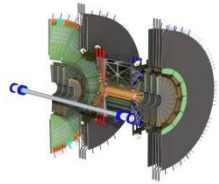
PHENIX



Introducing my work at the Phenix SpinFest 2013

Background reduction using FVTX for W study

Abraham Meles
New Mexico State University
3-Jul-13

Advisor: Xiaorong Wang (NMSU)
Work with: F. Wei (NMSU), J. Huang (LANL), M. Liu (LANL),

U.S. DEPARTMENT OF ENERGY

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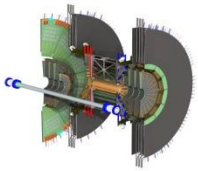
Ethiopia

Axum
~ 3000 years

Lalibela ~1000 years ago

Motivation



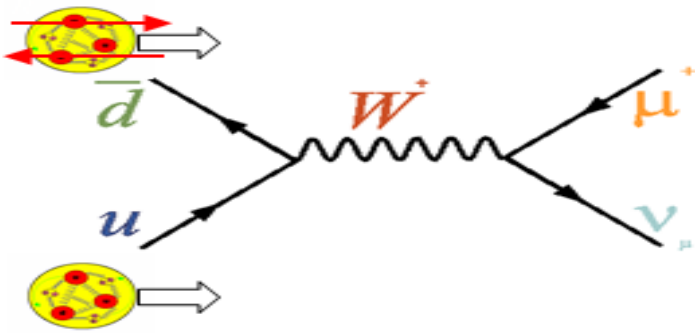
Spin dependent quark distribution
➔by the QCD analysis of (SI)DIS data

Polarized Parton distribution function (pPDF)

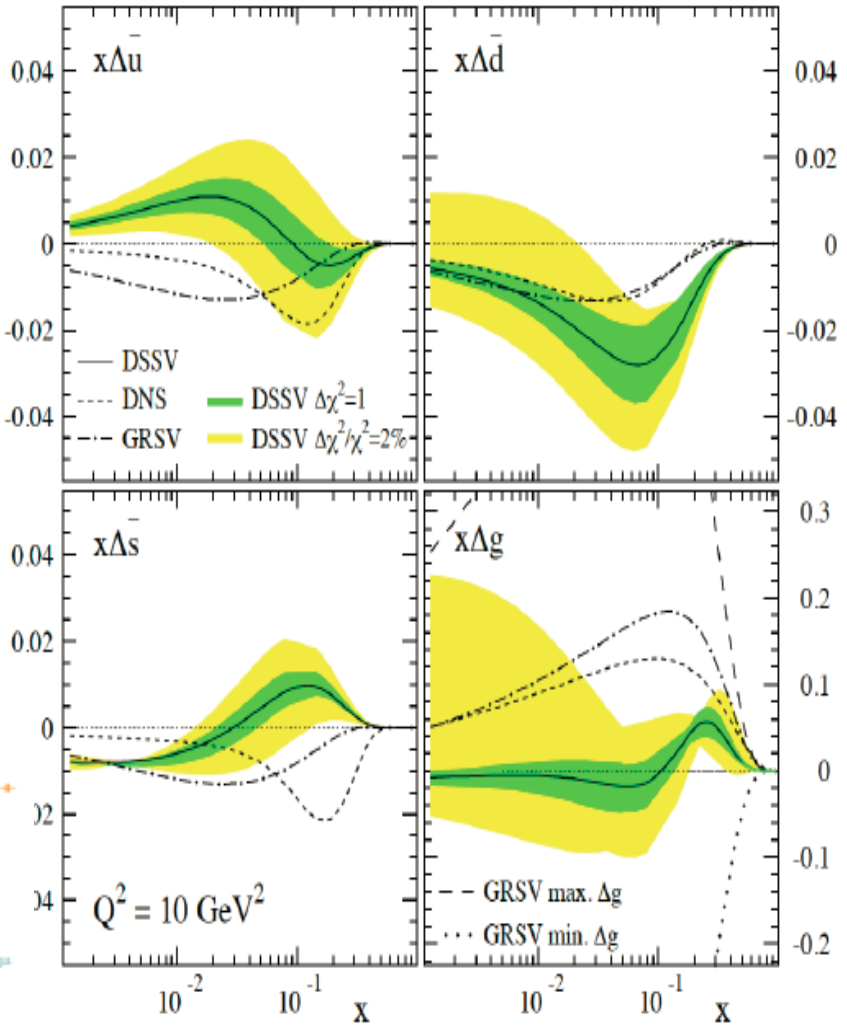
$\Delta q(x)$: well known,

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

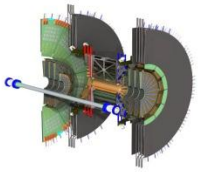
➔also, the Weak Interaction (flavor selection coupling) can be used to constrain sea quark distribution.



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**

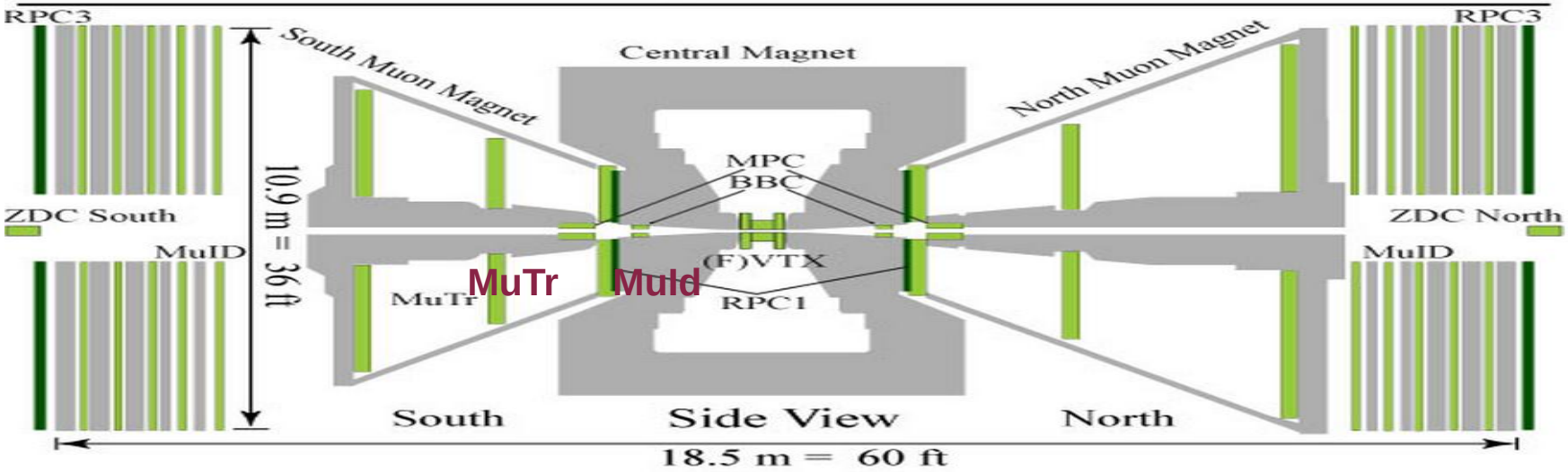
$$A_L^{l^+} = \frac{\Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 - \Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}{\bar{d}(x_1)u(x_2)(1+\cos\theta)^2 + u(x_1)\bar{d}(x_2)(1-\cos\theta)^2}$$

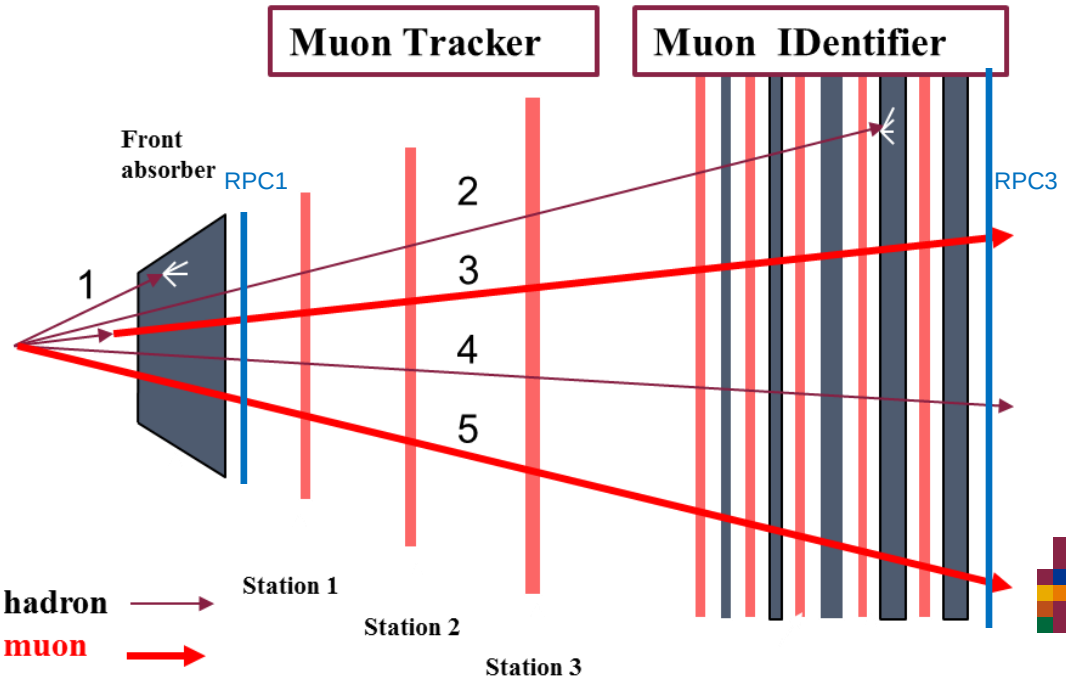
$$A_L^{l^-} = \frac{\Delta\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 - \Delta d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}{\bar{u}(x_1)d(x_2)(1-\cos\theta)^2 + d(x_1)\bar{u}(x_2)(1+\cos\theta)^2}$$

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





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

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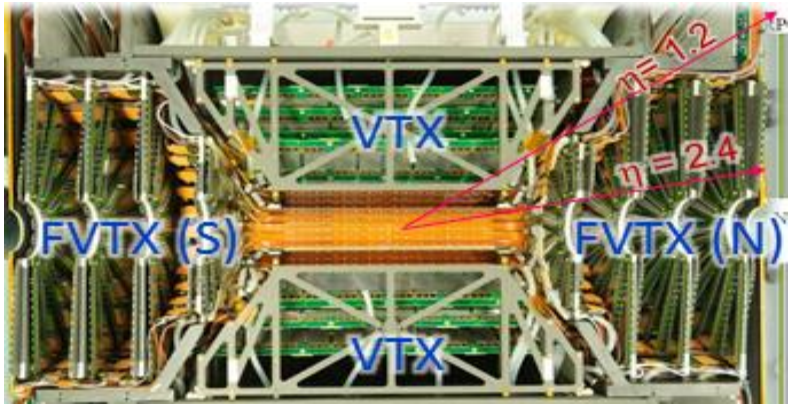
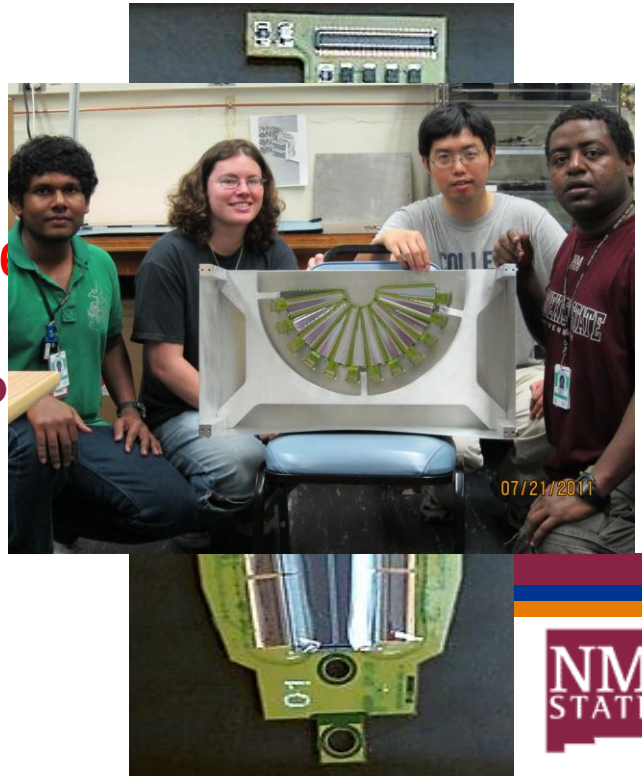
Silicon Forward Vertex Detector (FVTX)



