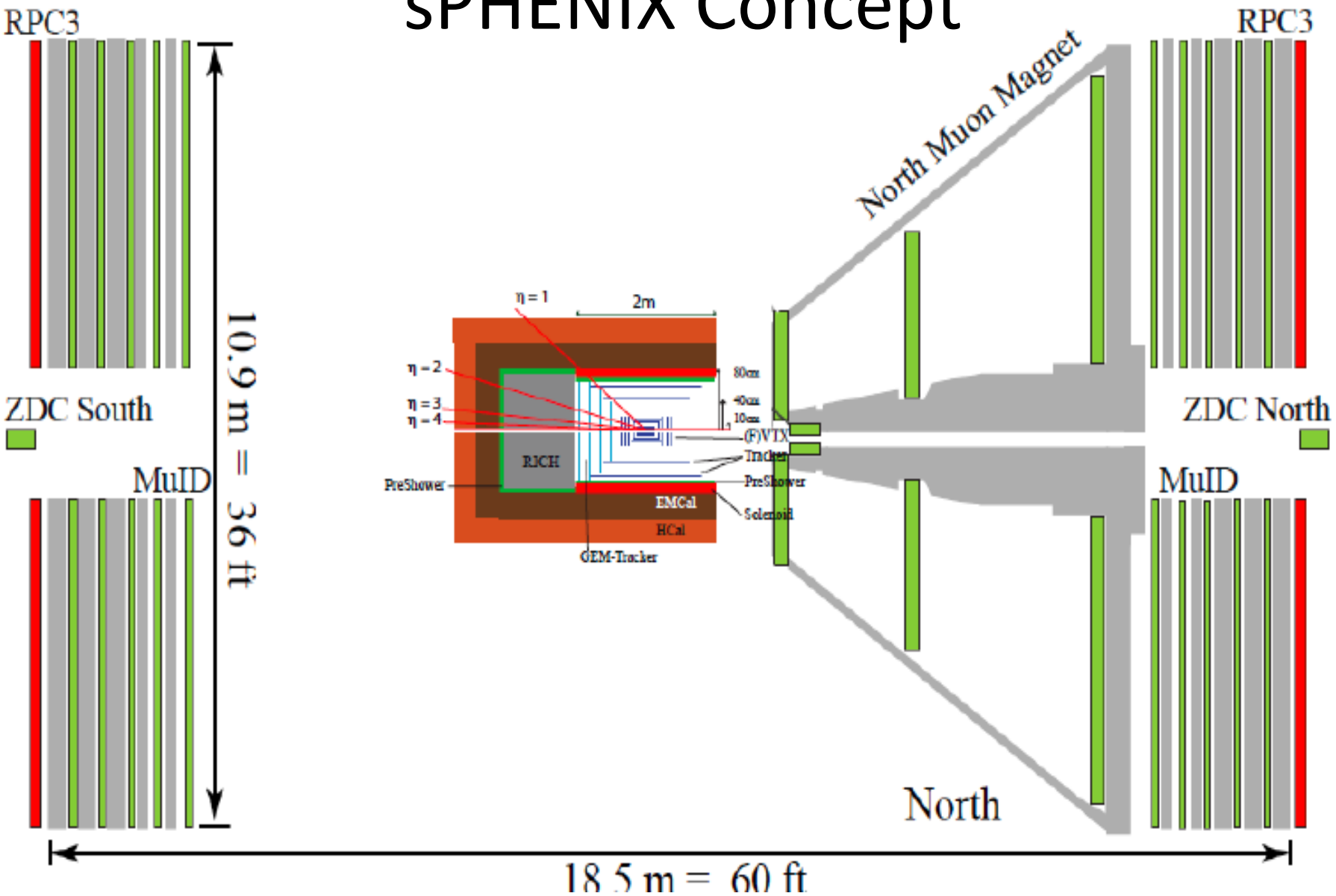
sPHENIX Upgrade for Forward Rapidity

RIKEN/RBRC

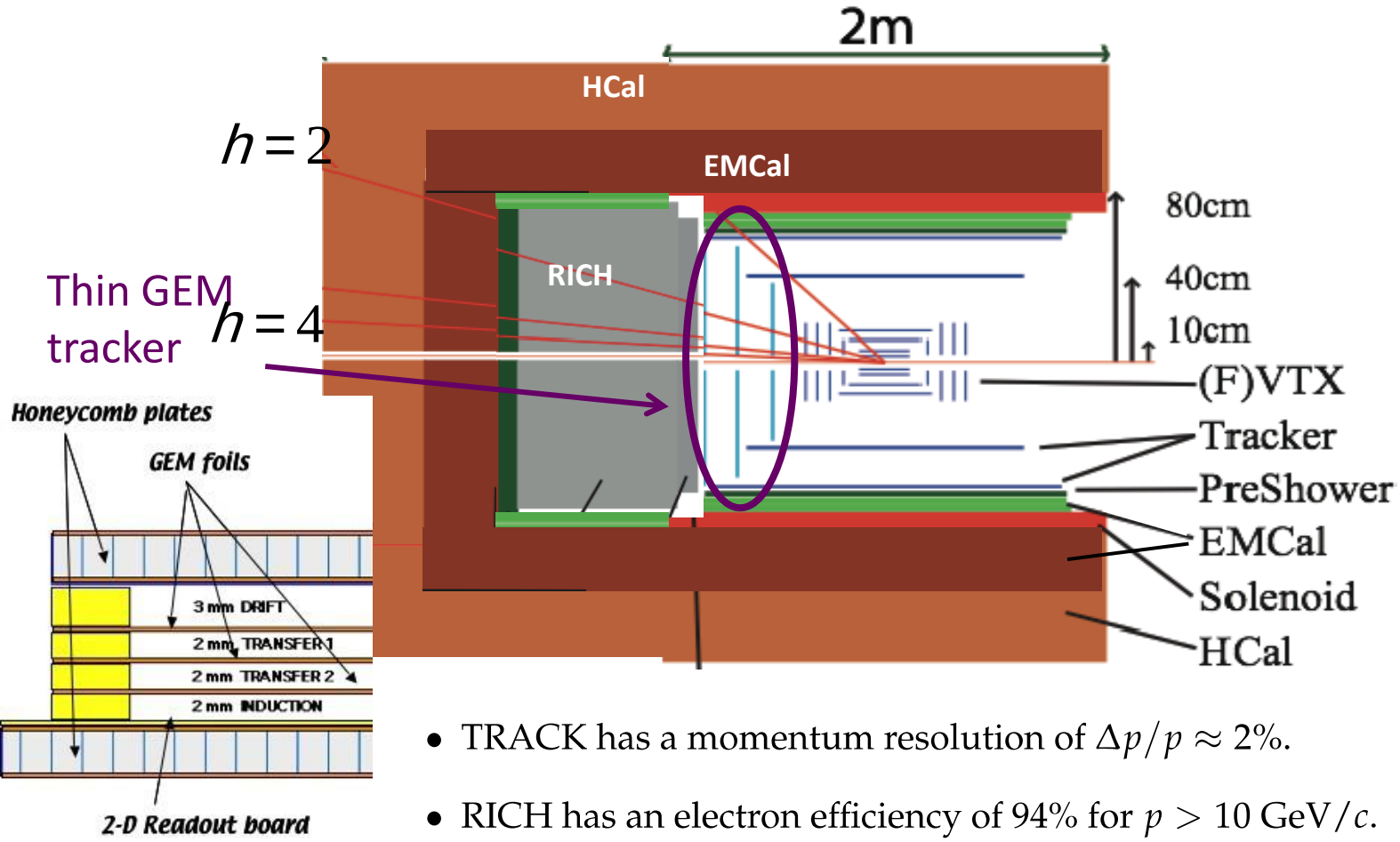
Itaru Nakagawa

sPHENIX Concept



Compact, hermetic, EM + hadron calorimetry

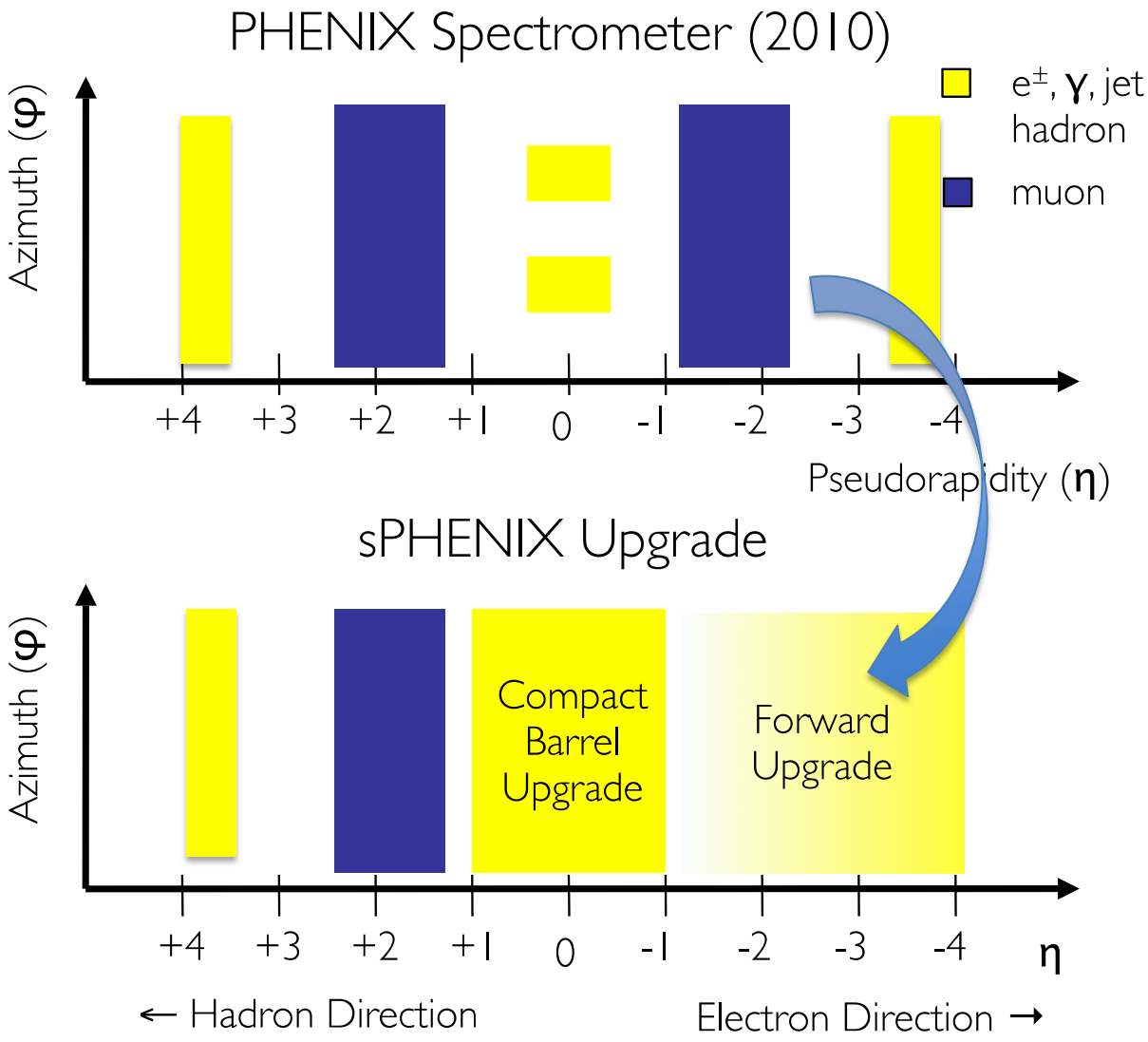
sPHENIX Forward



e.g. Compass, but with 3-d readout

- TRACK has a momentum resolution of $\Delta p/p \approx 2\%$.
- RICH has an electron efficiency of 94% for $p > 10$ GeV/c.
- EMCal has the resolution of the current PHENIX PbGl: $5.95\%/\sqrt{E} + 0.76\%$
- HCAL has the resolution: $50\%/\sqrt{E} + 5\%$ (similar to CMS or LHCb)

sPHENIX Acceptance

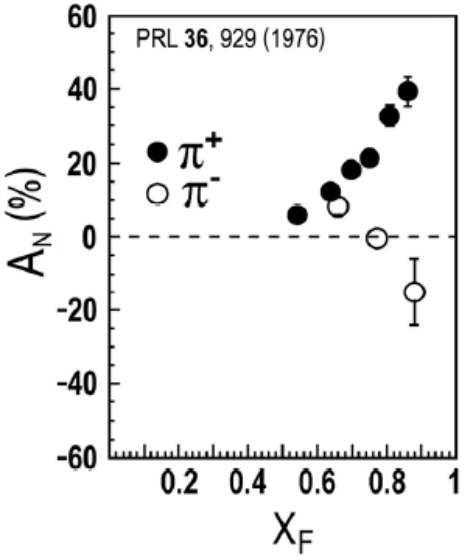


(Spin) Physics Highlights w/ Forward sPHNIEX

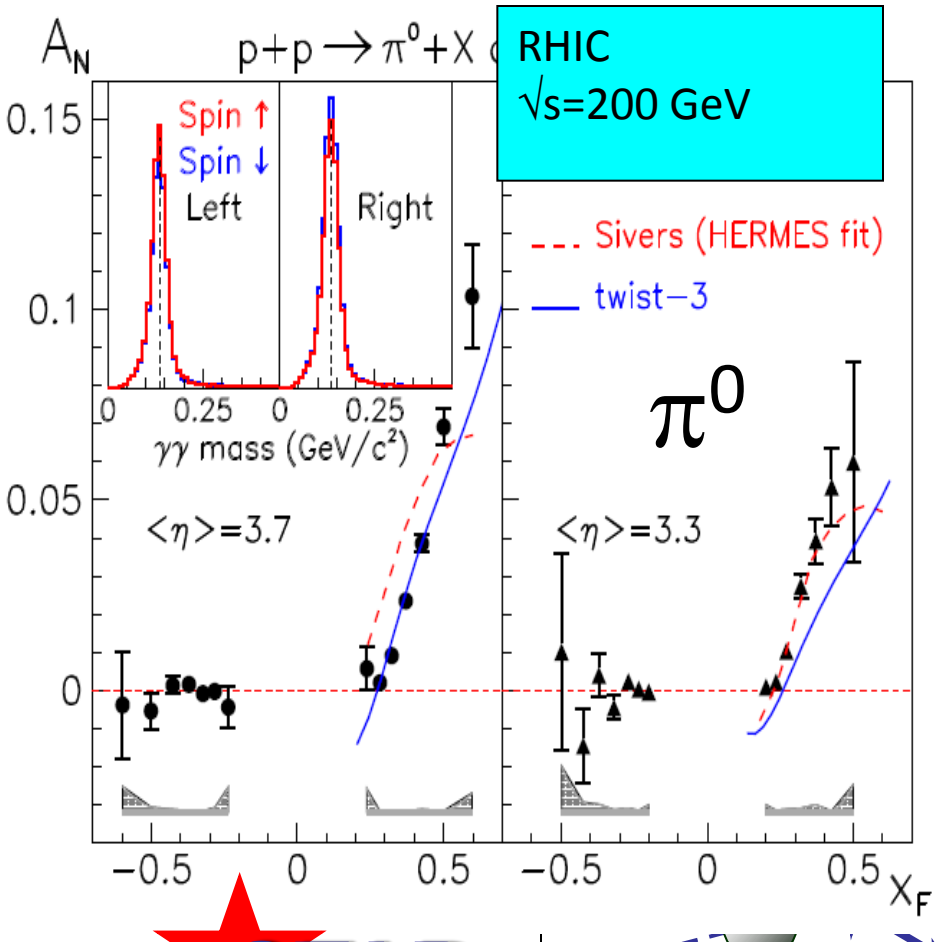
- Transverse Spin Program
  - Jet
  - Drell-Yan (DY) Process
- Longitudinal
  - ΔG via Jets, γ-Jet (correlated measurement)
- Polarized ^3He and RHIC Energy Upgrade
- (Cold Nuclear Matter, Low-x Gluon Saturation)

Transverse Single-Spin Asymmetries: From Low to High Energies!

