Drell-Yan Cross Section and Longitudinal Double Spin Asymmetry in the PHENIX Experiment at RHIC

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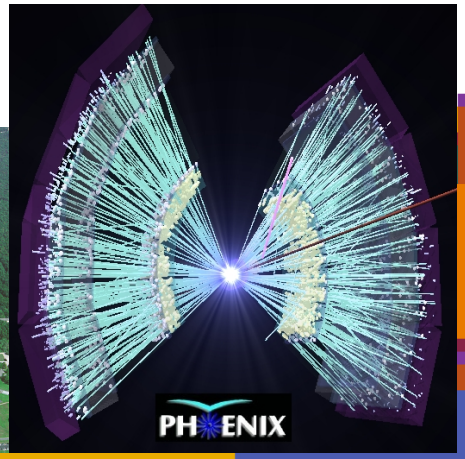
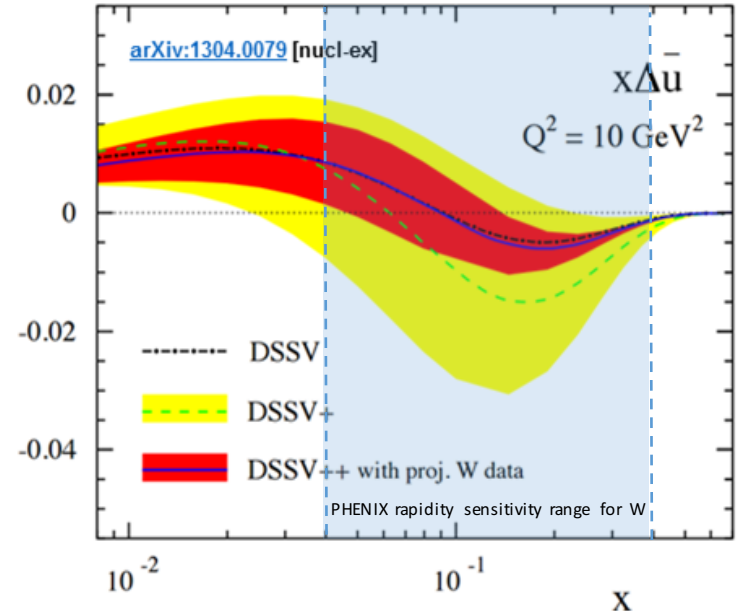


DNP October Meeting

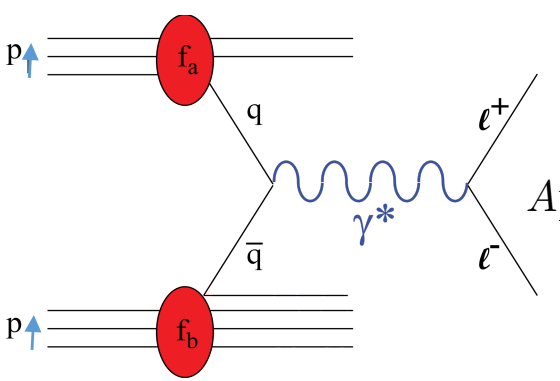
29th October 2015 Santa Fe

Motivation

- Spin dependent quark distribution
  Polarized Parton distribution function (pPDF)
  - $\Delta q(x)$: Δu and Δd are well known from the (SI)DIS data
  - $\Delta\bar{q}(x)$: $\Delta\bar{u}$ and $\Delta\bar{d}$ measured with larger uncertainties



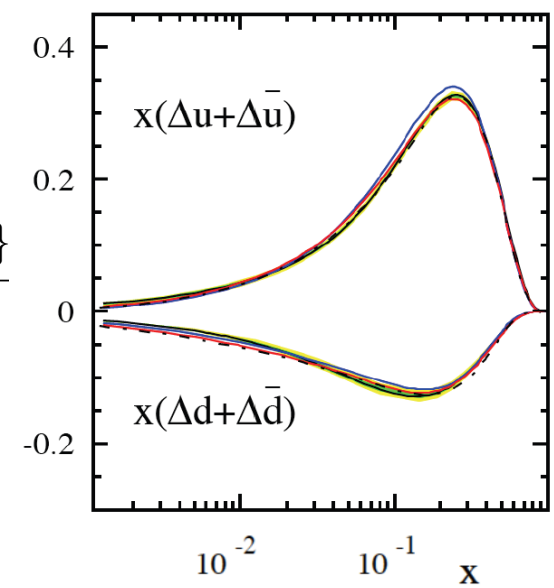
- Drell-Yan A_{LL} can cleanly access $\Delta\bar{u}/\bar{u}$ which gives the anti-quark helicity distributions in the nucleon sea



$$A_{LL}^{DY} = -\frac{\sum_q e_q^2\{\Delta q(x_1)\Delta\bar{q}(x_2) + \Delta\bar{q}(x_1)\Delta q(x_2)\}}{\sum_q e_q^2\{q(x_1)\bar{q}(x_2) + \bar{q}(x_1)q(x_2)\}}$$

$$\approx -\frac{\Delta u(x_1)}{u(x_1)} \cdot \frac{\Delta\bar{u}(x_2)}{\bar{u}(x_2)}$$

