

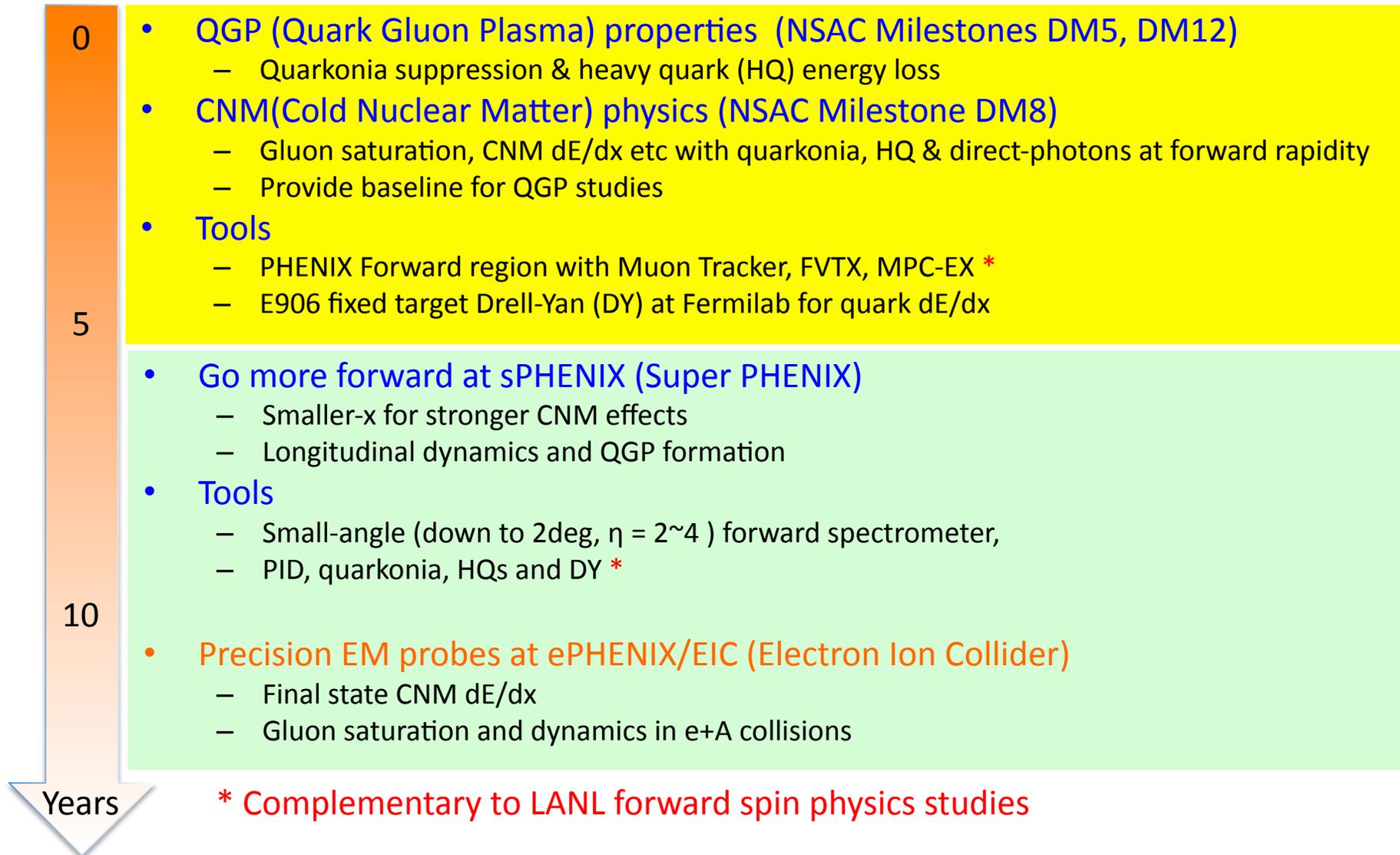
LANL Heavy Ion Program Overview

Ming X. Liu
P-25 Physics Division
Los Alamos National Laboratory

Outline:

- Current HI Physics Program
- Proposed Future Program
- Personnel, Group Efforts, Funding Sources

Overall LANL Heavy Ion Physics Visions



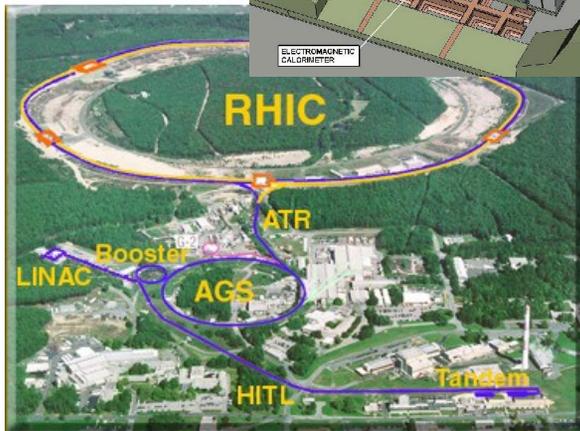
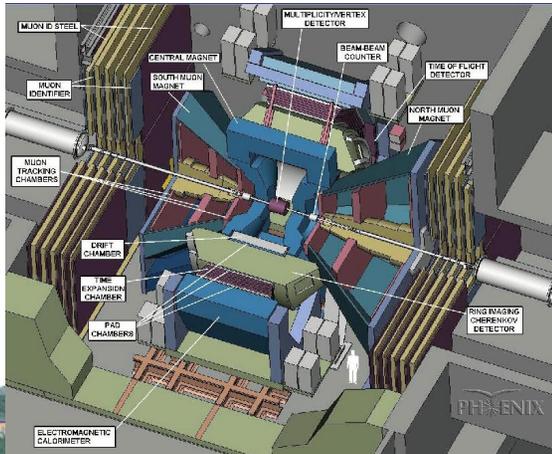
LANL HI Programs at RHIC and FNAL

PHENIX Detector at RHIC - comprehensive p+p, d+A, A+A program to study light and heavy quark production, vector meson production, take advantage of detector upgrades

FNAL E906 - unique access to unambiguous cold nuclear matter quark energy loss via Drell-Yan

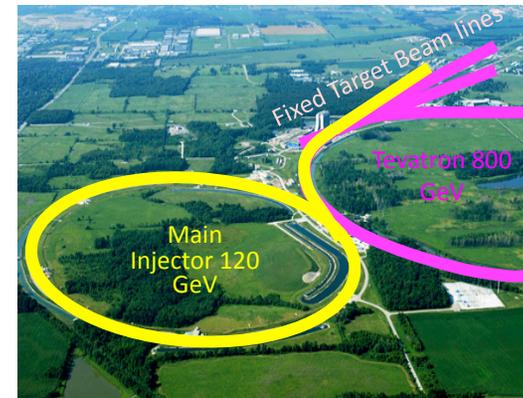
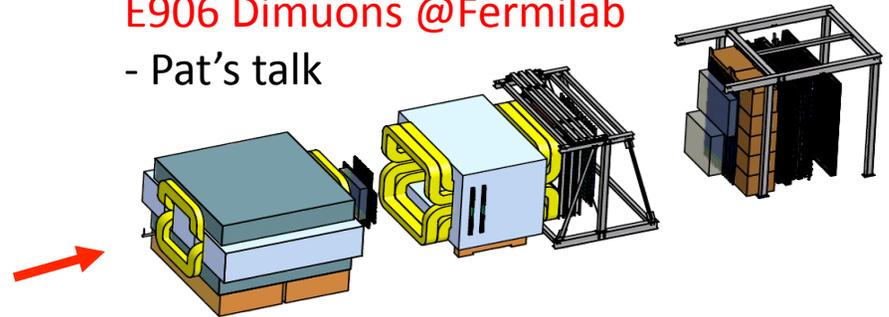
PHENIX@RHIC

- Mike
- Melynda
- Cesar
- Christine



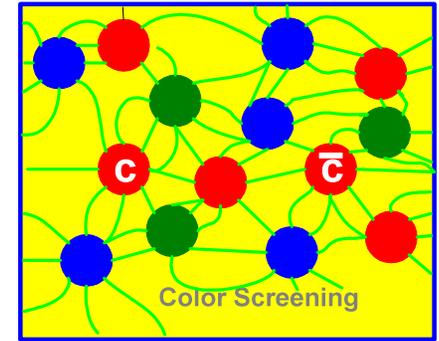
E906 Dimuons @Fermilab

- Pat's talk

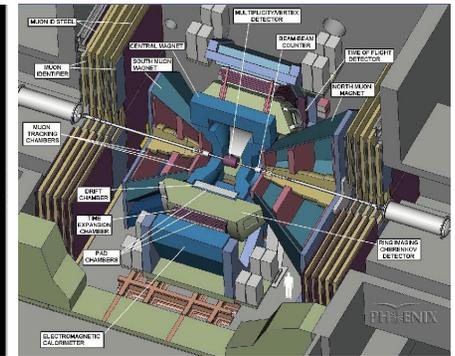
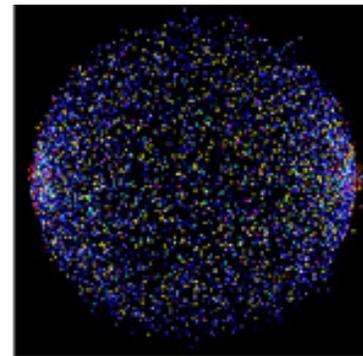
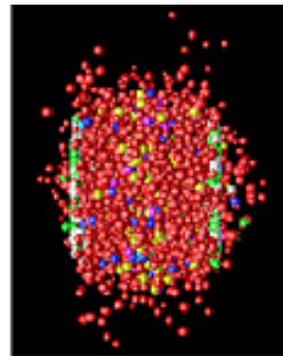
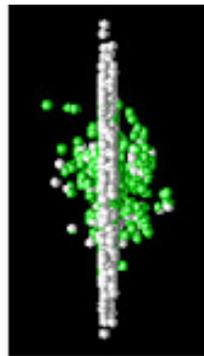
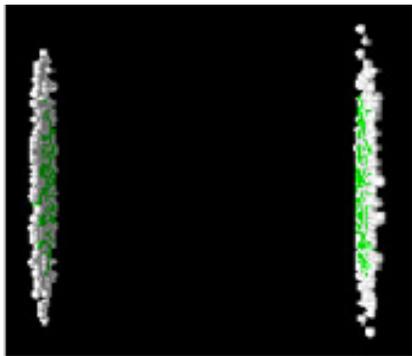