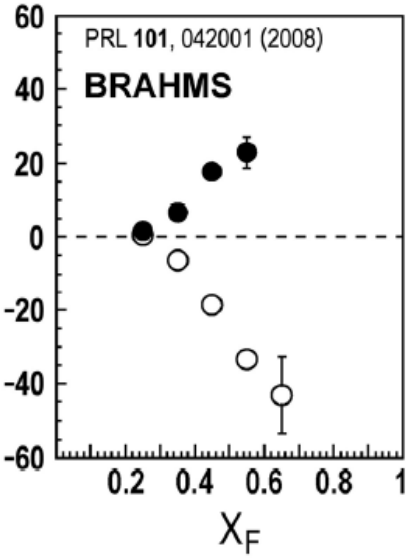
ANL
$\sqrt{s}$=4.9 GeV



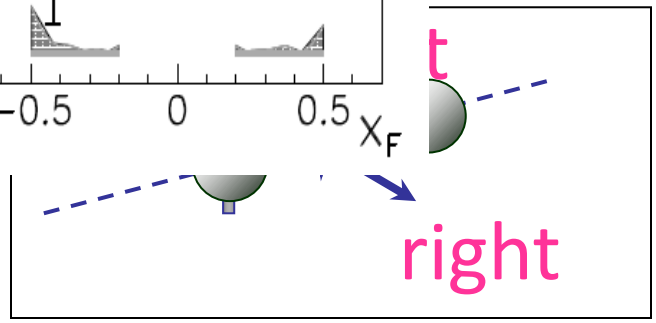
RHIC
$\sqrt{s}$=200 GeV



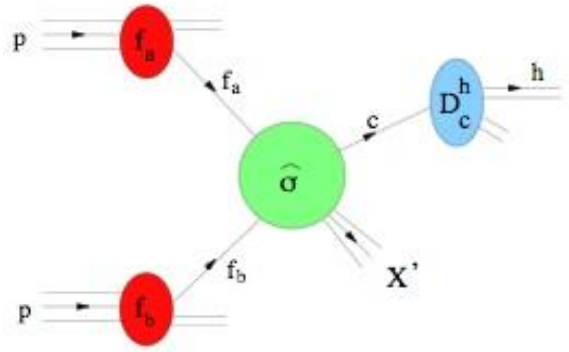
RHIC
$\sqrt{s}$=62.4 GeV



$$x_F = 2p_{lc}$$

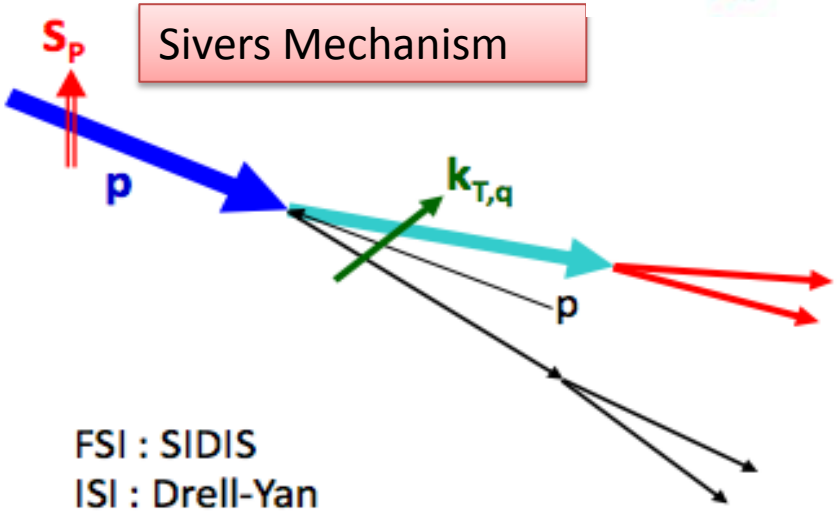


Initial State

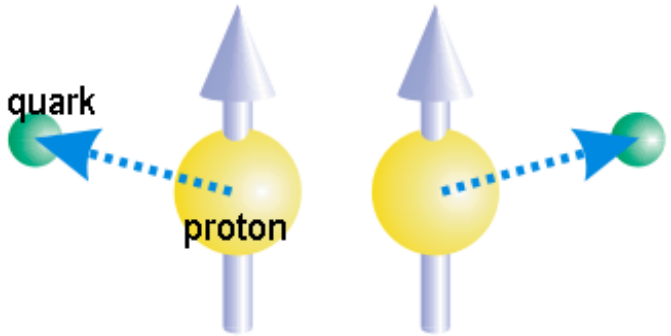


Final State

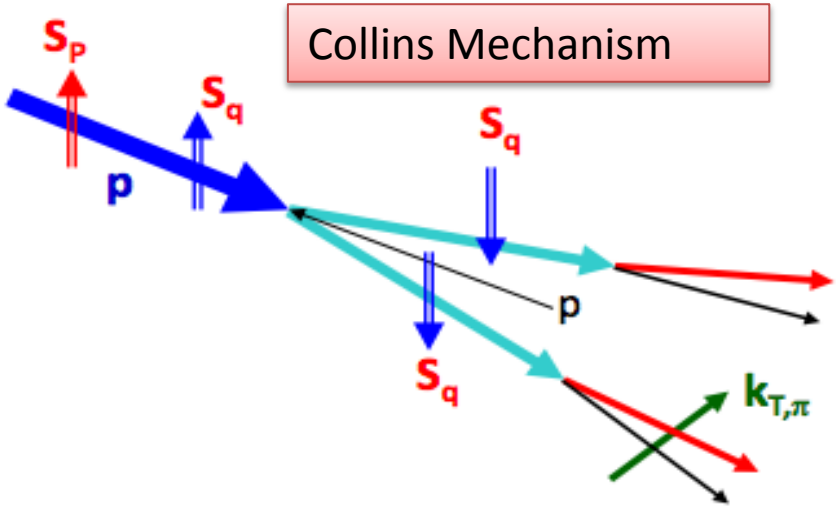
Sivers Mechanism

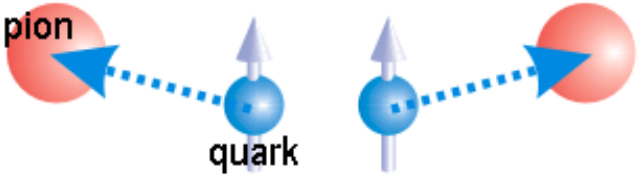


FSI : SIDIS
ISI : Drell-Yan



Collins Mechanism





A_N ~ (Initial State Correlation) + (Final State Correlation) + higher order

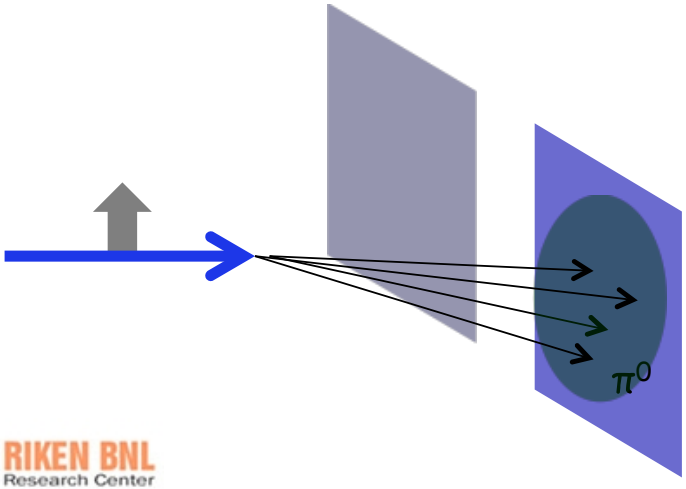
Isolation of Sivers & Collins

With a good enough detector, we can unambiguously separate all these pieces

Initial State Piece

Jets with identified hadrons (measure A_N for jets)

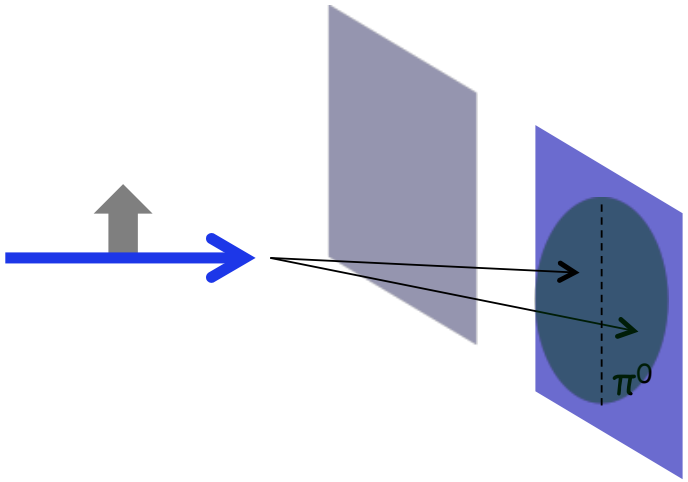
Do jets from certain quarks prefer to go left or right?



Final State Piece

Left-right asymmetry of identified particle inside a jet

Do certain hadrons fragment from certain quarks to the left or right of the jet axis?



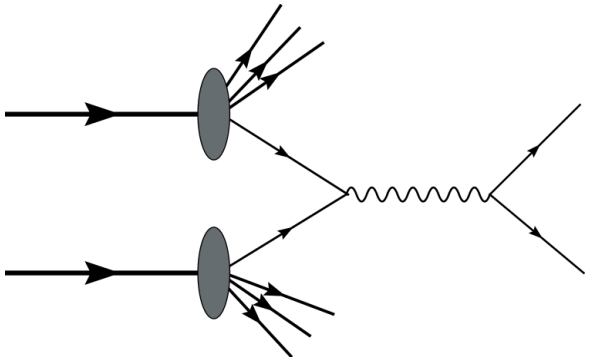
RIKEN BNL Research Center

Important to have Jet Detection Capability in Forward Region!

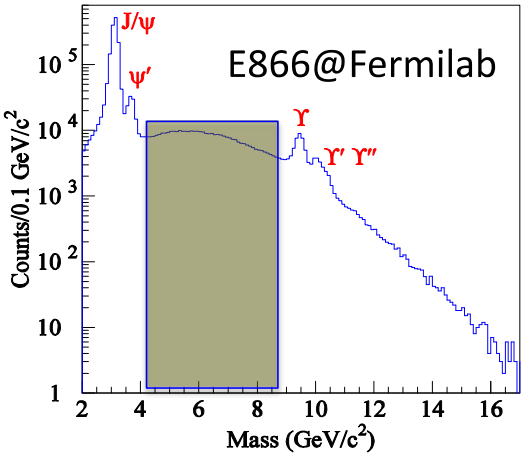
Slide from J. Seele from PHENIX Collaboration Meeting

Sivers Measurement vi Drell-Yan Process

The Drell-Yan Process



- M^2
- p_T

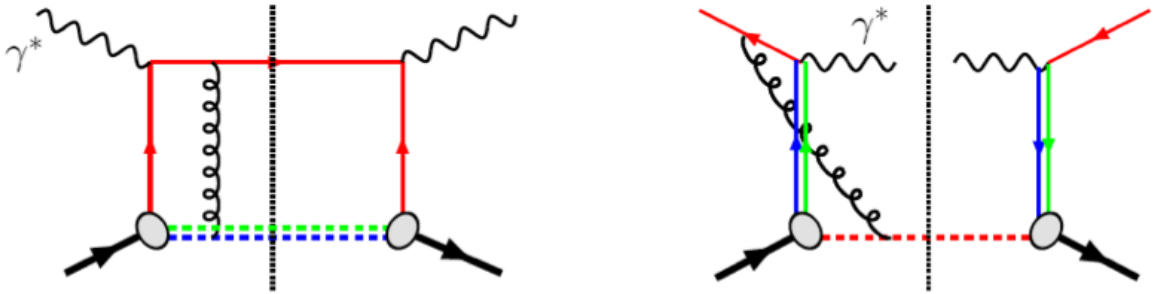


High Mass Low pT Drell-Yan

$$\left(\frac{d^2\sigma}{dx_1 dx_2}\right)_{D.Y.} = \frac{4\pi\alpha^2}{9 s x_1 x_2}\sum_a e_a^2\left[q_a(x_1)\bar{q}_a(x_2) + \bar{q}_a(x_1)q_a(x_2)\right]$$

DY vs. DIS

- solid factorization
- no fragmentation
  - direct correlation of intrinsic transverse quark momentum to the proton spin
- fundamental QCD test



