Spin Physics
with sPHENIX Detector

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For sPHENIX Collaboration
sPHENIX

New detector for the RHIC facility at BNL (USA)
   New Collaboration formed
   >70 institutions and counting

For studies of the strongly interacting quark-gluon plasma using jet, photon and heavy-flavor observables.

Time line:
   CD0 Review - Sep 2016
   CD1/3a Review - May 2018
   Installation complete - 2022
   Running – 2023

RHIC with polarized proton beams plus sPHENIX => strong capabilities for Spin Physics measurements
$|\eta| < 1.1$ and $2\pi$ in $\phi$:
Tracking in solenoidal field 1.4T
EMCal & HCal
15 kHz DAQ
Spin Physics with sPHENIX

- Jet
- Di-Jet
- Photon and γ-jet
- Hadrons
- Hadrons in jet and di-h
- Heavy Flavor
- h-h, γ-h, jet-jet, γ-jet

Gluon polarization ΔG
Transversity
Sivers effect (through Twist-3)
TMD factorization (breaking)
Jet and $h^\pm$

Good Calorimetry:

\[
\frac{\sigma_E}{E} \approx 15\% \frac{1}{\sqrt{E}} \\
\frac{\sigma_E}{E} \approx 100\% \frac{1}{\sqrt{E}}
\]

Excellent tracking:

- TPC: momentum measurements
- INTT: timing and pattern recognition
- MVTX: collision vertex

\[
\frac{\sigma_{p_T}}{p_T} \approx 0.1\% \cdot p_T
\]
Photon / π0

EMCal sector

Tungsten-scintillating fiber sampling EMCal:
Approx. projective in $\eta$ and $\phi$
18 $X_0$, 1 $\lambda$
$\Delta \eta \times \Delta \phi = 0.025 \times 0.025$
$\sigma_E/E \approx 15\%/\sqrt{E}$

$\pi^0 \rightarrow \gamma\gamma$ merging in EMCal

Clustering + shower profile

π0 eff. vs pT

π0 eff. vs pT

Allows for $\gamma/\pi^0$ discrimination up to ~20 GeV/c
The range of statistically significant measurements

Direct $\gamma$: S/B ~ 2 for pT=7-25 GeV/c
The main source of bg – merged $\pi^0$
Heavy Flavor

DCA

Counts tracks with DCA outside a cut relative to event vertex

Secondary Vertex

Secondary vertex within jet

Direct reco of heavy meson decays

Excellent DCA resolution (10 μm at high $p_T$)

Excellent mass resolution for quarkonia states
Gluon polarization $\Delta G$

With EIC data the dominant uncertainty to $\Delta G$-integral will be coming from “RHIC region”

$\Rightarrow$ We should do our best to improve it before RHIC stops pp running

EIC White paper: arXiv:1212.1701

DIS+RHIC($\leq$2009)

+ EIC
ΔG projection

Brings us to era of high precision ΔG measurements:
Will crucially improve ΔG constraint at x>0.05
ΔGdx-integral at x>0.05 expected to be improved by a factor >4
Multiple channels with different theoretical and exp. uncertainties
Crucial syst. cross check
Complementary to the future EIC
Crucial universality test in the overlapping x-range
Transversity

STAR:

First measurements in pp to access transversity:

Collins asymmetry (hadron within jet)
TMD approach
IFF asymmetry (di-hadron)
Collinear approach

sPHENIX expects to contribute high precision data for these

As a dedicated jet detector with excellent tracking resolution and high DAQ bandwidth
Will allow for multi-dim binning
Will provide crucial tests for factorization and universality of distr. functions
Other measurements

Open HF $A_N$:
Sensitive to Twist-3 tri-gluon correlation fnct.

sPHENIX will considerably improve it
Decay electron + DCA
Or D reconstruction

Direct $\gamma A_N$:
Sensitive to Twist-3 quark-gluon correlation fnct.

Nobody yet measured it
sPHENIX will do it!
Other measurements II

PHENIX: 1805.02450

Evolution of non-perturbative $k_T$ and $j_T$ through correlation measurements
Sensitive to TMD factorization breaking
sPHENIX will provide high precision measurements from jet-jet, $\gamma$-jet, h-h, $\gamma$-h, including correlations with spin

Quarkonia polarization
Sensitive to production mechanism

$J/\psi$ photoproduction in UPC
Access to GPD from pp!

STAR: PLB 739, 180; PHENIX: PRD 82, 012001
Forward Upgrade Proposal

Solenoid 1.4T
EMCal & HCal
Tracking

+ Forward EMCal & Hcal
+ Forward tracking
Forward Jet and $h^\pm$

Good jet resolution for $E$, $\eta$, $\phi$

Excellent charged track momentum resolution even in forward region
Jet $A_N$

$A_{N\,DY}$: PLB 750, 660

Sensitive to Sivers fnct.

Jet $A_N \sim 0 \Rightarrow$ cancellation from u&d?

Tagging jets with the charge of leading hadron changes jet composition

$\Rightarrow$ ability to separate effects from u and d
Hadron in Jet: Collins Asymmetry

Gives access to transversity
Expands x-range to higher values => necessary for tensor charge

\[ \delta q^a = \int_0^1 \left( \delta q^a(x) - \delta \bar{q}^a(x) \right) dx \]

Calculable on lattice
Di-jet $A_{LL}$: $\Delta G(x)$ to lower $x$

If we run at $\sqrt{s}=500$ GeV

STAR: 1805.09742

**fsPHENIX will considerably improve it**

Effective jet triggering and high DAQ rate

Higher rapidity $\Rightarrow$ Lower $x$ (down to $\sim 10^{-3}$)
Summary

Wide range of high precision spin measurements to be addressed by sPHENIX

sPHENIX – new collaboration with >70 institutions and is growing

Invite new collaborators:

New physics ideas
New instrumentation
The possibility to evolve sPHENIX to a DIS detector at future EIC
Backup
The Tracking detectors

Functions:
TPC - momentum measurement
MVTX - precise track vertex
INTT - timing & pattern recognition
The Tracking Detectors (in GEANT 4)

**TPC** - Gateless, continuous readout
- 90:10 Ne-CF4 gas - low diffusion + high ion mobility
- Electron drift velocity 8 cm/µs - 13.2 µs maximum drift time
- Quad GEM electron multiplier + chevron readout pads
- 48 layer readout covering 30 - 78 cm radius
- R-φ resolution ~ 150 µm
- Δp/p ~ 1% at 5 GeV/c

**INTT** - Silicon strips
- 4 layers 7 < R < 13 cm
- Pitch 78 µm, Z length 1.6-2 mm
- Fast - can resolve one beam crossing

**MVTX** - 30 µm x 30 µm MAPS pixels
- 3 layers 2.3 < R < 3.9 cm
- Readout time window ± 5 µs
- ~ 5 µm space point precision

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Average mass budget of inner detectors

- MVTX ~ 0.3% / layer (1% total)
- INTT ~ 1% / layer (4% total)
Calorimeters

**EMCal**
Tungsten-scintillating fiber sampling calorimeter
18 $X_0$, 1 $\lambda$
$\Delta\eta \times \Delta\phi = 0.025 \times 0.025$
Read out by silicon photomultipliers
2D projective geometry
Small Moliere Radius, short radiation length
Energy resolution $\leq 16%/\sqrt{E}$ @ 5%

**HCal**
Sampling calorimeter
Magnet steel plates / scintillator tiles
3.8 $\lambda$
$\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
Read out by silicon photomultipliers
Doubles as the flux return for the solenoid
Aschenauer, Sassot, Stratmann, PRD 92, 094030