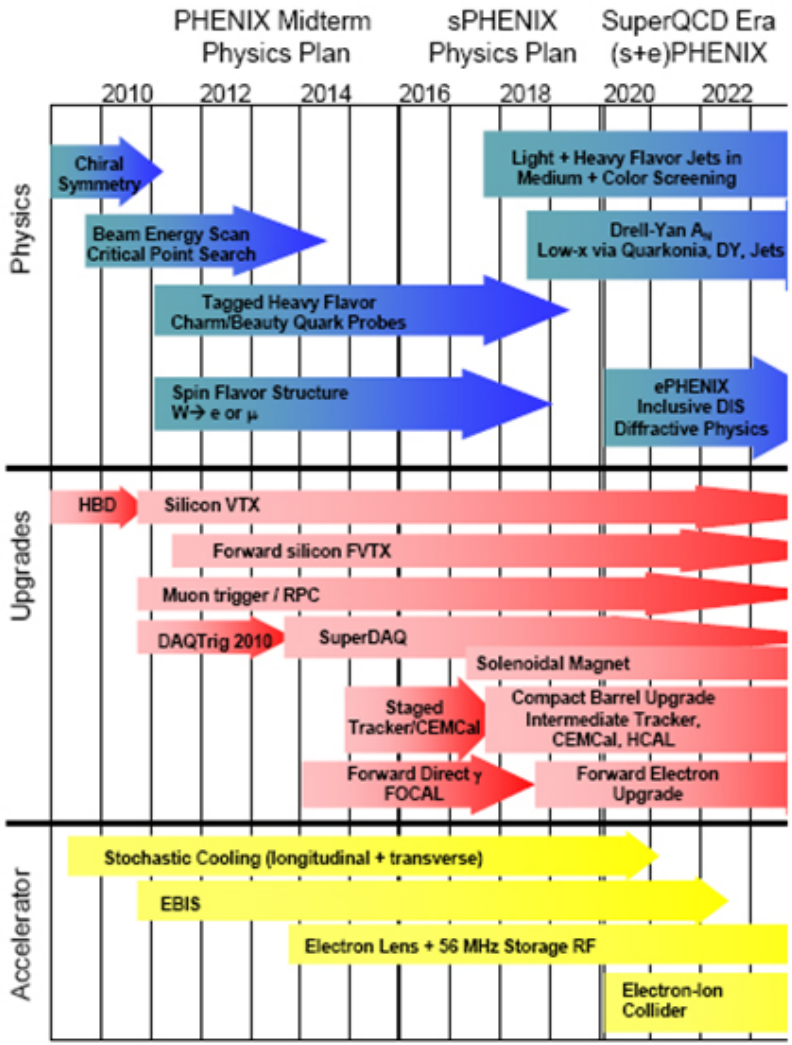
Nucleon structure experiments using proton beam - present and future -

RIKEN/RBRC

Itaru Nakagawa

RHIC Future Plan

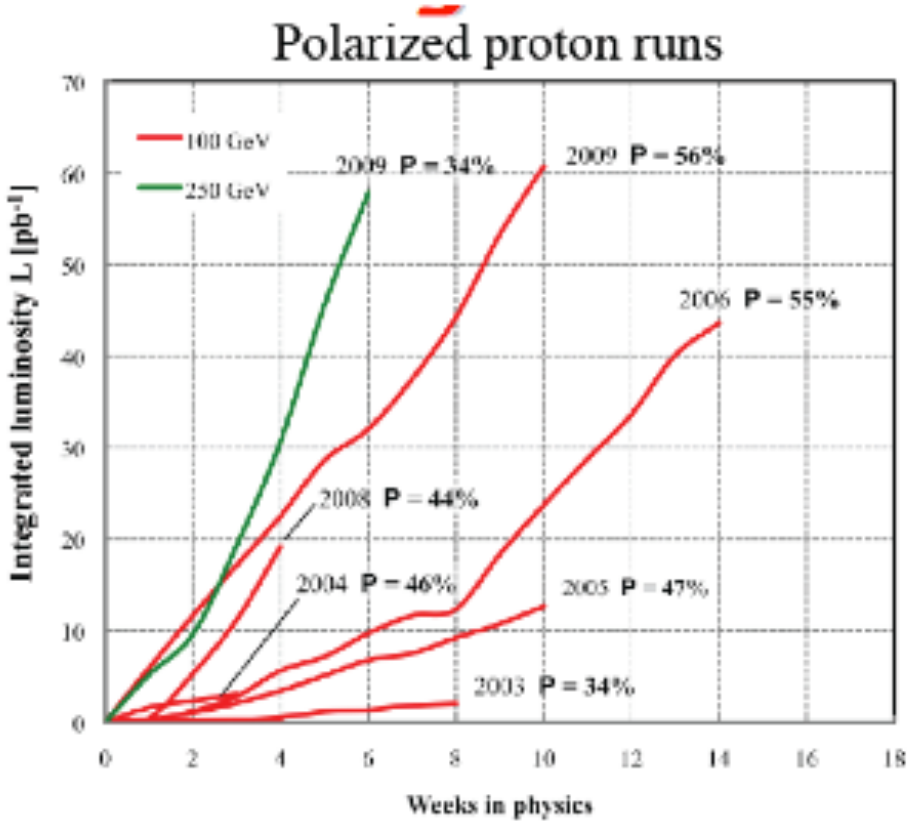


STAR Decadal Plan Synopsis

	Near term (Runs 11–13)	Mid-decade (Runs 14–16)	Long term (Runs 17–)
Colliding systems	p+p, A+A	p+p, A+A	p+p, p+A, A+A, e+p, e+A
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	Υ, $J/\psi \to ee$, m_{ee}, v_2	Υ, $J/\psi \to \mu\mu$, Charm v_2, R_{CP}, Charm corr, Λ_c/D ratio, μ-atoms	p+A comparison
(2) Mechanism of energy loss	Jets, γ-jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, c/b in CNM
(3) QCD critical point	Fluctuations, correlations, particle ratios	Focused study of critical point region	
(4) Novel symmetries	Azimuthal corr, spectral function	$e-\mu$ corr, $\mu-\mu$ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	W A_L, jet and di-jet A_{LL}, intra-jet corr, $(\Lambda+\bar{\Lambda})$ D_{LL}/D_{TT}		Λ D_{LL}/D_{TT}, polarized DIS, polarized SIDIS
(7) QCD beyond collinear factorization	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, J/ψ, F-F corr, Λ, DIS, SIDIS

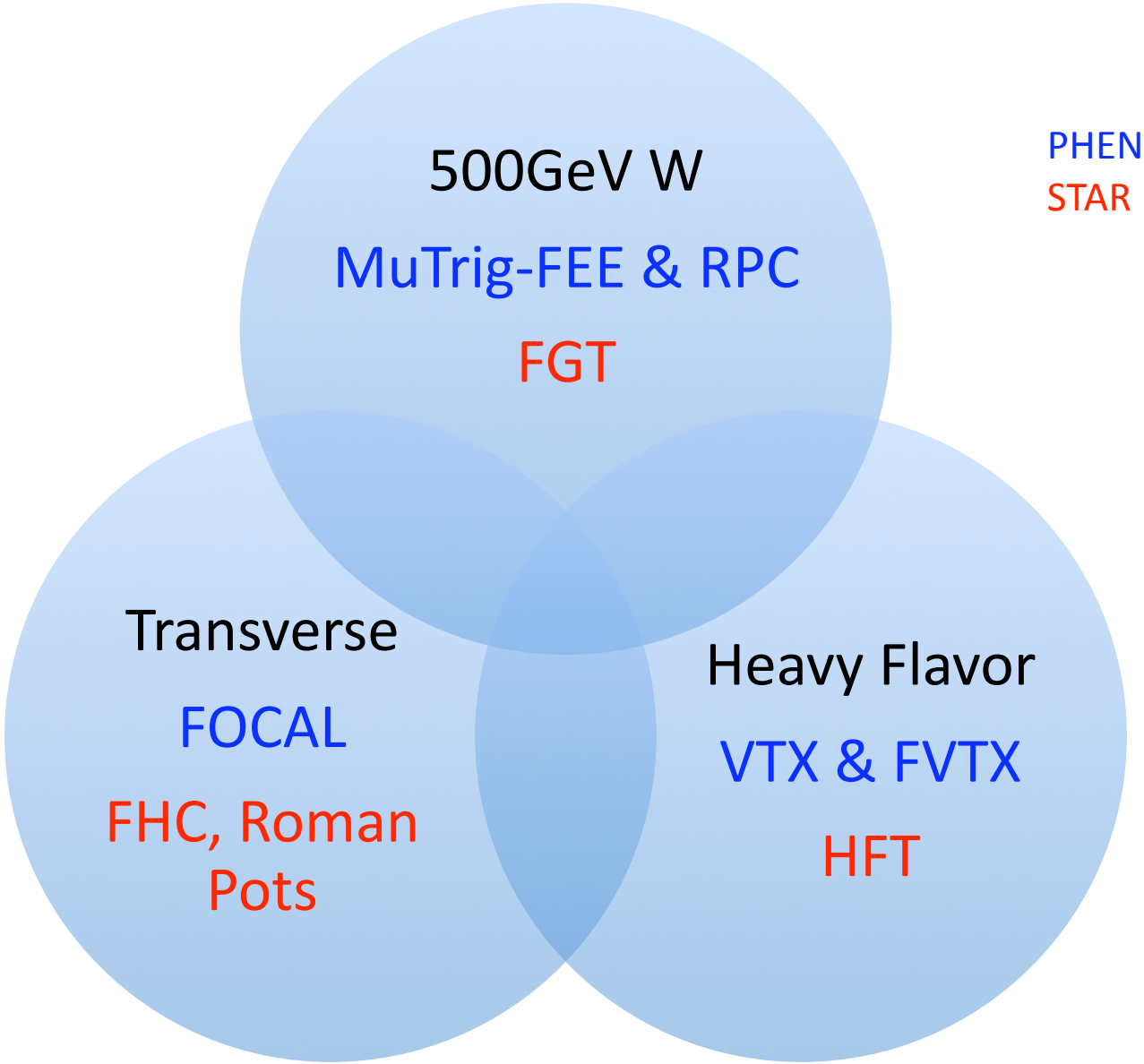
RHIC Performance Upgrades

- Not only detectors, but also RHIC accelerator performance also be developed
  - 9MHz cavity
  - Electron lenze
  - Spin flippers
  - …