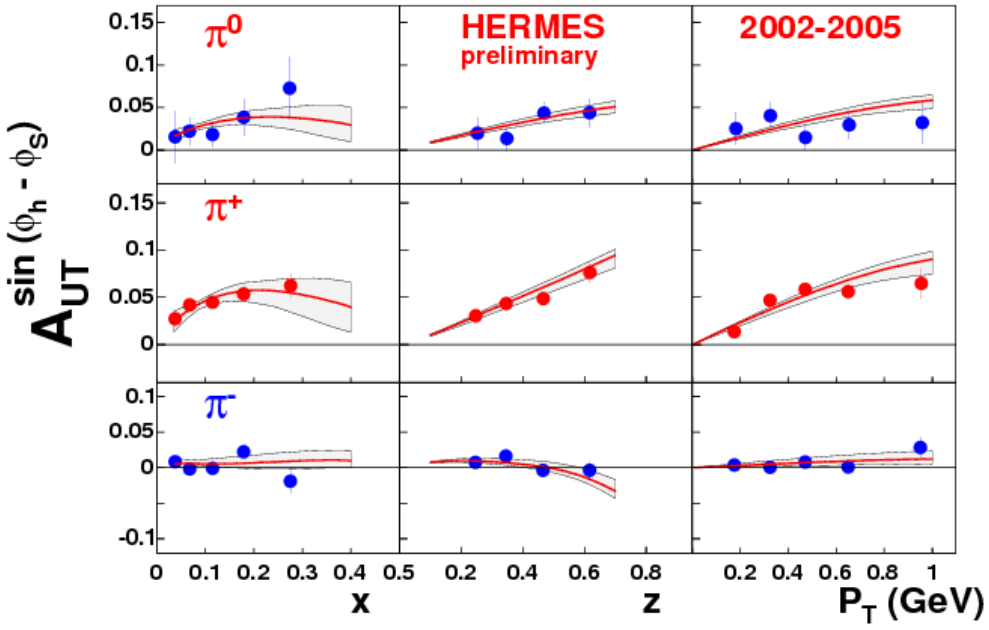
DIS DY

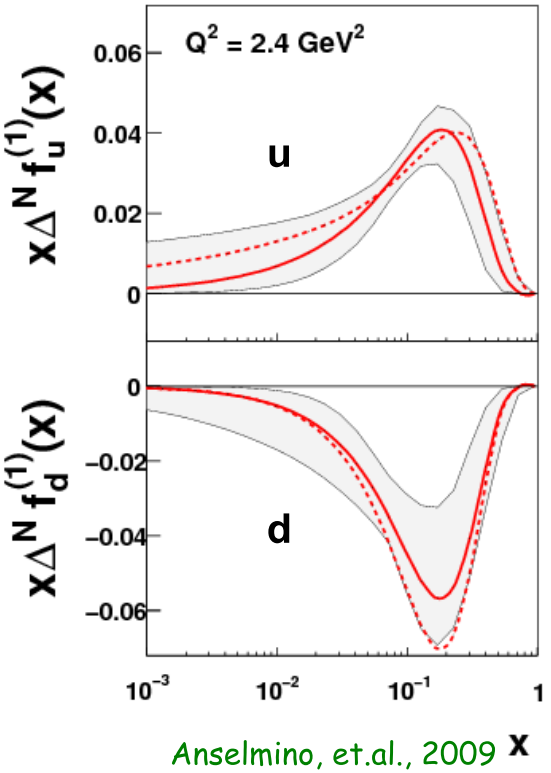
Figure 6.1: Feynman diagram for SIDIS (left) and Drell-Yan (right) showing the color structure and the final- and initial-state interaction via gluon exchange.

$$\Delta^N f_{q/p\uparrow}(x,k_\perp)_{SIDIS} = -\Delta^N f_{q/p\uparrow}(x,k_\perp)_{DY}$$

Existing Experiments of SIDIS

- Extract Sivers function from SIDIS (HERMES&COMPASS)

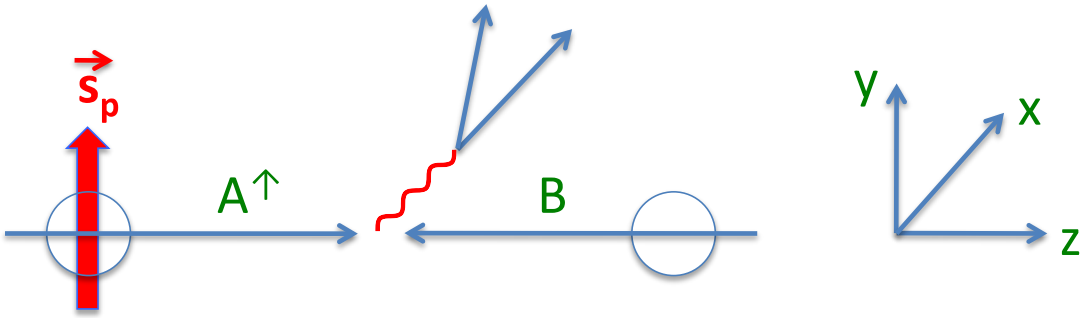




Anselmino, et.al., 2009

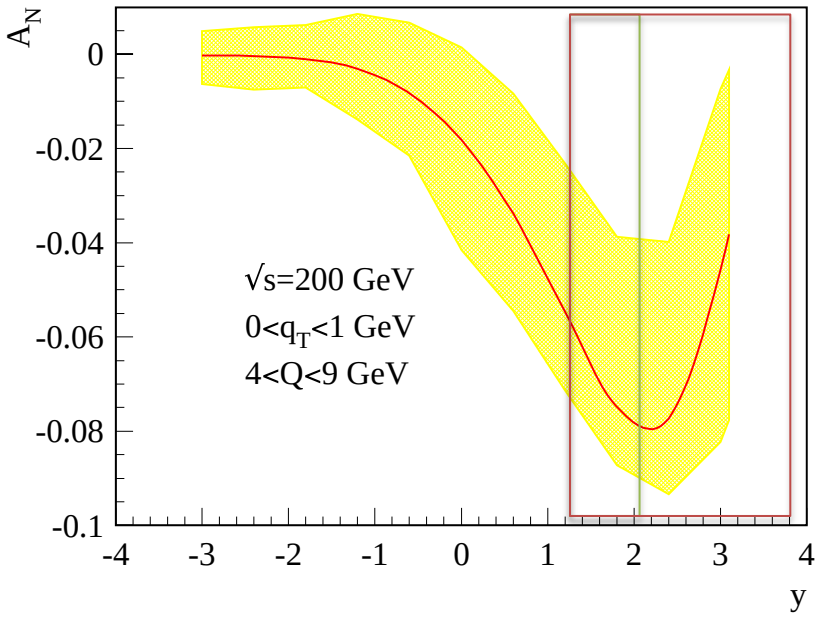
- u and d almost equal size, different sign
- d-Sivers is slightly larger