The Goals of QGP & CNM Physics

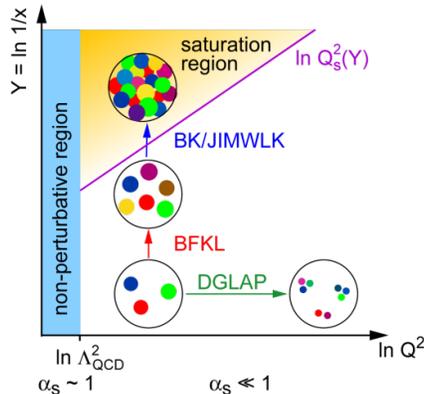
- Understand the Properties of QGP
- Explore the QCD phase diagram
- Novel CNM physics & QGP baseline



- Before collision
- Initial state
CNM effects
- QGP
- Hadron gas
- Hadrons detected



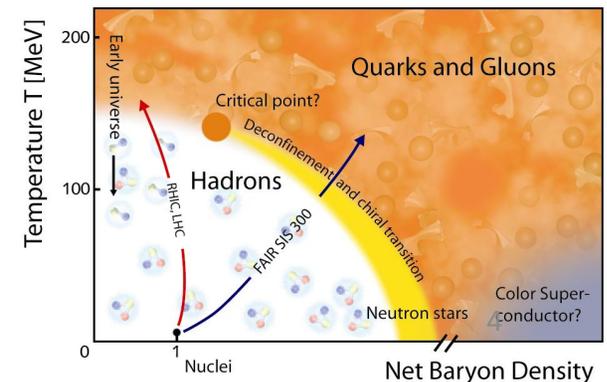
Heavy Ion Collision – Time Evolution



1 10

- Gluon saturation
- Parton shadowing
- CNM Parton energy loss

LANL Heavy Ion Internal Review



Outstanding Questions in QGP Physics

LHC ~ RHIC!

- Parton dE/dx & QGP properties

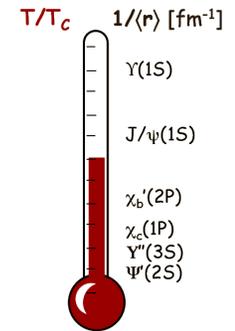
(NSAC DM10, 12)

- Radiation & collisional dE/dx
 - Light vs heavy quarks
- CNM effects

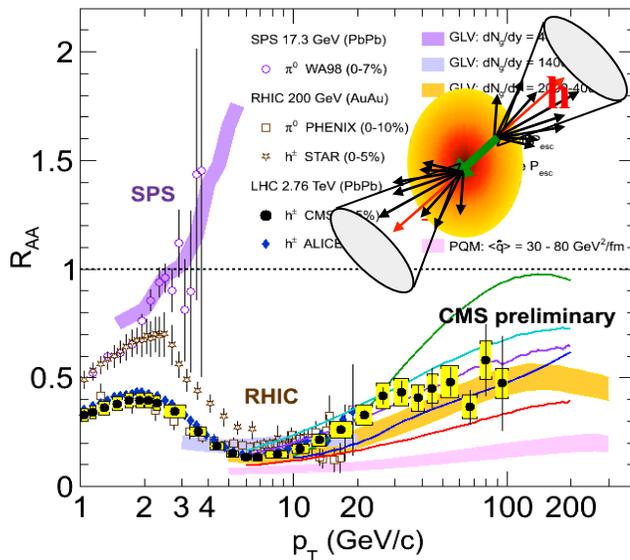
- QGP color screening & heavy quarkonia “melting”

(NSAC DM5)

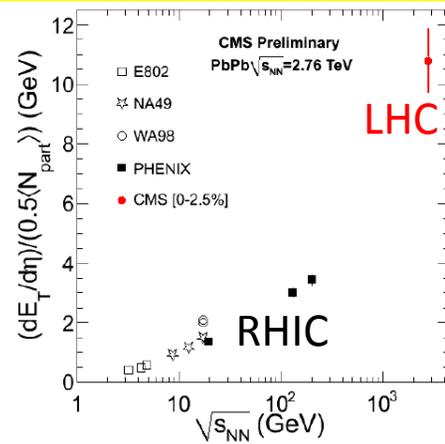
- Color screening & recombination
- CNM effects



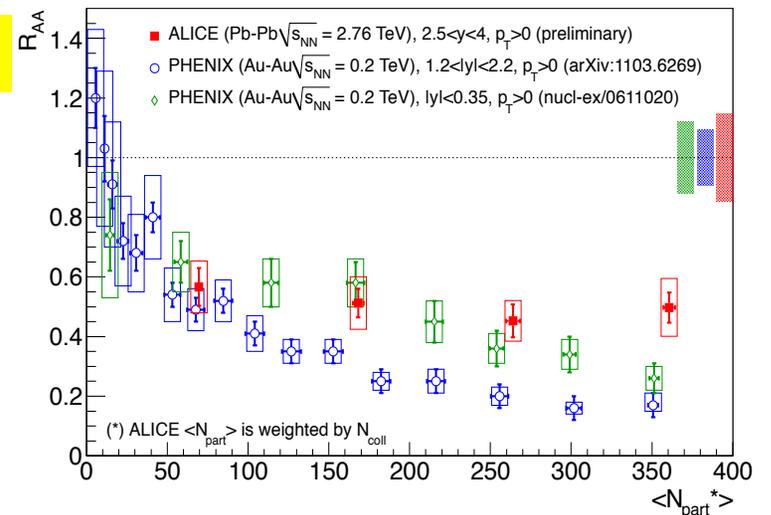
Jet suppression



Achieved QGP Densities



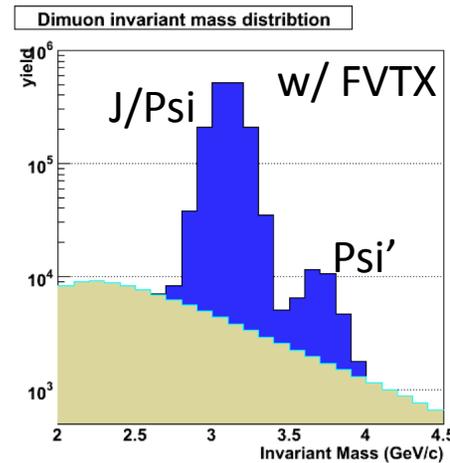
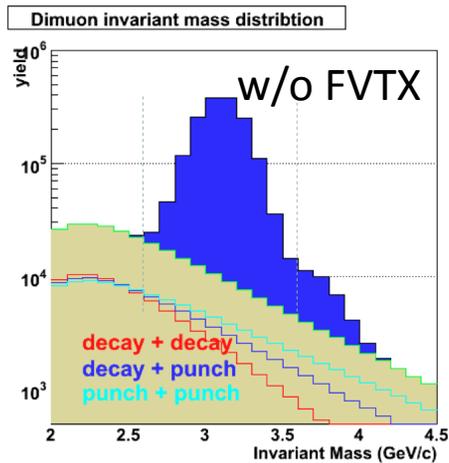
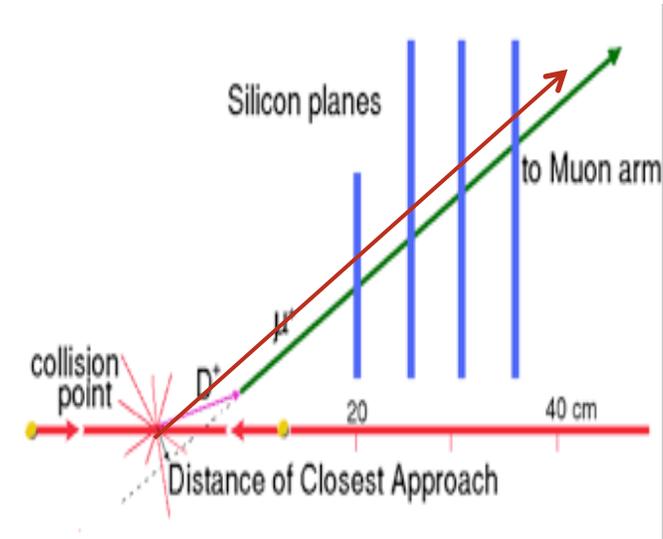
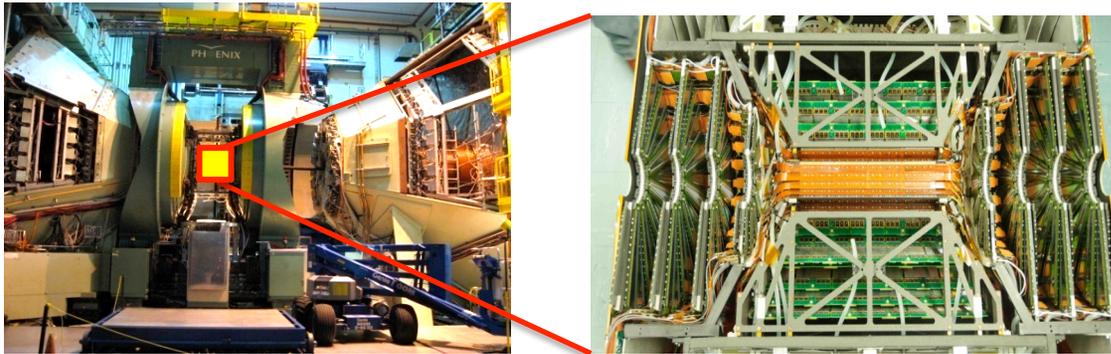
J/Psi suppression



