

The sPHENIX Upgrade (and ePHENIX)

The Physics of p+A Collisions at RHIC
(1/9/2013)

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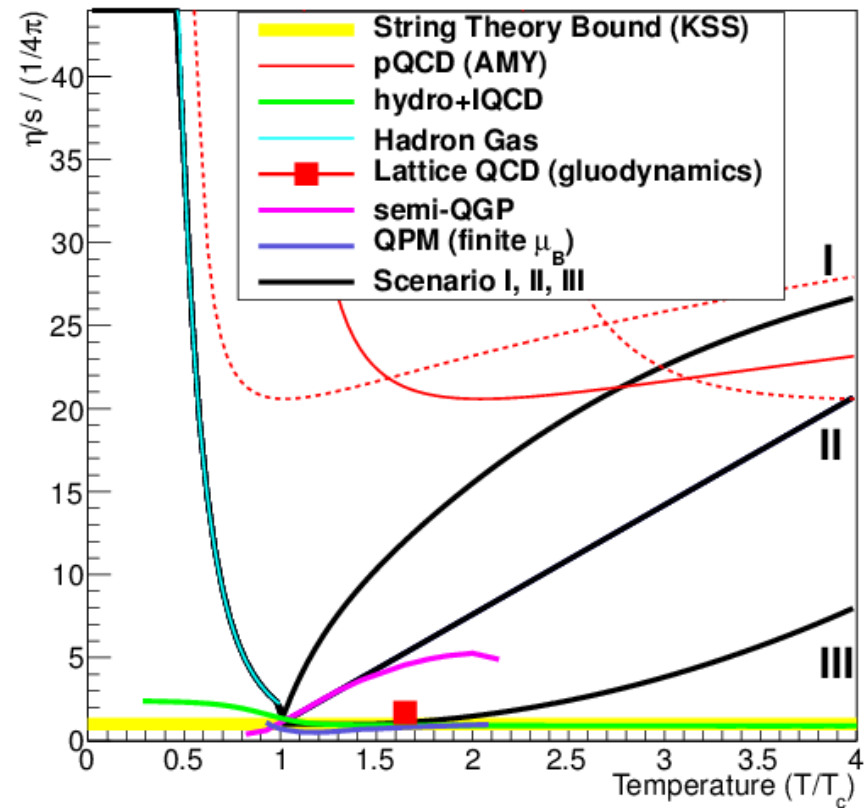
- Central Upgrade and Physics
- Forward Upgrade and Physics
- Towards ePHENIX



sPHENIX Central Physics and Upgrade

η/s

- How does η/s go from being nearly as small as possible near T_c to the weakly coupled limit?
- The figure shows several state-of-the-art calculations and three generic scenarios approaching T_c

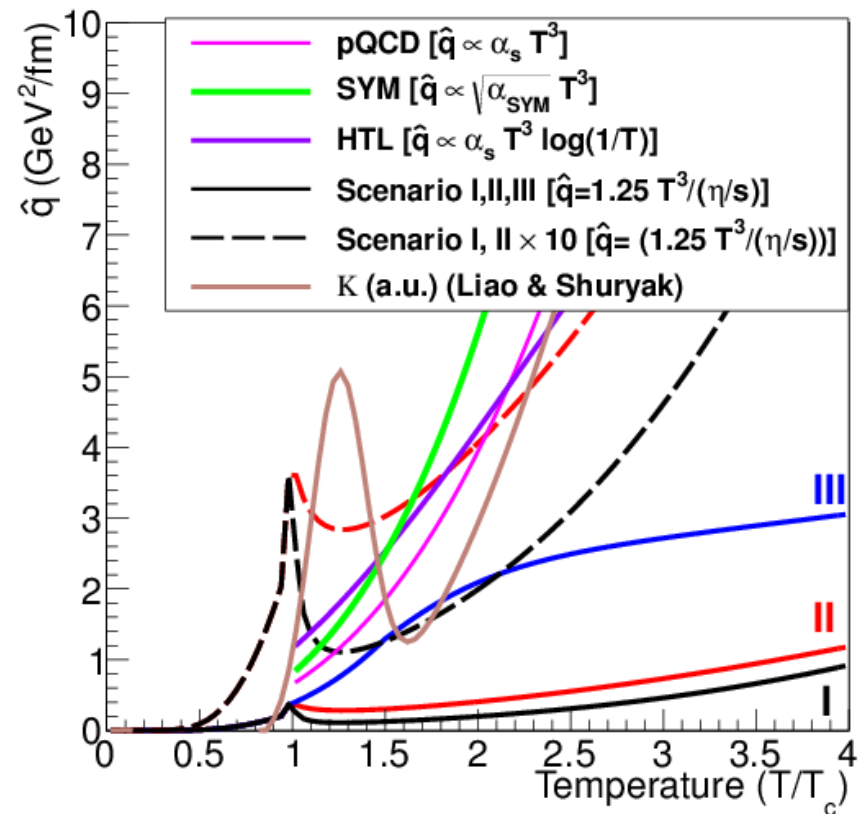


Jet observables

- A parton traversing the medium accumulates transverse momentum characterized by

