PHENIX Beam Use Proposal for Runs 13 & 14

Species	$\sqrt{s_{NN}}$ (GeV)	weeks	|z|<30cm	|z|<10cm	delivered	Polariz.
Run13:						
p+p	500	10-15	250 pb^{-1}	97 pb^{-1}	~750 pb^{-1}	55%
p+p	200	4	16 pb^{-1}	> 5.5 pb^{-1}	48 pb^{-1}	60%
or p+p	*39*	*1*	*0.2-0.3* pb^{-1}		*0.9 pb^{-1}*	
Run-14:						
Au+Au	200	6-8	1.7 nb^{-1}	1 nb^{-1}	5 nb^{-1}	
d+Au	200	Rest of run				

Barbara Jacak for the PHENIX Collaboration

http://www.phenix.bnl.gov/WWW/publish/jacak/sp/presentations/BeamUse12/BUP12.pdf

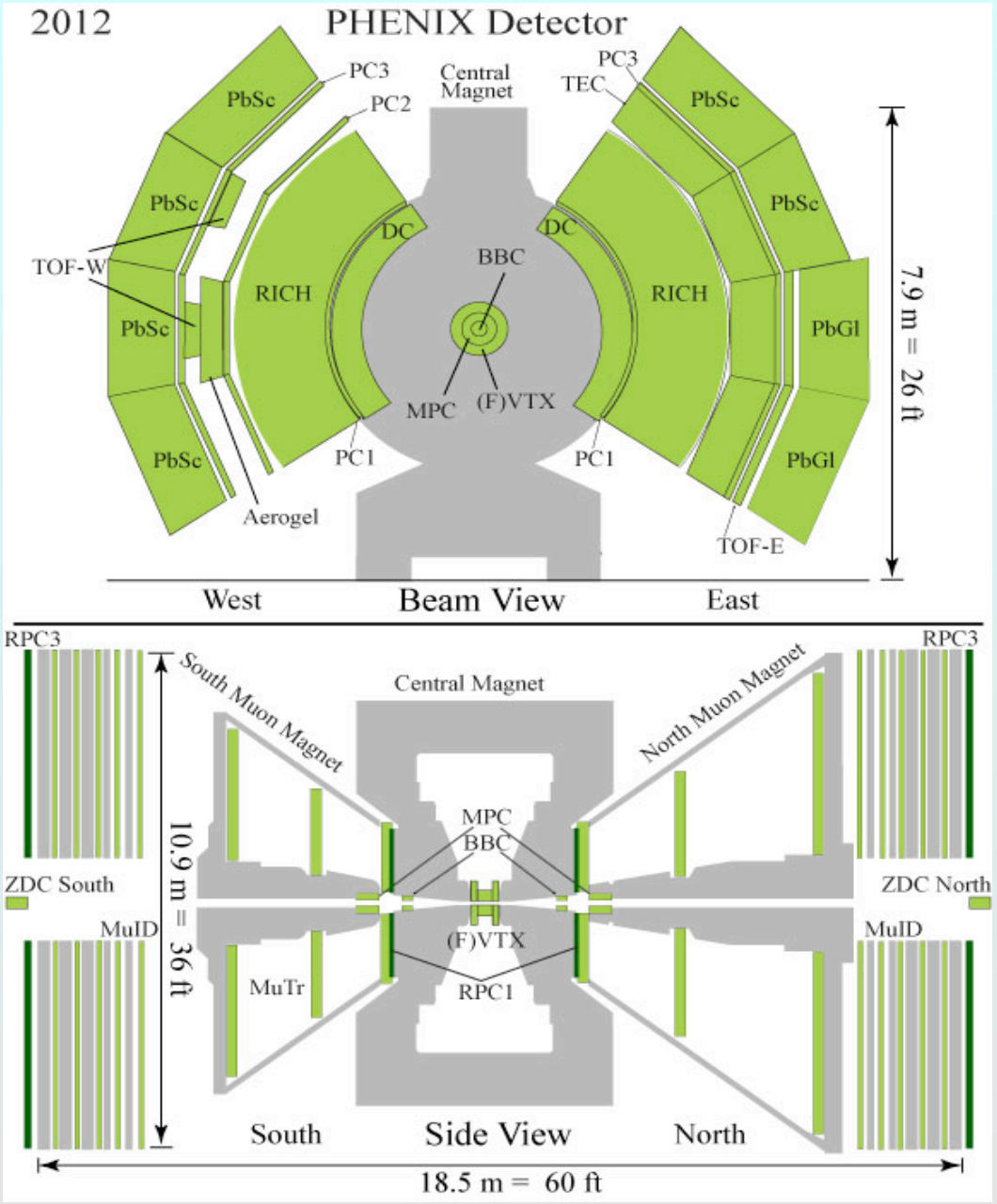
PHENIX

PHENIX and our upgrades

- VTX (2011)
- FVTX (2012)
- W trigger ('11 & '12)
  RPC's & MuTR FEE
- HBD (2009 & 2010)
- DAQ2010
- MPC-EX (2014)

With DAQ2010, PHENIX maintains high DAQ rate w/VTX & FVTX!

~5kHz (AuAu), ~7kHz(p+p)



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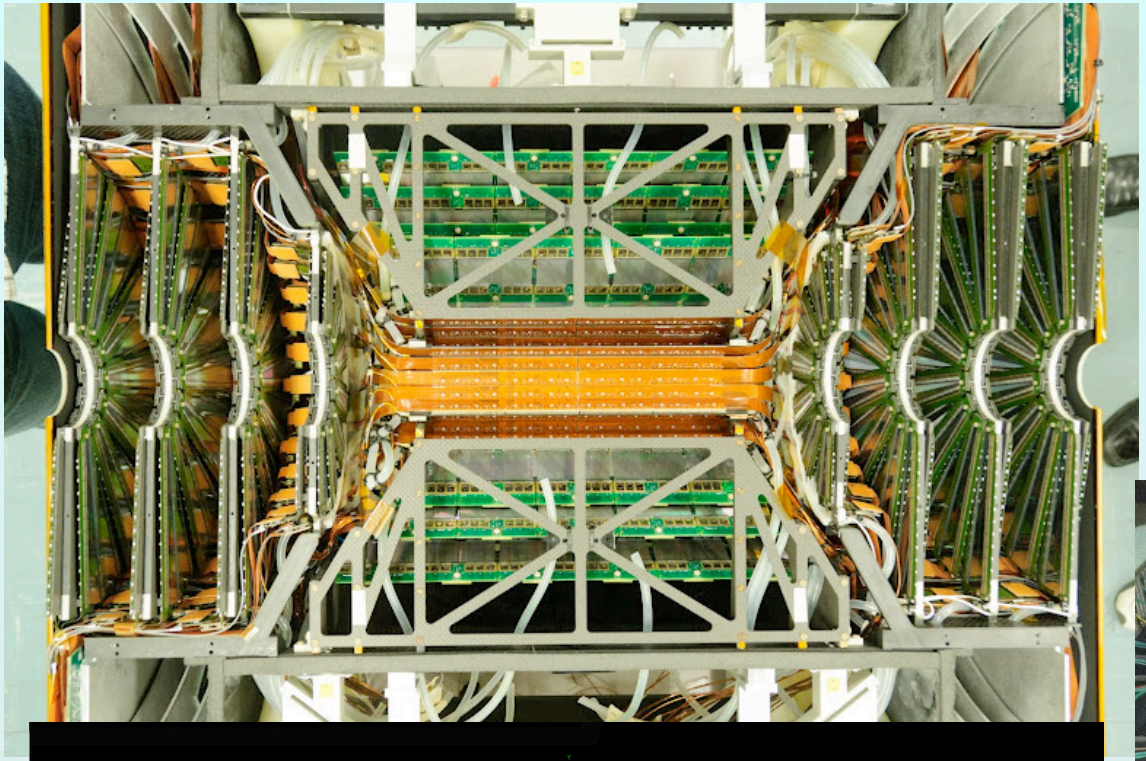
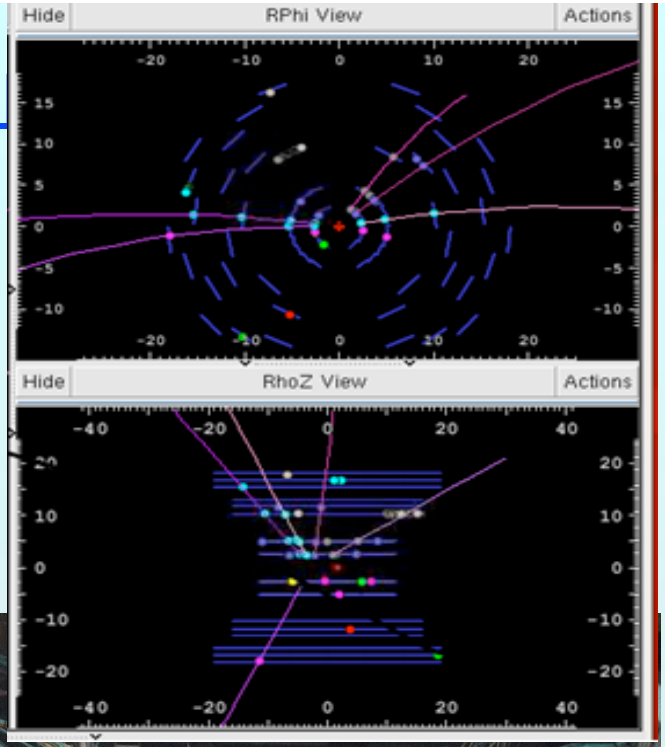
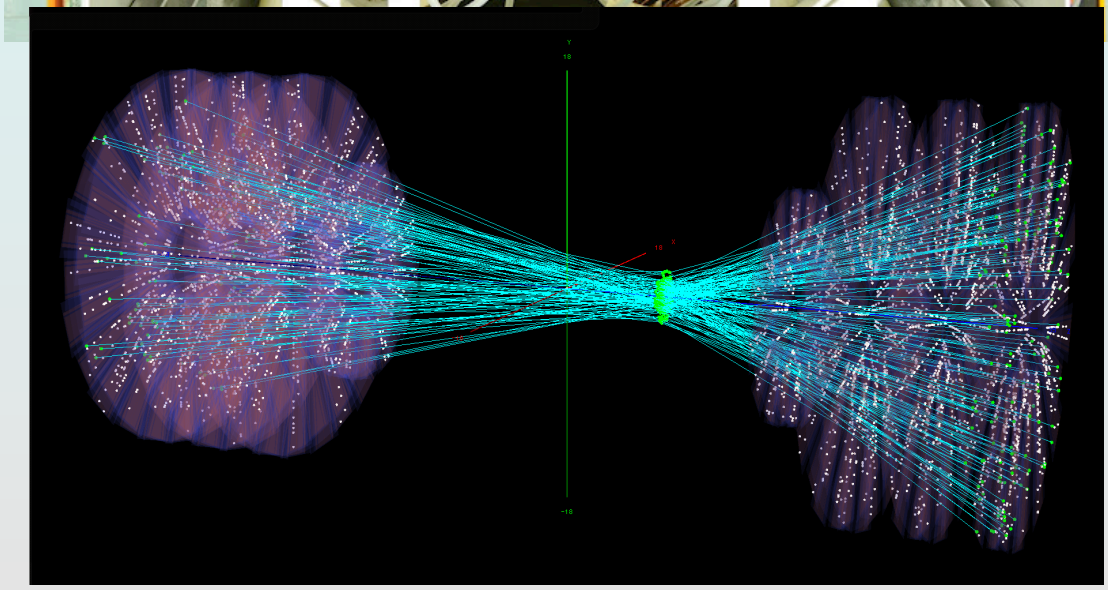
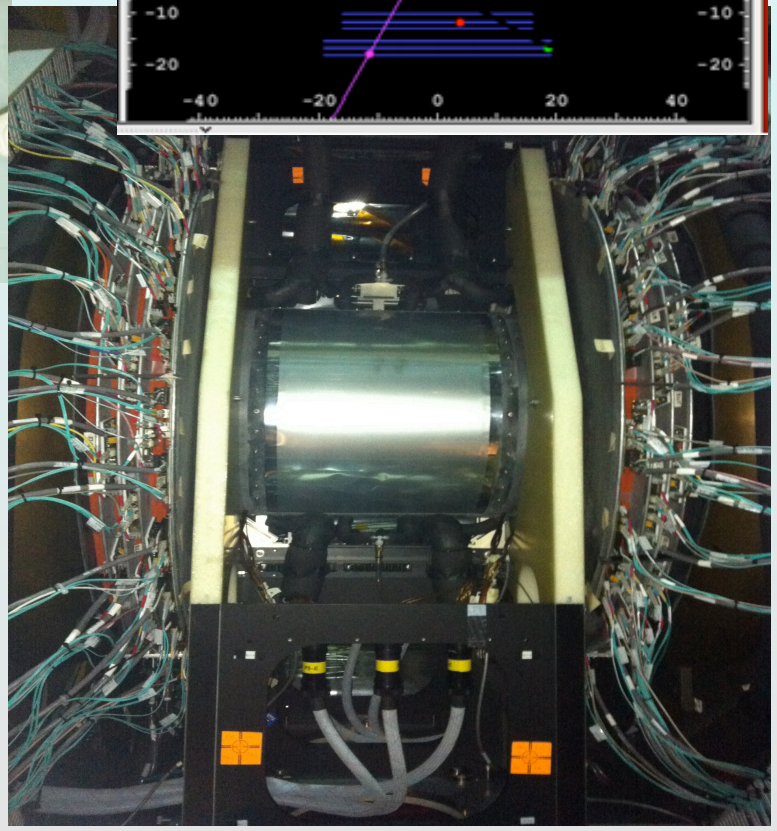
FVTX and VTX both in



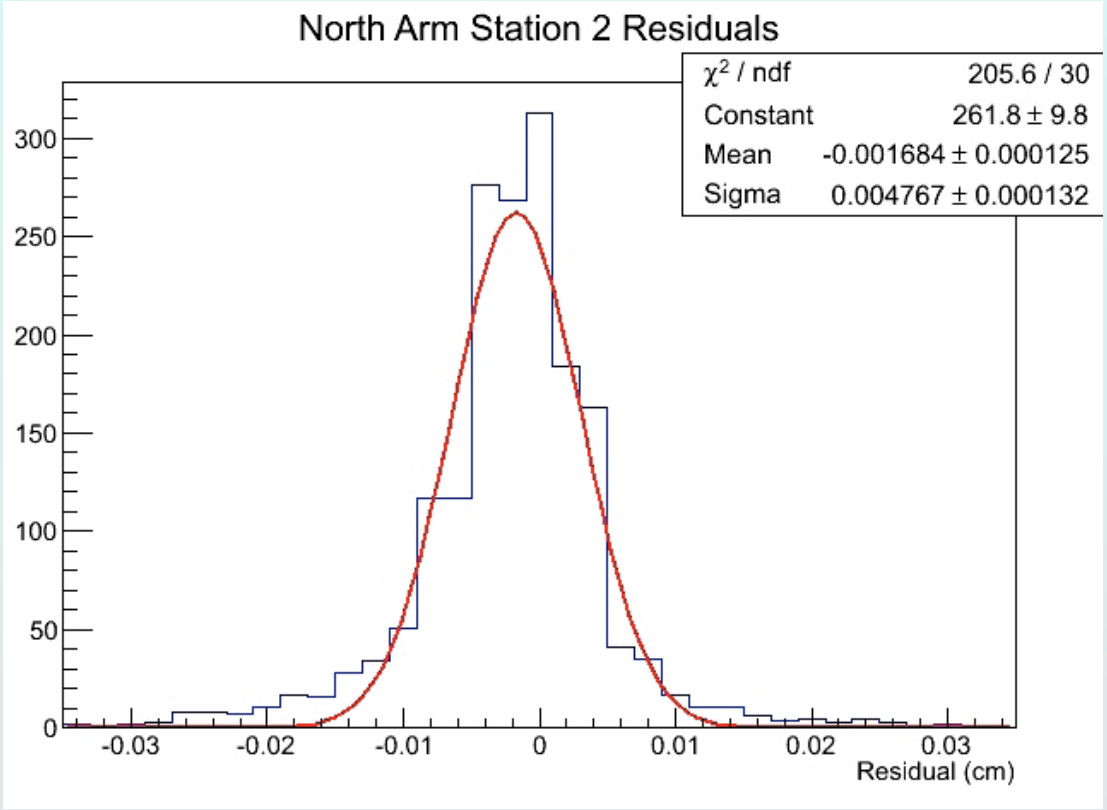






FVTX

- Successfully commissioned in 2012 run
  - Good data sets in 500 GeV p+p and 200 GeV Cu+Au
  - Sample of U+U collisions
- 90% of channels operational
  - 2 boards, 2 fibers out
- Performing to spec, e.g.
  - 430 electrons noise
- Software in place
  - Alignment & tracking tuning underway
  - Track residual: 48μ
  - As expected for 75μ strip pitch



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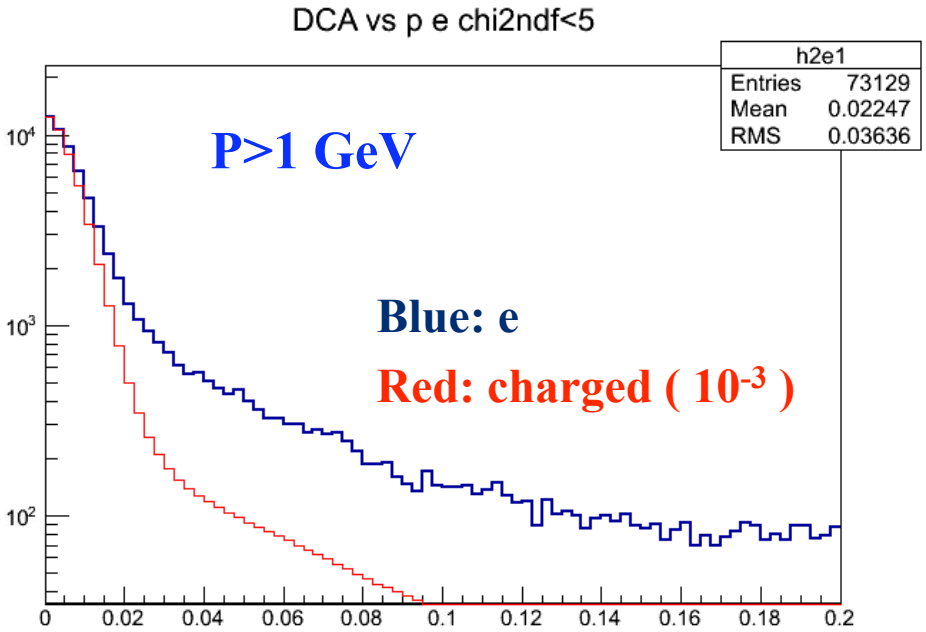
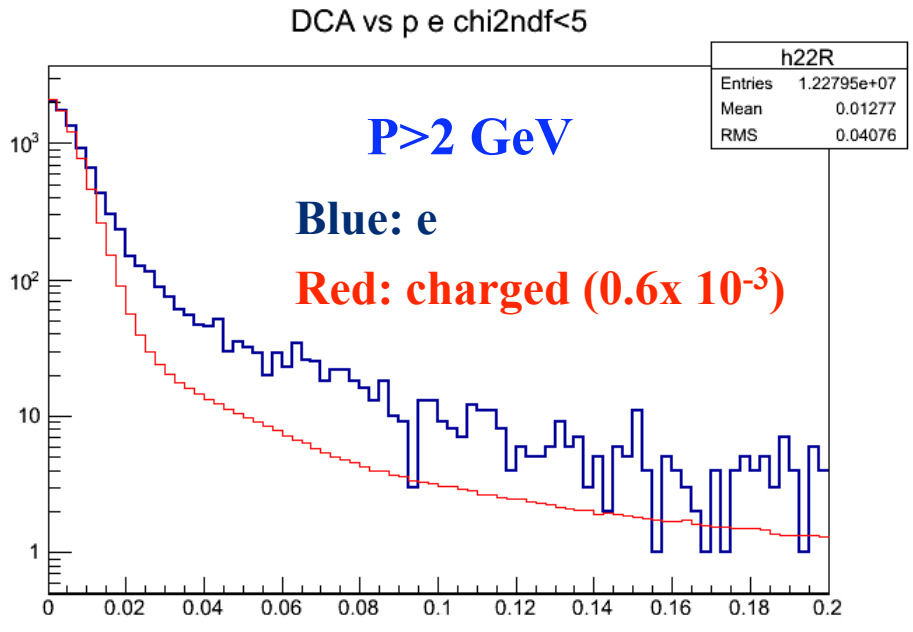
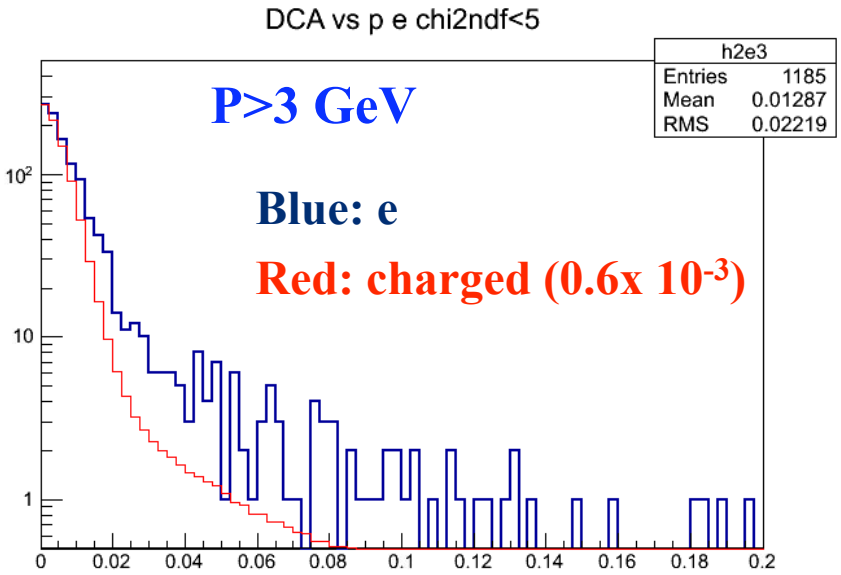
VTX working in Run-11 Au+Au and in Run-12







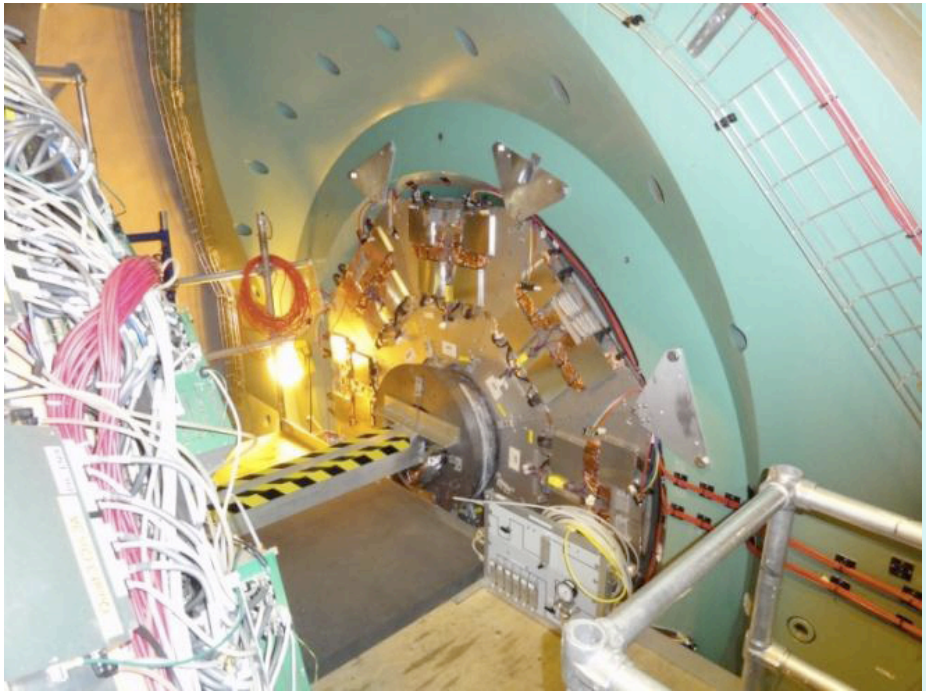
Matched central arm-VTX tracks

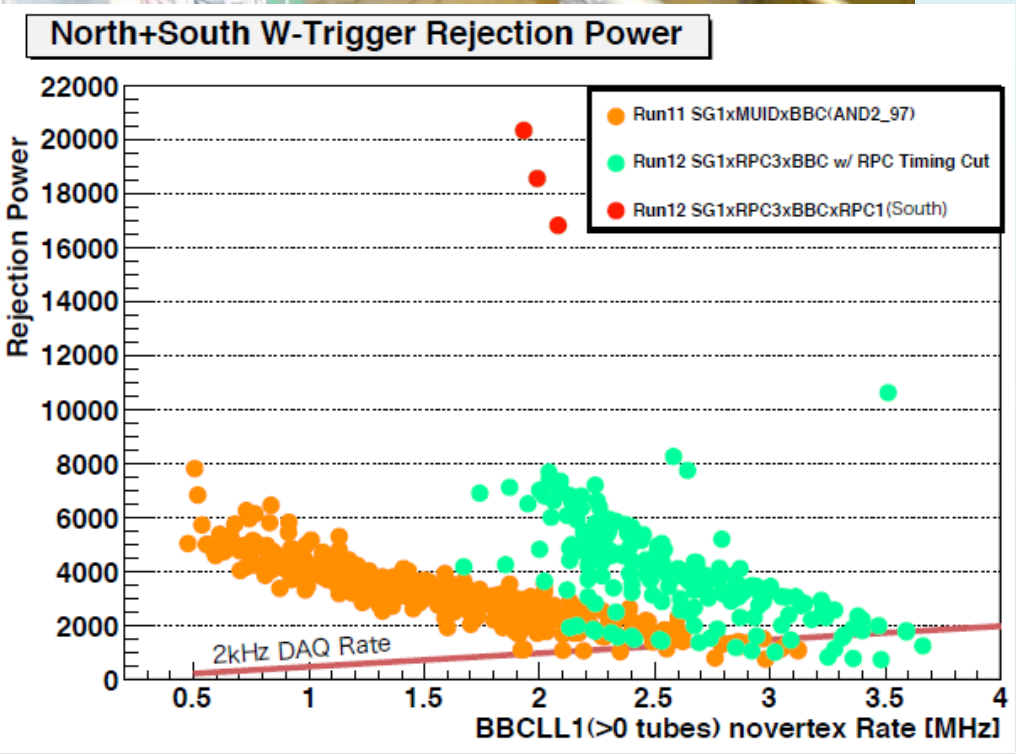
- DCA distributions of electrons are broader than those of all charged
- Broadened by heavy flavor decays
- Large DCA tail - b-signal?
- MC study of other decays in DCA shape underway