LANL-Led Latest PHENIX Upgrade: FVTX, Run12+

- Heavy Quark and heavy quarkonium physics
- and much more...

Melynda's Talk



Dimuon Mass (pp@200GeV simulation)

New Tools:

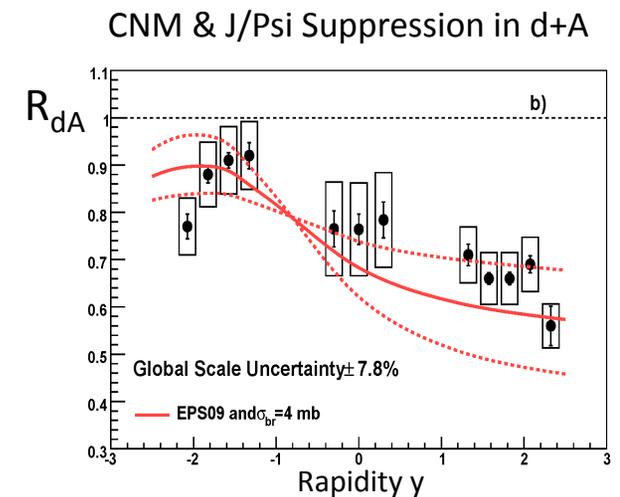
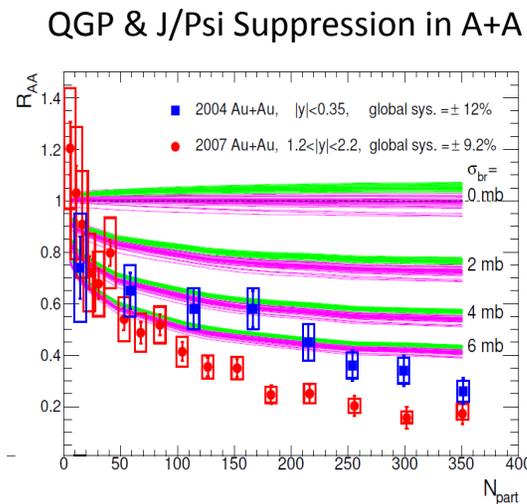
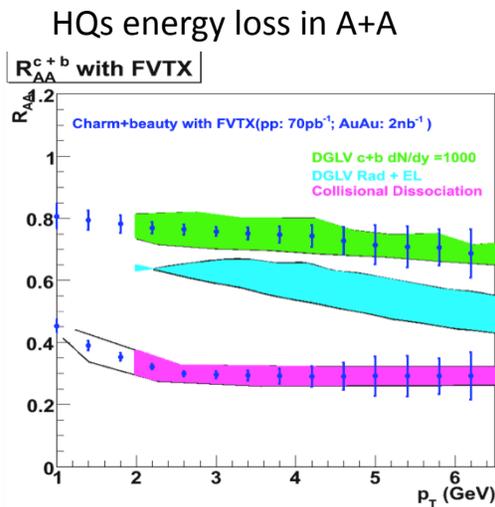
- Open D, B
- J/psi, Psi'
- Drell-Yan
- W^{+/-}

LANL Physics Program – QGP & CNM Now and Near Future

- Compare heavy and light flavor modifications to understand energy loss mechanisms in the medium.
 - FVTX+MuTr: D/B separation etc to study QGP dE/dx
- Use vector meson measurements to measure screening contributions, recombination
 - FVTX+MuTr: J/Psi, Psi', Upsilon etc to study QGP color screening

Mike's Talk

Close collaboration with T-Division: theoretical interpretations (FVTX, CMS)

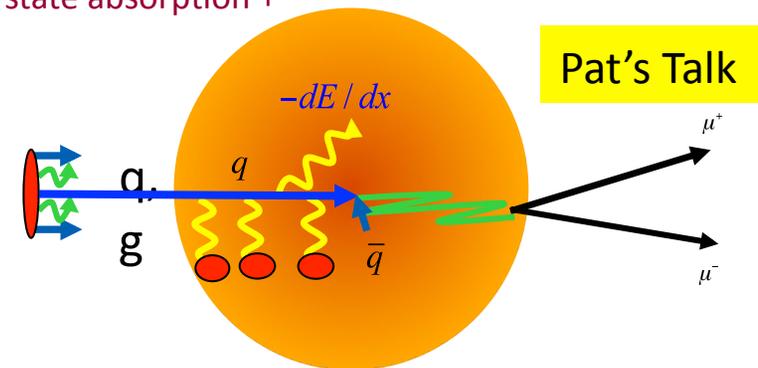
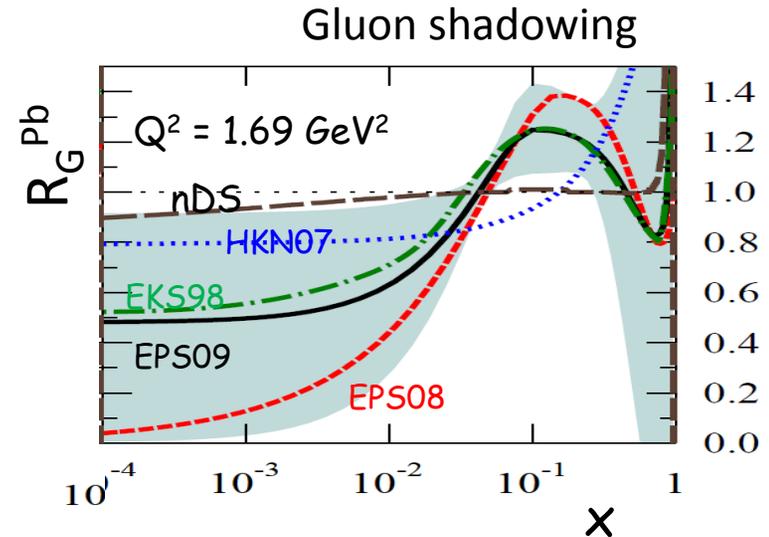
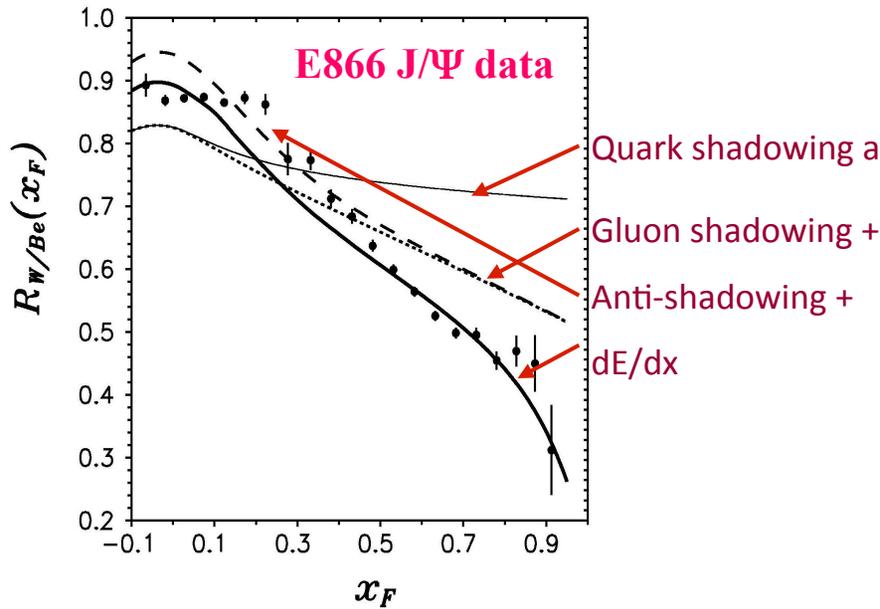


LANL Proposed Program: Precision heavy flavor measurements, better vector meson measurements with FVTX+MuTr in d+A and AA collisions at RHIC

Novel CNM Effects and QGP Baseline

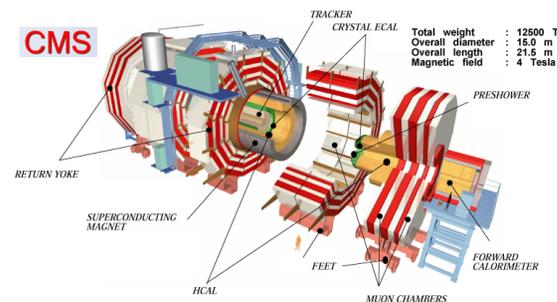
- Parton (anti)shadowing
- Gluon saturation physics
(NSAC DM08)
- Parton energy loss in CNM
(NSAC DM10,12)

Kopeliovich et al Nucl Phys A696 (2001) 669-714



The first unambiguous determination of quark dE/dx with DY at E906!