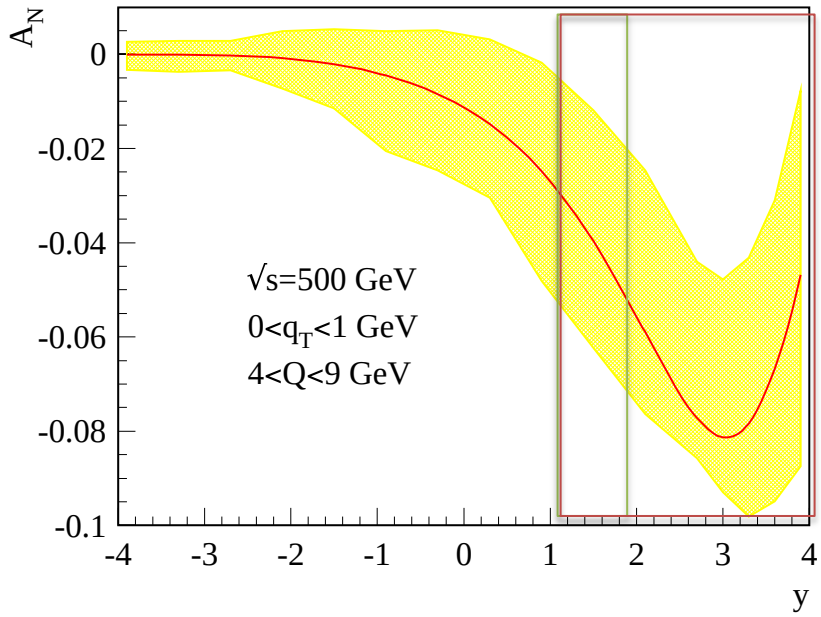
A_N DY Prediction at RHIC

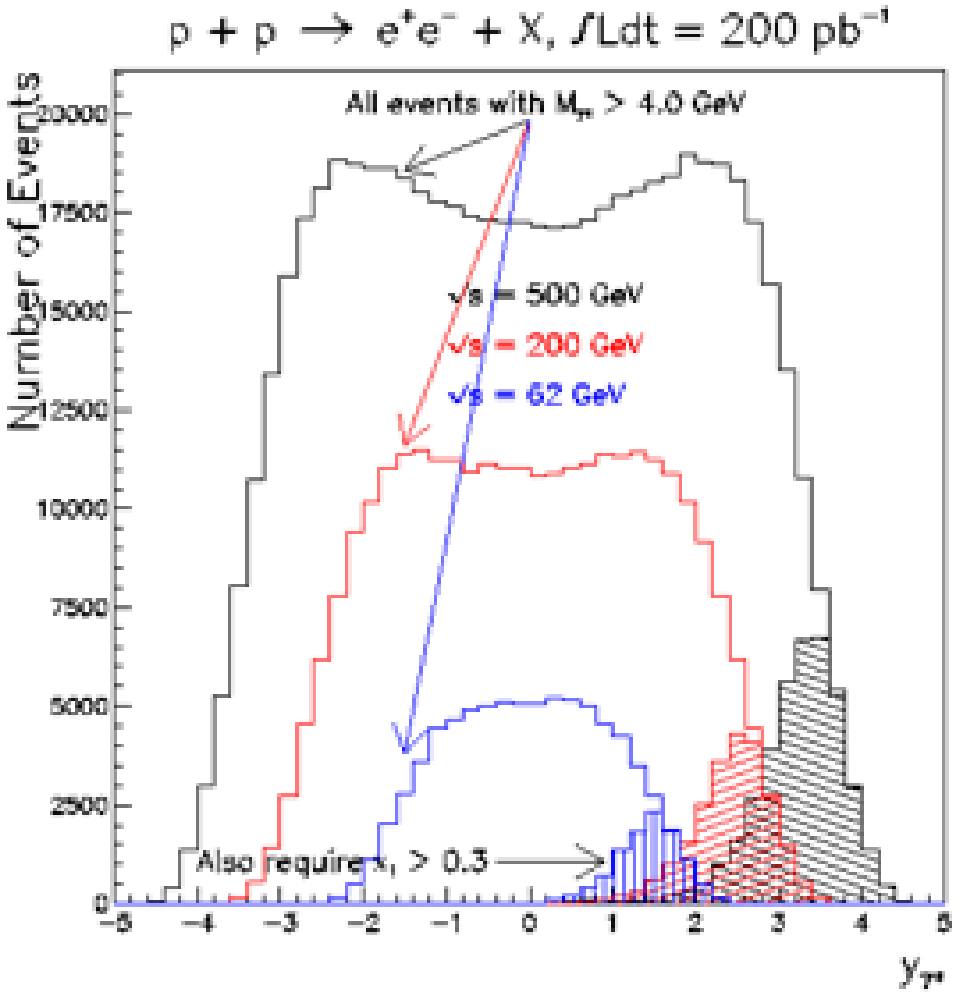


$$A_N \propto \frac{4}{9}\Delta^N u + \frac{1}{9}\Delta^N d < 0$$

Kang-Qiu, PRD81, 2010







Assuming $A_N \sim 4 - 5\%$

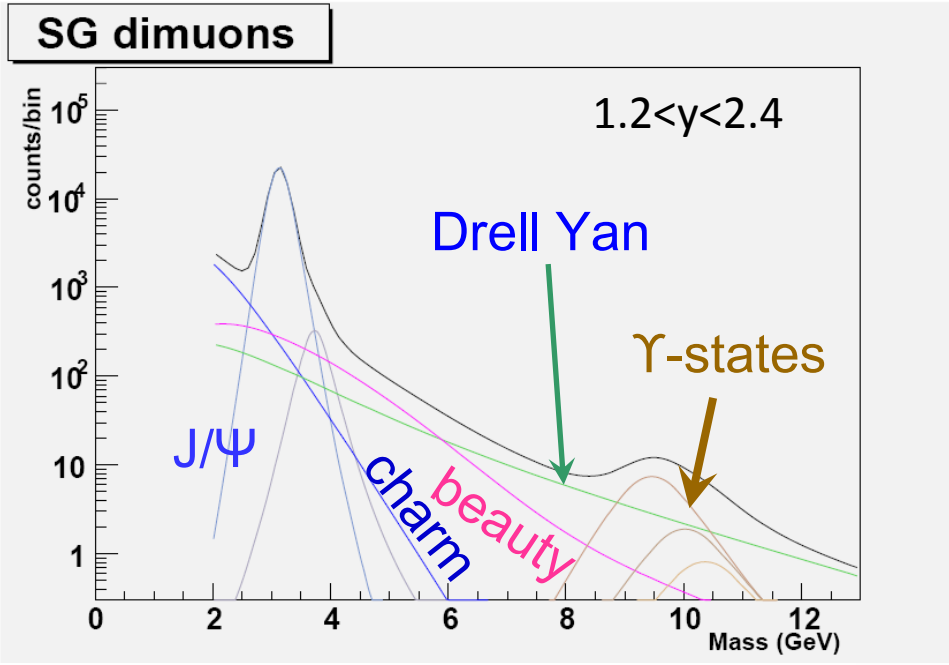
3σ from $A_N=0$

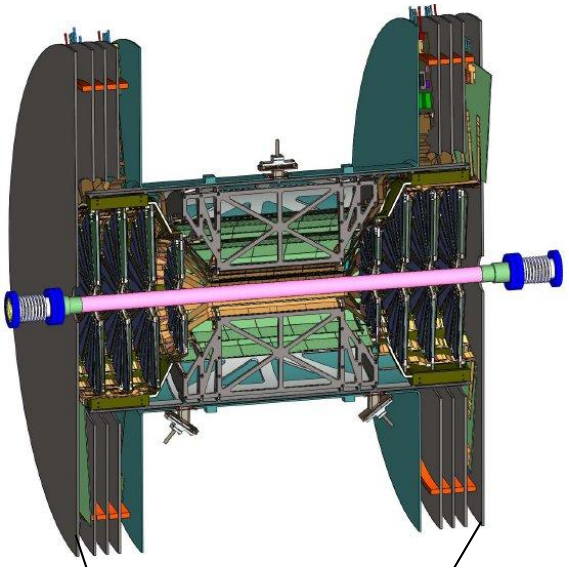
$1.2 < Y_{DY} < 2.4$

110 pb^{-1} @500GeV

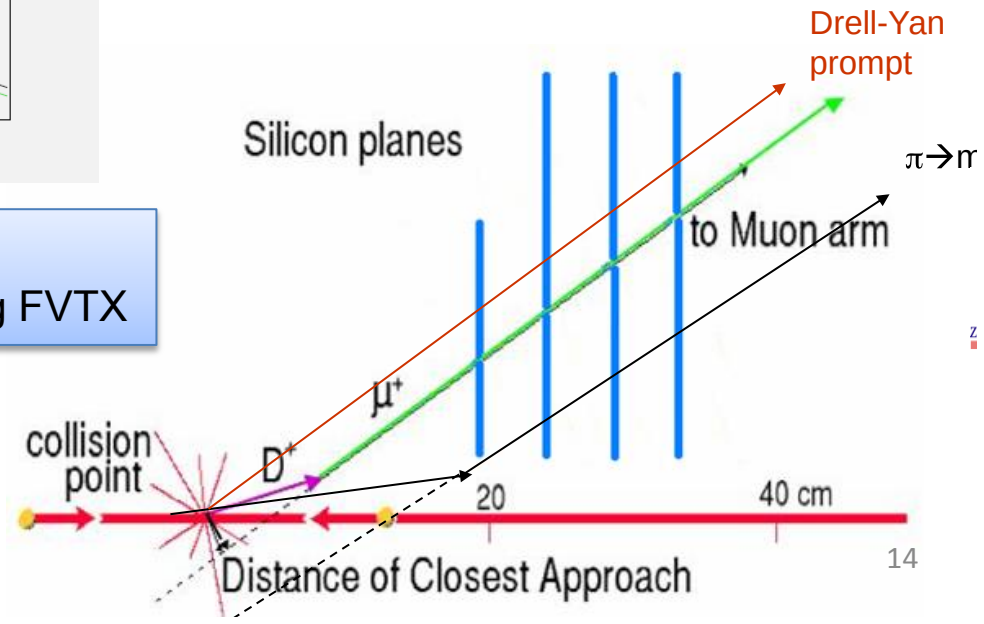
Drell-Yan measurement

Heavy flavor background

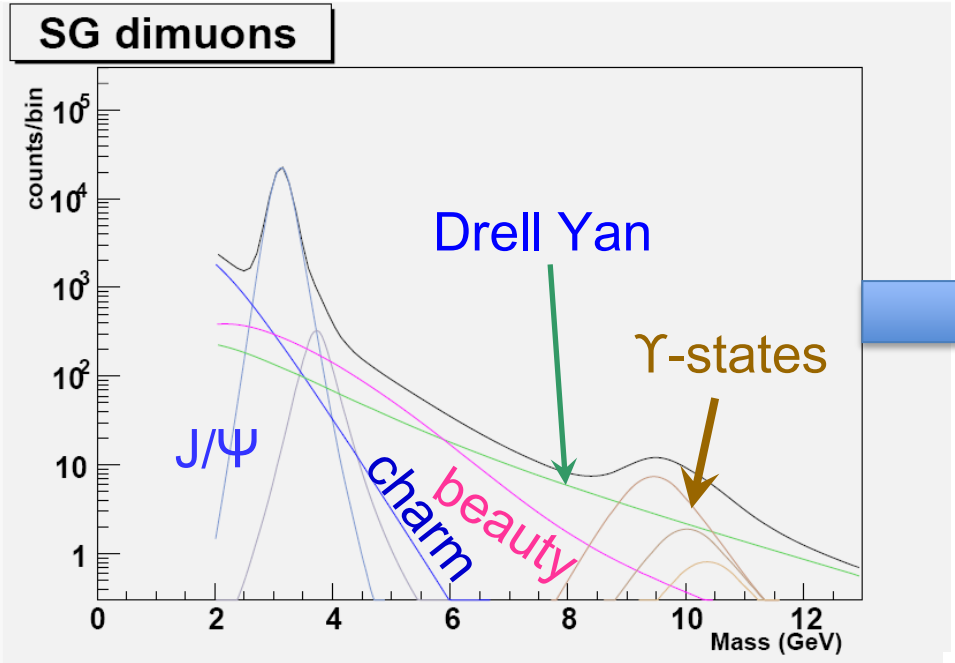


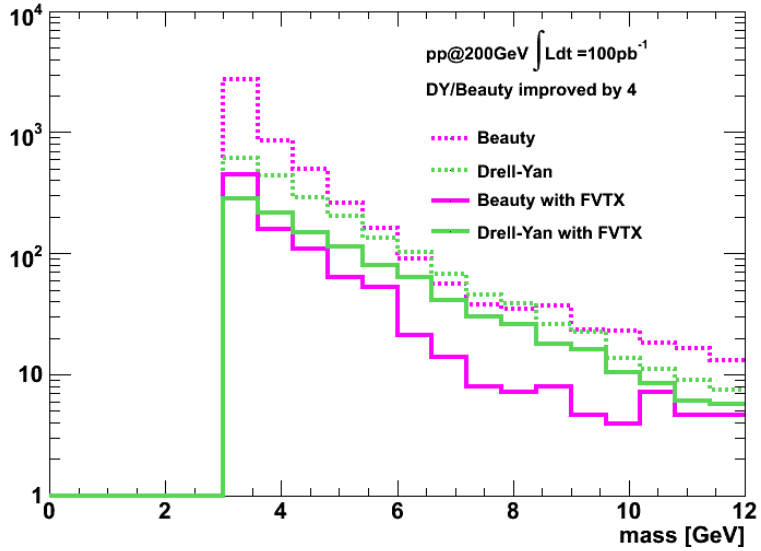


