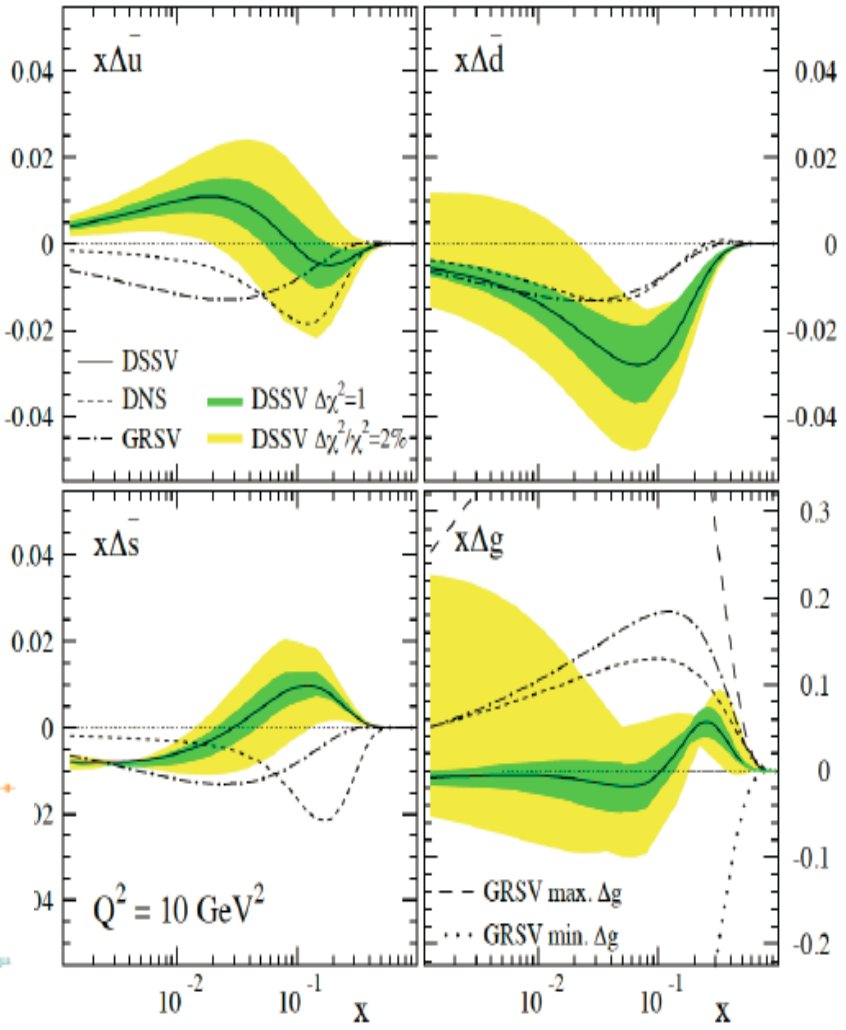
$\Delta q(x)$: well known,

$\Delta \bar{q}(x)$: not well known

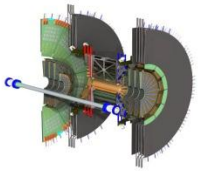
➔also, the Weak Interaction (flavor selection coupling) can be used to constrain sea quark distribution.



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



W Single Spin Asymmetry



- **We 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**

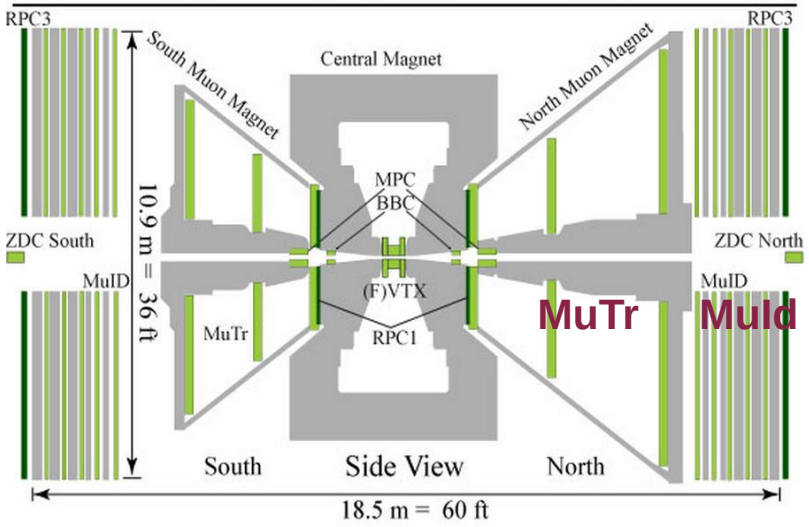
$$A_L^{l^+} = \frac{\Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 - \Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}{\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 + u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}$$

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

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

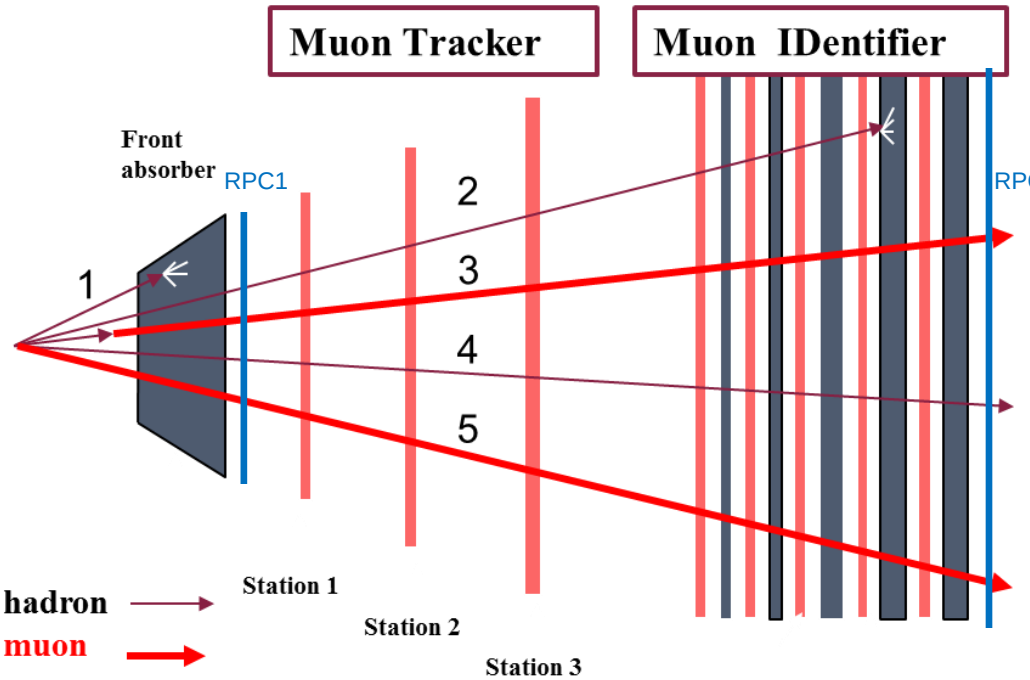
	Forward rapidity limit	Backward rapidity limit
W^+	$A_L^{\mu+} \approx \frac{\Delta\bar{d}}{\bar{d}}$	$A_L^{\mu+} \approx \frac{\Delta u}{u}$
W^-	$A_L^{\mu-} \approx \frac{\Delta d}{d}$	$A_L^{\mu-} \approx \frac{\Delta\bar{u}}{\bar{u}}$

PHENIX Forward Muon Spectrometer



- **P**ioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment at RHIC
- **North: 1.2<|η|<2.4 South: 1.2<|η|<2.2**
- **Azimuthal: Φ=2π**
- **Muon Tracker (MuTr): inside magnet to find tracks and measure momentum**
- **Muon Identifier (MuId) : μ/hadron separation**

