The High Energy Nuclear Physics group at Los Alamos National Lab

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Los Alamos National Lab

Aug 20th, 2018

Total reaction X-sec, **LAMPF**
1978

Bevelac
1988

Triumf

CERN-LEAP

SPS
NA-34, HELIUS

Traveling
2π spectrometer

BNL/AGS
E814

LEP, L3
SMD

SSC effort
GEM

SPS
NA-44

FNAL
E772, E866

FNAL
E906

RHIC
PHENIX

LHC
LHCb

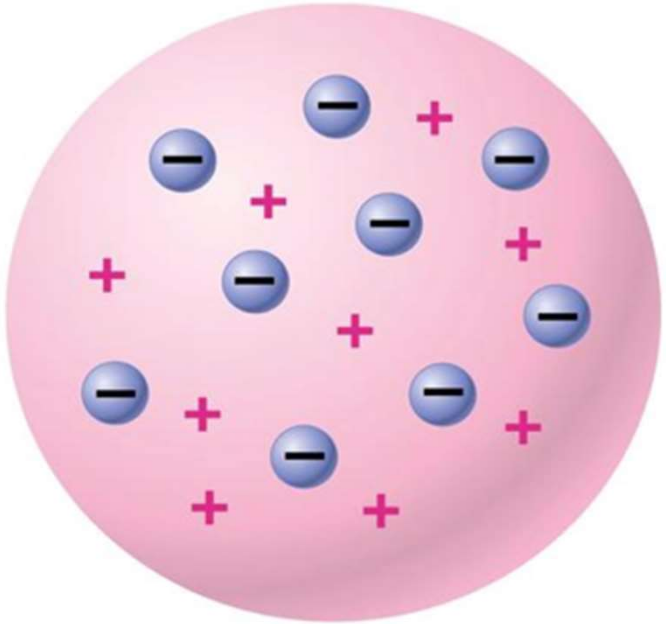
RHIC
sPHENIX

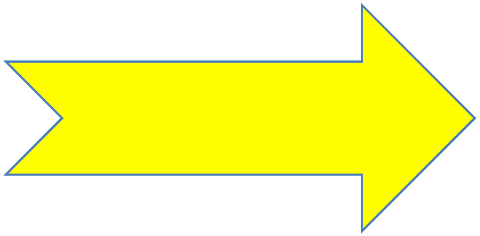
FNAL
E1039

PHYSICS PUNCHLINES

THOMPSON'S ATOMIC MODEL

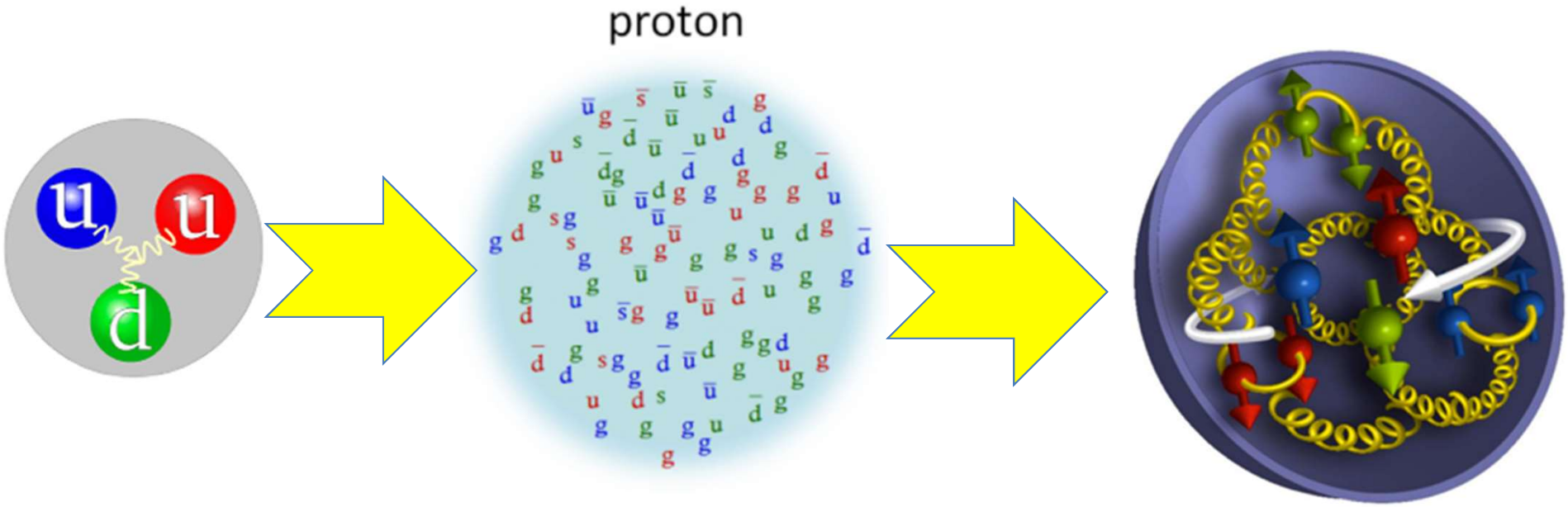
QUANTUM ELECTRODYNAMICS





Well understood ground for chemistry and material science during XX century.

Studying the Partonic Structure and Behavior in Protons and Nucleus



- What is the dynamics of partons (quarks and gluons) inside the nucleon ?
- How parton structure change when the nucleon is inside nucleus ?
- Is there any new physics when gluon density reach saturation ?
- Complex multi-body problem governed by non-abelian quantum field.

ANSWERS MAY DEFINE NULEAR PHYSICS IN 21th CENTURY

Where the proton spin comes from ?

Valence quarks | Gluons | Internal Orbital Momentum

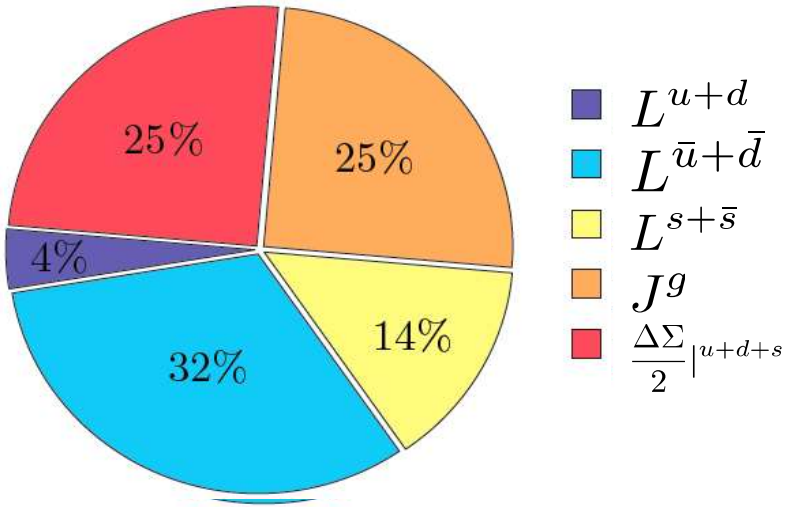
Nucleon Spin = ½ = ½ $\Delta\Sigma$ + ΔG + $L_q + L_g$

$$\Delta\Sigma_q \approx .25 + \Delta G \approx .2 \quad \textbf{???}$$

$\Delta\Sigma_q \approx 25\%$

$2\ L_q \approx 46\%$ (0%(valence)+46%(sea))