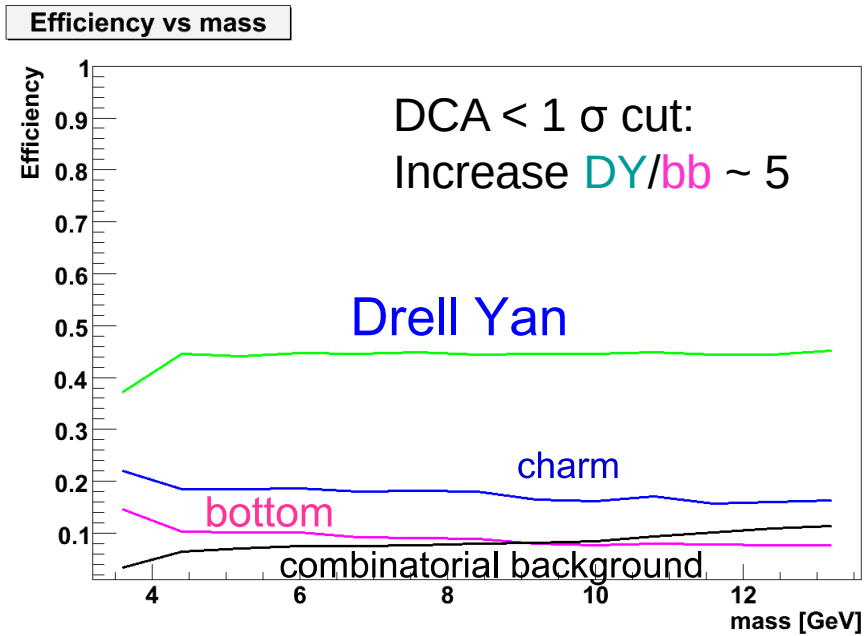
➔4 GeV < M < 10 GeV
Background (bottom,Charm) rejection using FVTX

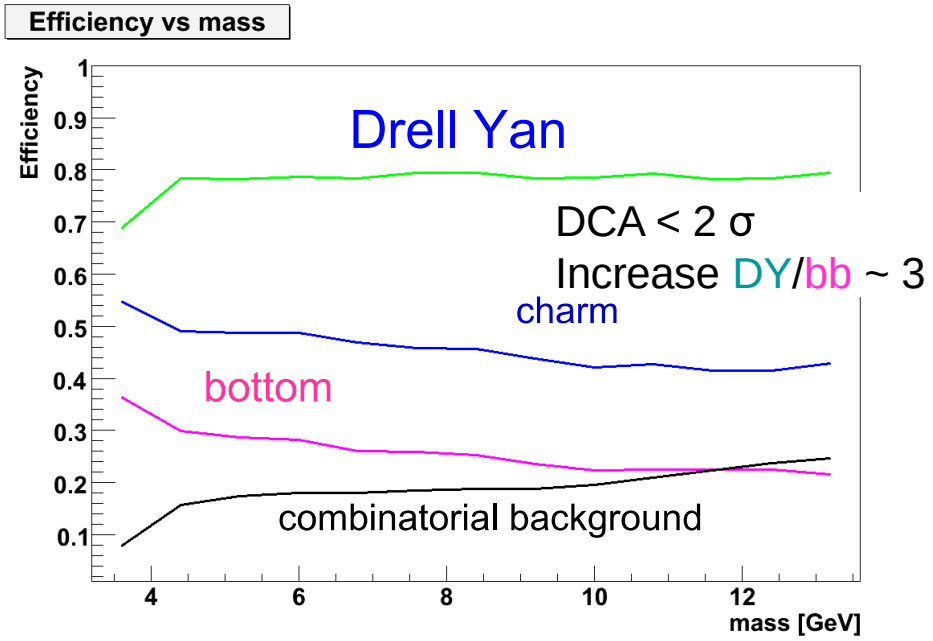


Heavy Flavor Background Suppression



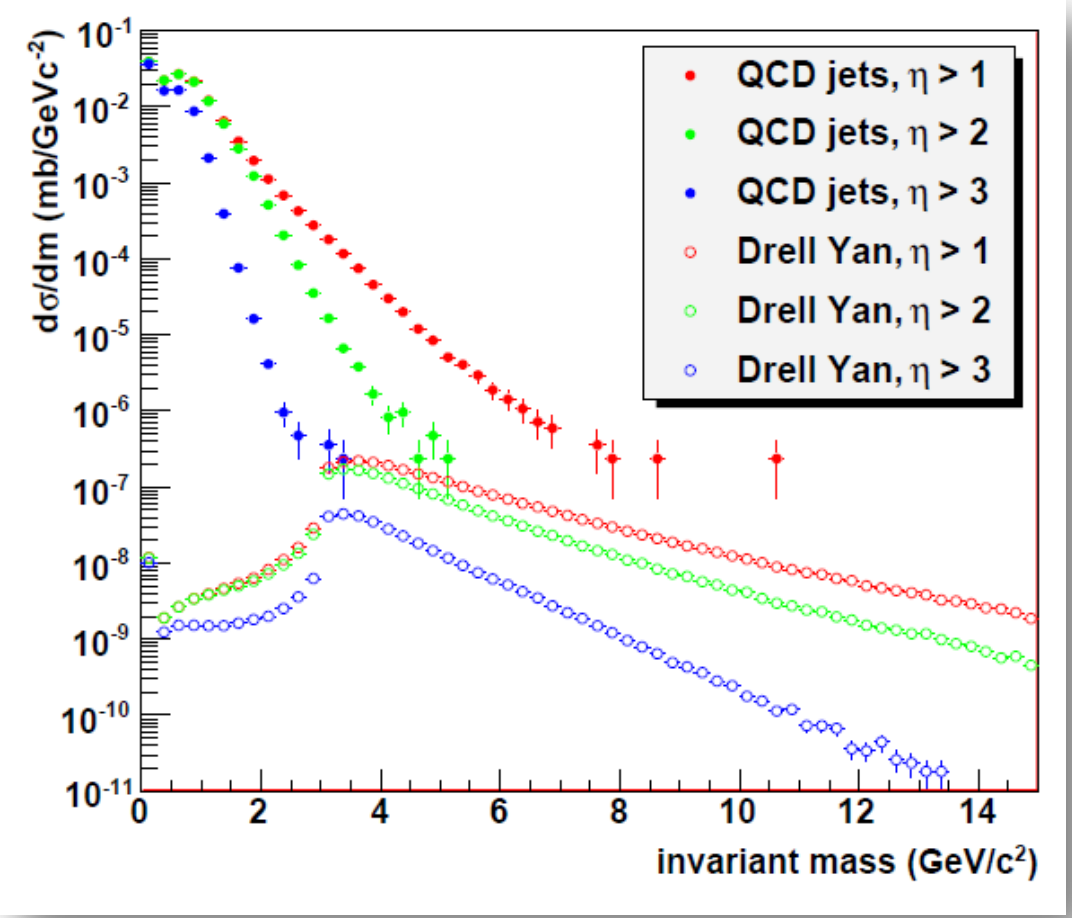






DY S/N w.r.t QCD backgrounds

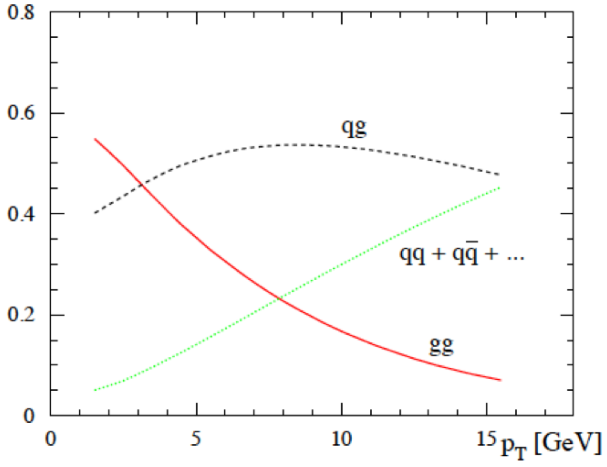
- Drell Yan signal
  - 3 – 10 GeV/c^2
- Energy cut
  - $E_{1,2} > 2$ GeV
- Forward rapidities
  - Effectively no background left
  - Statistically limited
  - Drell Yan for $m_{inv} < 3$ GeV/c^2 not physical (PYTHIA settings)