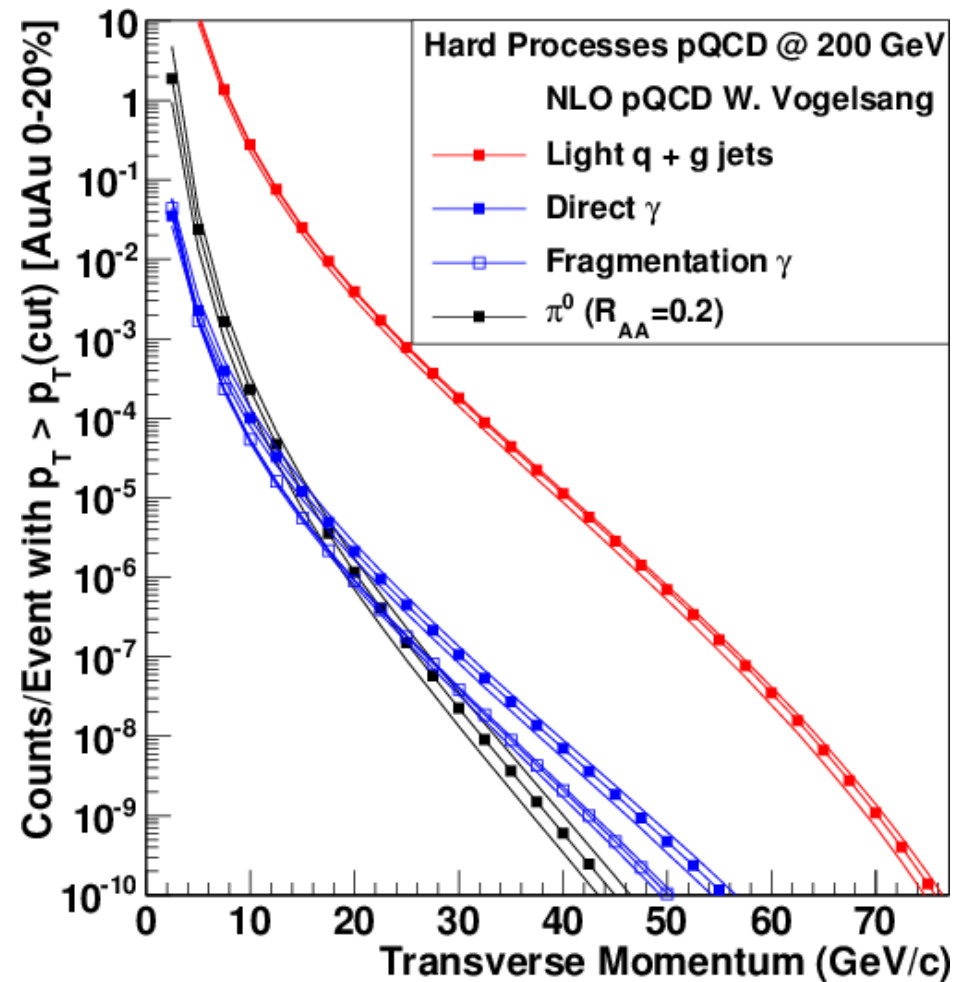
$$\hat{q} = d(\Delta p_T) / dx$$

- Coupling parameters like \hat{q} are scale dependent and must approach weak coupling at high energies and strong coupling at thermal energies



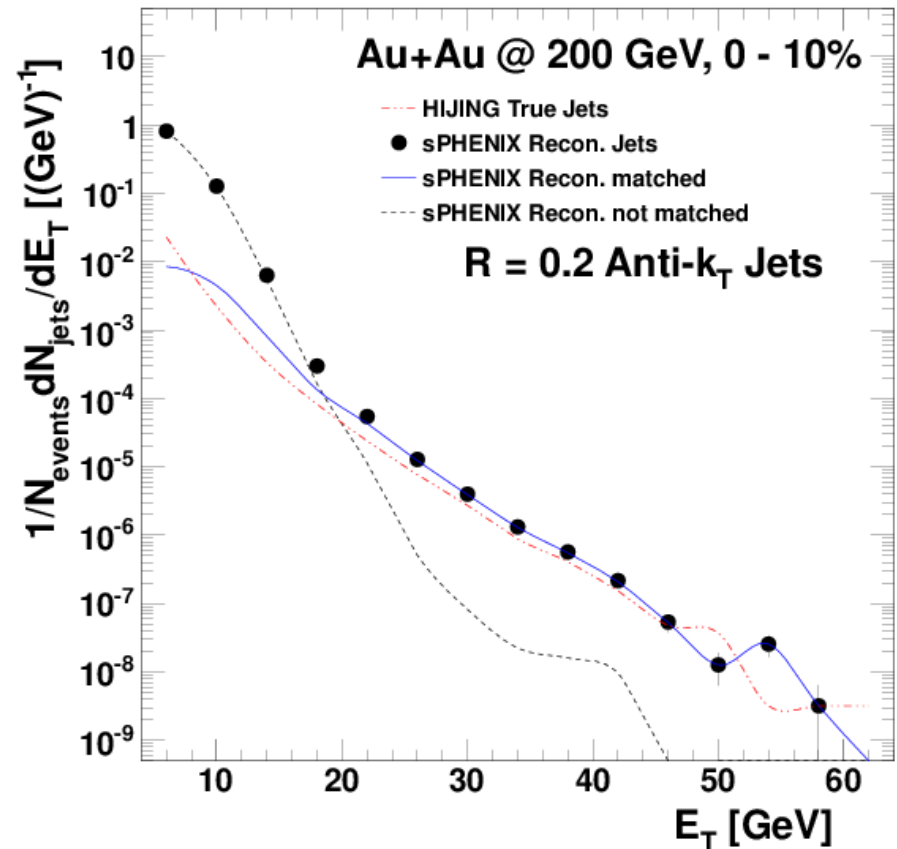
Jet rates at RHIC

- At present RHIC luminosity, in a 20 week Au +Au run we would have 10^6 jets above 30 GeV in 0-20% centrality