$2\ J_g \approx 25\%$

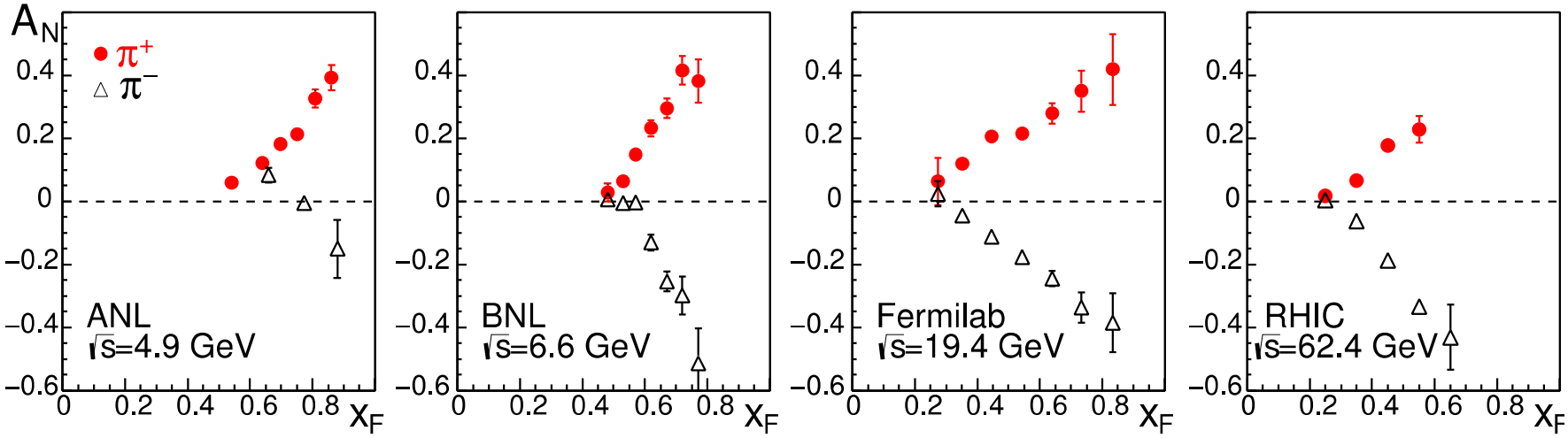


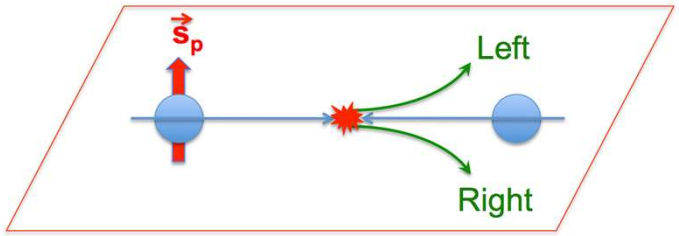
Lattice QCD: K.-F. Liu *et al* arXiv:12036388

Still an open question. WE DON'T UNDERSTAND THE PROTON !!!

INTERNAL TRANSVERSITY OF THE PROTON

Inclusive hadrons





$$A_N \equiv \frac{\Delta\sigma(\ell,\vec{s})}{\sigma(\ell)} = \frac{\sigma(\ell,\vec{s}) - \sigma(\ell,-\vec{s})}{\sigma(\ell,\vec{s}) + \sigma(\ell,-\vec{s})}$$

Indication of parton rotations inside the nucleon (not the language that spin folks appreciate)

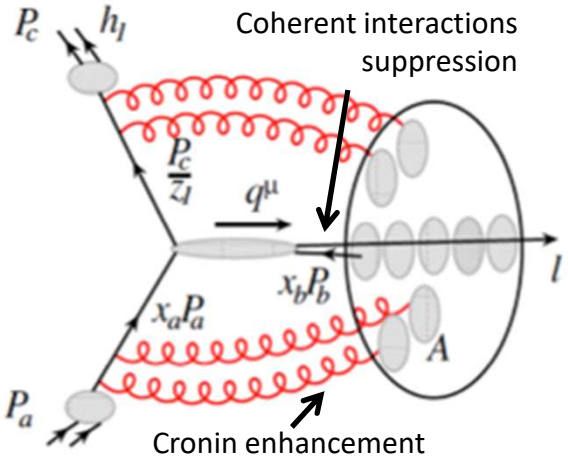
We don't know if transversity comes from initial parton (**Sivers effect**) or when it fragments (**Collins effect**).

Drell-Yan process (directly from sea-quarks and no fragmentation) is a direct probe for Sivers effect.