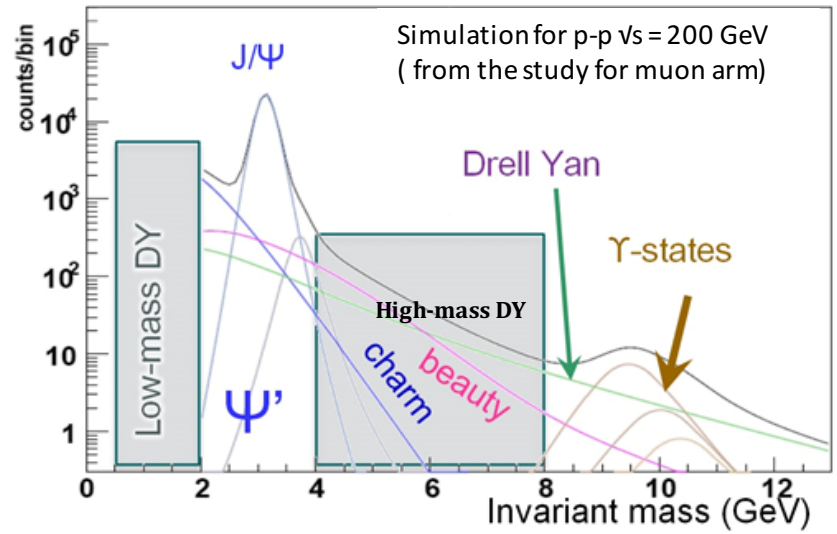
u-quark dominates in p+p
(84% of time Drell-Yan involves a u quark)

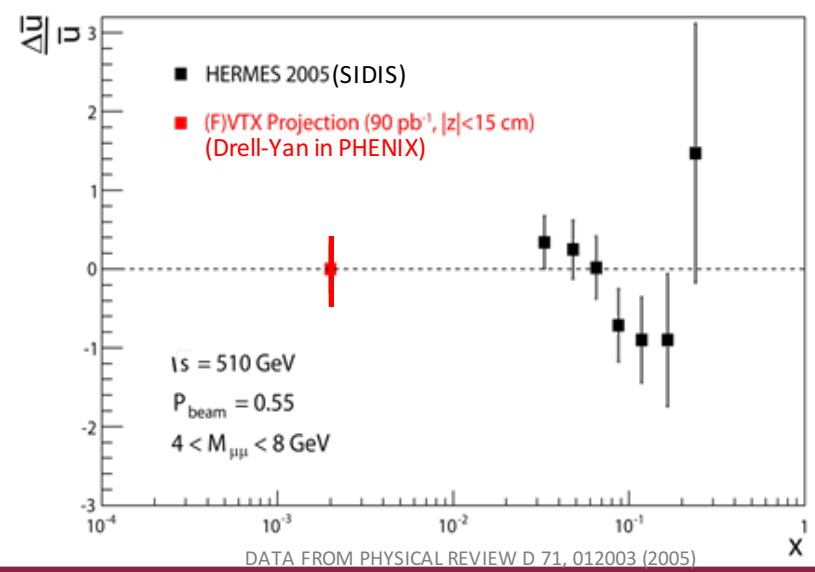


- No fragmentation functions are needed for the interpretation of Drell-Yan process

Drell-Yan Measurement at PHENIX

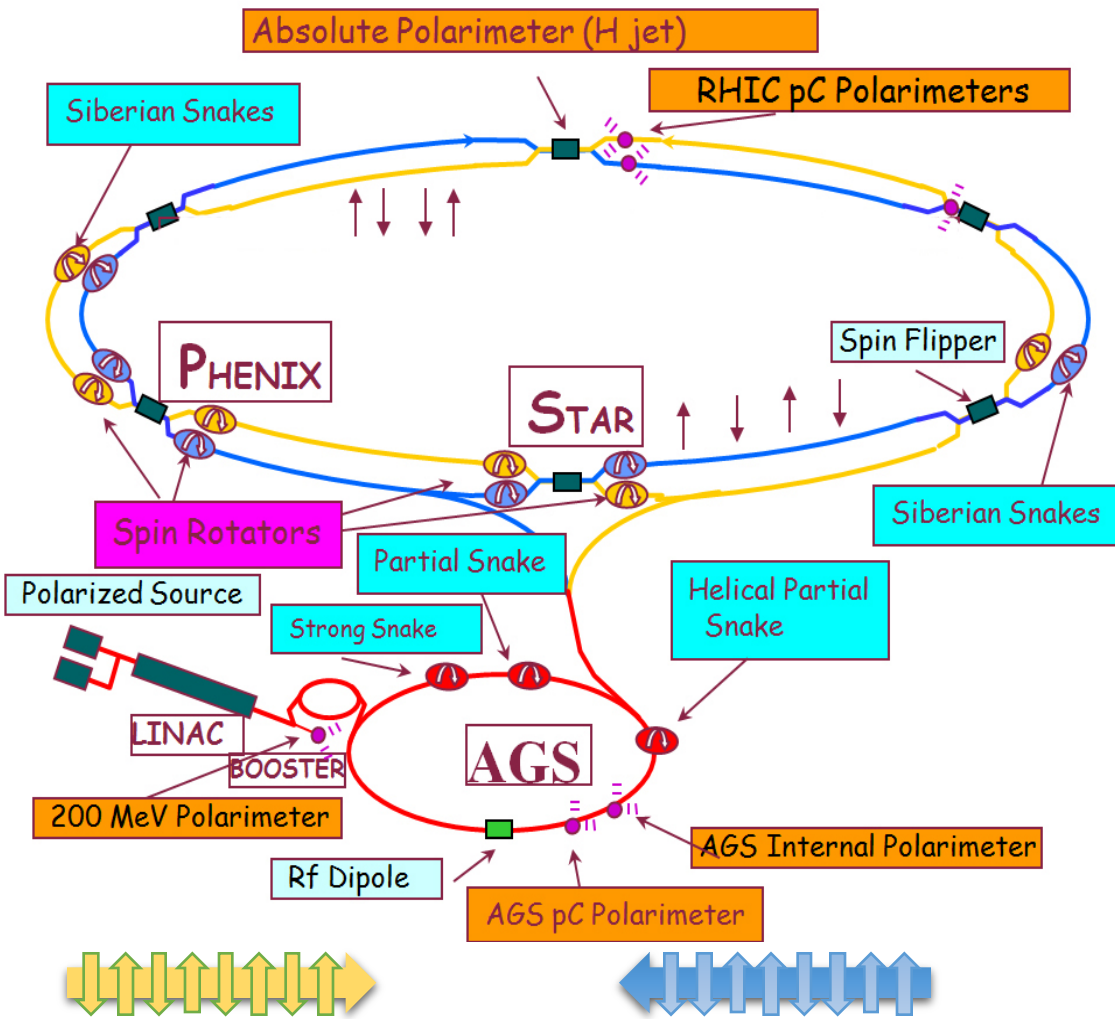
- We are interested in the Drell-Yan process between 4 GeV < M < 8 GeV of invariant mass
- We observe prompt muons from DY and Displaced muon tracks from heavy quark decays
- The PHENIX FVTX can help to reduce the dominant background from beauty decays in forward arm acceptance (1.2<|η|<2.4) in low x (~2×10^{-3}).
- The physics goal is to study the DY cross section, pT dependence, and relative yield of HF to DY
- These measurement will be used to extract double spin asymmetry (with limited statistics) and building towards the future measurements