Fake jets

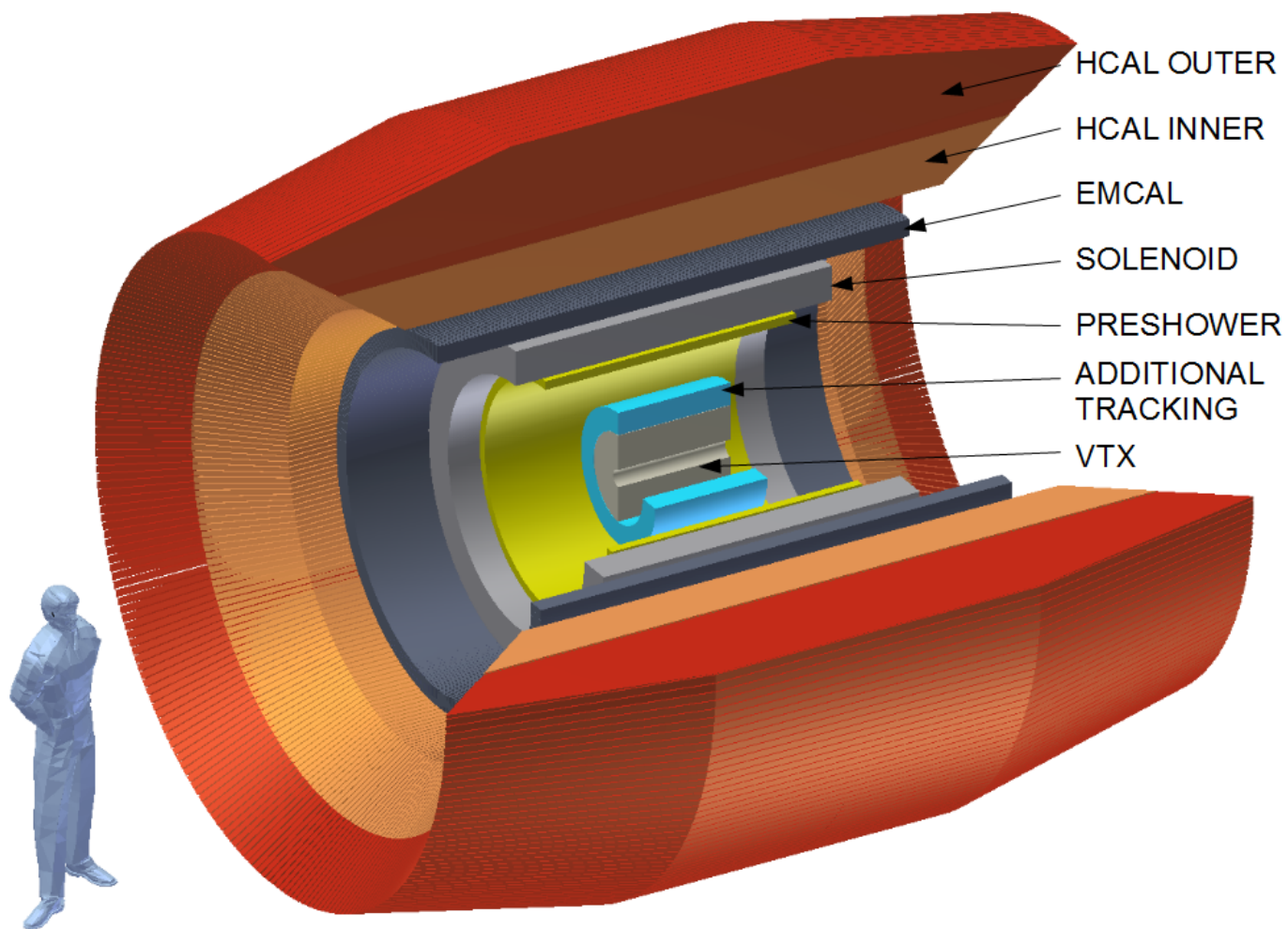
- Using 750M minimum bias HIJING events
- True jets outnumber fake jets for $p_T > 20 \text{ GeV}/c$
- Details published as Hanks et al., [arXiv:1203.1353](https://arxiv.org/abs/1203.1353), published in PRC August 10



Design Goals for a Jet Detector

- Full azimuthal coverage in a fiducial region $|\eta| < 1$
- 2T solenoid to ultimately allow high resolution tracking in a small volume
- Electromagnetic and hadronic calorimetry
 - Electromagnetic
 - $\Delta\eta \times \Delta\phi \approx 0.02 \times 0.02$
 - $\sigma_E/E \approx 15\%/\sqrt{E}$
 - Hadronic
 - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
 - $\sigma_E/E \approx 100\%/\sqrt{E}$
- Data acquisition capable of recording >10 kHz

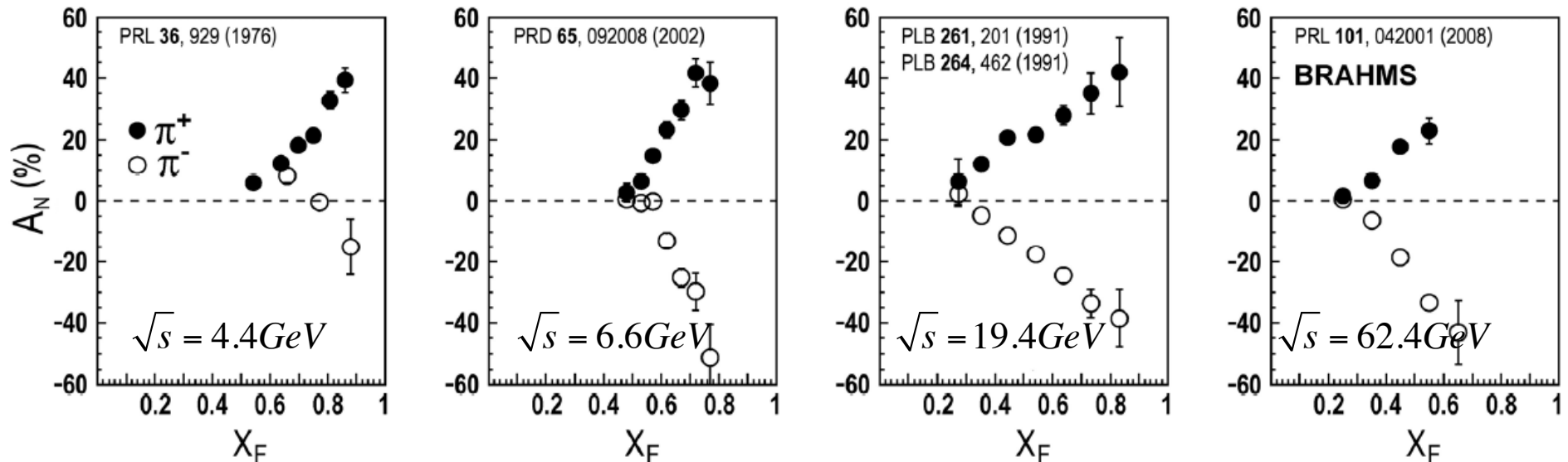
Central sPHENIX Upgrade



sPHENIX Forward Physics and Upgrade

Forward Spin Physics - I

Large, forward A_N s in hadron production in p+p (p+A) have been measured since the mid 70's



Since the mid to late 90's new extended factorization schemes (TMD and Twist-3) have provided a new mechanism to generate single spin asymmetries in these collisions.