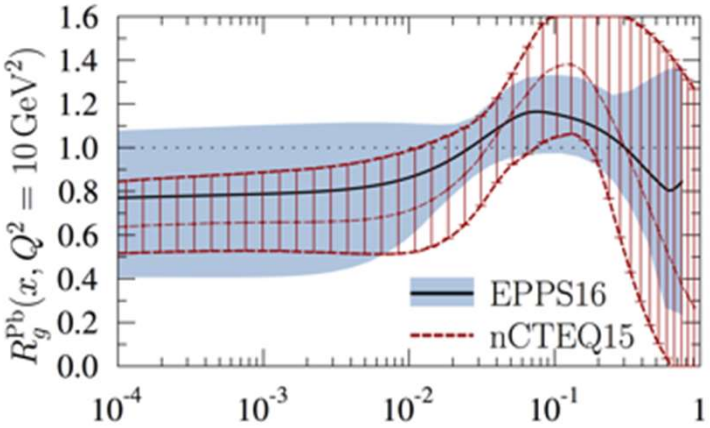
QCD in Nucleus

Los Alamos NATIONAL LABORATORY EST. 1943

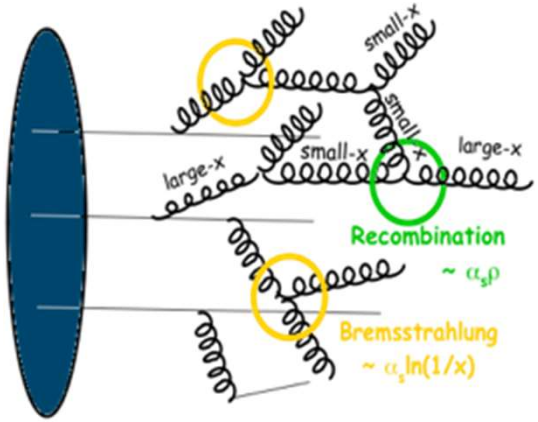
Multiple interactions



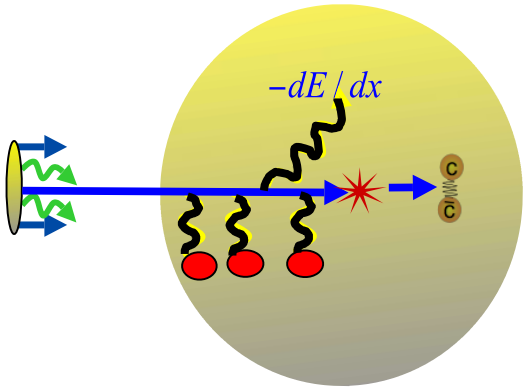
nPDF from DIS,DY world data fit



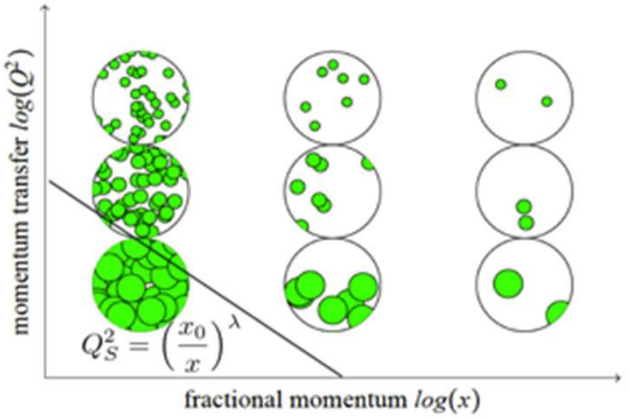
Radiation, recombinations



Parton energy loss

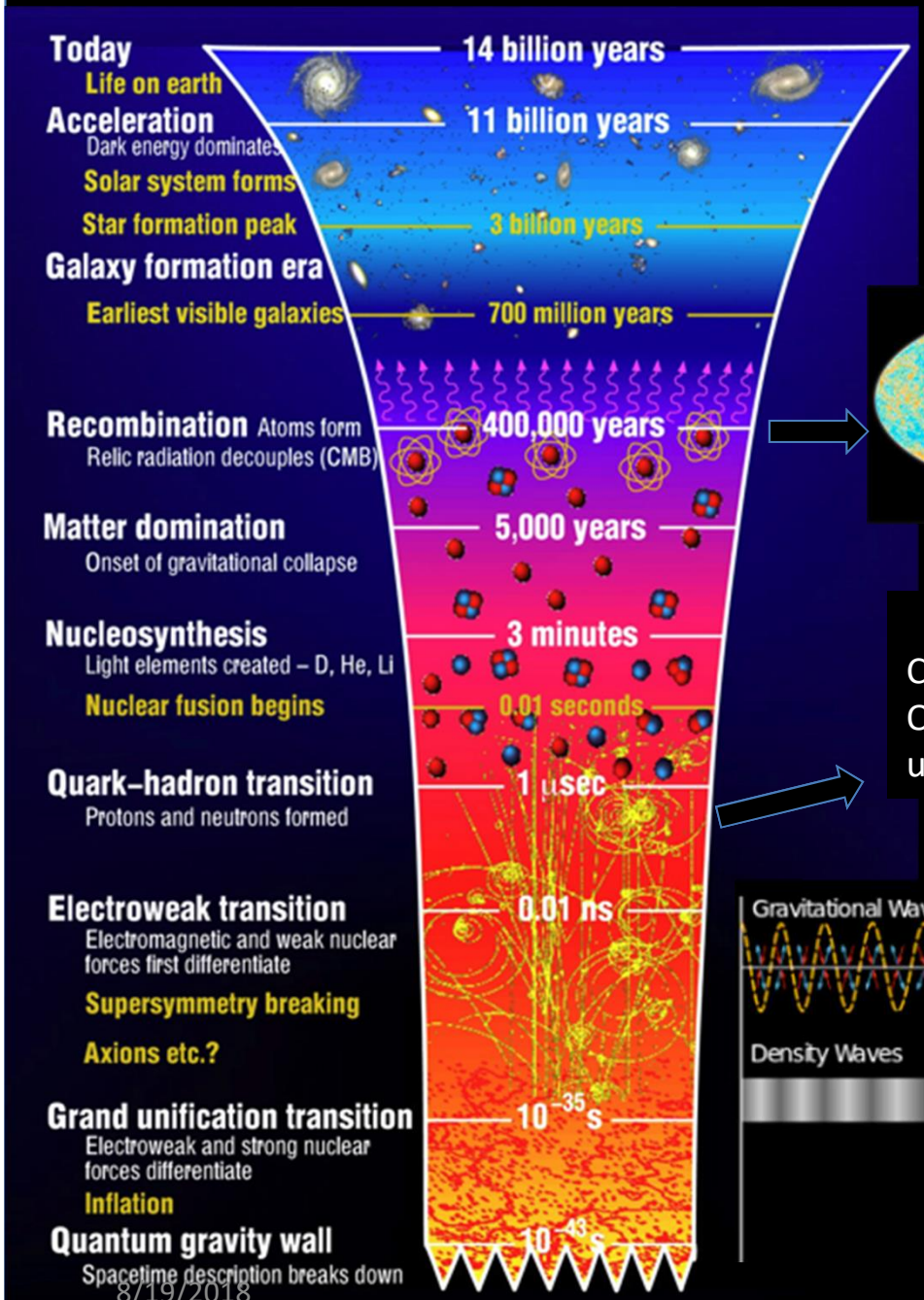


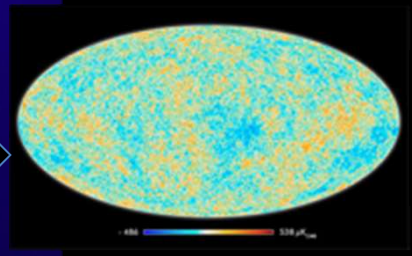
Gluon saturation



- Measure how QCD factorizes in nuclear medium.
- Understand nuclear effects on QCD probes:
  - jets, heavy quarks, quarkonia, photons, Drell-Yan

Early Universe Observation





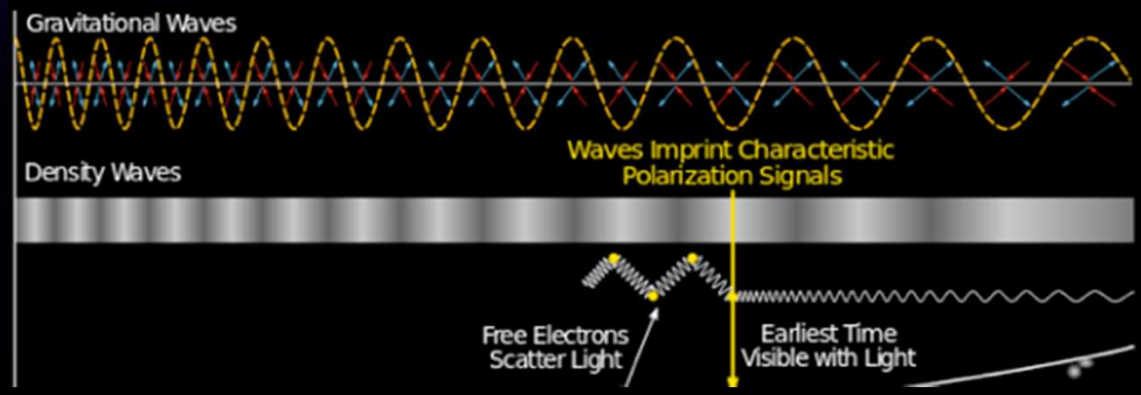
Cosmic Microwave Background

No hint of gravitational waves effects yet.

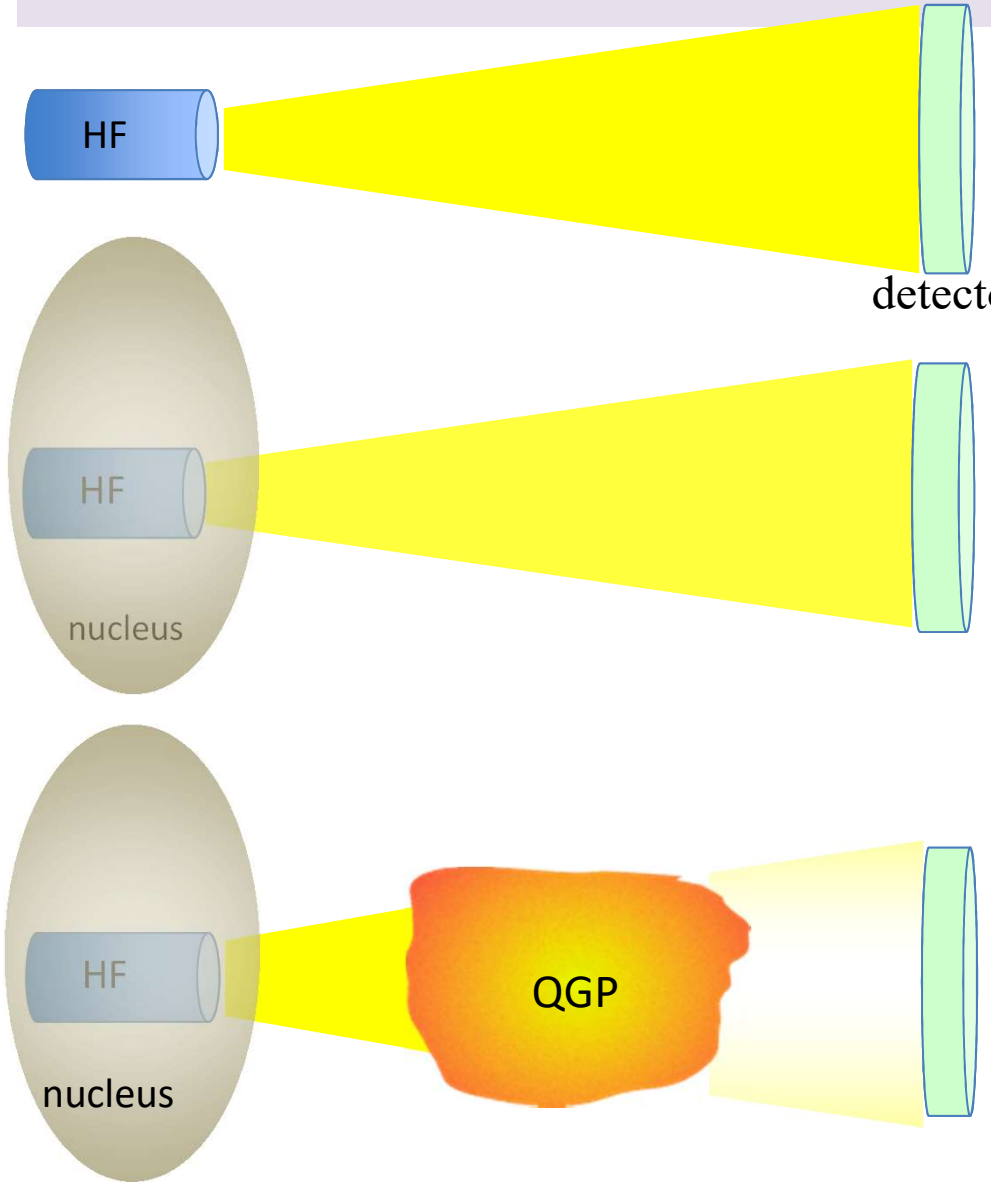
Quark-Gluon Plasma

Can it interfered on early gravitational waves ?

QGP fluctuations may also determine the fate of the universe.



QGP Tomography



Source intensity (cross section) measured in p+p collisions.