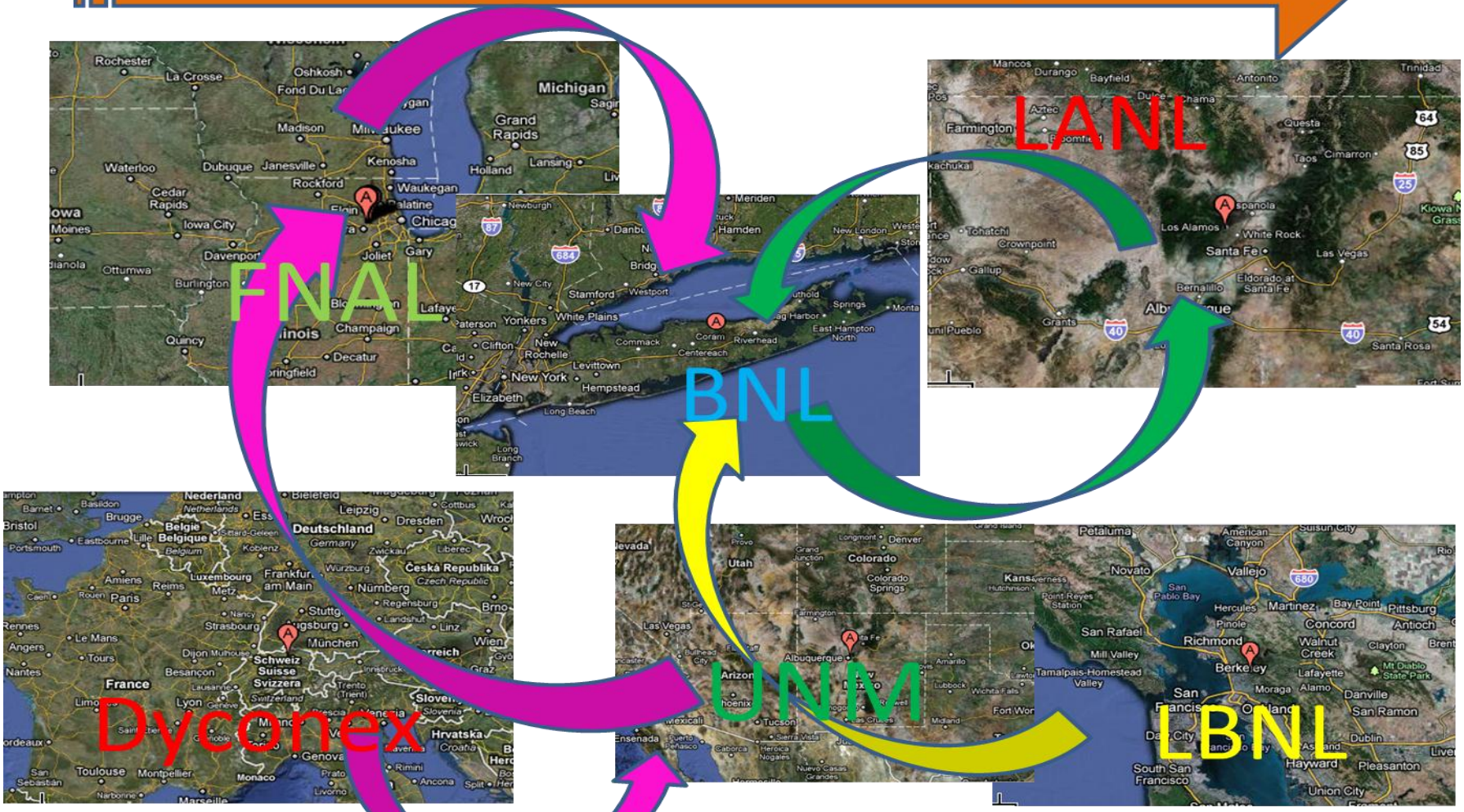
In 2012 pp collision

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

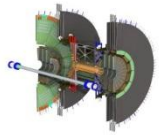
- **FVTX covers $1.2 < |\eta| < 2.4$, 2π in φ**
- **Each arm contains 4 discs, Each disc contains 9(**
  "wedges" made of Silicon mini-strips.
- **1.1 Million strips (75 μm pitch in radial, 3.75° in φ**



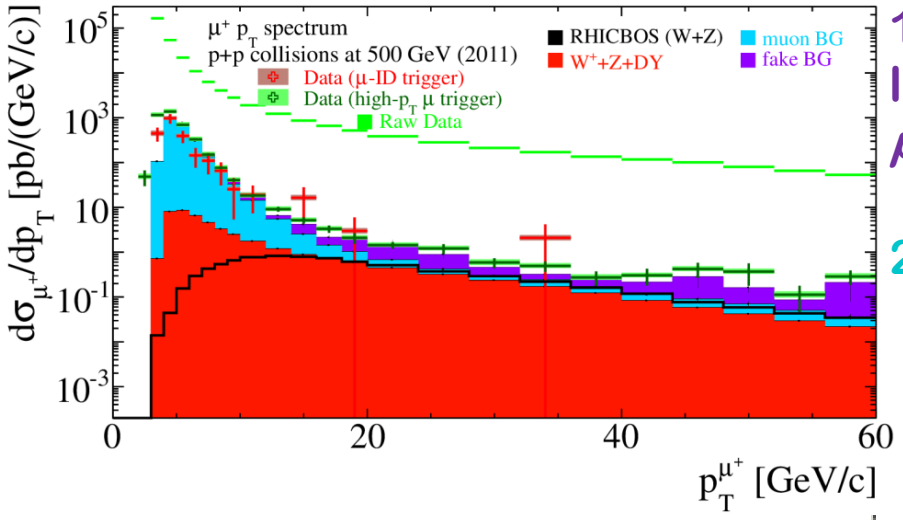
The life of a wedge



W→ muon at forward *W* Measurement

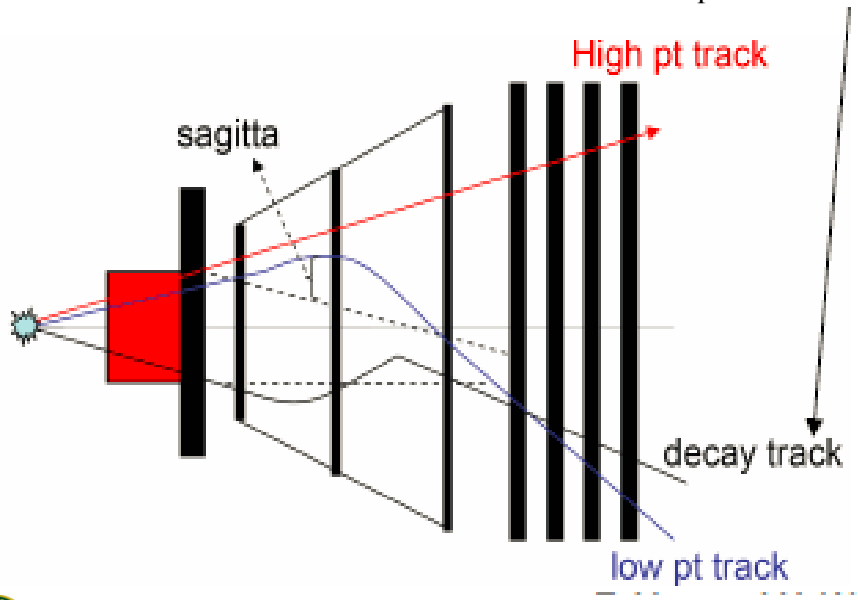


Run 11 data with signal and background simulation



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, ..



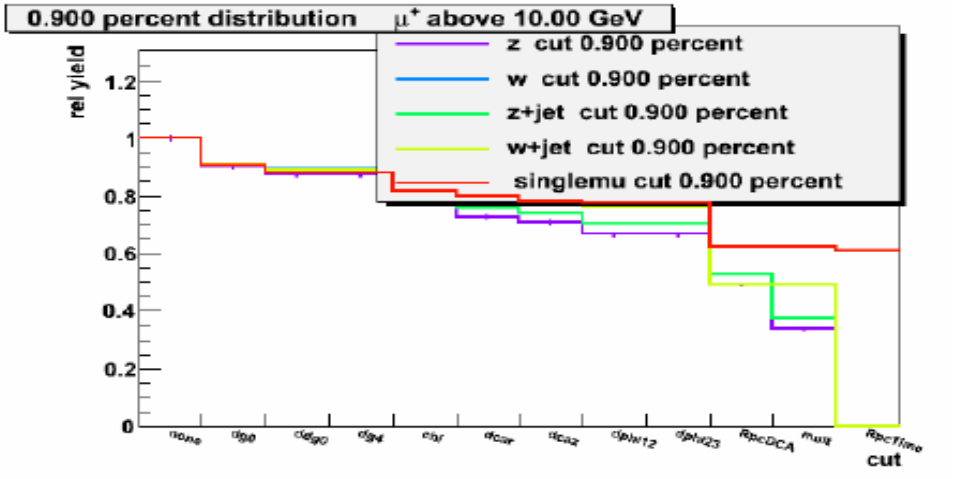
FVTX ;

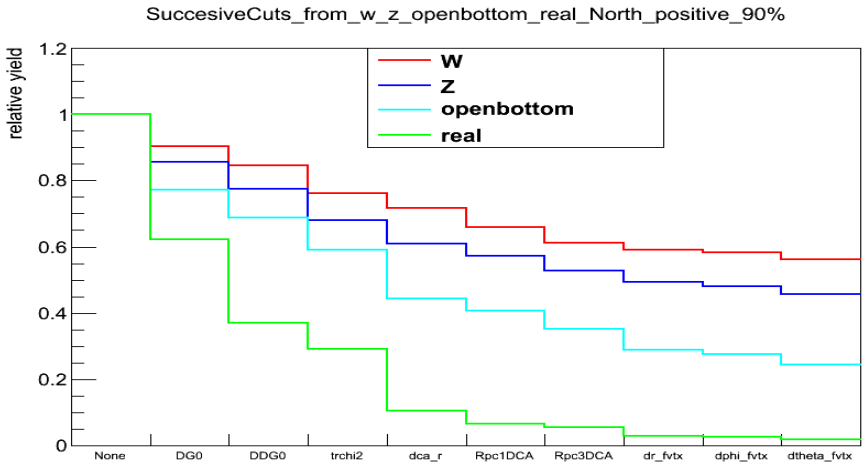
- **Better resolution and dca_r measurement (isolate heavy flavor from W)**
- **Combined FVTX+MuTr+MuID track matching.**
- **Isolation cut: : suppress hadrons from jet**

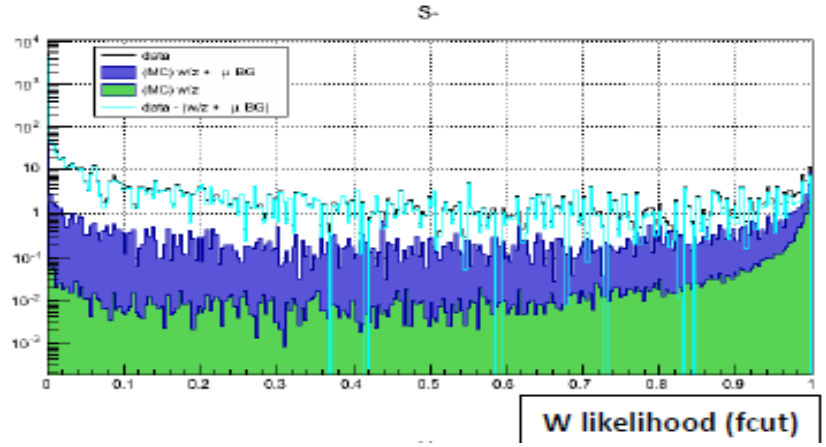
(More in Darshana Perera's talk. Session L9 Sun 3:54 pm)