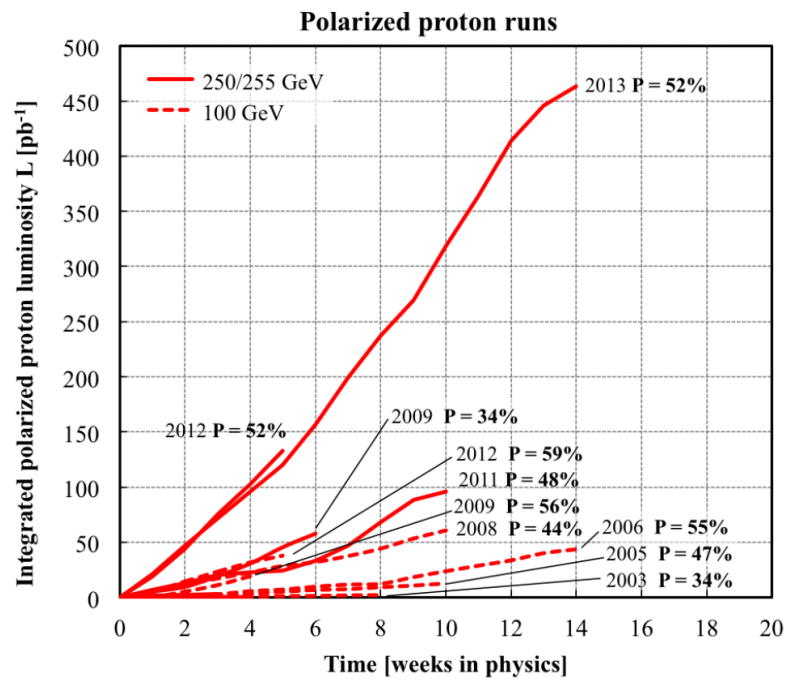




DATA FROM PHYSICAL REVIEW D 71, 012003 (2005)

RHIC as a Polarized p + p Collider





Run 12 Luminosity

- narrow vertex ($|z| < 15$ cm) : 15 pb^{-1}

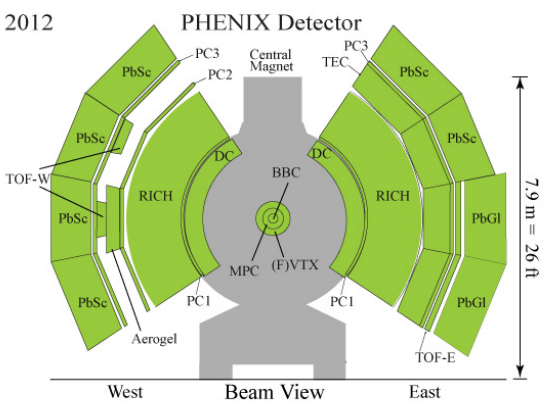
Run 13 Luminosity

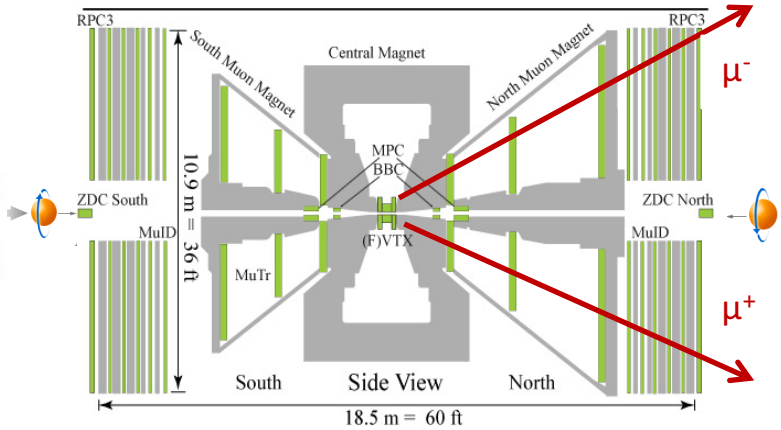
- narrow vertex ($|z| < 15$ cm) : 75 pb^{-1}