1. **Initial-state (Sivers-type) spin-momentum correlations** - Considers intrinsic transverse momentum in the nucleon and initial-state interactions
2. **Final-state (Collins-type) spin-momentum correlations** - Considers transverse momentum inside a jet and final-state interactions
3. Other Higher Order Correlations

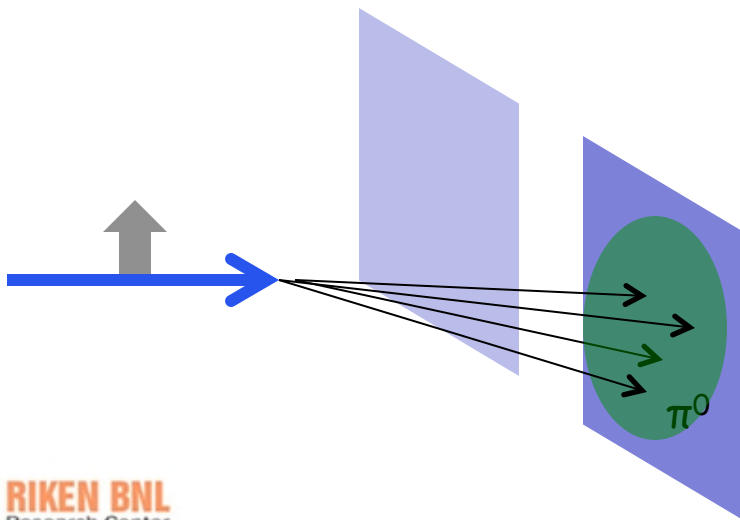
Forward Spin Physics - II

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

Initial State Piece

Jets with identified hadrons
(measure A_N for jets)

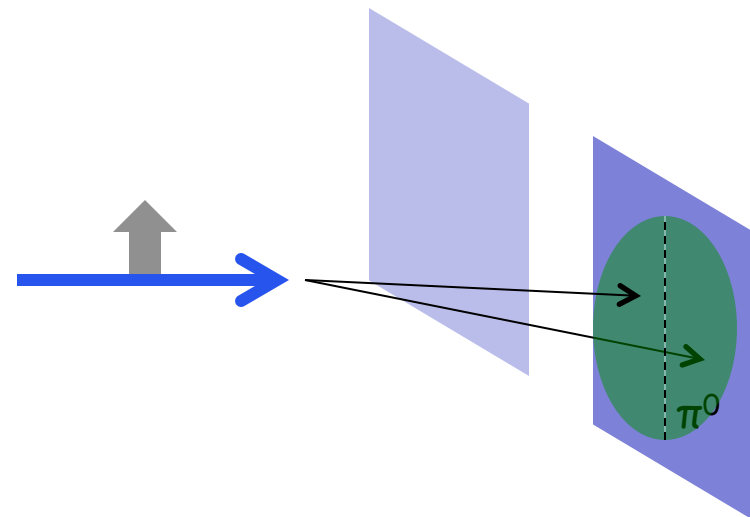
Do jets from certain quarks
prefer to go left or right?



Final State Piece

Left-right asymmetry of identified
particle inside a jet

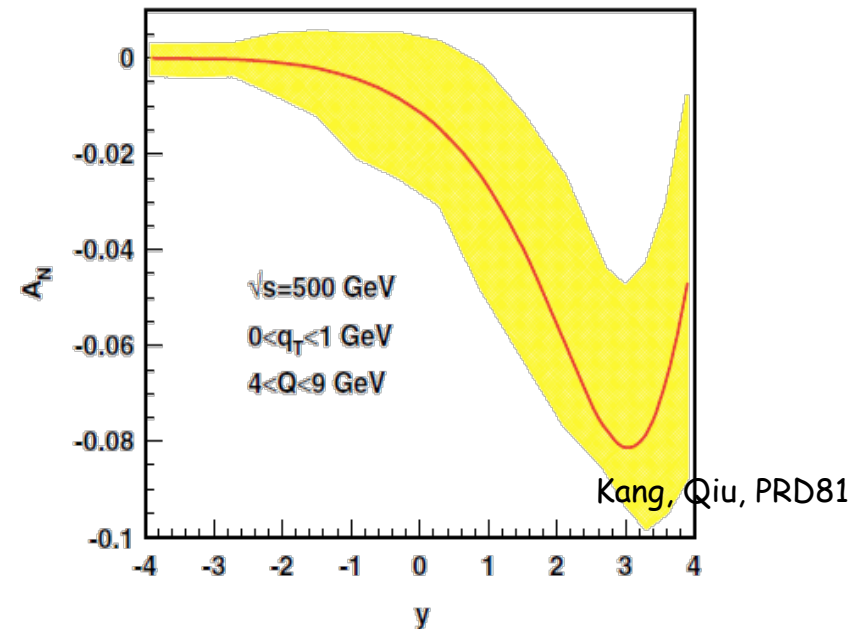
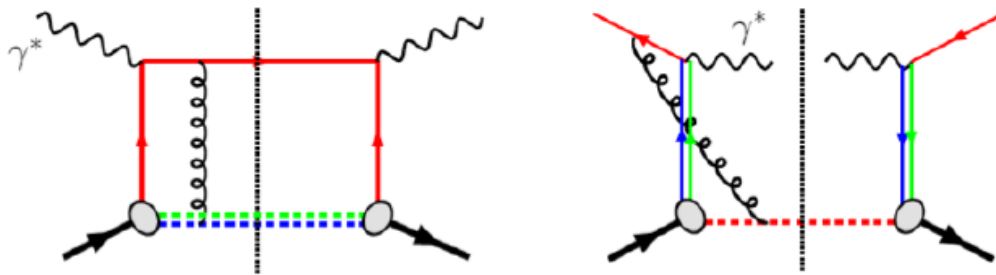
Do certain hadrons fragment
from certain quarks to the left
or right of the jet axis?