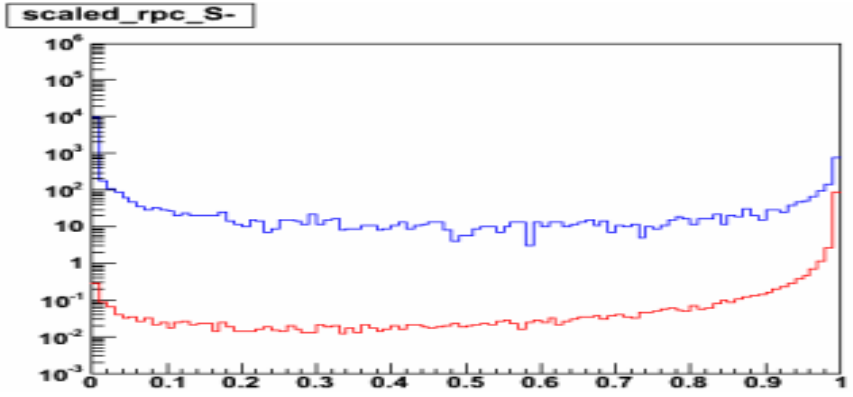
MuTr/MuID and RPC variables on background rejection studied in run11 analysis (an1024)

In this talk
-MuTr/MuID and FVTX
- MuTr/MuID + RPC and FVTX variables on background rejection ….with S/B









- Data Set
  - Run12pp510Muon set (almost all data) taxi 1264
  - Simulation: MC (w signal + μ BGs) produced by Ralf /direct/phenix+user02/phnxreco/Wsims_Ralf/run12sim/muonsims/simdata/pytune100_367593/old2
- FVTX Observables for W analysis
  - FVTX provide additional separation of W-signal and background. Therefore, improve the estimation for S/B ratio and systematic uncertainty
    (preliminary: acceptance, efficiency, rejection)
  - Multi-vertex finder. Active work on-going by M. McCumber and C. Da Silva
    (acpt:|z|<50 cm, eff. >80% w/ two blind spot)
  - Joint FVTX – MuTr track matching and fit
    (<acpt>~20%, eff. ~ 90%, rej. ~ **2x**)
  - Isolation-cone observables (Jin Huang)
    (acpt:|z|<10 cm, eff. ~60%)

This talk

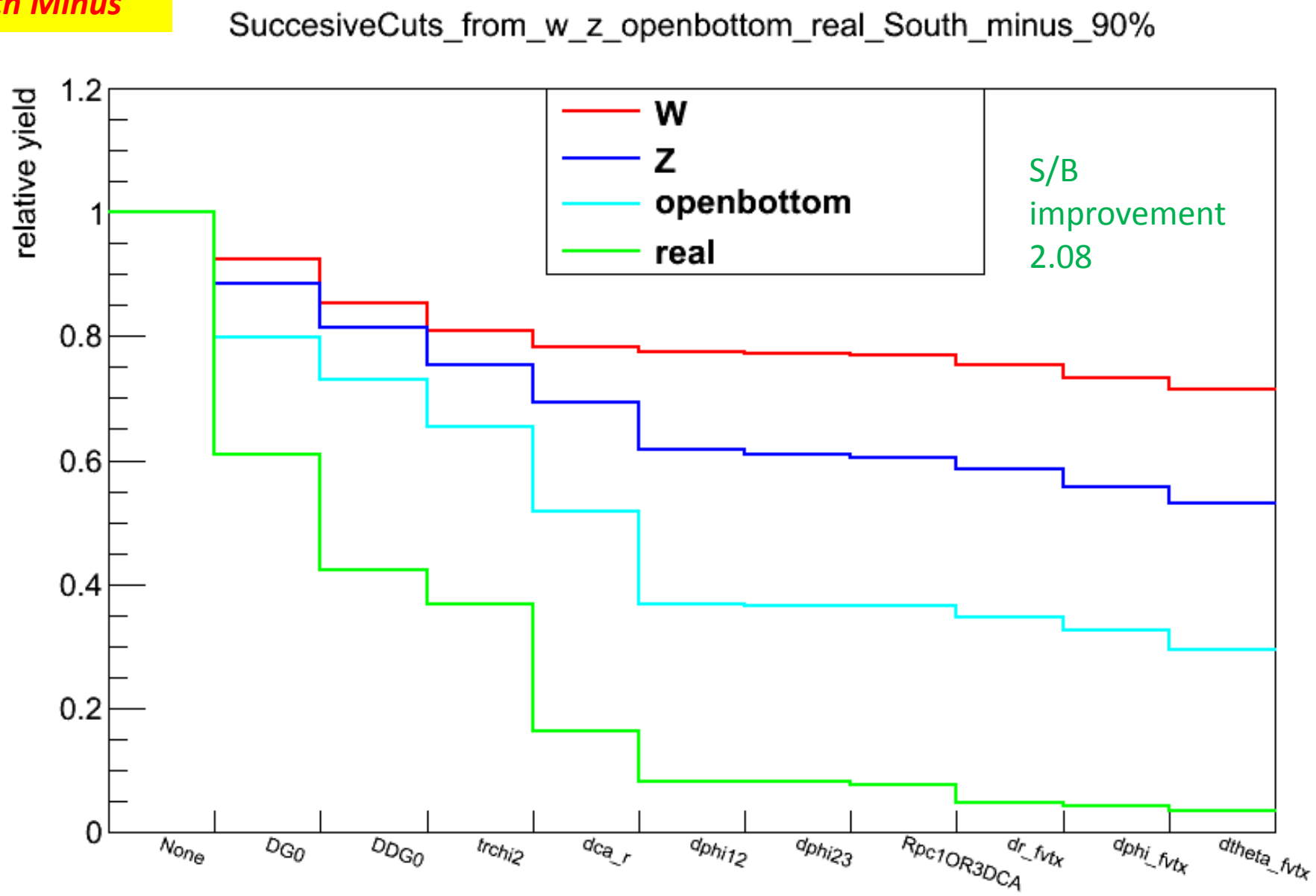
initial Strategy

- Identify good track matching variables of MuTr and FVTX using signal simulation at reco pT 10 GeV/c.
  - DG0, DDG0, $\Delta\phi_{12}$, $\Delta\phi_{23}$,chi2, dca_r (mutr),
  - Δr_fvtx/ $\Delta\theta$_fvtx/ $\Delta\phi$_fvtx: radius/theta/phi residual btw. MuTr and FVTX track at Z=+/-40cm
  - RPC1 DCA, RPC3DCA,
  - chi2fvtxmutr, dca_fvtx
  - Isolation cut

- Develop selection criteria that keep 99.5%, 97%, 95% and 90% of signal for each variable at 10 GeV/c.
- Apply it for high pT(>10 GeV/c);
  - On *W* candidate single muons (w,z, openbottom, z+jet, w+jet….).
  - On background simulation and real data.

*Green font DONE, red in progress

South Minus


SuccesiveCuts_from_w_z_openbottom_real_South_minus_90%
relative yield
1.2
1
0.8
0.6
0.4
0.2
0
W
Z
openbottom
real
S/B
improvement
2.08
None
DG0
DDG0
trchi2
dca_r
dphi12
dphi23
Rpc1OR3DCA
dr_fvtx
dphi_fvtx
dtheta_fvtx

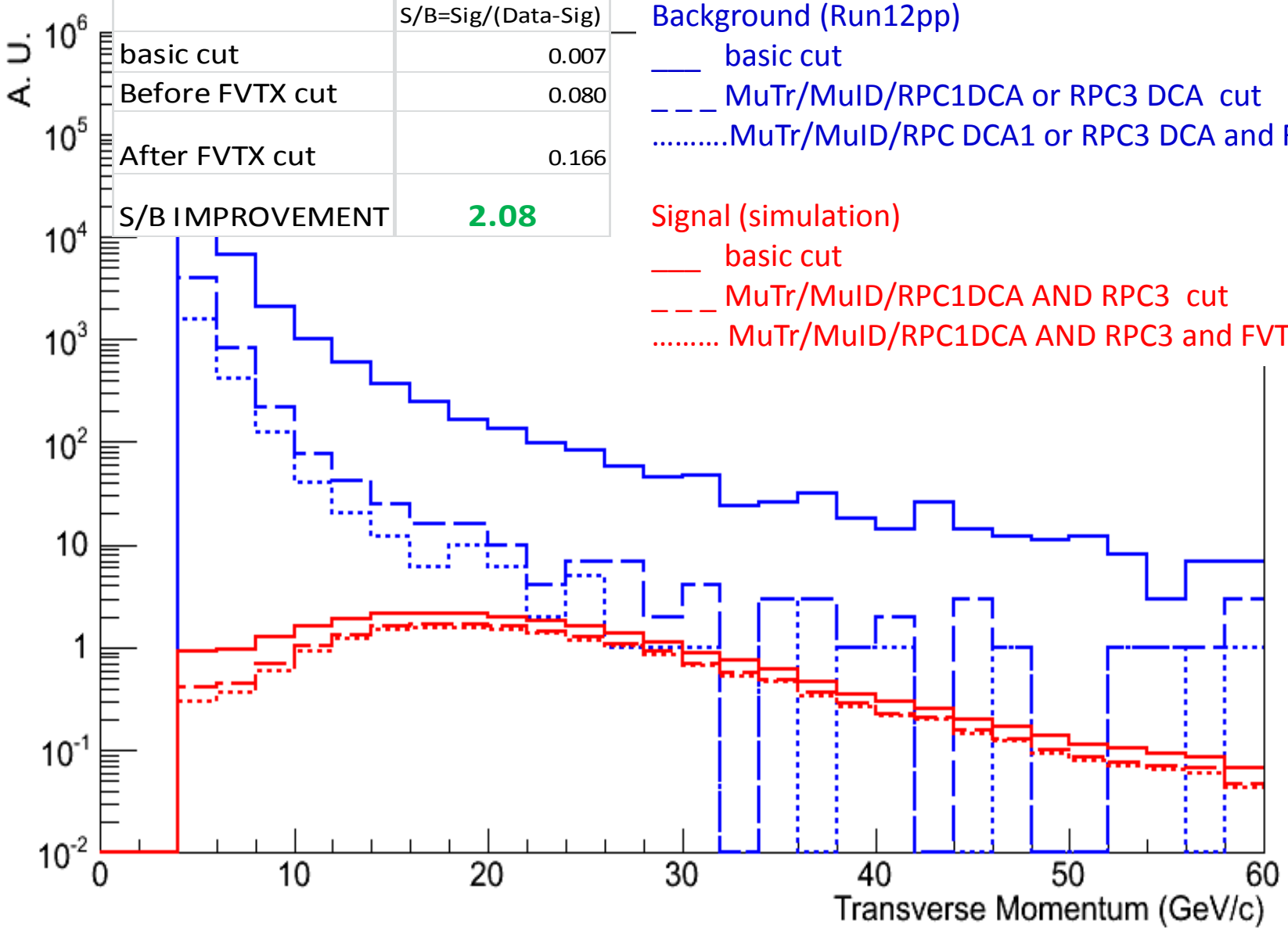
South Minus

Transverse Momentum Distribution

	S/B=Sig/(Data-Sig)
basic cut	0.007
Before FVTX cut	0.080
After FVTX cut	0.166
S/B IMPROVEMENT	**2.08**

Background (Run12pp)
___ basic cut
_ _ _ MuTr/MuID/RPC1DCA or RPC3 DCA cut
…….MuTr/MuID/RPC DCA1 or RPC3 DCA and FVTX cut

Signal (simulation)
___ basic cut
_ _ _ MuTr/MuID/RPC1DCA AND RPC3 cut
…… MuTr/MuID/RPC1DCA AND RPC3 and FVTX cut



- Define likelihood for sig/BGs

λ=p(DG0,DDG0)p(chi2)p(DCA_r)p(Rpc1/3dca)