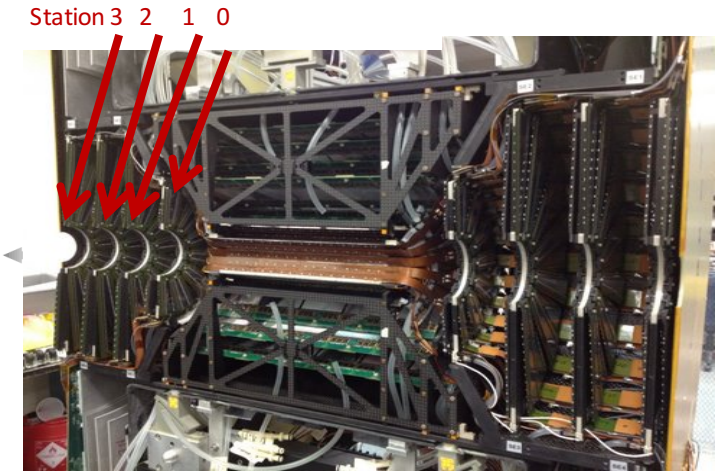
Run 12 Average Proton Polarization - 52%

Run 13 Average Proton Polarization - 52%

PHENIX Detectors







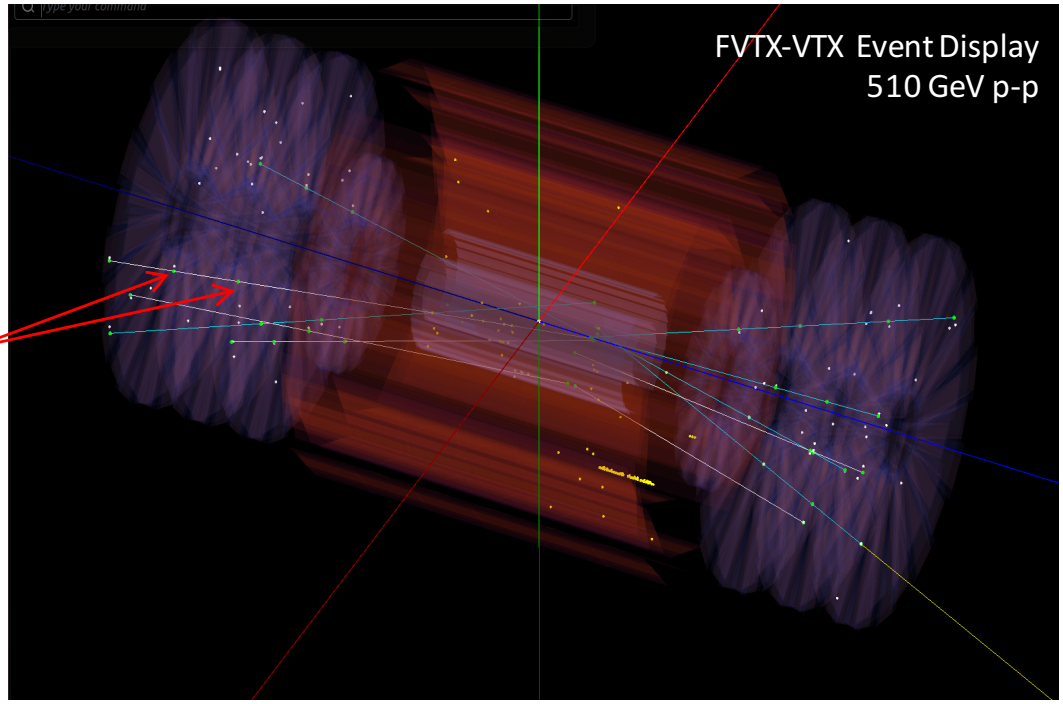
- Muons and Hadrons in the forward regions
  - Mu ID
  - Mu Trackers
  - RPC
  - FVTX

▪ FVTX for forward tracking

➢ 4 planes per end-cap
➢ Coverage
  - $1.2 < |\eta| < 2.4$
  - 2π in ϕ
  - $|z| < 15$ cm
➢ Resolution
  - Hit ~ 25μm
  - DCAR ~ 150μm (Combined VTX and FVTX)