Needs to understand how the source is affected by the nucleus immediately after the collision (initial state effects). Studied in small systems (p+A, d+A, …)

QGP tomography done in A+A collisions. Measurements are

- nuclear modification factor

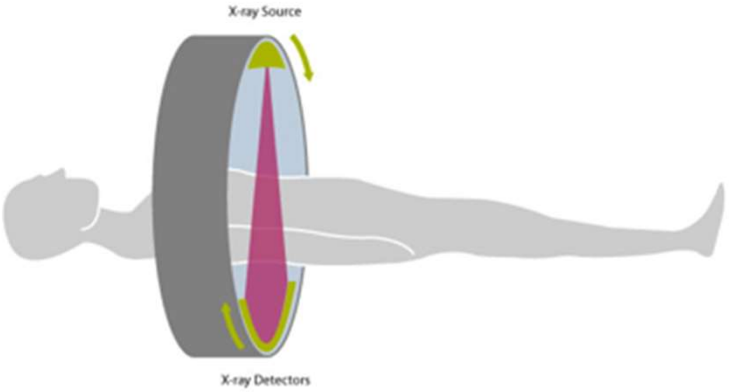
$$R_{AA} = \frac{\text{yield in A+A}}{N_{\text{coll}}(\text{yield in p+p})}$$

- Fourier expansion of particle azimuthal asymmetries

$$\frac{dN}{d\phi} \propto 1 + 2\sum_{n=1}^{\text{inf}} v_n \cos n\left(\phi - \Phi_{RP}\right) \quad \text{(event plane meth.)}$$

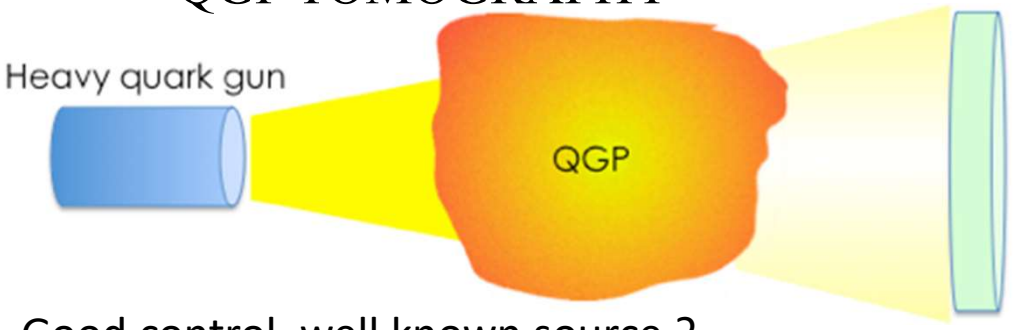
Are Nuclear Physicists Well Paid for This ?

MEDICAL TOMOGRAPHY

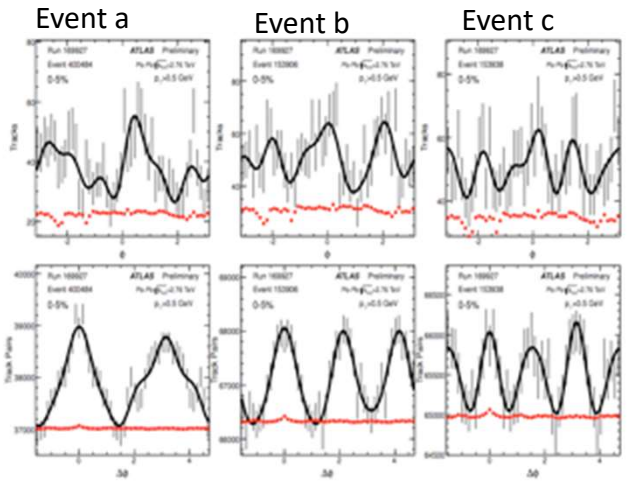


- Good control, well know source
- Medium to probe (patient) is still
- Patient is the same for many events

QGP TOMOGRAPHY

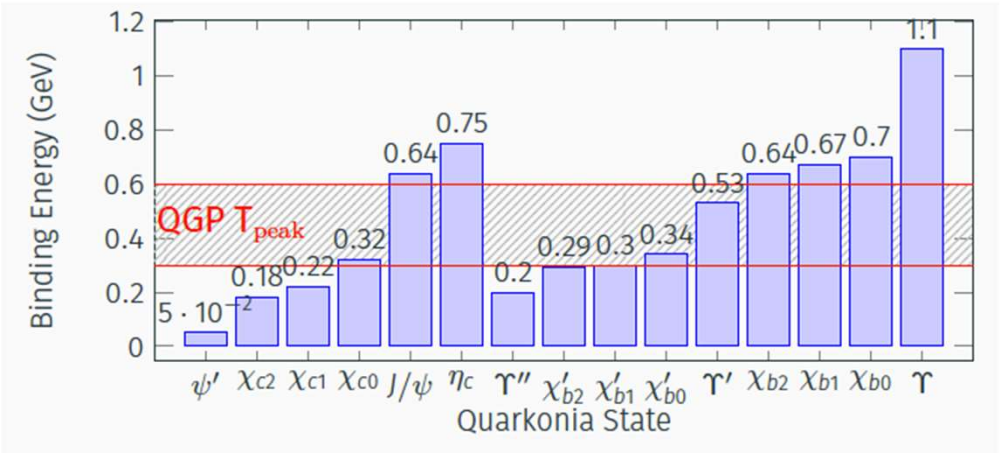


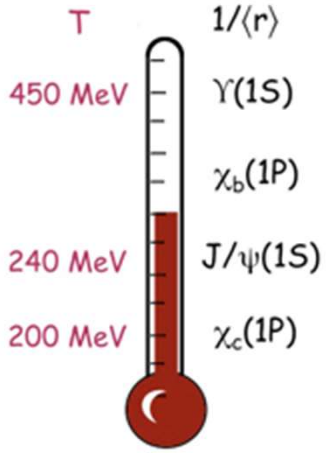
- Good control, well known source ?
- Medium to probe expands almost at the speed of light
- Medium geometry change every event

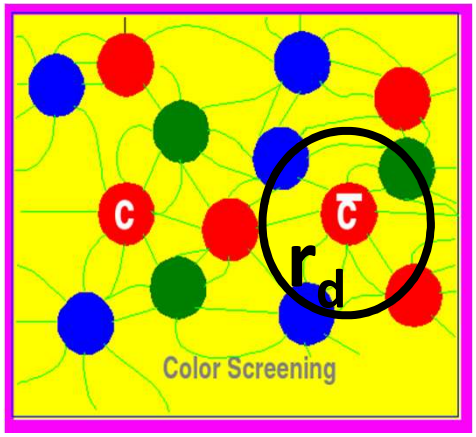


ATLAS

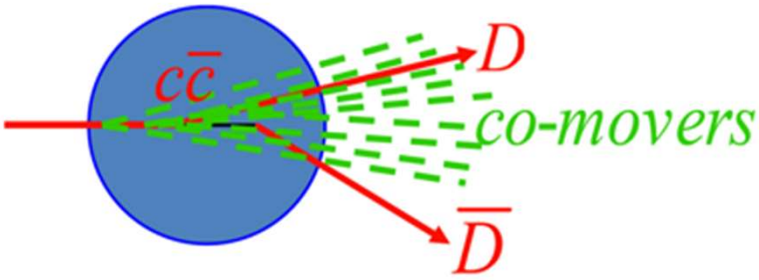
Measuring QGP Temperature with Quarkonia



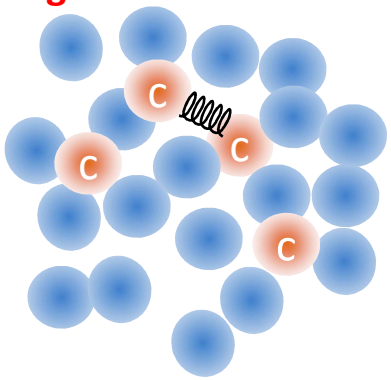




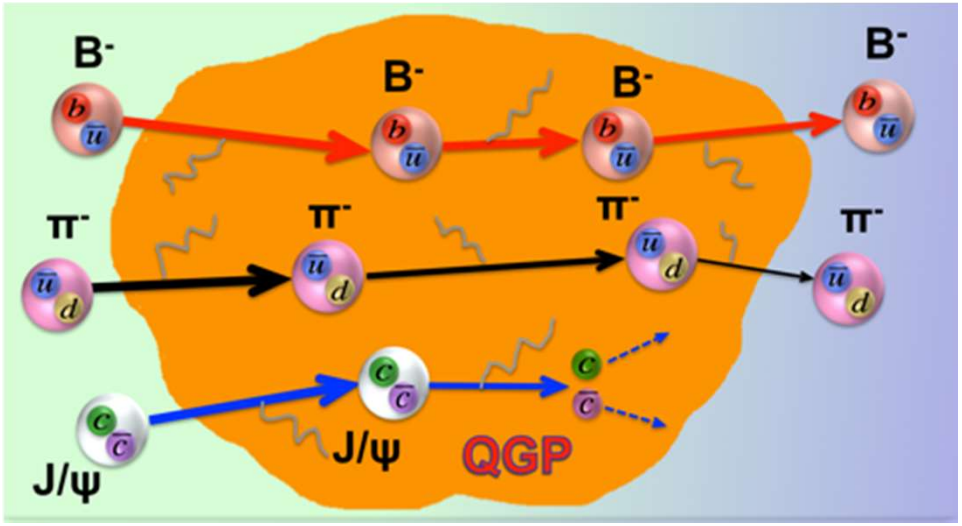
But, besides the need to understand initial-state effects, we need to understand competing final-state effects.