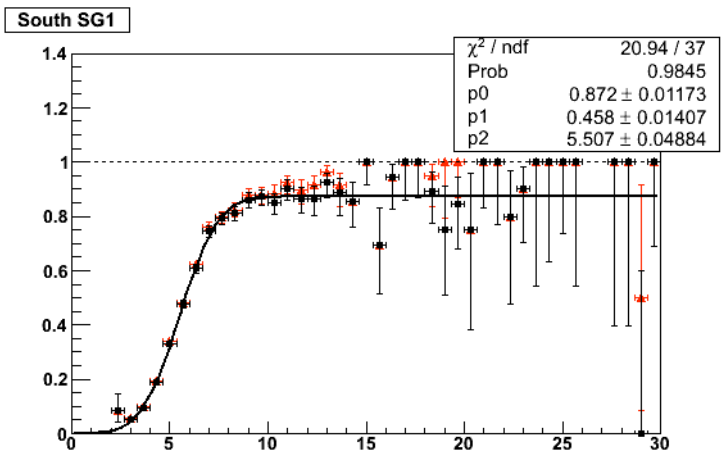
W Trigger is complete

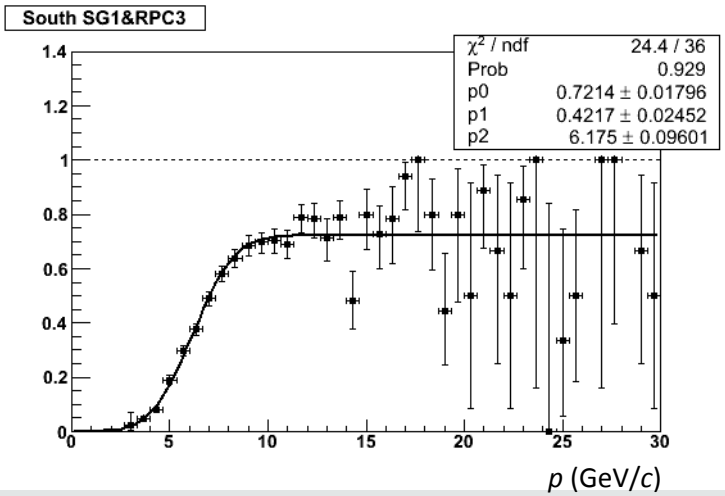
RPC1 installed for 2012

both RPC stations in trigger



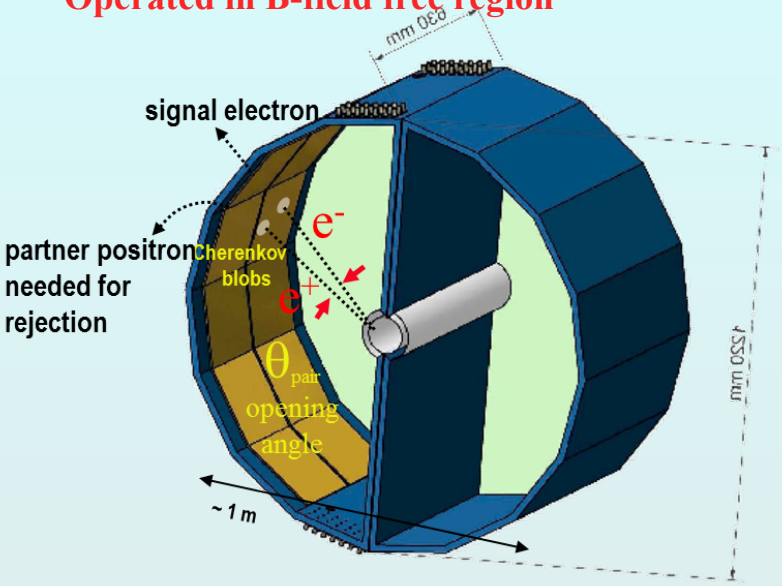




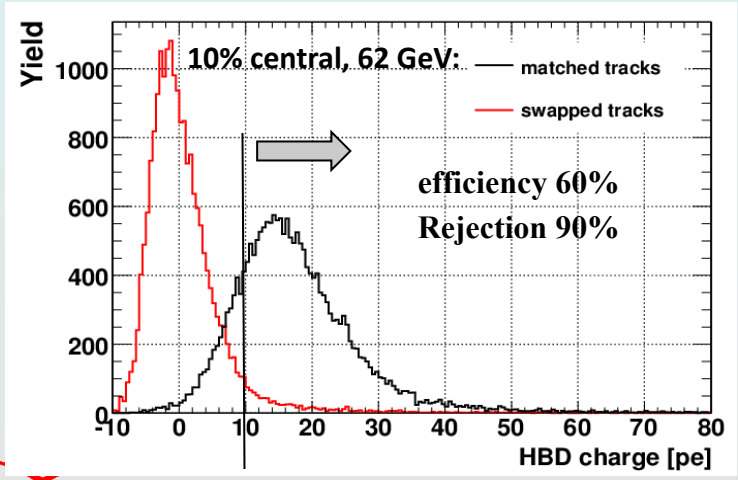


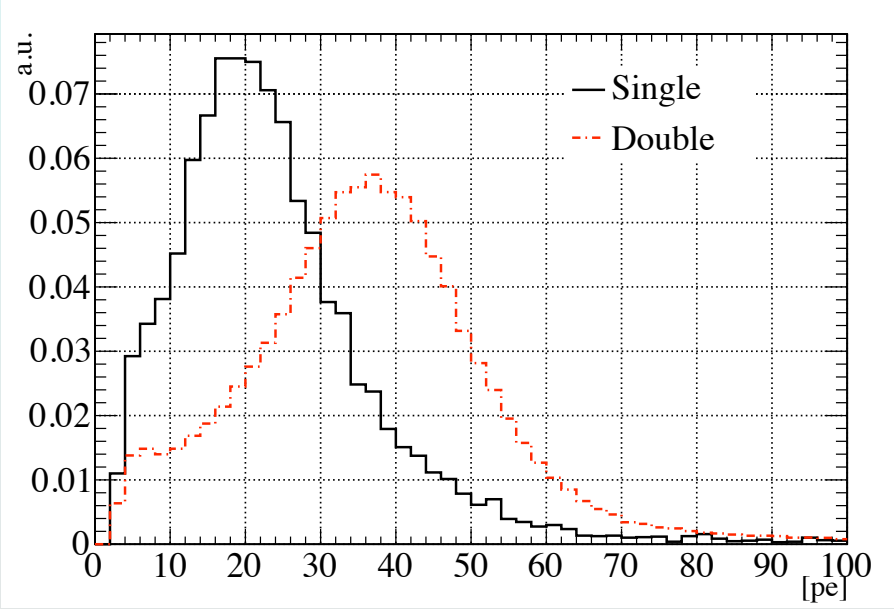
HBD for Dalitz rejection in 2009/10

Window less CF4 Cherenkov detector
GEM/CSI photo cathode readout
Operated in B-field free region



- **HBD was operational:**
  Single electron ~ 20 P.E.
  Conversion rejection ~ 90%
  Dalitz rejection ~ 80%
- **S/B x 5 vs. published results**





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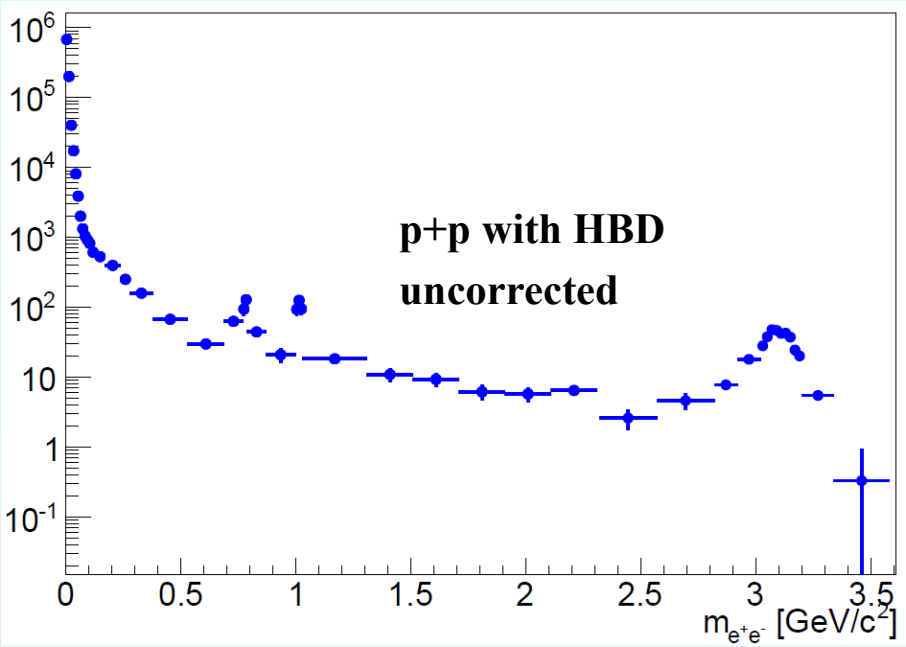
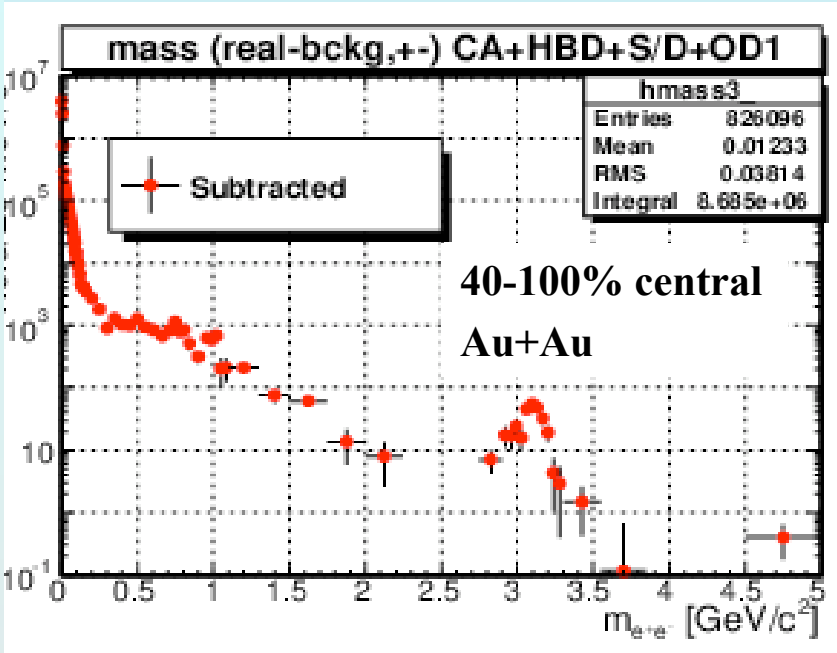
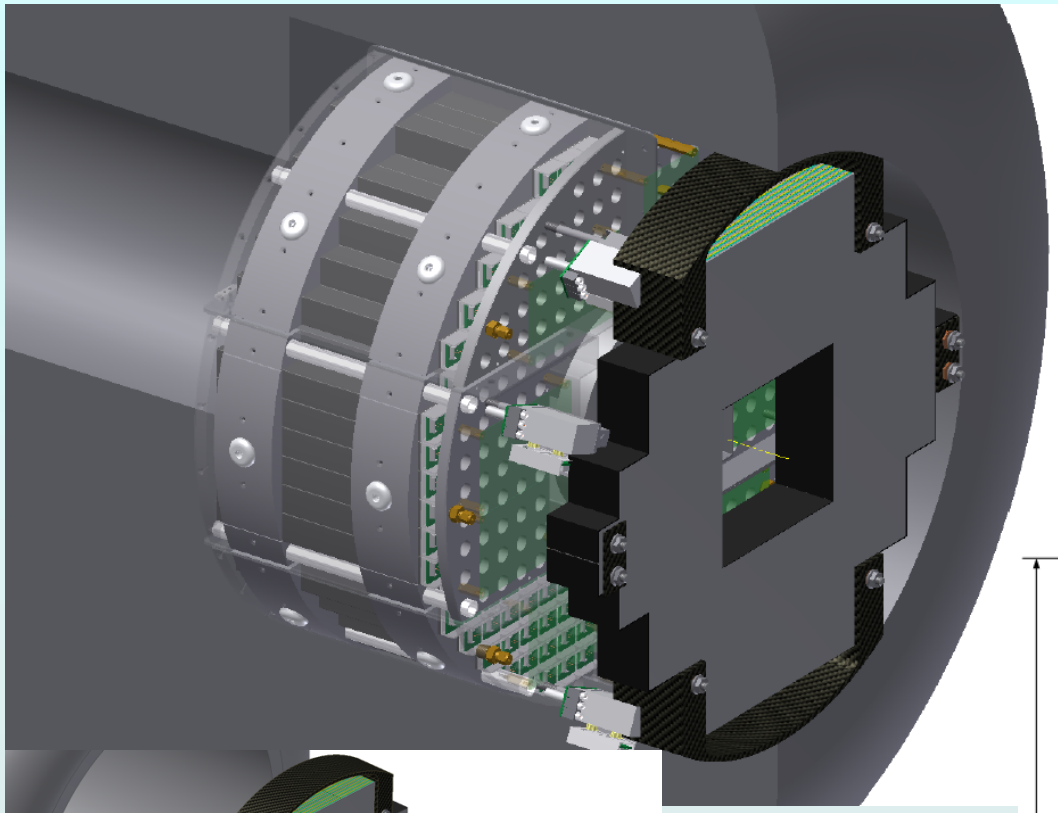
Analysis is in progress

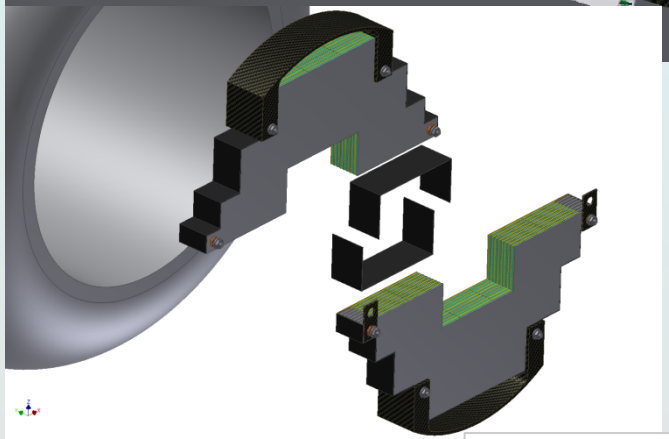




PHENIX

MPC-Extension Detector



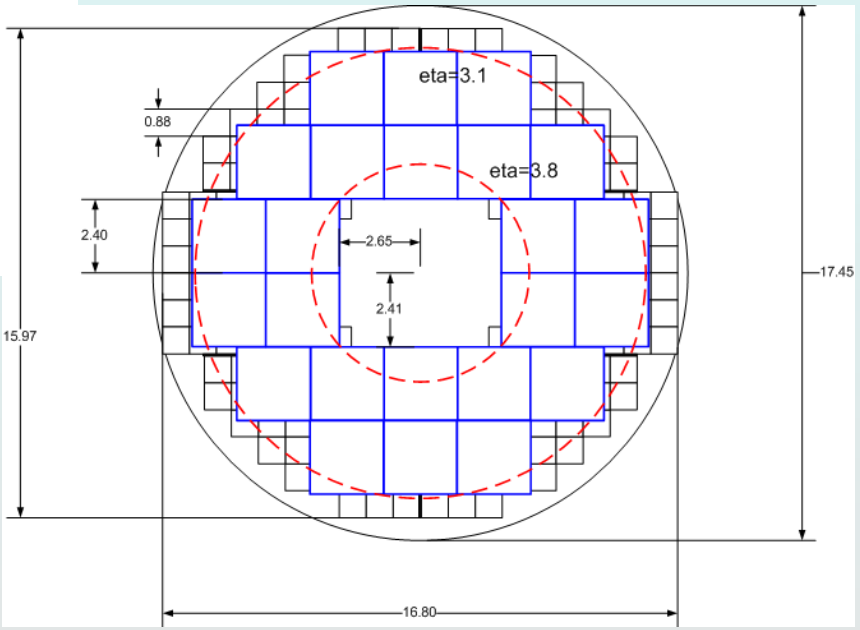


Charged particle tracker and EM preshower detector

Dual gain readout: sensitive to MIPS + EM showers.

- **Charged track identification**
- **π^0 reconstruction to >80GeV**

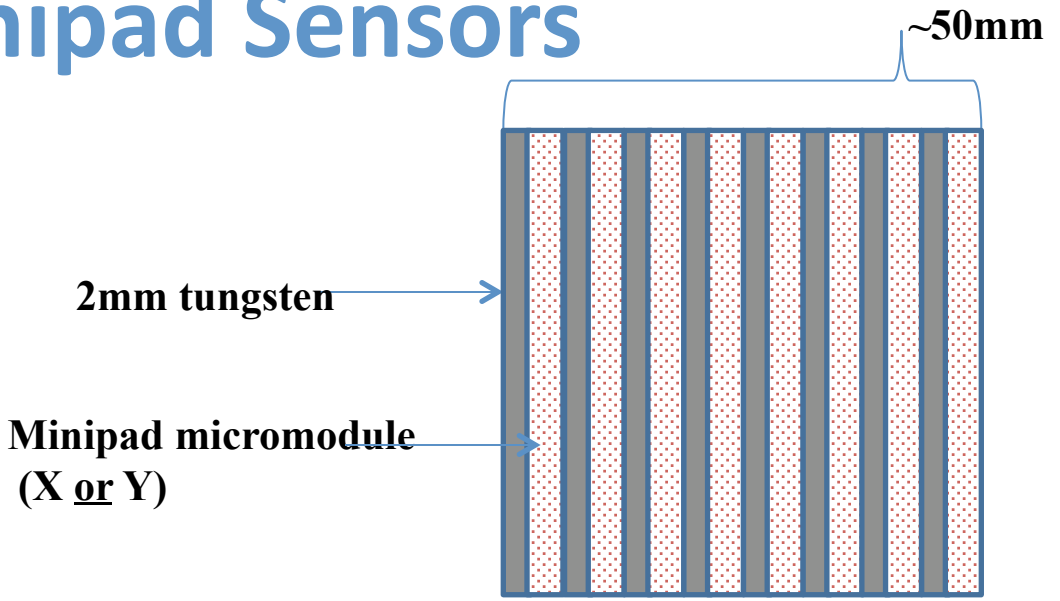
$3.1<\eta<3.8$



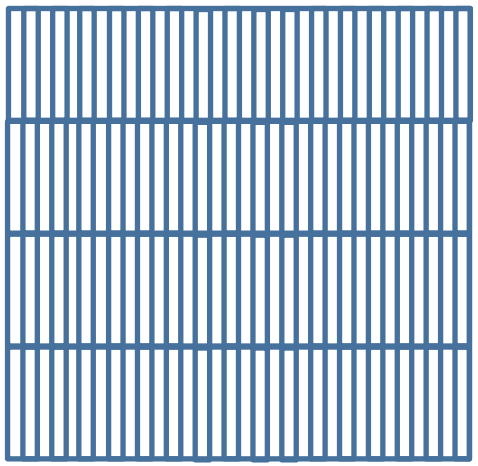
To be ready for Run-14

Minipad Sensors

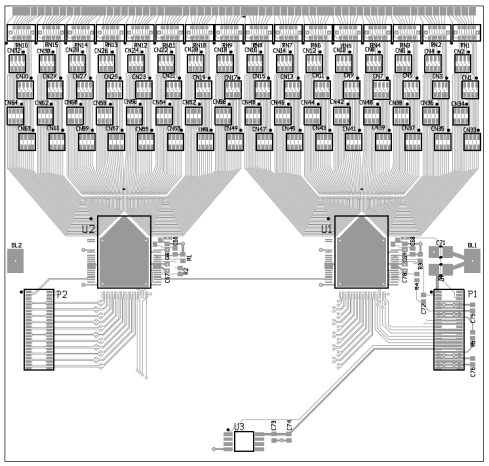
Detector elements are Si "minipad" detectors, one per tungsten gap, oriented in X and Y (alternating layers).



1.8mm x 15mm "minipad" sensor



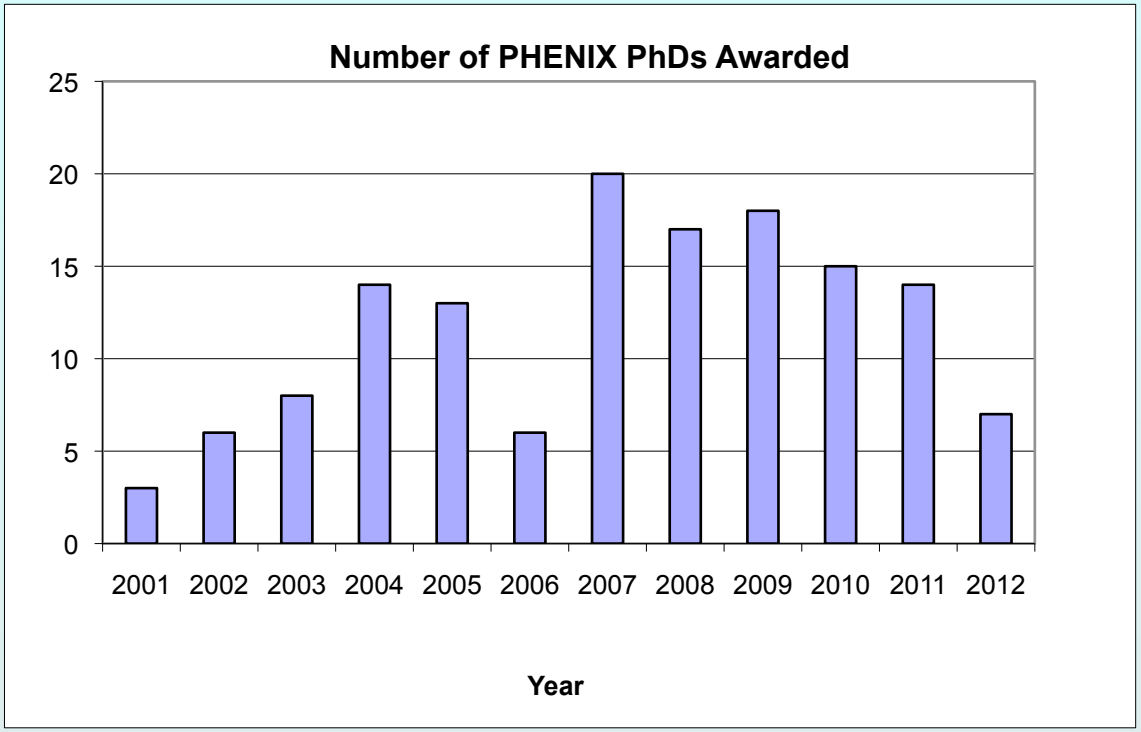
Dual SVX-4 Readout Card



Recent Accomplishments

PHENIX Productivity is High

- 132 Ph.D's and 27 M.S.
  - Pipeline implies more in 2012 than 2011
- 109 papers published
  - 8 in referee review
  - 4 in internal review
- 12637 citations
  - 2600 in past year
  - Higher citation rate than previous years!



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Impact is truly impressive

INSPIRE HEP

Welcome to INSPIRE! INSPIRE is now in full operation and supersedes SPIRES. SPIRES front end at all mirrors has been switched off. Please direct questions, comments or concerns to feedback@inspirehep.net.

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recid:899065 | recid:900703 | recid:894560 | recid:901235 | recid:854475 | reci | Citesummary | Search | Easy Search | Advanced Search

find j "Phys.Rev.Lett.,105*" :: more

Sort by: latest first | desc. | – or rank by – | Display results: 25 results | single list

Citation summary results	All papers	Published only
Total number of citable papers analyzed:	109	108
Total number of citations:	12,637	12,629
Average citations per paper:	115.9	116.9
Breakdown of papers by citations:		
Renowned papers (500+)	3	3
Famous papers (250-499)	8	8
Very well-known papers (100-249)	27	27
Well-known papers (50-99)	27	27
Known papers (10-49)	37	37
Less known papers (1-9)	7	6
Unknown papers (0)	0	0
Additional Citation Metrics [?]		
h-index [?]	60	60

:) π^0 suppression paper has >490 cites

PHENIX

Physics Questions addressed recently*

- Are direct photons at high p_T affected by QGP?
- How much do thermal photons flow?
- How do cold nuclear matter affects hard probe production?
- How much color screening in the QGP?
  Use d+Au, pathlength & √s dependence to help sort it out
- How does $T_{initial}$ affect high p_T suppression/energy loss?
- Are there features in √s dependence of particle production & fluctuations? How does energy loss vary with √s?
- What is the rapidity dependence of heavy quark energy loss?
- Under what conditions does hadron flow scale with the number of quarks?
- What is A_{LL} for charged hadrons?