- Cut parameter for pre-selection: f > f_cut

$$f \equiv \frac{\lambda_{sig}}{\lambda_{sig} + \lambda_{BGs}}$$

Liklihood study

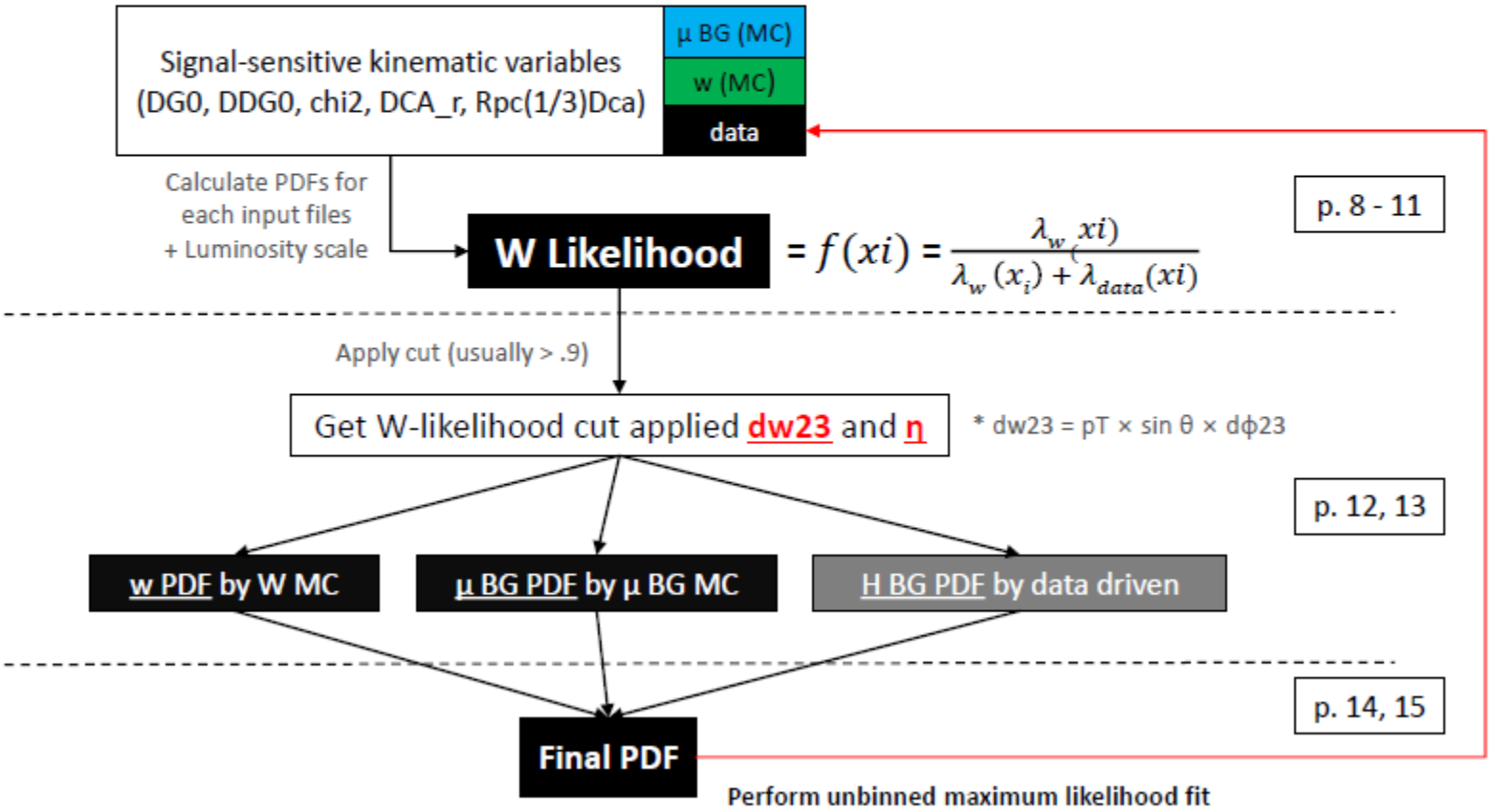
- code-with help of Feng Wei

-testing our code

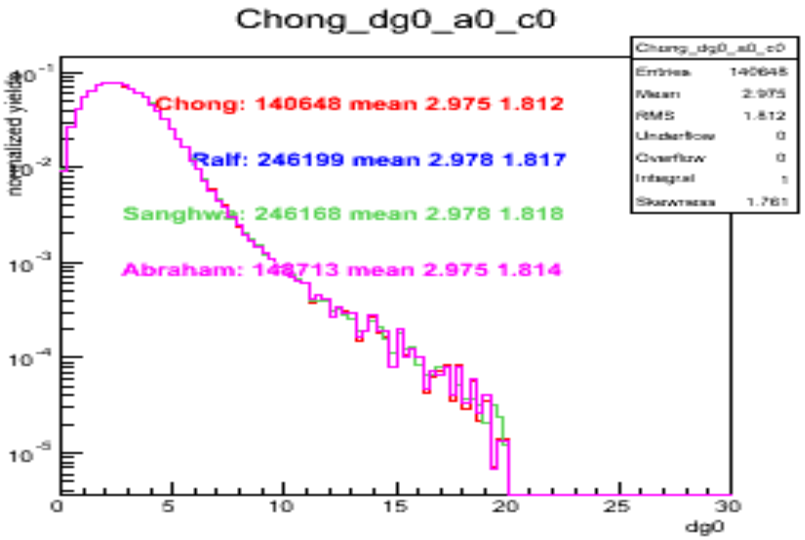
-Start with the DG0-DDG0, chi2, DCA_r, Min of RPC1 and RPC3 dca-> cross check output with Ralf group -> Add FVTX variables

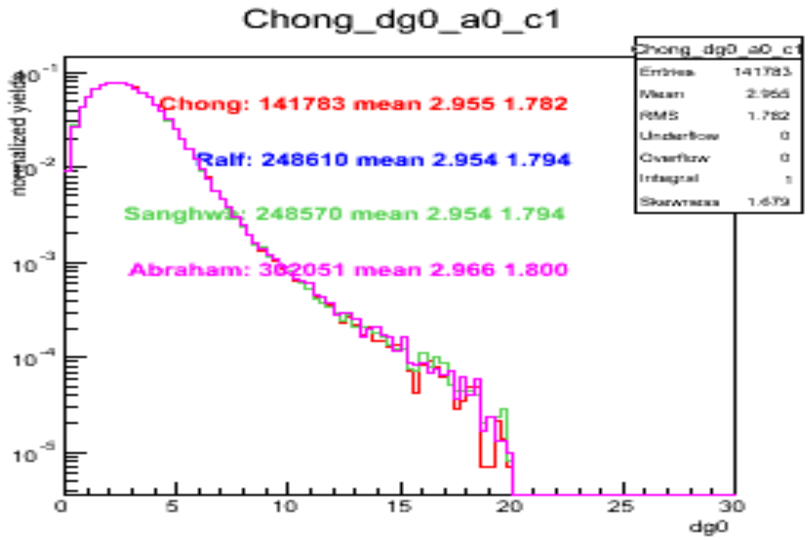
Progress (unbinned maximum likelihood fit)

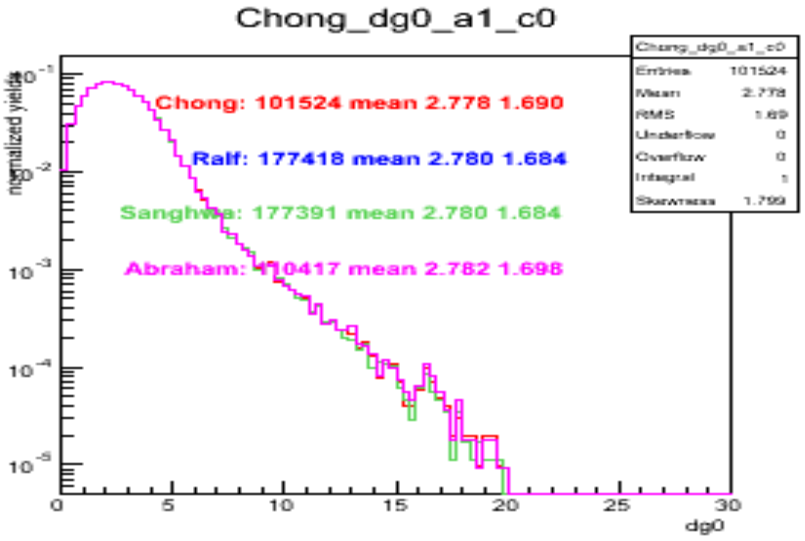
- Process of unbinned maximum likelihood fit:

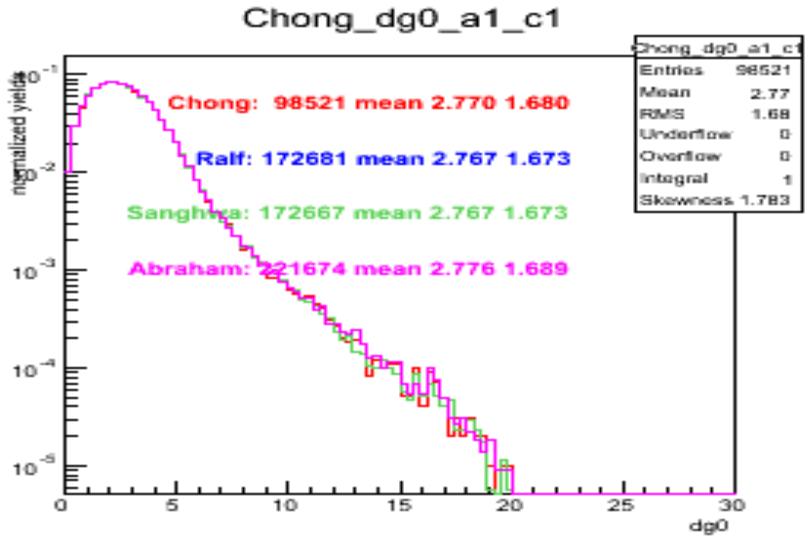


W signal simulation

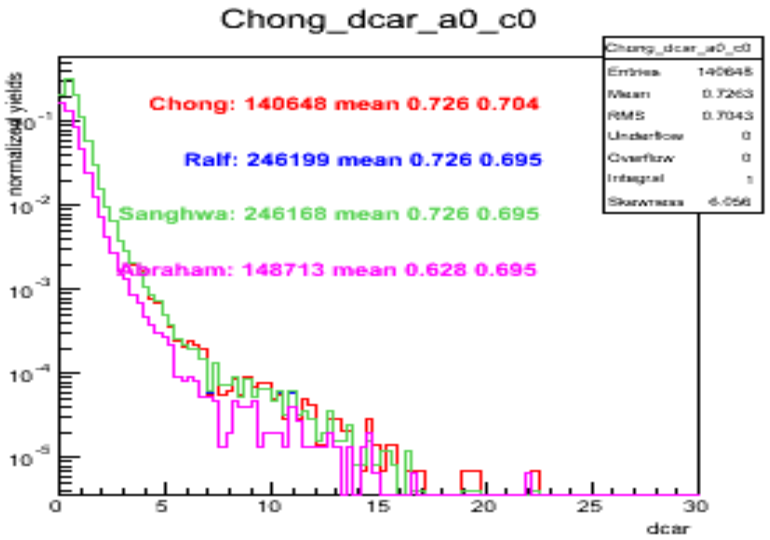


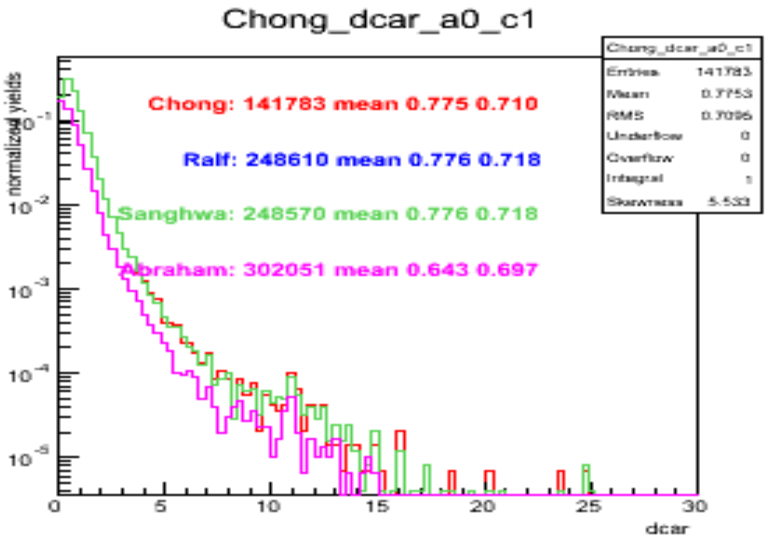


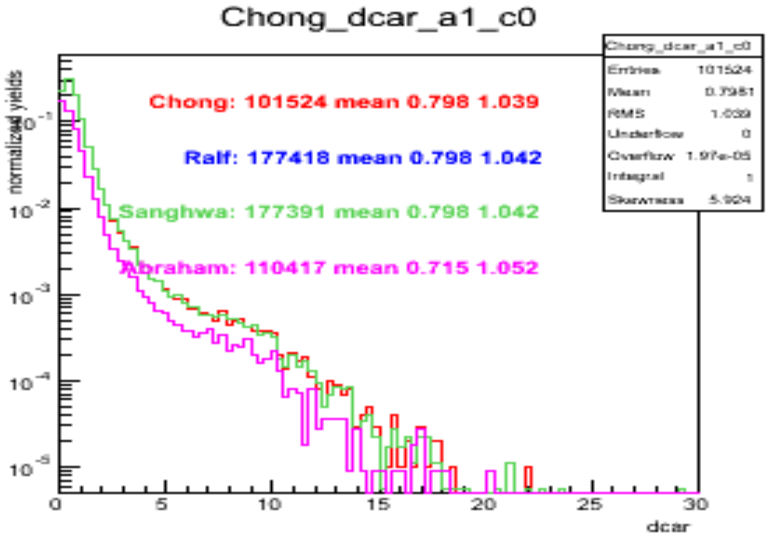


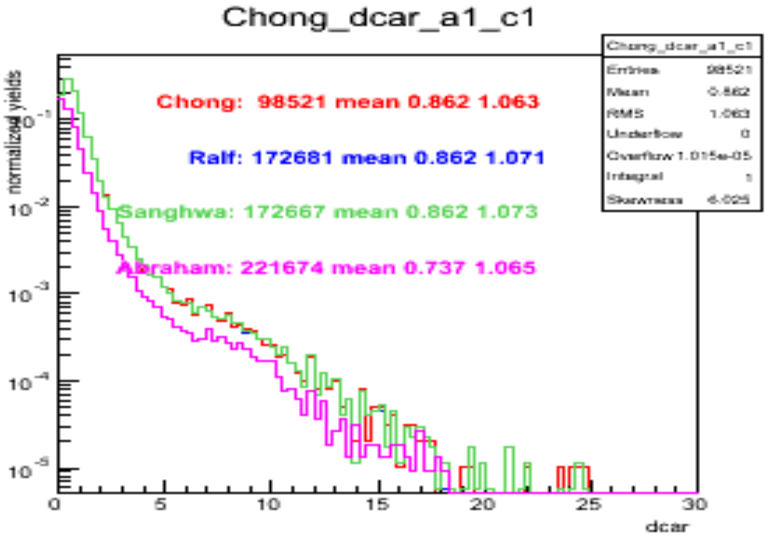


W signal simulation

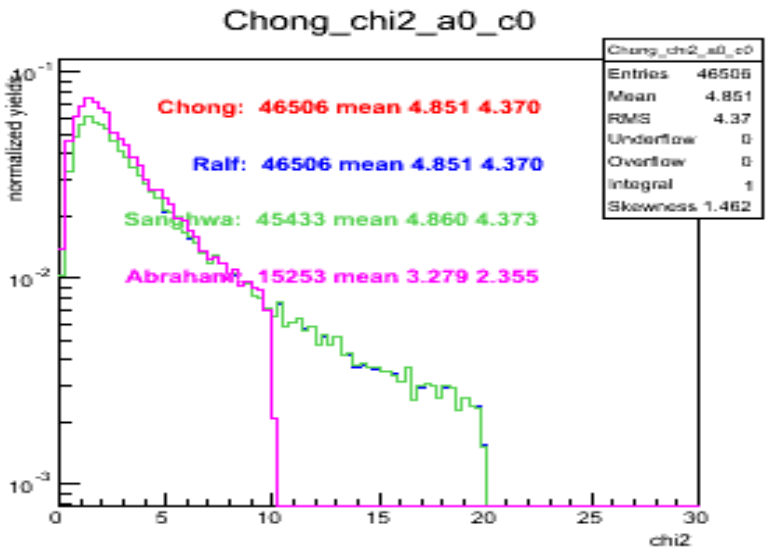


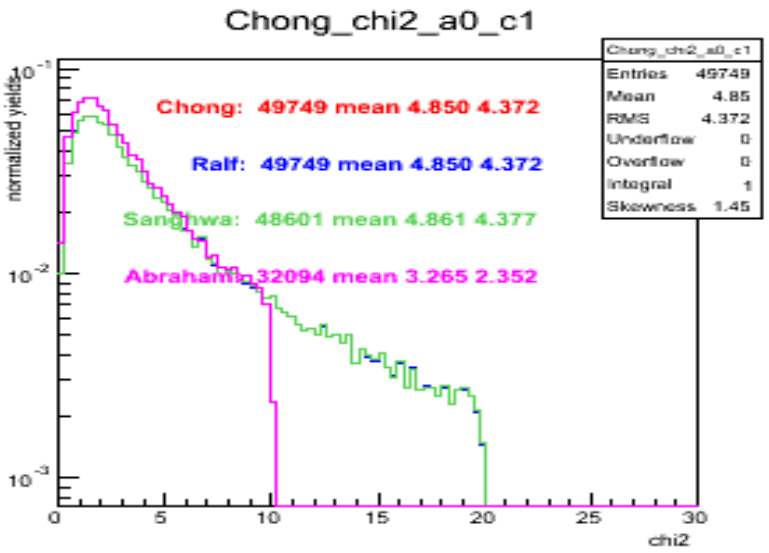


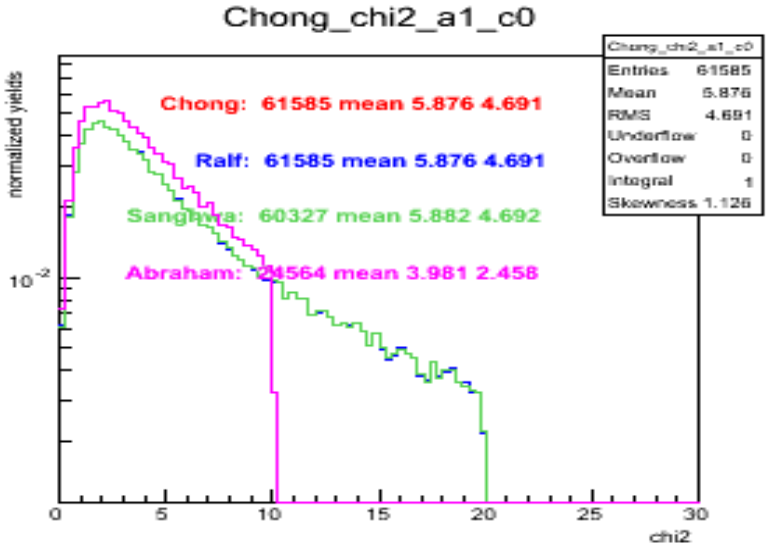


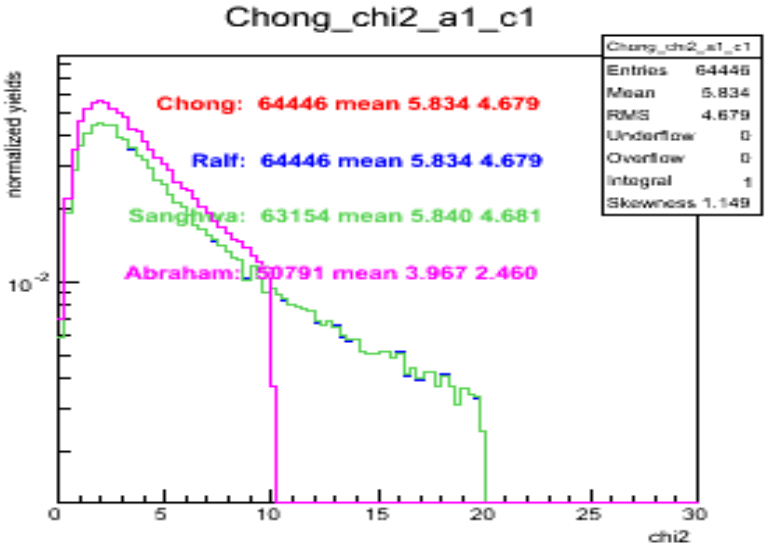


W signal simulation