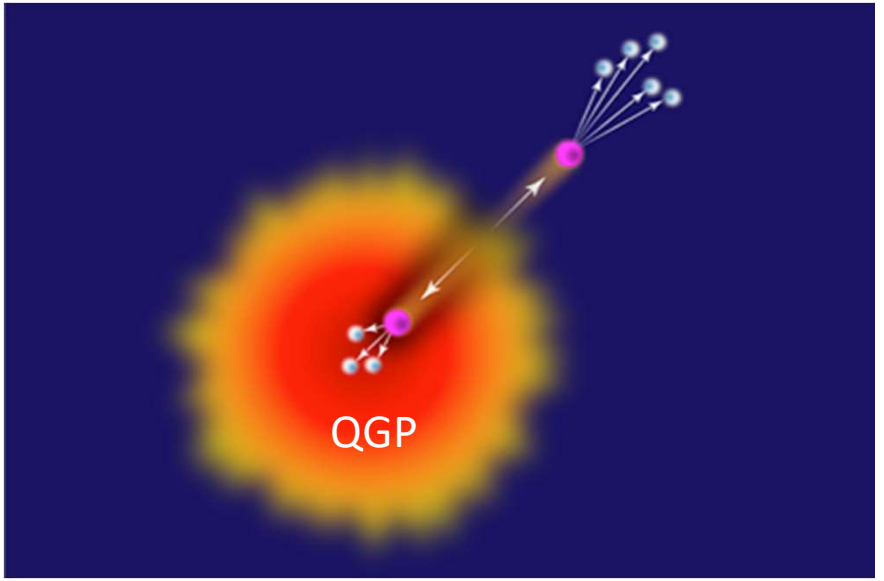


Coalescence, Regeneration



Measuring QGP Density, Interaction length and Difusion with Heavy Quarks





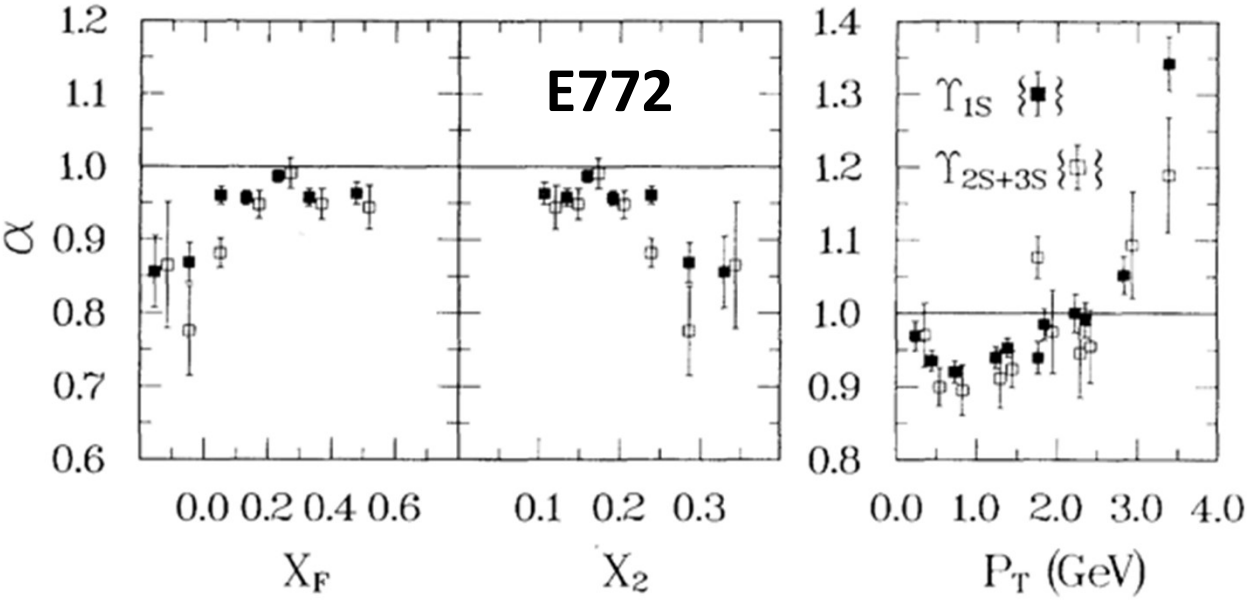
Modification on the momentum and angular distributions of quarks (light and heavy) probe the characteristics of the QGP.

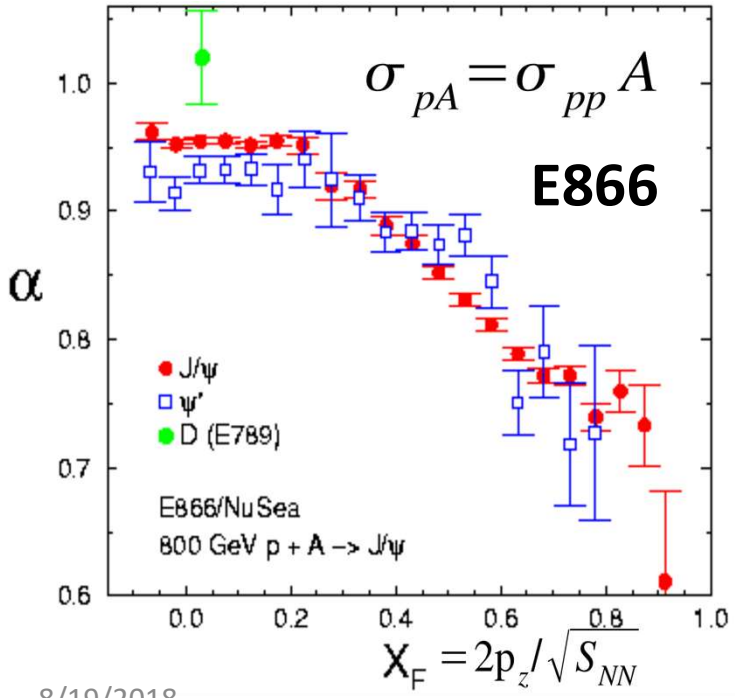
Meson decays: large statistics, probes macroscopic and microscopic scale but needs to consider fragmentation in the medium

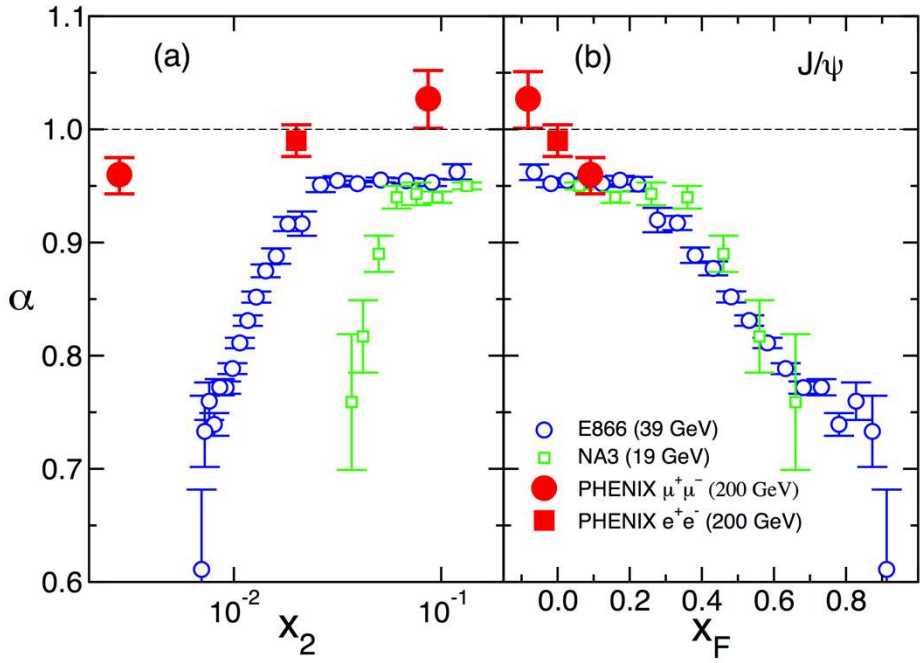
Jets: almost direct access to initial quark kinematics, probes microscopic scale, low statistics