** Details on selected highlights*

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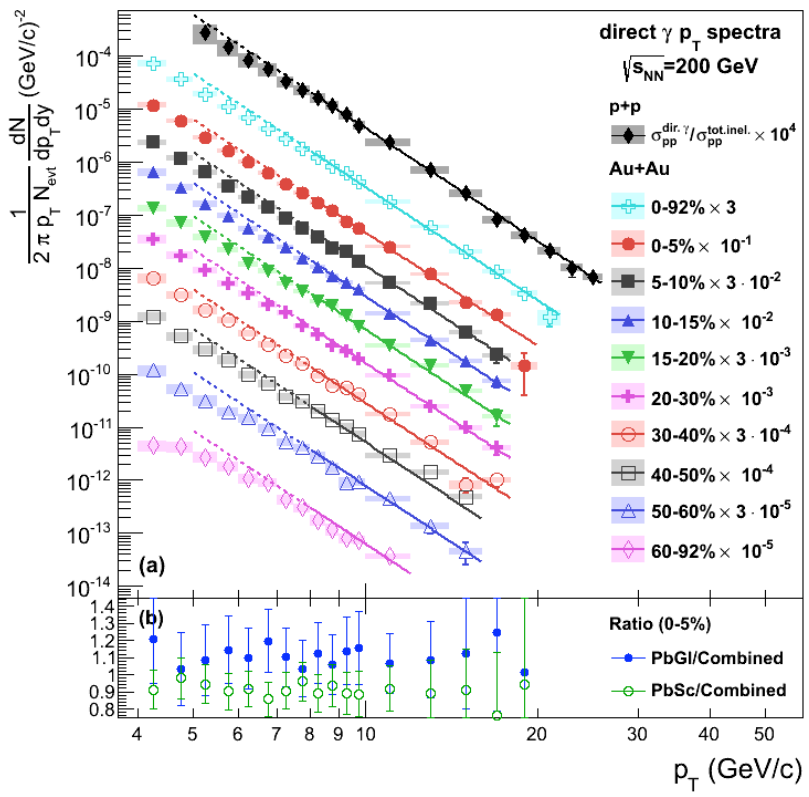
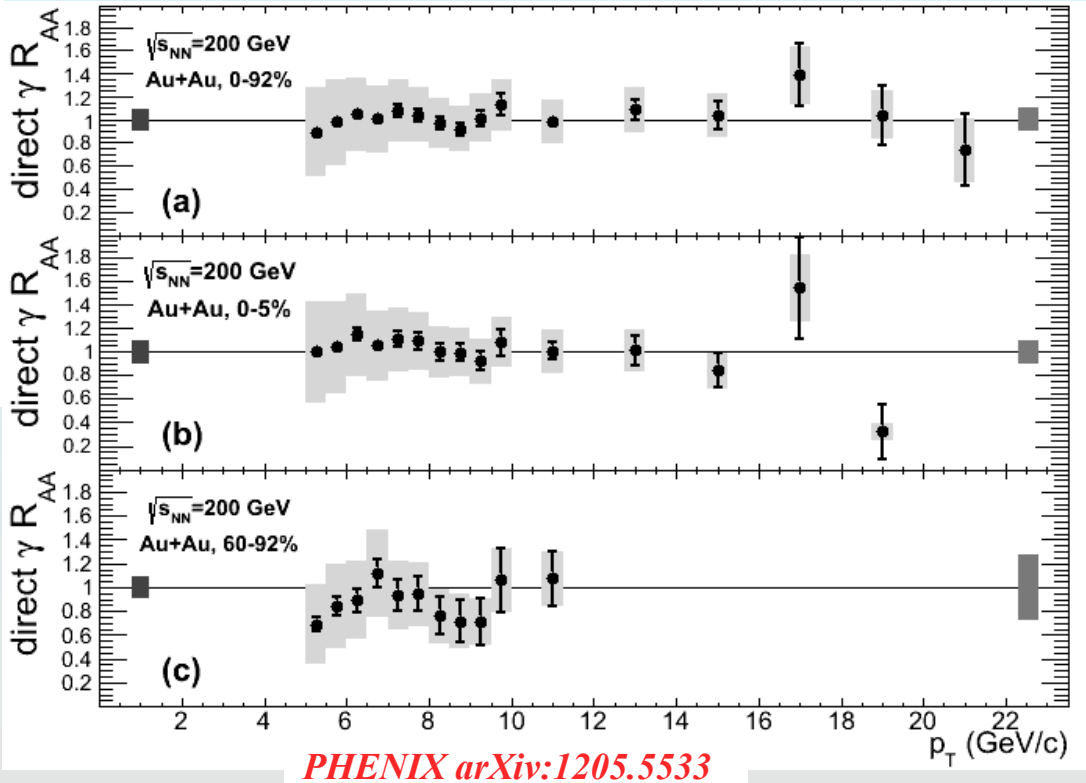
Direct photons in Au+Au collisions

PHENIX arXiv:1205.5533



- **PHENIX photon data**
  - High p_T (4 to 25 GeV) from calorimeter
- **Nuclear Modification Factor**
  - Consistent with binary scaling of p+p
  - No evidence for cold nuclear matter or hot medium effects out to 20 GeV/c . Isospin?
  - (or else they cancel exactly…)



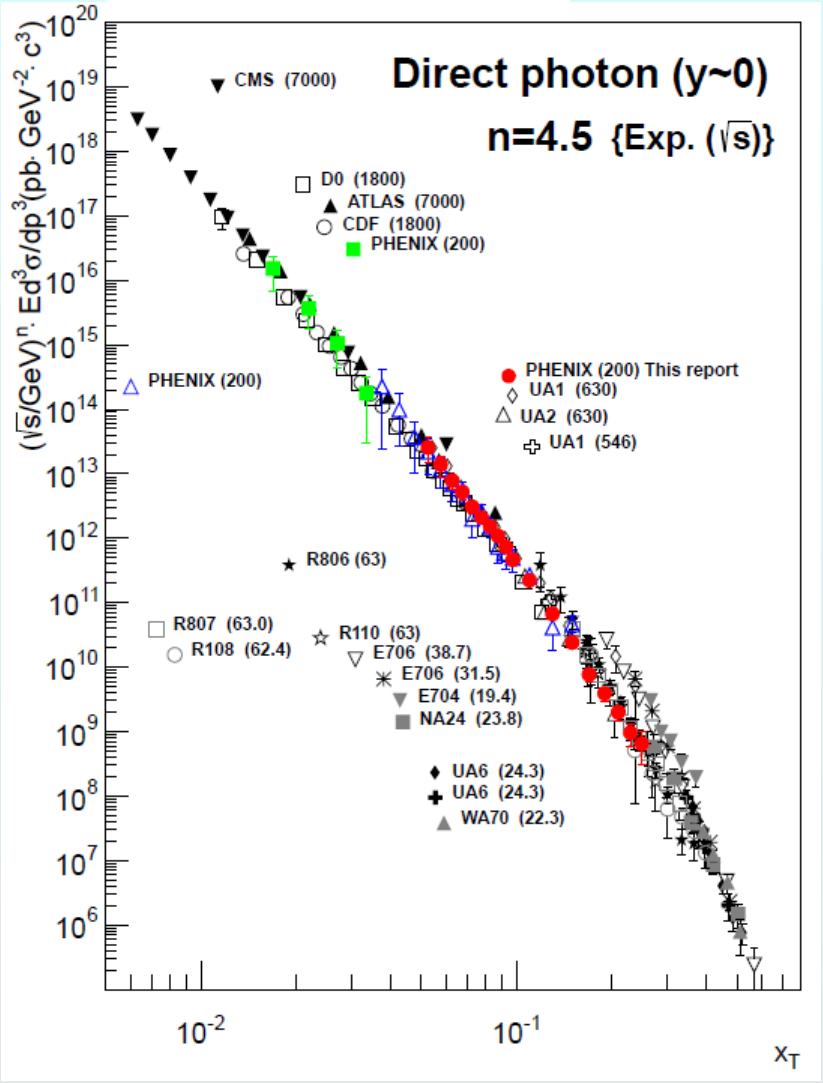
PHENIX arXiv:1205.5533

Axel Drees, HP2012

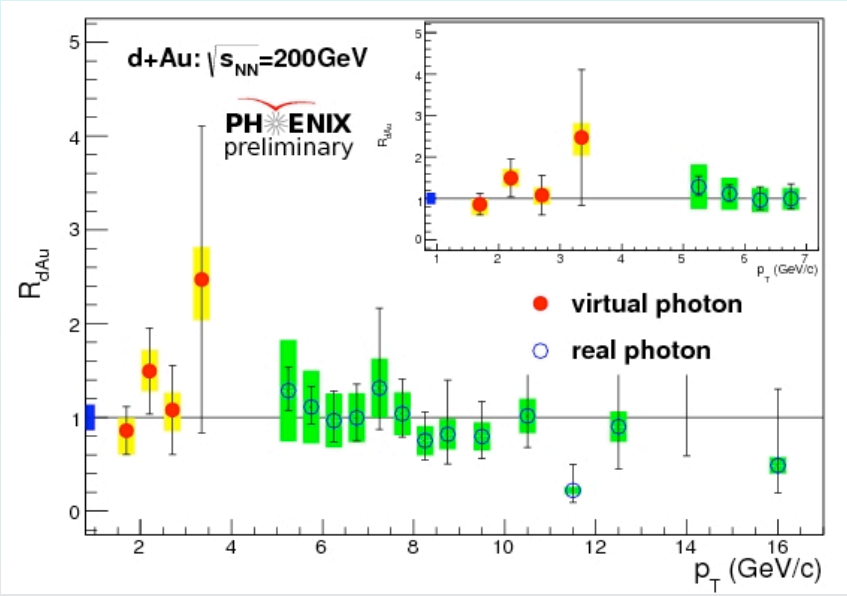
PHENIX

p+p and d+Au: reference & additional physics

PHENIX arXiv:1205.5533



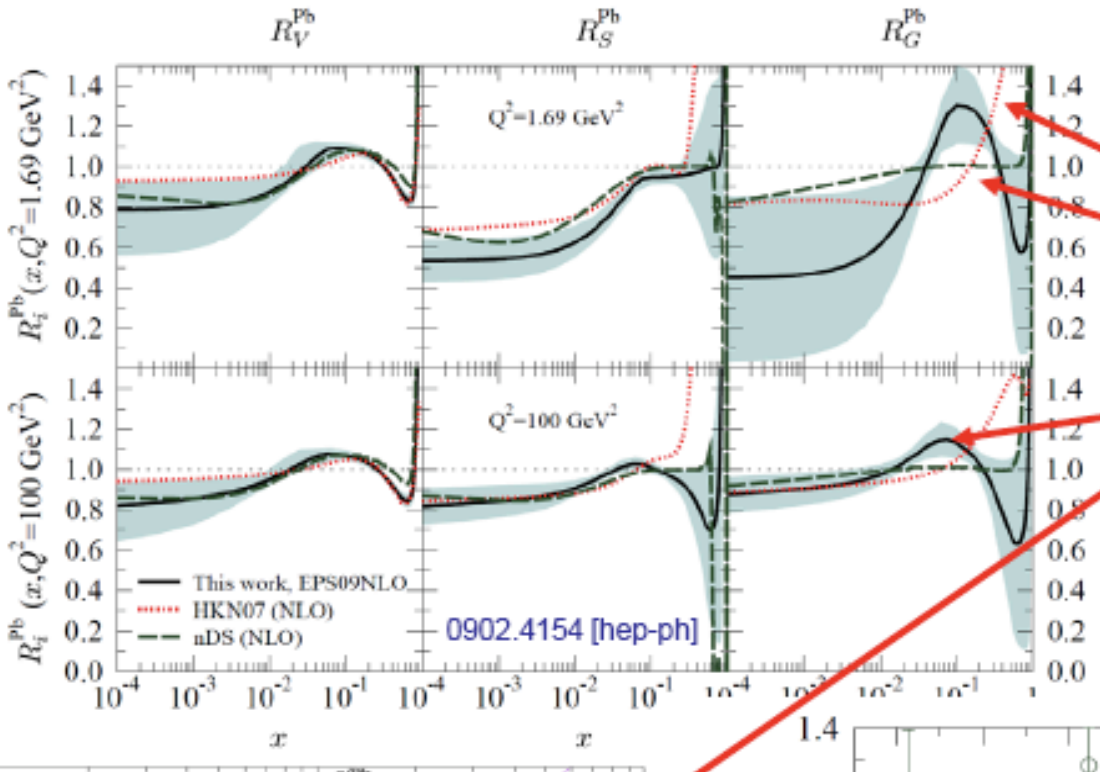
- **PHENIX photon data**
  - High p_T (4 to 25 GeV) from calorimeter
  - Low p_T (<4 GeV) from virtual photons
- **p+p data consistent with pQCD**
  - x_T scaling of cross section
  - NLO calculation agree well with data
- **d+Au consistent with N_{coll} scaling**



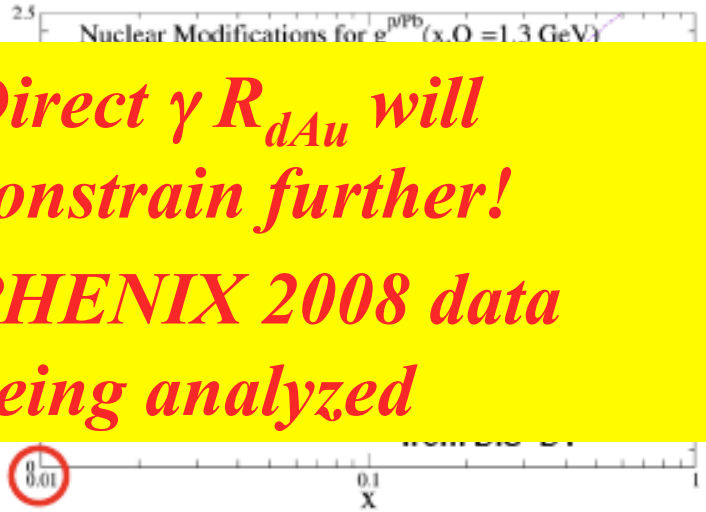
PHENIX

Axel Drees, HP2012

Kari Eskola at Hard Probes 2012 conference:

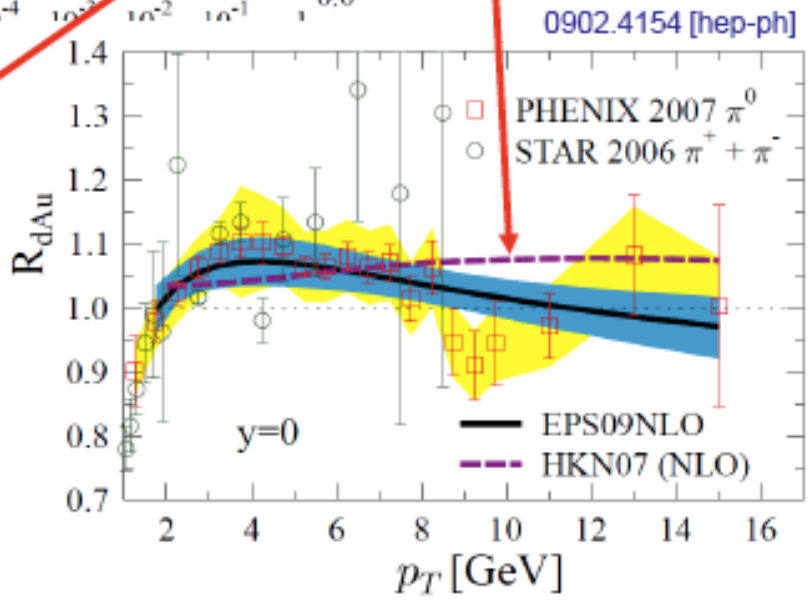


Difference here →R_{dAu} constrains gluons!



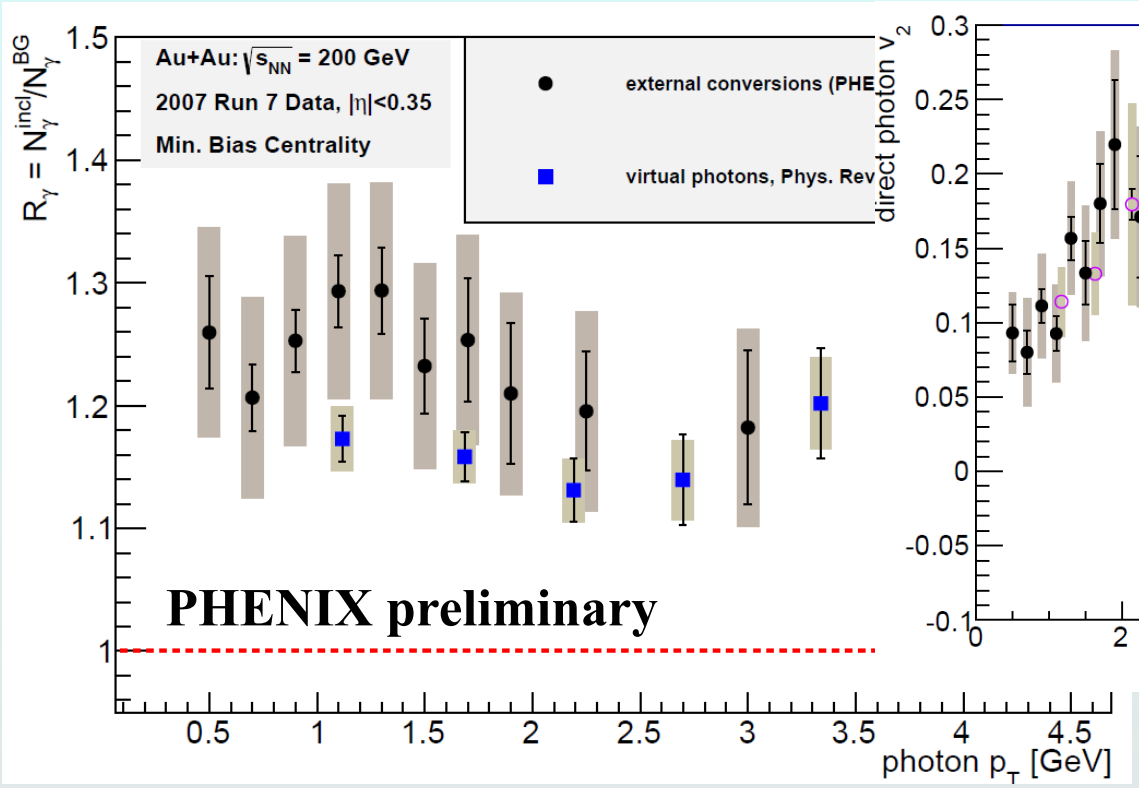
Direct γ R_{dAu} will constrain further!

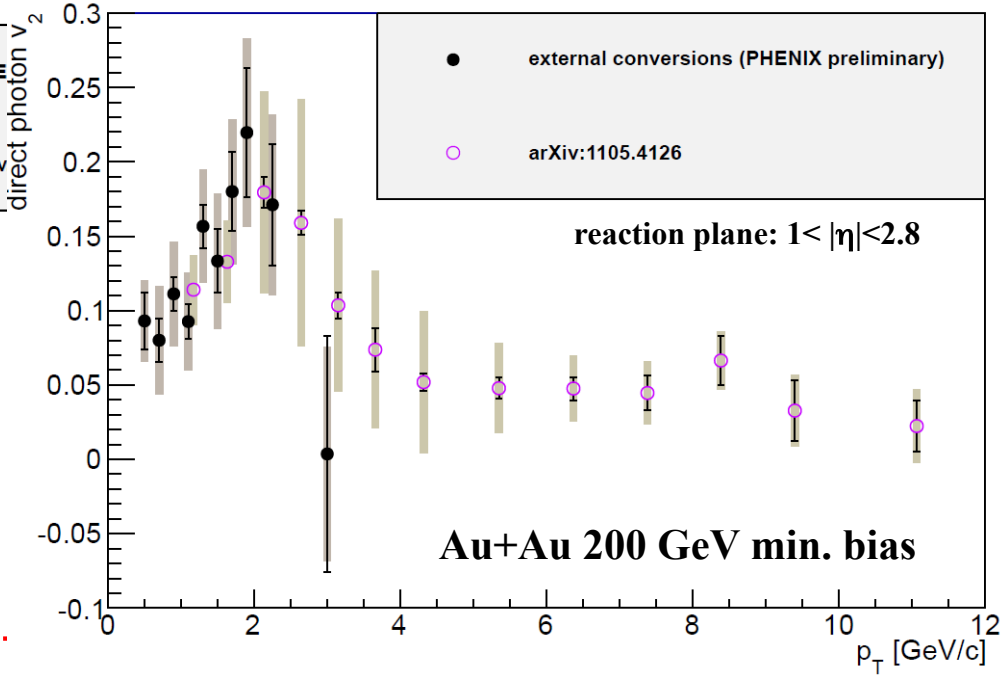
PHENIX 2008 data being analyzed



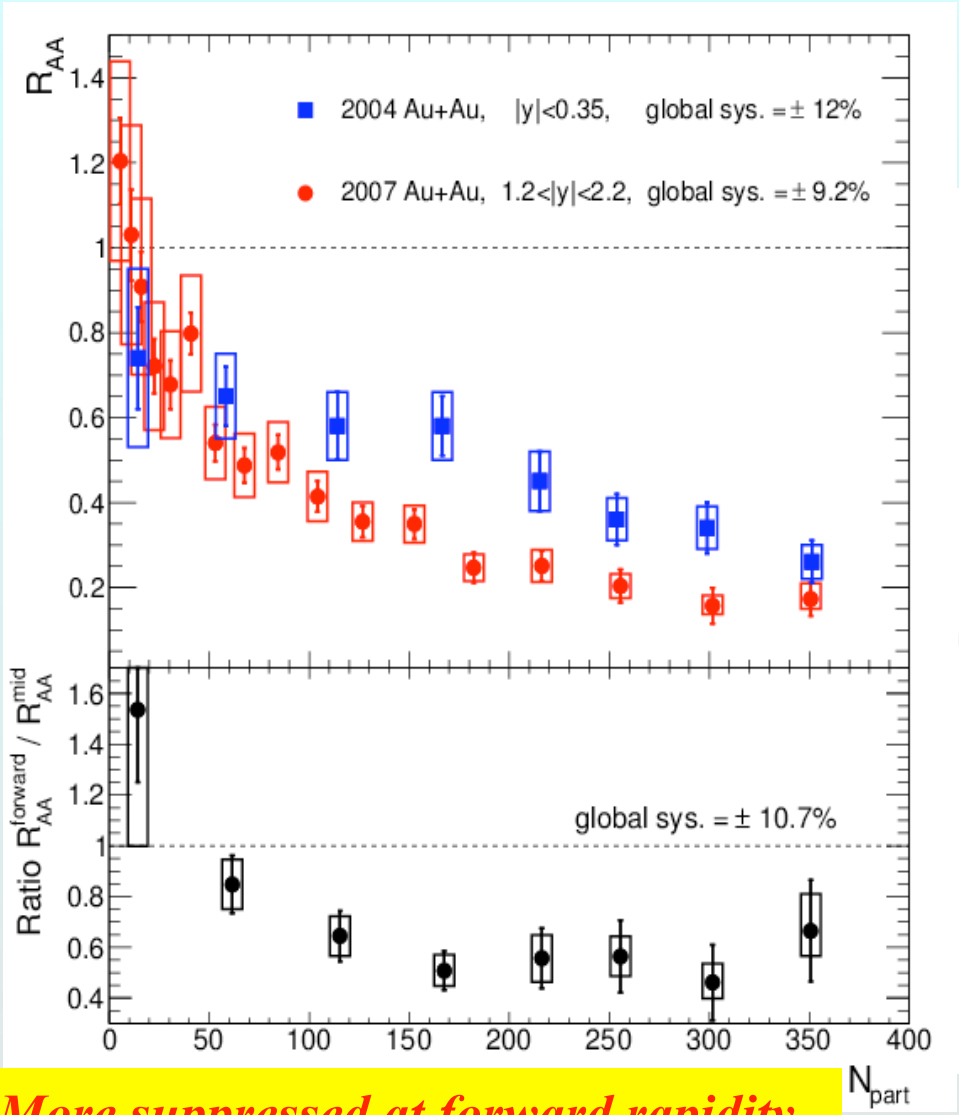
New measurement of thermal photons

- **PHENIX has developed new method to detect direct photons:**
  - **Use photon conversions to e^+e^-**
  - **Tag contribution from π^0 decays & compare to MC**
  - **Independent systematic uncertainties**

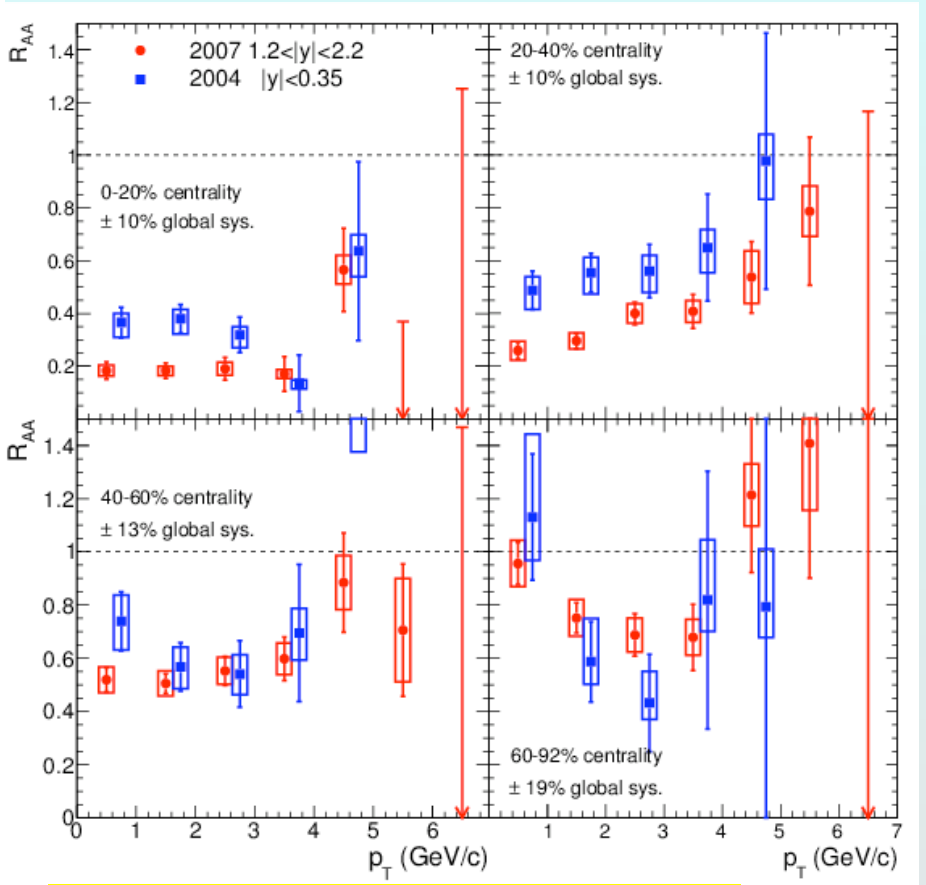




J/ψ suppression: the plot thickens



PRC84, 054912 (2011)