Recent LHC Efforts – Jet Energy Loss

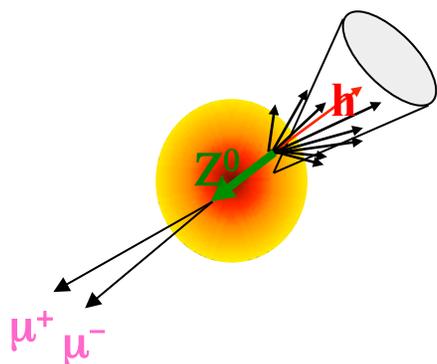


LANL roles:

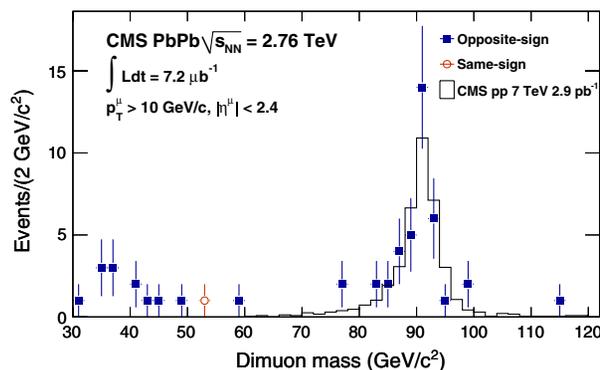
- Led first CMS Z^0 analysis in Pb+Pb collisions and publication!
- T-2 providing theoretical model calculations

LANL LDRD funded (\$2.4M) FY09-11

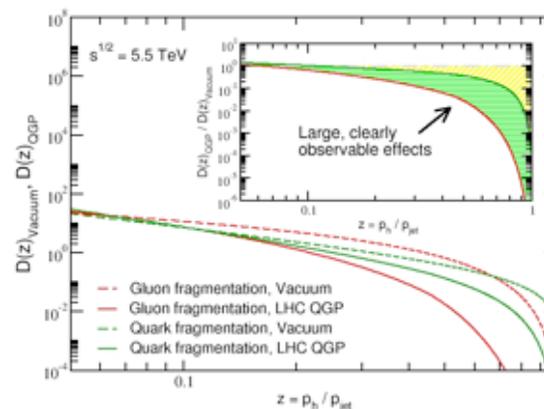
Not supported by DOE at present, but may have an opportunity in the future



PRL 106, 212301 (2011)



Jet fragmentation in QGP, LANL LDRD



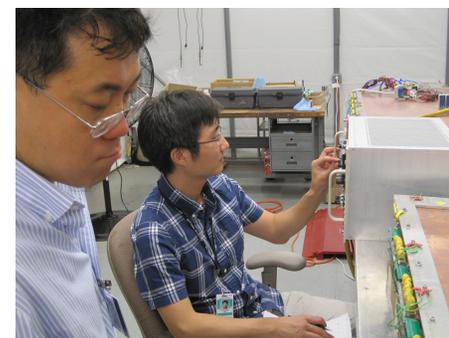
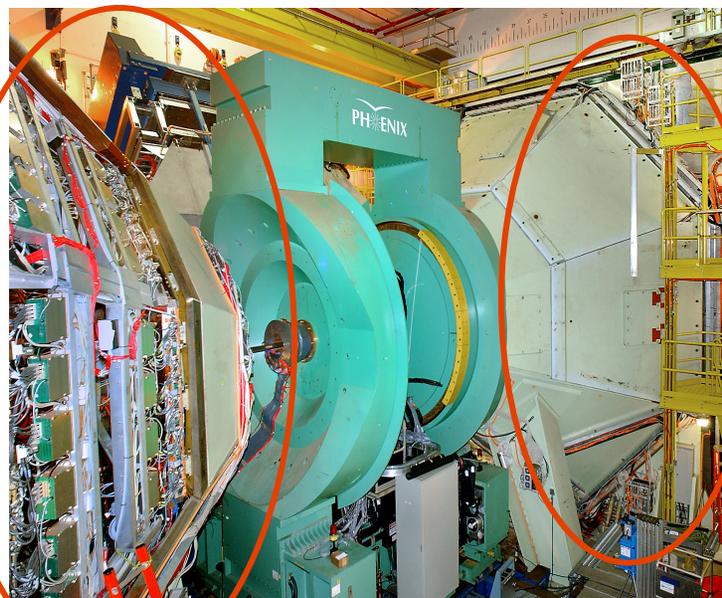
LANL Contributed PHENIX Muon Trackers (10 years ago)

Muon Tracker Contributions - Designed, built, installed, commissioned muon tracker systems.

Current Responsibilities - DC Member, provide on-call expert shifts per run, coordinate and perform maintenance and improvement each shut down, working closely with Muon Trigger upgrade

Muon Tracker Analyses - Have provided much of the simulation and reconstruction software, as well as online QA software for the Muon Trackers. Lead roles in most muon physics analyses (QGP, CNM & Spin)

Improvement every year!



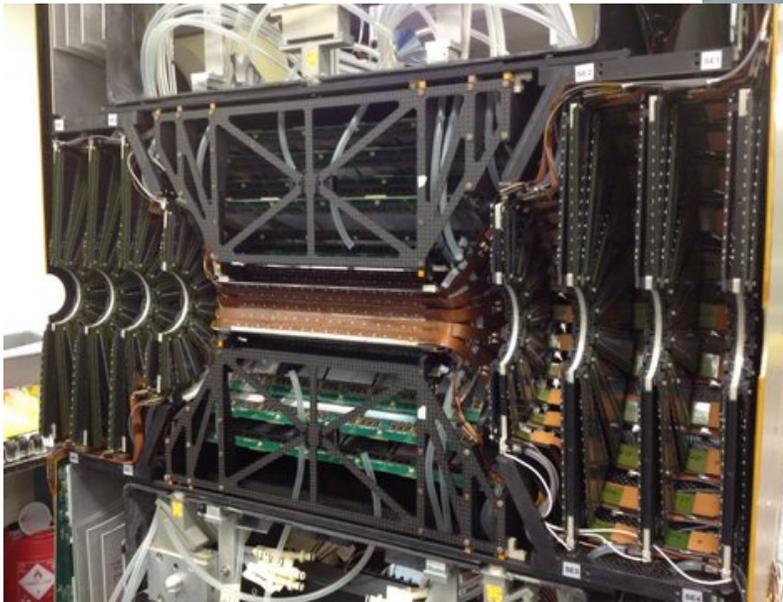
Forward Silicon Vertex Detector (Today)

Completed – installed end of 2011, significant effort needed for commissioning

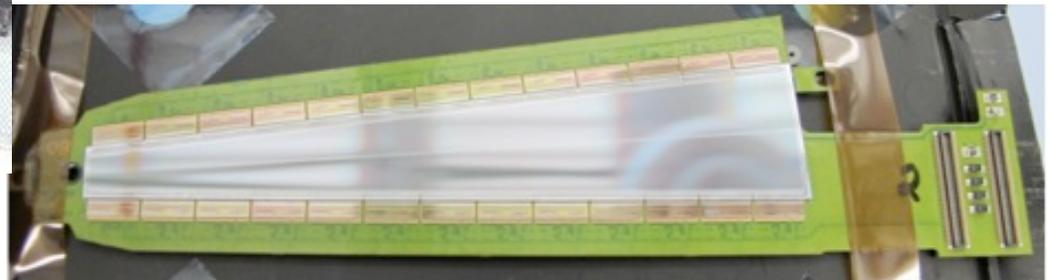
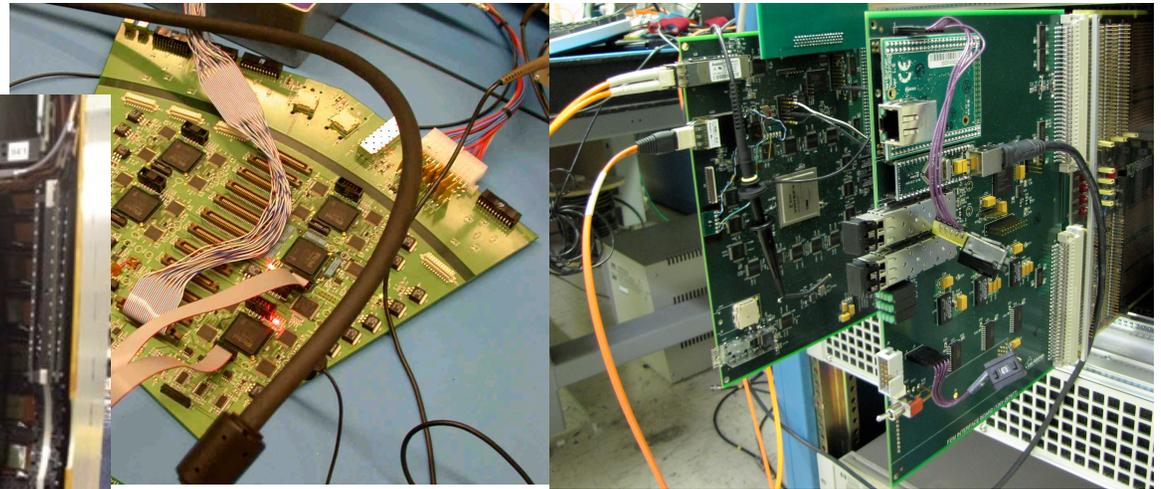
Physics Running – FY12, plus 5-10 years (multiple beam types, energies, etc.)