OLD AND RECENT ACCOMPLISHMENTS

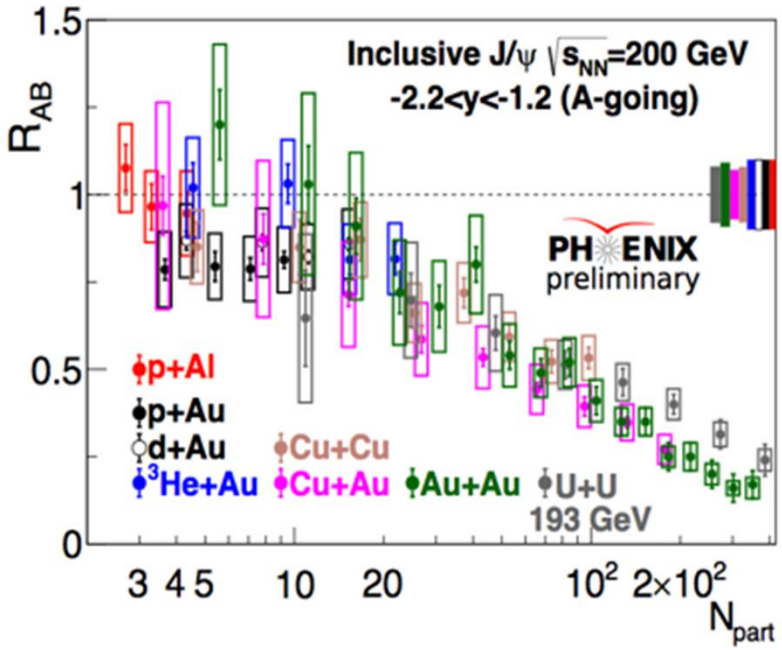
Accomplishments with FNAL

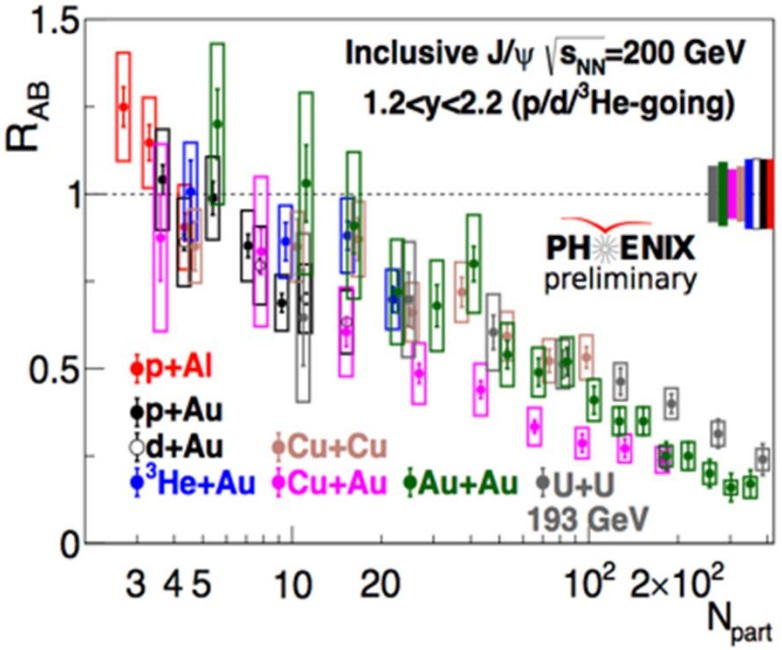


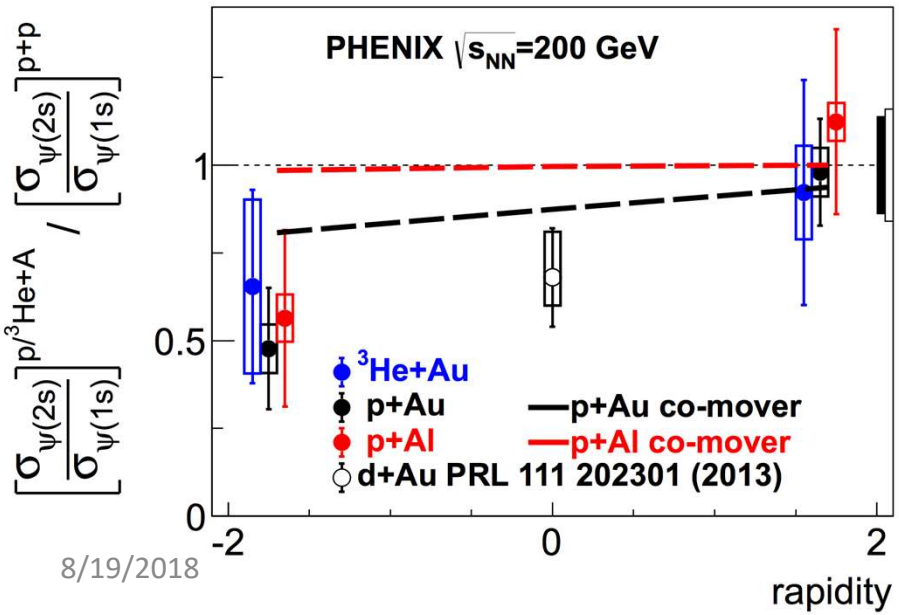


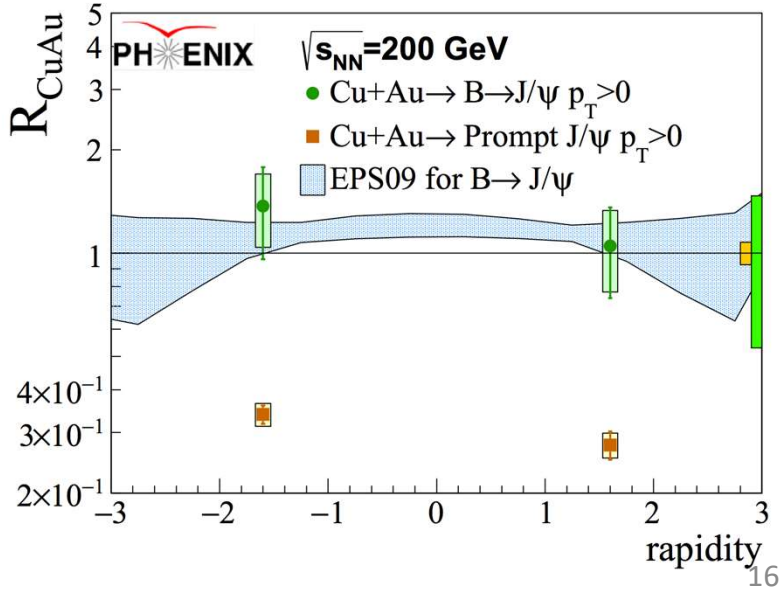


Accomplishments with PHENIX



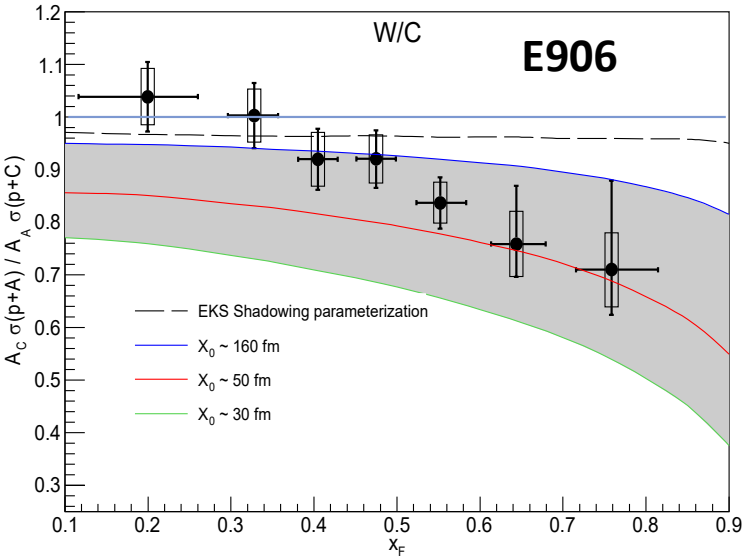


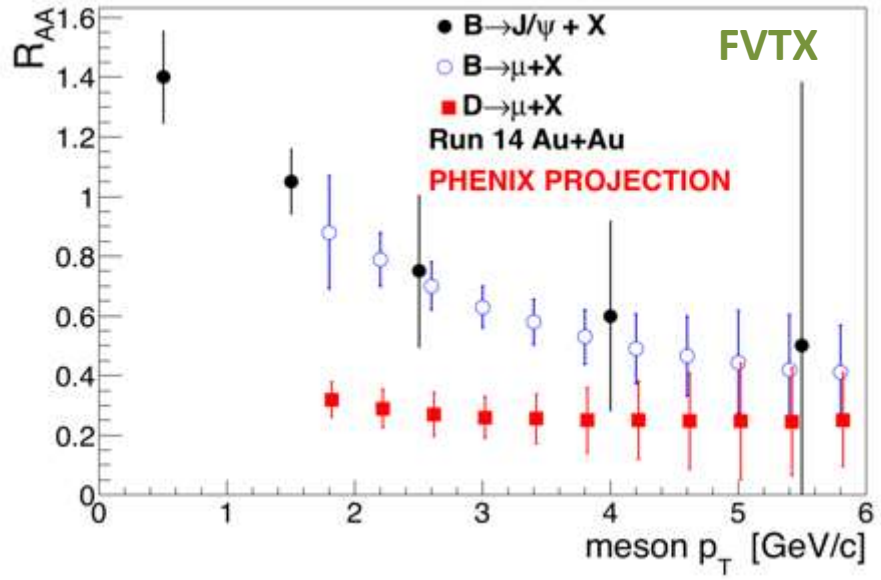


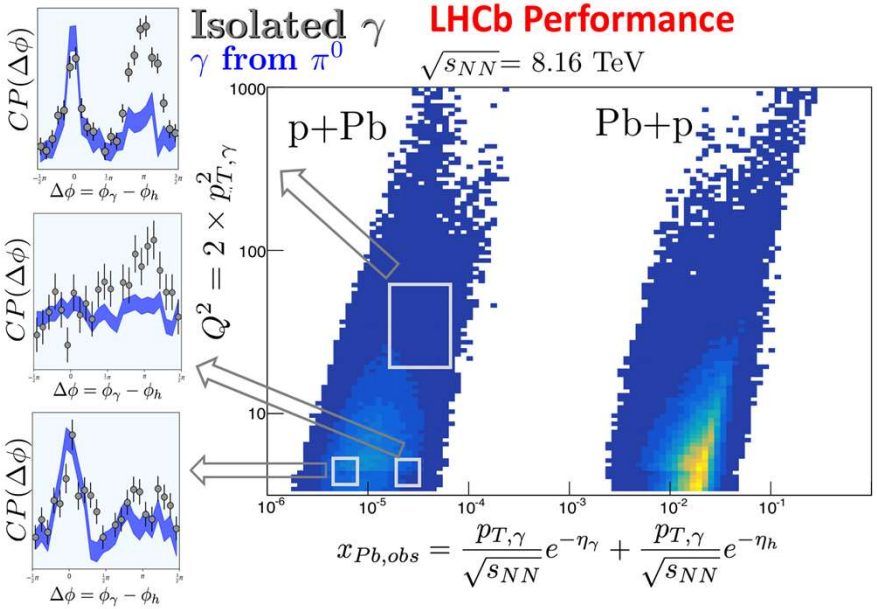