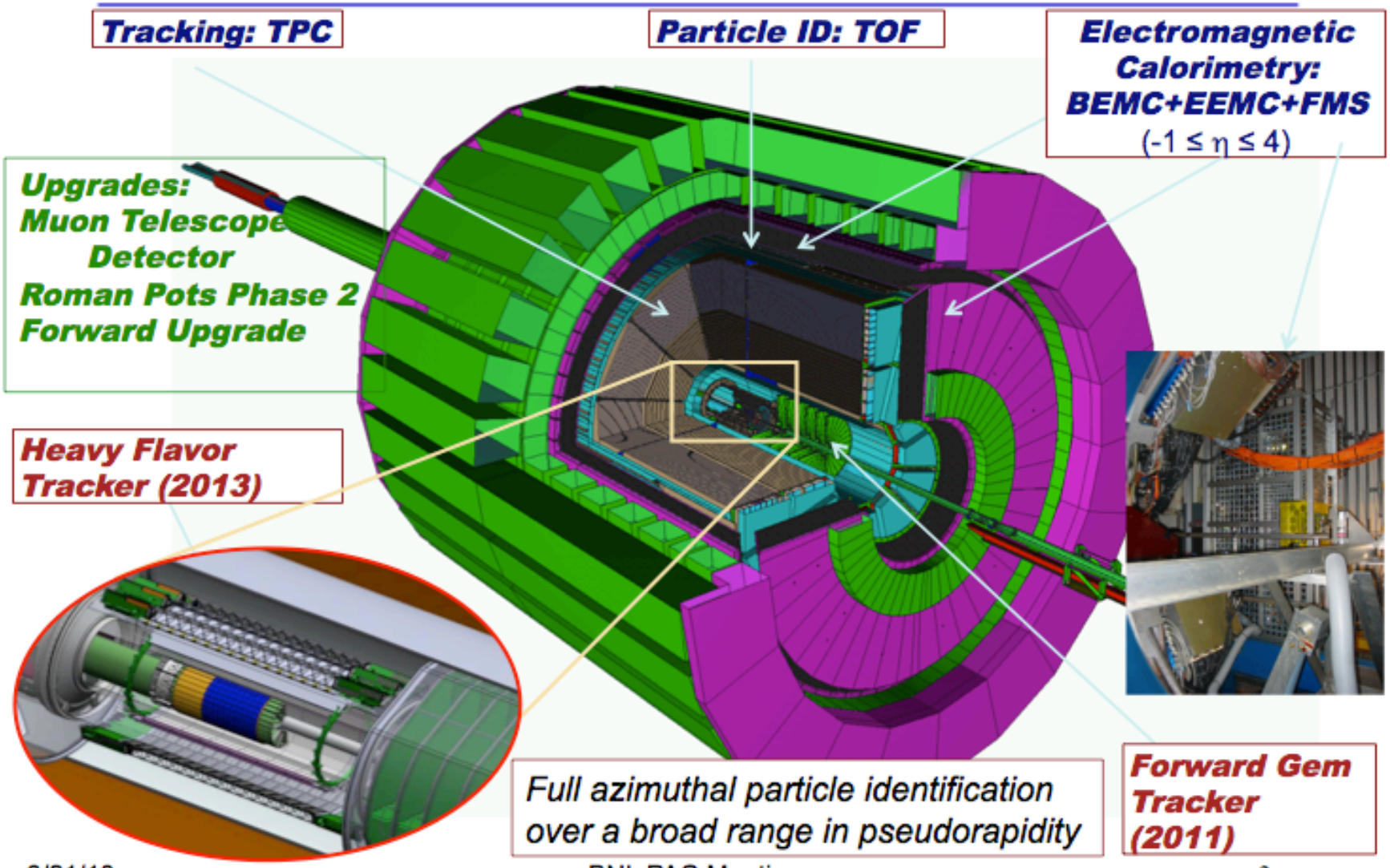
Next 5 years

PHENIX and STAR Upgrades and Spin Physics



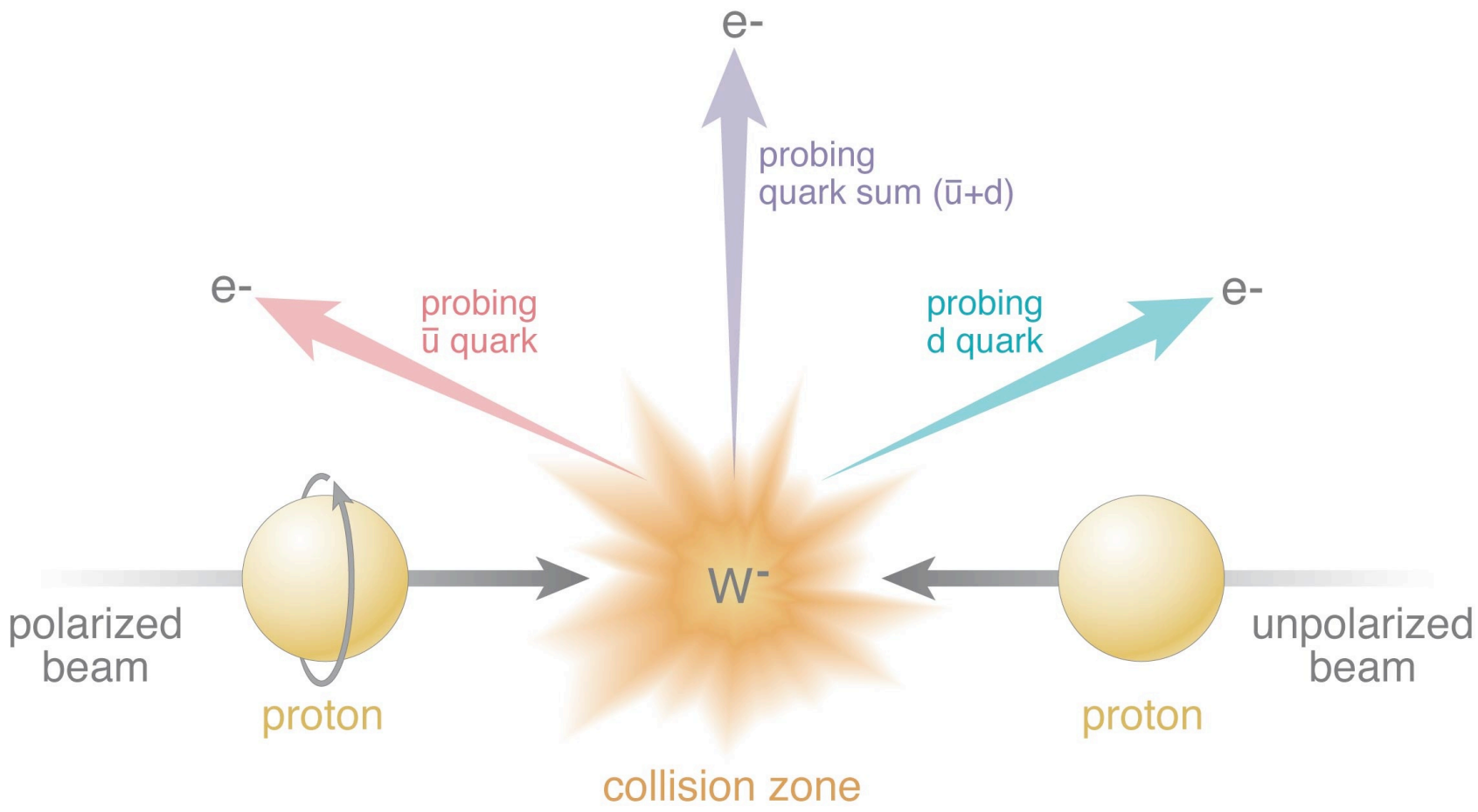
PHENIX Upgrade
STAR Upgrade

STAR: A Correlation Machine

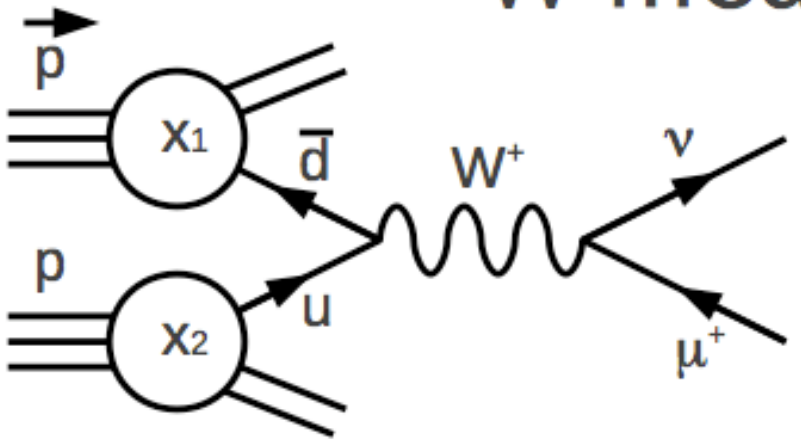


Slide from STAR Decadal Plan Status James Dunlop 6/21/10 1 BNL PAC Meeting

Sea Quark Polarization Measurement via W-boson Production



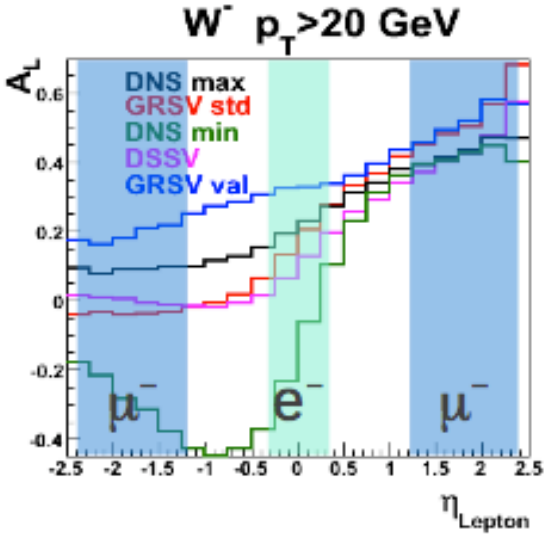
Sea Quark Polarization by W measurement

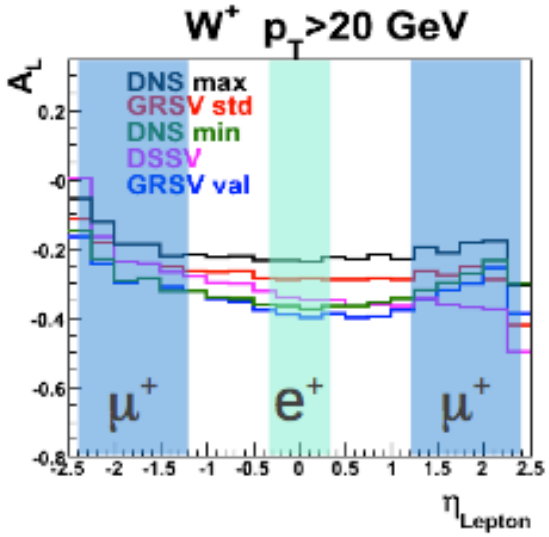


$$A_L^{W^+} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \sim -\frac{\Delta u(x_1)\bar{d}(x_2) - \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)}$$