LANL Role – Project Management, oversight of commissioning, support throughout data taking runs, leading role in physics analysis

FVTX Sensor and Readout Electronics Developed at LANL

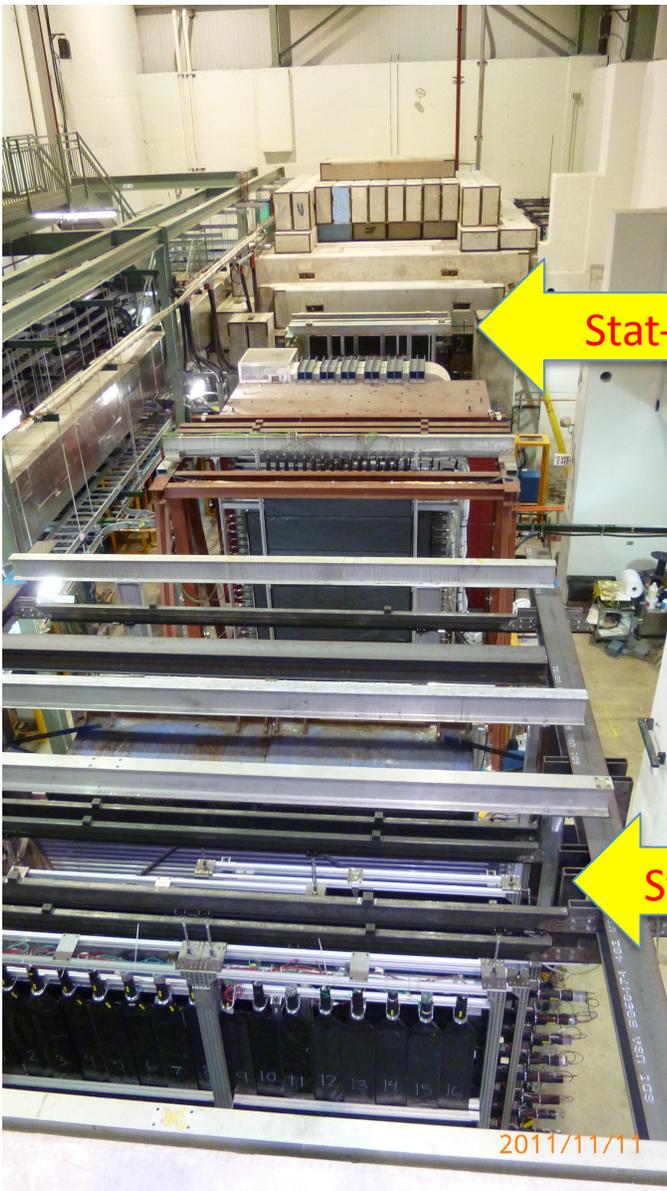


VTX/FVTX side view

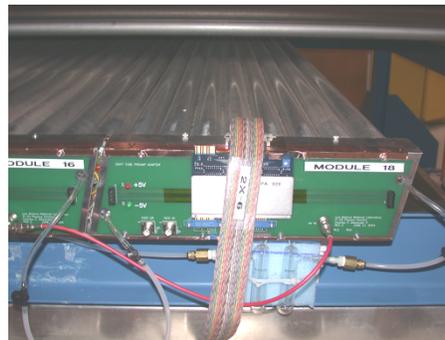


Fermilab E906 ST-1 Chambers and ST-4 MuonID

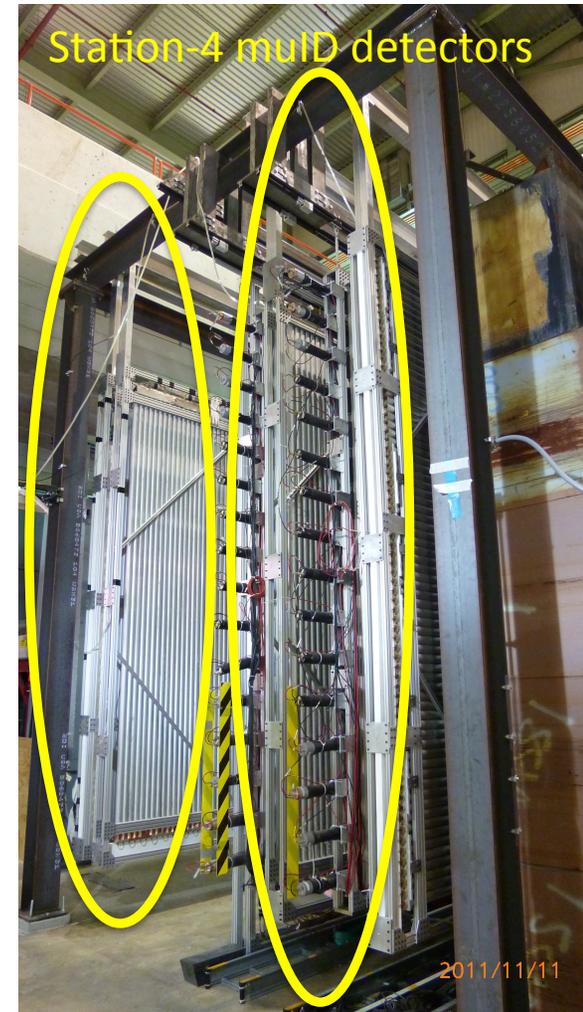
- Installed in March, 2011
- Tested with cosmic rays
- Ready for beams



Stat-1 DC (old E866)



Stat-4 MuID (new LDRD)



Station-4 muID detectors

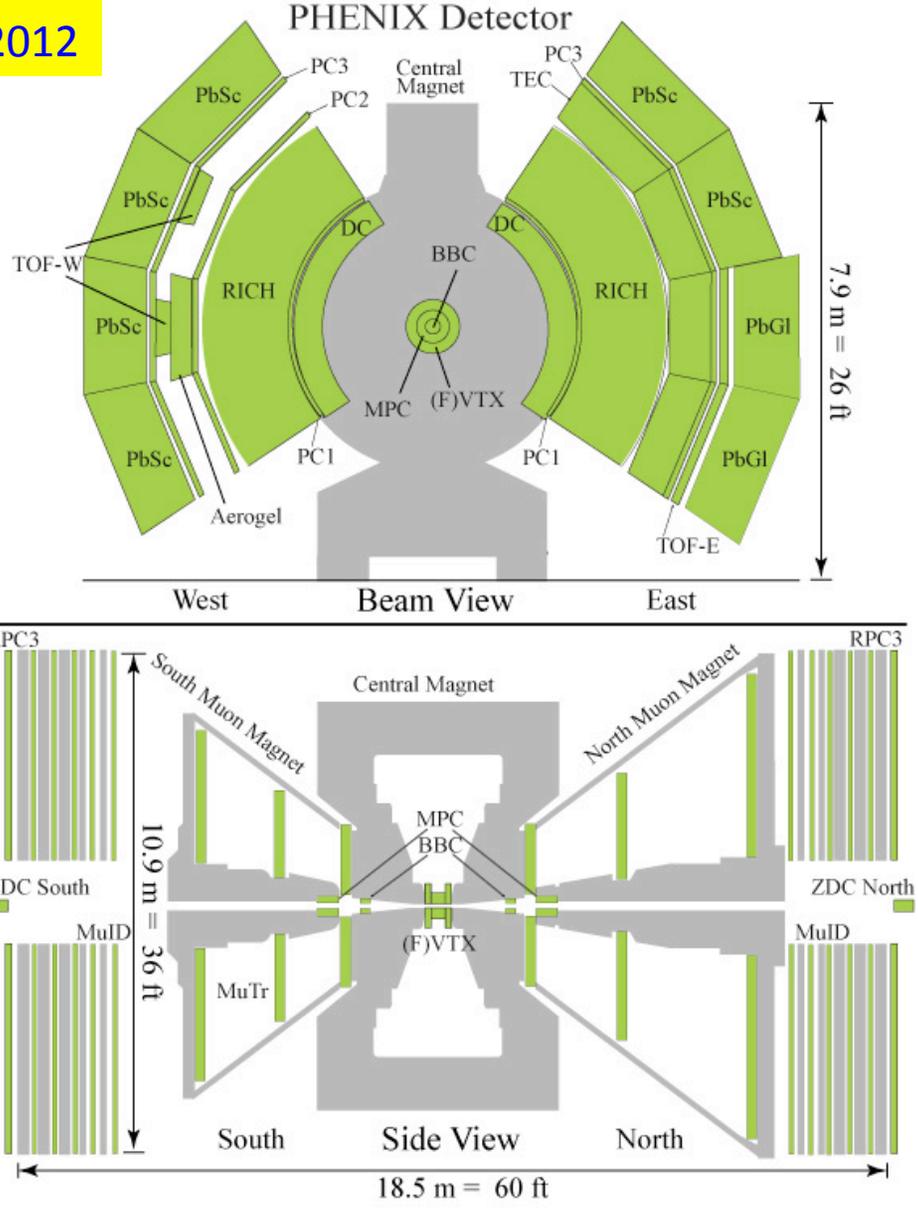
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LANL Heavy Ion Internal Review

