Cold QCD measurements with sPHENIX Detector

A.Bazilevsky (BNL)
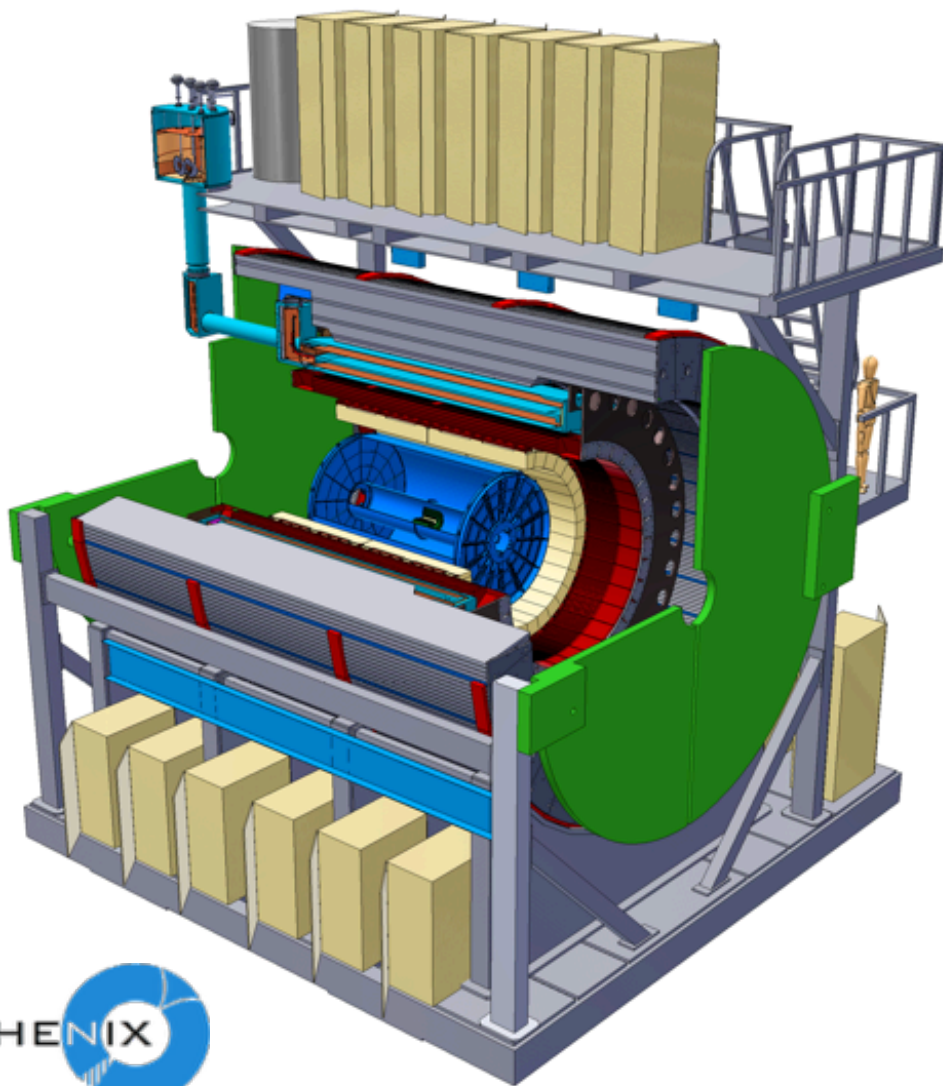
For sPHENIX Collaboration

The 35th Winter Workshop on Nuclear Dynamics

6-12 January 2019
Beaver Creek Resort

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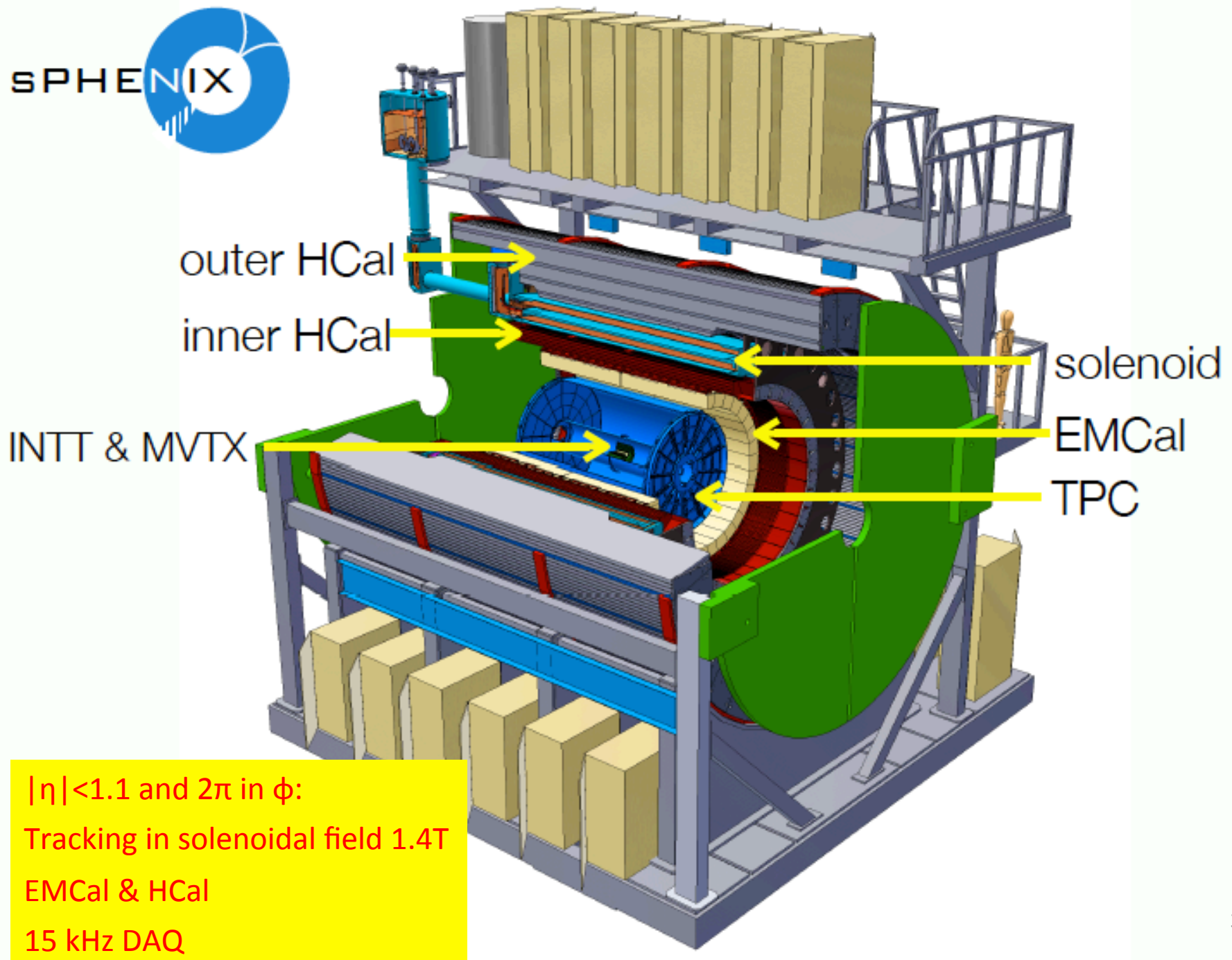
Time line:
> CD0 Review - Sep 2016
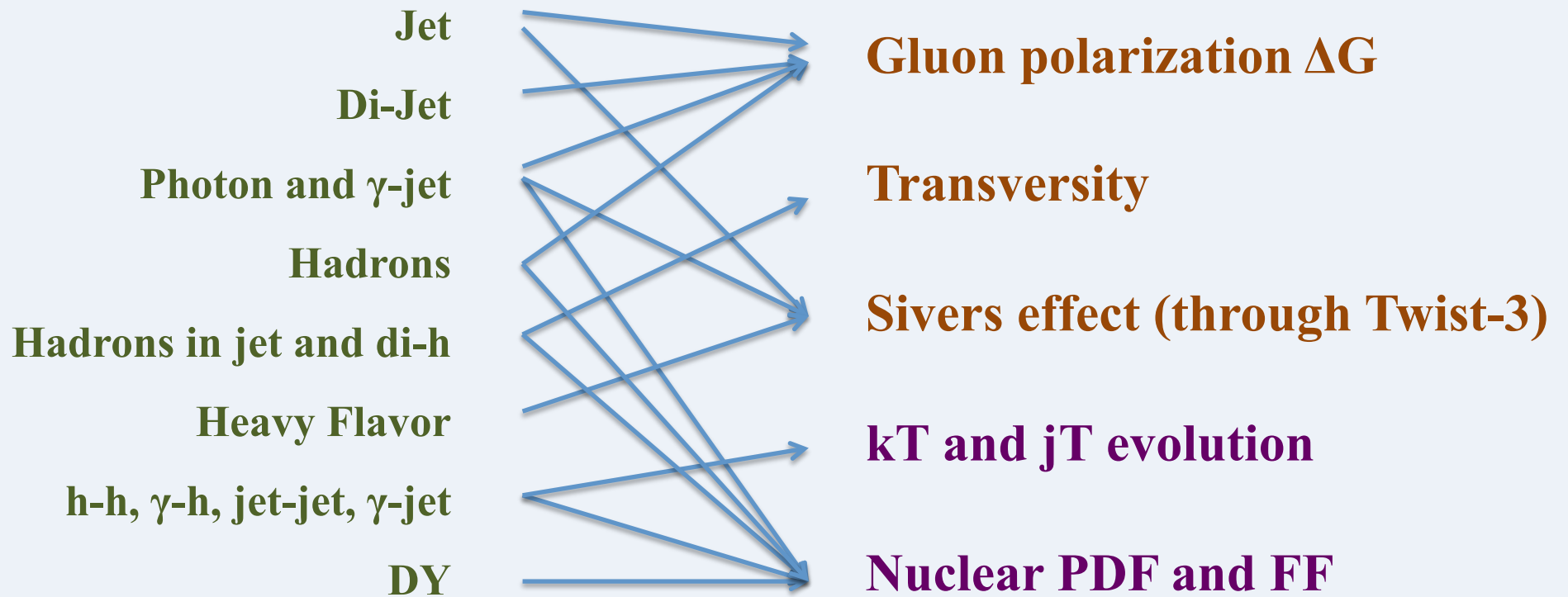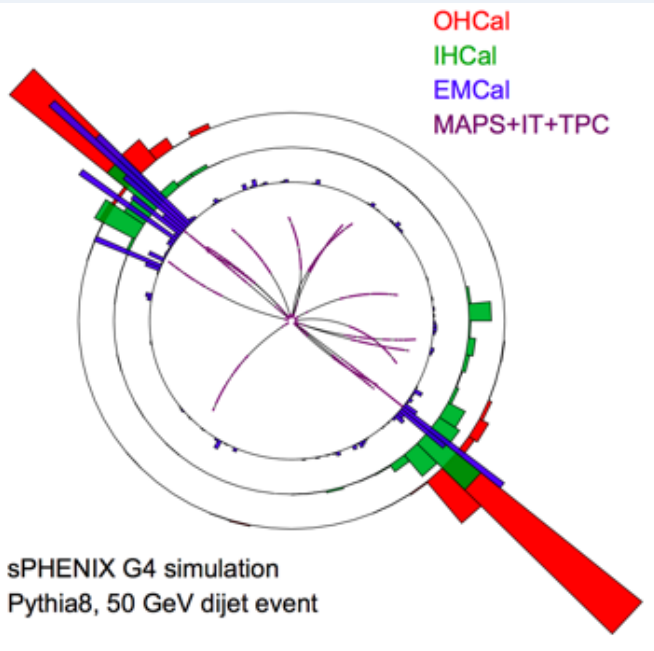> CD1/3a Review - May 2018
> Installation complete - 2022
> Running – 2023