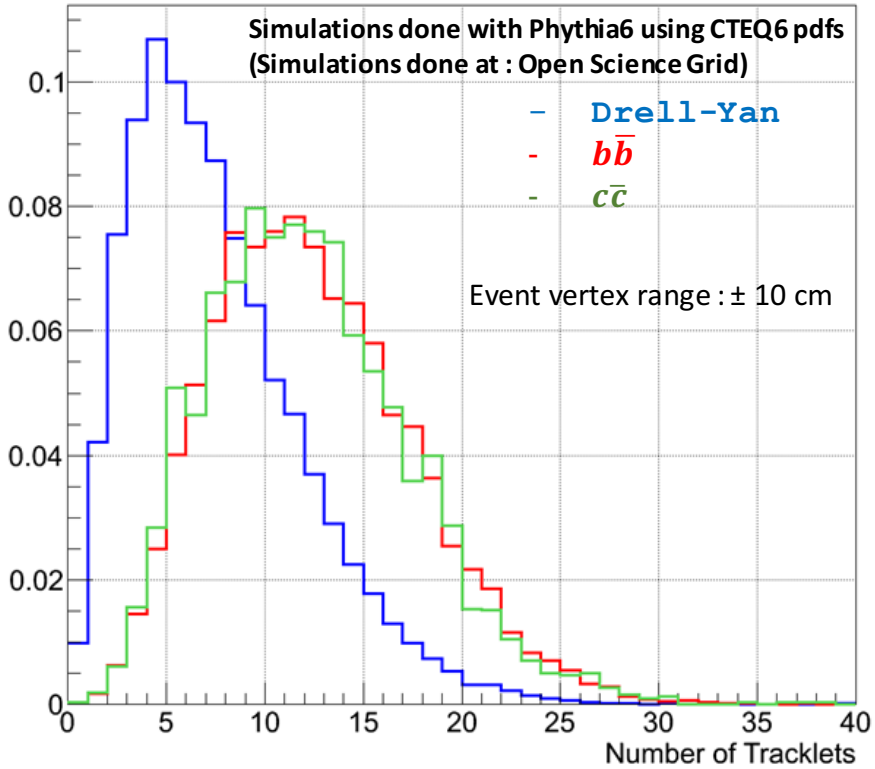
Introduction to Tracklets

2 or more hits reconstructs a tracklet

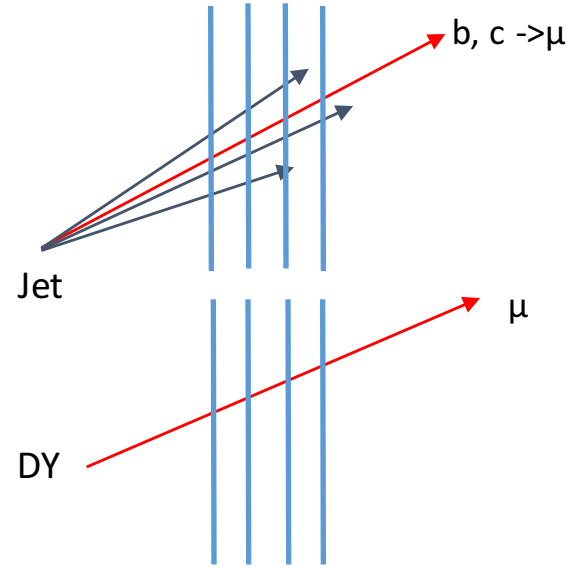


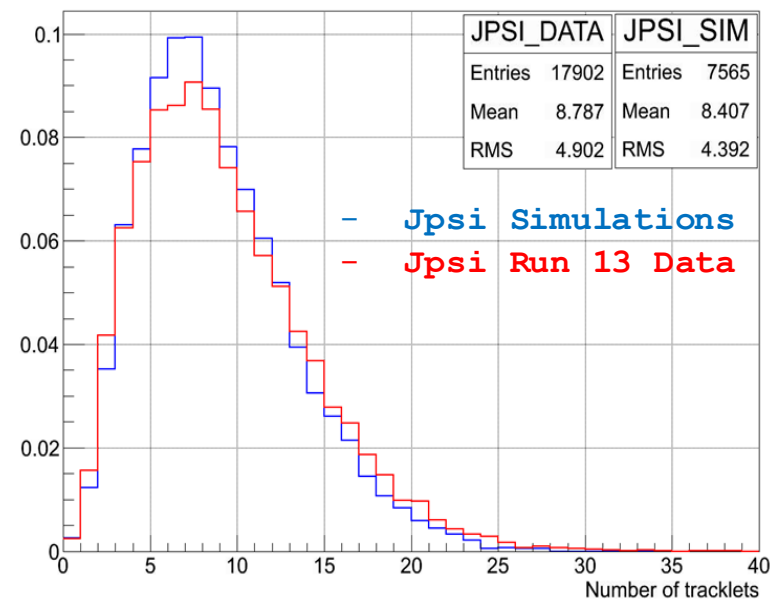
- Two hits in FVTX detector + the primary vertex / three hits in FVTX can be used to reconstruct a tracklet
- For each event, we observe tracklets in both arms of FVTX
- We count the number of tracklets pointing to the primary vertex

Comparison of the Tracklet Activity in FVTX



A jet generate more tracklets in FVTX than the Drell-Yan event

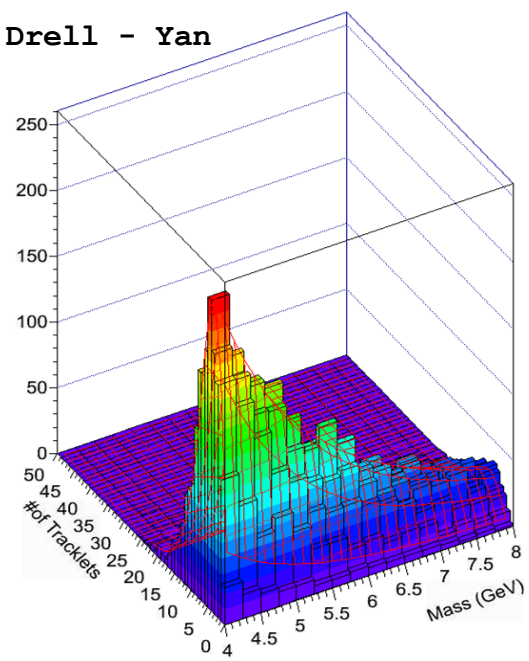




- The simulation show that the tracklet distribution in FVTX is a powerful tool to separate Drell-Yan from the heavy flavor backgrounds
- Comparison of J/Psi simulations and Run 13 Data shows that tracklet simulations match with the Data

Analysis Procedure

- Main challenge is to determine the signal fraction in our data
- Simulated events are plotted in to two dimensional histograms of Number of Tracklets Vs. Mass (For Drell-Yan, $b\bar{b}$ and $c\bar{c}$)
- Fit the histograms with 2-D functions and obtain the templates for the simulated signal and backgrounds