Forward Spin Physics - III

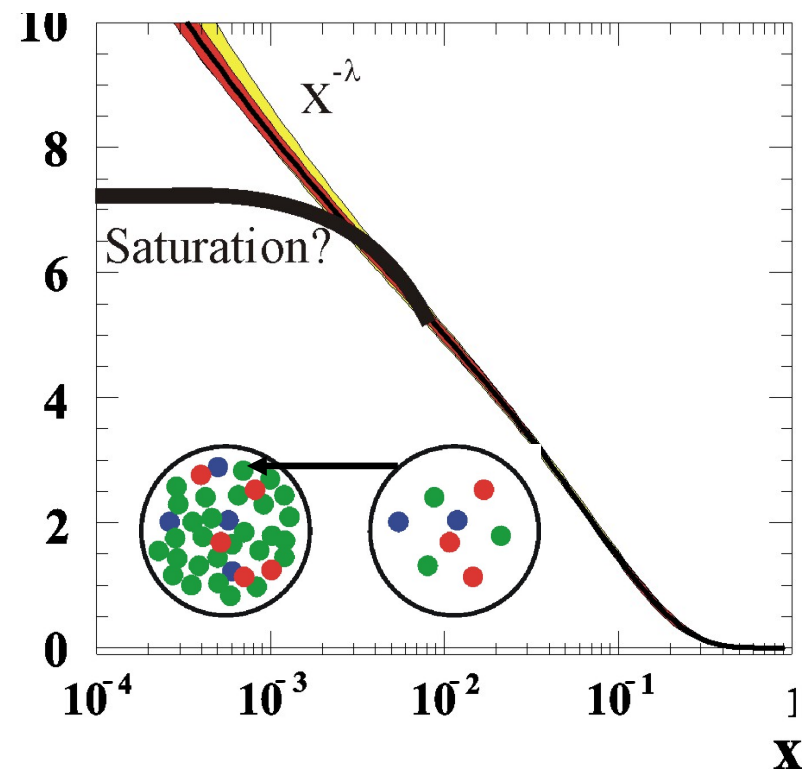
- An elegant test of Transverse Momentum Dependent pdf factorization/description through measurement of forward Drell-Yan pairs

sign flip in asymmetry
between DIS and DY



Forward CNM Physics - I

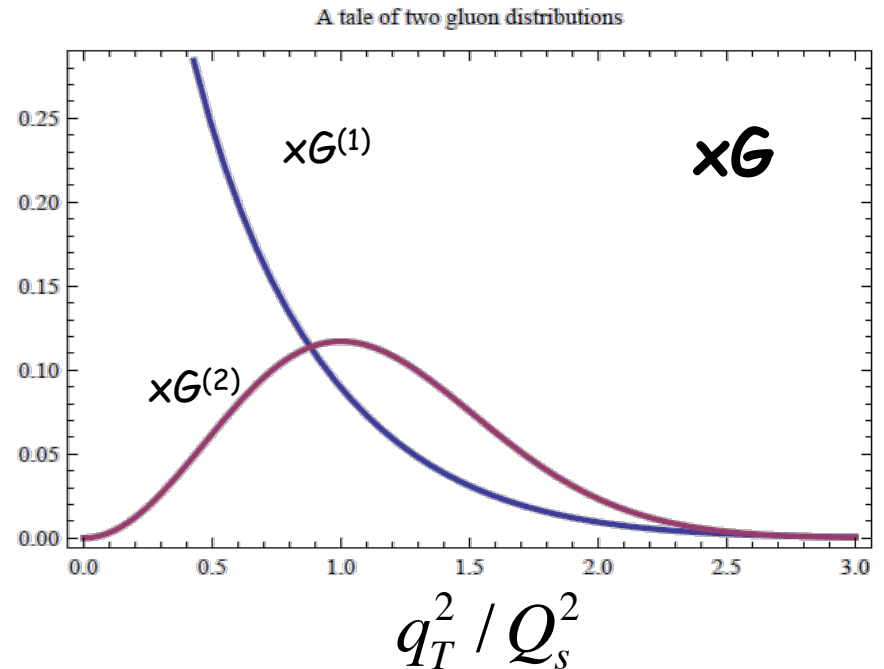
- The forward region also corresponds to the low- x region where saturation is expected (below a scale Q_S) and/or a CGC description of the data is relevant
- As in other QCD related phenomena, many measurements will be needed to substantiate and understand the validity of a CGC as the description of gluons in the nucleus as well as correlated structures
- Other theoretical tools are beginning to help elucidate the low- x region in hadrons and nuclei (TMDs)



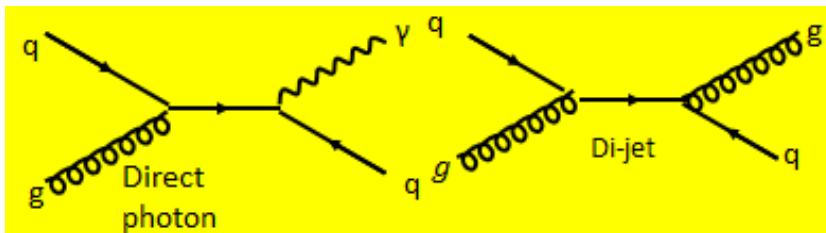
A major push is to observe saturation experimentally, and understand and map out the x and saturation scale, Q_S , dependencies

Forward CNM Physics - II

- G now comes in two flavors $G^{(1)}$ and $G^{(2)}$ in the low- x limit
- All CS described using $G^{(1)}$ and $G^{(2)}$
- Measure G 's via γ -jet, dijet