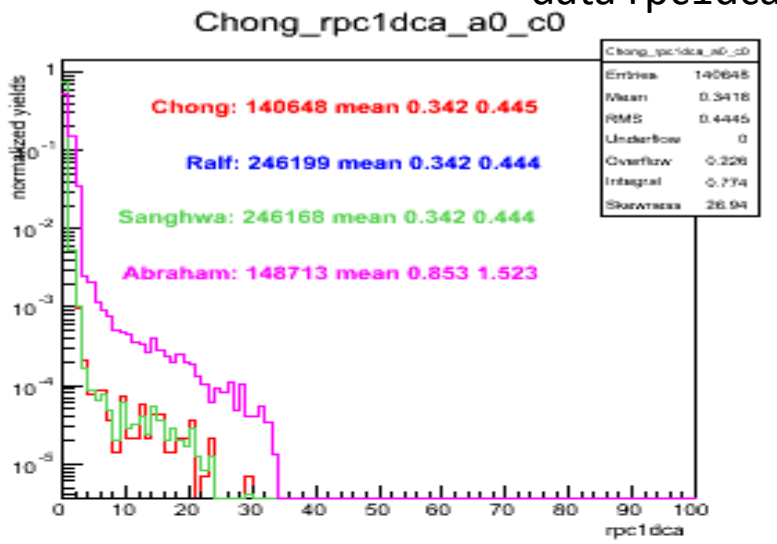


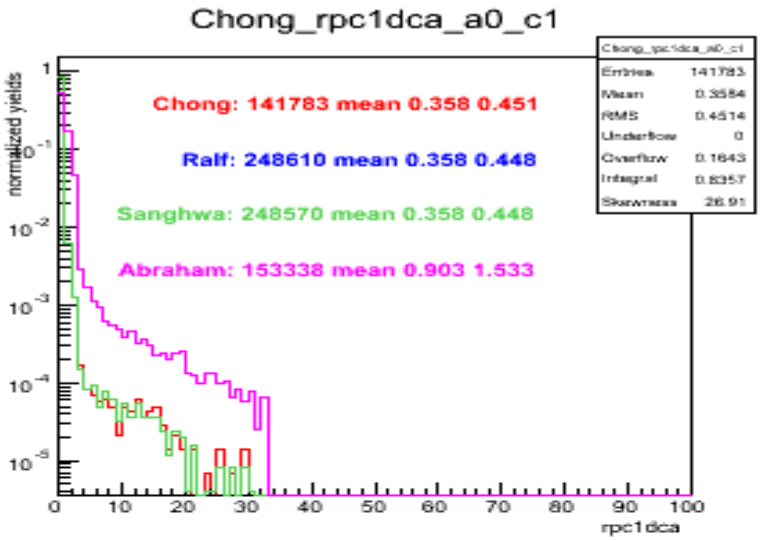


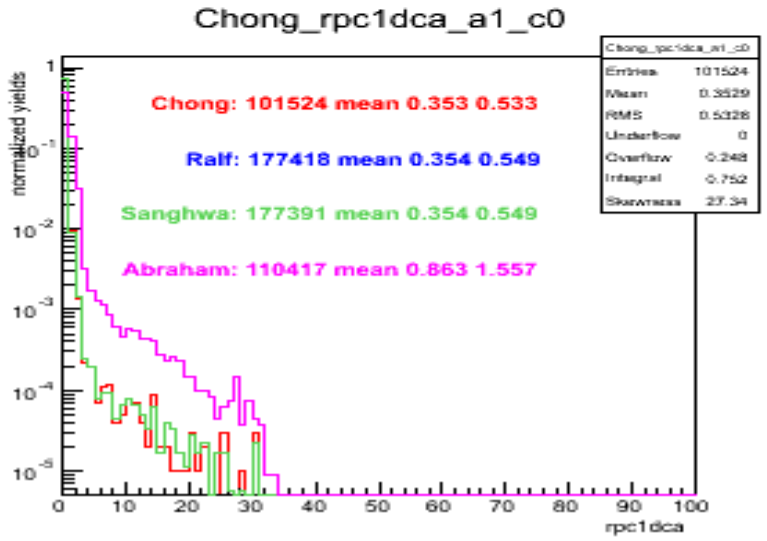


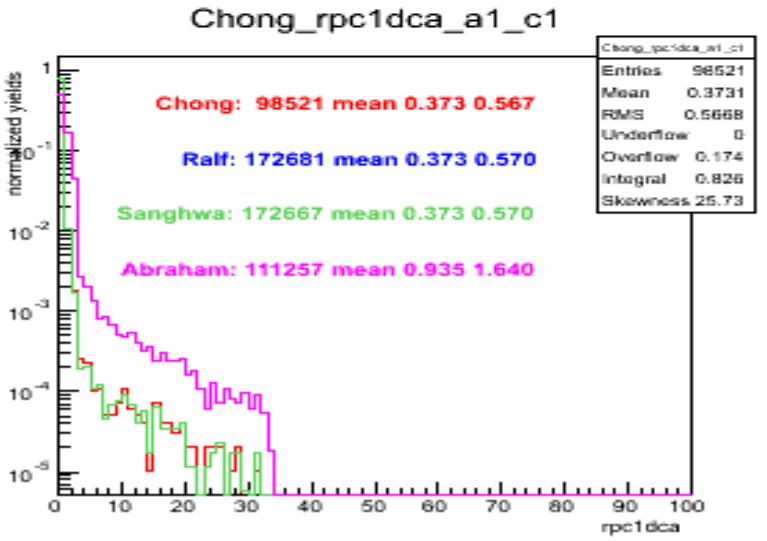


W signal simulation-
inconsistancy both in signal and data rpc1dca

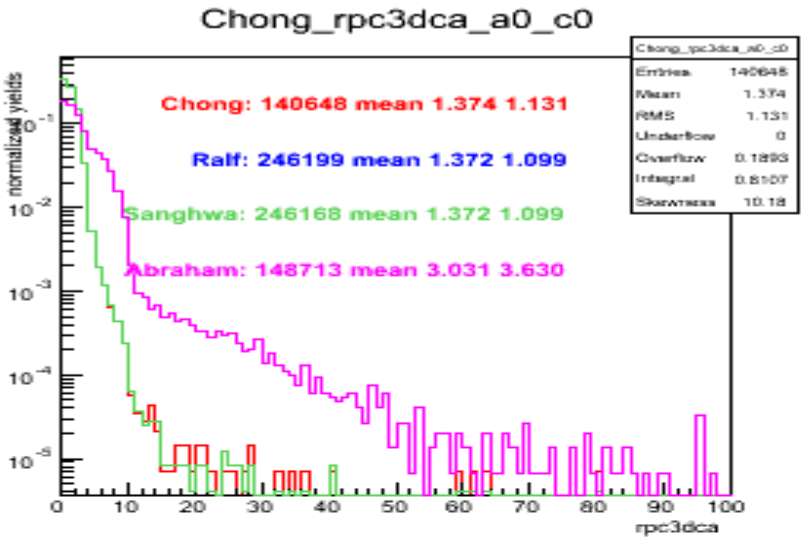


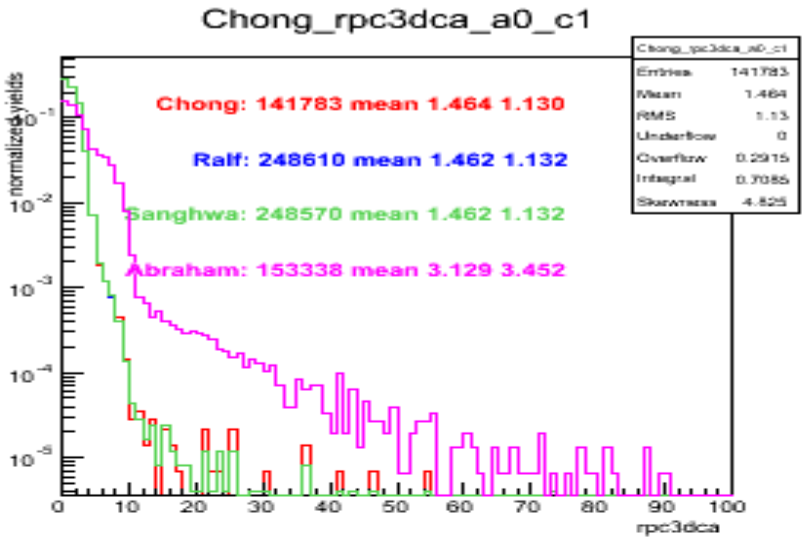


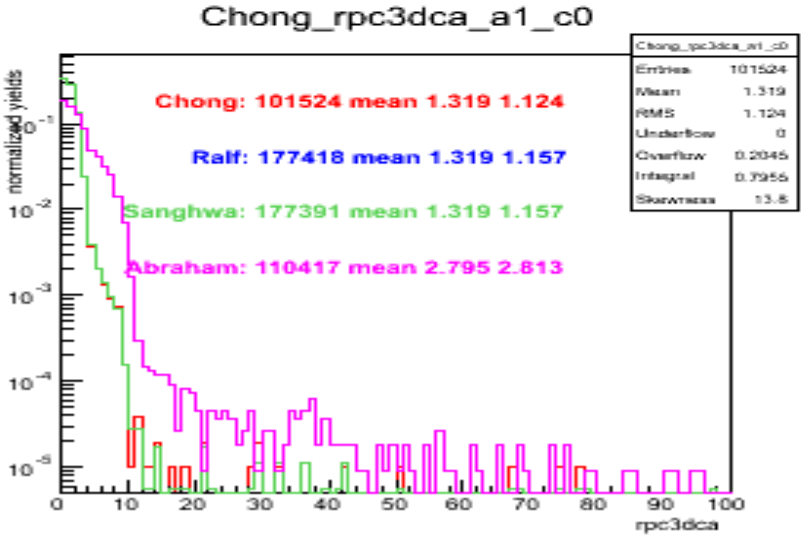


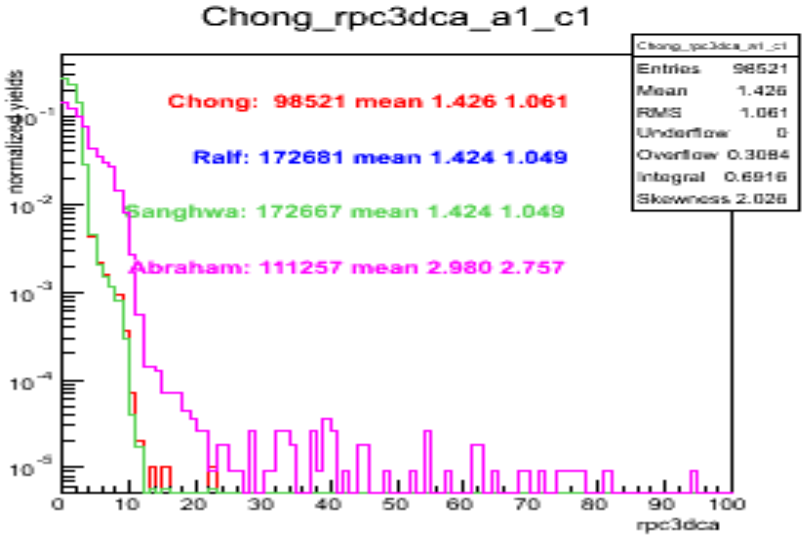


W signal simulation- rpc3dca
(but in data they agree)