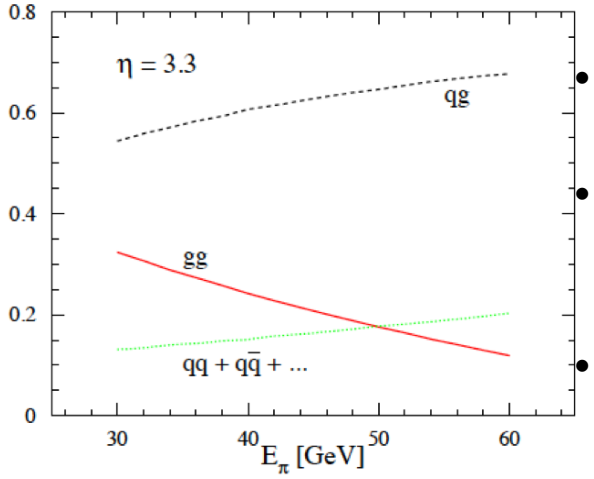


Longitudinal

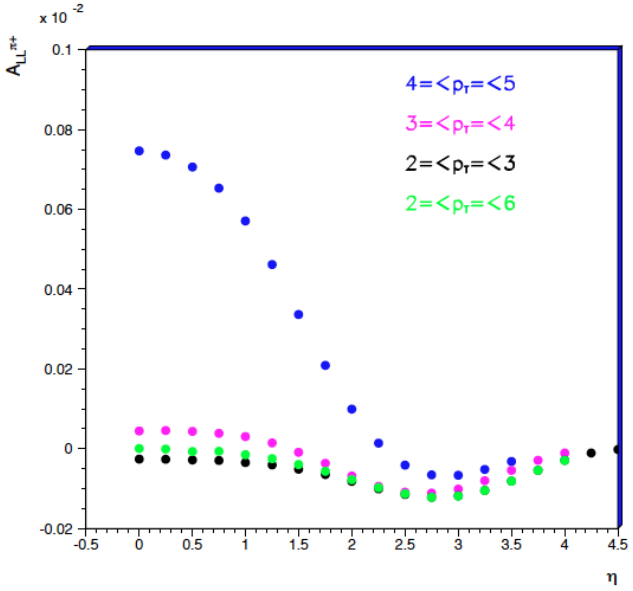
ALL

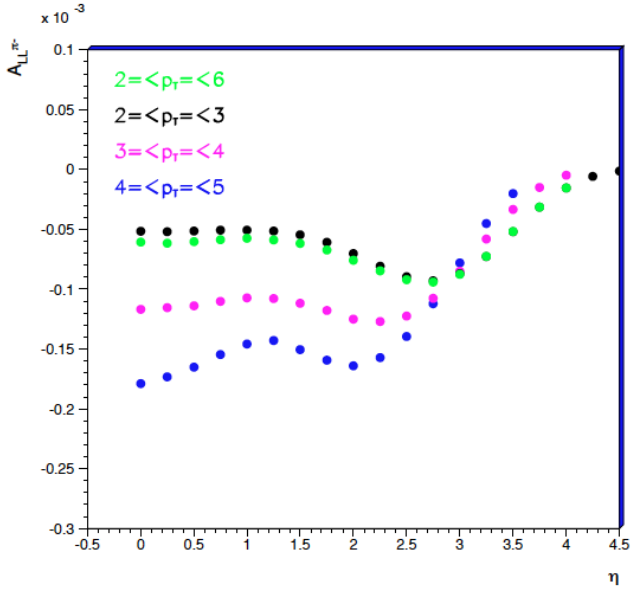
$$A_{LL} = \frac{\Delta\sigma(gg \to gg) + \Delta\sigma(qg \to qg) + \Delta\sigma(qq \to qq)}{\sigma(gg \to gg) + \sigma(qg \to qg) + \sigma(qq \to qq)}$$



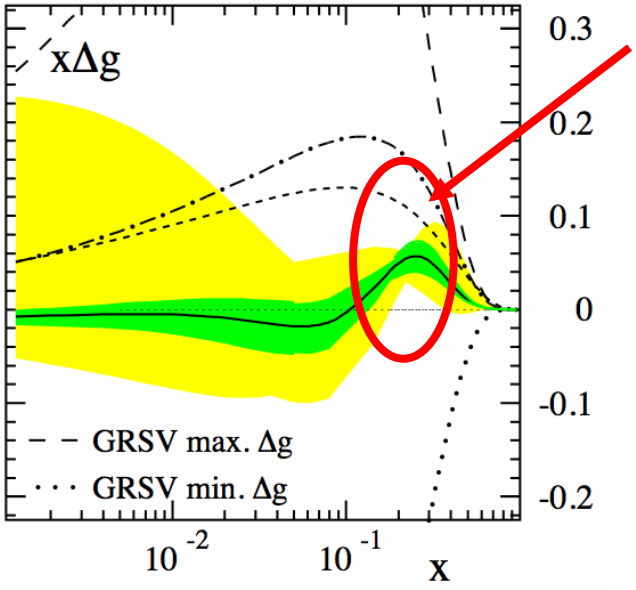


- Broader kinematic coverage
- Different combination of underlying hard subprocess.
- Important inputs to Global fit.