PRD 49, 2233, 3352
NPB 529, 451



	DIS and DY	SIDIS	hadron in pA	photon-jet in pA	Dijet in DIS	Dijet in pA
$G^{(1)}$ (WW)	x	x	x	x	✓	✓
$G^{(2)}$ (dipole)	✓	✓	✓	✓	x	✓

A Link Between CNM and Spin

RHIC is unique in its ability to collide polarized protons with nuclei

Exploiting the link between the TMD and CGC framework, it has been shown that transverse single spin asymmetries in polarized p+A collisions are sensitive to the saturation scale in the nucleus

$$\frac{A_N^{pA \rightarrow hX}}{A_N^{pp \rightarrow hX}} \Big|_{p_T^h \ll Q_s^2} \approx \frac{Q_{s,p}^2}{Q_{s,A}^2} f(p_T^h) \qquad \frac{A_N^{pA \rightarrow hX}}{A_N^{pp \rightarrow hX}} \Big|_{p_T^h \gg Q_s^2} \approx 1$$

[Kang, Yuan, PRD84 034019]

A_N measures the azimuthal modulation of particle/jet production with respect to the proton's spin

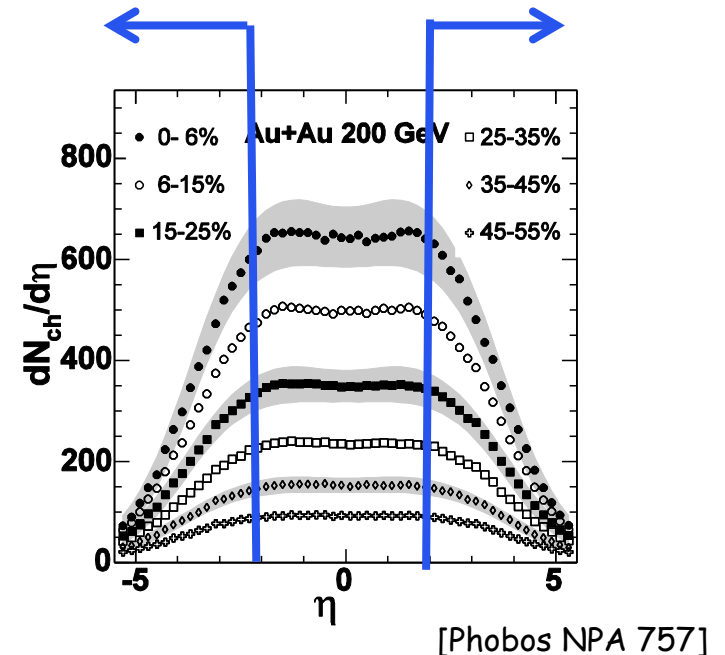
These spin effects are large. Spin " R_{AA} " could be $\sim O(0.5)$

Forward Heavy Ion Physics

An area largely pioneered by PHOBOS and BRAHMS. We hope to expand upon their measurements (away from Bjorken plateau)

At forward rapidities

- Direct photons can give information about the expansion of the medium
- Correlation measurements can test models of longitudinal expansion (3d hydro)
- Extended (di-)jet coverage to study jet energy loss in the medium

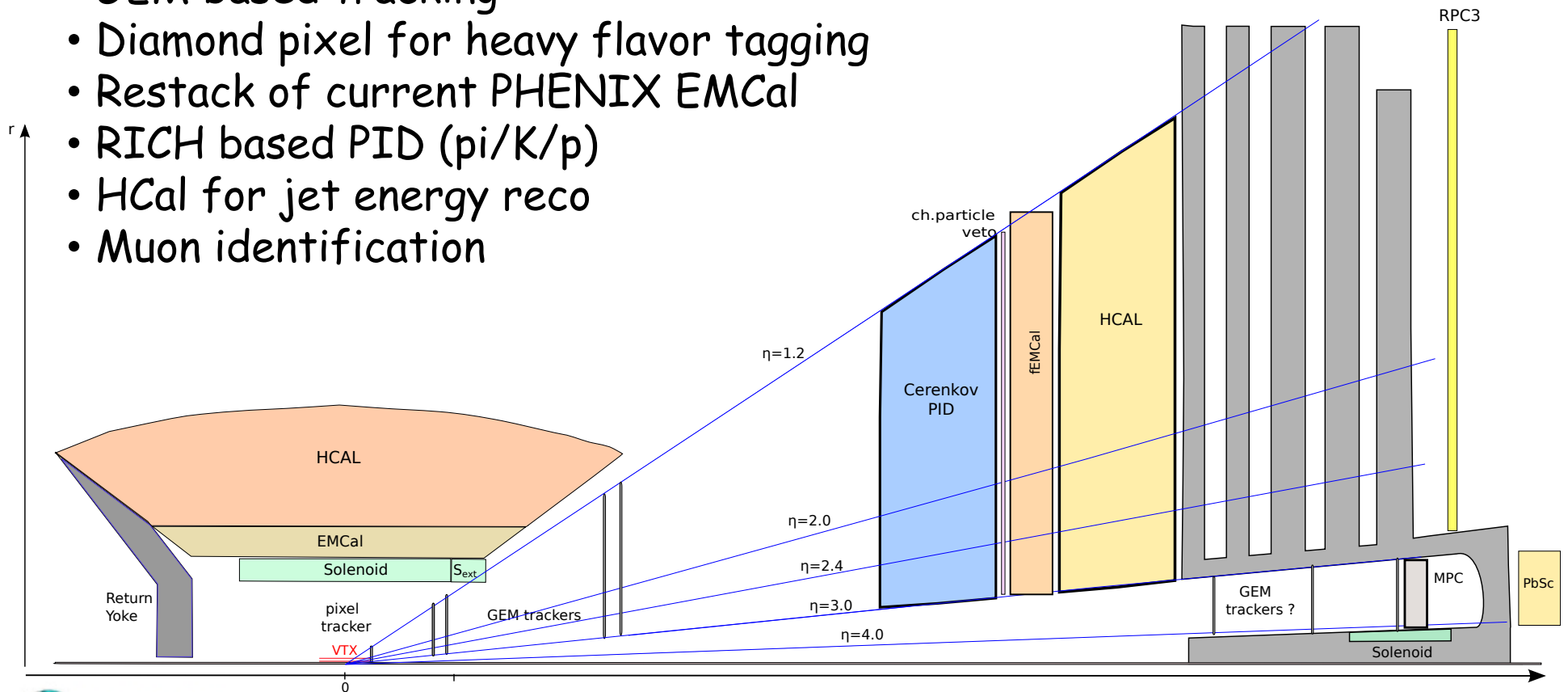


Currently it is question of how far forward the measurements will be able to be made