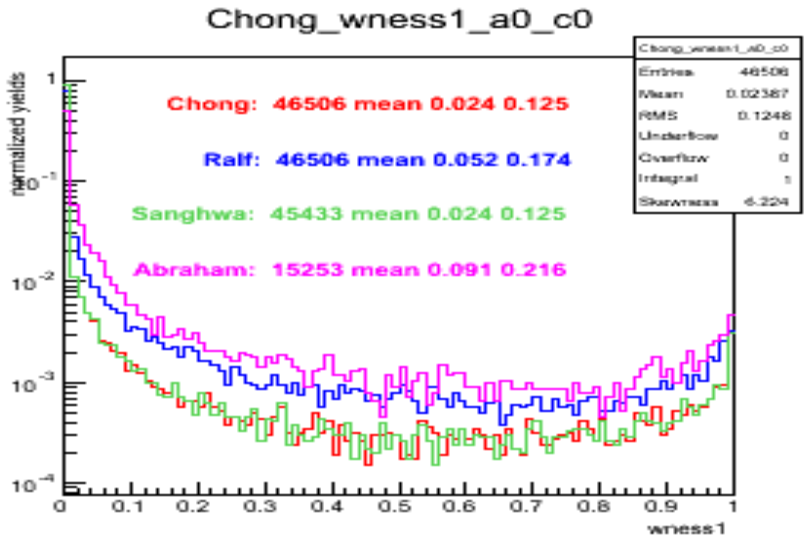


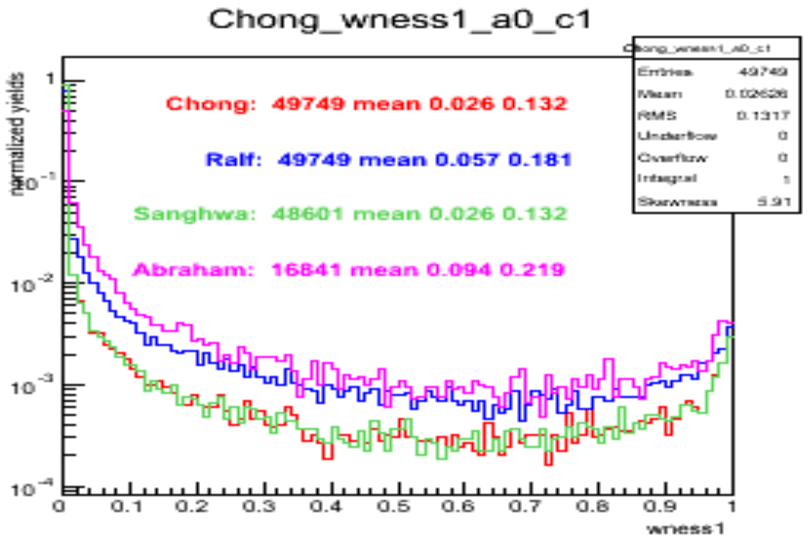


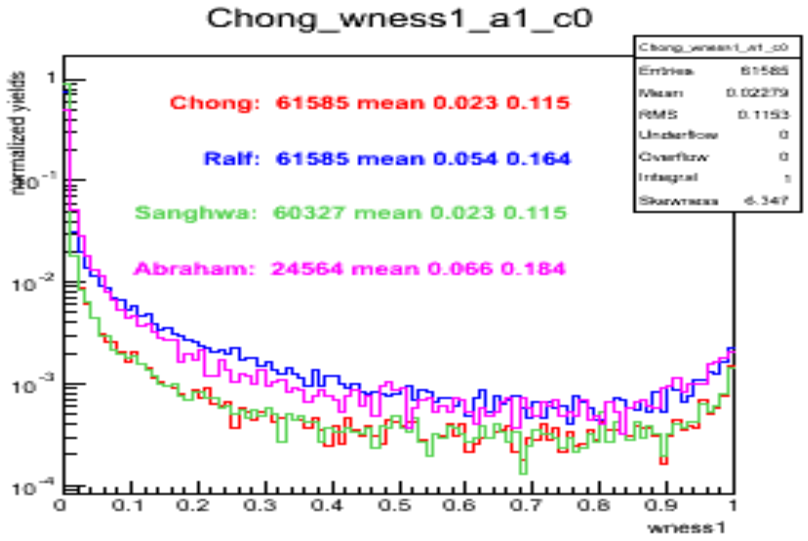


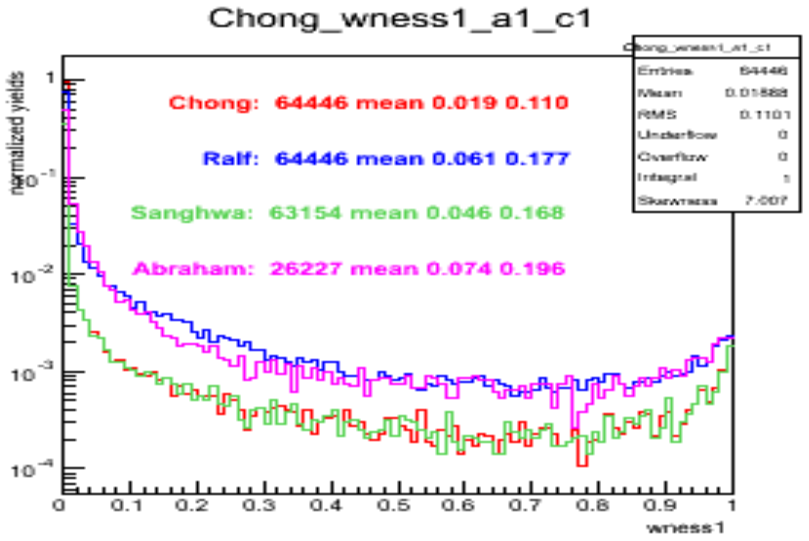


Data-W ness, sig?



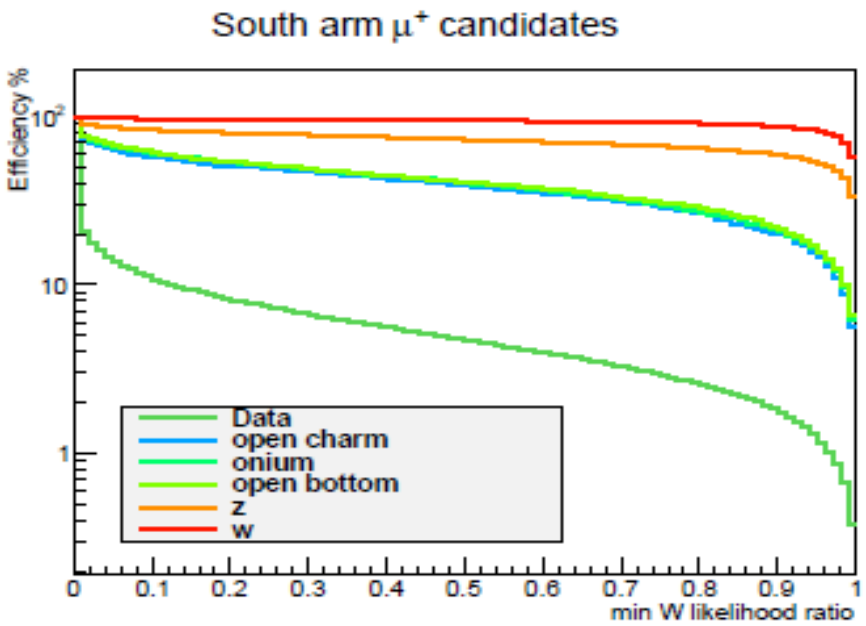


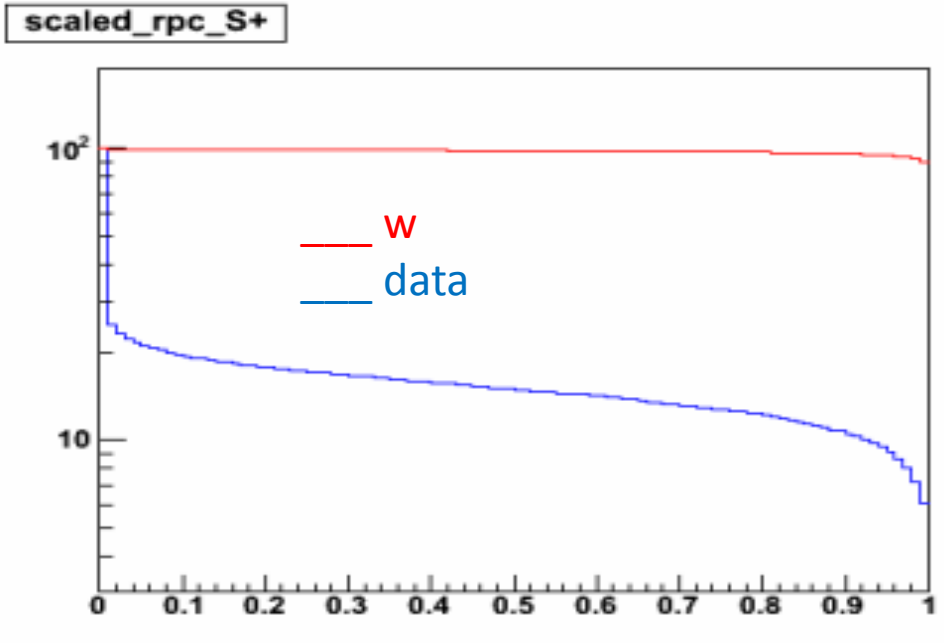


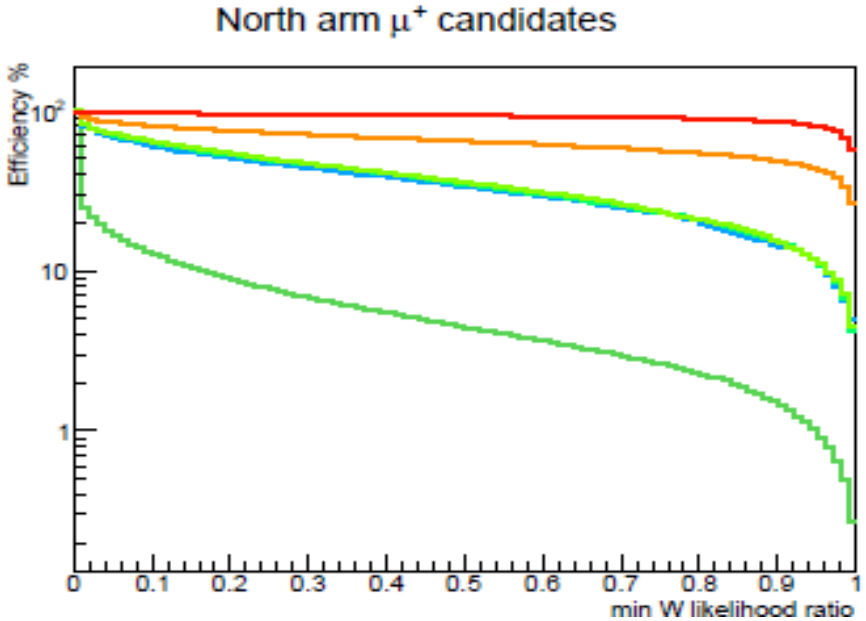


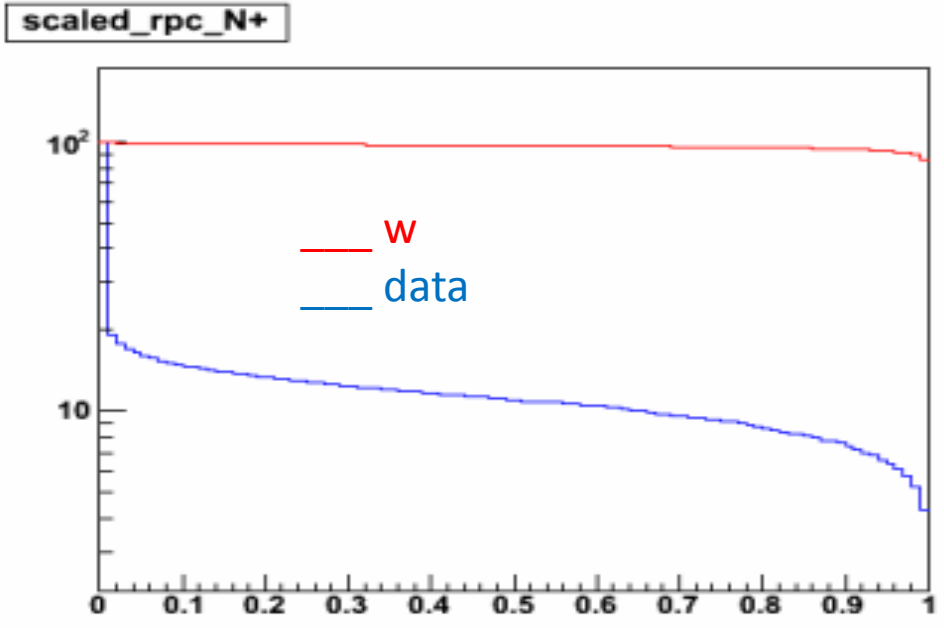
Summary and outlook

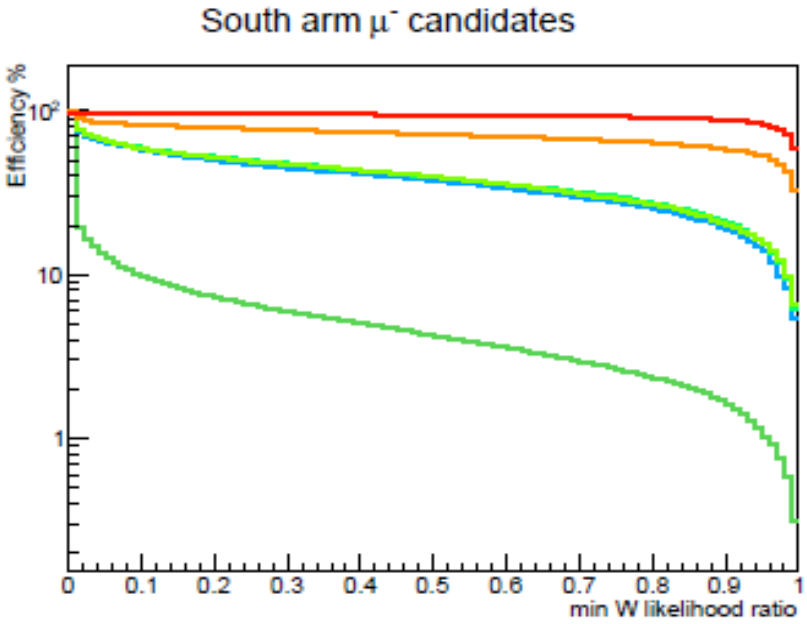
- MuTr/MuID/RPC/FVTX matching variables study for:
  - DG0, DDG0, chi2, dca_r, $\Delta\phi_{12}$, $\Delta\phi_{23}$,RPC1 DCA OR RPC3 DCA, Δr_fvtx, Δθ_fvtx, Δϕ_fvtx
- Inprogress
  - Isolation cut
  - W Likelihood ratio (based on several agreed Variables) as pre-selection
  - Crosscheck with forward analysis group
  - More work during spinfest