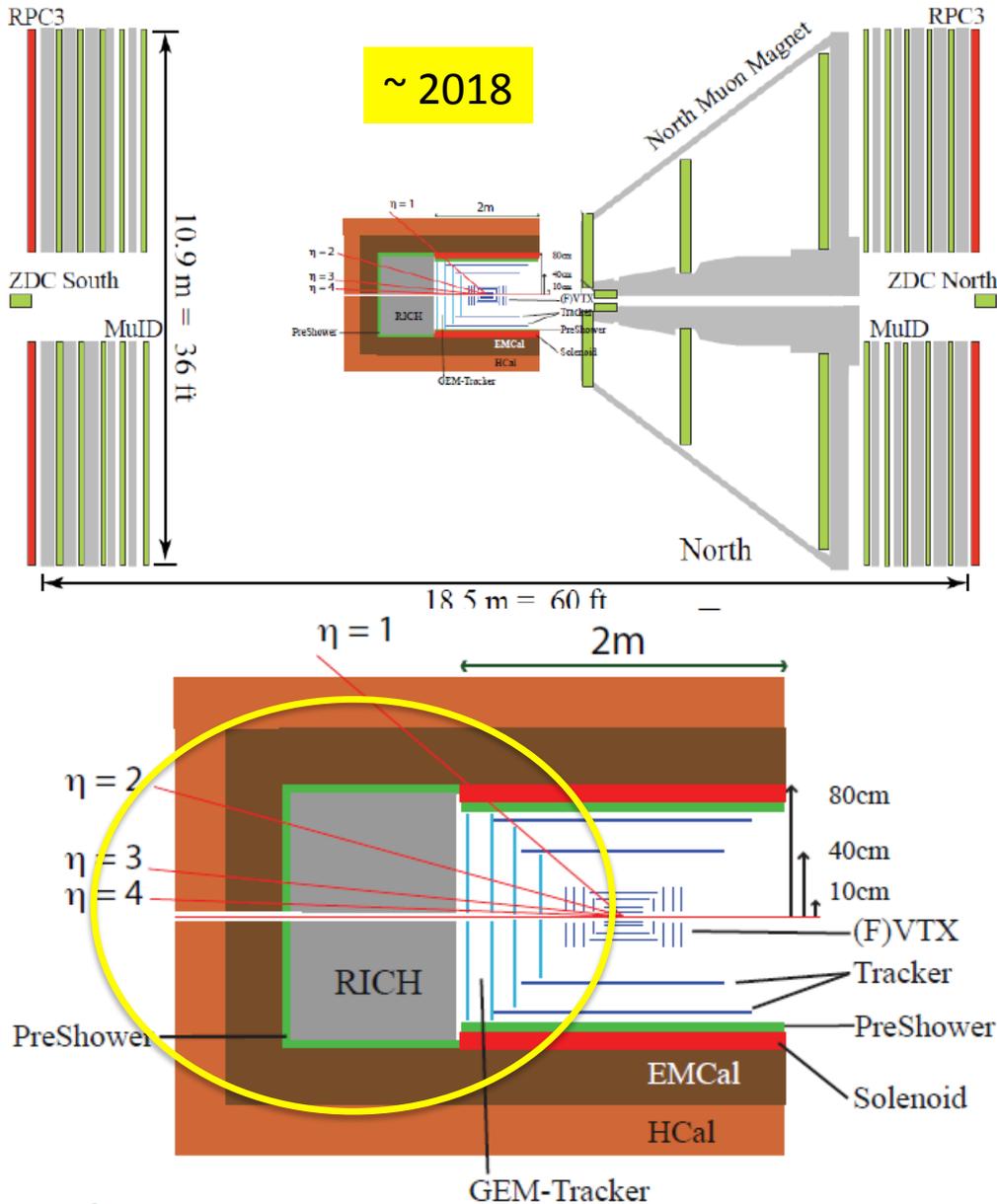
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Plan for the Future: Super-PHENIX