Forward sPHENIX

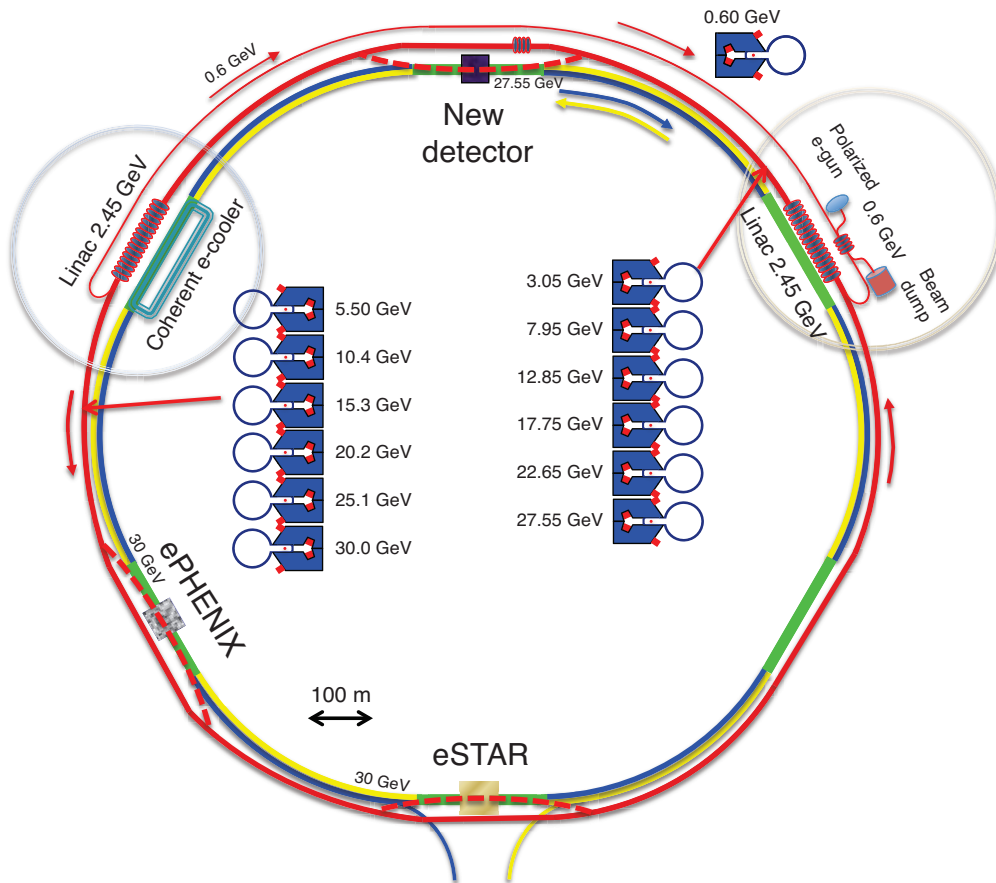
Optimized for jets and photons/DY over a large range in rapidity ($\eta \sim 4$)

- Extension/modification of the central solenoid for B field
- GEM based tracking
- Diamond pixel for heavy flavor tagging
- Restack of current PHENIX EMCal
- RICH based PID (pi/K/p)
- HCal for jet energy reco
- Muon identification