(More in Darshana Perera's talk. Session L9 Sun 3:54 pm)



1. $Absorbed : (\pi, K...)$
2. $Stopped\ \ hadron : (\pi, K)$
3. $Decay\ \ muon : (\pi^{\pm} \rightarrow \mu^{\pm} + X,\ K^{\pm} \rightarrow \mu^{\pm} + X)$
4. $Punch\ \ through : hadron\,(\pi^{\pm}, K^{\pm})$
5. $prompt\ \ muon : (W, B, D \rightarrow \mu + X)$

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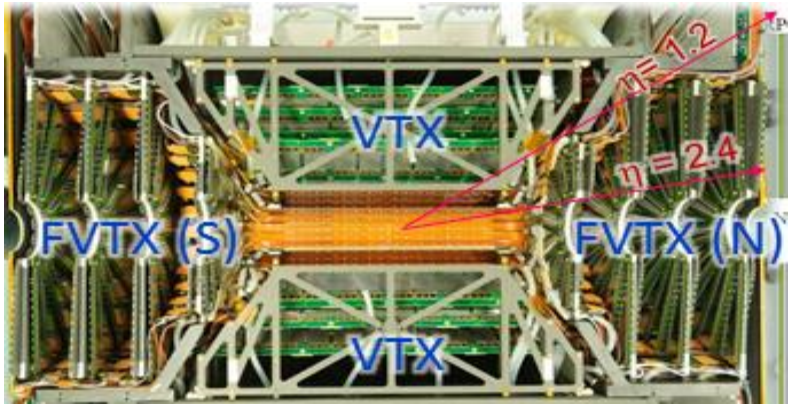
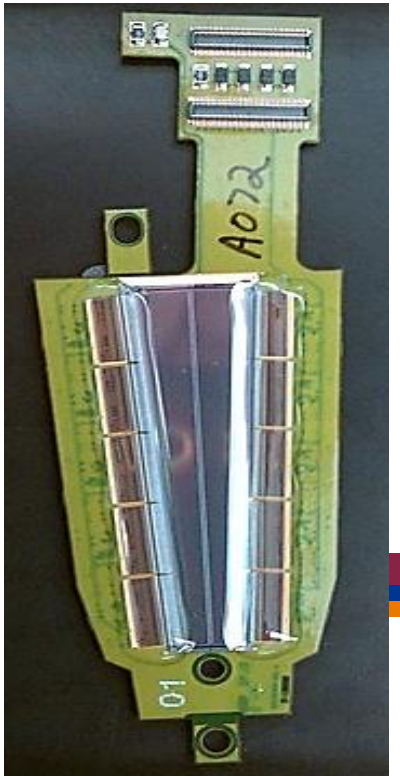
Silicon Forward Vertex Detector (FVTX)



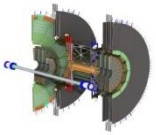
In 2012 pp collision

- **PHENIX recorded integrated luminosity of 30 $(pb)^{-1}$ $|z| < 30$ cm vertex.**
- **Over 90% of FVTX operational during 510 GeV *p-p***

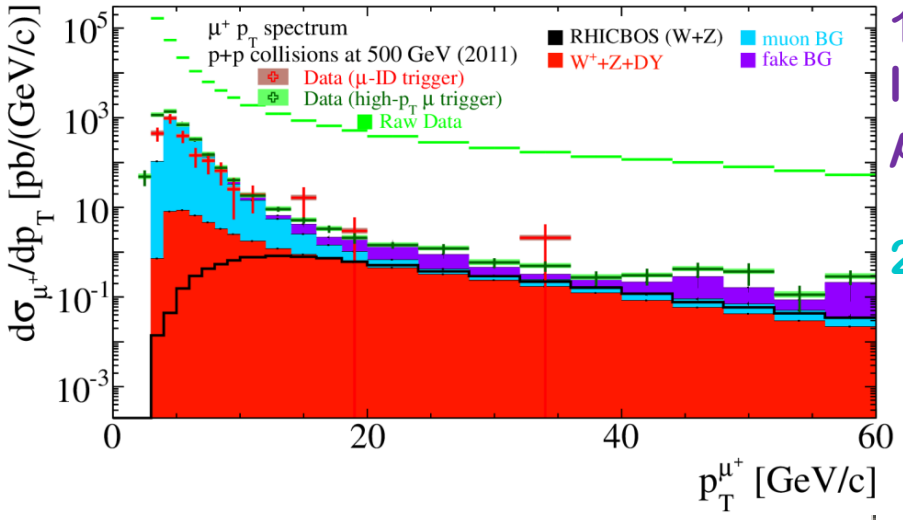
- **FVTX covers $1.2 < |\eta| < 2.4$, 2π in φ**
- **Each arm contains 4 discs, Each disc contains 96 "wedges" made of Silicon mini-strips.**
- **1.1 Million strips (75 μm pitch in radial, 3.75° in φ).**

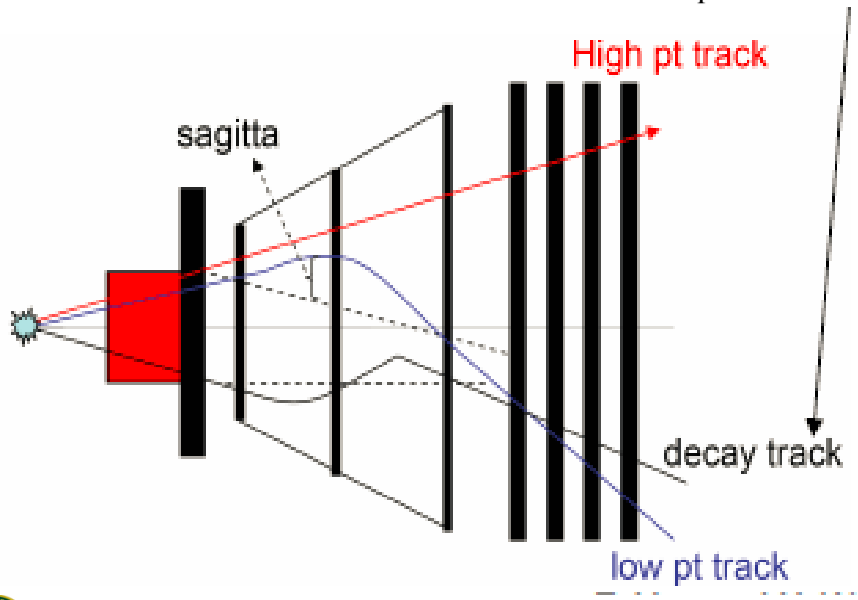


W→ muon at forward *W* Measurement



Run 11 data with signal and background simulation





1) Hadronic backgrounds: decay inflight low p_T muons misreconstructed as high p_T.

2) Muon backgrounds from open bottom, open charm, z, W→ τ→μ, ..