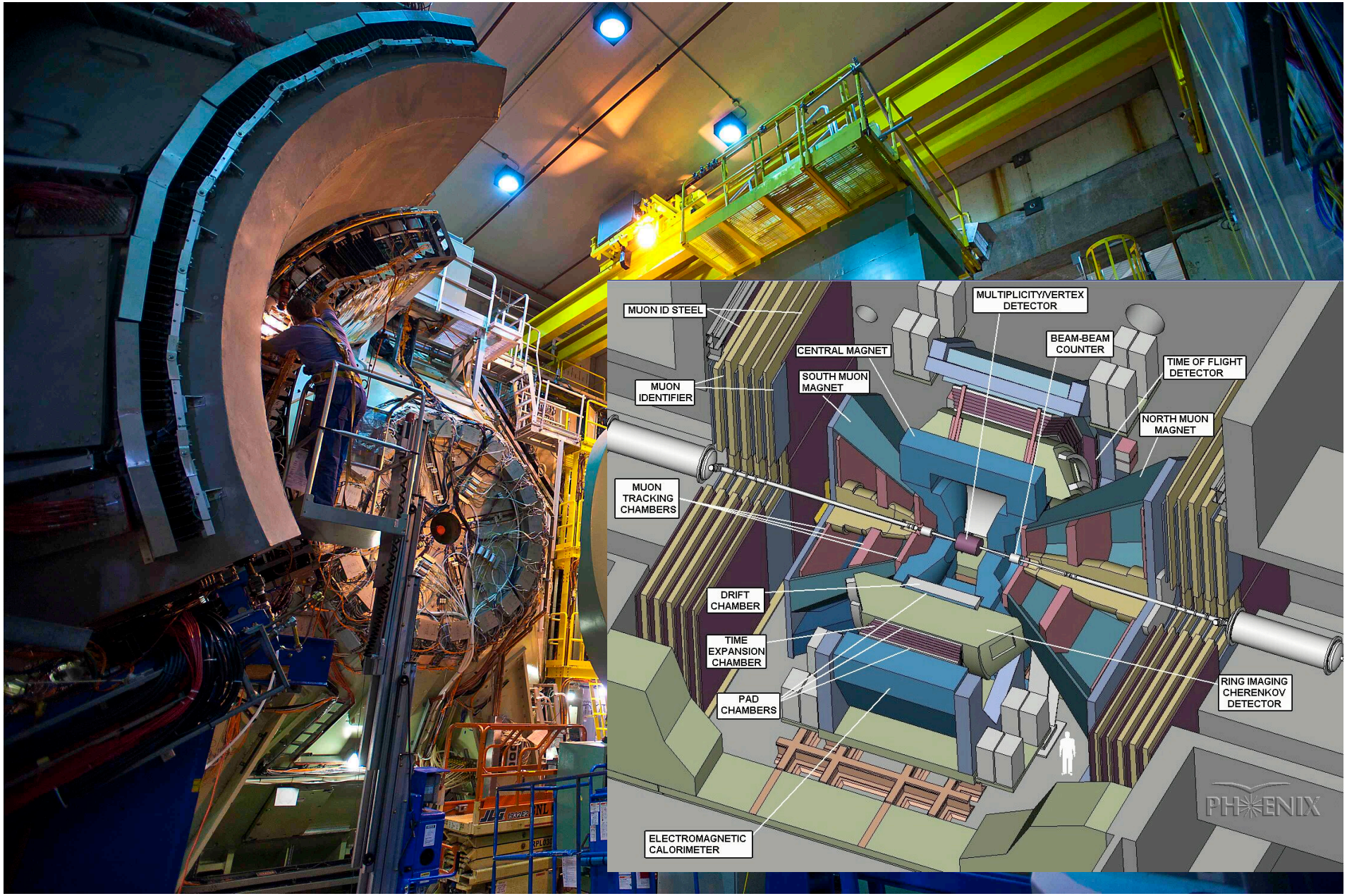
Feature of $pp \to W$

- $u+\bar{d} \to W^+$, $\bar{u}+d \to W^-$
- q : helicity−, $\bar{q}$: helicity+
- No uncertainty from fragmentation function.
- Small Cross Section → High efficiency is required.