sPHENIX

outer HCal
inner HCal
INTT & MVTX
solenoid
EMCal
TPC

|η|<1.1 and 2π in φ:
Tracking in solenoidal field 1.4T
EMCal & HCal
15 kHz DAQ

Cold Nuclear and Spin Physics with sPHENIX

Jet and h±

OHCal
IHCal
EMCal
MAPS+IT+TPC

sPHENIX G4 simulation
Pythia8, 50 GeV dijet event

Good Calorimetry:

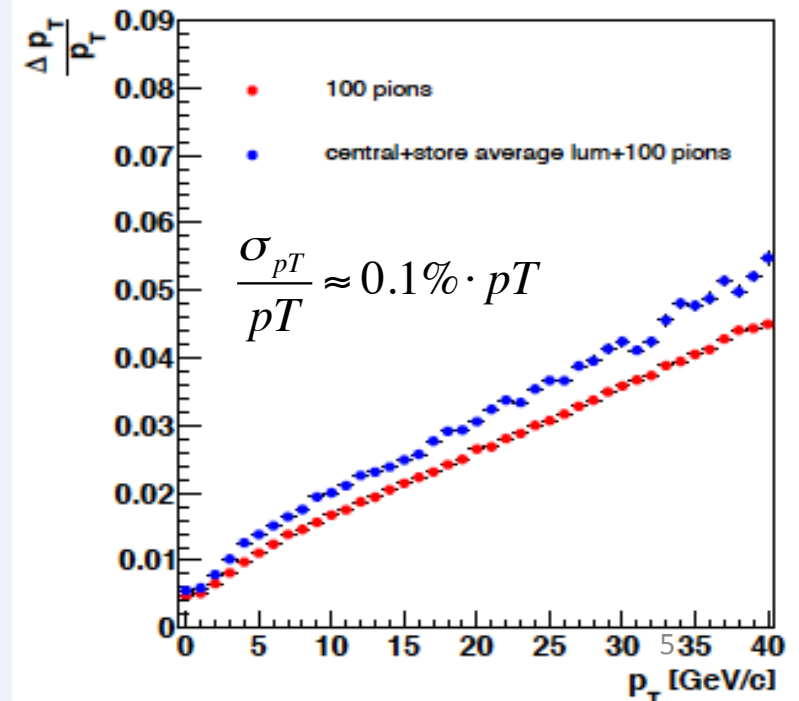EMCal: $\dfrac{\sigma_E}{E} \approx \dfrac{15\%}{\sqrt{E}}$

HCal: $\dfrac{\sigma_E}{E} \approx \dfrac{100\%}{\sqrt{E}}$
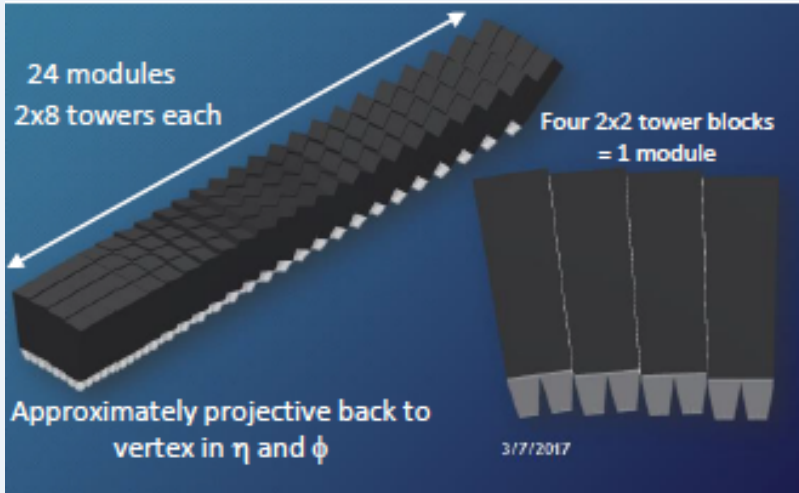
Excellent tracking:

TPC: momentum measurements

INTT: timing and pattern recognition

MVTX: collision vertex

$\dfrac{\sigma_{pT}}{pT} \approx 0.1\% \cdot pT$

100 pions

central+store average lum+100 pions

$\dfrac{\Delta p_T}{p_T}$

p_T [GeV/c]

Photon / π0

EMCal sector

24 modules
2x8 towers each

Four 2x2 tower blocks
= 1 module

Approximately projective back to
vertex in η and φ

3/7/2017

Tungsten-scintillating fiber sampling EMCal:

Approx. projective in η and φ

$18\ X_0$, $1\ \lambda$

$\Delta\eta \times \Delta\varphi = 0.025 \times 0.025$

$\sigma_E/E \approx 15\%/\sqrt{E}$

π0→γγ merging in EMCal
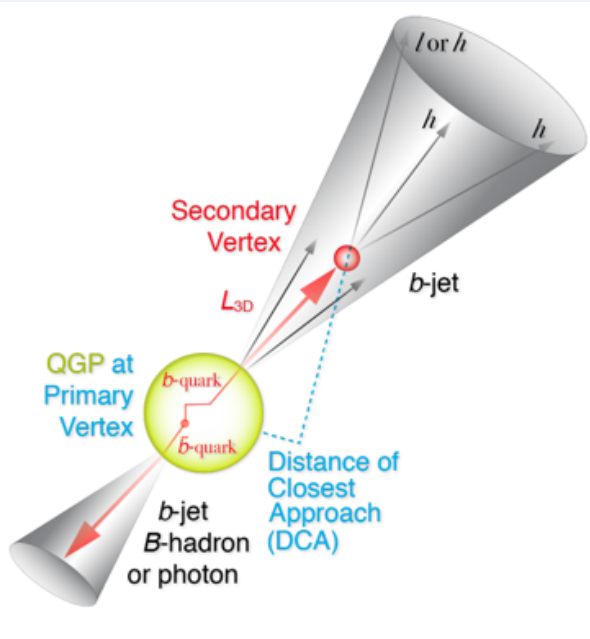

π0 eff. vs pT

Clustering
+ shower profile

pT (GeV/c)

Allows for γ/π0 discrimination up to ~20 GeV/c
The range of statistically significant measurements