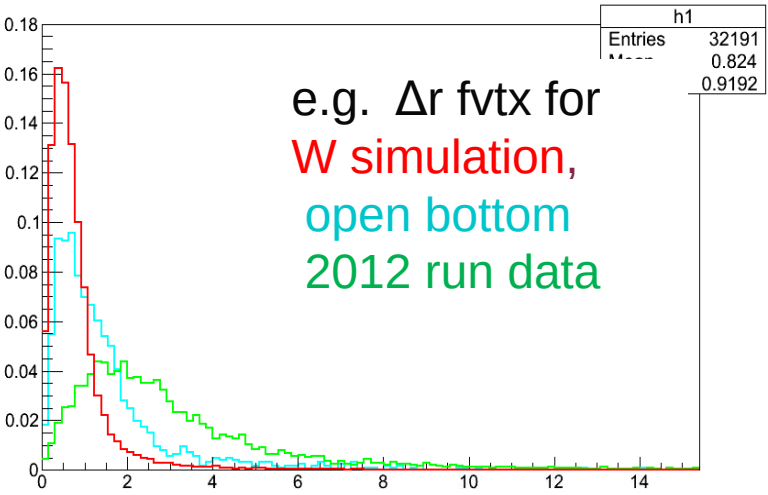
FVTX expected to improve analysis power by;

- **Better resolution and dca_r measurement (isolate heavy flavor from W)**
- **Combined FVTX+MuTr+MuID track matching.**
- **Isolation cut: : suppress hadrons from jet**

(More in Darshana Perera's talk. Session L9 Sun 3:54 pm)

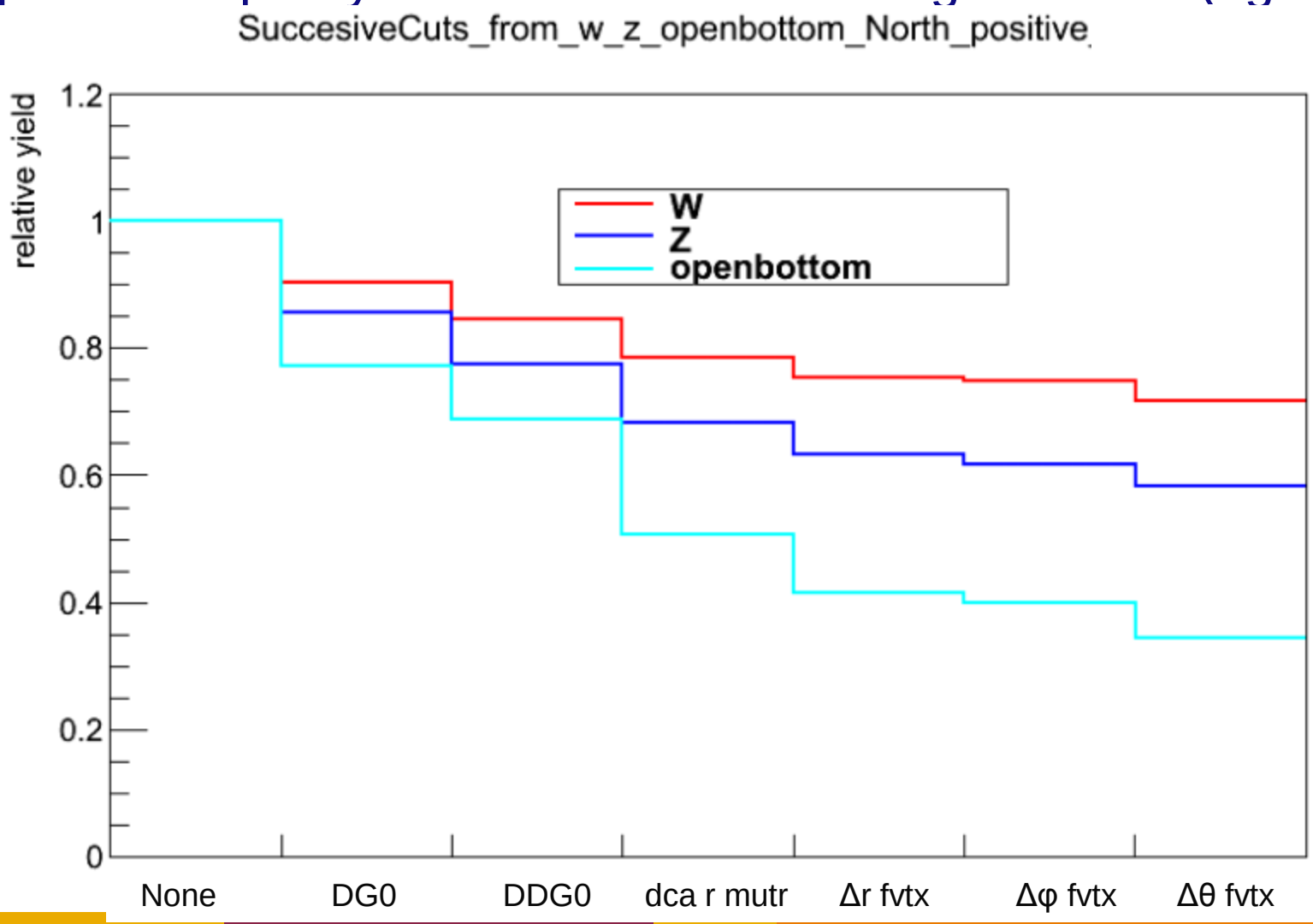
Strategy for initial analysis

- Strategy based on 2011 run analysis.
- Identify good track matching variables of MuTr/MuID and FVTX using signal simulation.
  - Δr fvtx/ Δθ fvtx/ Δφ fvtx: radius/theta/phi residual between MuTr and FVTX track
  - DG0/DDG0: distance/angle between the projected MuTr track and the MuID road at the gap 0 z position.
  - dca r MuTr: distance of closest approach of MuTr track and vertex