Forward (North&South) Muon Arms



High Momentum Muon Trigger

Run11 500 GeV Projection

Rate

σ_{tot}=60mb

L=1.5x10^{32}cm^{-2}s^{-1}

9 MHz

BBC×MuID Rejection Power

RP~100

90 kHz

Trigger Upgrade

RP ~ 45

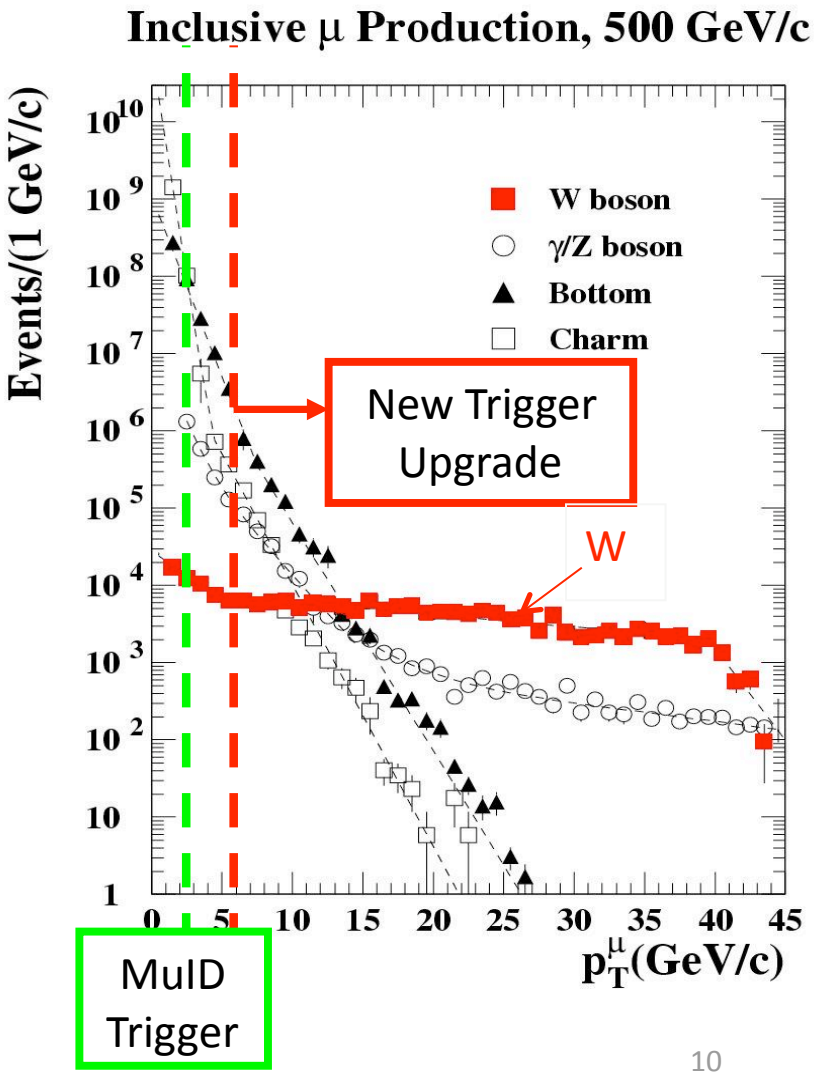
RP_{tot} ~ 4500

2 kHz

PHENIX Band Width for Muon

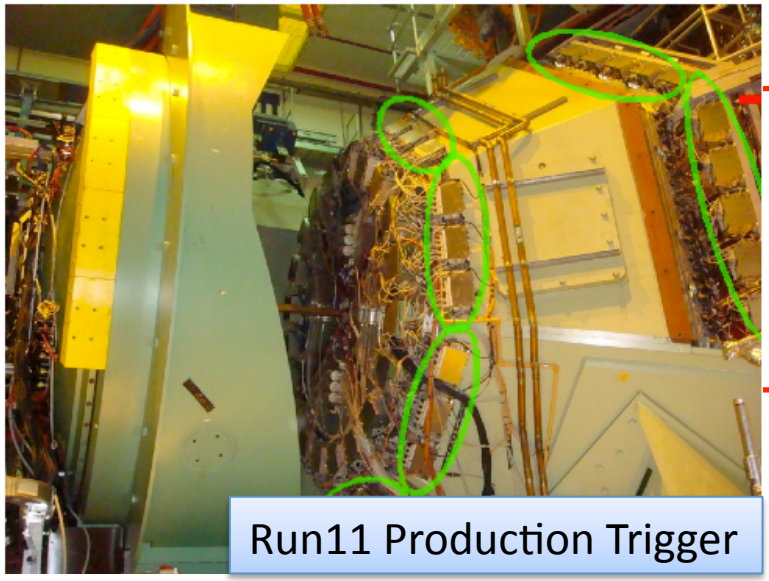
Required Rejection Power

1. High Rejection Power
2. High Efficiency

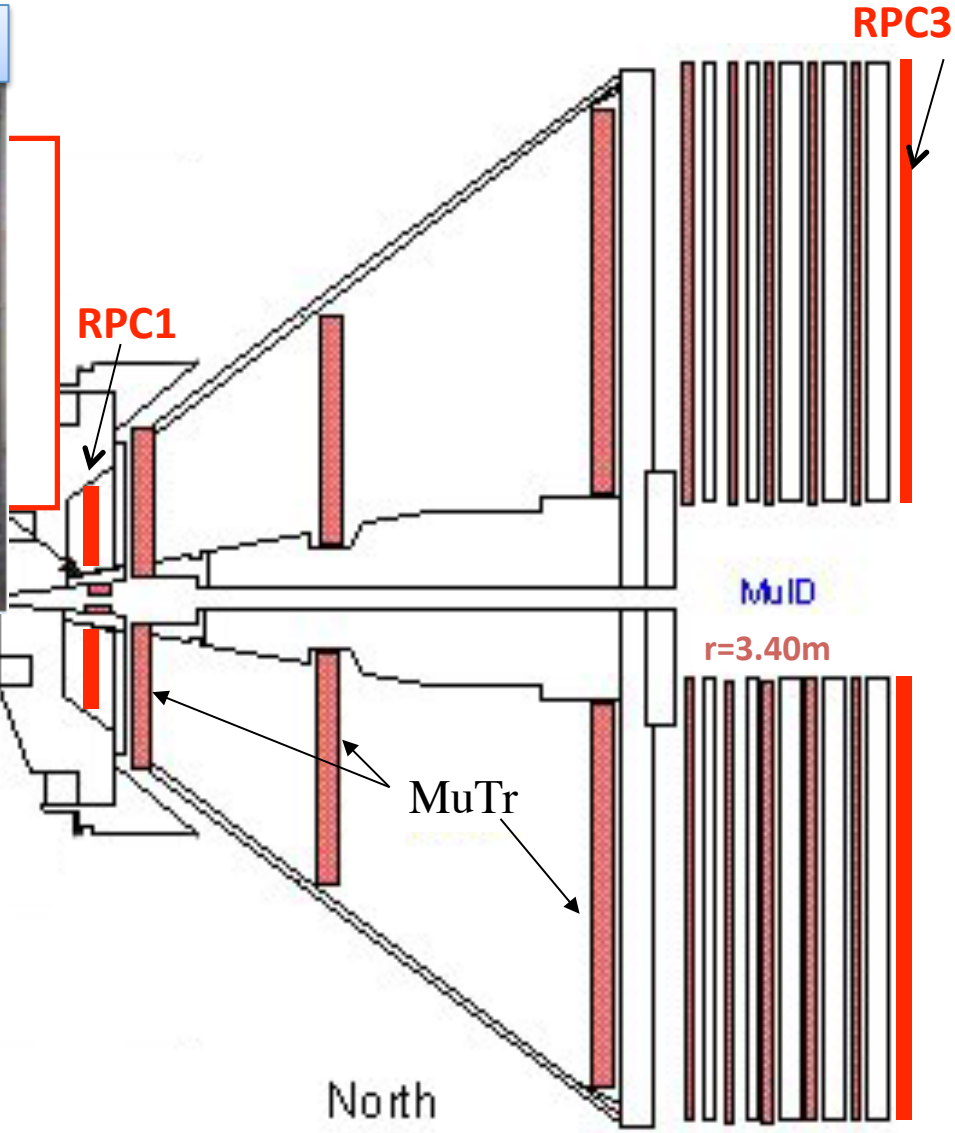


PHENIX Muon Trigger Upgrade

Run11 under commissioning

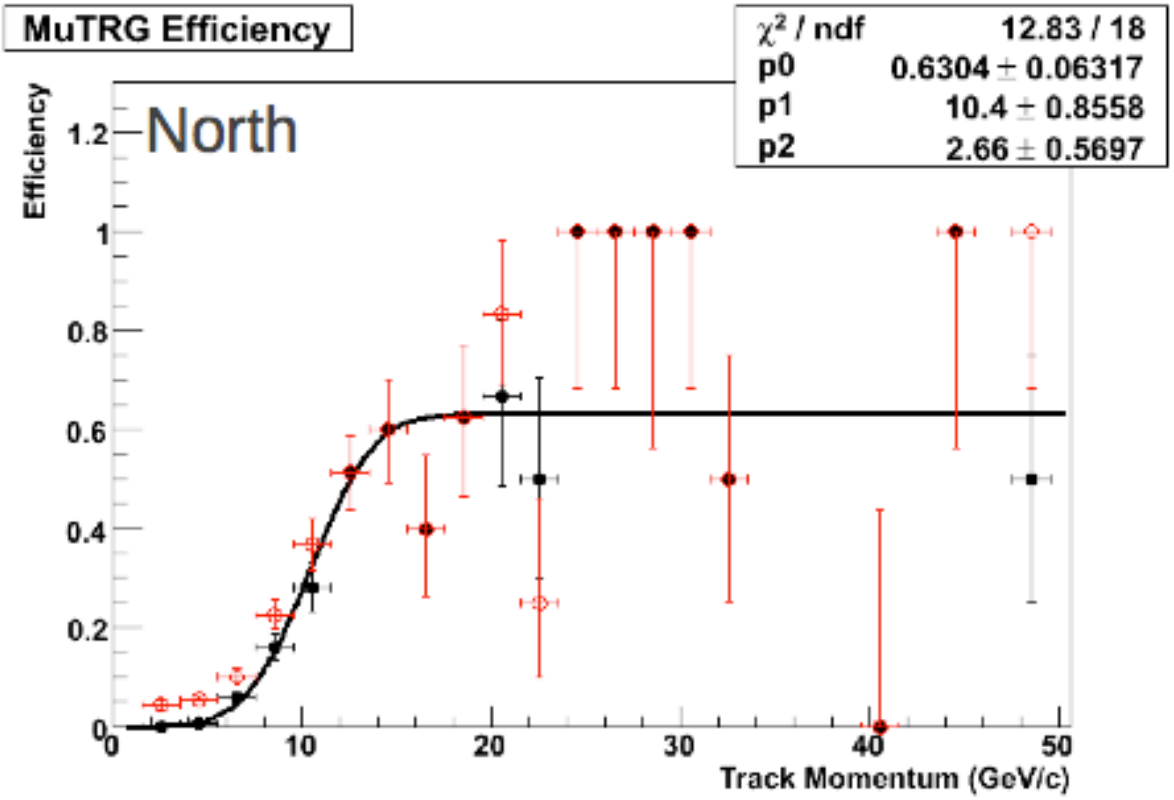


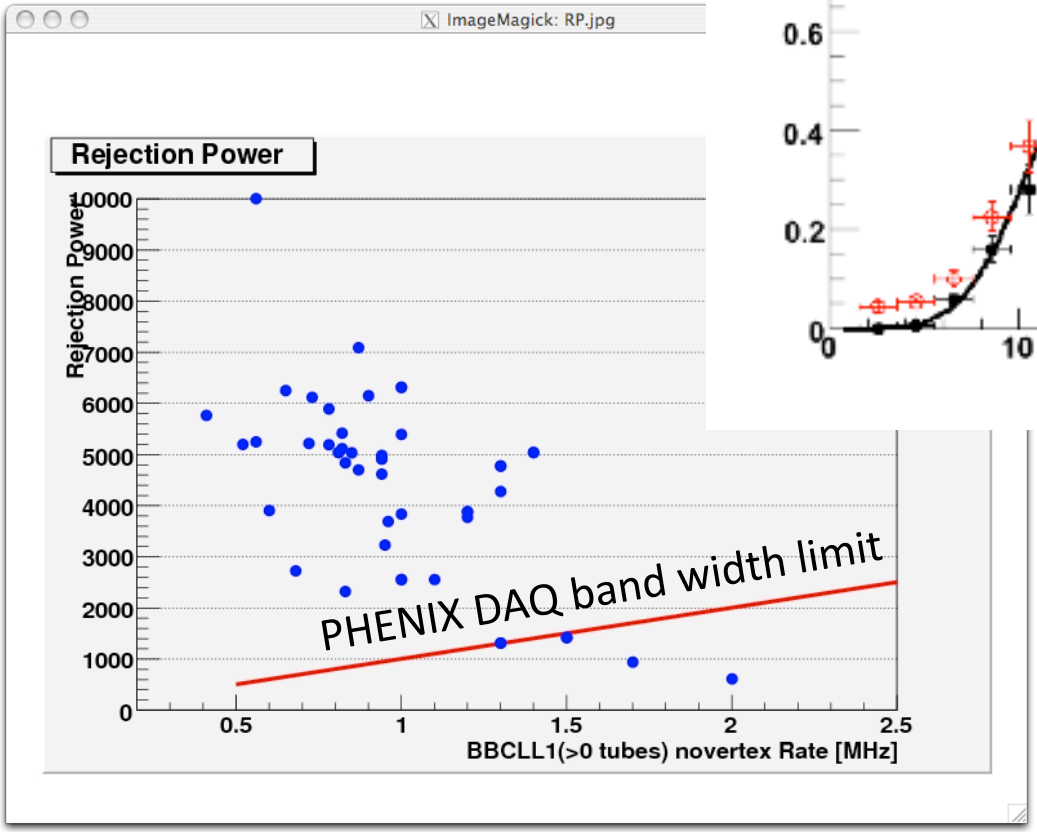
Run11 Production Trigger



Muon Trigger FEE Performance

Goal :
- High Efficiency > 90%
- High Rejection Power > 3000

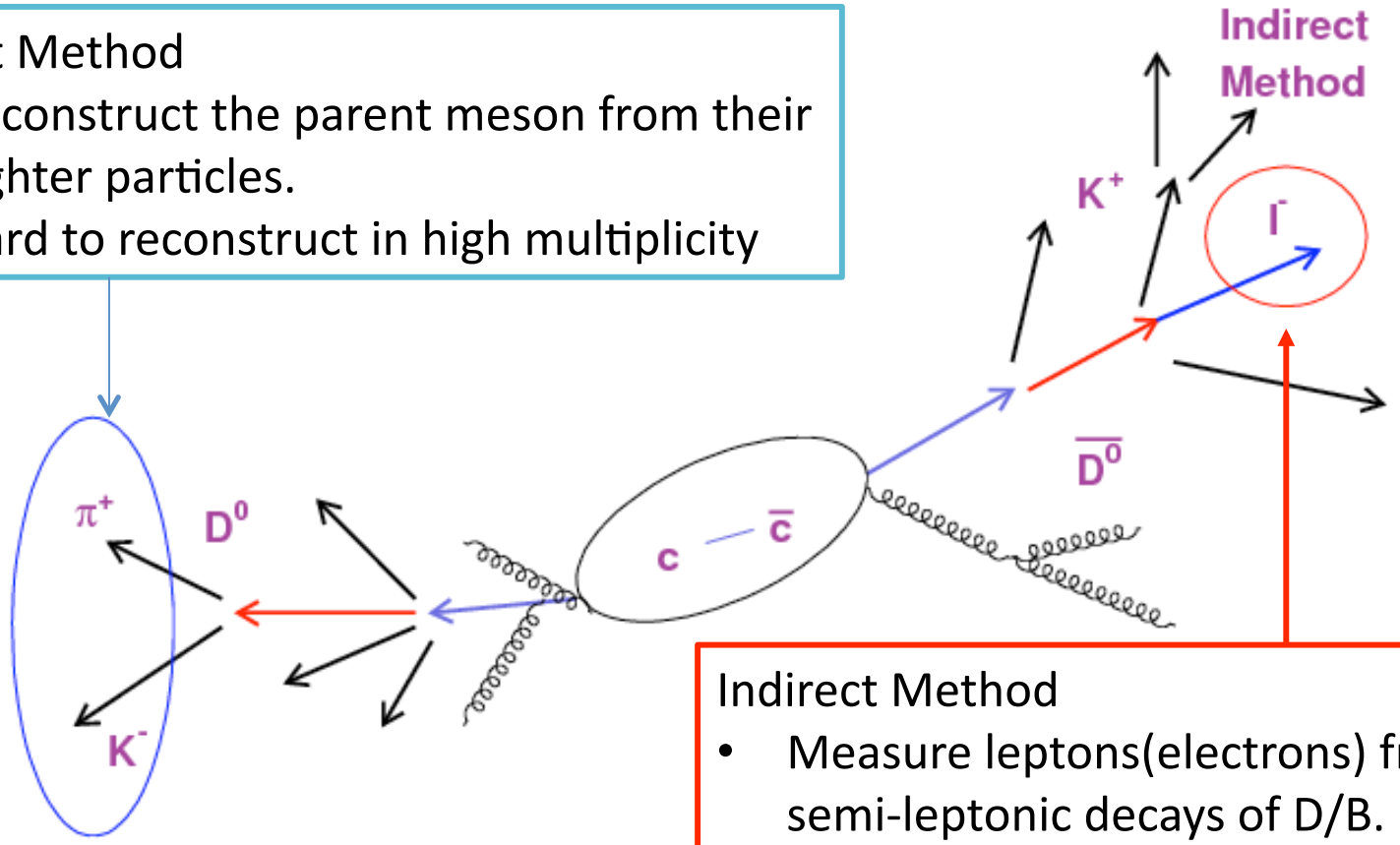




New MuTrig-FEE operation is on its way to be optimized.