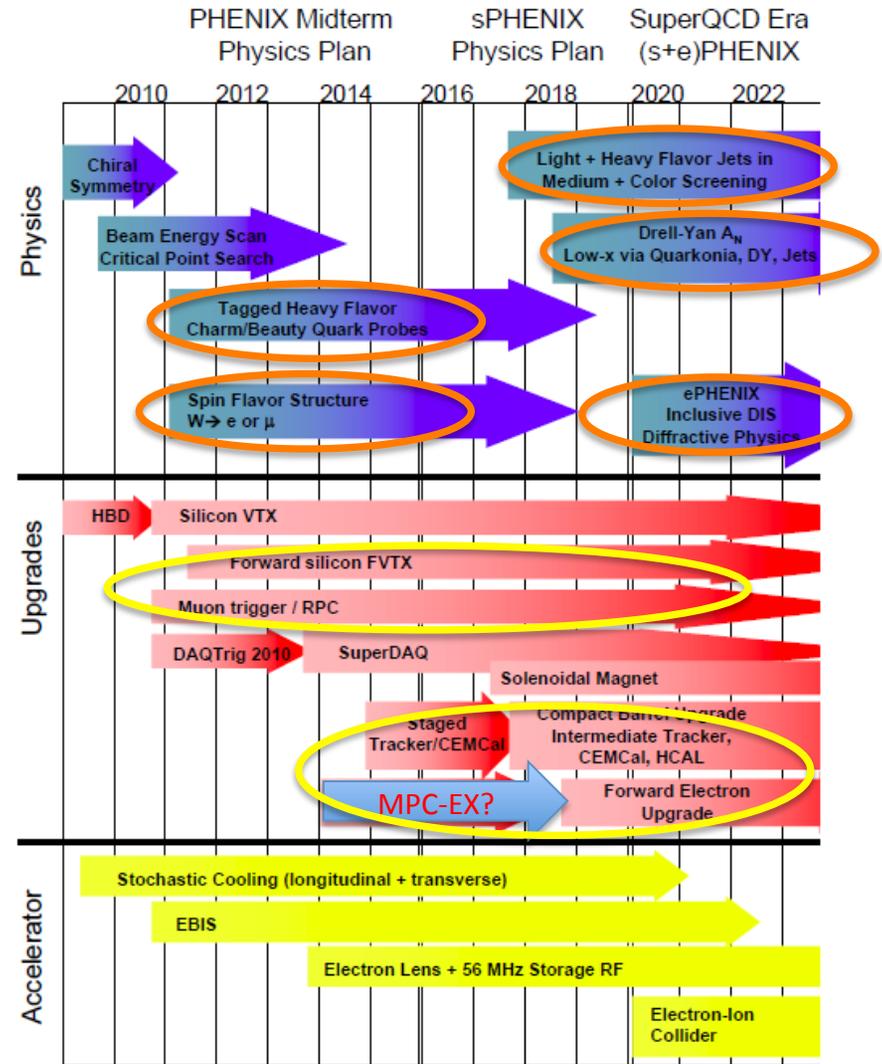
PHENIX as of 2012



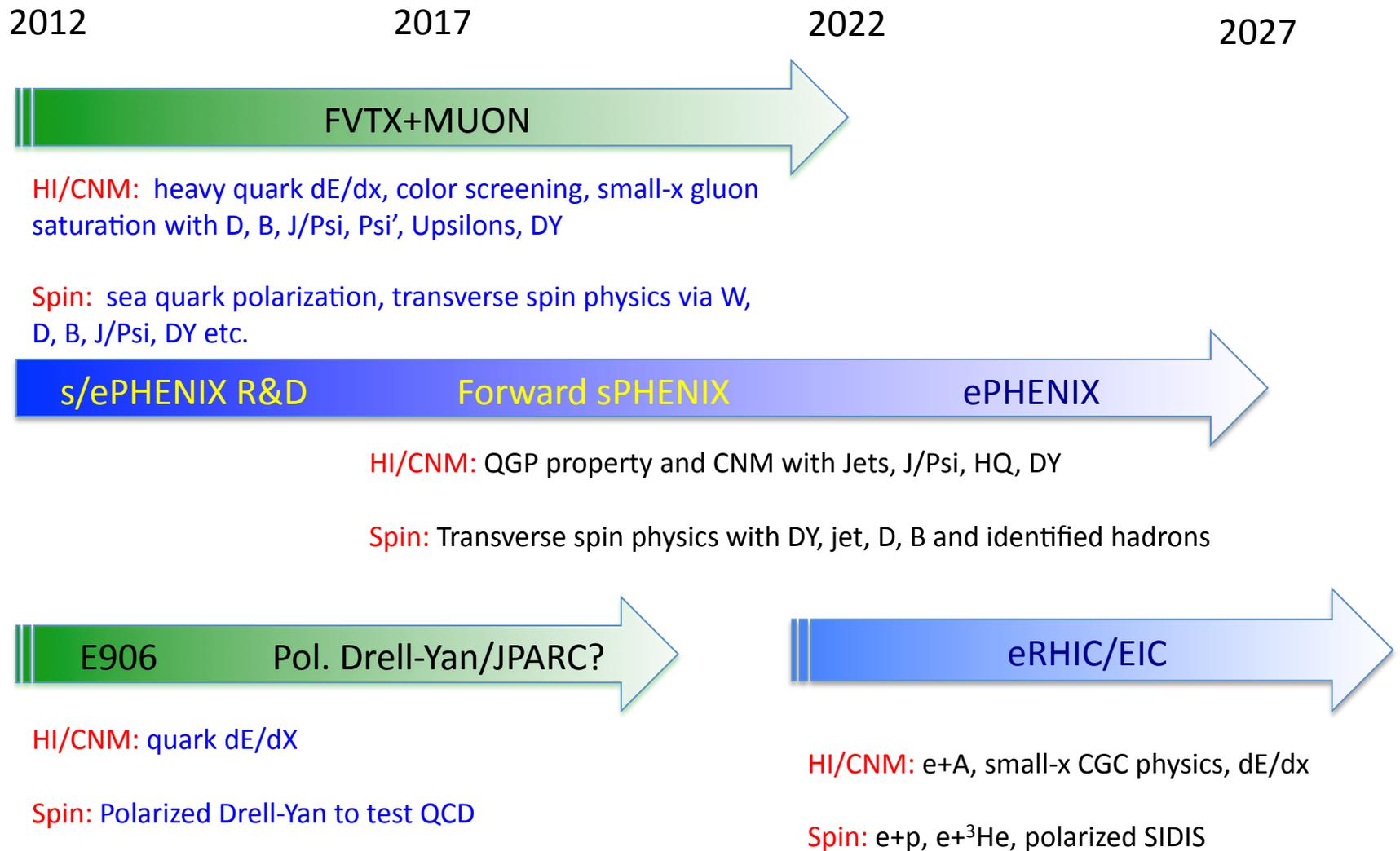
The PHENIX Decadal Plan 2011-2020



Leitch (d+Au), Aidala (spin), van Hecke



LANL Future Program: the Big Picture



Funds Supporting PHENIX Team Efforts



DOE Supported Efforts

- Heavy Ion Physics - RHIC Heavy Ions and Cold Nuclear Matter ~\$2.5M/year
- Medium Energy Physics - RHIC and JLAB Spin, Cold Nuclear Matter ~\$1M/year
- FVTX (Project management, construction funds) ~\$2.5M at LANL
- VTX (construction funds for Walt Sondheim)
- PHENIX Muon Tracker - continued maintenance & improvement, expert shifts, etc.



LDRD-Supported Efforts

- First Unambiguous Measurement of Jet Fragmentation and Energy Loss in the QGP (P-25, P-23, T-2)*
2009-2011 \$575k/year (\$2.4M/6 yrs)
- The First Precise Determination of Quark Energy Loss in Nuclei (P-25, T-2)*
2008-2010 \$250k/year
- Christine Aidala, Frederick Reines Post-Doc, 2009-2011 \$180k/year
- Andrew Puckett, Director's funded Post-Doc, 2010-2011 \$125k/year
- Cesar Da Silva, Director's funded Post-Doc, 2010-2012 \$125k/year

Personnel Contributing to Heavy Ion Program in FY12

Technical Staff Members :

HI (4.5 FTE): Christine Aidala (0.75), Melynda Brooks (0.9), Jon Kapustinsky (0.2), David Lee (0.2), Mike Leitch (0.4) , Ming-Xiong Liu(0.25), Pat McGaughey (0.7) , Hubert van Hecke (0.9) , Walt Sondheim (0.2)

MEP (1.95 FTE): Xiaodong Jiang (1.0), Mike Leitch (0.2) , Ming-Xiong Liu (0.75)

Post-Docs/Students :

HI (3.5 FTE): Matt Durham, Kwangbok Lee, Cesar Da Silva (LDRD), Kun Liu (GRA), Lei Guo, Zhengyun You, Catherine Silvestre (LDRD)

MEP(1.7): Christine Aidala (LDRD), Jin Huang, Kun Liu (GRA), Han Liu, Andrew Puckett (LDRD)

Additional LDRD-supported Staff in FY11:

Andi Klein (P-23), Gerd Kunde, Pat McGaughey, LDRD PD mentors (Brooks, Leitch, Jiang)

Full-Time Visitors:

Xiaorong Wang (NMSU), Hugo Pereira (Saclay)

Note: HI, MEP, Left recently

LANL Heavy Ion and Medium Energy Physics Activities

RHIC Analyses - HI

- QGP and CNM studies using vector meson, open heavy flavor analyses from d+A and A+A, especially using FVTX + Muon Trackers

E906

- Providing station-4 muon identifier system and station 1 chambers
- CNM energy loss using FNAL E906, data collection starting FY12

RHIC Analyses - Spin

- Share many analysis tools with HI program
- Sea quark contribution to spin through W program, FVTX improvement of background rejection, LANL expertise in MuTr performance; Sivers universality test with DY, Transverse Single Spin Asymmetry (TSSA) measurements of D, B, η , J/ψ

CMS HI Efforts (done)

- Z^0 -tagged jet analysis, heavy-flavor jet analyses, fixed pixel detector readout

JLAB Spin efforts (done)

- Neutron TSSA (Puckett through LDRD)

PHENIX & E906 Hardware Efforts

- Continued maintenance of Muon tracker systems; MuID system for E906
- Lead FVTX detector installation, commissioning, maintenance and data analysis
- MPC-EX, s/ePHENIX upgrade R&D and physics program development

Some Key Roles

PHENIX Deputy Director for Upgrades: Leitch

PHENIX Executive Council: Aidala, Leitch

PHENIX Physics Working Group Conveners: Aidala, Brooks, Leitch, da Silva

PHENIX Detector Council Members: Leitch (current muon), Brooks (past muon, fvtx), McGaughey (past muon), van Hecke (past MVD)

FVTX Project Managers: Brooks, Kapustinsky

Integration & Engineering, VTX/FVTX Mechanical Lead Engineer: Sondheim

PHENIX Subsystem managers: Lee (Muon Tracker Mechanical), Kapustinsky (FVTX sensor, FPHX)

PHENIX Run coordinator: Leitch (run07, run08), van Hecke (run13)

PHENIX Period coordinators: Aidala, Butsyk, Leitch, Liu, van Hecke, da Silva

PHENIX Single Muon Working Group Convener: Liu

PHENIX Single Electron Working Group Convener: Durham

PHENIX Quarkonia Working Group Convener: da Silva

PHENIX Paper writing committees: all

PHENIX Decadal Plan Writing Committee – Leitch, Aidala

PHENIX Speakers Bureau: Leitch, Aidala, Brooks, da Silva

Co-Convenor of RHIC II pA/Forward physics group – Leitch

NSAC Long Range Planning Committee: Lee

APS Hadron Physics Topical Group Executive Member - Leitch (past)

E906 Subsystem Manager: Liu

JLab Experiments Co-Spokespersons: Jiang, Guo, Huang, Puckett

CMS Heavy Ion Dilepton Physics Convener: Silvestre

Summary: Proposed LANL 5+ Years Heavy Ion Program

RHIC Physics

- QGP parton energy loss, color screening, recombination, CNM physics
- Advance vector meson analyses, precision open heavy flavor analyses from d+A and A+A, especially using FVTX + Muon Trackers
- Develop a new physics program with forward sPHENIX, a joint effort of HI/CNM/Spin

RHIC Hardware Efforts

- Continued maintenance of Muon Tracker and FVTX Systems
- MPC-EX and s/ePHENIX upgrade at forward direction

E906@Fermilab

- Providing muon identifier and station-1 tracking systems
- Cold nuclear matter energy loss using FNAL E906, data collection starting FY12

Funds Requested from DOE

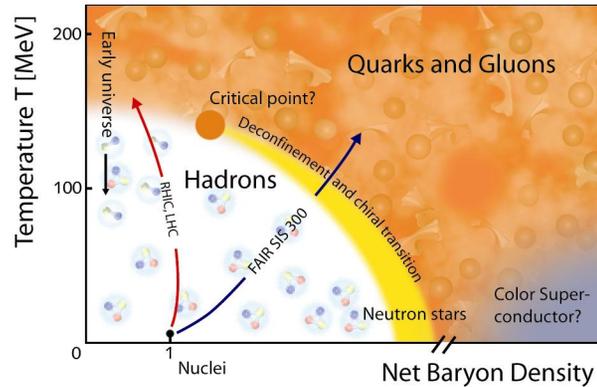
- 0.5 FTE increase to maintain RHIC efforts including new FVTX support
- Plus 1 post-docs added to support s/ePHENIX upgrade in FY12

New Staff Hiring:

- New hire 1 HI staff in FY12 to maintain current Heavy Ion effort
- 1~2 staffs in next 3~5 years to replace retiring seniors