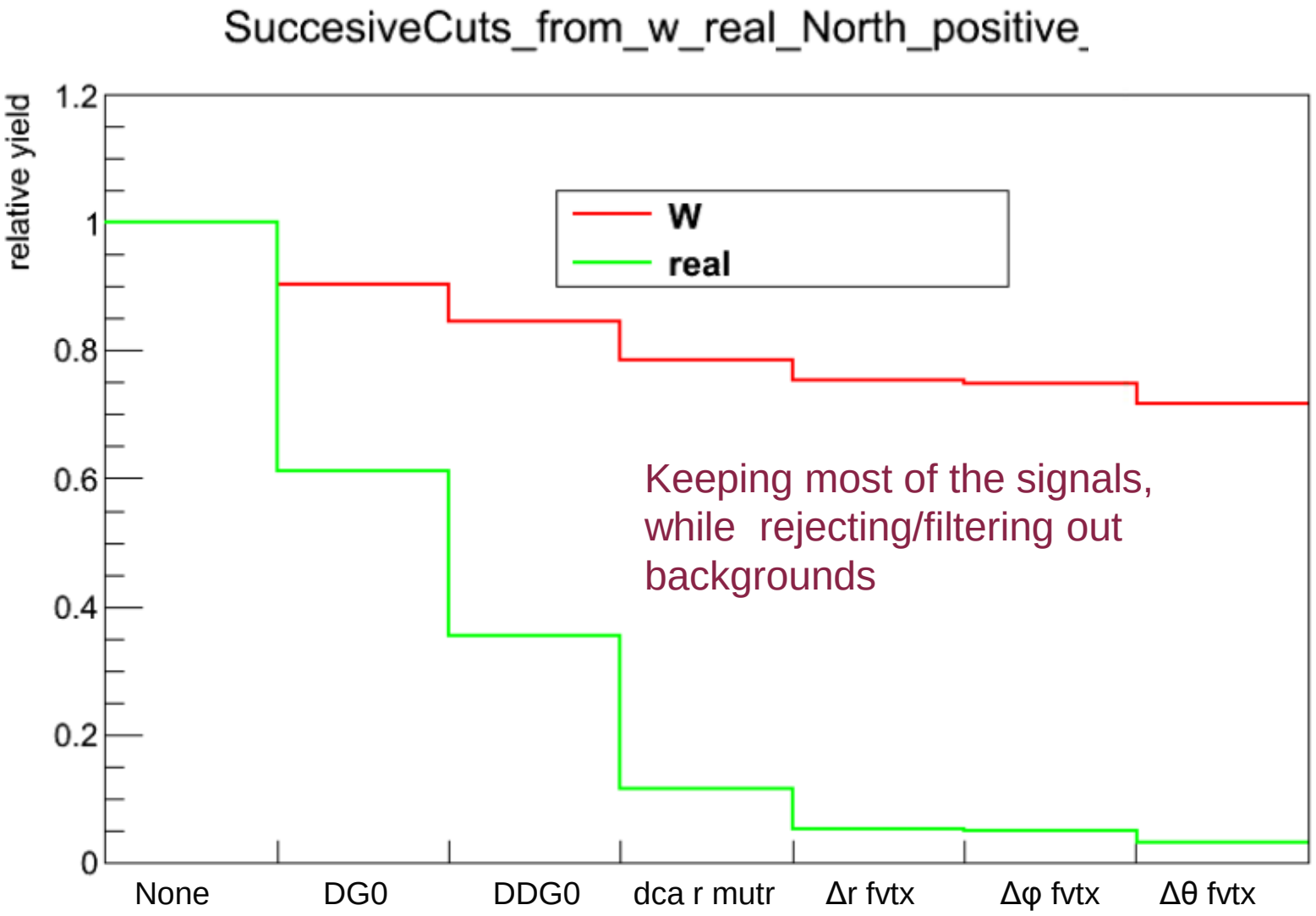


- Develop selection criteria that keep 99.5%, 97%, 95% and 90% of signal for each variable at p_T =10 GeV/c
- Apply the cut for high p_T events (p_T>10 GeV/c)
- Other promising FVTX parameters like Isolation cut, χ2 fvtx are being studied

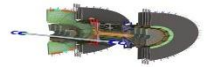
Improve the purity of the W candidate single muons (tight cut)



2012 data (as a background)



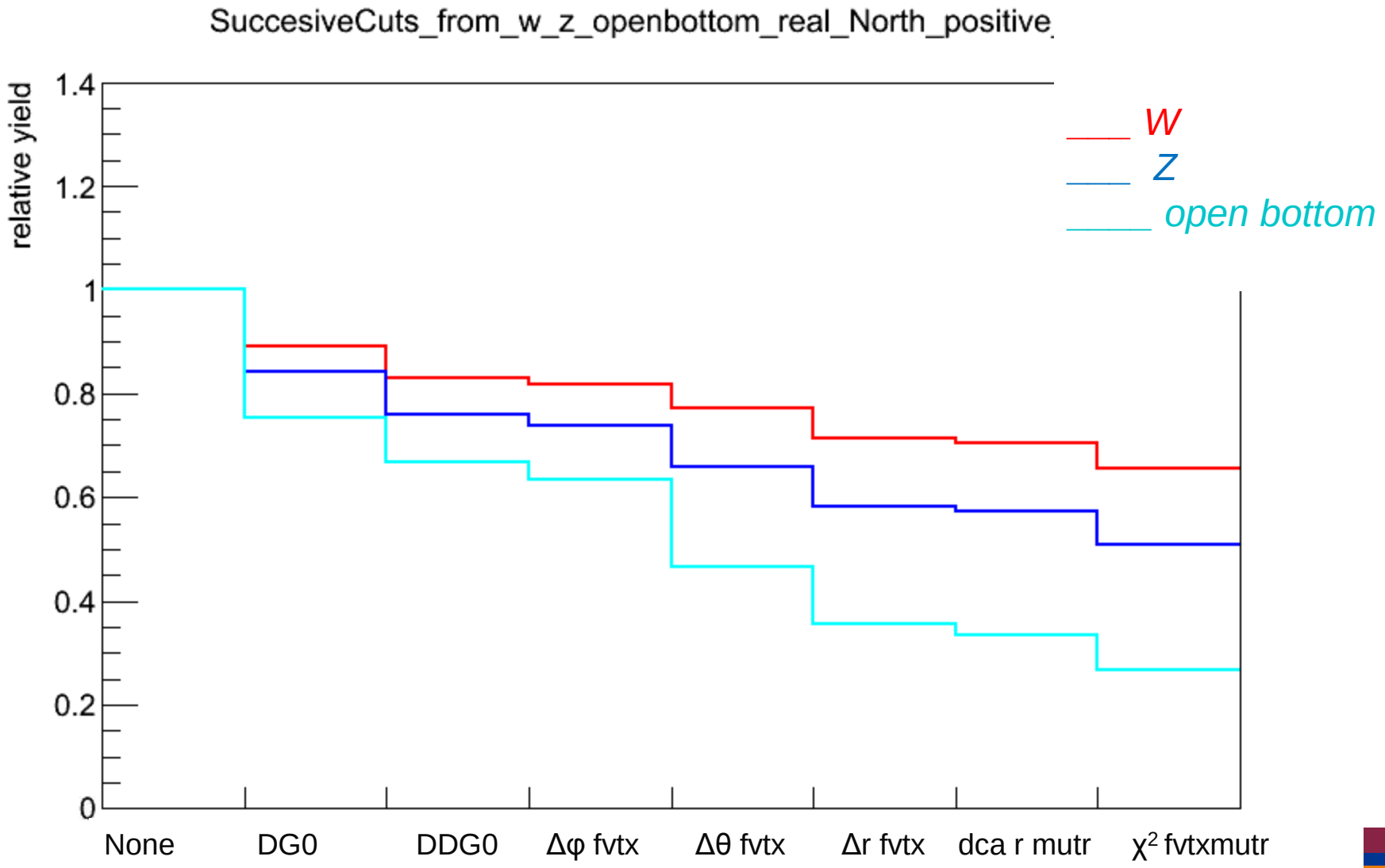
Keeping most of the signals, while rejecting/filtering out backgrounds