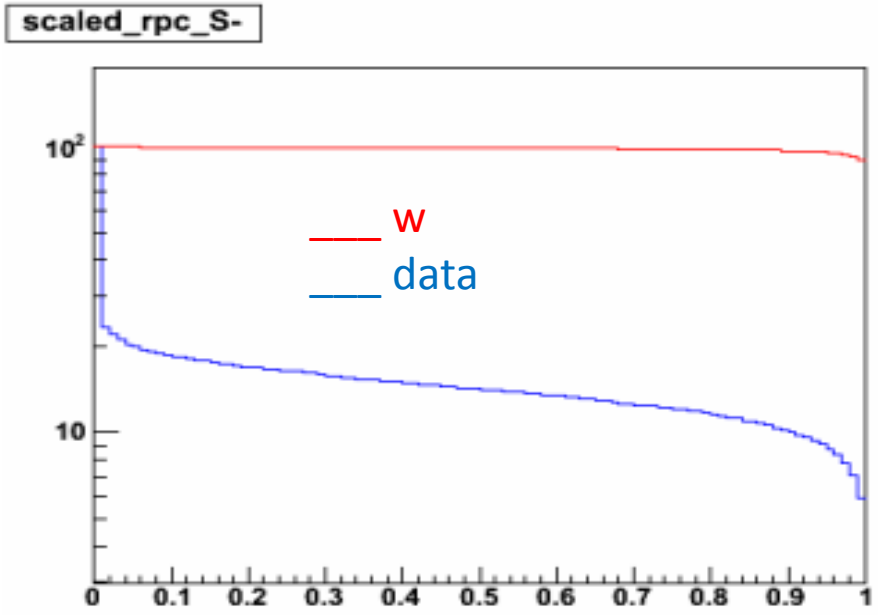

South arm μ⁺ candidates
Efficiency %
10²
10
1
Data
open charm
onium
open bottom
z
w
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
min W likelihood ratio

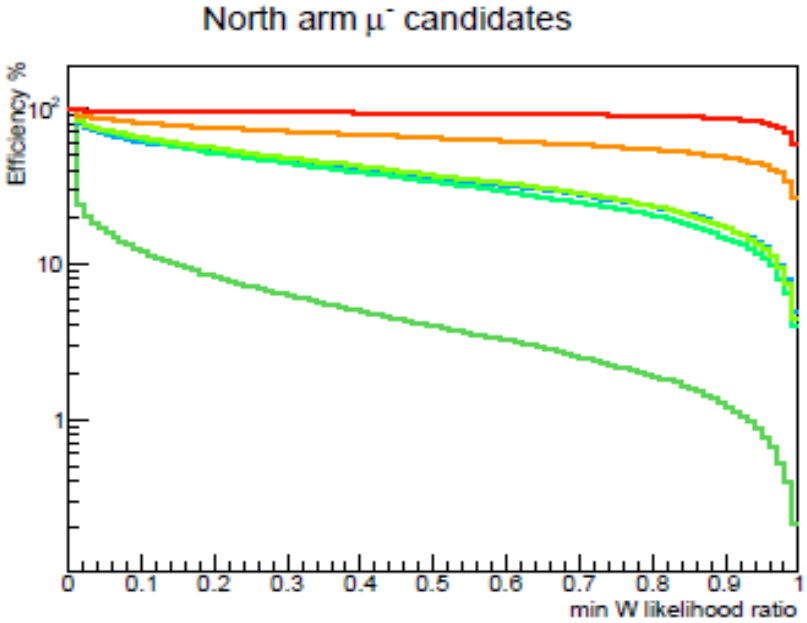

scaled_rpc_S+
10²
10
w
data
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

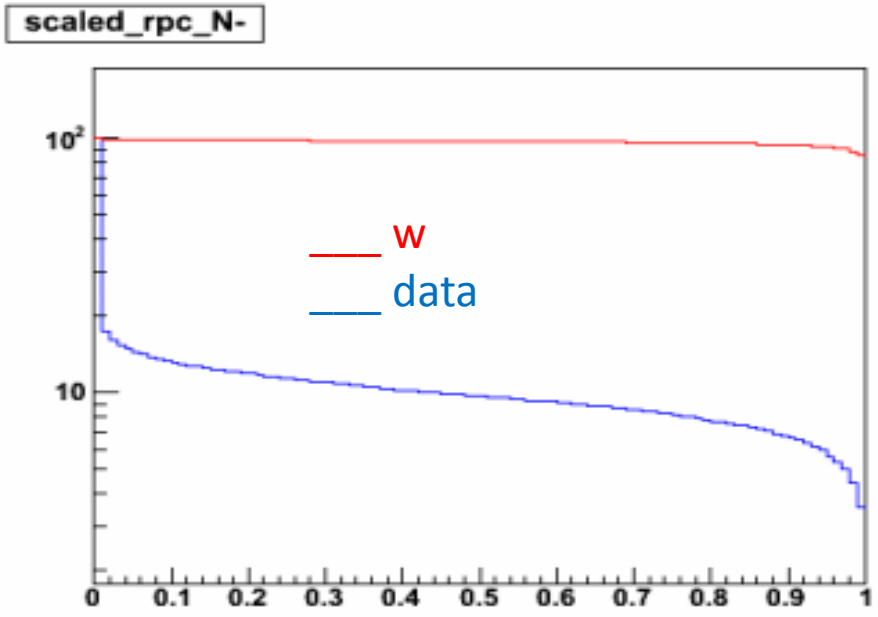

North arm μ⁺ candidates
Efficiency %
10²
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
min W likelihood ratio


scaled_rpc_N+
10²
10
w
data
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

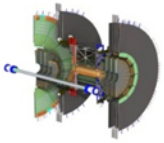

South arm μ⁻ candidates
Efficiency %
10²
10
1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
min W likelihood ratio


scaled_rpc_S-
10²
10
w
data
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

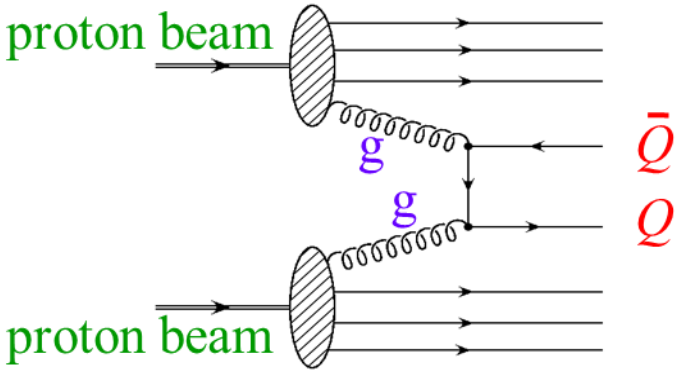

North arm μ⁻ candidates
Efficiency %
10²
10
1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
min W likelihood ratio


scaled_rpc_N-
10²
10
w
data
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

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"

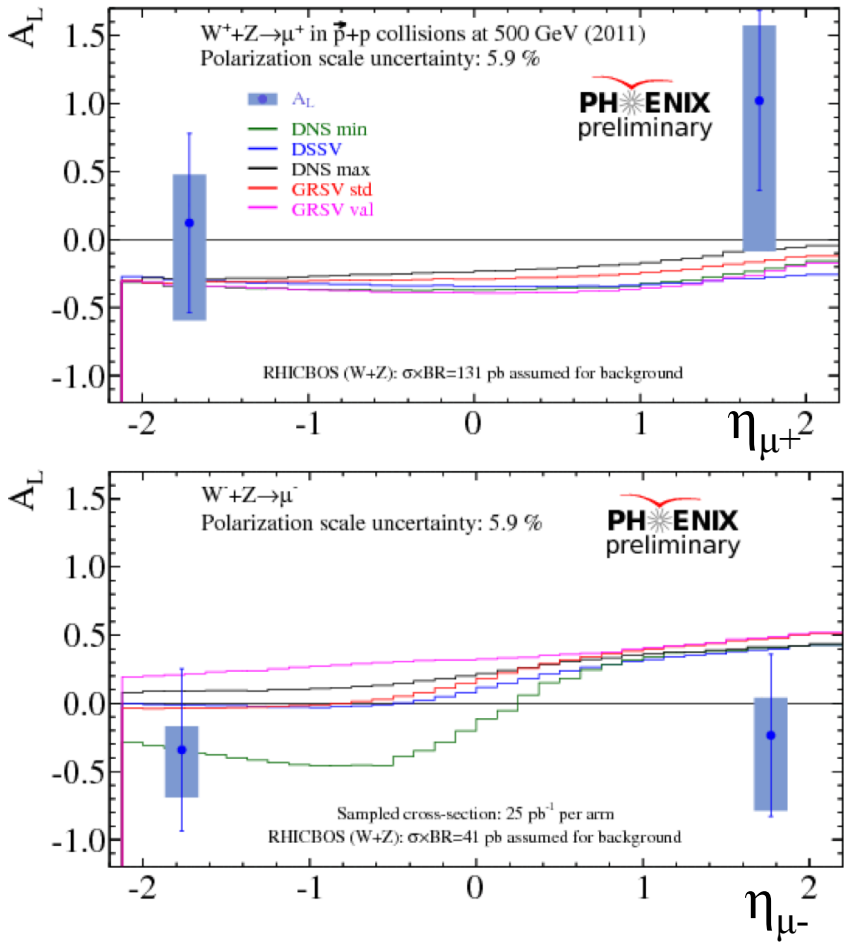
E.g. $c \rightarrow D \rightarrow \mu + X$

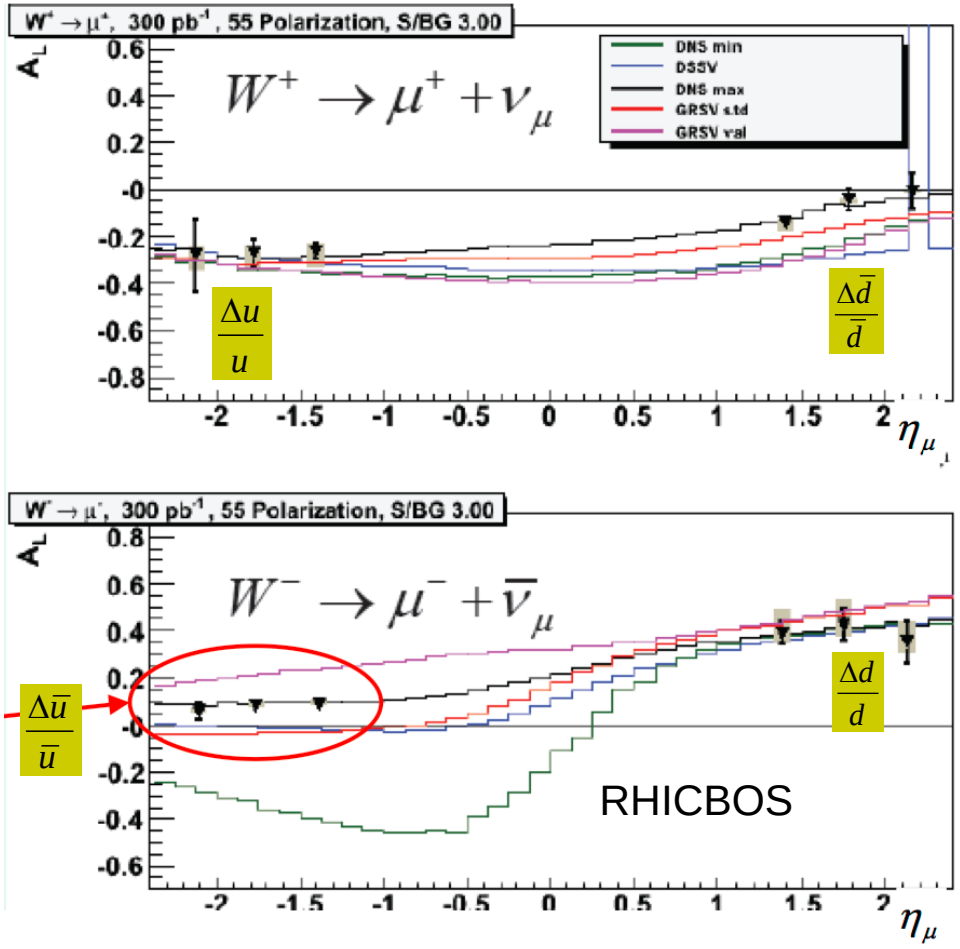
This is a weak meson decay and so is slow. $\tau \approx 10^{-12}$ s $\quad c\tau \approx 10^{-2}$ cm

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