Heavy Quark Measurement

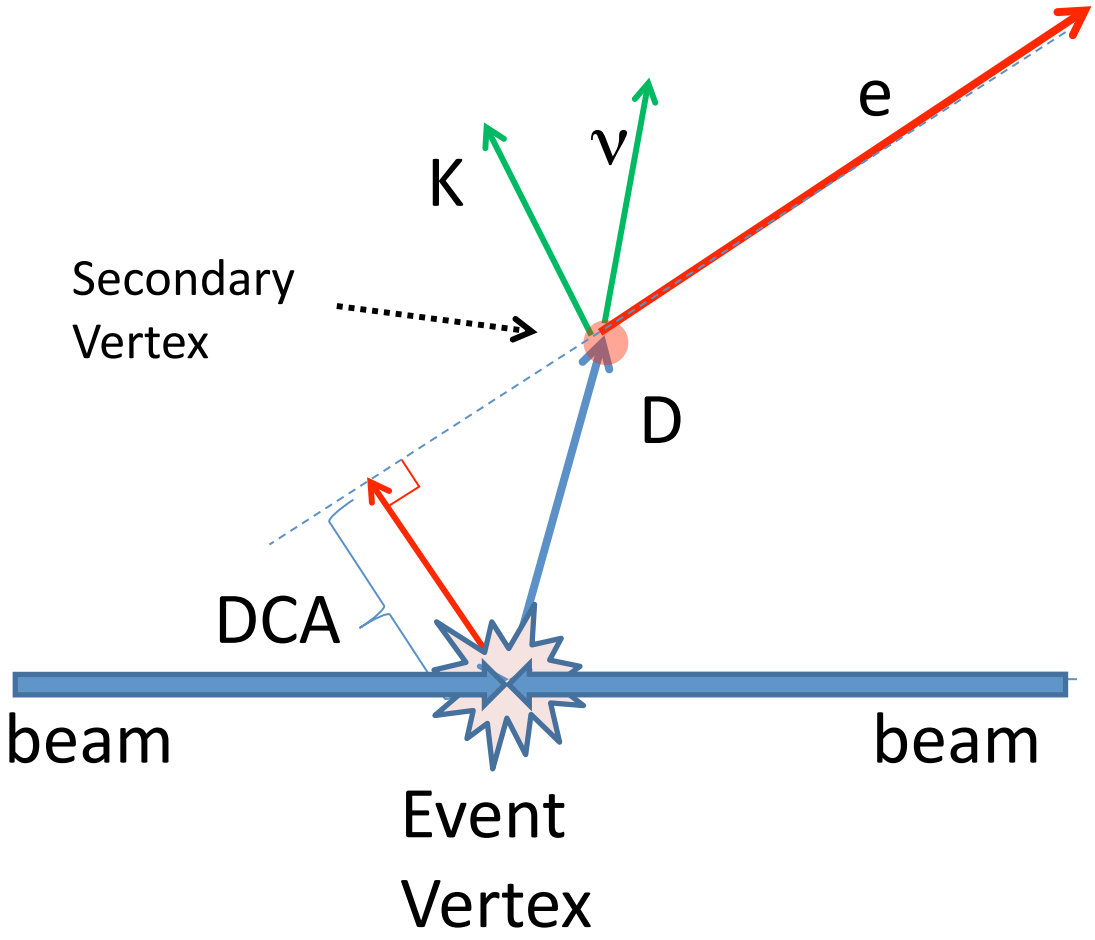
Direct Method
- Reconstruct the parent meson from their daughter particles.
- Hard to reconstruct in high multiplicity



Indirect Method
- Measure leptons(electrons) from semi-leptonic decays of D/B.
- Standard method in PHENIX

VTX can improve both Indirect and Direct method by DCA measurement.

Distance of Closest Approach (DCA)



1. Collision happens
2. D meson is emitted from the event vertex
3. This D meson will decays in flight. Decay products are scattered at secondary vertex.
4. Electron is measured by VTX. The track is reconstructed.
5. DCA = Distance of Closest Approach of a reconstructed track to the event vertex

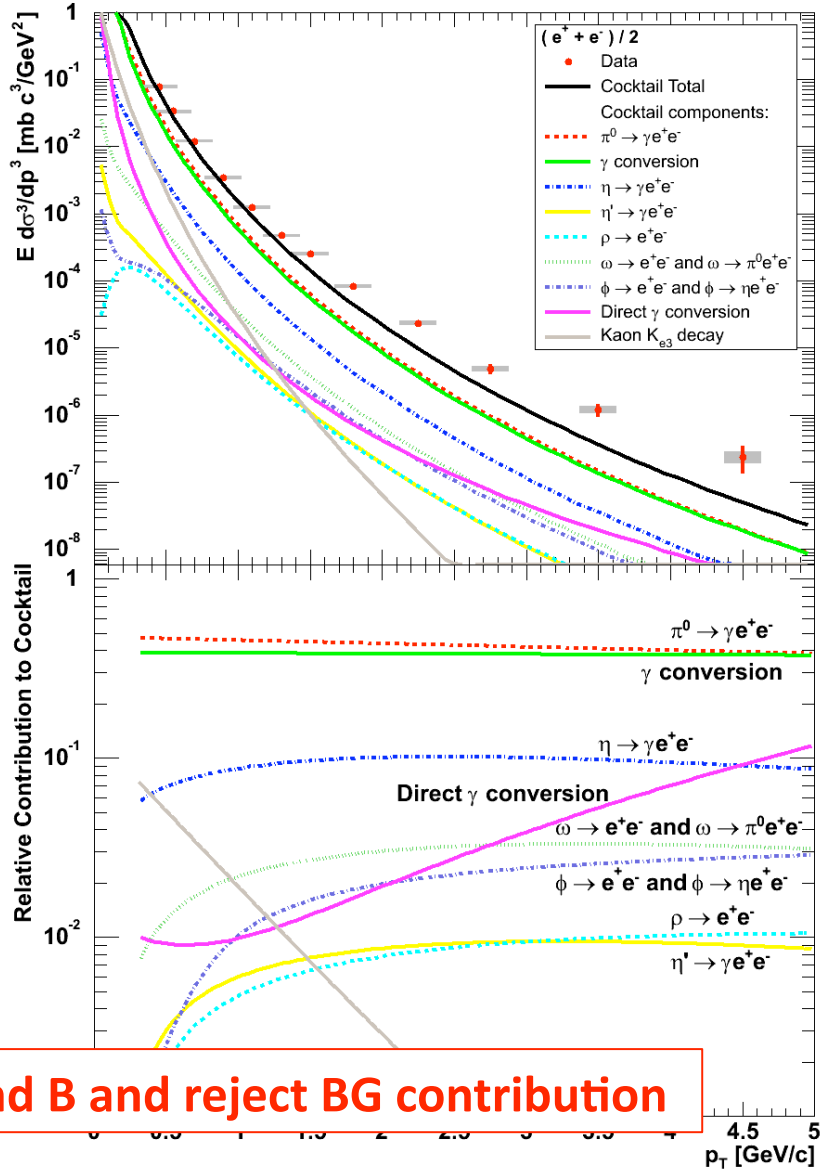
DCA : Flight path length of Signal and Background

Back Ground

- π0 cτ = 25.1 nm
- η for Γ = 1.30 ± 0.07 keV
- ω for Γ = 8.49 ± 0.08 MeV
- ρ for Γ = 149.1 ± 0.8 MeV
- ϕ for Γ = 4.26 ± 0.04 MeV
- j/ψ for Γ = 28.6 ± 2.2 MeV
- K+/-e3 cτ = 3.712 m
- K0S cτ = 2.6842 cm
- K0L cτ = 15.34 m
- γ conv @ material

Emitted from Zvtx

Far from Zvtx

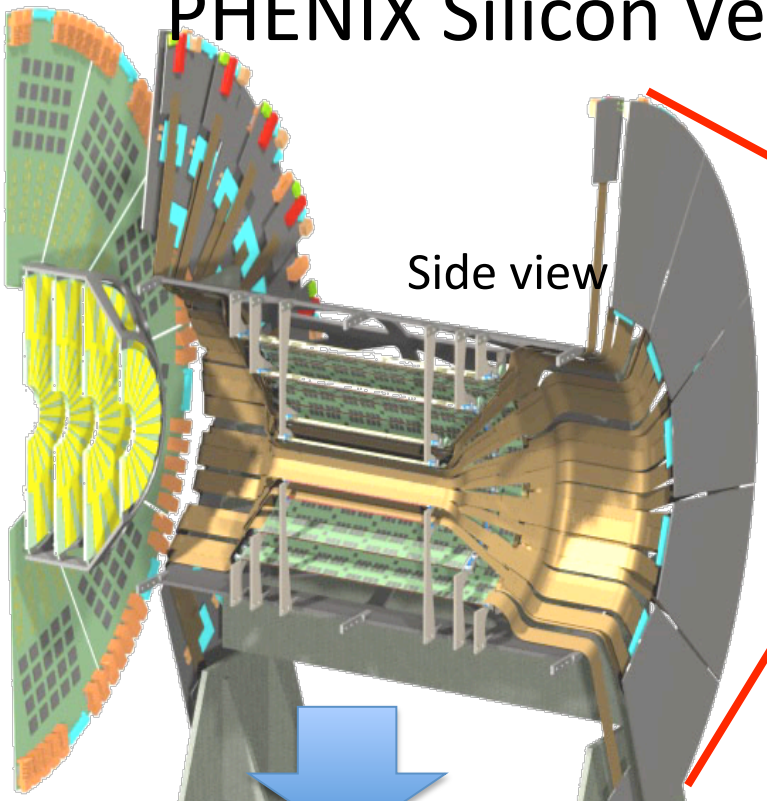


Signal

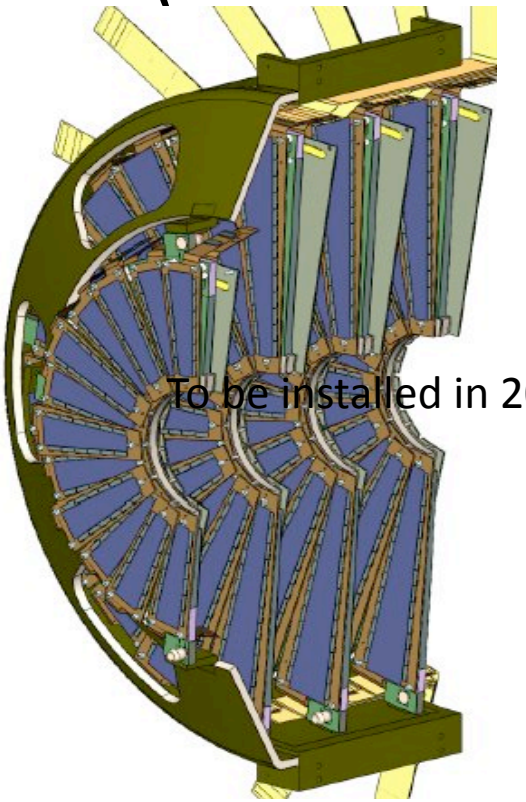
- **D0 cτ = 122.9 μm**
- **D+ cτ = 311.8 μm**
- **B0 cτ = 457.2 μm**
- **B+ cτ = 491.1 μm**