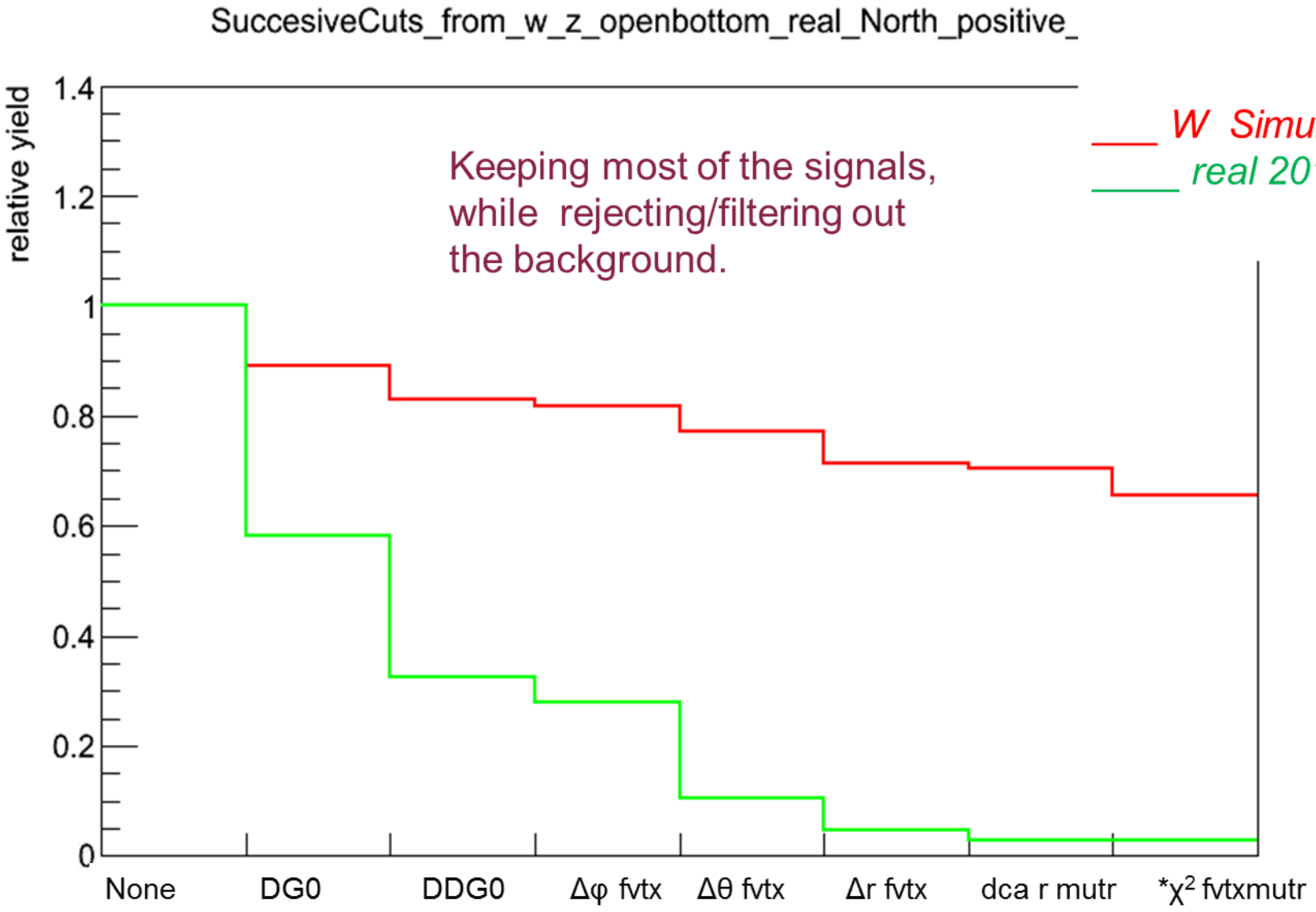
Summary

- In addition to (SI)DIS experiments, sea-quark polarized distribution can be studied using *W* Production Asymmetry in *pp collision*.
- 2012 – FVTX collected its first commissioning and physics data - analysis in progress.
- FVTX parameters combined with MuTr and MuId add more tracking information and reduce backgrounds while having high efficiency on the signals.

Backup

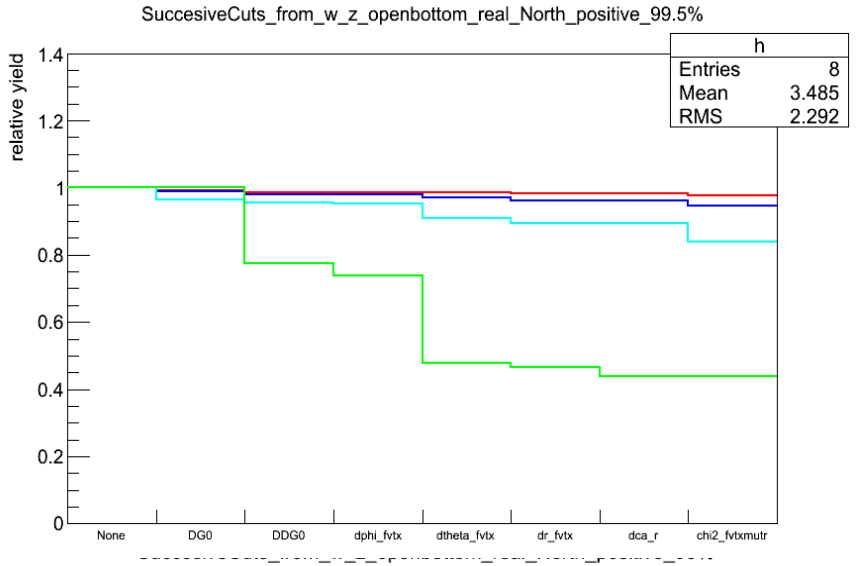

SuccesiveCuts_from_w_z_openbottom_real_North_positive
relative yield
1.4
1.2
1
0.8
0.6
0.4
0.2
0
W
Z
open bottom
None
DG0
DDG0
Δφ fvtx
Δθ fvtx
Δr fvtx
dca r mutr
χ2 fvtxmutr

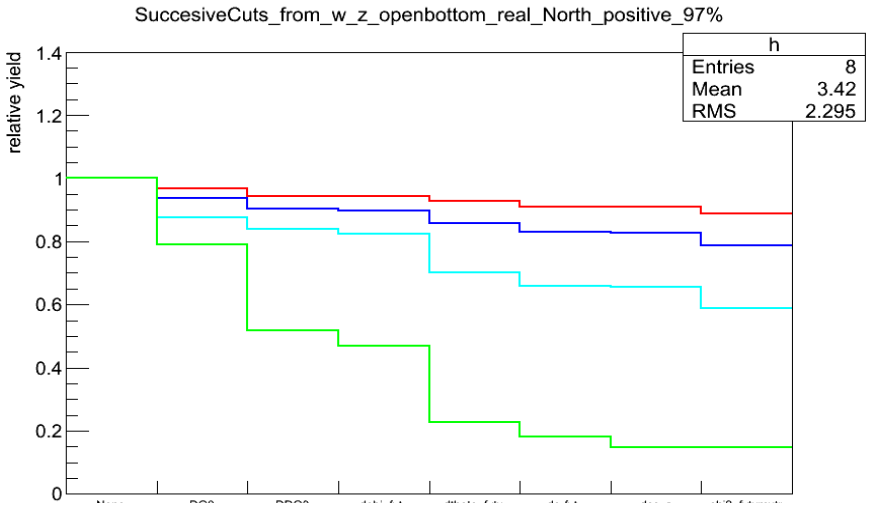
Backup

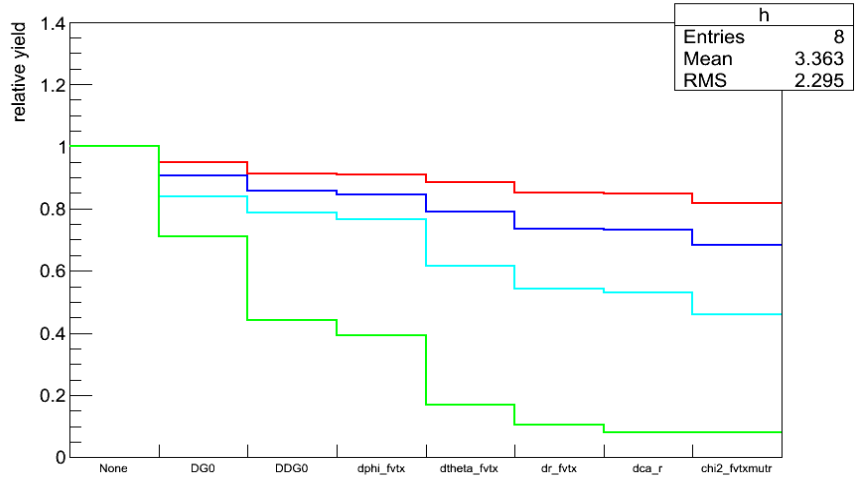


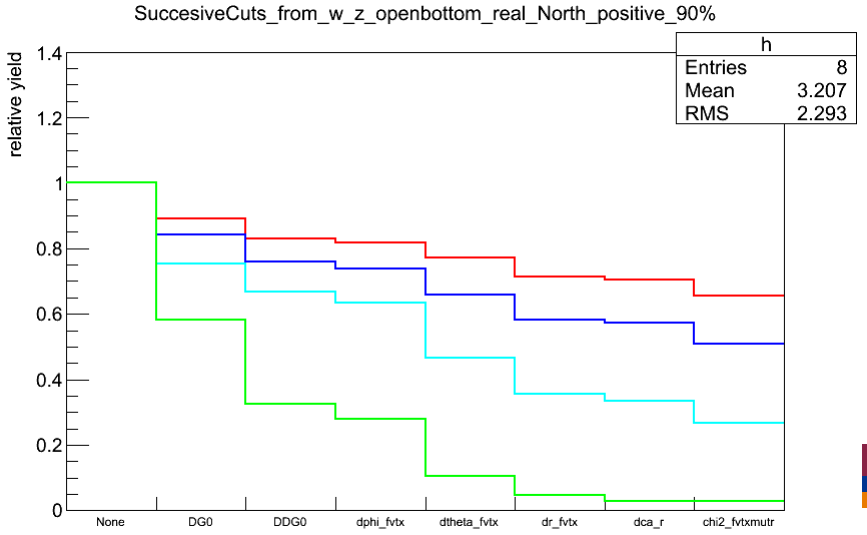
*χ^2 fvtxmutr not implemented for real data