Direct γ: S/B ~ 2 for pT=7-25 GeV/c
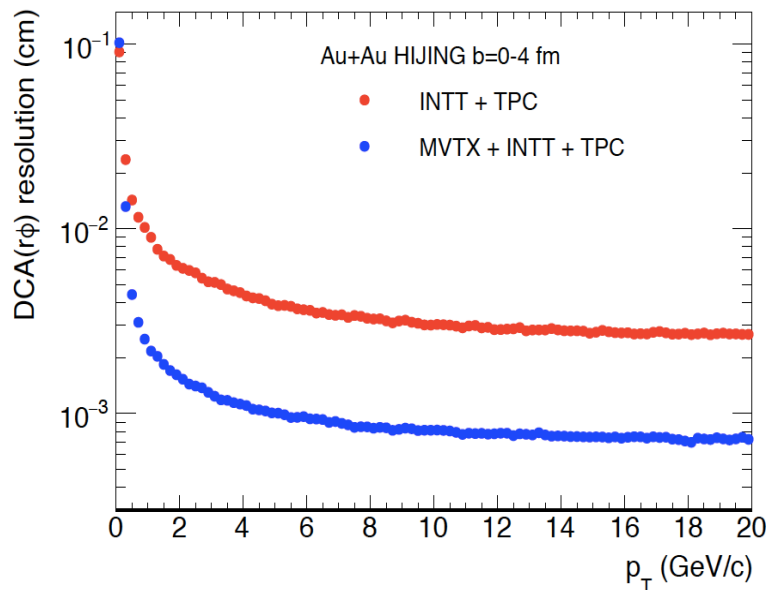The main source of bg – merged π0

6
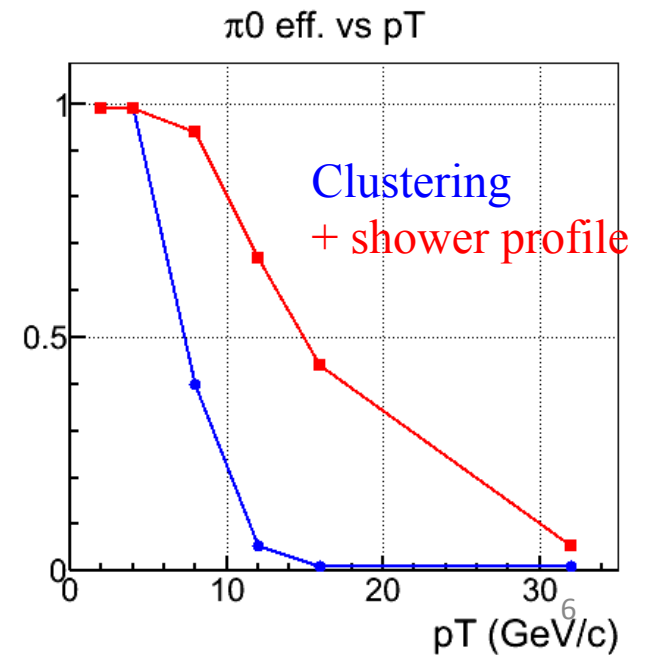
Heavy Flavor

DCA
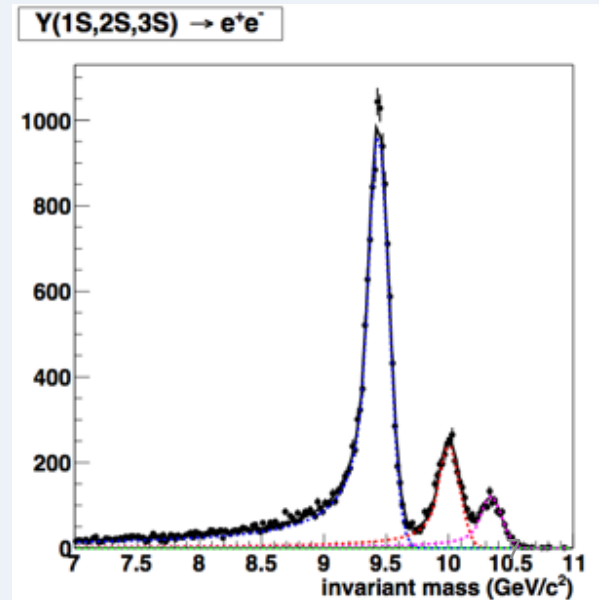 Counts tracks with DCA outside a cut relative to event vertex

Secondary Vertex
  Secondary vertex within jet

Direct reco of heavy meson decays
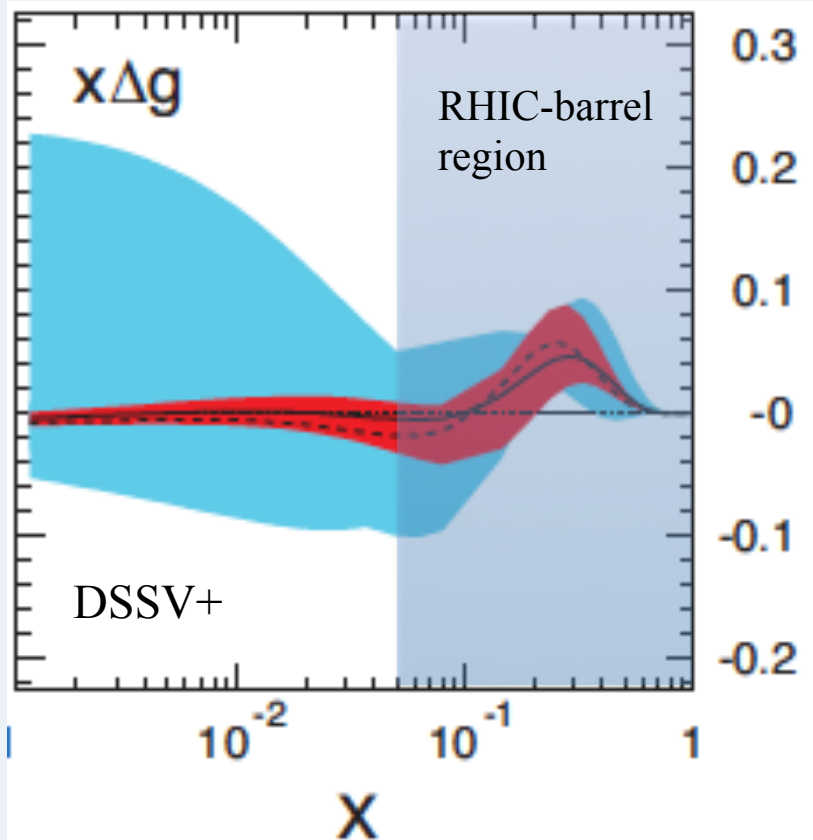

Excellent DCA resolution
(10 μm at high pT)

Excellent mass resolution for quarkonia states

Gluon polarization ΔG

$$\frac{1}{2} = \frac{1}{2}\left(\Delta q + \Delta \bar{q}\right) + \Delta G + L_z$$

EIC White paper: arXiv:1212.1701

DIS+RHIC(≤2009)
+EIC

RHIC: $\displaystyle\int_{0.05}^{1} dx\,\Delta g(x) = 0.2^{+0.06}_{-0.07}$ (90% CL)

(DSSV: Phys Rev Lett, 113, 012001)

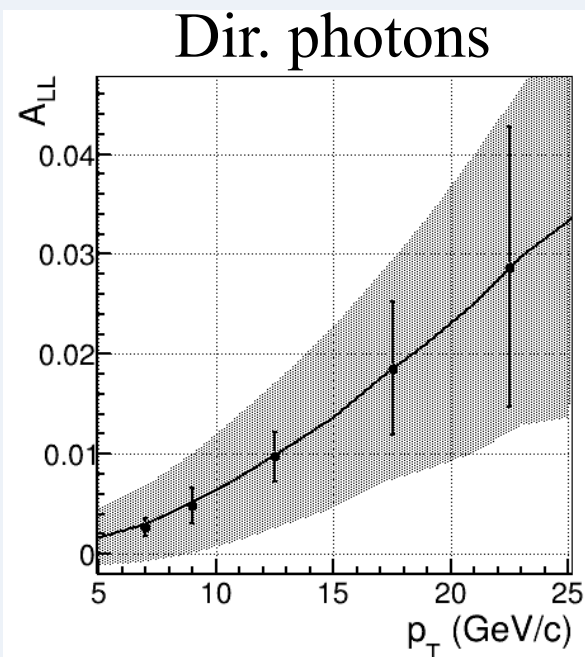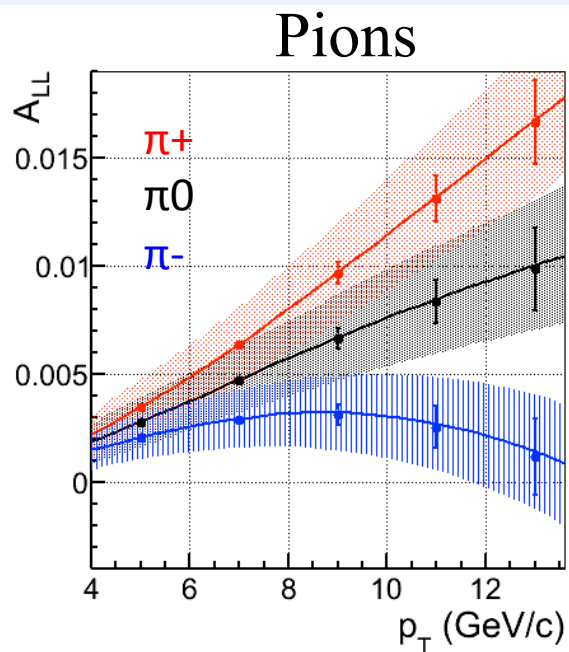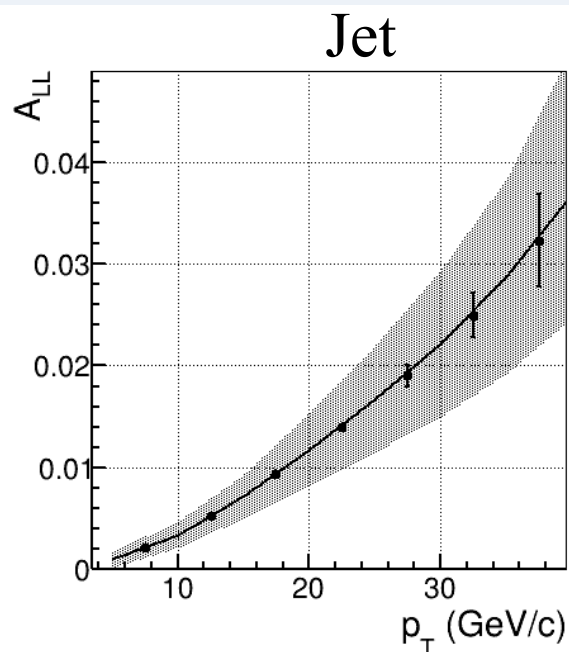With EIC data the dominant uncertainty to ΔG-integral will be coming from "RHIC region"