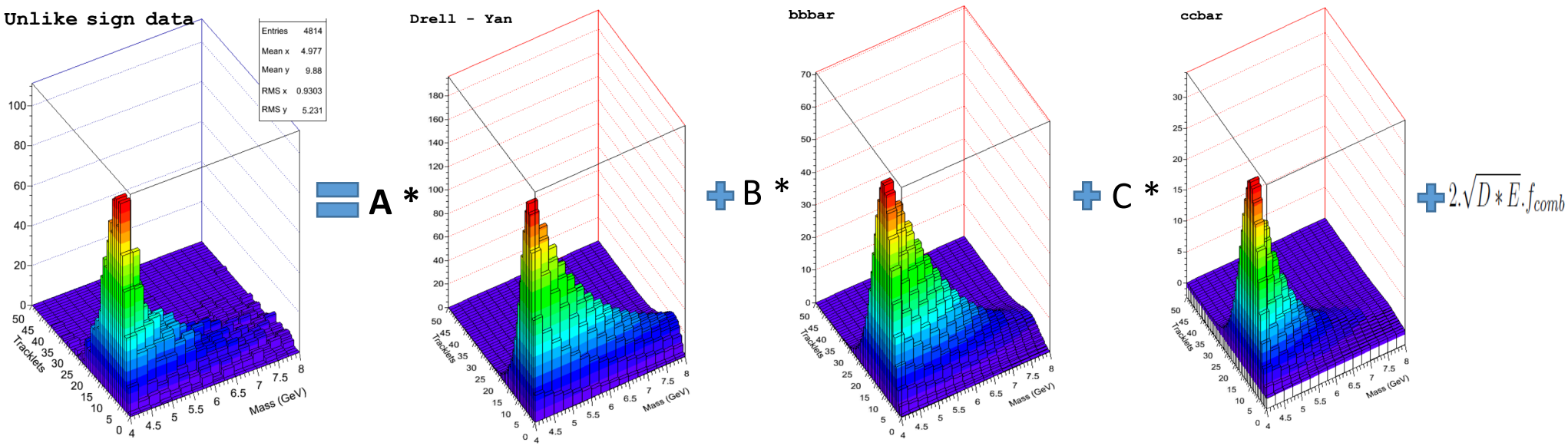


$$f_{DY}(x,y) = exp(ax + bx^2).\left(\frac{c + d * x}{e + f * x}\right)^{y/(e+f*x)}.$$

$$\frac{exp(-((c + dx)/(e + fx)))}{Gamma((y/(e + f * x)) + 1)}.(g + h * y + iy^2)$$

Analysis Procedure

- Two sets of like sign dimuon data and the unlike sign dimuon data are fitted simultaneously with the template functions



$$f^{+-}_{Final}(x,y) = A.f_{DY} + B.f_{b\bar{b}} + C.f_{c\bar{c}} + 2.\sqrt{D*E}.f_{comb}$$

D and E come from the likesign fitting

- The fractions of signal and each background are determined from the fitting parameters

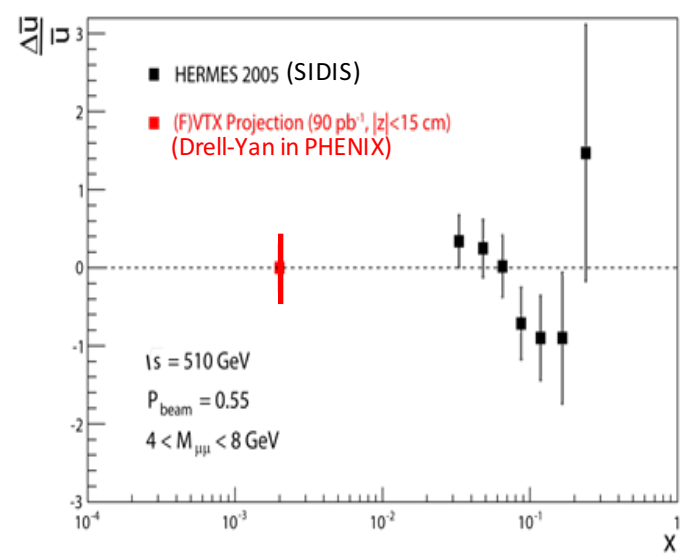
Summary

- Correlated $b\bar{b}$, $c\bar{c}$ and the combinatorial background are the sources of background for the Drell-Yan measurement for the high mass region

- PHENIX muon tracker and FVTX play a major role in the forward arm Drell-Yan Measurements

- Analysis Method for determining signal fraction: Likelihood fitting with 2-D templates

  - Tracklet count distribution Vs Mass



- Currently, we are working on
  - Measuring the Drell-Yan signal fraction
  - Measuring the Drell-Yan longitudinal double spin asymmetry
- Future plan
  - Measure the Drell-Yan cross section