Backup

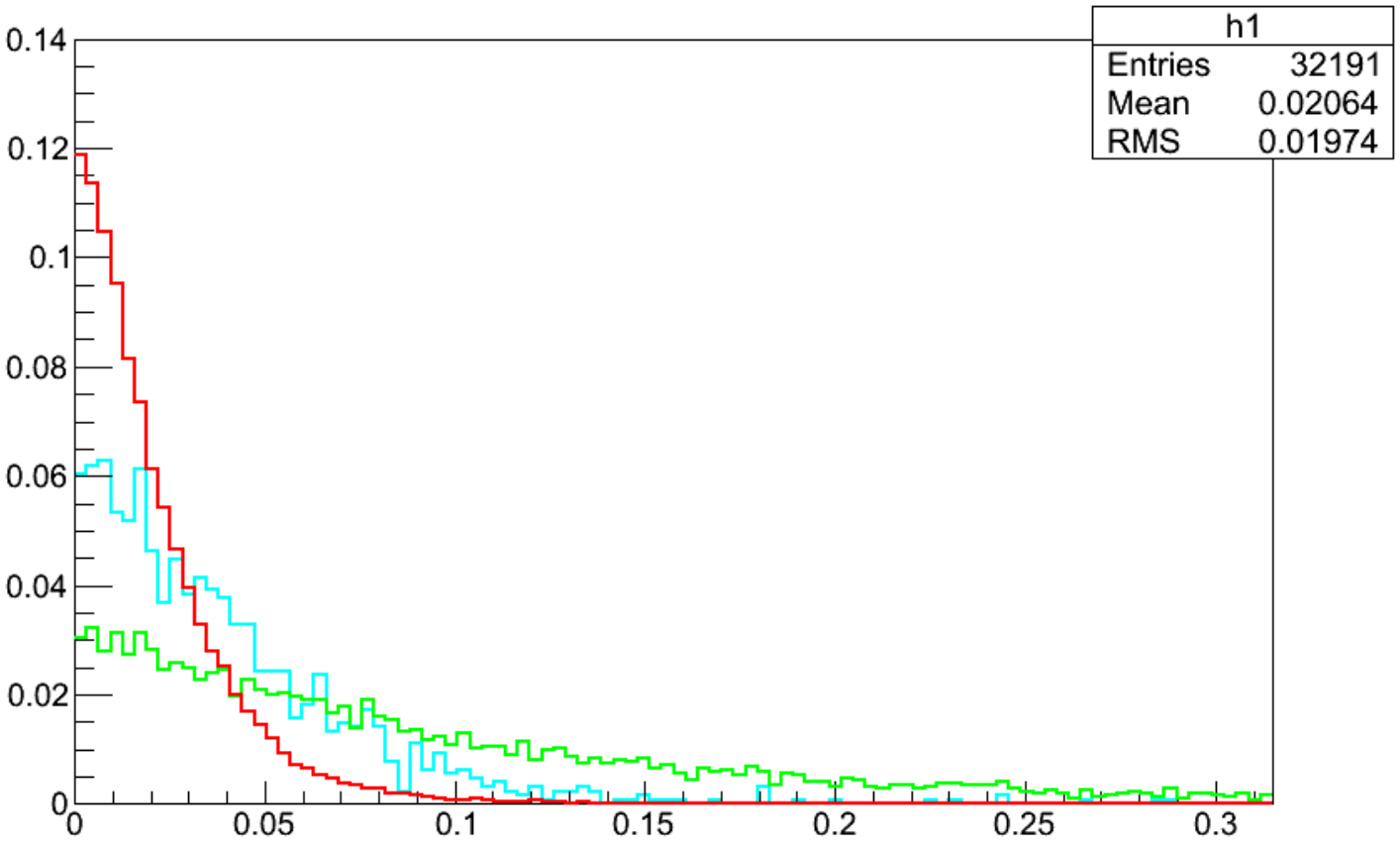

SuccesiveCuts_from_w_z_openbottom_real_North_positive_99.5%
h
Entries 8
Mean 3.485
RMS 2.292
relative yield
None
DG0
DDG0
dphi_fvtx
dtheta_fvtx
dr_fvtx
dca_r
chi2_fvtxmutr


SuccesiveCuts_from_w_z_openbottom_real_North_positive_97%
h
Entries 8
Mean 3.42
RMS 2.295
relative yield


h
Entries 8
Mean 3.363
RMS 2.295
relative yield
None
DG0
DDG0
dphi_fvtx
dtheta_fvtx
dr_fvtx
dca_r
chi2_fvtxmutr

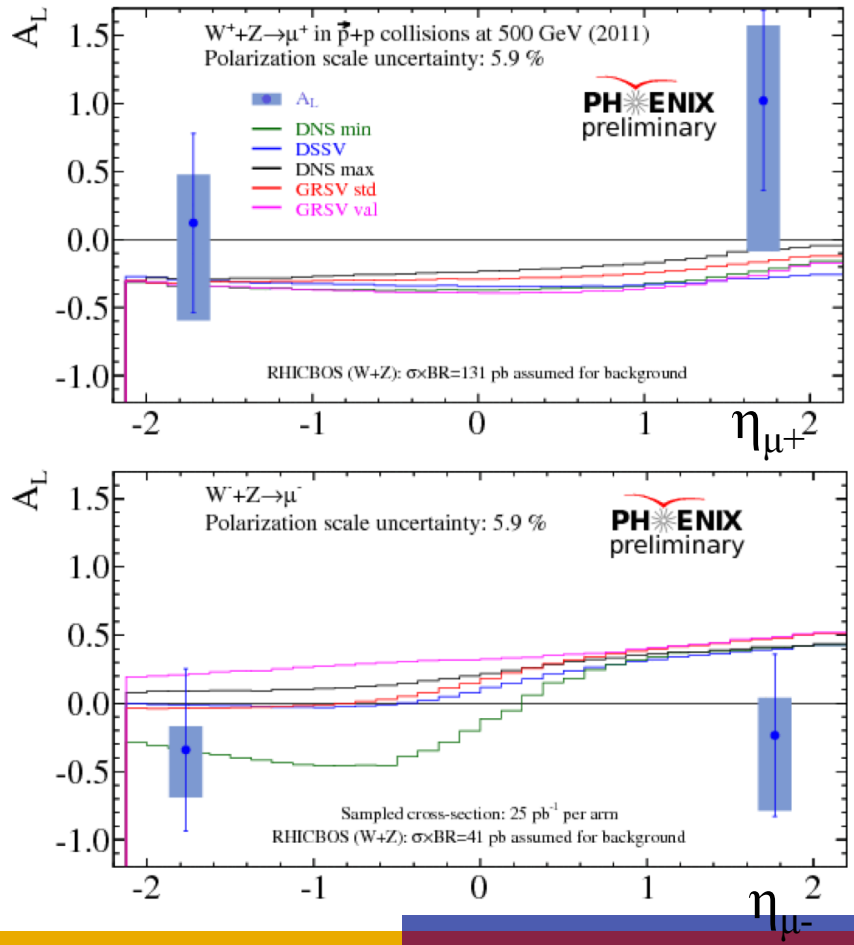

SuccesiveCuts_from_w_z_openbottom_real_North_positive_90%
h
Entries 8
Mean 3.207
RMS 2.293
relative yield
None
DG0
DDG0
dphi_fvtx
dtheta_fvtx
dr_fvtx
dca_r
chi2_fvtxmutr