More suppressed at forward rapidity

Unexpected for QGP screening

Trends upward at higher p_T

Expected for QGP screening

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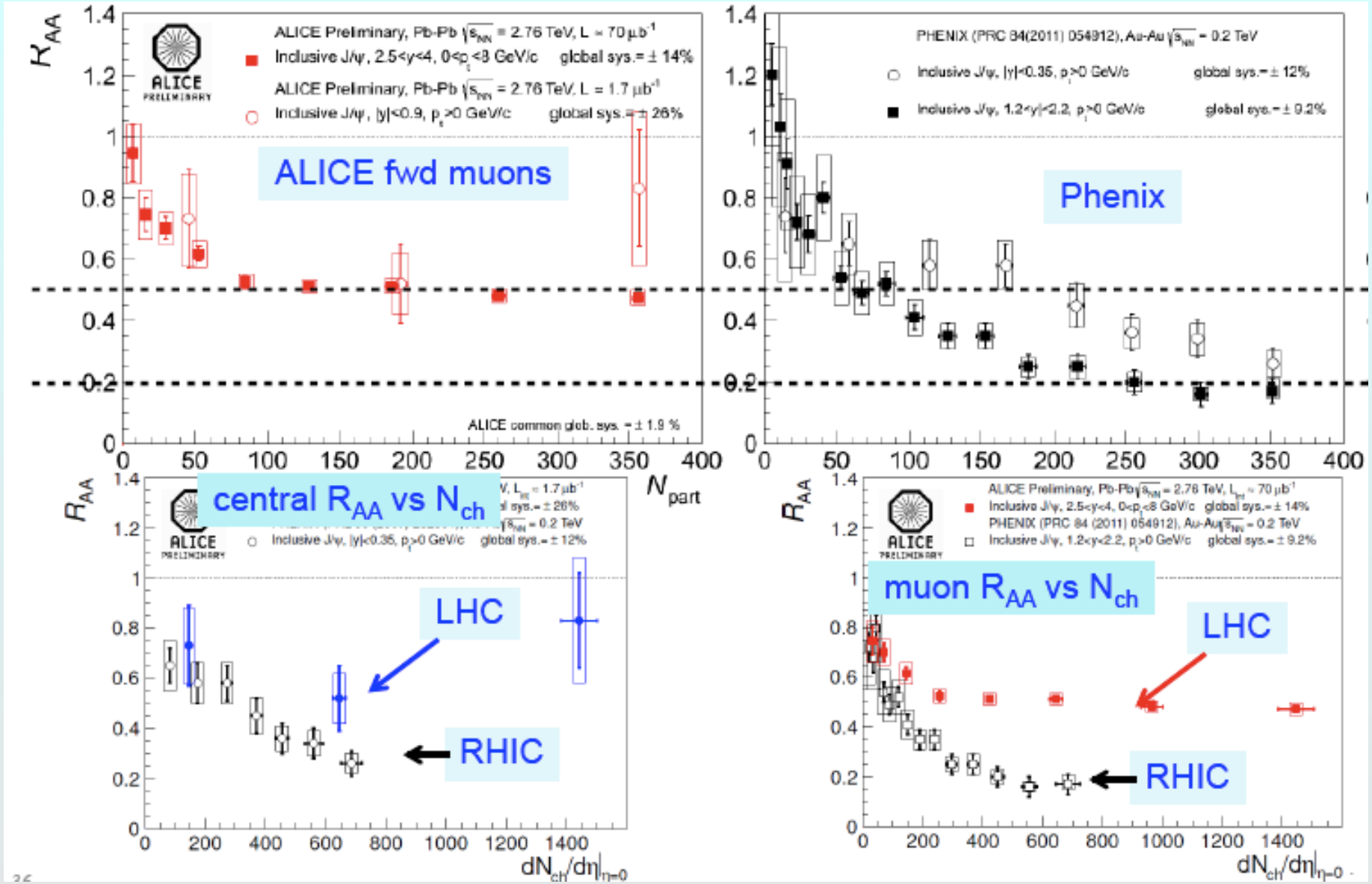
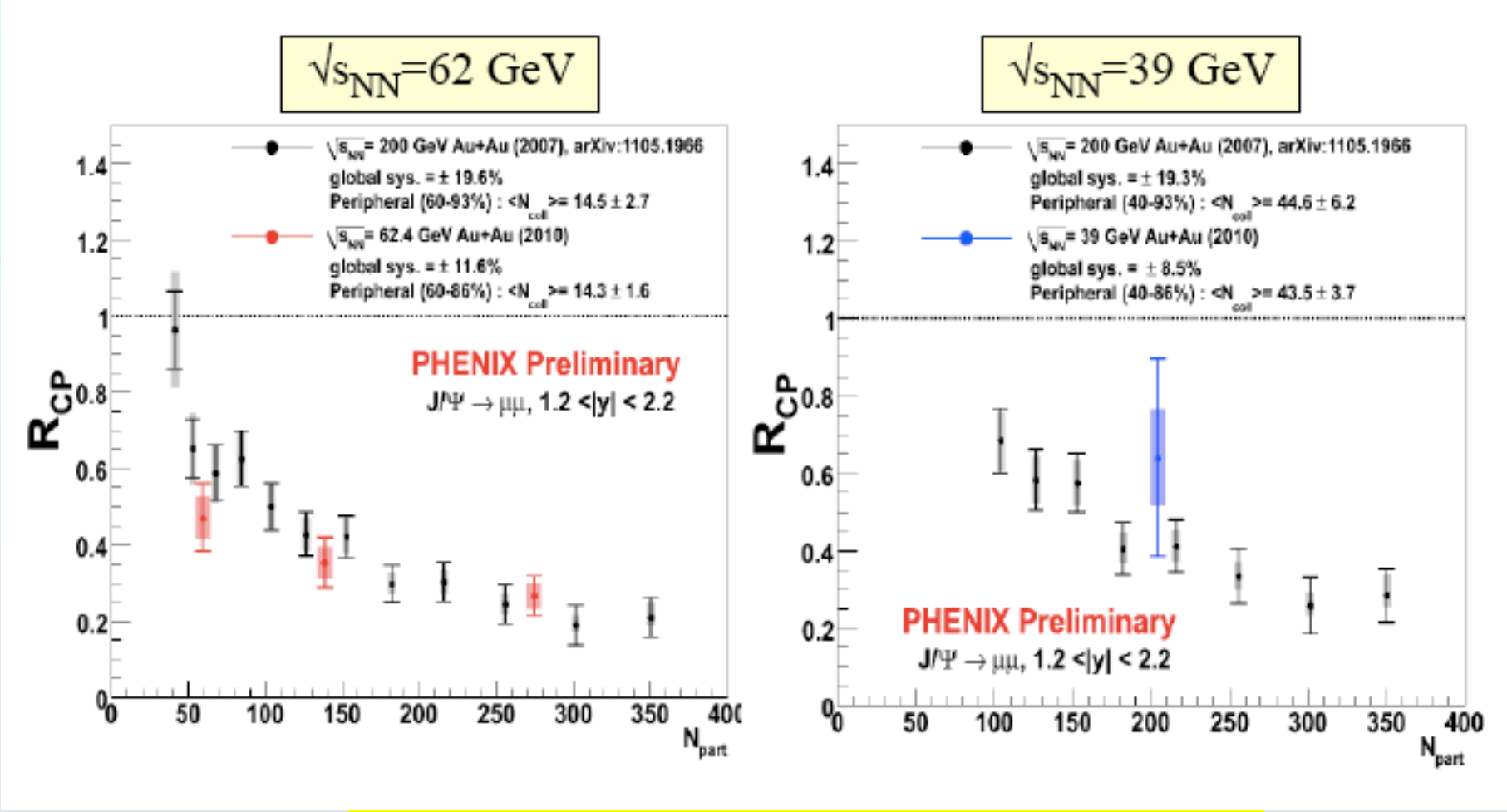
√s dependence: compare to LHC



J/ψ less suppressed at LHC! Final state recombination...

Lower energies at RHIC



Similar to 200 GeV, but comparison suffers from lack of precision – longer runs needed!

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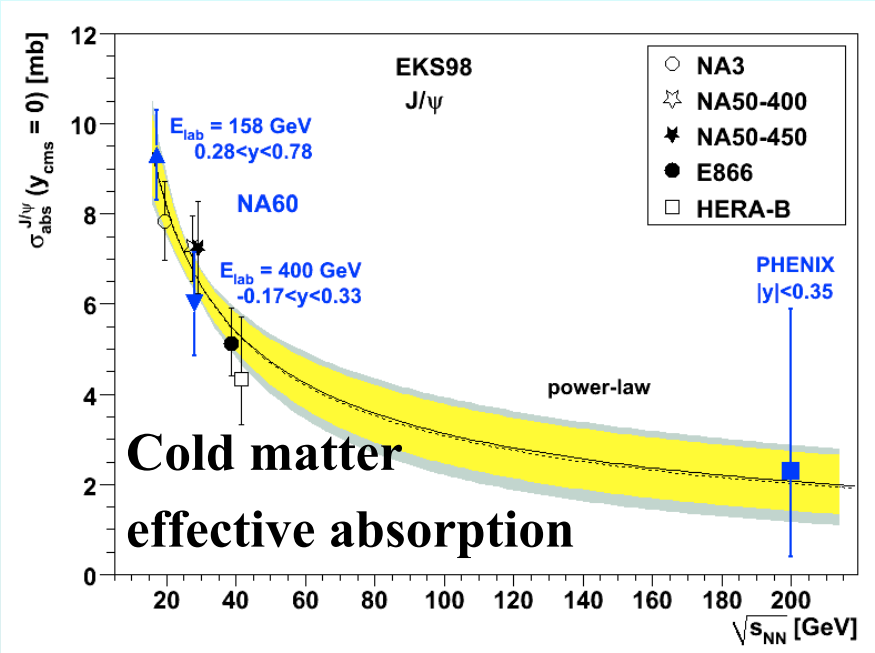
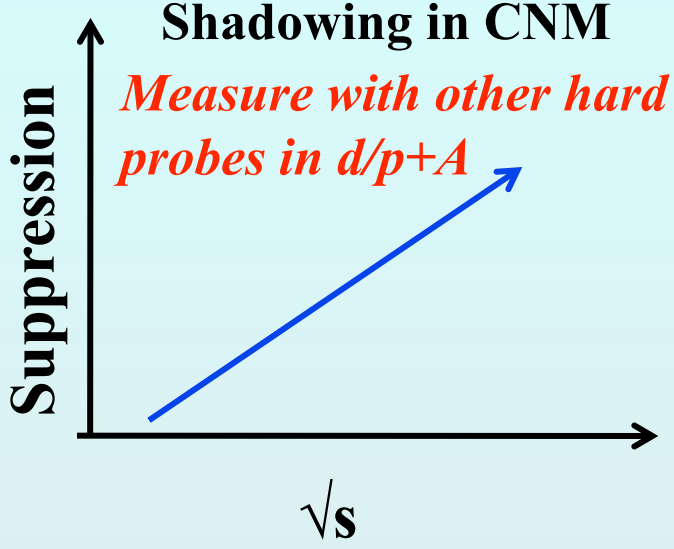
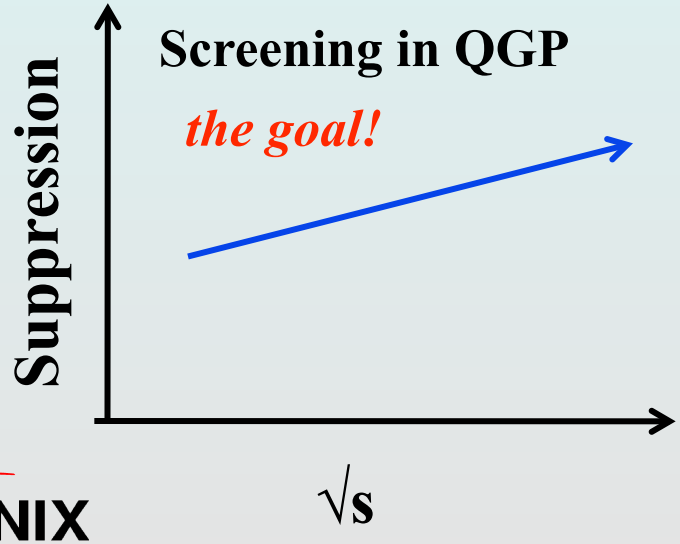
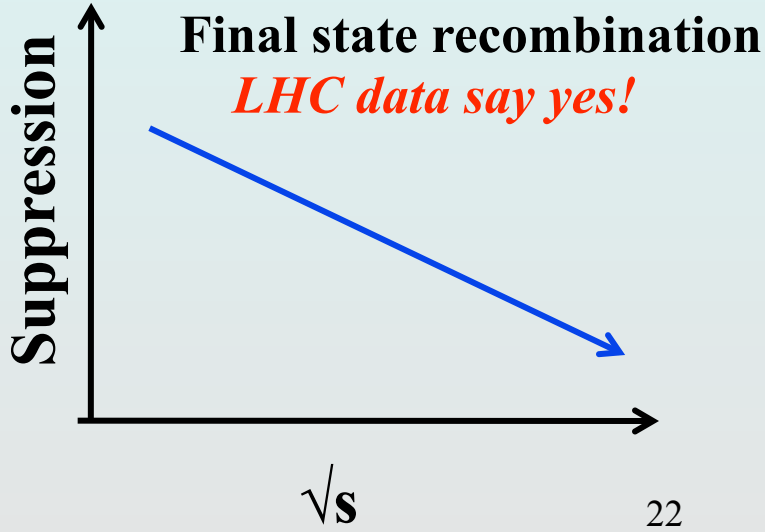
suppression ingredients: √s dependence is key!









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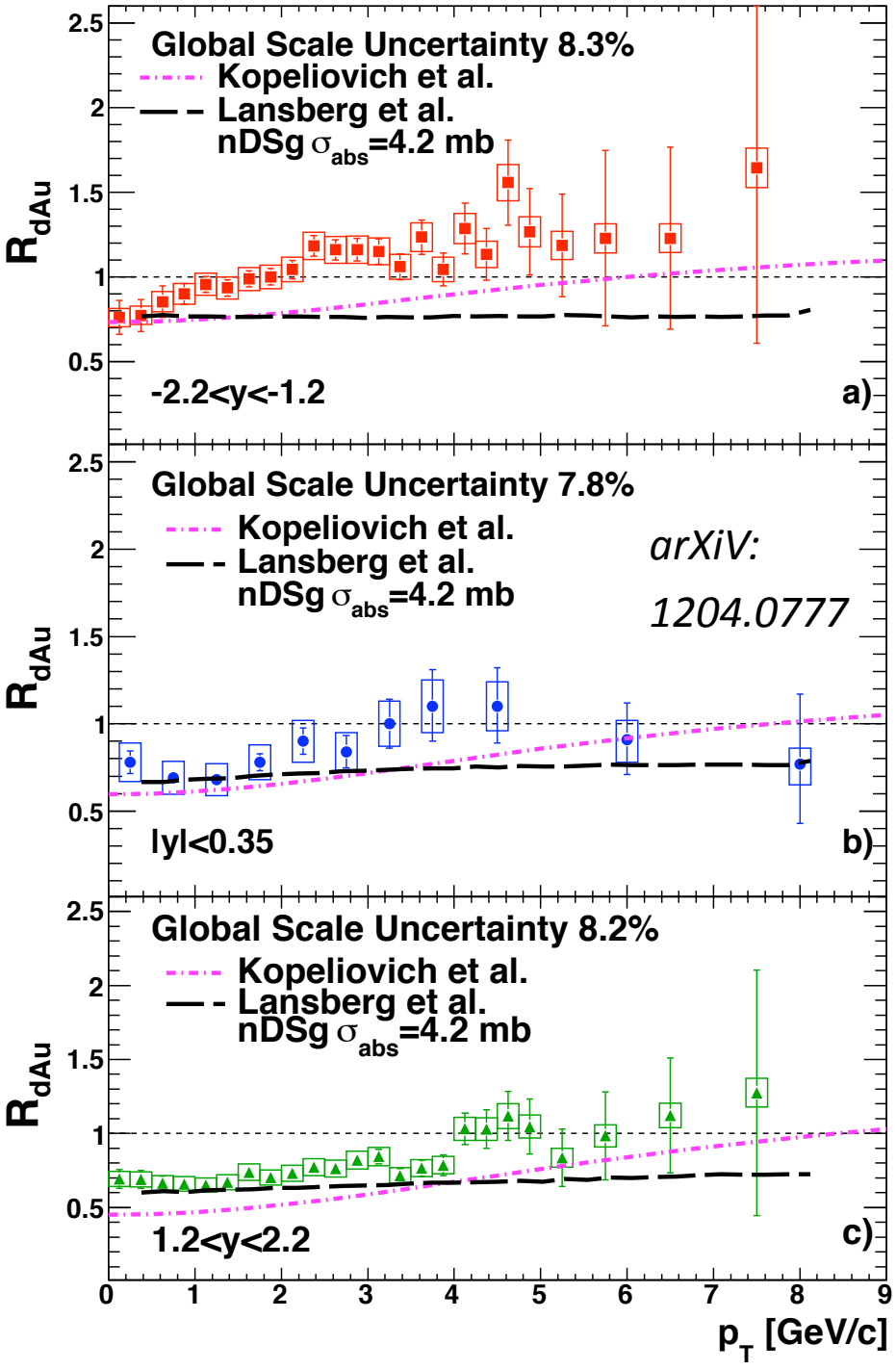
d+Au -> J/ψ

- rapidity & p_T dependence
  - Help pin down cold nuclear matter effects
- Also measure open heavy flavor
  - Muons *arXiV: 1204.0754*
  - Electrons
  - Compare to Cu+Cu and Au+Au



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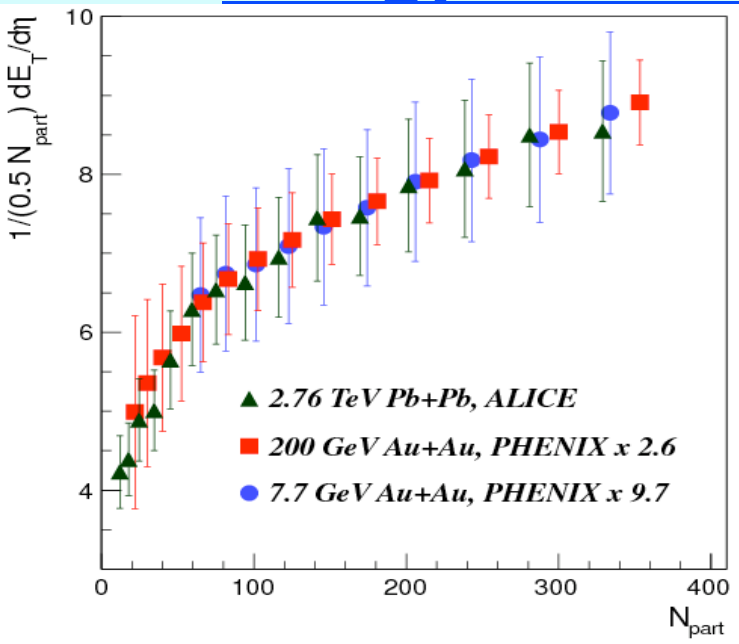
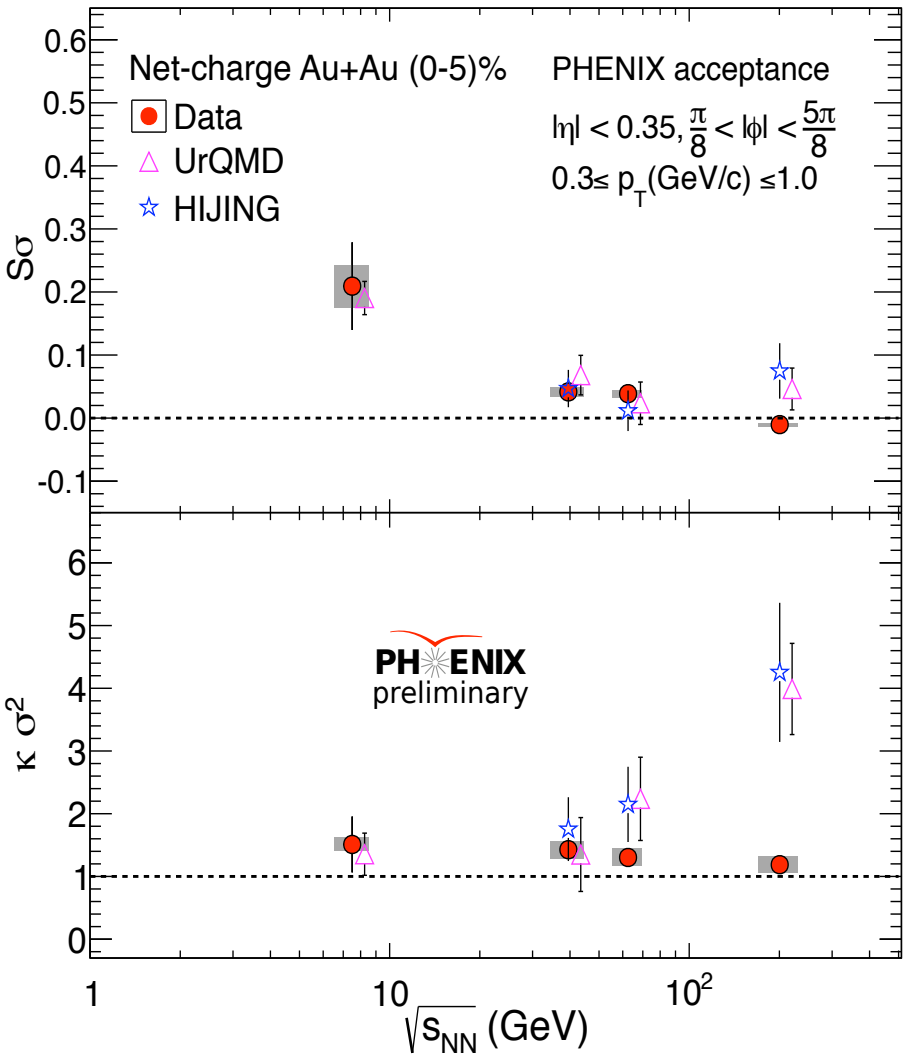
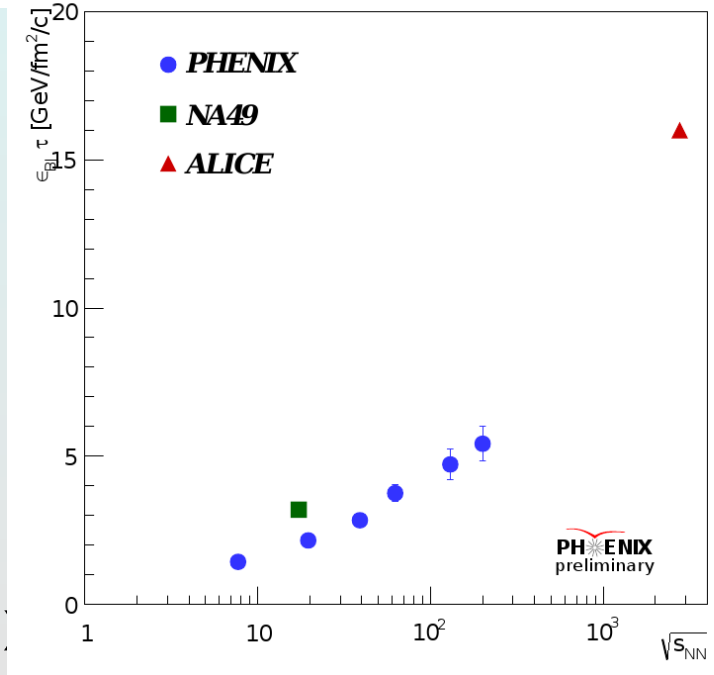
Energy scan for soft particle production

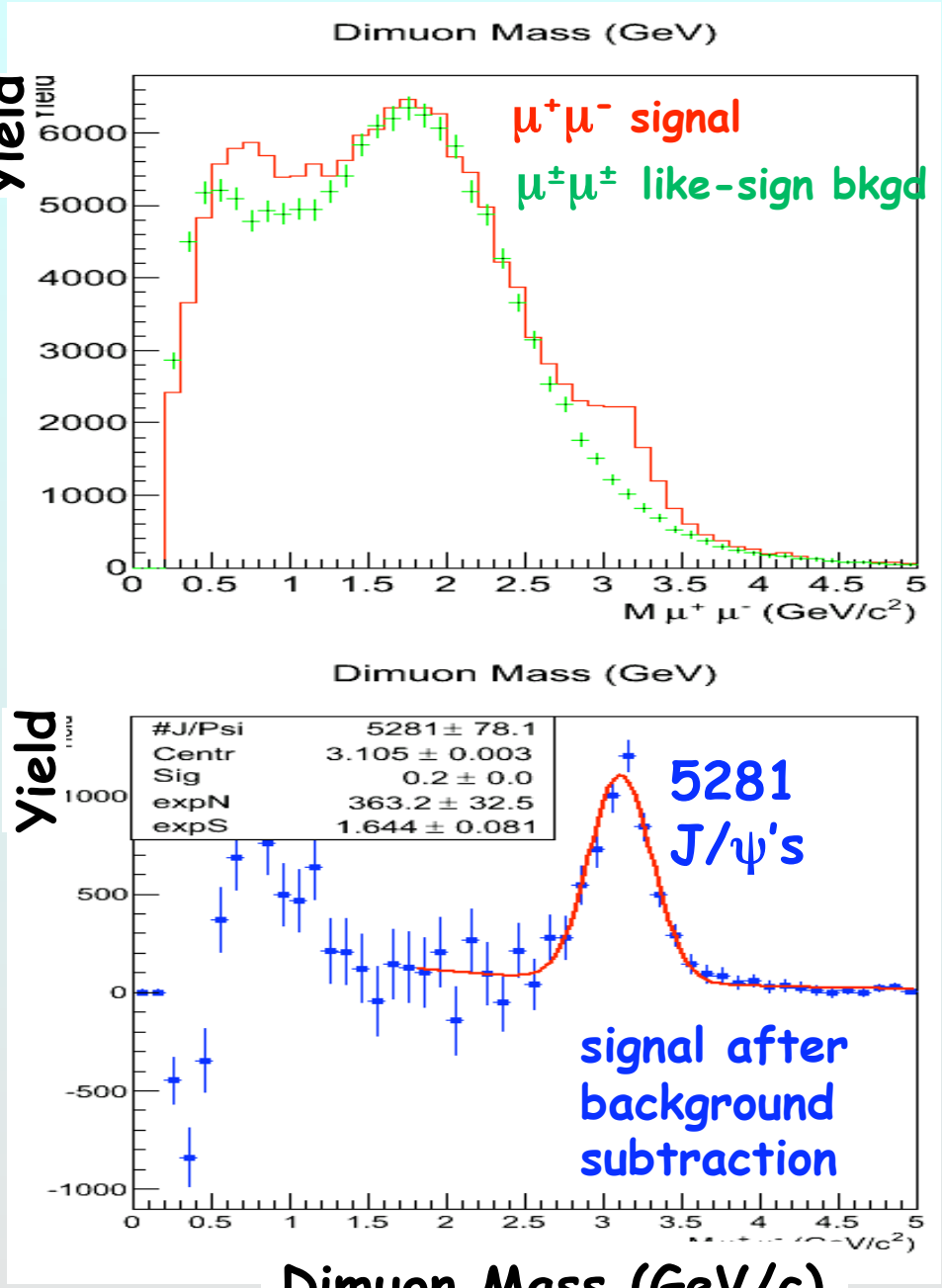






Cu+Au!