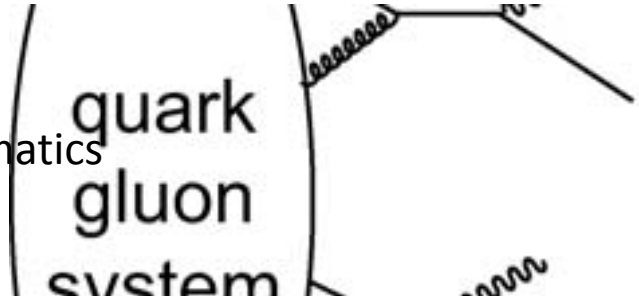


ΔG Smaller-x w/ γ–Jet , di-Jet



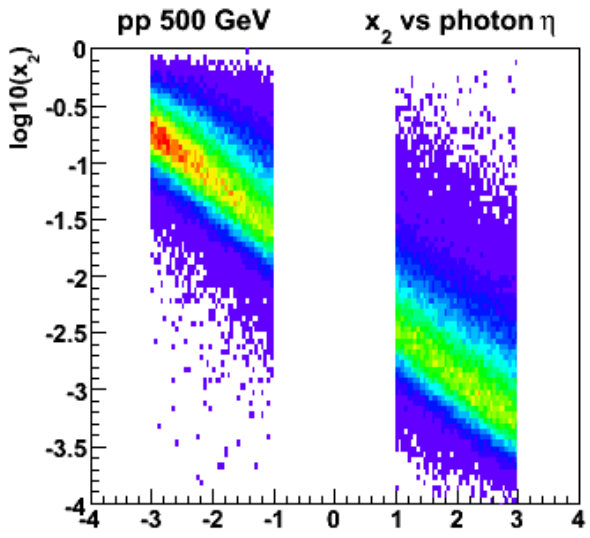
Present RHIC Region

Cleaner probe, fixed kinematics
Simple interpretation
of experimental data

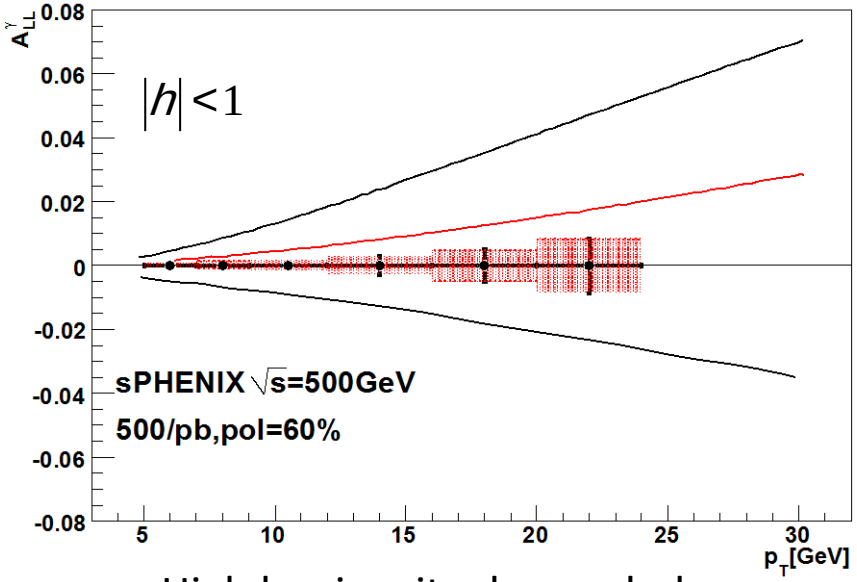


Golden Channels

- No fragmentation
- Sign of ΔG



Jet detected
mid rapidity

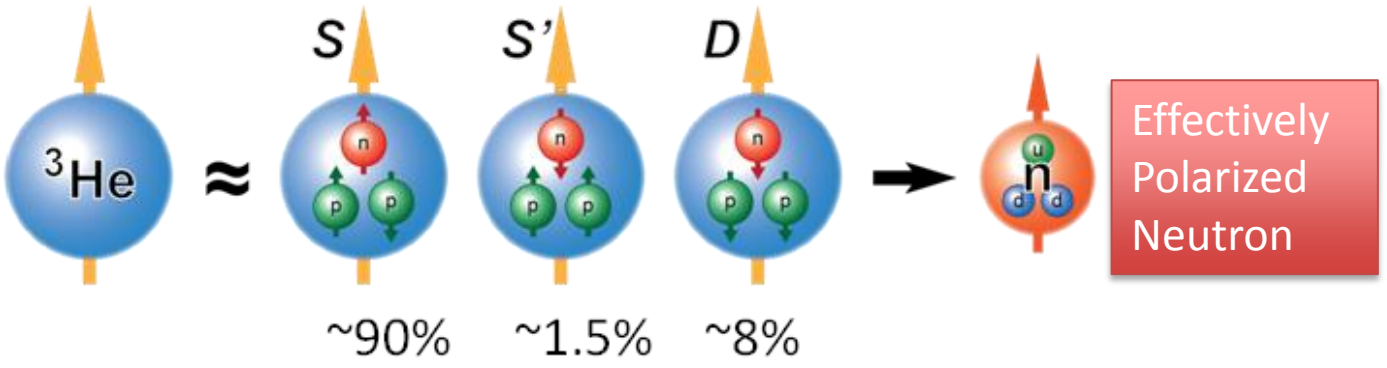


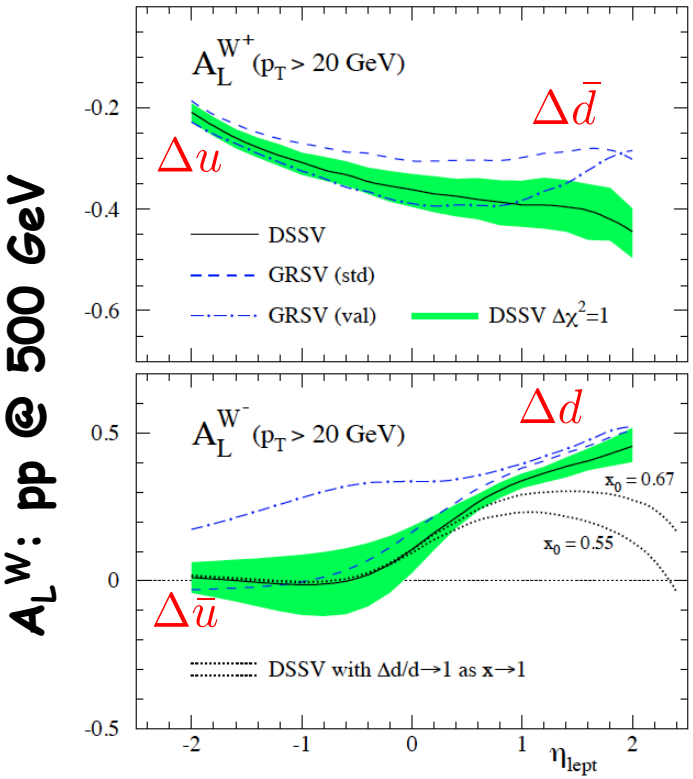
High luminosity demanded

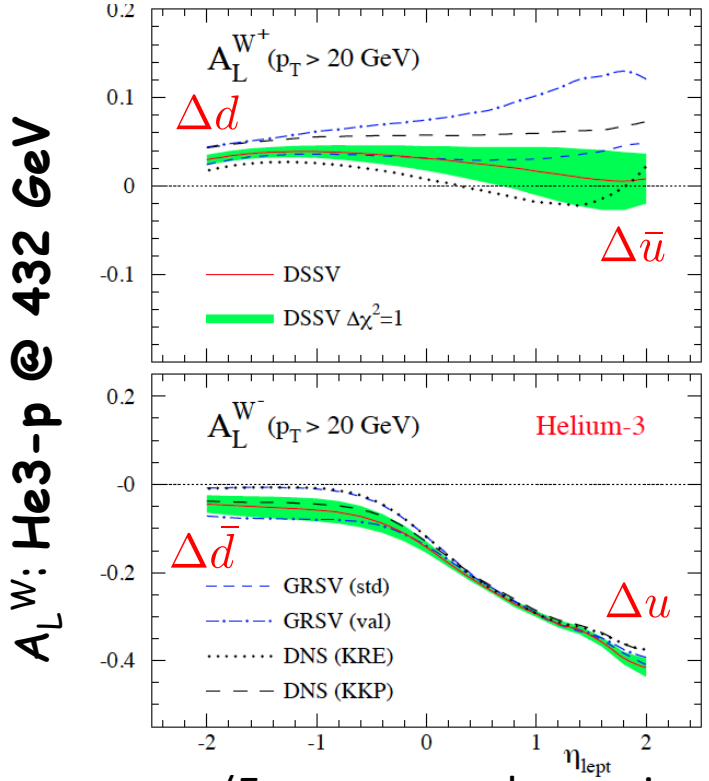
Polarized ^{3}He-p Collision

Polarized ^{3}He as "Effective" Polarized Neutron

img from http://www.lns.mit.edu/nig/programs.html

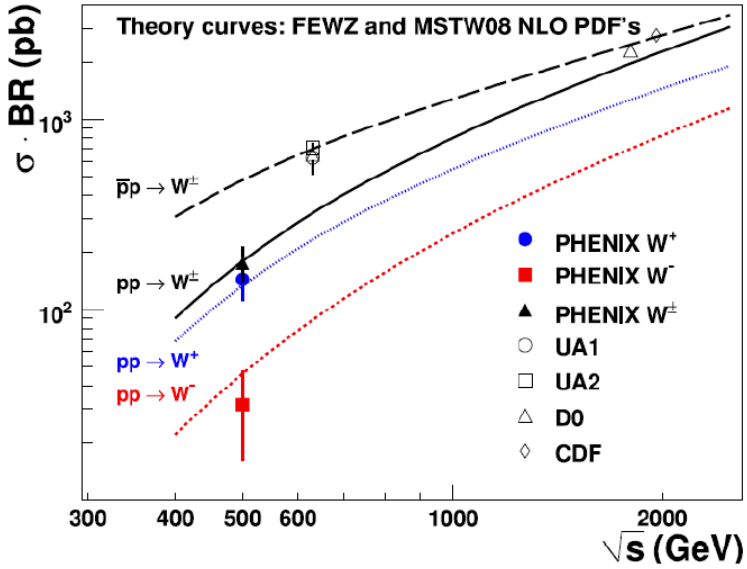






Full Flavor Separation (Energy upgrade required)

RHIC Energy Upgrade

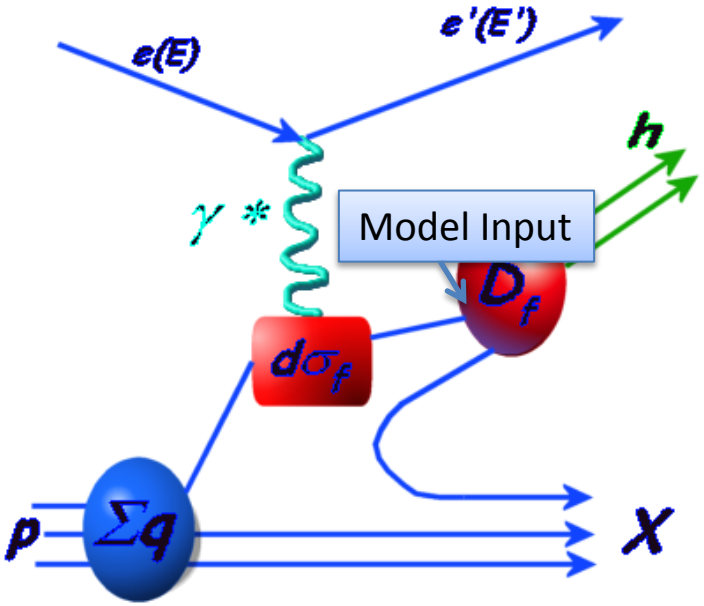


$$\frac{s_w(650GeV)}{s_w(500GeV)} \sim 2$$

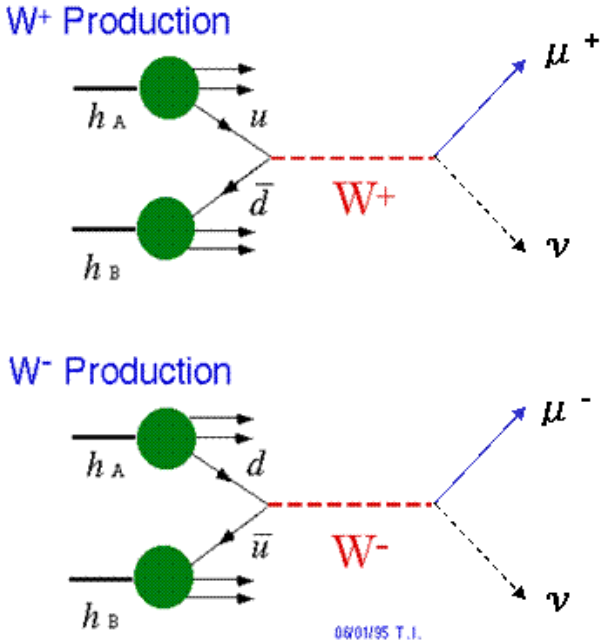
Need to overcome machine issues:

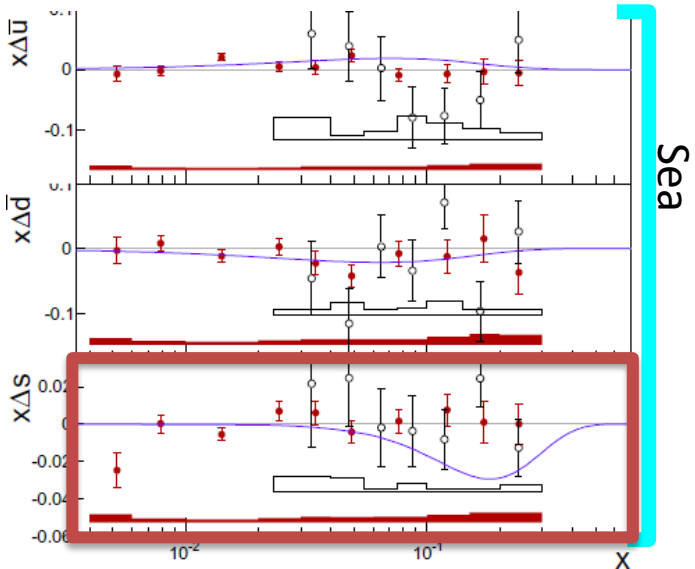