sPHENIX → ePHENIX

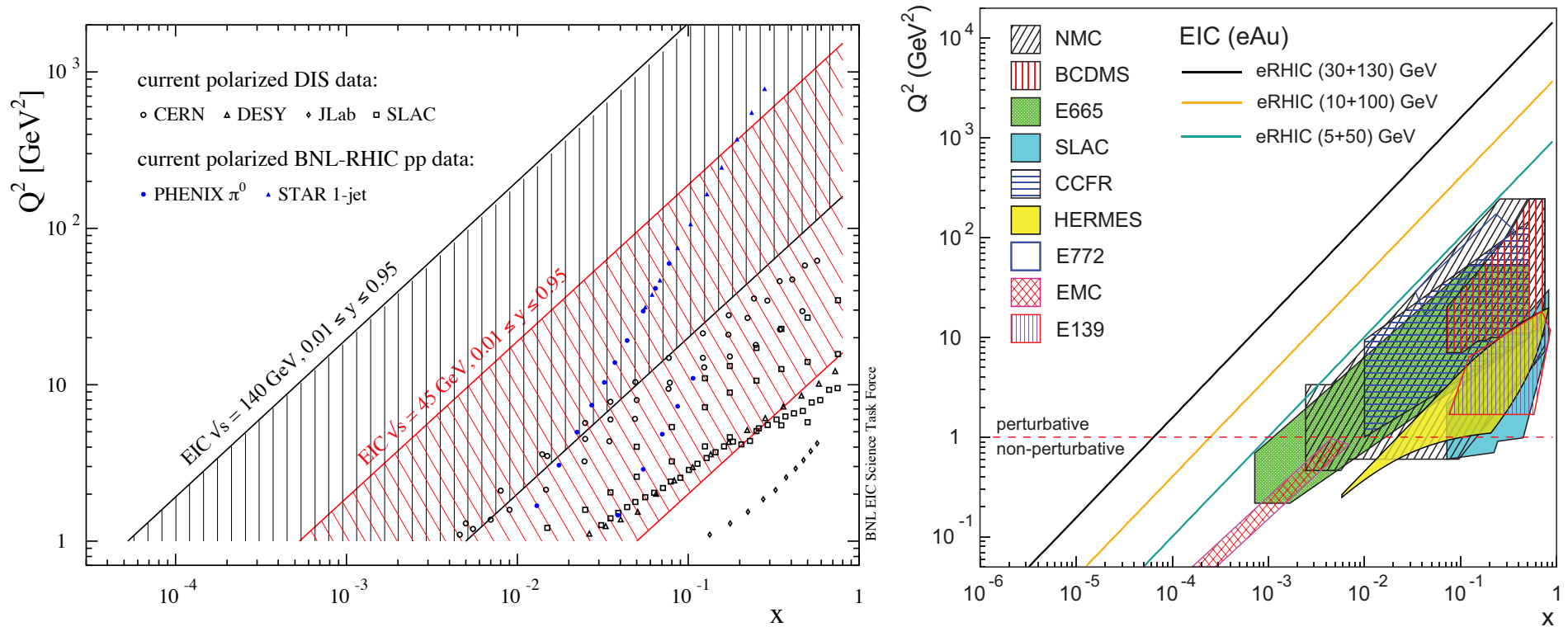
EIC and eRHIC



- One possible manifestation of EIC is eRHIC
- eRHIC will add electron accelerations capabilities to RHIC
- eRHIC is thought to happen in two stages (the difference being the electron beam momentum)
- Through the sPHENIX/decadal plan exercise, BNL charged the RHIC collaborations to imagine how their upgrades could lead to detectors for phase I of eRHIC

ePHENIX Physics

- A major purpose of eRHIC is to measure the 3d structure of the nucleon and nuclei over a large kinematical range

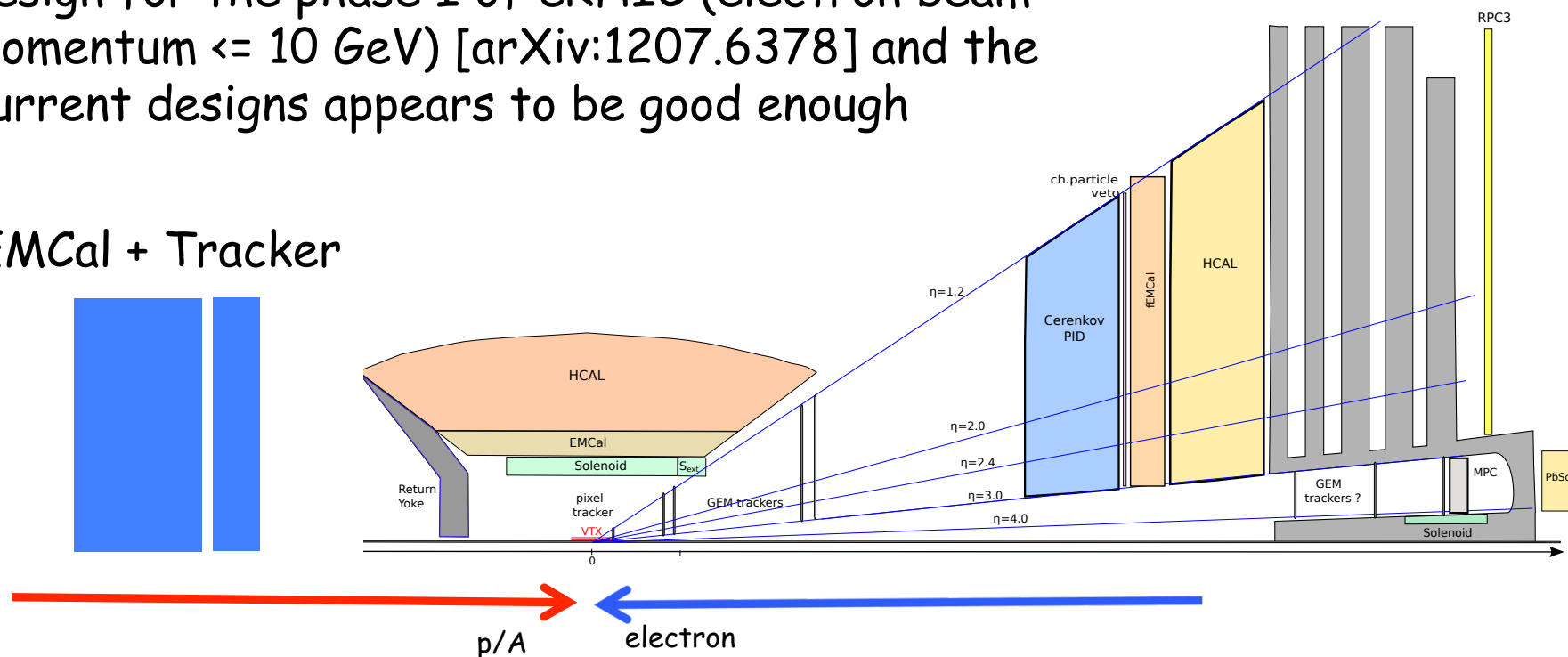


- ePHENIX needs to measure the scattered electron and complete and exclusive final states

sPHENIX to ePHENIX

- Many studies were done to test the central barrel design for the phase I of eRHIC (electron beam momentum ≤ 10 GeV) [arXiv:1207.6378] and the current designs appears to be good enough

EMCal + Tracker



- Forward sPHENIX is being designed with ePHENIX in mind
- A forward EMCAL + tracker on the opposite side will need to be added for ePHENIX

Conclusions

- PHENIX is planning upgrade programs aimed at both central and forward rapidity measurements.
- The central rapidity upgrade aims to understand jet-medium interactions as a tool to understand the QGP
- Forward sPHENIX is being designed and optimized to study forward jets, photons and DY for understanding all major facets of the RHIC program
- Sensitivity studies are ongoing
- An evolution of sPHENIX to ePHENIX is being planned for in the design of sPHENIX

Backups

Physics at RHIC