- J/ψ yields from the PHENIX Muon Arms for Cu+Au Collisions – taking data right now
- For about 0.4 nb^{-1} from the Counting House fast production – 5.3k J/ψ from sum of two muon arms
- Run12 Cu+Au expectation: 62k J/ψ - for PHENIX wide-vertex (±30 cm) luminosity goal of 4.6 nb^{-1}
- Allows study vs. reaction plane to control path length
- Well controlled initial state v3 for flow study; help pin down η/s



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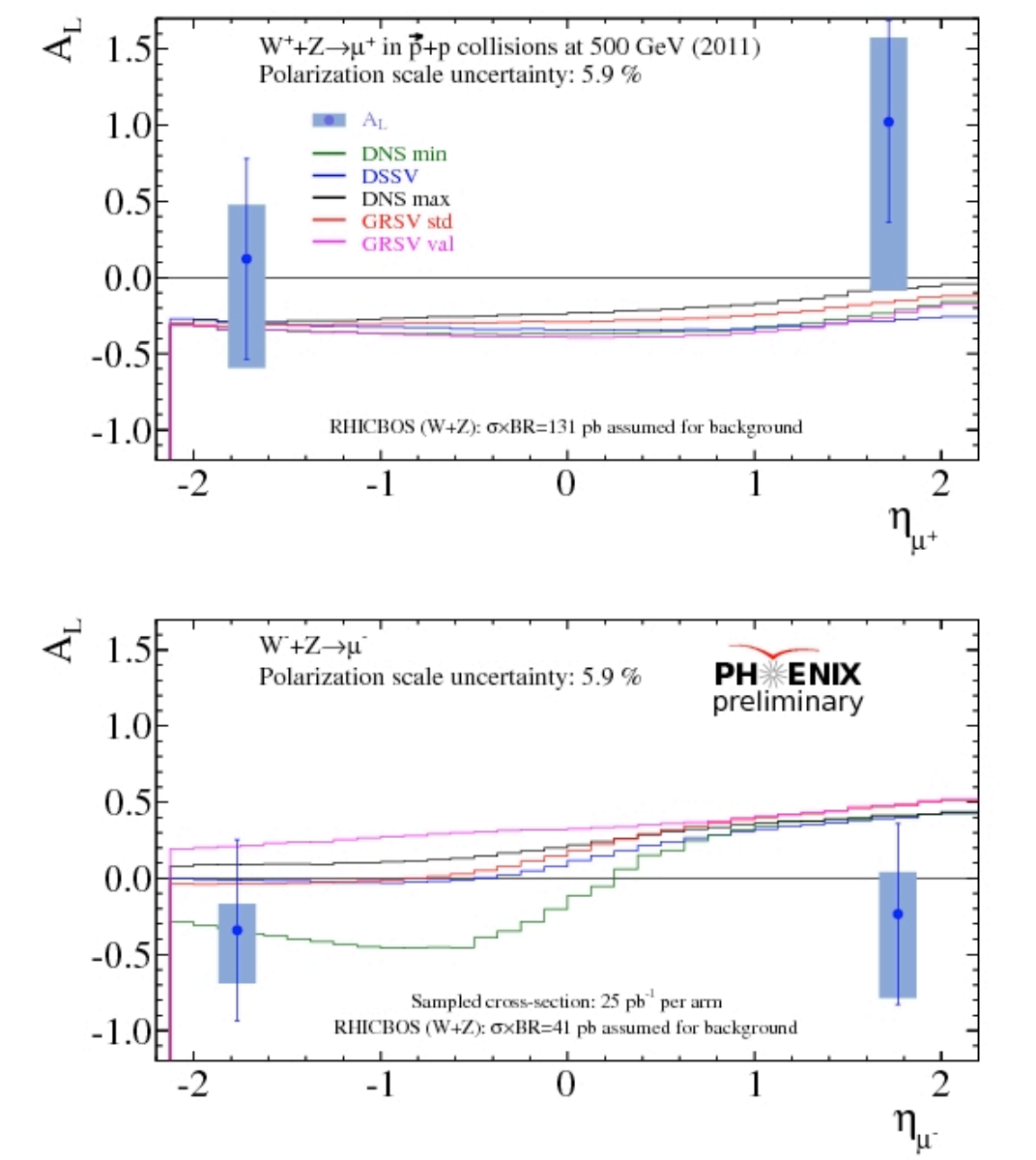
First W -> μ result



- **Run-11**
  - first use of RPC3
  - sampled 25 pb^{-1}
  - polarization ~ 50%
- **Proof of principle**
  - Clearly needs more statistics
  - Statistics ↑ also = systematics ↓

Compelling physics questions in Run-13 & 14

- **What are the light antiquark polarizations inside a polarized proton?**

  Precision measurement of W± in polarized 500 GeV p+p

- **What is the gluon asymmetry at smaller x?**

  Forward π^0/cluster A_{LL} in polarized 500 GeV p+p

- **How much are B mesons suppressed by QGP?**

  c/b separation in 200 GeV Au+Au and p+p w/VTX & FVTX

- **What is π^0 A_N at forward rapidity?**

- **What is the gluon shadowing at x~10^{-2} - 10^{-3} in a Au nucleus?**

  Install and commission MPC-EX

  Measure forward direct photon yield in 200 GeV d+Au (or p +Au) and p+p reference

  NB: if isospin effects require p+Au, need dedicated Run-15

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PHENIX beam use proposal

run	species	$\sqrt{s_{NN}}$	weeks	$\int L\,dt$ $\lvert z\rvert < 30$ cm	$\lvert z\rvert < 10$ cm	pol.	comments

	Species	$\sqrt{s_{NN}}$ (GeV)	weeks	|z|<30cm	|z|<10cm	delivered	Polariz.
1	Run13:						
	p+p	500	10-15	250 pb^{-1}	97 pb^{-1}	~750 pb^{-1}	55%
	p+p	200	4	16 pb^{-1}	> 5.5 pb^{-1}	48 pb^{-1}	60%
	or p+p	*39*	*1*	*0.2-0.3* pb^{-1}		*0.9 pb^{-1}*	
	Run-14:						
	Au+Au	200	6-8	1.7 nb^{-1}	1 nb^{-1}	5 nb^{-1}	
	d+Au	200	Rest of run				

PHENIX Efficiency & vertex cut effects

- DAQ livetime = 91% for high lumi/high rate conditions
- PHENIX uptime

  75% for ion running

  70% for polarized p+p running

  due to polarization measurements & HV ramp for them

  Penalty for commissioning new detector: 10% in uptime
- Vertex cuts vary with physics goal (detector systems)

  No cut (MPC): 65% of delivered pp luminosity, 68% for ions

  ± 30cm cut (muon arms)= 50%: sample 1/3 of delivered lumi

  ± 10cm cut (VTX/FVTX) = 20% in p+p (13% of delivered lumi)

  30% in ions (stochastic cooling!!)

  (20% of delivered lumi)
- We are working on the 75/70% number e.g.

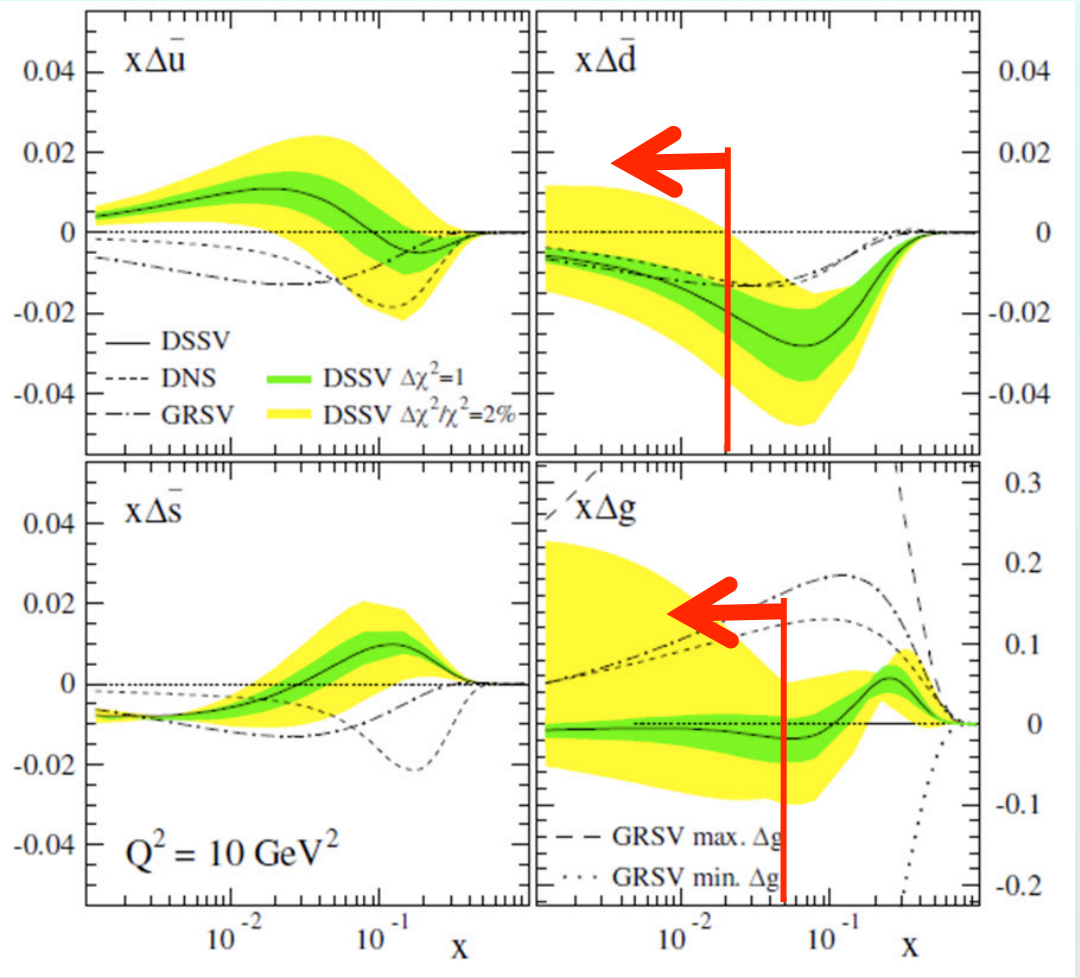
  improve HV control, longer run between DAQ resets

PHENIX

gluon & sea quark polarization

Current best knowledge from global fits

Still surprisingly small



- 500 GeV p+p: π^0 A_{LL} to constrain Δg (0.01<x<0.3) **NSAC milestone HP12**
  central/forward correlations tag kinematics **NSAC milestone HP8**
- W A_L at forward, backward, mid rapidity for $\Delta\bar{u}$, Δu, $\Delta\bar{d}$, Δd

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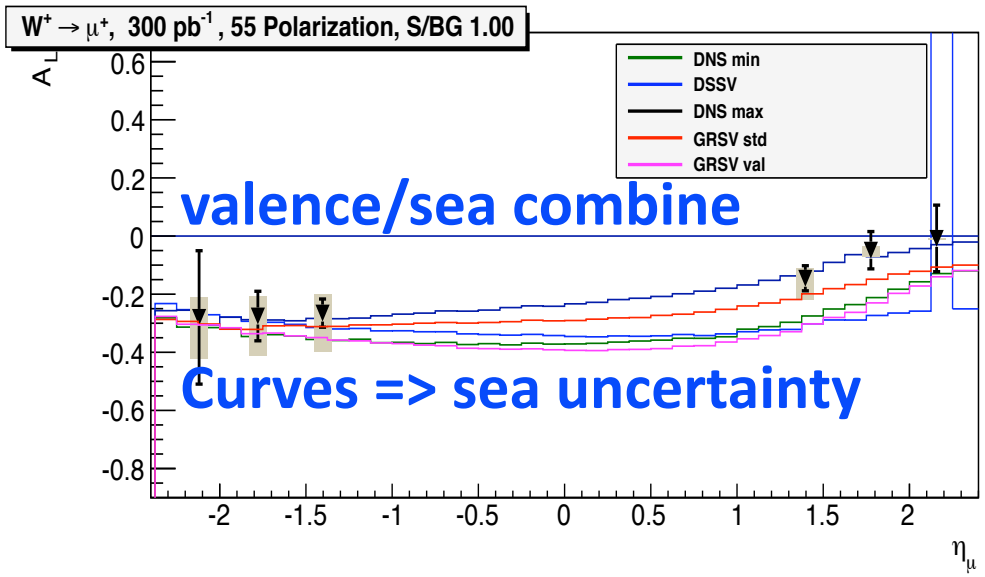
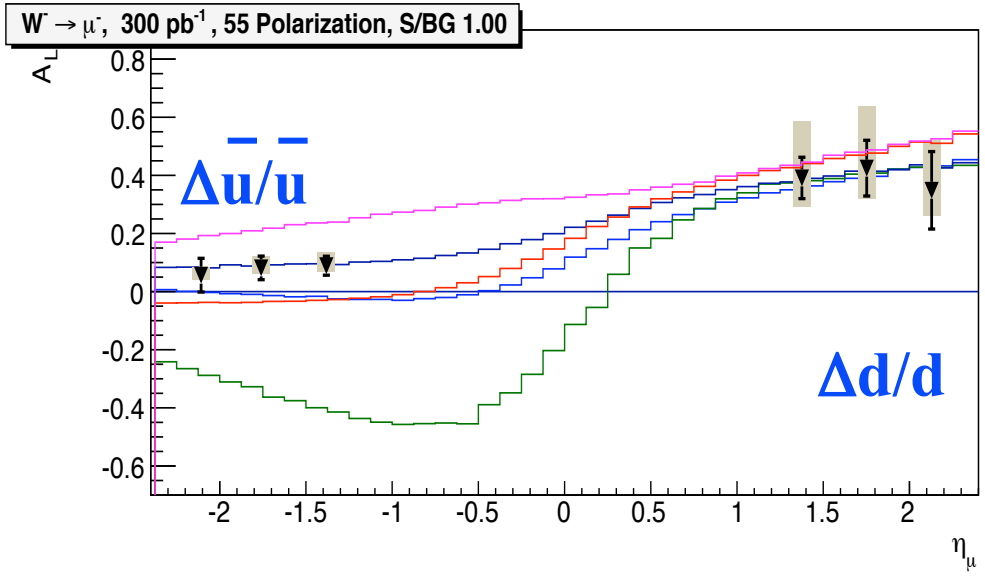
Run-13 top priority: finish W measurement!

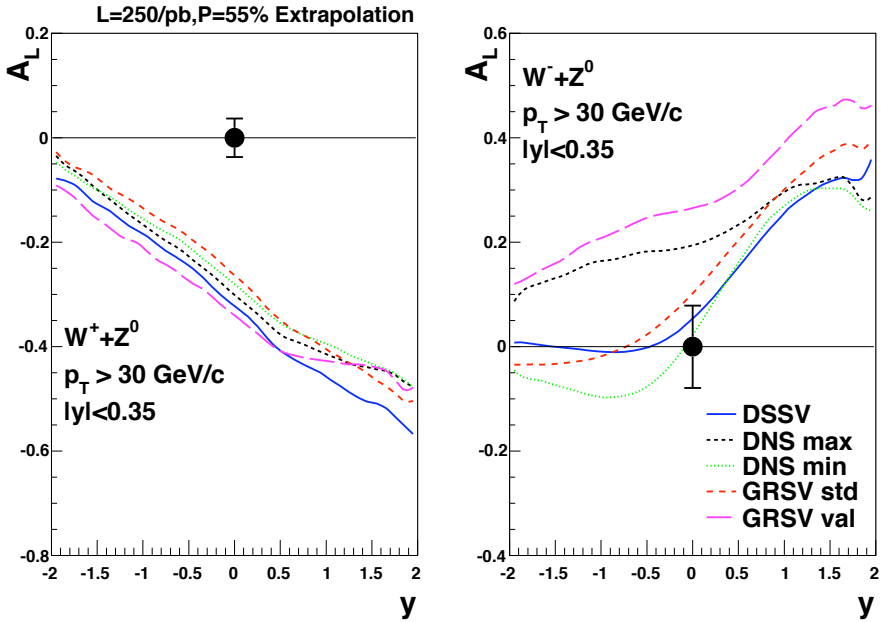




inclusive high p_T leptons

∫Ldt=300pb^{-1} in 30cm, P≥0.55

Need 250pb^{-1} in Run-13



Requires ∫Ldt=900pb^{-1}

Combined Run-11,12,13

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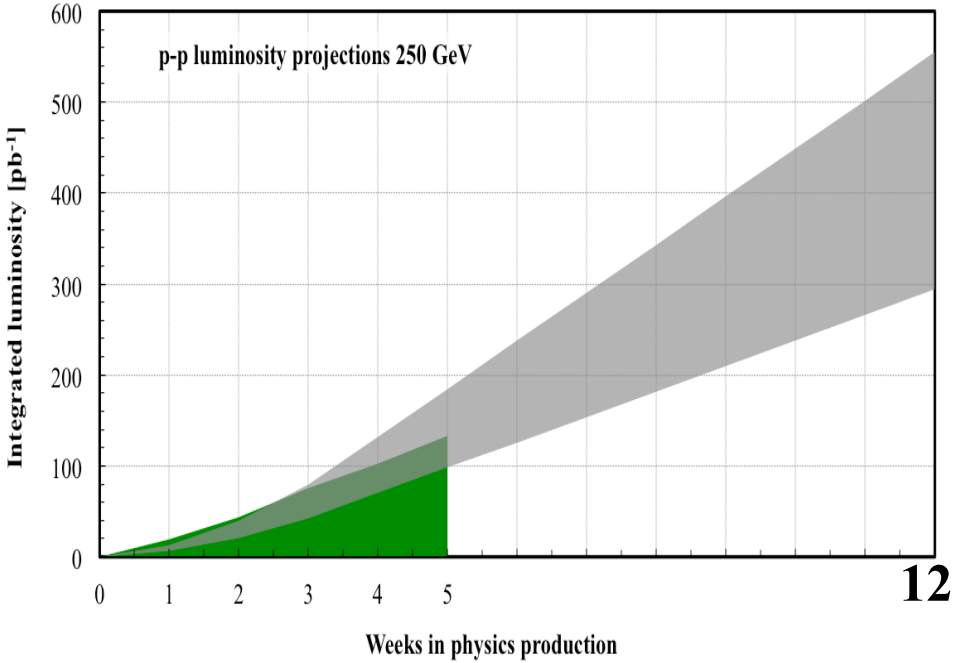
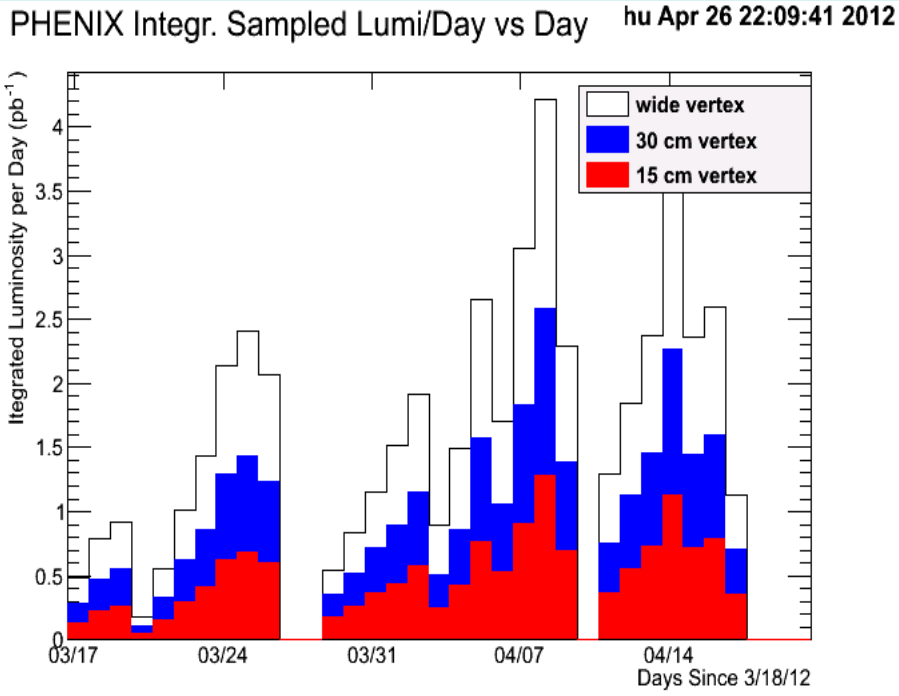
A concern

- **Can this program be completed in 2013?**
  - **NSAC milestone HP8 is set for 2013, RIKEN milestone in 2014**
  - **Curtailed running weeks also preclude stretch-out**
- **300 pb^{-1} in 30 cm is necessary for impactful measurement!**
  - **Plots are for 55% polarization, RHIC will match/exceed**
  - **The issue is integrated lumi – must optimize ops approach**
  - **PHENIX working to improve efficiency & vertex cut impact**