⇒ We should do our best to improve it before RHIC stops pp running

8

ΔG projection

Jet — Pions — Dir. photons

(Pions panel labels: $\pi+$, $\pi0$, $\pi-$)

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. uncertainites
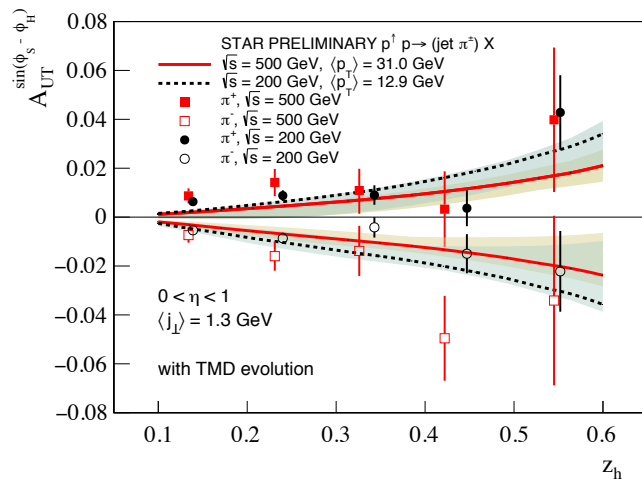
Crucial syst. cross check

Complementary to the future EIC

Crucial universality test in the overlapping x-range

9

Transversity

Quark transverse polarization within transversely polarized proton

STAR:

First measurements in pp to access transversity:

Collins asymmetry (hadron within jet)
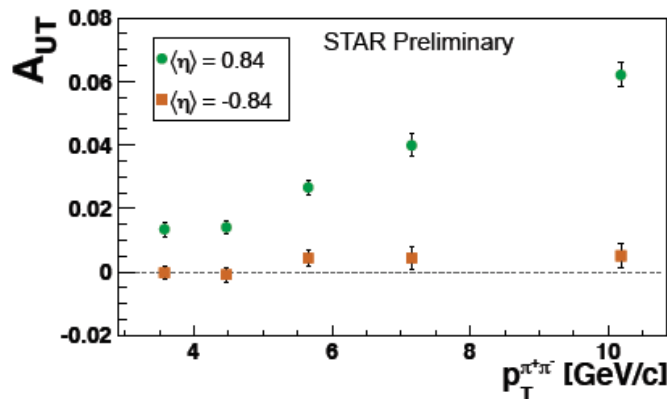
 TMD approach

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
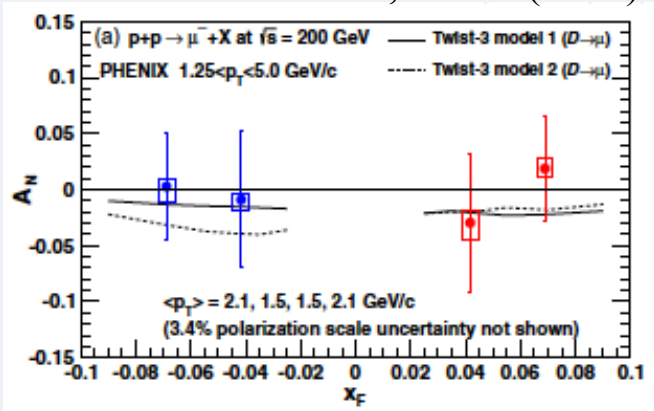
 Will allow for multi-dim binning

 Will provide crucial tests for factorization and universality of distr. functions

Twist-3 structure

PHENIX: PRD95, 12001 (2017)

Open HF A_N:

Sensitive to Twist-3 tri-gluon correlation fnct.

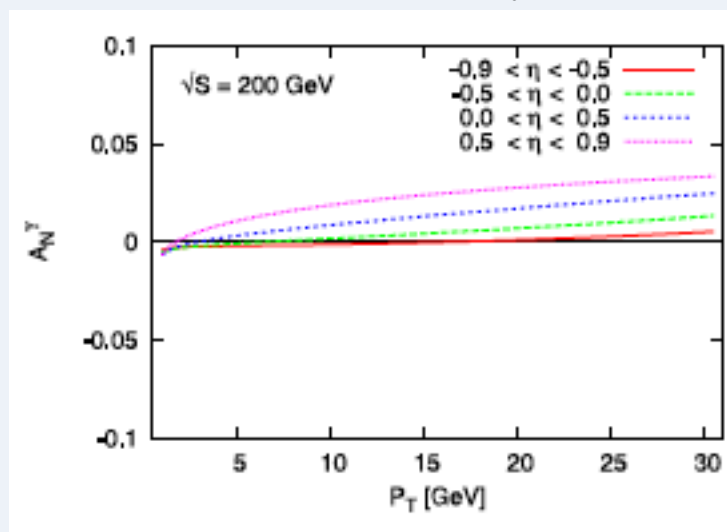sPHENIX will considerably improve it

Decay electron + DCA
Or D reconstruction

K.Konazawa and Y.Koike: Phys. Lett. B 720, 161

Direct γ A_N:

Sensitive to Twist-3 quark-gluon correlation fnct.

Nobody yet measured it,
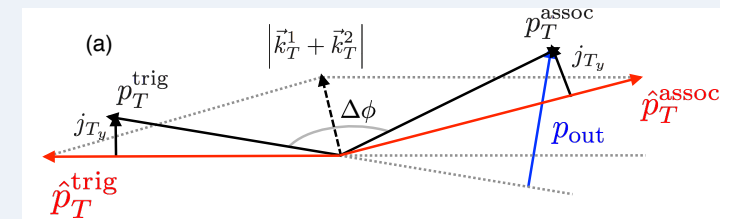sPHENIX will do it!

kT and jT evolution

PHENIX: PRD 98, 072004 (2018)
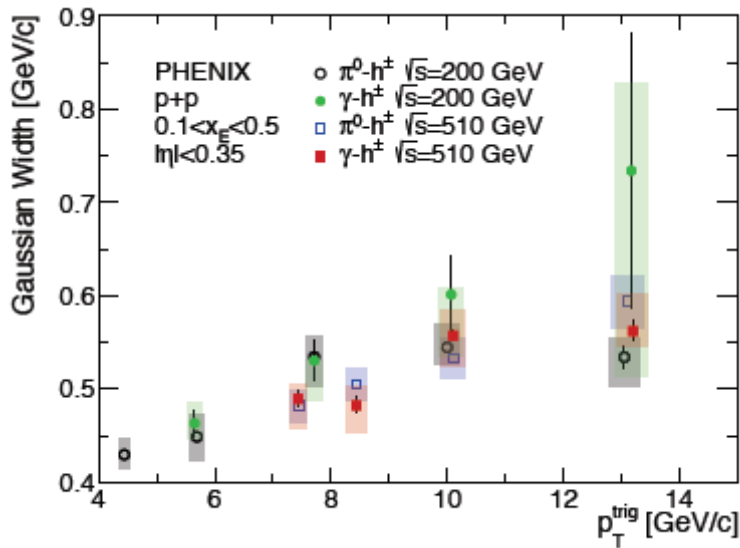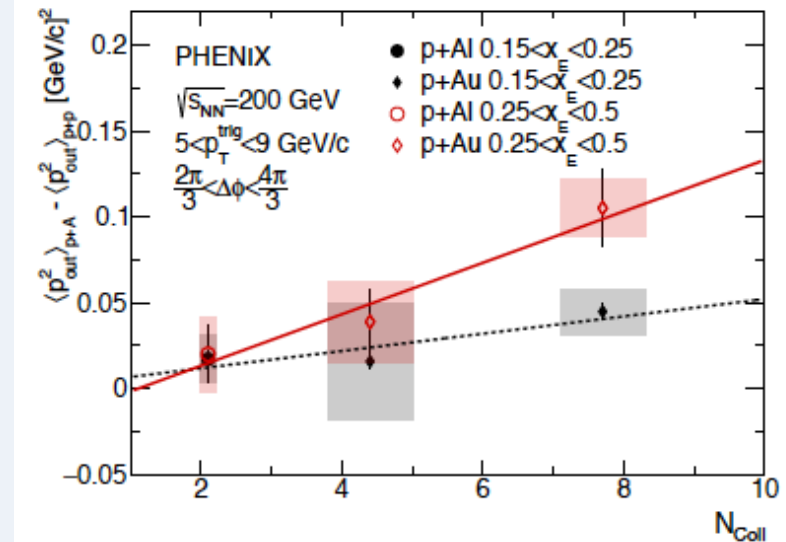
PHENIX: 1809.09045