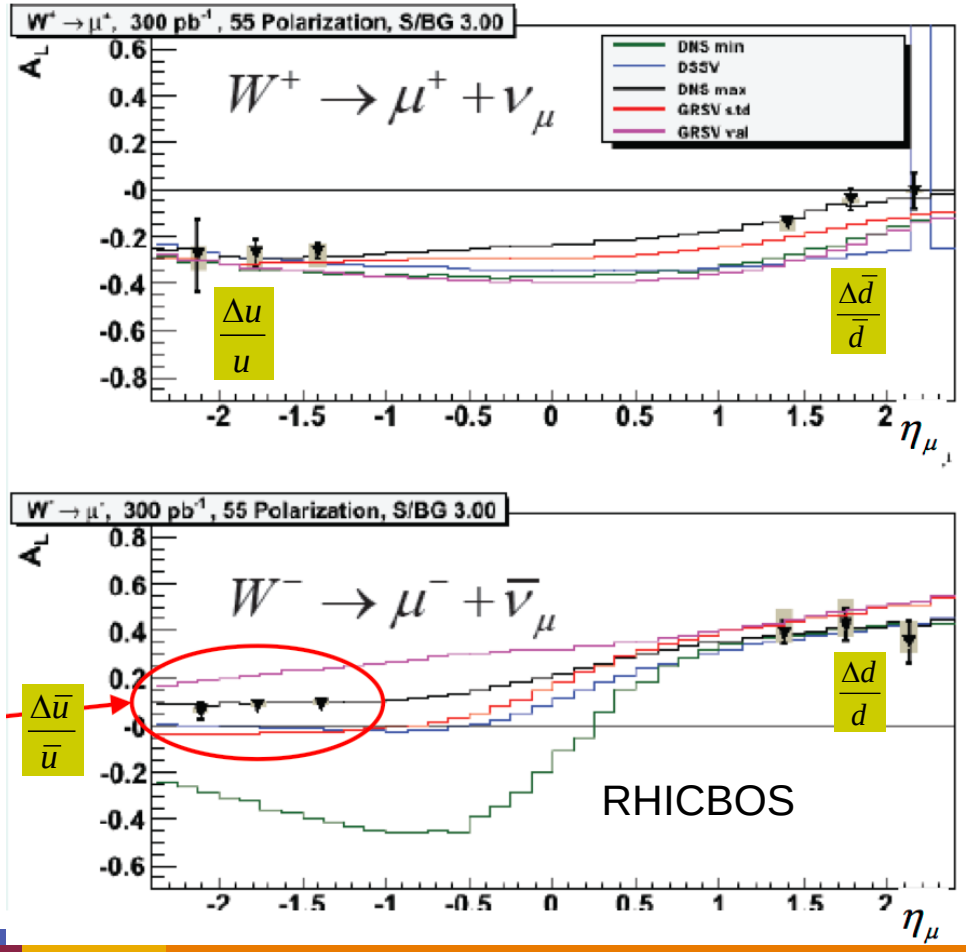
Delta phi

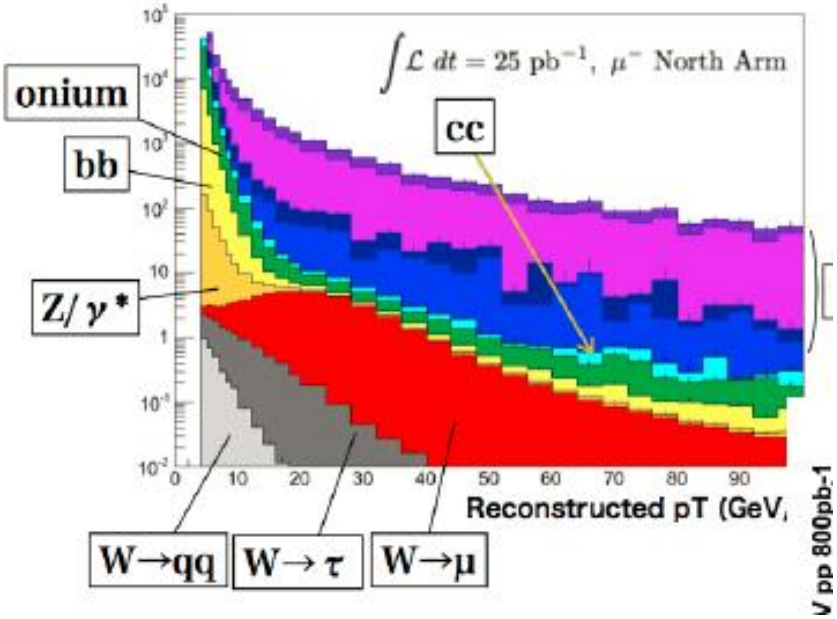

h1
Entries 32191
Mean 0.02064
RMS 0.01974
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
0.25
0.3

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

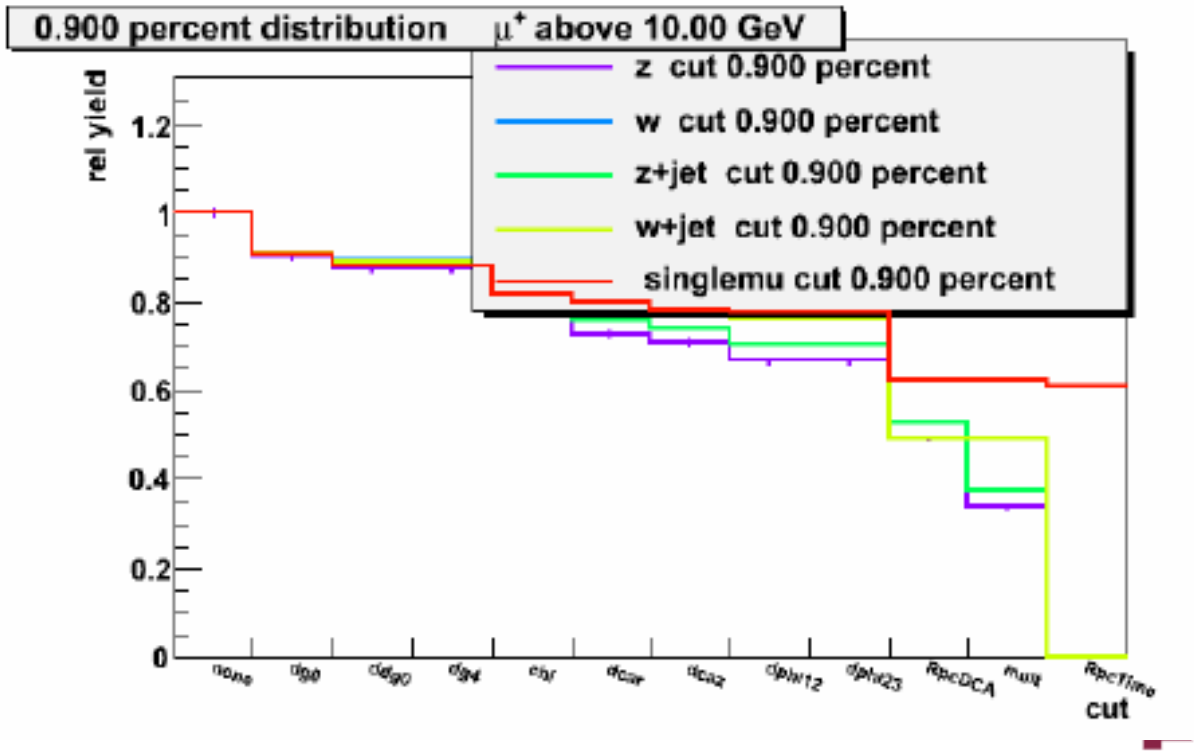
L = 300pb-1, P =55%, S/B =3.0



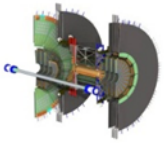




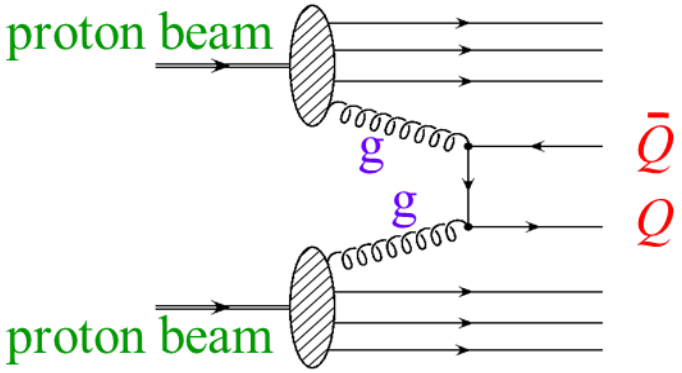
Past studies: run11 analysis strategy to improve the purity of the W candidate single muons using mutr and rpc variables