With 50um resolution, VTX separate D and B and reject BG contribution

PHENIX Silicon Vertex Trackers (VTX & FVTX)

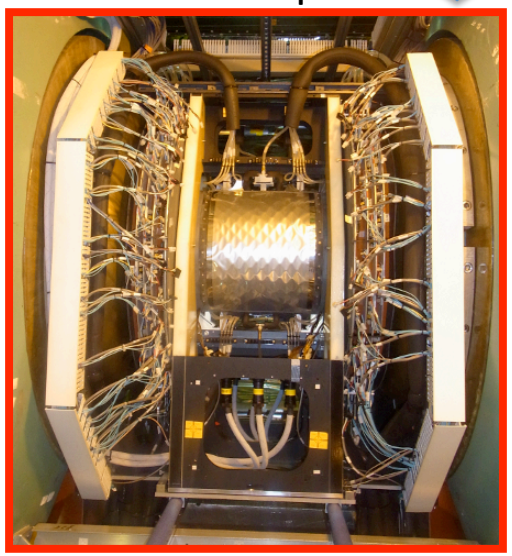


Side view



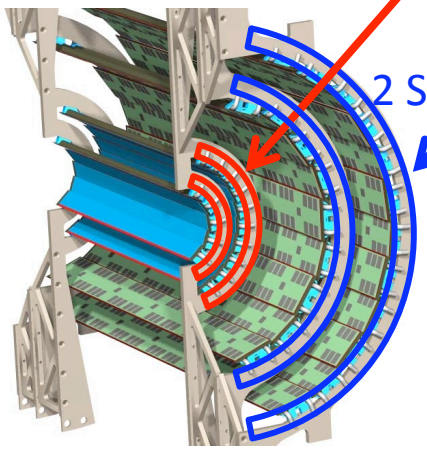
To be installed in 2011!

Installation Completed!

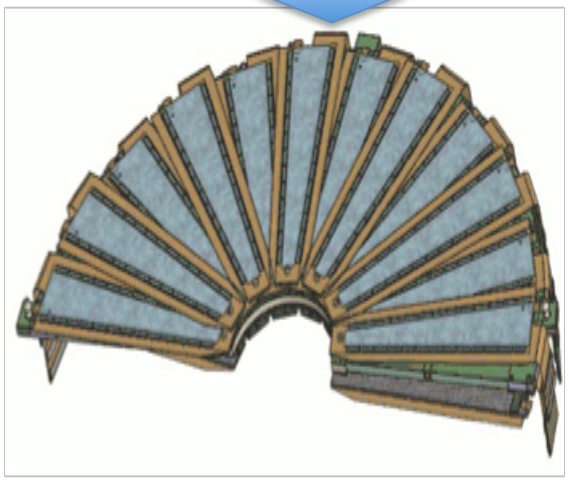


2 Pixel layers

2 Stripixel



Beam view



Physics Motivation

Measurement in p + p, d + Au and Au + Au Collisions

Single Muons measurements:

- Precision heavy flavor and hadron measurements.
- Separation of c and b in semi-leptonic decays via decay kinematics.
- Improve W background rejection.

Dimuons measurements:

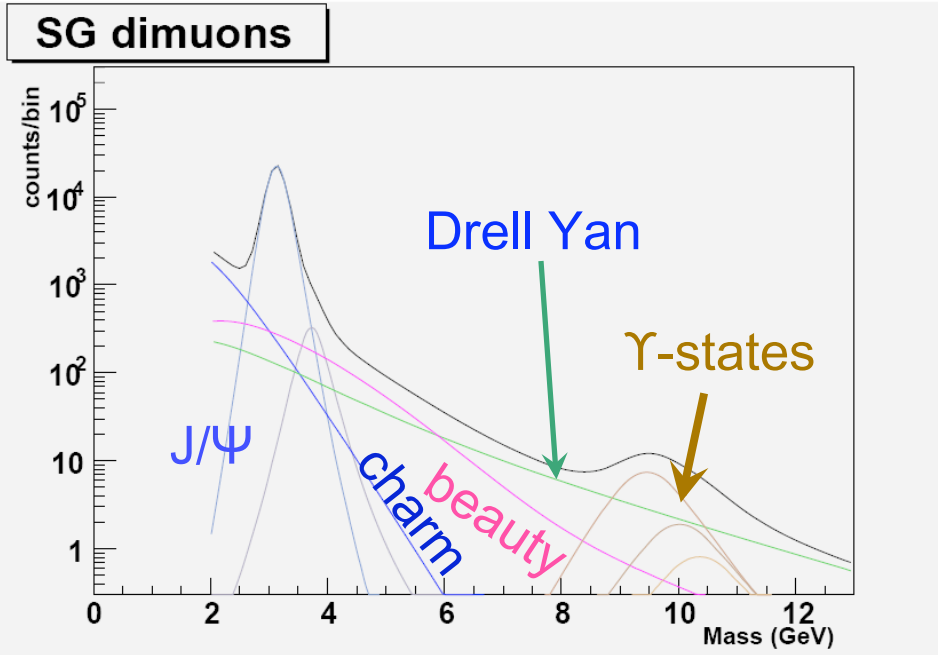
- Separation of ψ' from J/ψ at forward rapidity.
- $B \rightarrow J/\psi$, golden channel to measure B cross section.
- First Drell-Yan measurement at RHIC.

Physics FVTX Can Access:

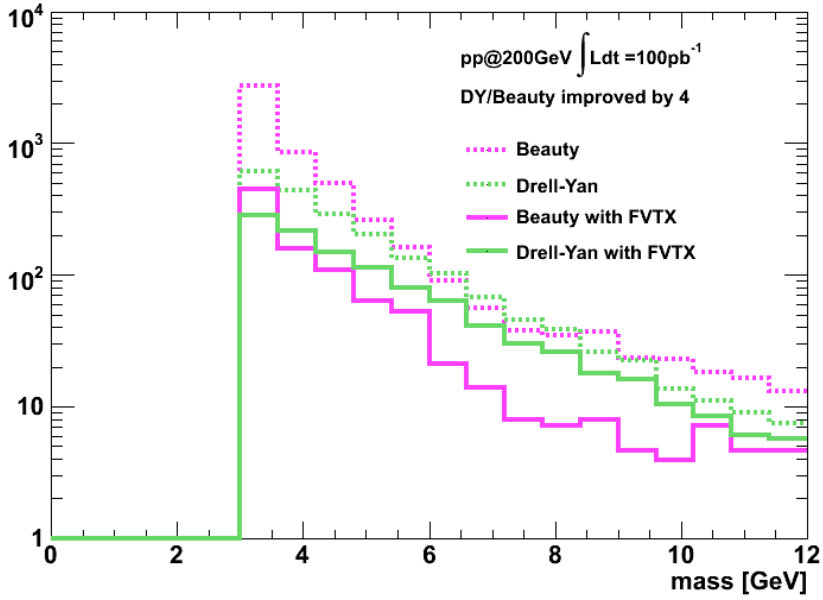
- Energy loss mechanism in hot dense medium (Heavy flavor $R_{AA,}$ v_2)
- Cold nuclear effects (Heavy flavor R_{dAu})
- Gluon polarization $\Delta G/G$ (Heavy flavor A_{LL})
- Sivers function, higher twist (Heavy flavor A_N)
- Crucial test of QCD universality (Drell-Yan A_N)

Drell-Yan measurement

Heavy flavor background



b-bbar background rejection with FVTX
In Drell-Yan process



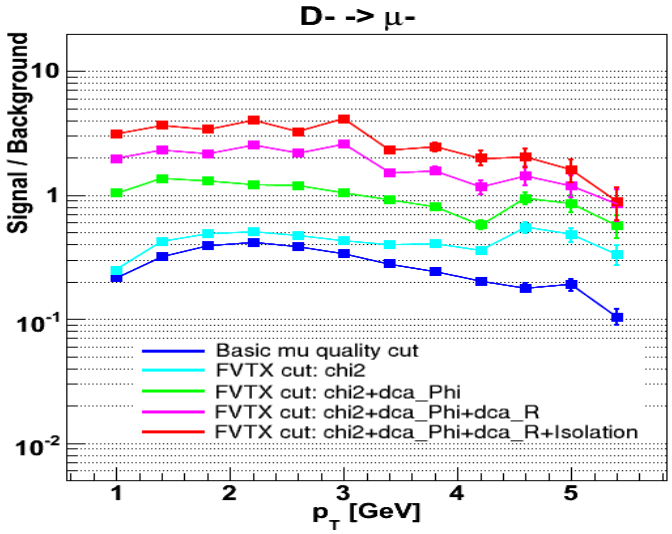
➔4 GeV < M < 10 GeV
Background (bottom,Charm) rejection using FVTX

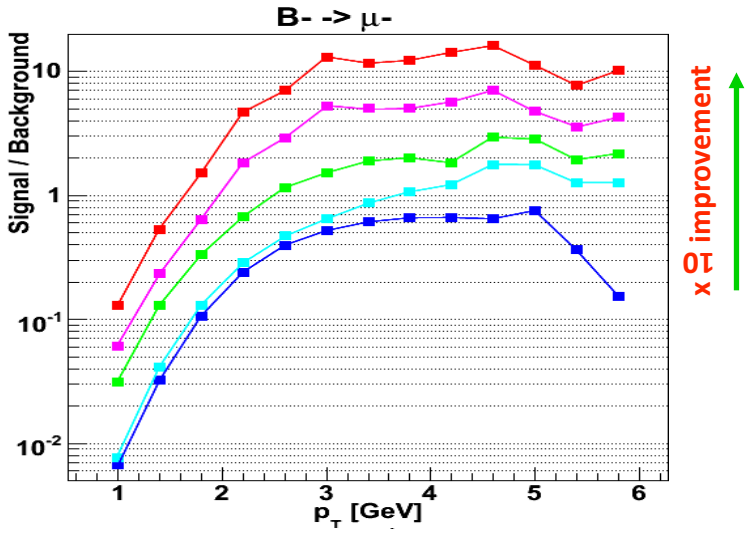
Improve Signal / Background Ratio by factor ~4

FVTX + new muon trigger will open up wide variety of physics opportunities from forward arm!