Evolution of non-perturbative kT and jT through correlation measurements

- Sensitive to TMD factorization breaking

- sPHENIX will provide high precision measurements from jet-jet, γ-jet, h-h, γ-h, including correlations with spin
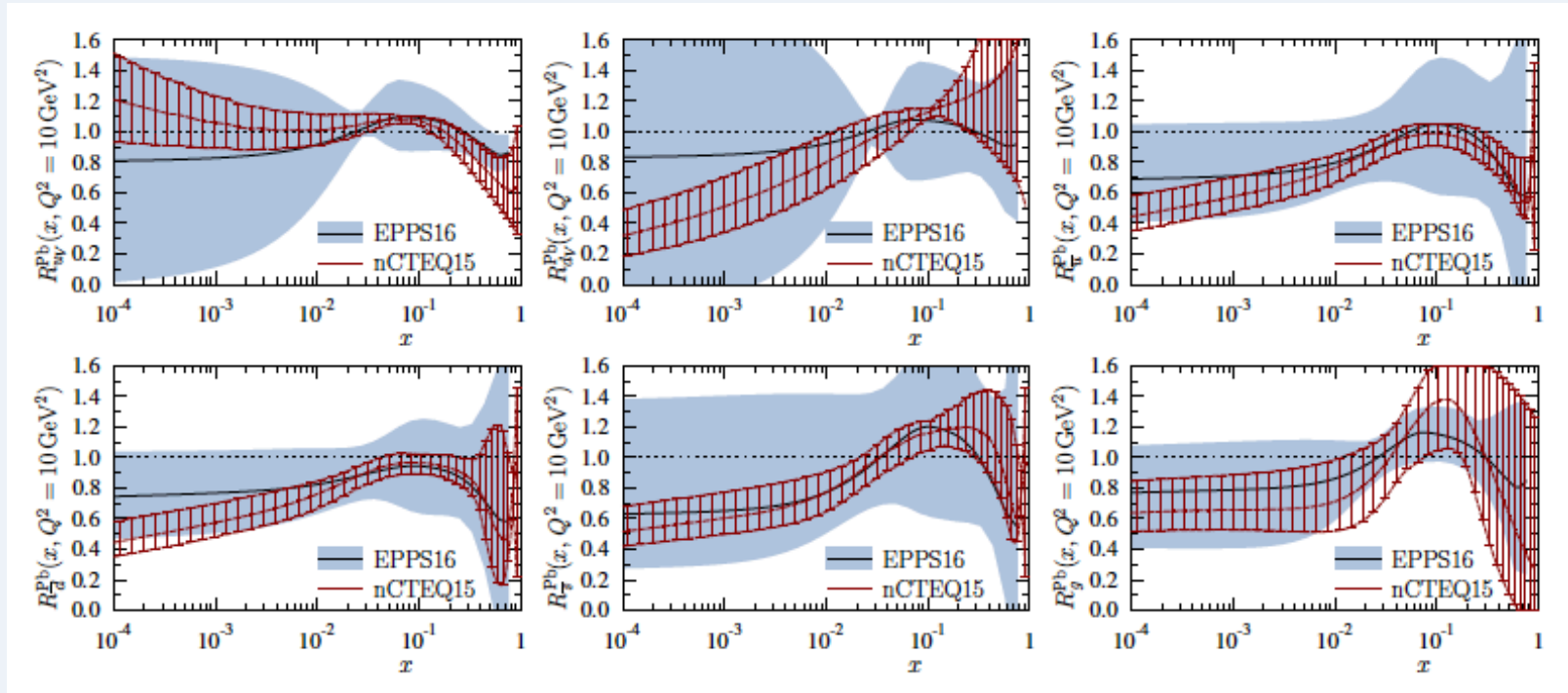
Away side peak broadening in pA

- No modification of near side peak => fragmentation not modified

- Different mechanisms under consideration: Cronin, energy loss, additional initial kT

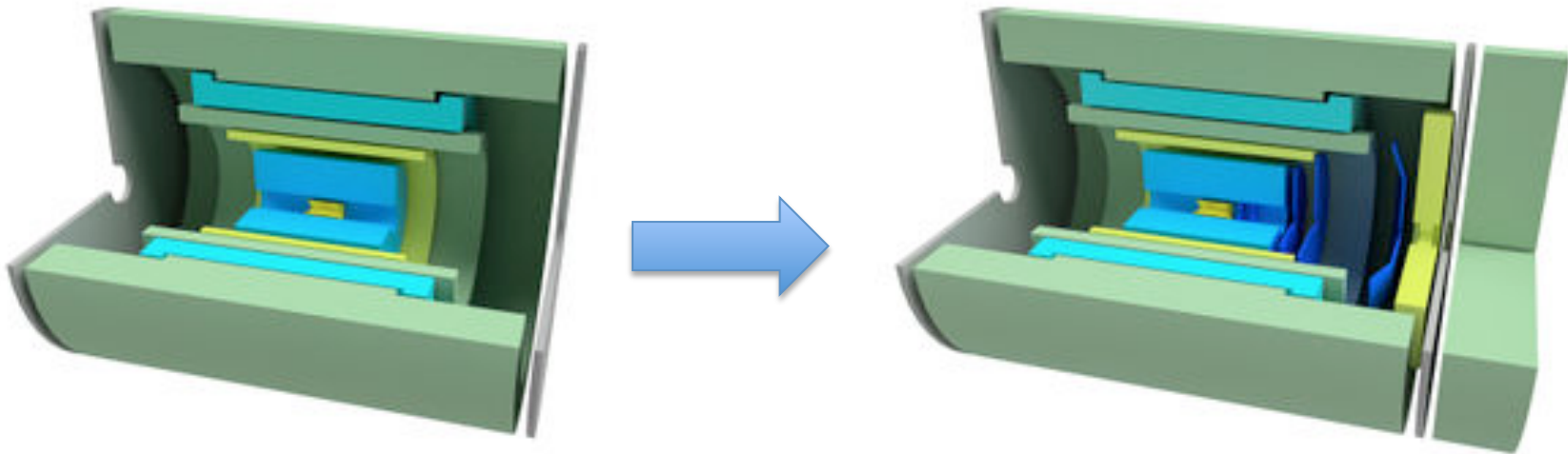# nPDF

Eur. Phys. J. C77(3):163 (2017)

sPHENIX will provide a comprehensive set of measurements:
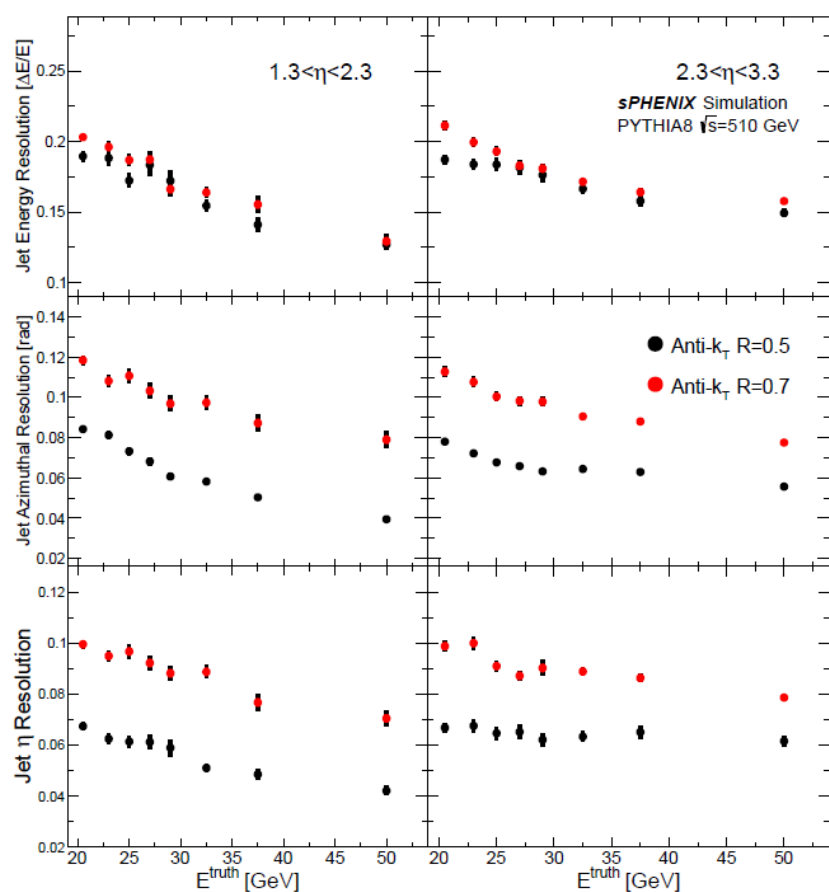h, jet, dijet, γ, γ-jet, DY to cover 0.02<x<0.4