Backup

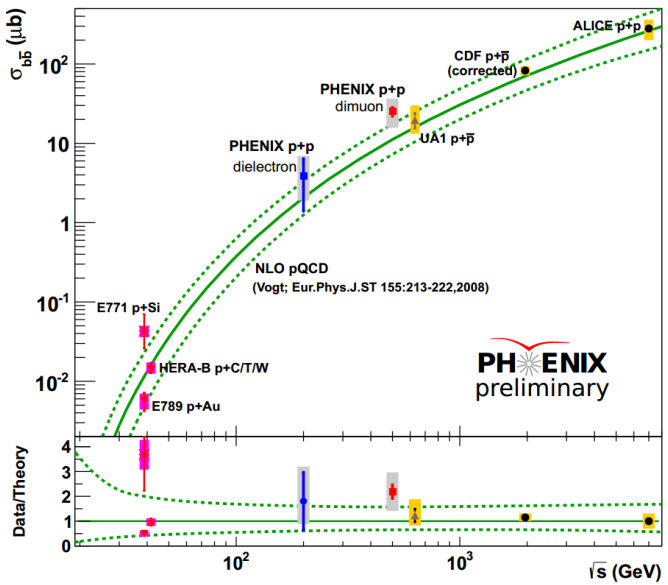
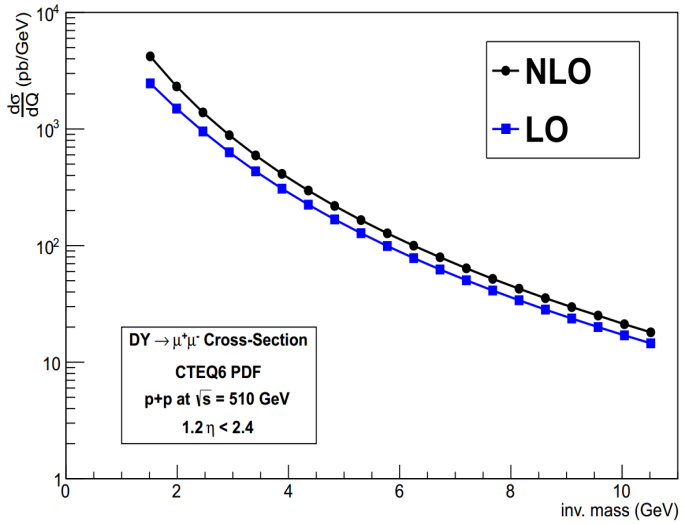
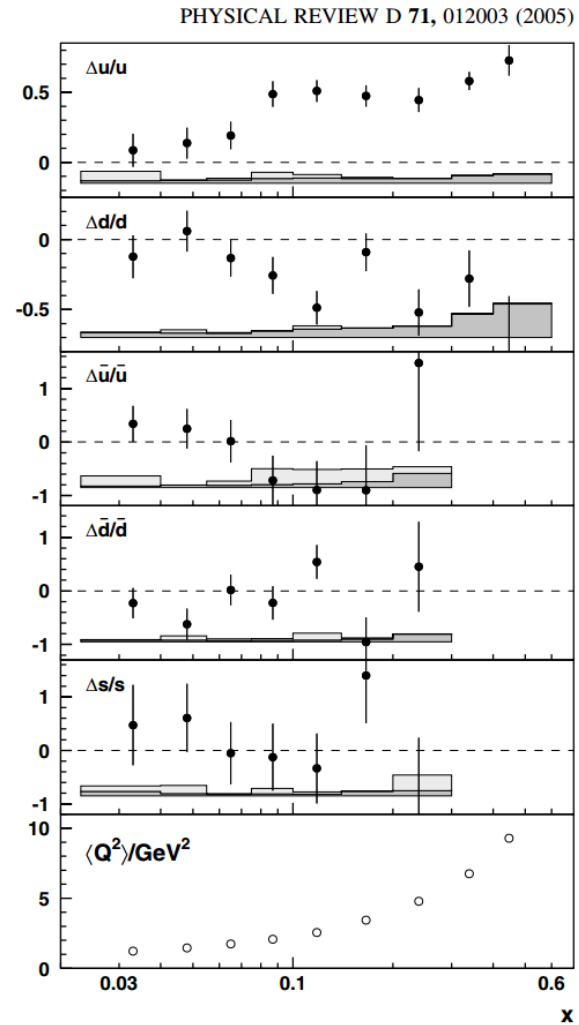


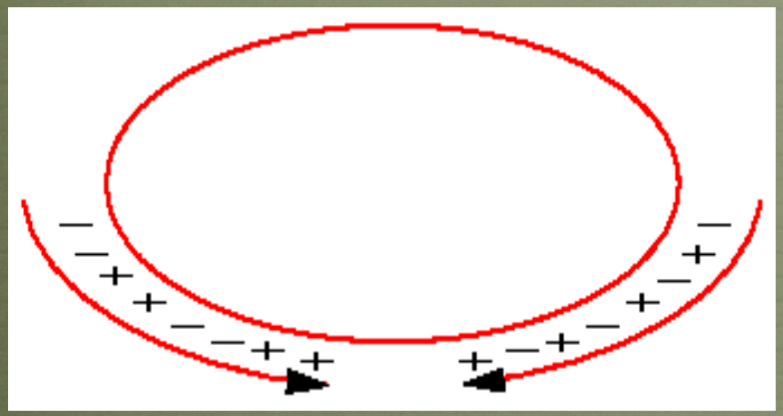
Figure 6.17: Comparison of $\sigma_{b\bar{b}}$ at different center of mass energies with NLO pQCD theory. The data point labeled "dimuon" is from this analysis. The bottom panel shows the ratio of data to NLO theory.





Measuring A_{LL} in a collider

$$A_{LL} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}} = \frac{1}{|P_1 P_2|} \frac{N_{++} - RN_{+-}}{N_{++} - RN_{+-}}; \qquad R = \frac{L_{++}}{L_{+-}}$$



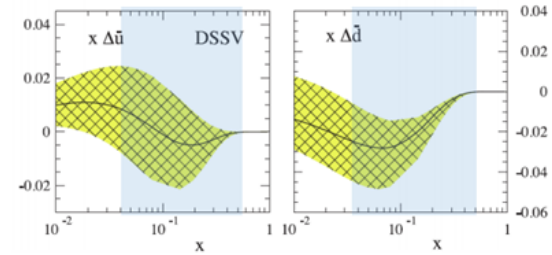
(N) Yield
(R) Relative Luminosity
(P) Polarization

- ✓ Bunch spin configuration alternates every 106 ns
- ✓ Data for all bunch spin configurations are collected at the same time

⇒ Possibility for false asymmetries are greatly reduced

Message: Spin measurements at a collider enable exquisite control over false asymmetries due to ultra fast rotations of the target and probe spin.