Signal / Background improvements

S/B improvement with FVTX cuts

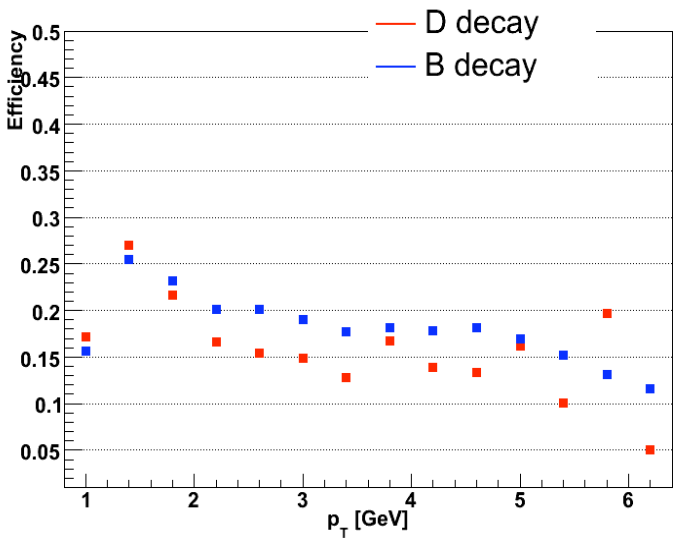




Cut :

- Basic mu quality Cut
- FVTX Cut : chi2
- FVTX Cut : chi2+dca_Phi
- FVTX Cut : chi2+dca_Phi+dca_R
- FVTX Cut : chi2+dca_Phi+dca_R+Isolation

Efficiency



FVTX improve S/B ~10 ;

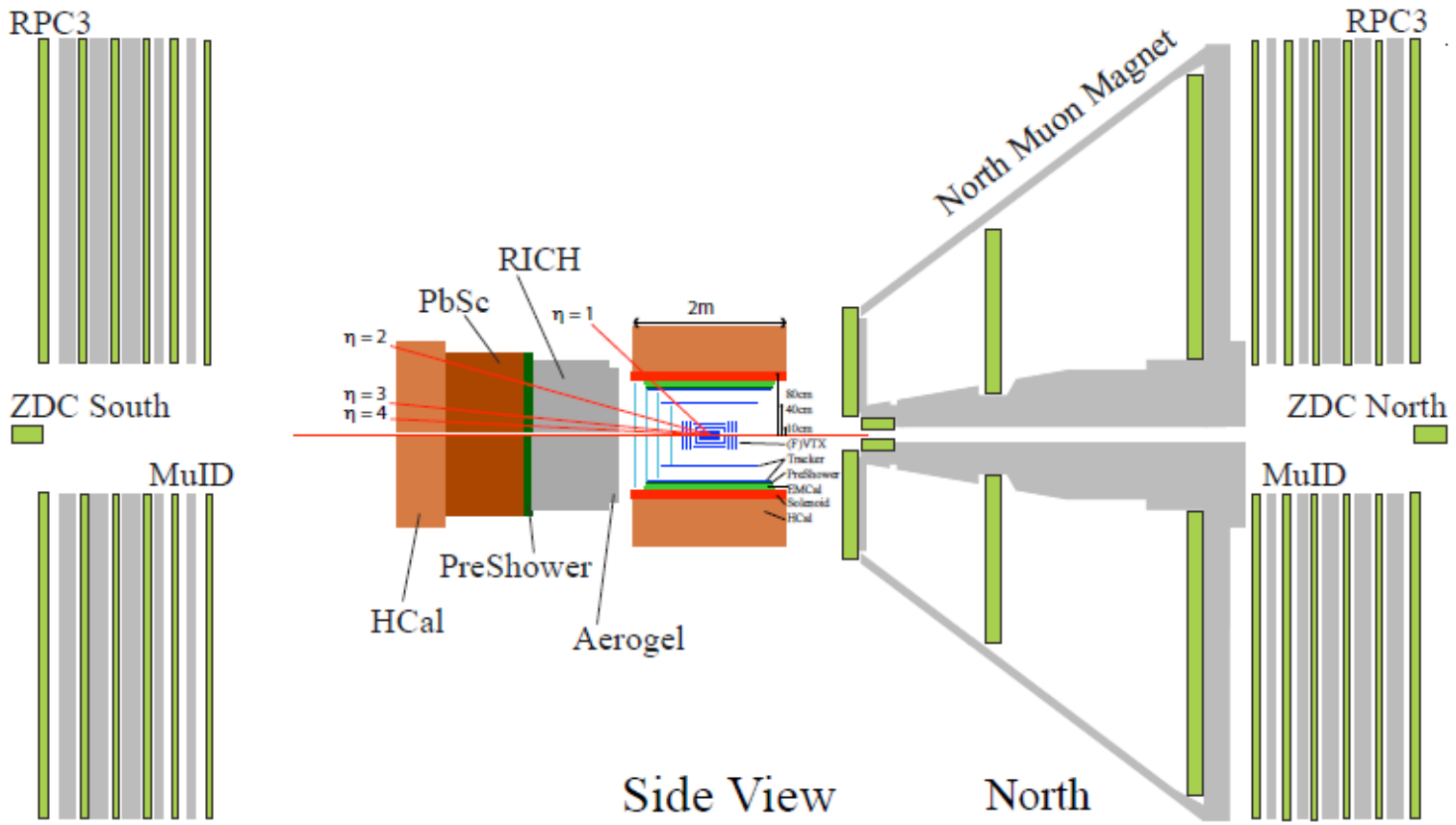
Efficiency 15% ~ 20% ;

10 years

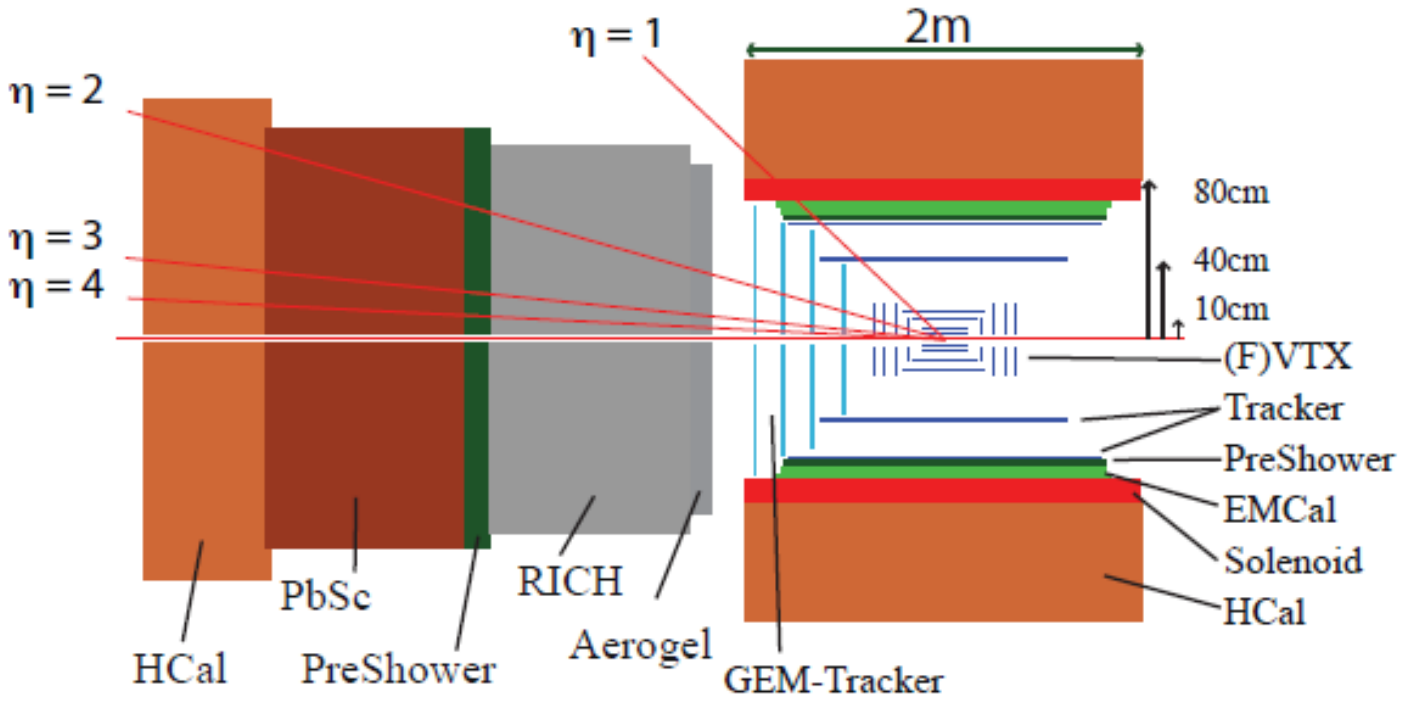
Some thoughts on future detectors

- Multipurpose, flexible—ready to address new questions as they arise!
- Uniform, compact
- Two multipurpose detectors? One optimized for hadronic/nuclear collisions with secondary capabilities in e+A, e+p; other vice versa? (Challenging to optimize for both!)
- Staged implementations?
- Renewed collaborations!
  - Major new program should attract new collaborators!