Forward Upgrade Proposal

Solenoid 1.4T
EMCal & HCal
Tracking
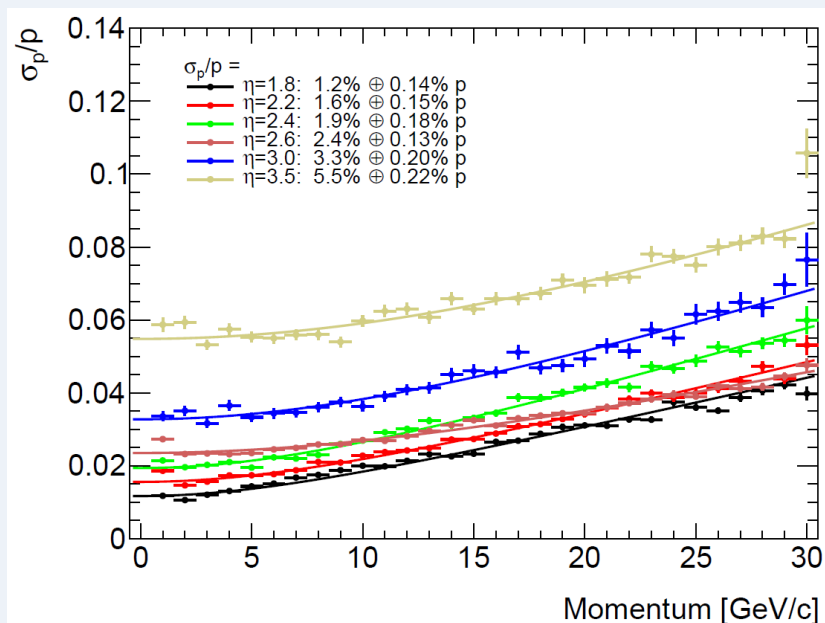
+ Forward EMCal & Hcal
+ Forward tracking
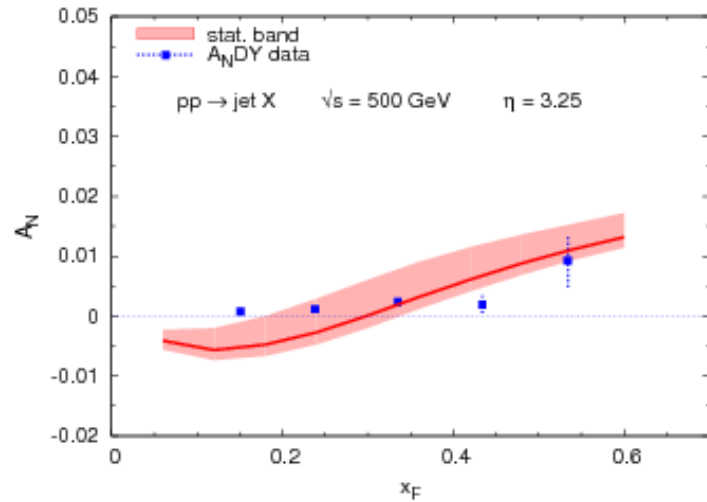
Forward Jet and h±

Good jet resolution for E, η, φ

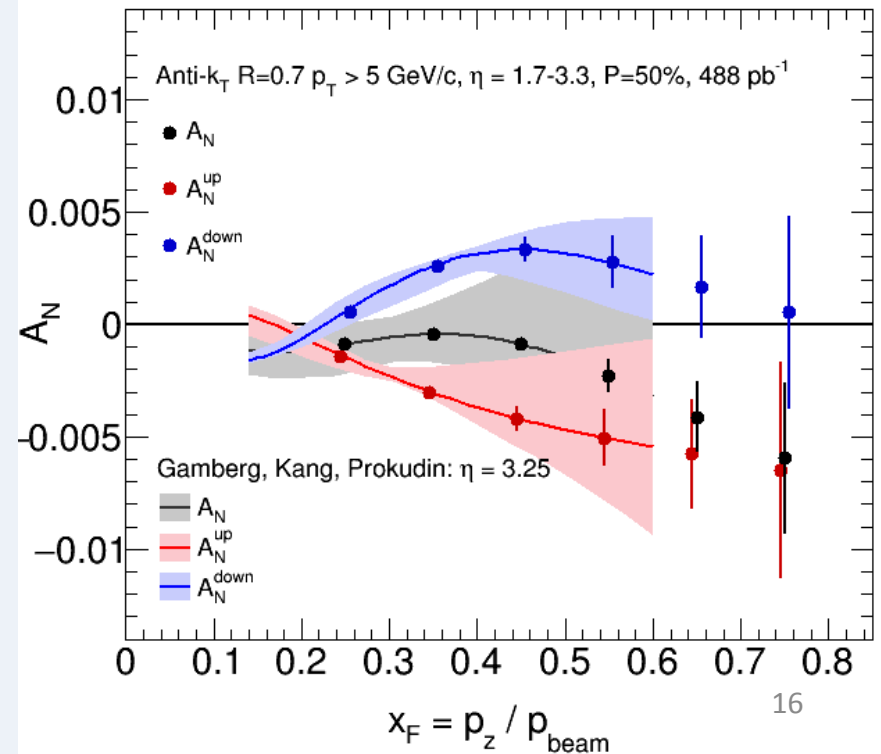Excellent charged track momentum resolution even in forward region

Jet A_N
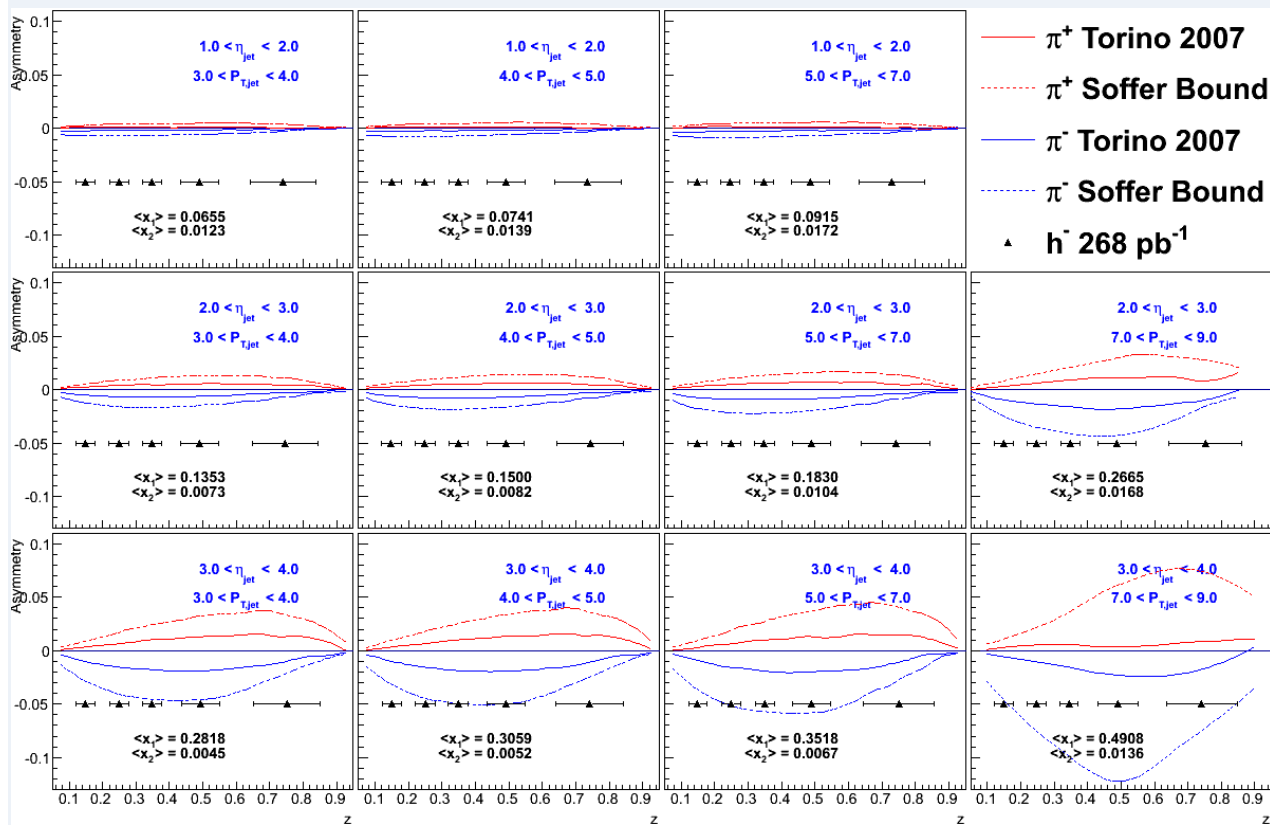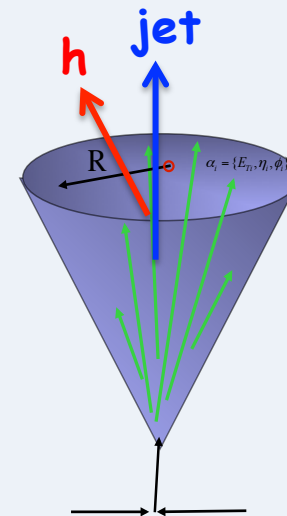
Sensitive to Sivers fnct.