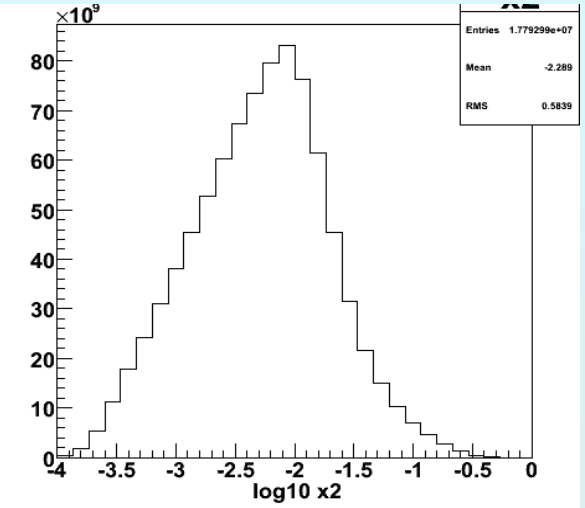


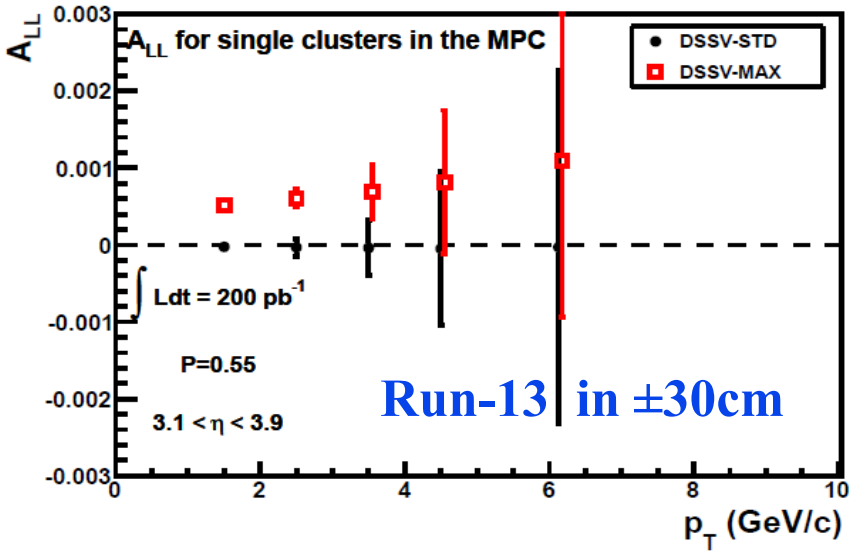


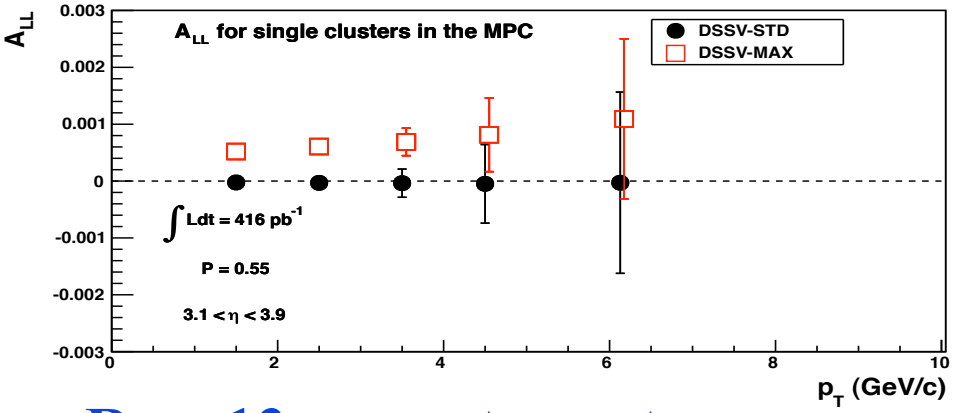
$\Delta g : \pi^0 A_{LL}$

Δg is small! 500 GeV offers lower x, higher luminosity

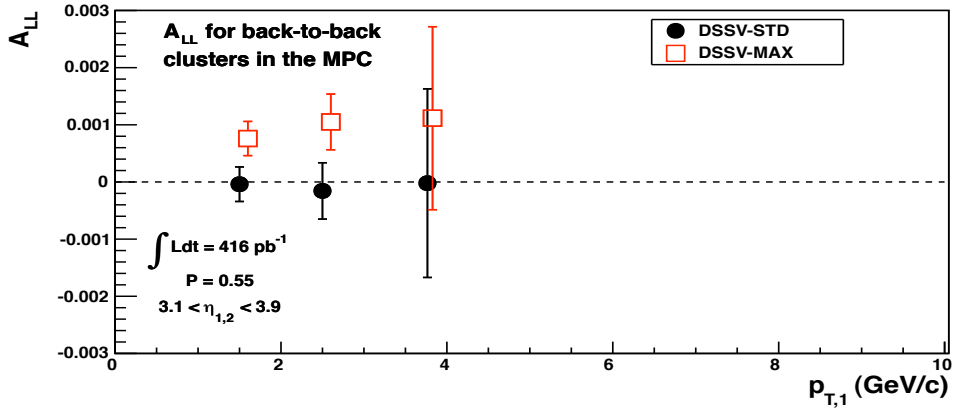
x gluon for π^0 in MPC

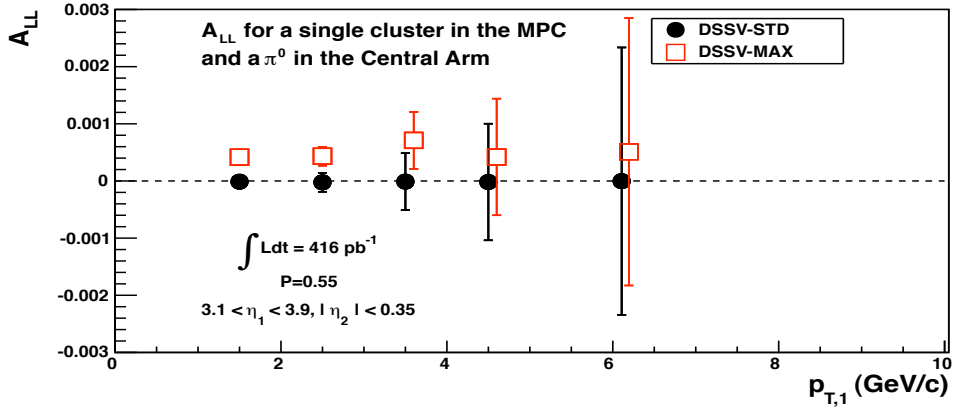




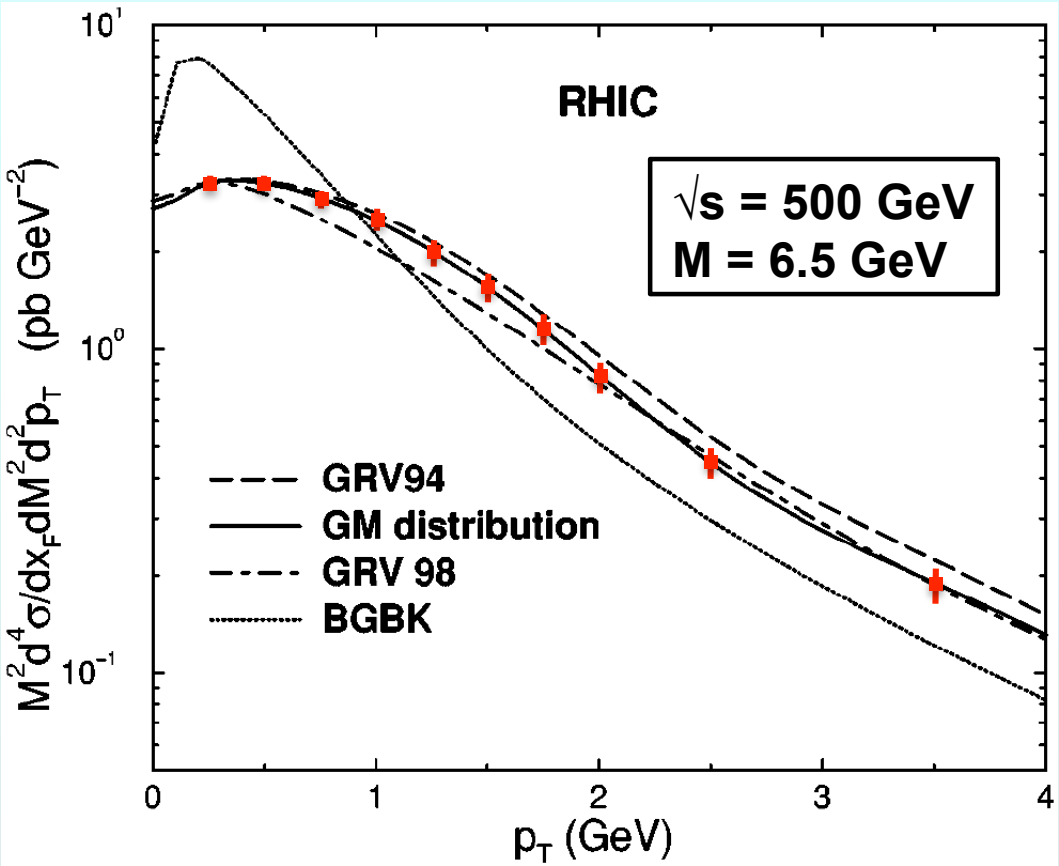


Run-13 no vertex cut





Drell Yan proof of principle



50 pb^{-1} into ±10cm, assuming 50% matches in FVTX

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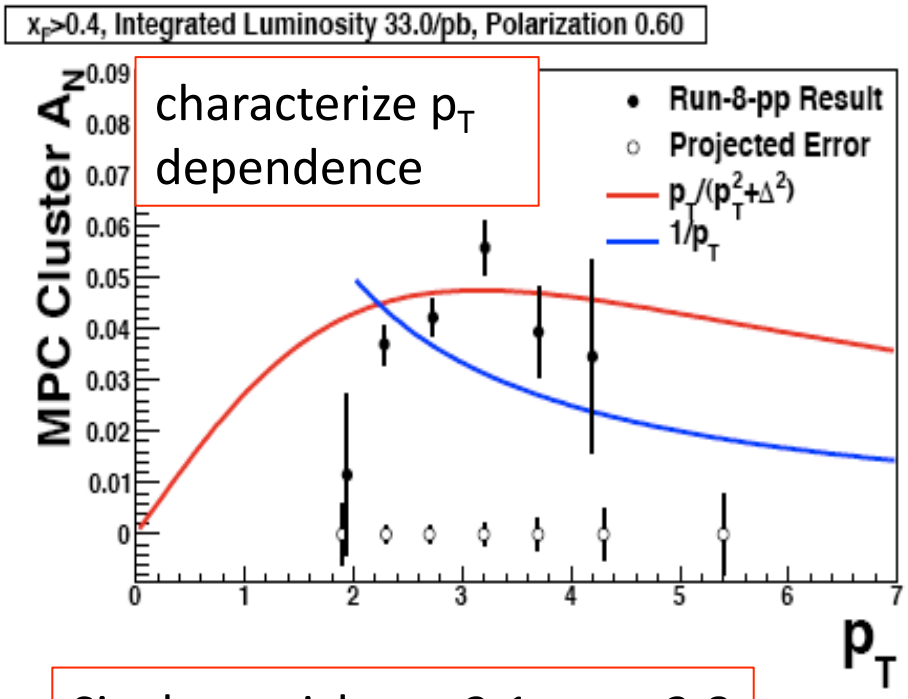
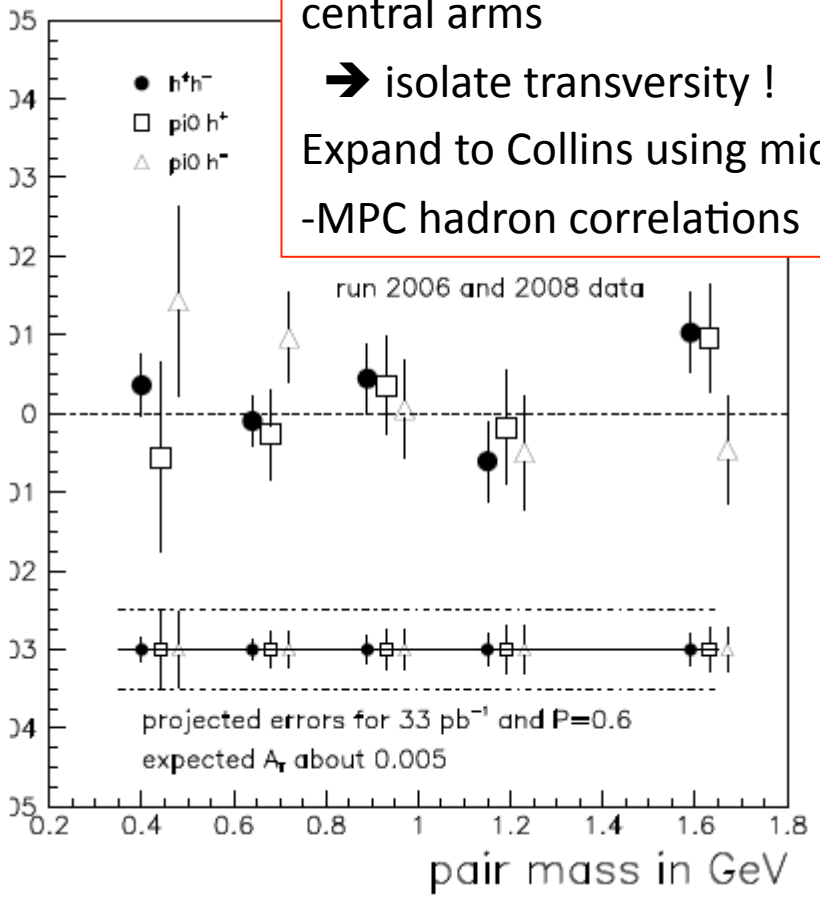
2nd priority for Run-13: 200 GeV p+p

- **Double duty:**
  reference for c,b in AuAu + transverse spin physics
- **Assume ∫Ldt=33pb^{-1} in 30cm (Run 8+12+13)**
  (4 x existing lumi, better polarization)



Single particles at $3.1 < \eta < 3.8$

Hadron pairs: IFF in central arms
➔ isolate transversity !
Expand to Collins using mid--MPC hadron correlations



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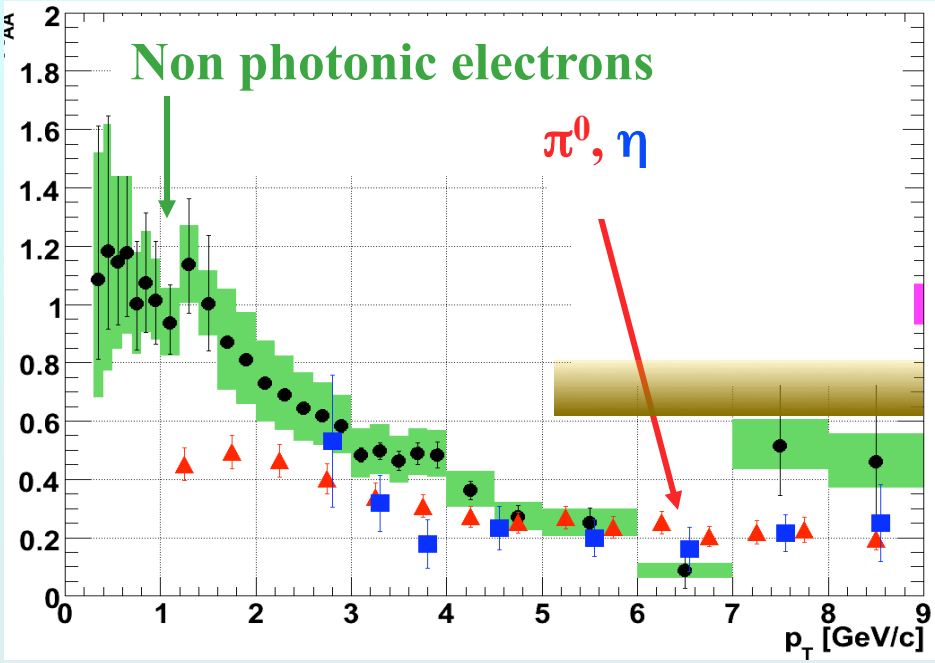
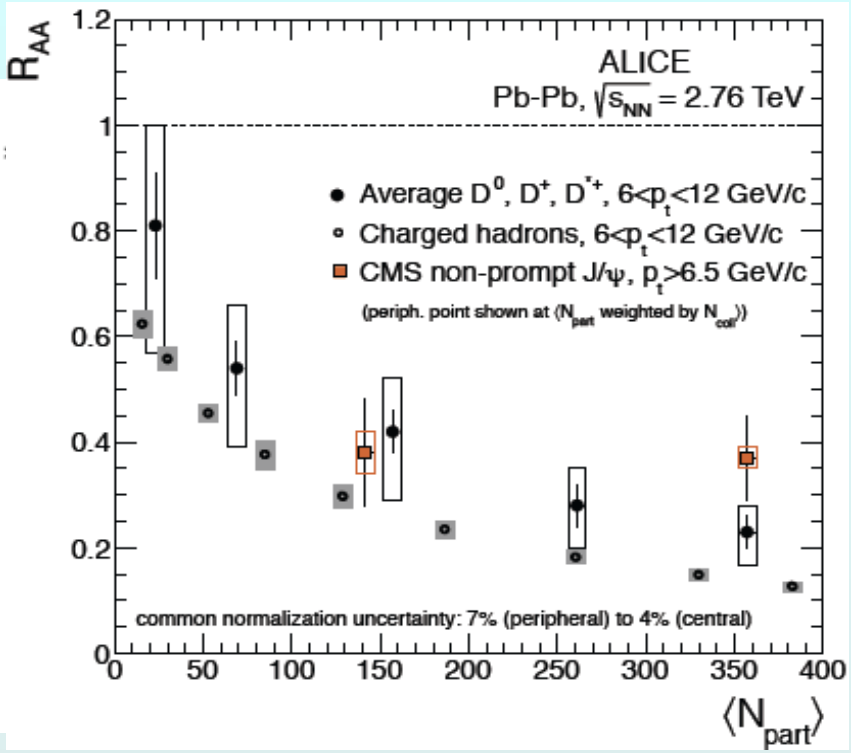
Heavy quark energy loss: a wakeup call





- more energy loss than gluon radiation can explain!
- charm quarks flow along with the liquid

Mix of radiation + collisions (diffusion)

but collisions with what?

Drag force of strongly coupled plasma on moving quark?

Test with b quarks…

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Run-14 highest priority: 200 GeV Au+Au

- Separate charm and bottom measurements
  - Constrain energy loss mechanism
    - radiative energy loss differs; role of collisions?
    - compare with AdS/CFT picture
  - Heavy quark diffusion: different, sensitive probe of η/s
  - Also important to measure ψ' at forward rapidity
    - help sort out initial state effects vs. dissociation
- Utilize our new silicon detectors
  - Key data set with VTX – Au+Au and p+p comparison
  - First Au+Au with FVTX at forward rapidity

2^{rd} priority: 200 GeV p+p comparison for c, b R_{AA}

Hopefully this is already done in Run-13…

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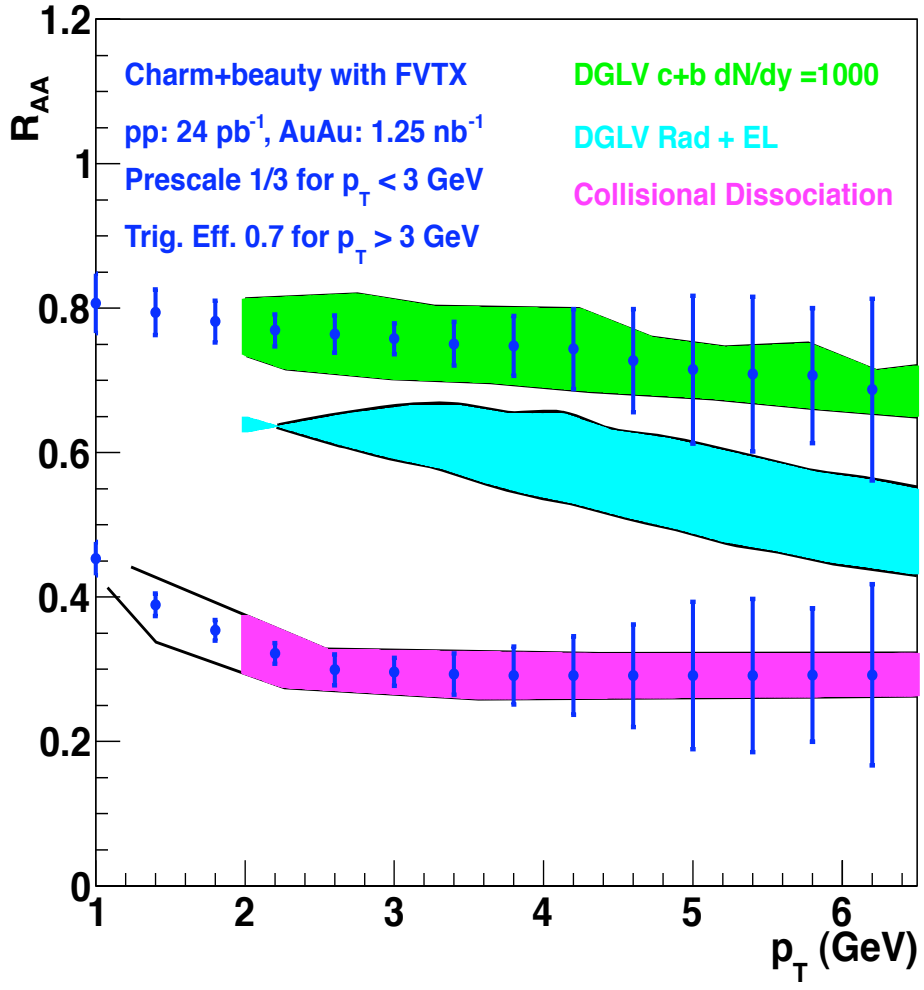
FVTX physics

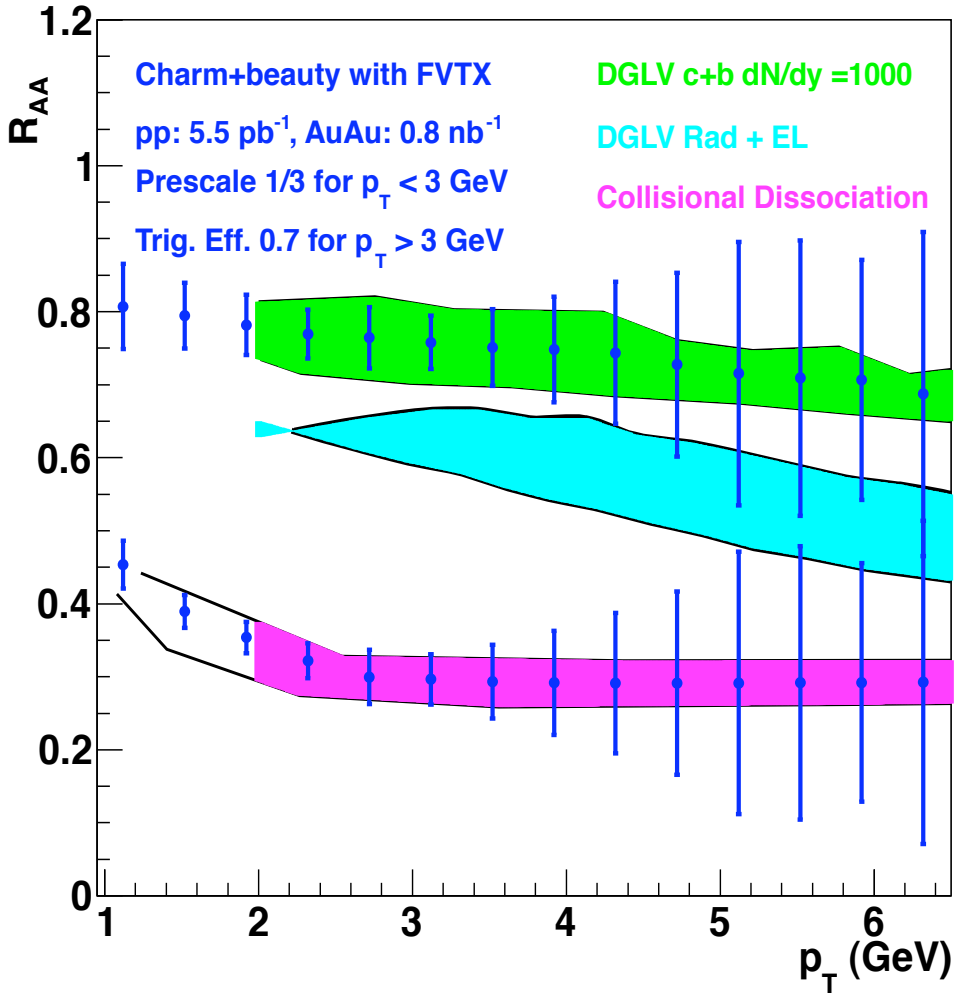
R_{AA}^{c+b} with FVTX

The goal



R_{AA}^{c+b} with FVTX

Run-14 alone



NB: plots account for trigger rejection (non)power

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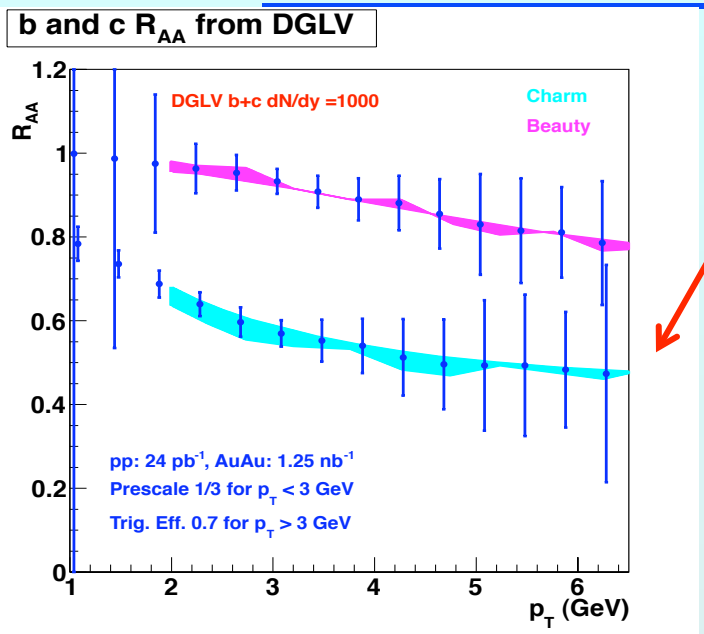
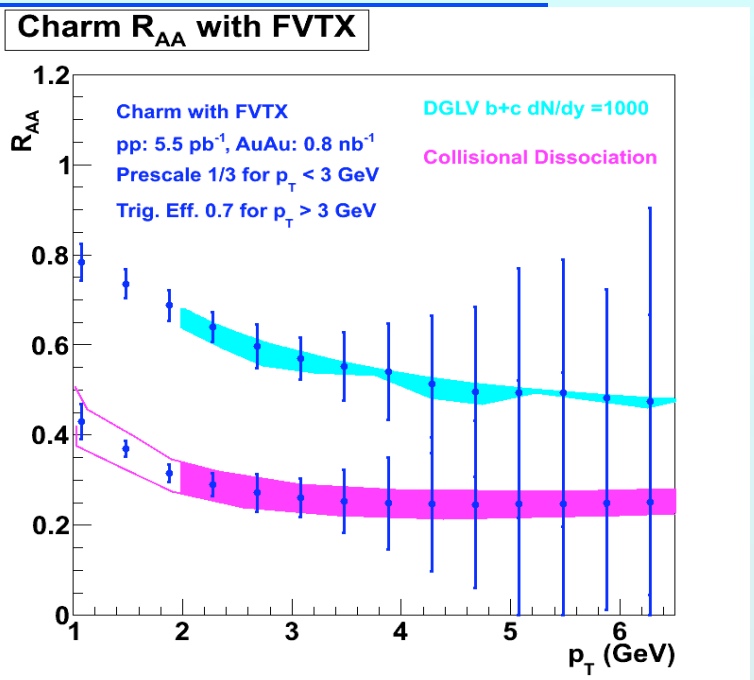
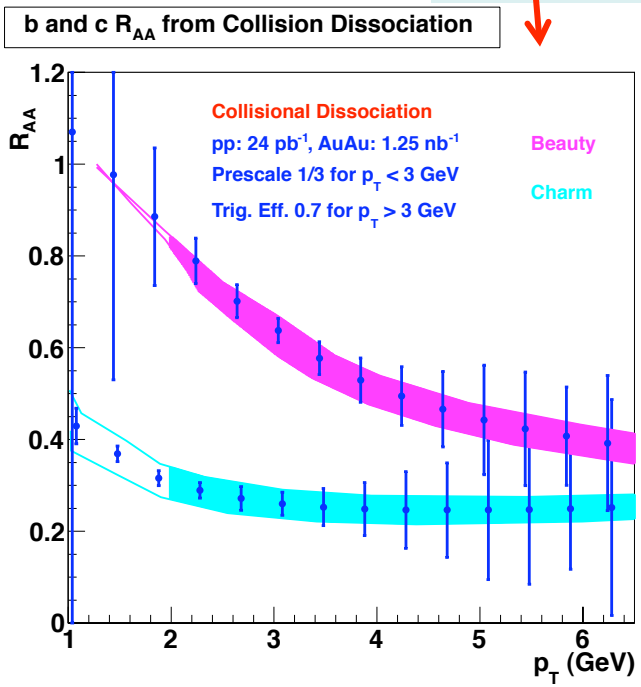
D vs. B meson decays via DCA in FVTX

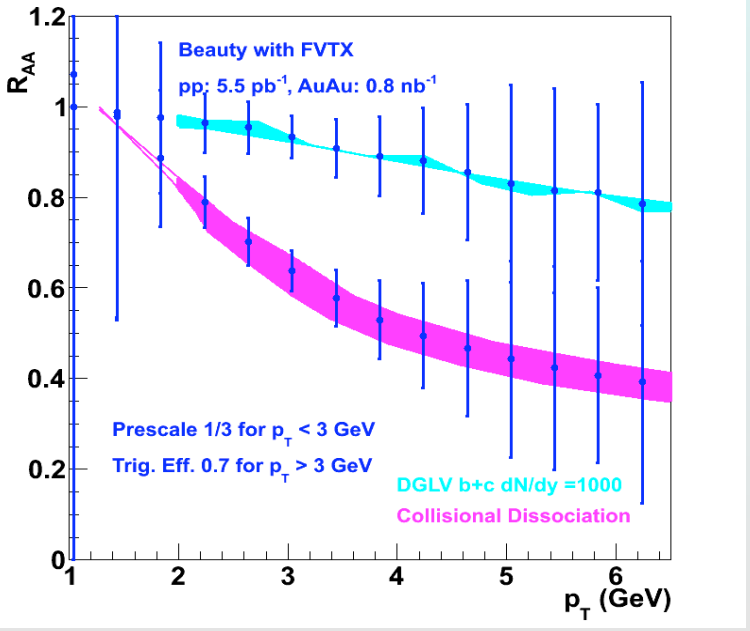


goal

Run-14







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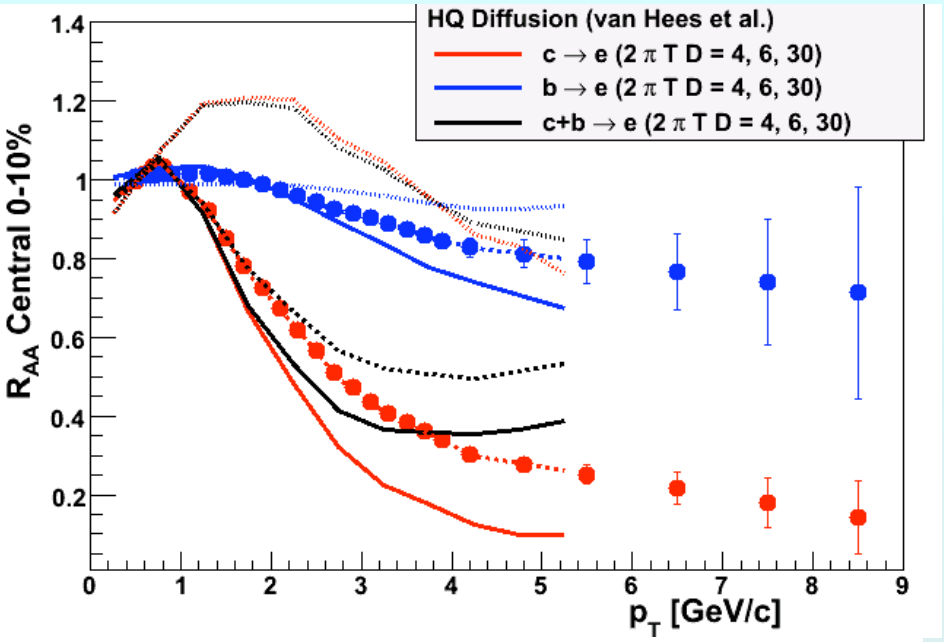
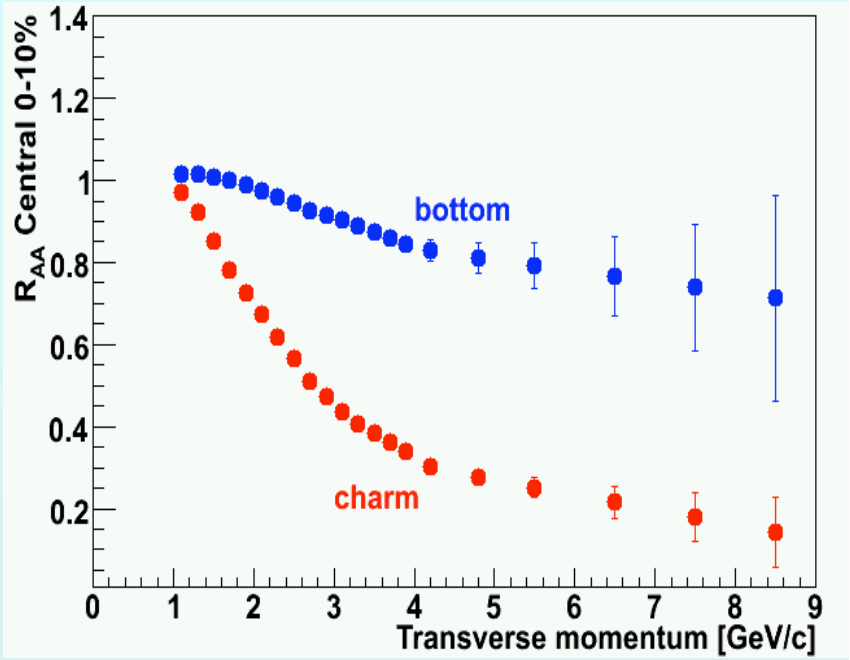
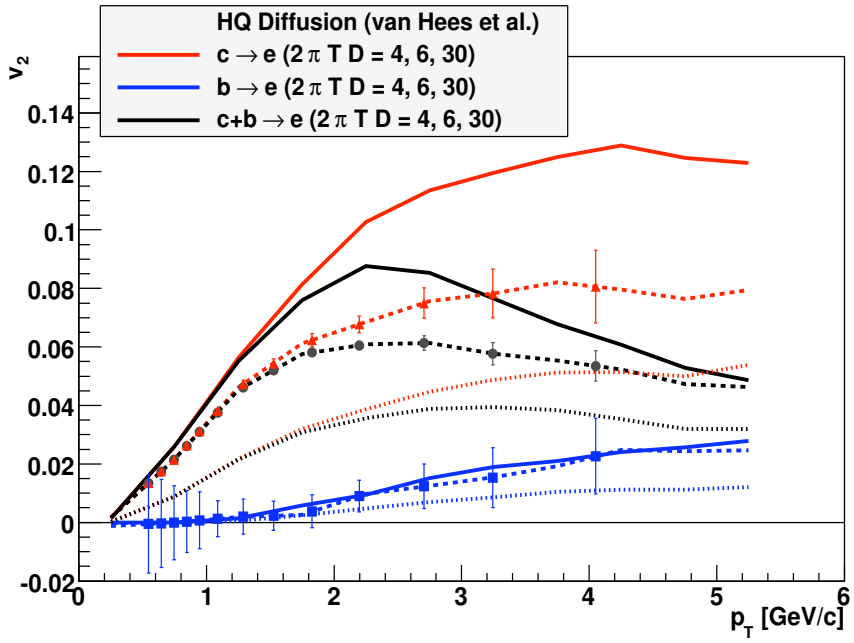
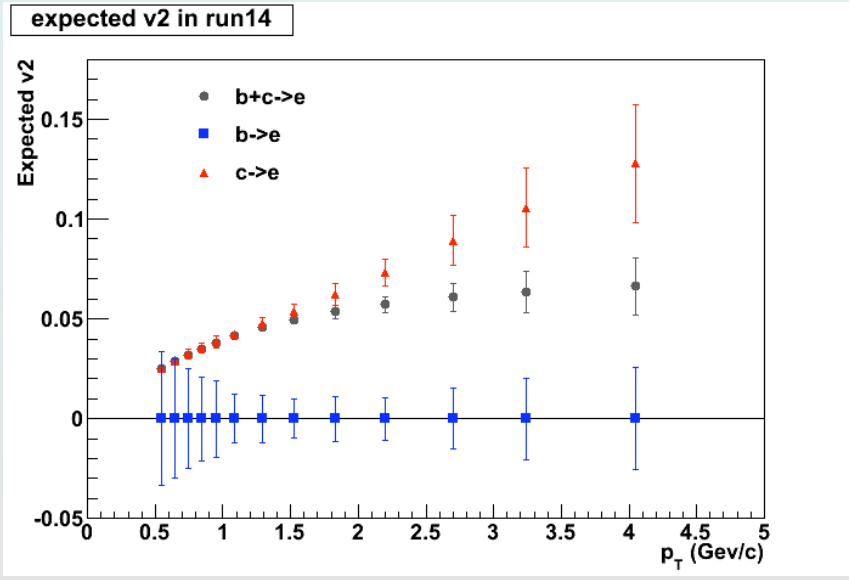
VTX expected performance