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"

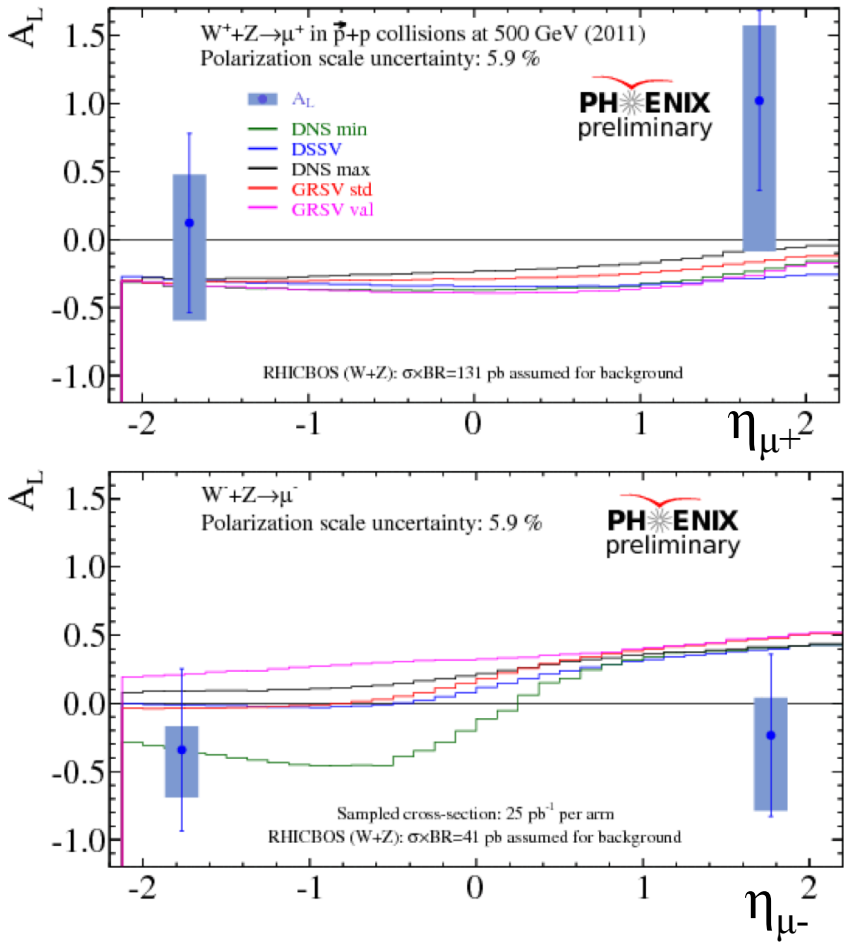
E.g. $c \rightarrow D \rightarrow \mu + X$

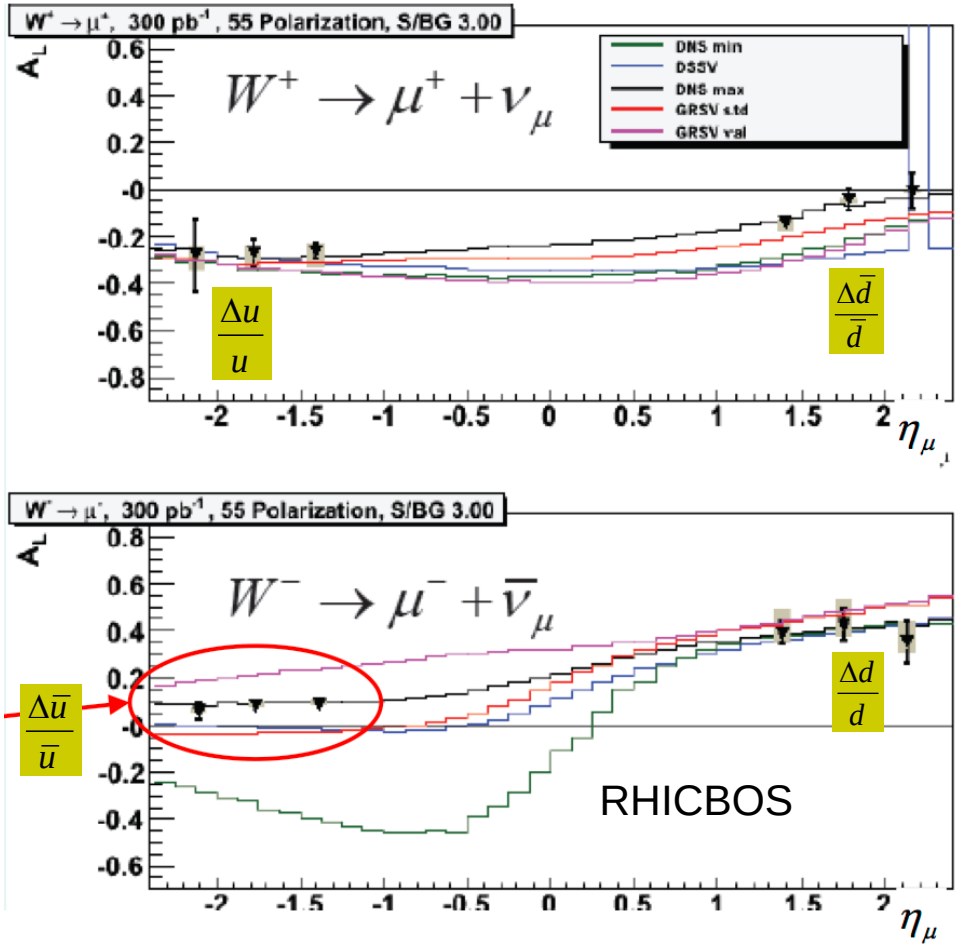
This is a weak meson decay and so is slow. $\tau \approx 10^{-12}$ s $\quad c\tau \approx 10^{-2}$ cm

First $W^{\pm} \to m^{\pm}$ 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!

- Parton distribution function (pdf)--probability of scattering off of a parton carrying a particular fraction of the proton's momentum
- *Polarized* pdf--the *difference in probability* between scattering off of a parton with one spin state vs. the other
  - Still as a function of the momentum fraction ("Bjorken-x")

Magenta

Optimal selection criteria

at pT=10GeV/c from Simulation based on ref run 367593

Optimal selection criteria						
Variable	Arm	Charge	99.50%	97.50%	95%	90%
DG0	North	Positive	10.564	6.764	5.852	4.778
DDG0	North	Positive	4.242	3.066	2.814	2.394
dca_r	North	Positive	8.658	3.666	2.73	1.794
dr_fvtx	North	Positive	6.93	2.97	2.046	1.386
dphi_fvtx	North	Positive	0.1254	0.077	0.0656	0.0518
d_theta_fvtx	North	Positive	0.0395	0.0255	0.0225	0.0185
chi2_fvtxmutr	North	Positive	12.11	6.88	5.4625	4.0375