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

Tagging jets with the charge of leading
hadron changes jet composition
=> 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

$$\delta q^{a} = \int_{0}^{1} \left(\delta q^{a}(x) - \delta \overline{q}^{a}(x) \right) dx$$

Calculable on lattice

Di-jet A$_{LL}$: ΔG(x) to lower x

If we run at √s=500 GeV

STAR: 1805.09742
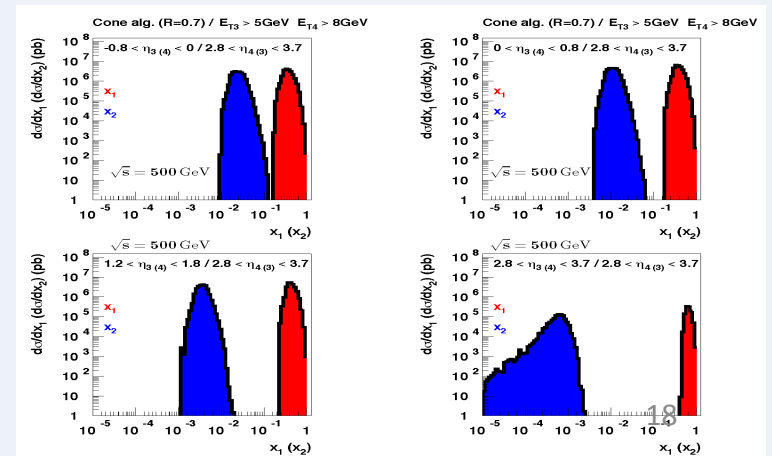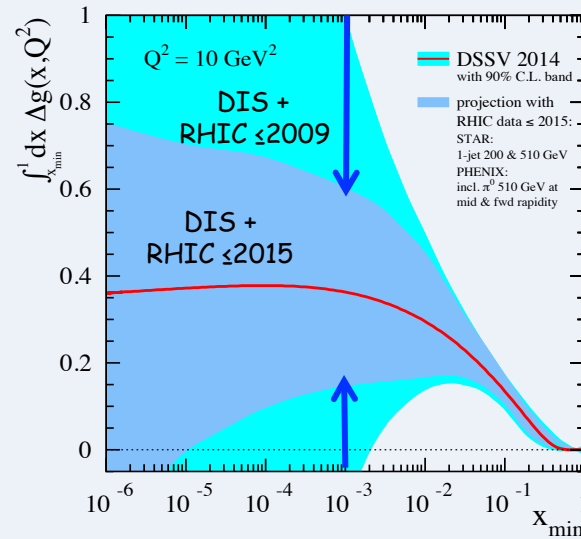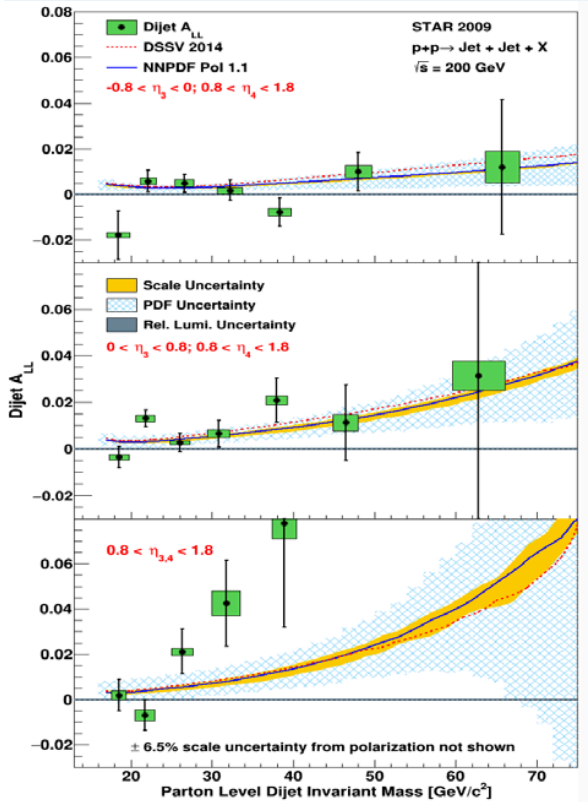
fsPHENIX will considerably improve it

Effective jet triggering and high DAQ rate

Higher rapidity => Lower x (down to ~10^{-3})

DY for nPDF

Current nPDF are mainly constrained by DIS data (affected also by final state effect)
DY: no final state effect, kinematics reconstruction at LO, directly tag antiquarks

Full GEANT simulation
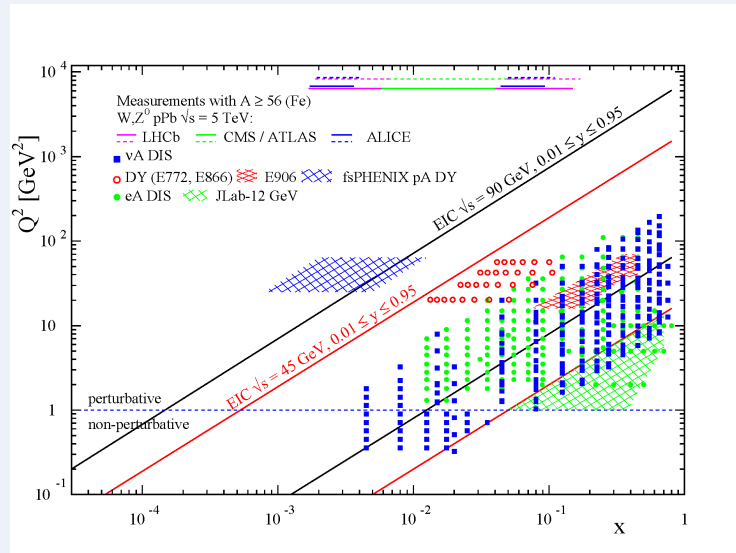
Unique kinematics coverage
compared to fixed target and LHC
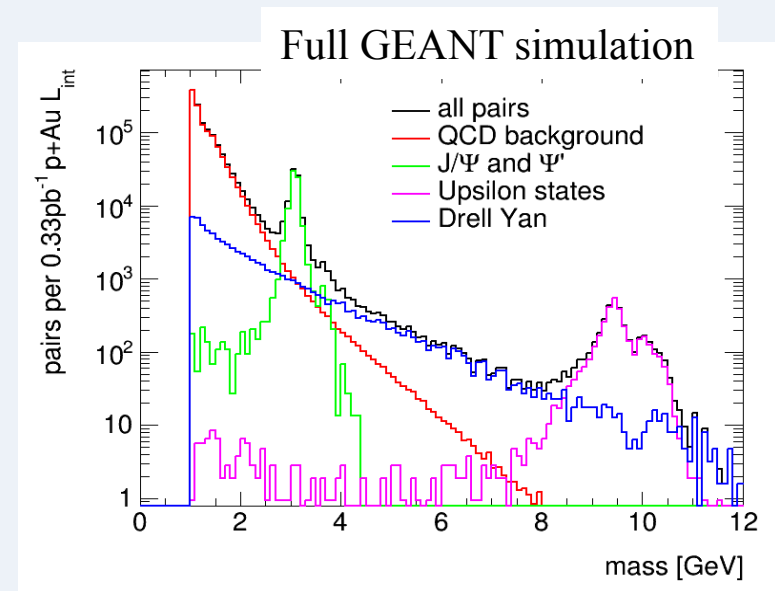
Can do measurements at $5<m<8$ GeV/c^2

A comprehensive set of measurements will be crucial for nPDF: DY, γ+jet, jet+jet, HF

Fragmentation in a Nuclear Environment

Phys. Lett. B577, 37 (2003)
Phys. Lett. B684, 114 (2010)
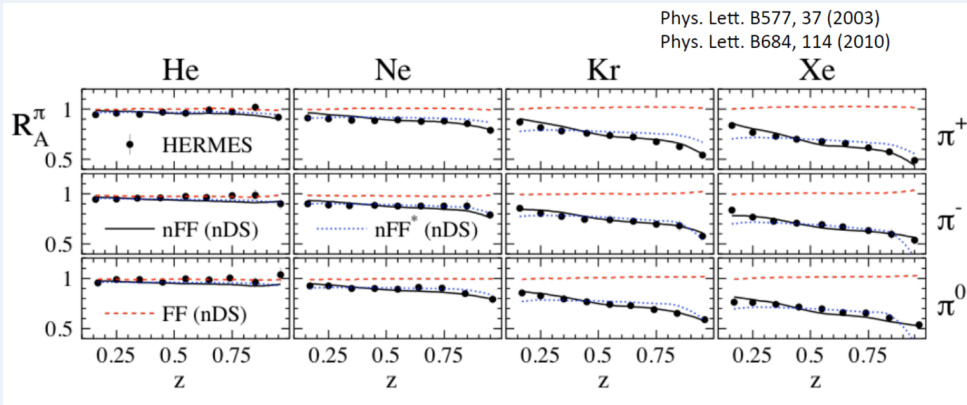
Hadron production in e+A suppressed compared to e+p => fragmentation modification