Run-14

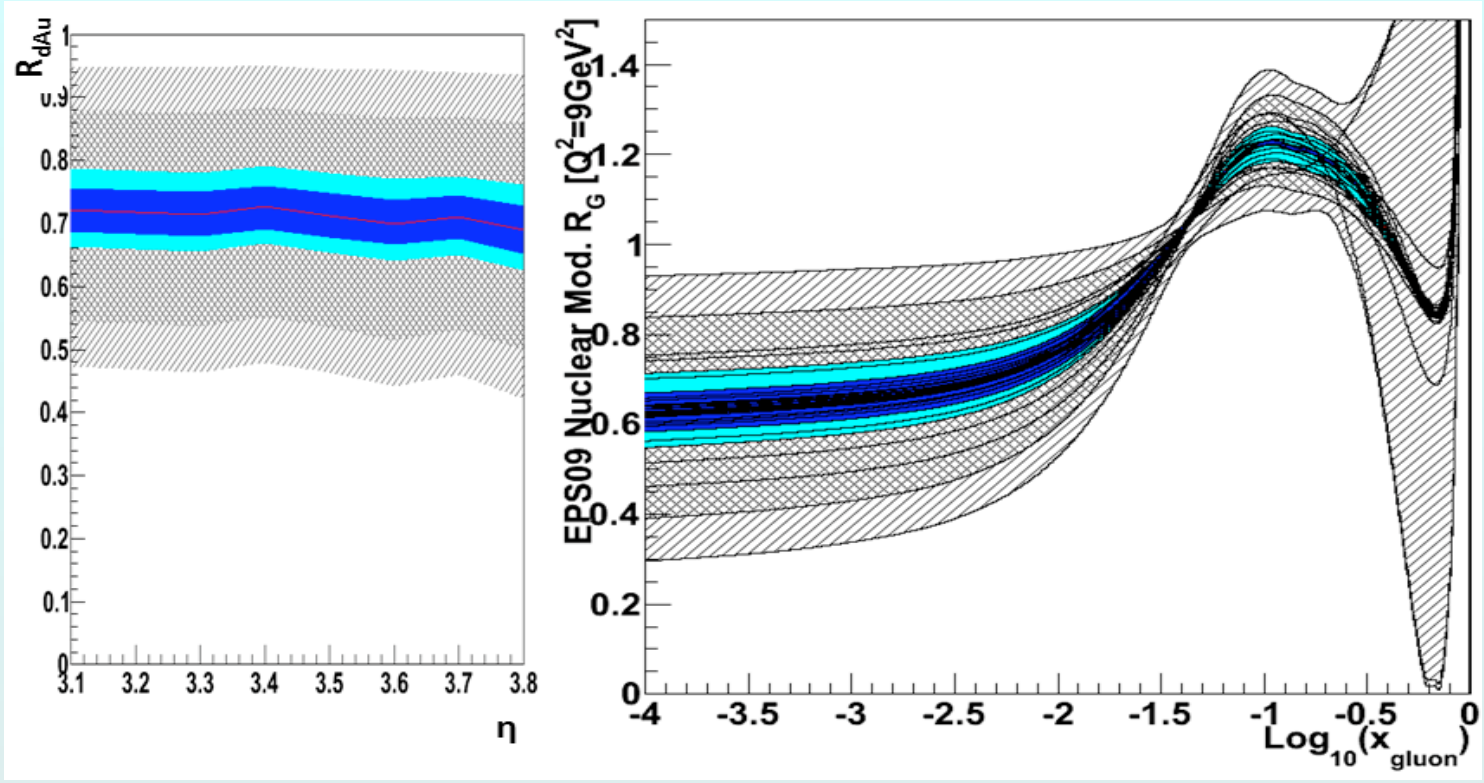








3rd priority: Direct photons in MPC-EX in CNM



- Anticipated performance with direct γ in MPC-EX

  49 pb^{-1} of p+p and 0.35 pb^{-1} of d+Au (full vertex)

  ~ 12 weeks of d+Au and p+p. *Start in Run-14*

- May require p+Au instead, due to dilution from isospin effect on q+g -> q+γ. If so, will request dedicated p+Au run in 2015

  Issue is being investigated…

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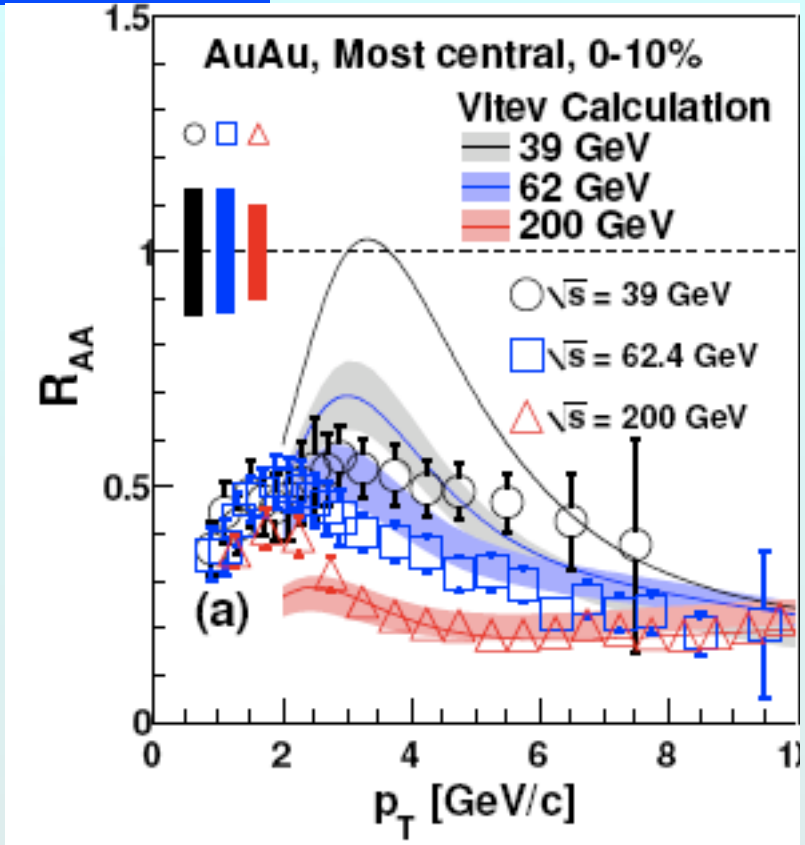
low E p+p comparison

- 39 GeV requirements
  - R_{AA} for J/ψ: 0.72 pb^{-1} in 30 cm
  - R_{AA} for π^0
    - p_T=6.5 GeV/c: 0.28 pb^{-1} in 30 cm



- RHIC can deliver
  - 0.6 pb^{-1} per week, or 86 nb^{-1}/ day
  - Recorded in 30 cm: 28 nb^{-1}/ day
  - 10 days would yield 280 nb^{-1}
  - 7 days would yield 196 nb^{-1}

- Request 1 week of comparison running
  - But if feasible to deliver 2.2 pb^{-1}, PHENIX would deliver
    - R_{AA} instead of R_{CP} for J/ψ

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PHENIX beam use proposal

Species	$\sqrt{s_{NN}}$ (GeV)	weeks	|z|<30cm	|z|<10cm	delivered	Polariz.
Run13:						
p+p	500	10-15	250 pb^{-1}	97 pb^{-1}	~750 pb^{-1}	55%
p+p	200	4	16 pb^{-1}	> 5.5 pb^{-1}	48 pb^{-1}	60%
or p+p	*39*	*1*	*0.2-0.3* pb^{-1}		*0.9* pb^{-1}	
Run-14:						
Au+Au	200	6-8	1.7 nb^{-1}	1 nb^{-1}	5 nb^{-1}	
d+Au	200	Rest of run				

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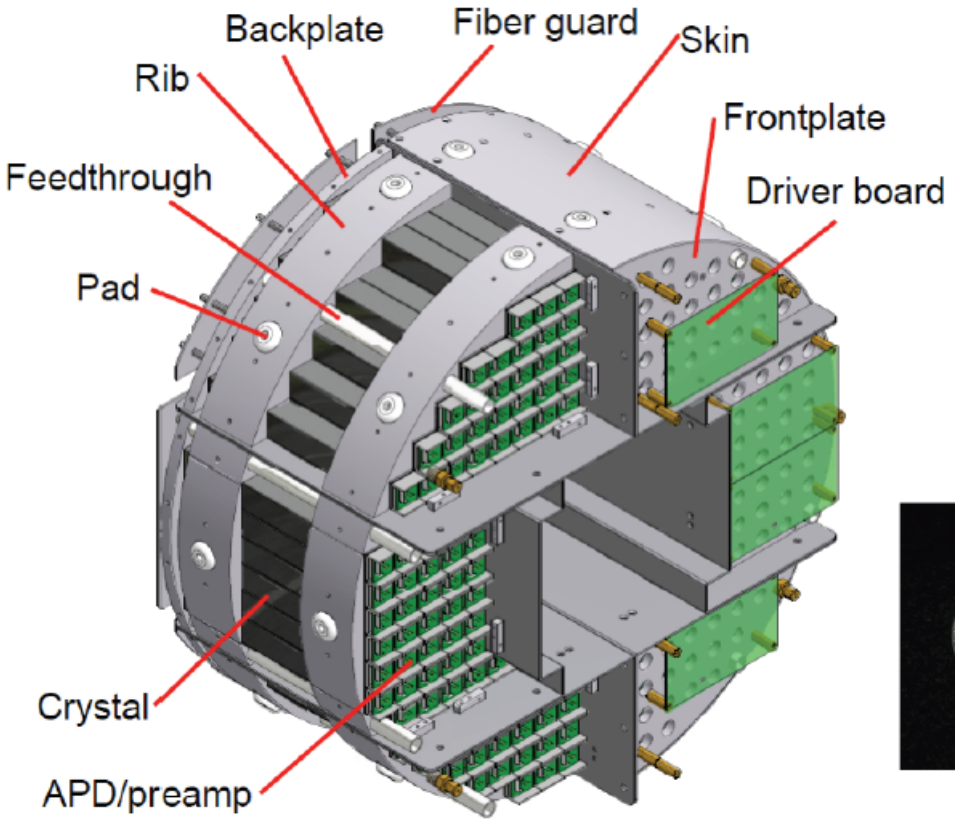
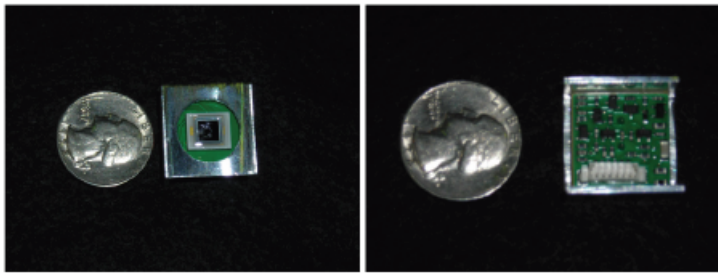
- **backup slides**

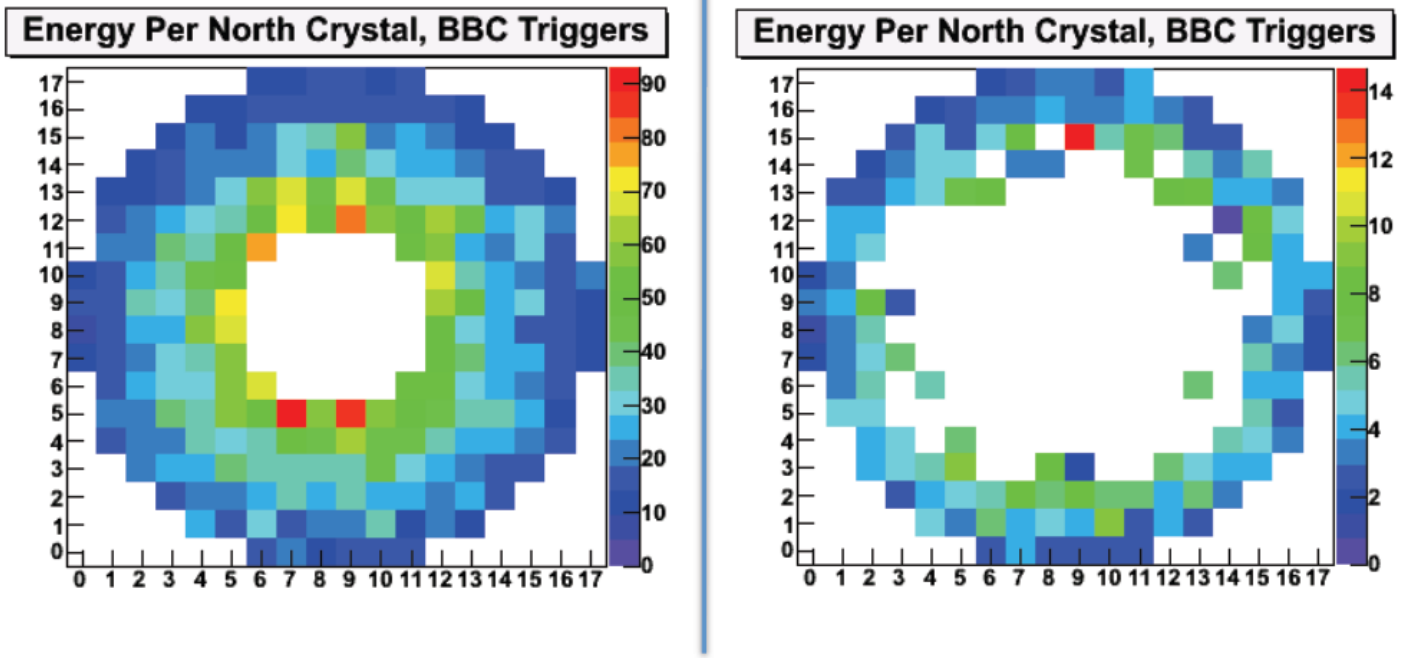
MPC Damage in Run-12





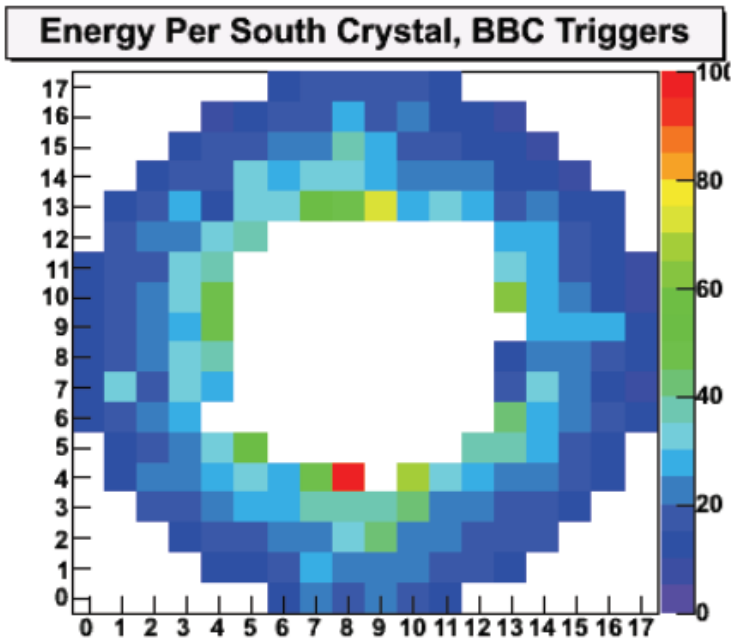
- **APD/Preamp had seen beam-loss damage in the past but not on such a large scale**
- **The last significant loss occurred during Run-10 where we lost in each of two unexpected beam dumps.**

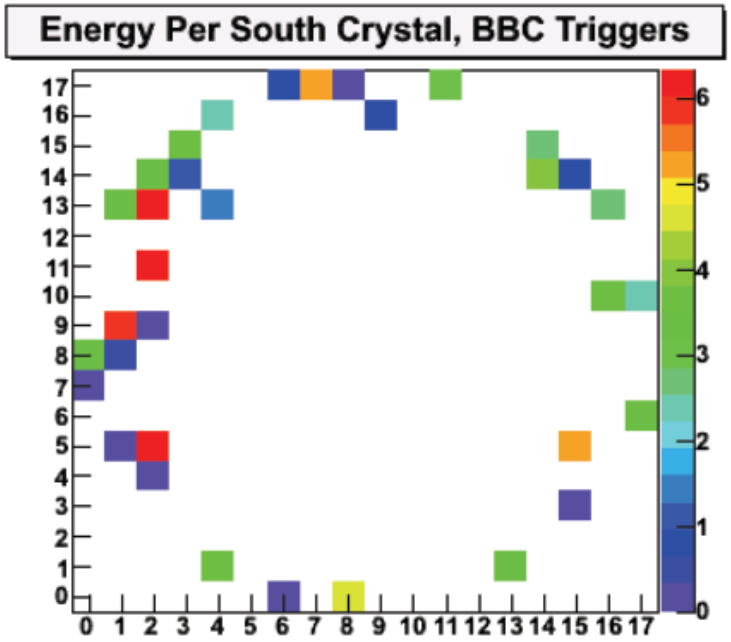
MPC North Damage Before and After Beam Dump



Damage by Au beam

MPC South Damage Before and After Beam Dump

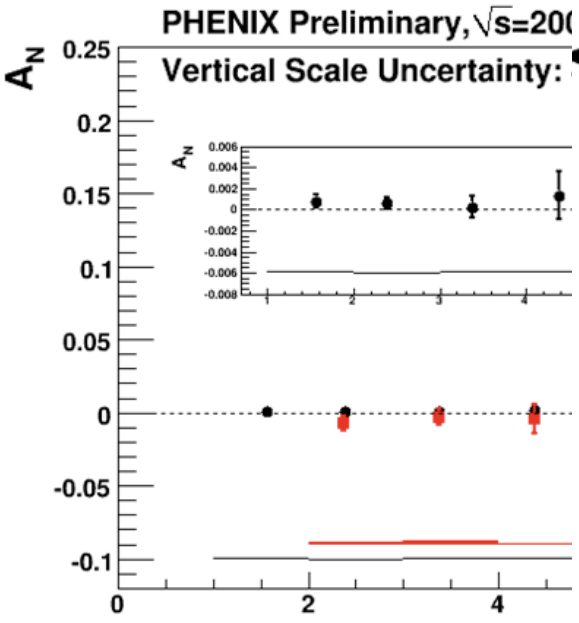


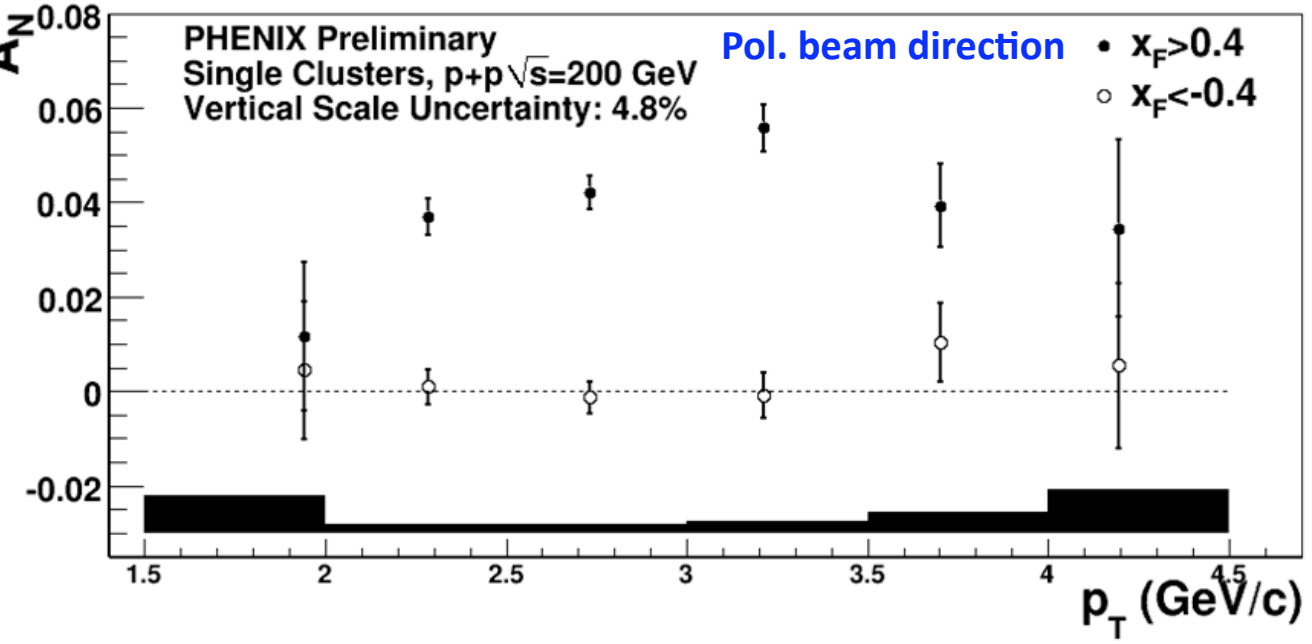


- We lost 300/416 readout channels total
- Repair must wait until the summer shutdown
- Work will take ~ 2 additional weeks beyond the pre-accident scheduled MPC maintenance time
- We will add diode protection to the preamp hybrid. Requires making 400+ new hybrids
- C-AD agrees to add collimators between beam dump near 10 o'clock and the PHENIX IR

Transverse single spin asymmetries

- A_N ~ 0 at mid-y, large at forward rapidity. Why??
  - Initial state correlations between k_T & p spin? (Sivers)
  - Spin dependent fragmentation functions? (Transversity x Collins)
  - Effects at sub-leading twist? (Qiu, Sterman)





- Past measurements statistics limited ➔more 200 GeV data!

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NSAC milestone HP13 (sign change in Sivers asymm. in DY) requires 125 pb^{-1} in PHENIX

Future HI Milestones

Requires upgrade

Year	#	Milestone
2009	DM4	Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.
2010	DM5	Measure the energy and system size dependence of J/Ψ production over the range of ions and energies available at RHIC.
2010	DM6	Measure e^+e^- production in the mass range $500 \leq m_{e+e-} \leq 1000$ MeV/c2 in $\sqrt{s_{NN}} = 200$ GeV collisions.
2010	DM7	Complete realistic calculations of jet production in a high density medium for comparison with experiment.
2012	DM8	Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions.
2015	DM9 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ from 5 to 40 GeV to search for evidence of a critical point in the QCD matter phase diagram.
2014	DM10 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
2014	DM11 (new)	Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies from $\sqrt{s_{NN}} = 30$ GeV up to 5.5 TeV.
2016	DM12 (new)	Measure production rates, high pT spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}} = 200$ GeV.