- Quench performance of magnets (DX, arc dipoles and quads, IR quads)
- Crossing angles at IPs and luminosity
- Polarization
- Current feed-throughs
- Power supplies and transformers
- Dump kicker (strength, pre-fires)
- Reliability generally reduced at higher energies
- etc…

With More Luminosity …

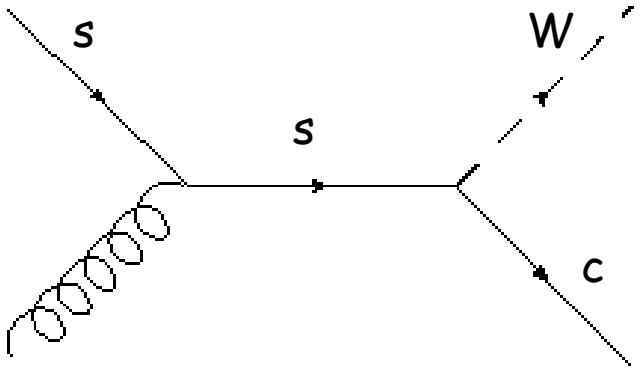


$$u\bar{d} \rightarrow \pi^+$$
$$\bar{u}d \rightarrow \pi^-$$
$$u\bar{s} \rightarrow K^+$$
$$\bar{u}s \rightarrow K^-$$





Δs via W+charm production



Summary

- Hermetic EM and hadron calorimeters in forward acceptance:
  - Jet (cleaner measurement of ΔG, Sivers, Collins)
  - γ-Jets, di-Jets (golden channel for ΔG, fix kinematics)
  - Different subprocesses combinations for input to global analysis
- Sivers measurement via DY tests fundamental QCD
- Full flavor separation of sea quark polarization using “effective” neutron target of 3He beam
- Luminosity, Luminosity, Luminosity….

Thank you for coming to RIKEN!