Backup

RHIC Physics Focus

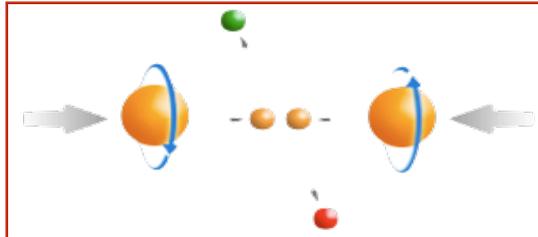


1) At 200 GeV top energy

- Study *medium properties, EoS*
- pQCD in hot and dense medium

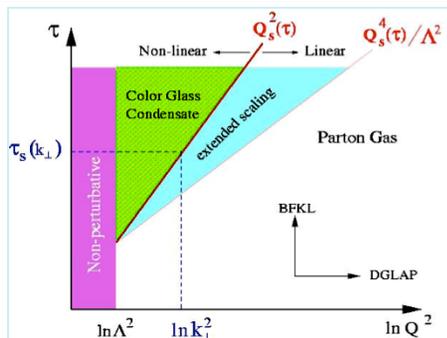
2) RHIC beam energy scan

- Search for *critical point*
- Chiral symmetry restoration



Polarized spin program

- Study *proton intrinsic properties*



Forward program

- Study low-x properties, search for *CGC*
- Study elastic (inelastic) processes (pp2pp)
- Investigate *gluonic exchanges*

A 6-year View for the LANL HI Physics Program

| 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|--|--|--|---|---|--|
| 200,500 GeV p+p 200 GeV Au+Au | 200,500 GeV p+p 200 GeV Cu+Au | 500 GeV p+p 200 GeV d+Au | 500 GeV p+p 200 GeV Cu+Au, U+U | 200 GeV Au+Au 62 GeV Au+Au p+He ³ | ??? |
| Physics with FVTX for multiple species of collisions | | | | | |
| PHENIX Decadal Upgrades | | | | | |
| $R_{AA} c+b$ $R_{AA} J/\psi, \Psi'$ | $R_{AA} c, b$ $J/\psi, \Psi'$ DY in pp | $R_{dAu} c, b, J/\psi,$ Ψ', Υ, DY | $R_{CuCu} c,b,J/\psi,$ Ψ', Υ, DY | $R_{AA} \Upsilon, DY$ 62 GeV c,J/ $\psi,$ Ψ' | (yr. data taken; analysis ~1 yr later) |
| E906 startup | E906 dE/dx | | | Fermilab/ JPARC Pol. DY? | |
| LHC: | | 1 st high-lumi HI Run | 2 nd high-lumi HI Run | | |
| $Z_0, \Upsilon R_{AA}$ & jet shapes | | Z_0 -jet tagging | Z_0 -jet A+A fragm. Modif. | | |

Distribution of Personnel for HI Efforts: FY12-FY15

| | FY12 (TSM + PD) | FY13 (TSM + PD) | FY14 (TSM + PD) | FY15 (TSM + PD) |
|---------------------|--------------------|----------------------|----------------------|----------------------|
| RHIC Analyses | 3.5 + 2.8 | ~3.85 + 2.8 | ~3.85 + 2.8 | ~3.85 + 2.8 |
| FVTX* | 0.25 + 0.1 | 0.25 + 0.1 | 0.25 + 0.1 | 0.25 + 0.1 |
| MuTr * | 0.25 + 0.1 | 0.25 + 0.1 | 0.25 + 0.1 | 0.25 + 0.1 |
| E906 ** Analyses | 0.5 + 0.42 | ~0.5 + 1.0 (LDRD) | ~0.5 + 1.0 (LDRD) | ~0.5 + 1.0 (LDRD) |
| Total Staff*** | 4.5 + 3.42 | ~4.85 + 4.0 | ~4.85 + 4.0 | ~4.85 + 4.0 |

* FVTX/MuTr have additional effort supported by Medium Energy, construction

** E906 Effort is co-supported by Heavy Ions and Medium Energy

*** Assume additional DOE (0.5FTE + 1PD) from FY13

Distribution of Personnel for HI Efforts: FY08-FY11

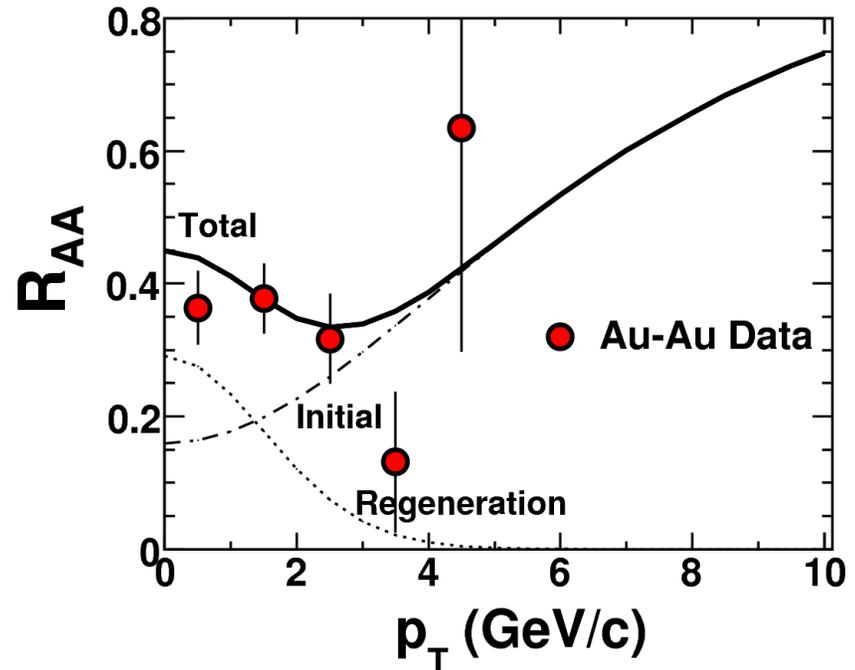
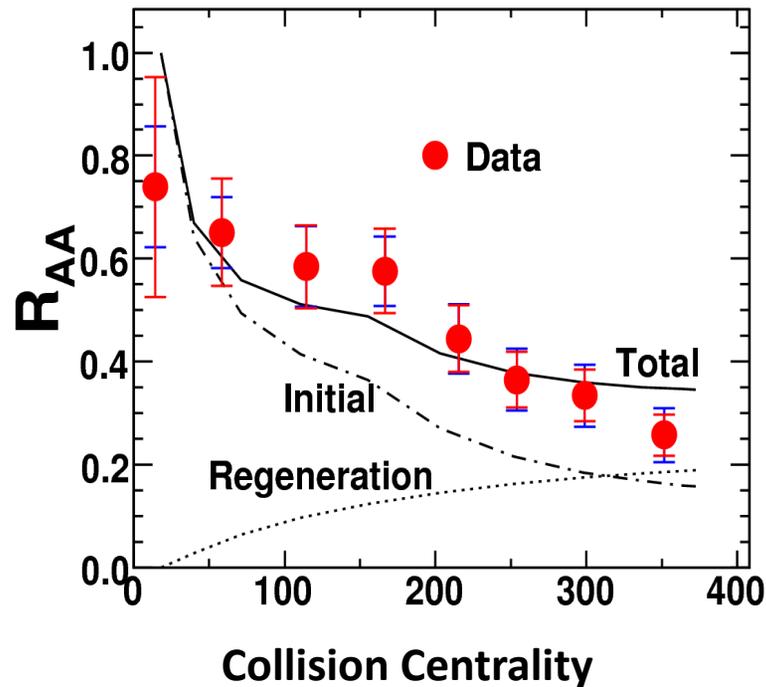
| | FY08 (TSM + PD) | FY09 (TSM + PD) | FY10 (TSM + PD) | FY11 (TSM + PD) |
|----------------------|---------------------|--------------------|--------------------|--------------------|
| RHIC Analyses | 2.35 + 1.5 | 2.4 + 1.1 | 2.4 + 1.0 | 3.5 + 1.9 |
| FVTX* (plus LDRD) | 1.5 + 0.4 | 1.7 + 1.0 | 1.9 + 1.0 | 0.25 + 0.1 |
| MuTr Maint. | 0.25 + 0.1 | 0.25 + 0.1 | 0.25 + 0.15 | 0.25 + 0.1 |
| LHC Analyses | 0.5 + 1.0 (LDRD) | ~1.0 + 1.0 | ~1.0 + 1.0 | ~1.0 + 1.0 |
| Total Staff | 4.1 + 2.0 | 4.35 + 2.25 | 4.55 + 2.35 | 4.5 + 2.5 |

*FVTX will have additional effort supported by Medium Energy, construction

**E906 Effort will be co-supported by Heavy Ions and Medium Energy

R_{AA} versus p_T

200 GeV Au + Au Collisions at RHIC



- 1) **Left-plot:** At the most central collision, both initial and regeneration are important.
- 2) **Right-plot:** The low p_T region is controlled by both initial production and regeneration, while high p_T region is governed by only initial production including the Cronin effect and leakage effect.

PHENIX Muon Tracker Repair Work in 2010 Shutdown & Status for Run11

Fixing cross-talk problems by terminating anodes in Muon Tracker – Important especially for W measurements in muon arms (*LANL, RIKEN, Korea U.*)

Work on station-1 to put termination on



1/10/2012

LANL Heavy Ion Internal Review



Terminators designed and installed

New capacitors that connect anodes to terminators



28