CURRENT COMMITMENTS

Deliver Physics Results from Available Data

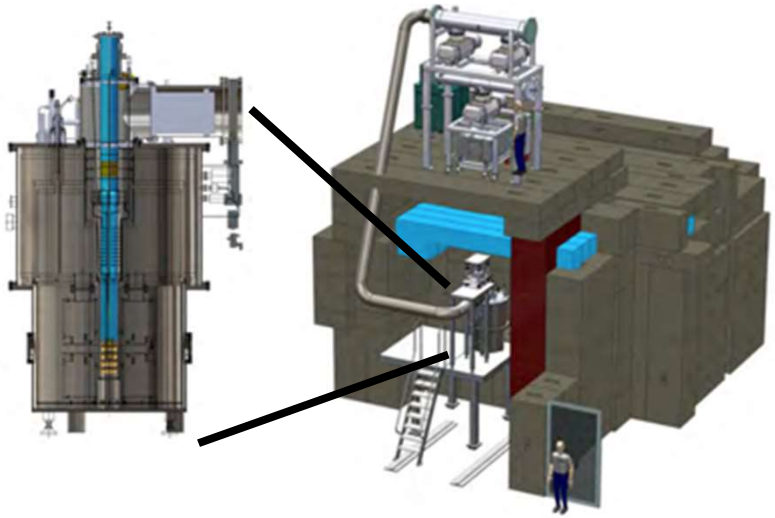


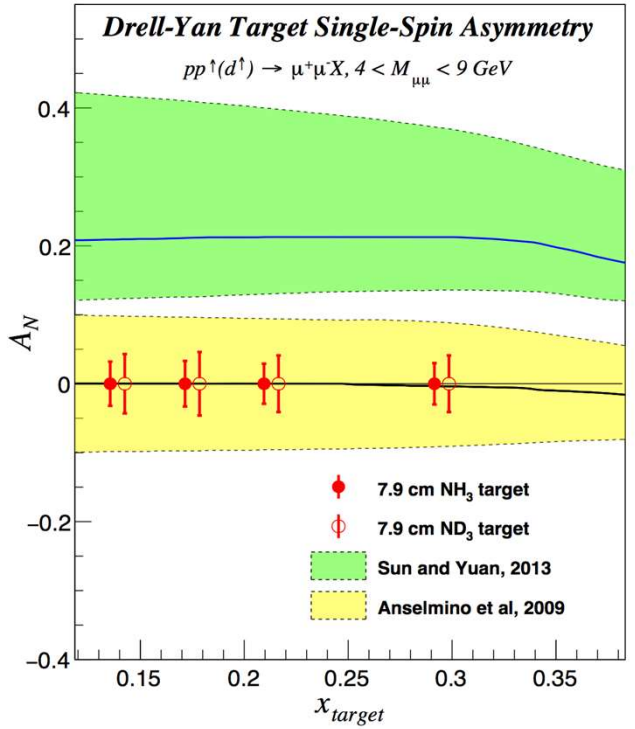




- Next 4-years DOE National Lab review next spring
  - We will be asked about E906 and PHENIX results
- LANL ECR review on September 10th
  - I will be asked a LHCb result
- Any physics results on the Dark Photon ER this year