Kaufmann, Mukherjee, Vogelsang: PRD 92, 054015

Access fragmentation function (FF) through p+p(A) –> (jet h)+X

Direct access to gluon FF
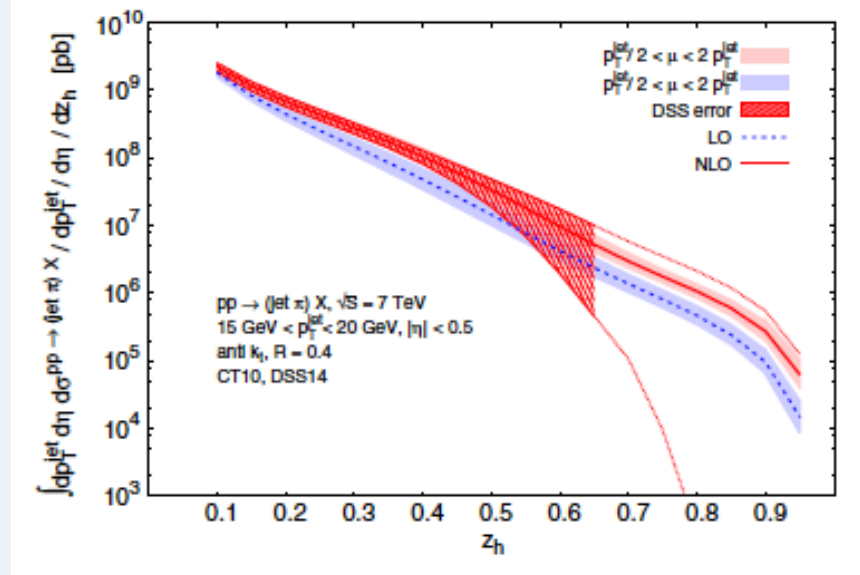
Summary

In additional to exciting QGP program sPHENIX will provide a broad range of **high precision** Cold QCD measurements

Even more opportunities with proposed forward instrumentation

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

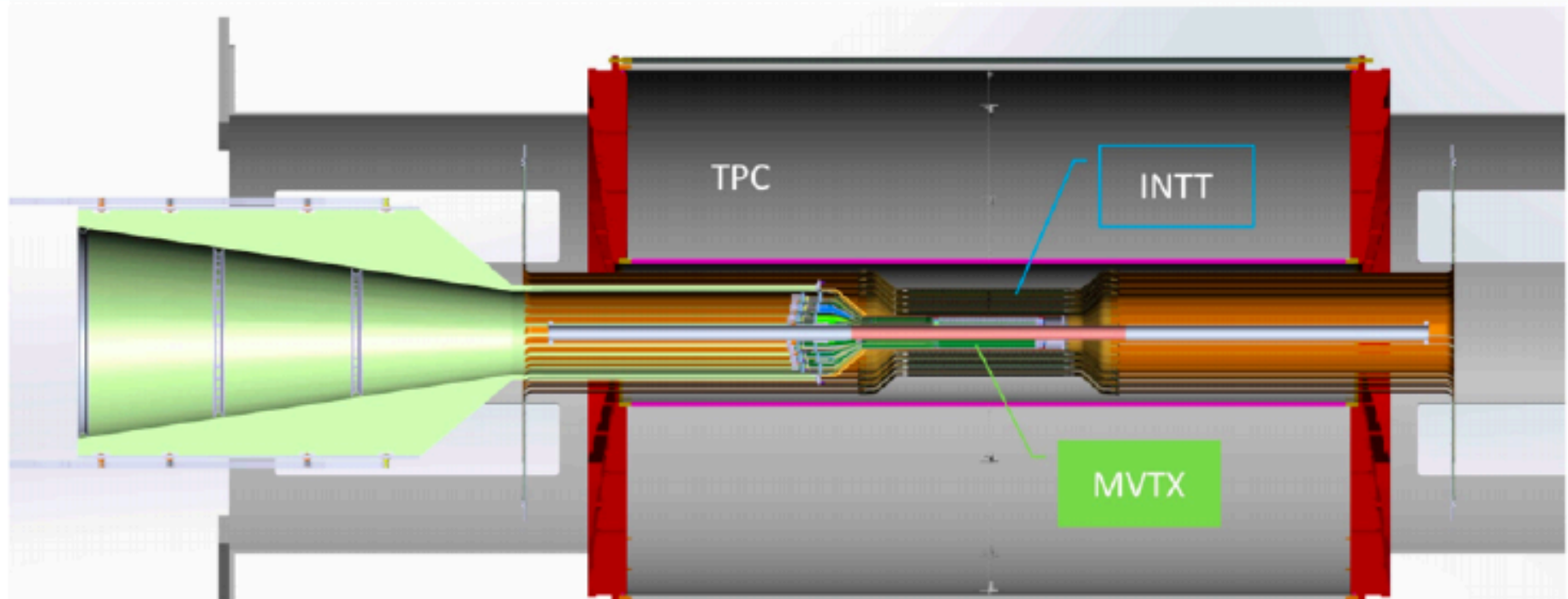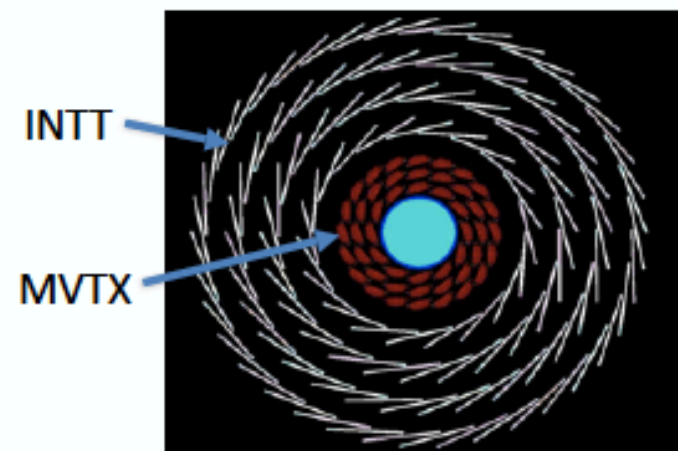# The Tracking detectors

Functions:

TPC - momentum measurement

MVTX - precise track vertex

INTT - timing & pattern recognition

The Tracking Detectors (in GEANT 4) SPHENIX

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

> **Average mass budget of inner detectors**
>
> MVTX ~ 0.3% / layer
>   (1% total)
>
> INTT ~ 1% / layer
>   (4% total)

Calorimeters

EMCal

Tungsten-scintillating fiber sampling calorimeter

$18 X_0$, 1λ

$\Delta\eta \times \Delta\phi = 0.025 \times 0.025$

Read out by silicon photomultipliers

2D projective geometry

Small Moliere Radius, short radiation length

Energy resolution $\leq 16\%/\sqrt{E}$ @ 5%
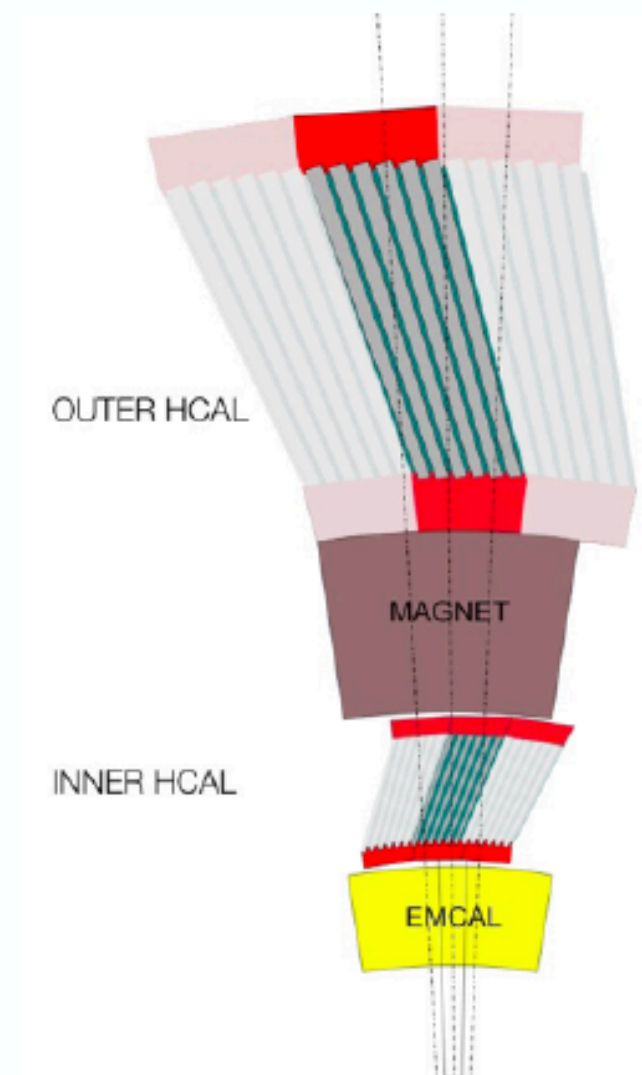

HCal

Sampling calorimeter

Magnet steel plates / scintillator tiles

3.8λ

$\Delta\eta \times \Delta\phi = 0.1 \times 0.1$

Read out by silicon photomultipliers

Doubles as the flux return for the solenoid

OUTER HCAL

MAGNET

INNER HCAL

EMCAL

Aschenauer, Sassot, Stratmann, PRD 92, 094030