Conceptual Design sPHENIX



sPHENIX strawman

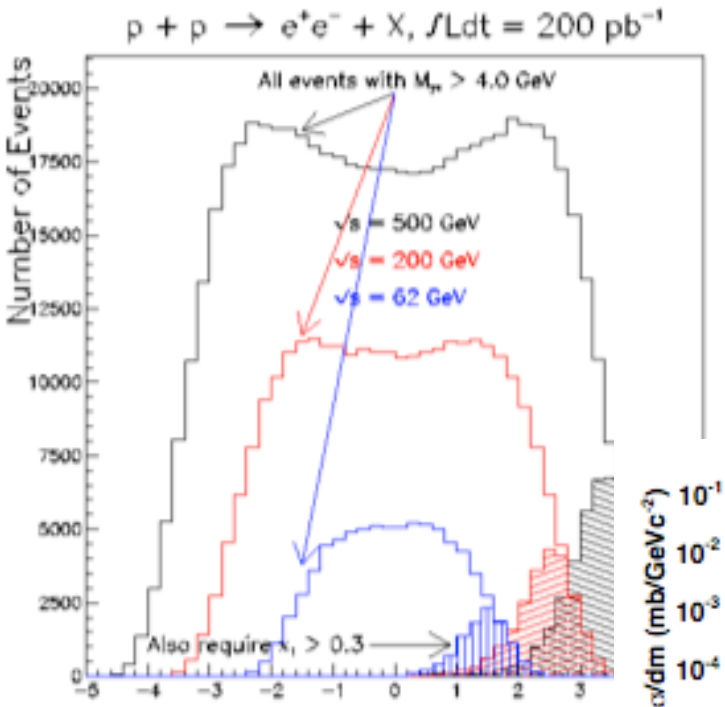


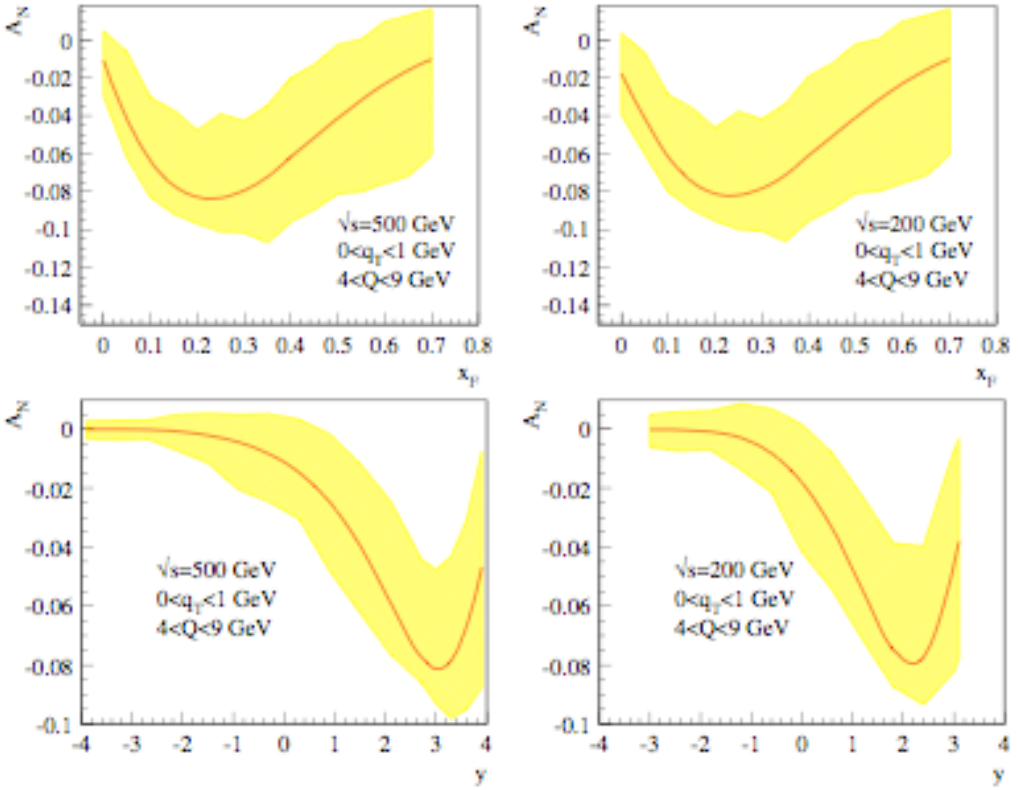
dimensions, technology, additional capabilities still under investigation

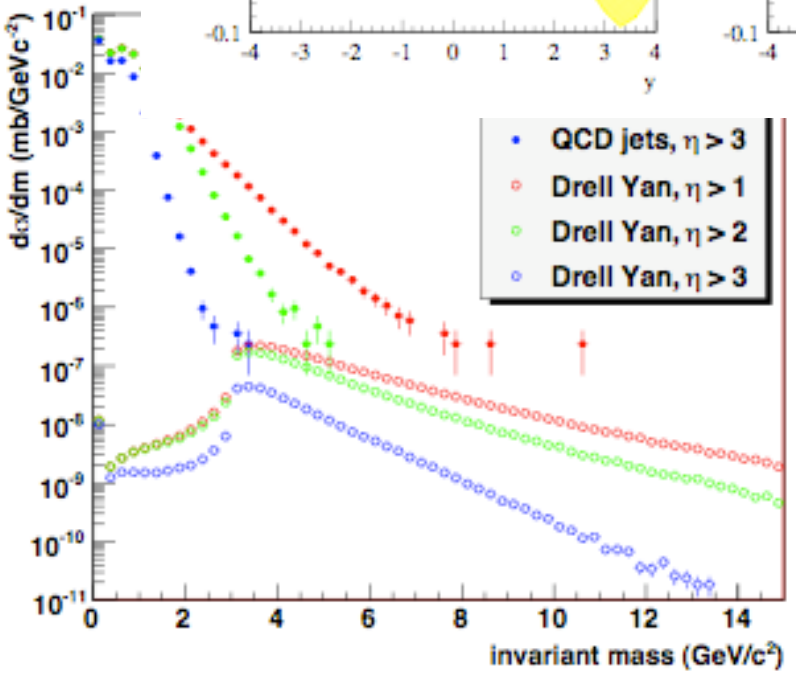
Target Physics

- Dynamical Origin of Spin Dependent Interactions -> DY vs. SIDIS
- New probes of Longitudinal Spin Effects -> Direct g
- Measurements with polarized 3He (different valence quark components) and higher energy (sqrt(s)=650 GeV by upgrading DX magnets)

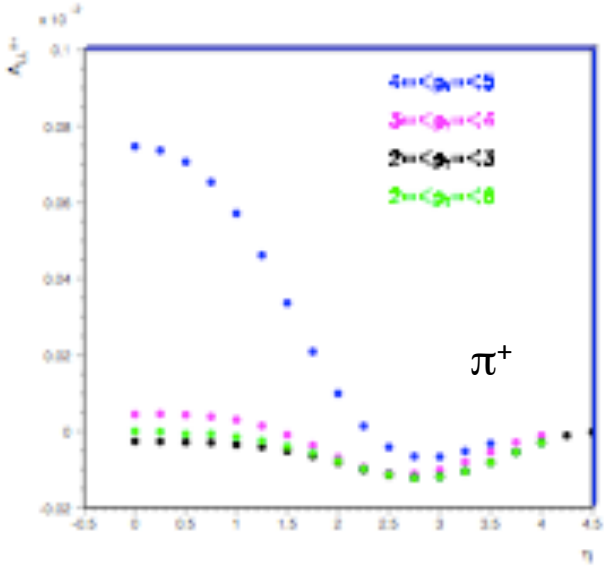
DY

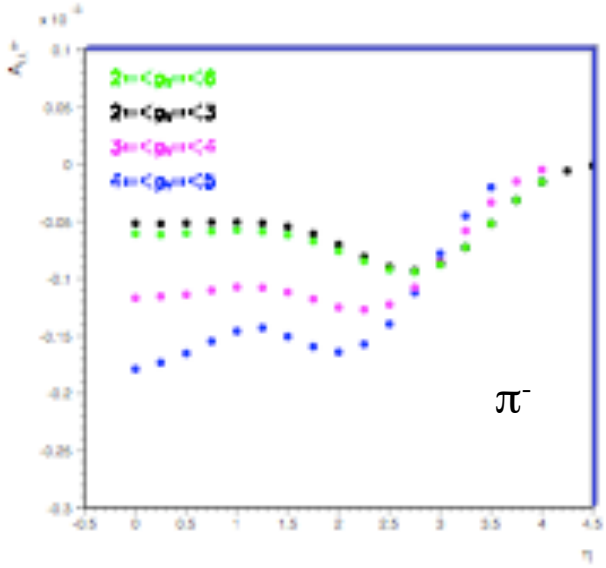

p + p → e⁺e⁻ + X, ∫Ldt = 200 pb⁻¹
All events with M_ee > 4.0 GeV
√s = 500 GeV
√s = 200 GeV
√s = 62 GeV
Also require x_1 > 0.3
Number of Events

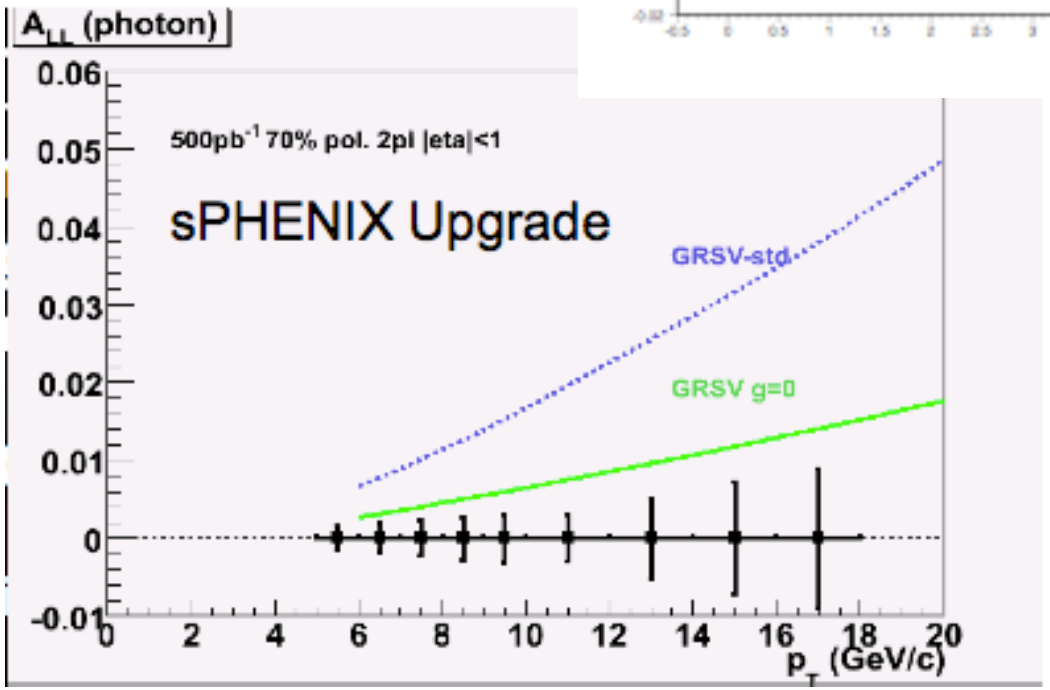

√s=500 GeV
0<q_T<1 GeV
4<Q<9 GeV
√s=200 GeV
0<q_T<1 GeV
4<Q<9 GeV
x_F
y


QCD jets, η > 3
Drell Yan, η > 1
Drell Yan, η > 2
Drell Yan, η > 3
dσ/dm (mb/GeVc⁻²)
invariant mass (GeV/c²)

Longitudinal







p-^{3}He collision