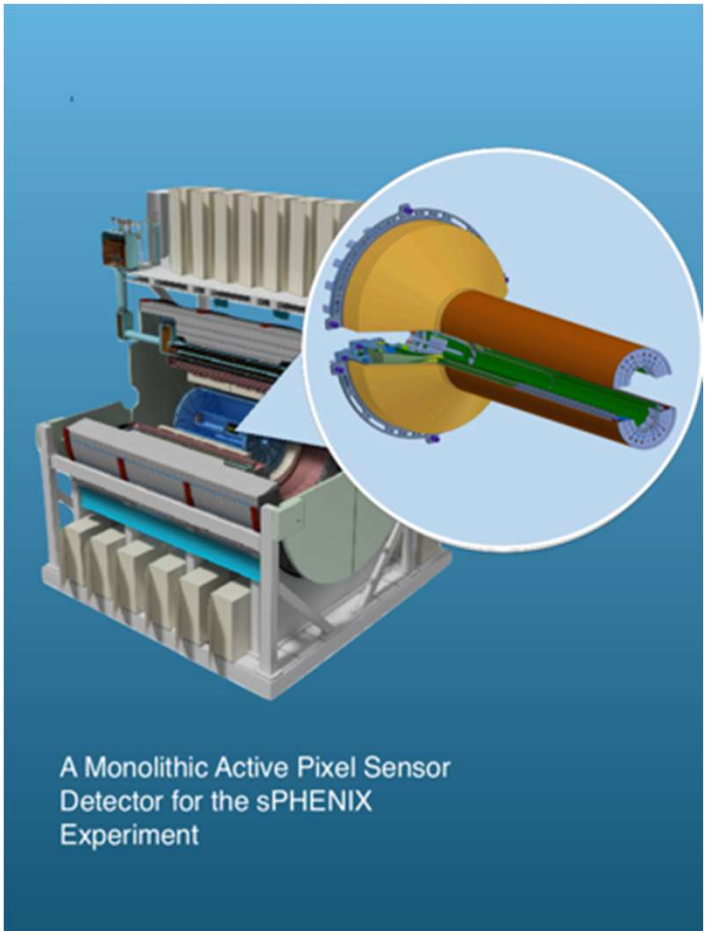
FNAL/E1039

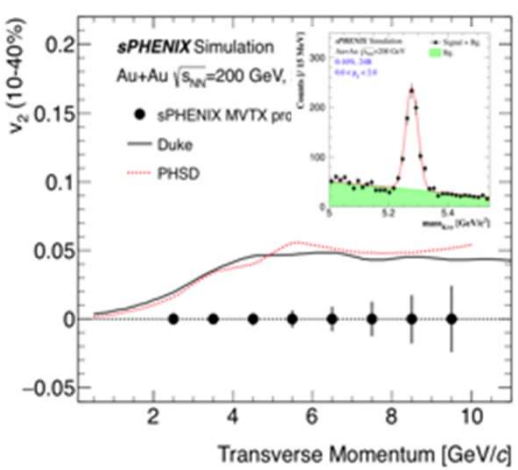


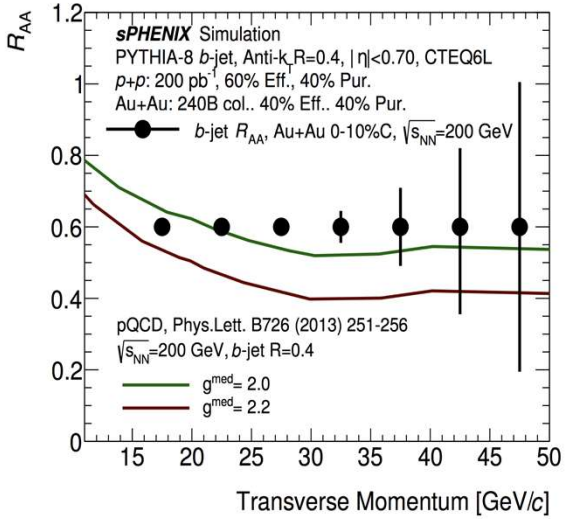


- Deliver a 4% precision Drell-Yan SSA result in the next 3 years
  - Preparation of the polarized target, NMR system
  - SeaQuest repair and commissioning
  - Stable and quality data acquisition
  - simulation, analysis ready for prompt deliver of the results

RHIC/sPHENIX

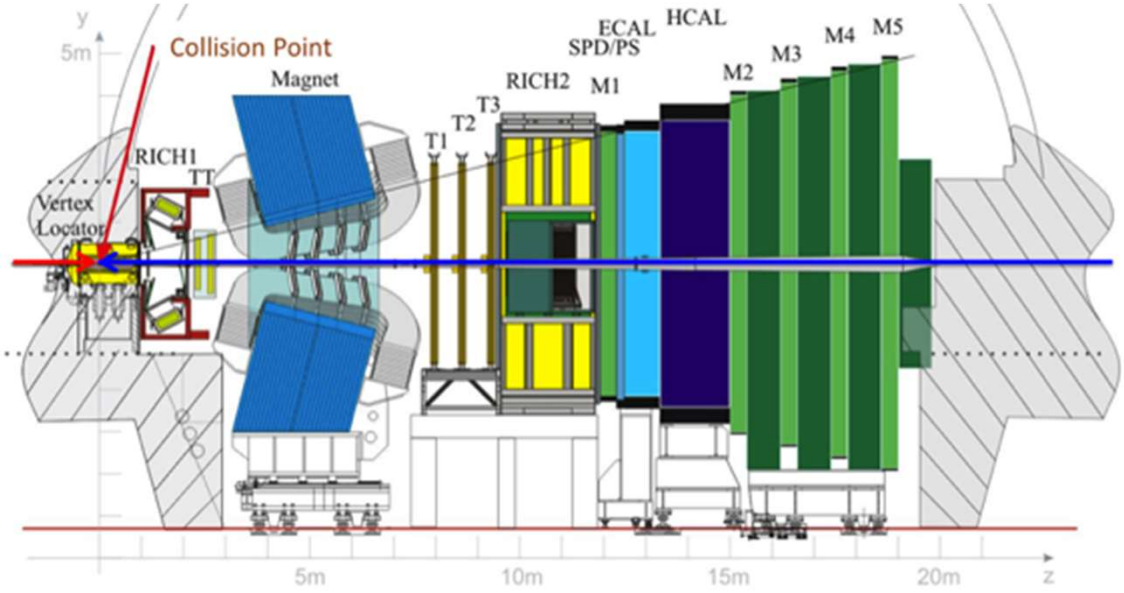


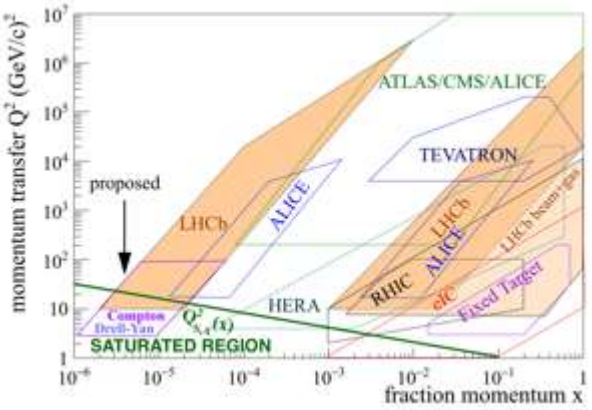


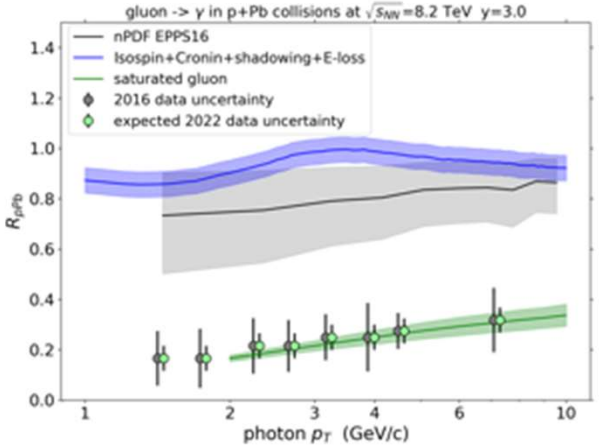


- Deliver the nuclear modification of b-jets and B-meson flow in Au+Au collisions by 2027
  - MVTX R&D + Assembly + Commissioning + Operation
  - Robust and sophisticated data analysis

CERN/LHCb







- Determine the transition between dilute and saturate gluon regimes using direct photons and Drell-Yan by 2023
  - Data analysis of 2016 pPb data
  - Develop a high-level trigger for isolated photons in preparation for 2022 pPb run
  - Implementation of nuclear effects in PYTHIA
  - R&D for a magnet station tracker

OTHER DEVELOPMENTS

- If we find time, funding and workforce available we can plan future activities or extend our physics scope
  - Electron-Ion Collider
  - Dark photon
  - Fixed target in LHCb
  - Applications

- The capacity to pursue new ideas and look for the future is one of our assets

- But keep in mind our commitments, if we don't deliver we don't get funding in the future

GROUP FOR 2019

	Heavy Ion	Medium Energy	DOE/NP ECR(LHCb)	Nuclear Phys. LDRD (MVTX)	Other Non-NP	Total NP FTE
Staff						
C. da Silva	0.4	0.05	0.5	0.05	0	1.0
M. Durham	0.3	0.1	0.1	0.0	0.5	0.5
New Staff	0	1.0	0	0.0	0	1.0
X. Li	0.5	0.2	0.1	0.1	0.1	0.9
K. Liu	0.2	0.8	0	0.0	0.0	1.0
M. Liu	0.5	0.2	0	0.3	0.0	1.0
E. Guardincerri	0	0.5	0	0	0.5	0.5
C. O'Shaughnessy	0	0	0	0.2	0.8	0.2
G. Kunde	0	0	0.1	0	0	0.1
New Engineer	0.2	0	0.05	0.0	0.75	0.25
Temporary	0	0	0	0	0	0
D. Lee (affiliate)	0	0	0	0.10	0	0.1
D. McGlinchey (PD)	0.5	0	0	0.0	0.5	0.5
A. Tkatchev (Eng.)	0	0	0.05	0.5	0.45	0.55
H. van Hecke (aff.)	0.0	0.1	0.05	0.1	0	0.25
S. Uemura (PD)	0	0.4	0	0.6	0.0	1.0

GROUP FOR 2019 (continuation)

	Heavy Ion	Medium Energy	DOE/NP ECR(LHCb)	Nuclear Phys. LDRD (MVTX)	Other Non-NP	Total NP FTE
M. Yurov (PD)	0	1.0	0	0	0	1.0
M. Jen (PD)	0	1.0	0	0	0	1.0
Y. Morales (PD)	0	0.0	0	1.0	0	1.0
A. Khativada (PD)	1.0	0.0	0	0	0	1.0
New postdoc I	1.0	0	0	0	0	1.0
New postdoc II	1.0	0	0	0	0	1.0
New postdoc III	1.0	0	0	0	0	1.0
New postdoc iV	0.0	0	1.0	0	0	1.0
A. Wicks (grad.st)	1.0	0	0	0.0	0	1.0
B. Garcia (posbac)	0.7	0	0	0.3	0	1.0
Total	8.3	5.35	1.95	3.25	3.1	18.85

- 20 people already involved in the HENP team.
- 5 more to come after hiring process
- Expected to have ~19 FTE in the team starting in 2019