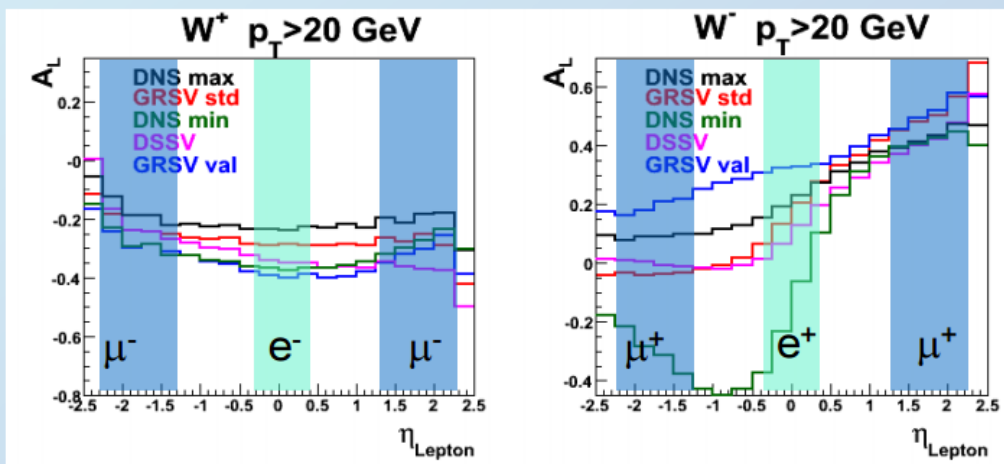
W-Analysis at PHENIX



Spin dependent PDF's for $\bar{u}$, $\bar{d}$ from DSSV global fit PHENIX rapidity sensitivity range

Sea quark polarization via W production

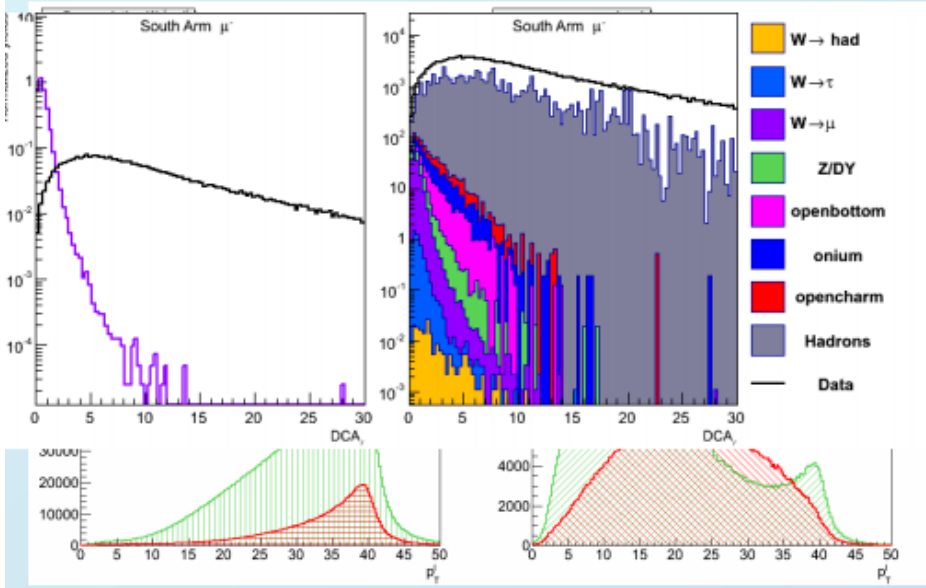
- Single spin asymmetry proportional to quark polarizations
- Large asymmetries
- Forward/backward separation smeared by W decay kinematics

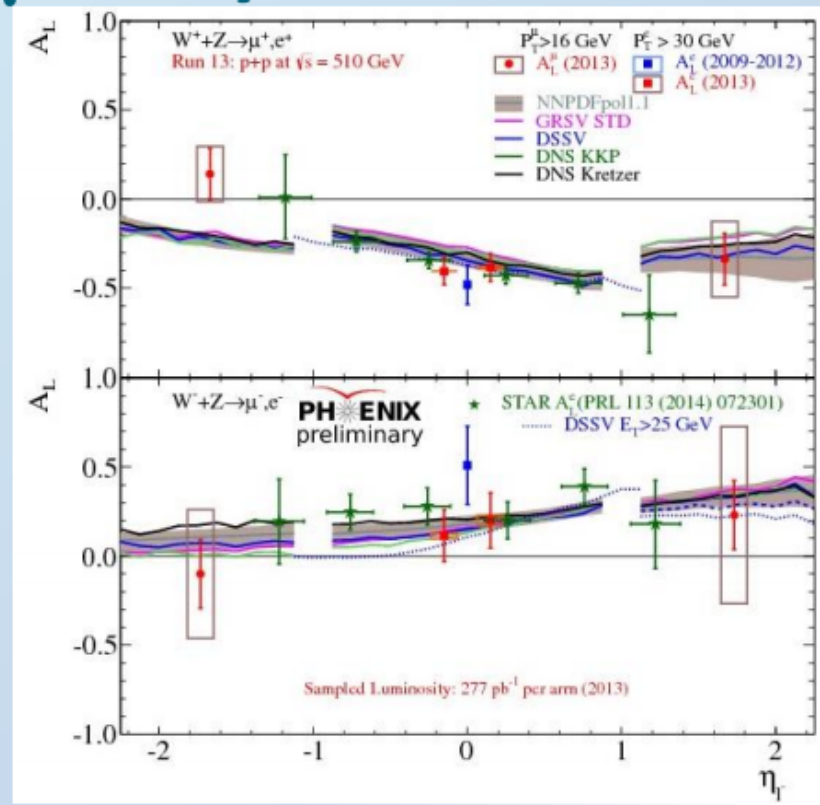


$$A_L^{W^+} \approx \frac{-\Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2 + \Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2}{u(x_1)\bar{d}(x_2)(1-\cos\theta)^2 + \bar{d}(x_1)u(x_2)(1+\cos\theta)^2}$$

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

Forward W+Z →μ asymmetries





- At forward rapidities no Gaussian peak to identify W decay muons
- Lower P_T hadrons as fake high P_T "muons"
- Successfully performed unbinned max likelihood analysis to identify signal

- Asymmetries as expected
- Still working on improving the uncertainties