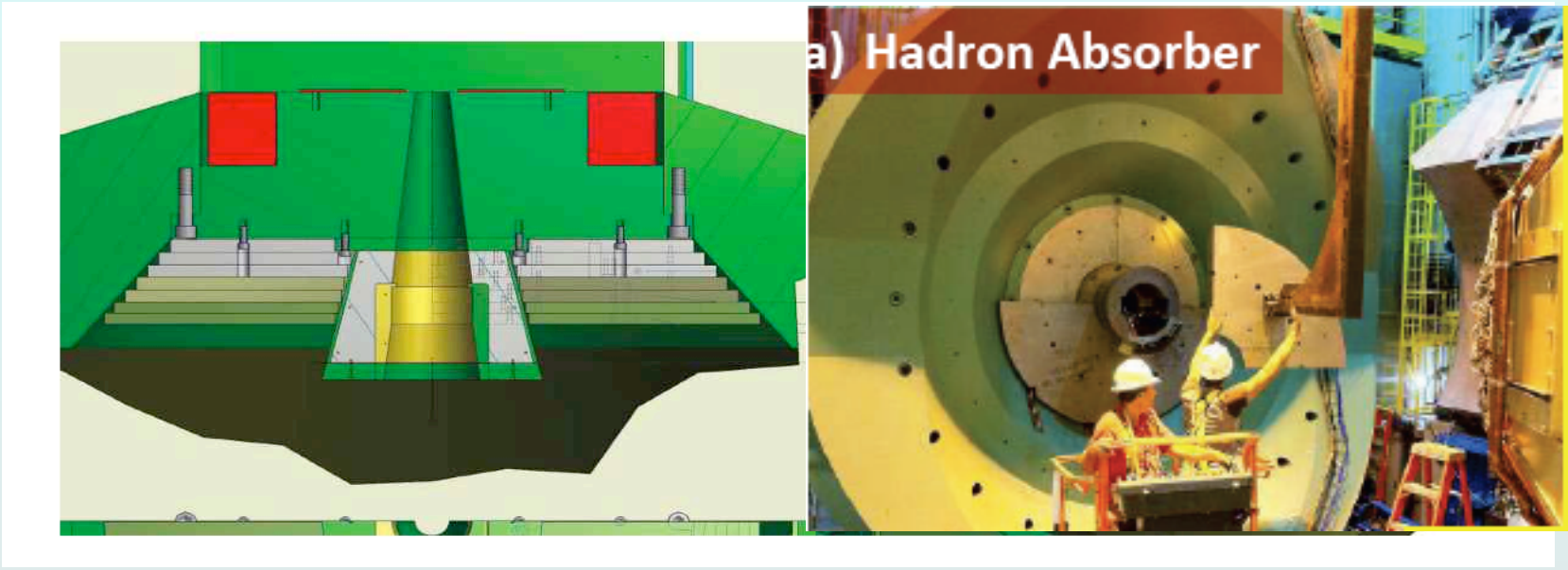
Spin Physics Milestones

Year	#	Milestone
2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12	Determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.

Muon arm background reduction

Stainless steel SS-130 absorbers, 12 tons each side (!)

2 interaction lengths, based upon simulations



Installed on both muon arms during 2010 shutdown

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Muon trigger status, first look at Run-11 data

Rejection power
~1100 @ 2.7MHz

S/B~1/2 first look

Anticipate 3/1 after tuning

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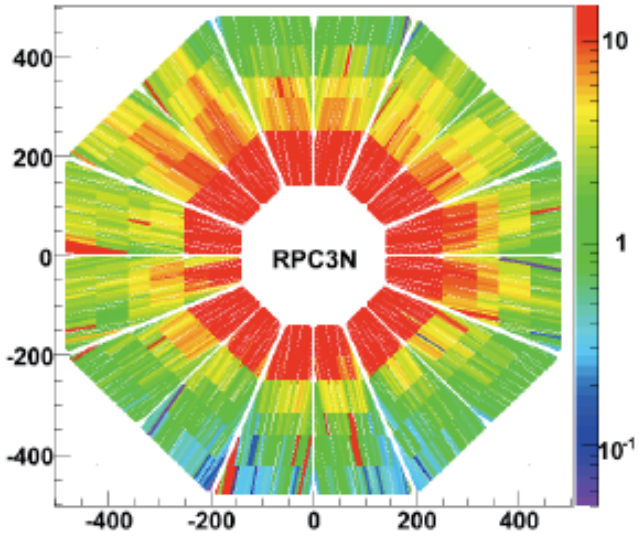
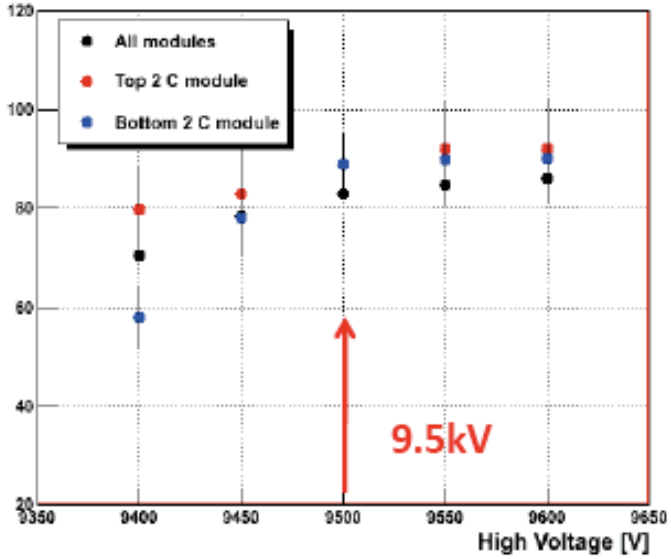
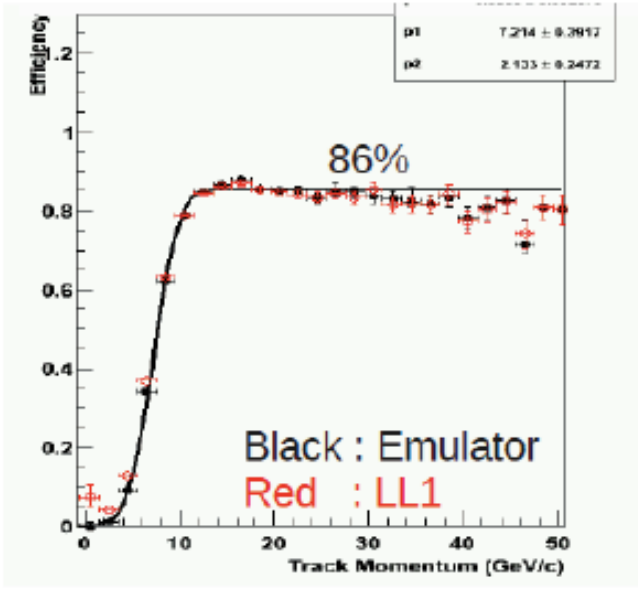
a) RPC Hit Map



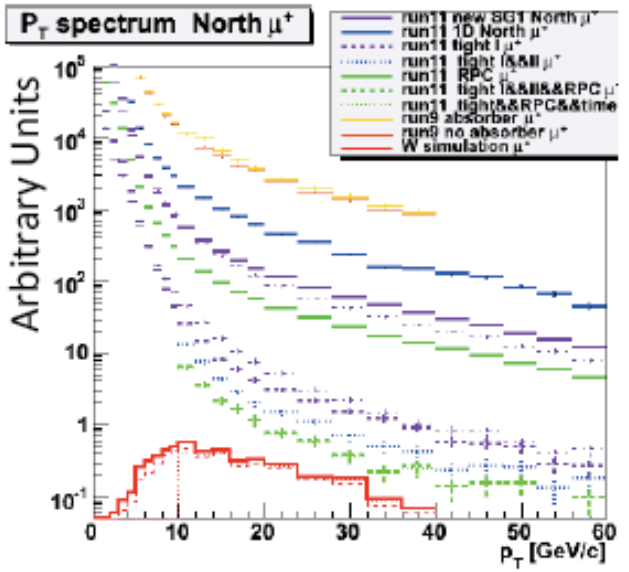
b) RPC-3 Efficiencies



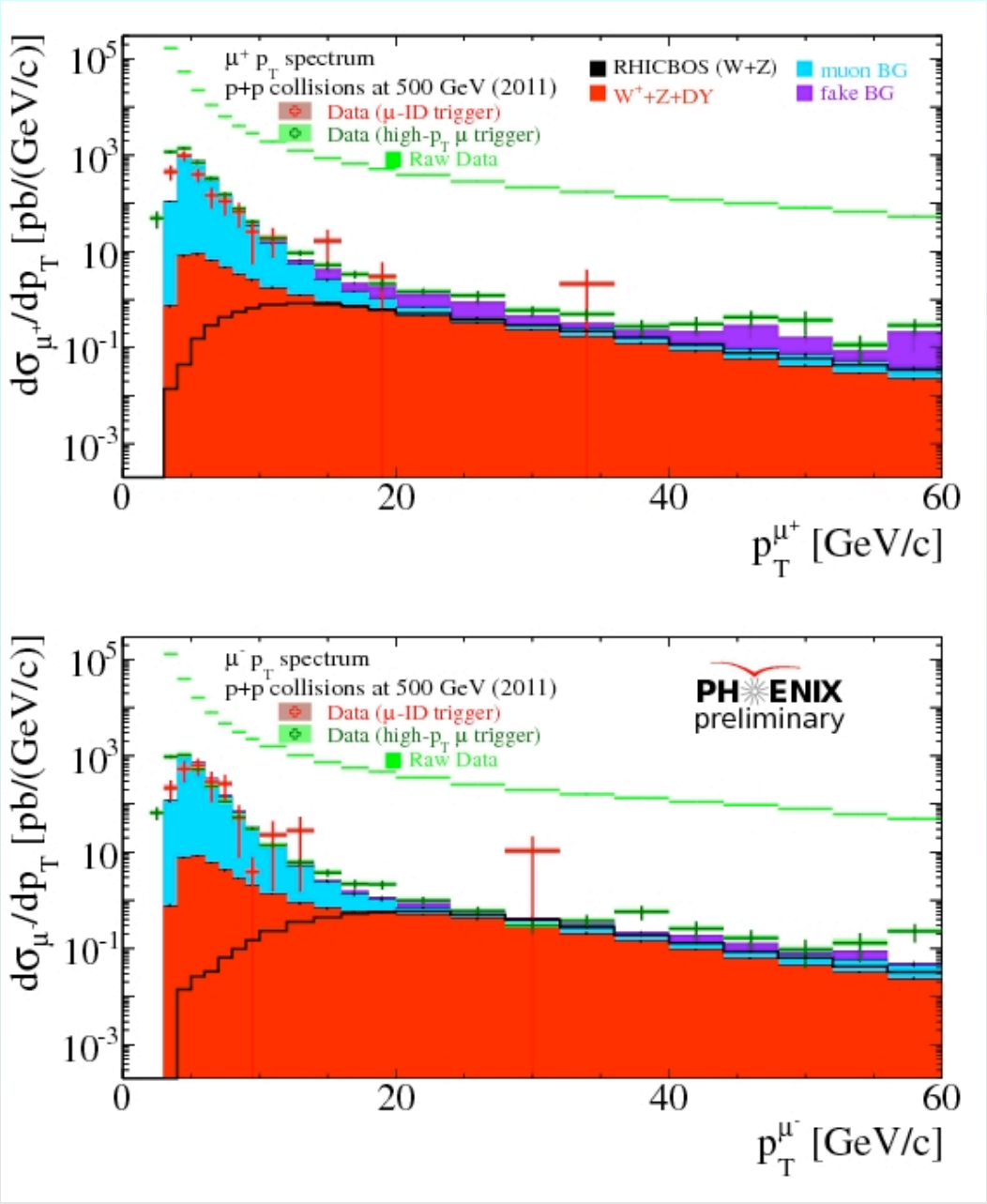
c) MuTrig-Efficiencies



d) High p_T Background



W decay muon spectra



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Status: Thermal Radiation at RHIC Energies

- PHENIX measured thermal e^+e^- and γ from $\sqrt{s_{NN}}$ = 200 GeV

- Soft low mass dilepton puzzle

  larger excess beyond contribution from hadronic phase with medium modified ρ-meson properties… not from hadronic phase

  soft momentum distribution … not from hot partonic phase

- Thermal photon puzzle

  Large thermal yield with T > 220 MeV (10-20% of decay photons)

  … suggests early emission

  Large elliptic flow (v2) … suggests late emission

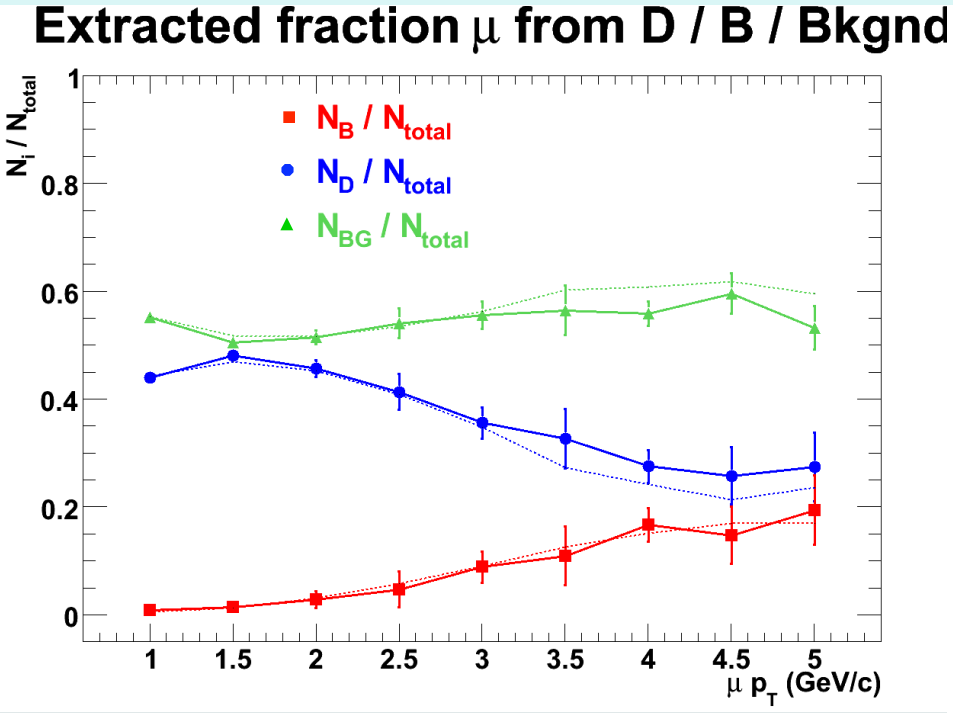
PHENIX data on E&M probes seems INCONSISTENT with standard hydro space-time evolution!

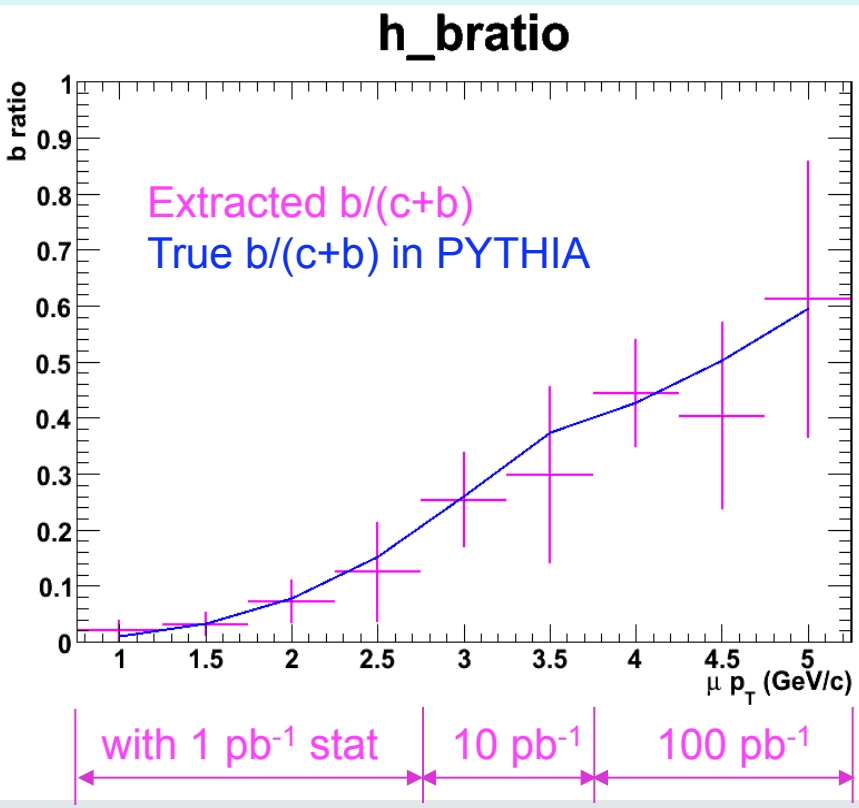
And exhibits UNKOWN additional sources!

Speculation: look between impact (t=0) and τ_0

PHENIX *Axel Drees, HP2012*

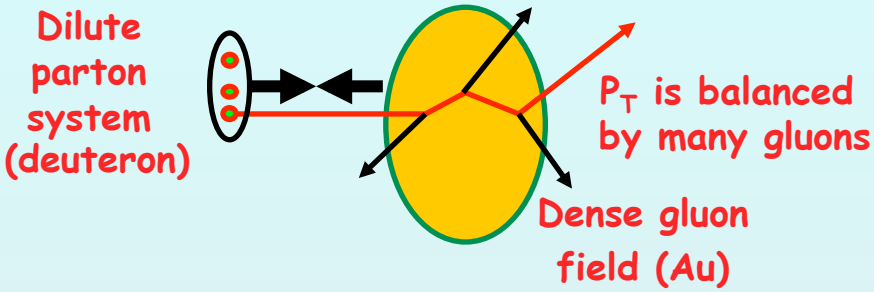
Beauty & charm separation at different muon p_T

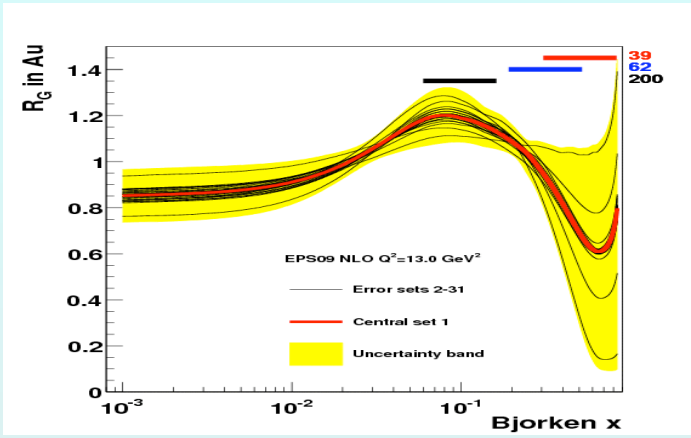




Cold Nuclear Matter (CNM) and Low-x Partons in Nuclei

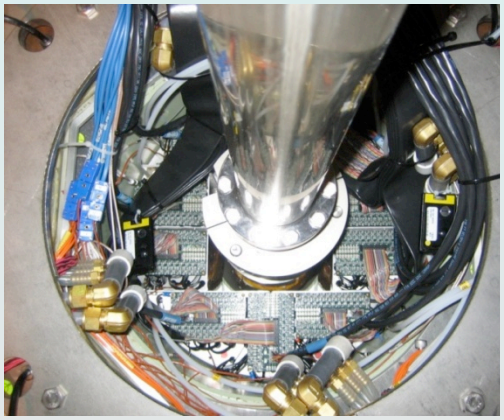
other probes of shadowing & gluon saturation – forward hadrons

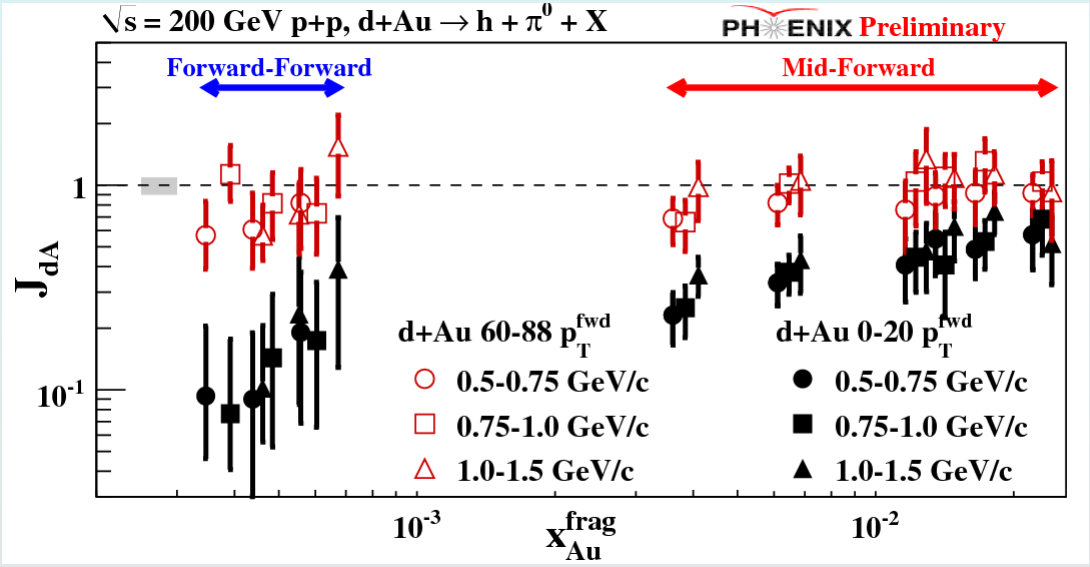




Mono-jets in the gluon saturation (CGC) picture give suppression of pairs per trigger and some broadening of correlation

Kharzeev, NPA 748, 727 (2005)





$$x_{Au}^{frag} = \frac{< p_{T1} > e^{-<\eta_1>} + < p_{T2} > e^{-<\eta_2>}}{\sqrt{s}}$$

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6/21/2011

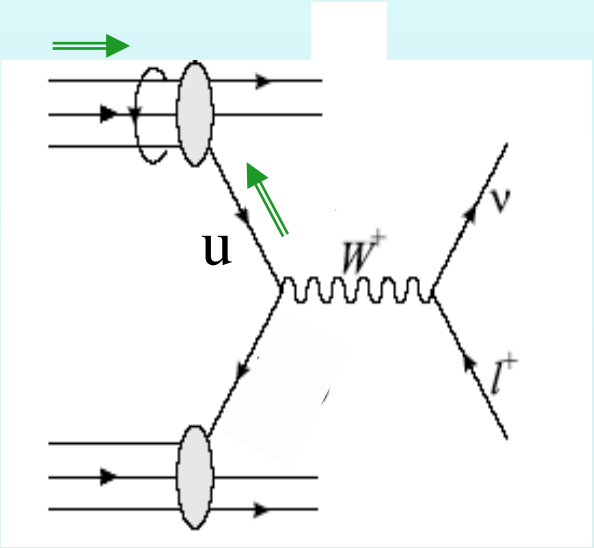
ΔG not large: sea quarks polarized? d vs. u?

Probe $\Delta\bar{q}$-Δq via W production

$$\Delta d + \bar{u} \rightarrow W^-$$
$$\Delta \bar{u} + d \rightarrow W^-$$
$$\Delta \bar{d} + u \rightarrow W^+$$
$$\Delta u + \bar{d} \rightarrow W^+$$

$\vec{p}$

p unpol.



100% Parity-violating: $A_L = \dfrac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

Start: 2009(tests)/2010(trigger) with 500 GeV p+p

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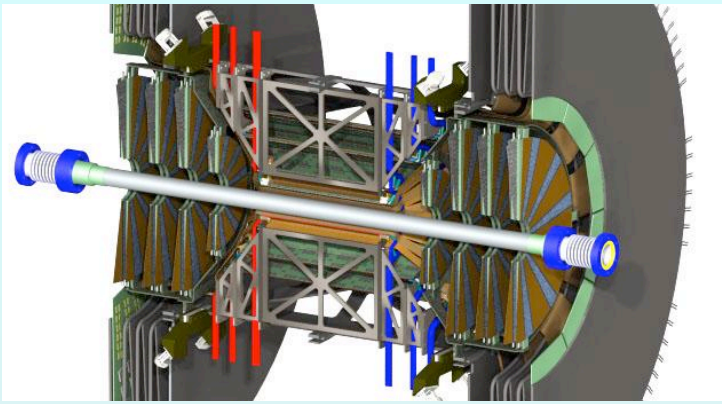
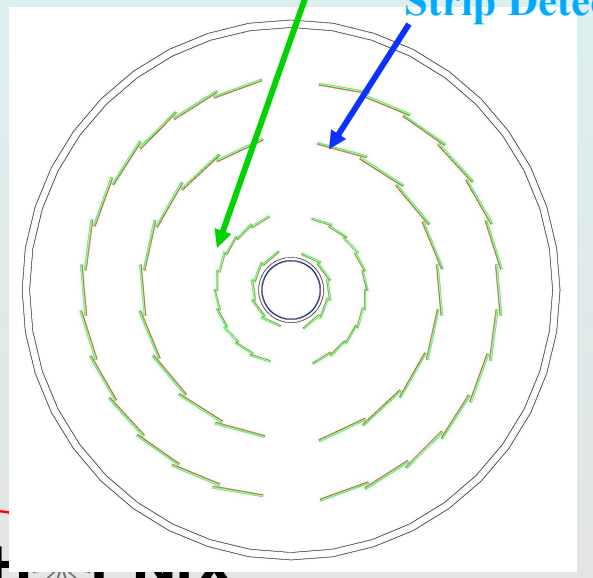
Barrel VTX Detector

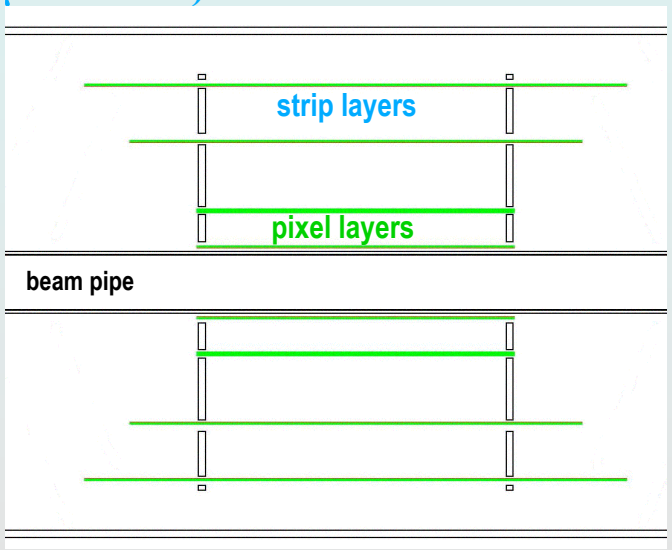


- **Specifications:**
  - Large acceptance ($\Delta\phi \sim 2\pi$ and $|\eta| < 1.2$)
  - Displaced vertex measurement $\sigma < 40$ μm
  - Charged particle tracking $\sigma_p/p \sim 5\%$ p at high pT
  - Detector must work for both HI and pp collisions.
- **Technology Choice**
  - Hybrid pixel detectors developed at CERN for ALICE
  - Strip detectors, sensors developed at BNL with FNAL's SVX4 readout chip

Hybrid Pixel Detectors (50 μm x 425 μm) at R ~ 2.5 & 5 cm

Strip Detectors (80 μm x 3 cm) at R ~ 10 & 14 cm





$|\eta|<1.2$
$\phi \sim 2\pi$
$z \sim \pm 10$ cm

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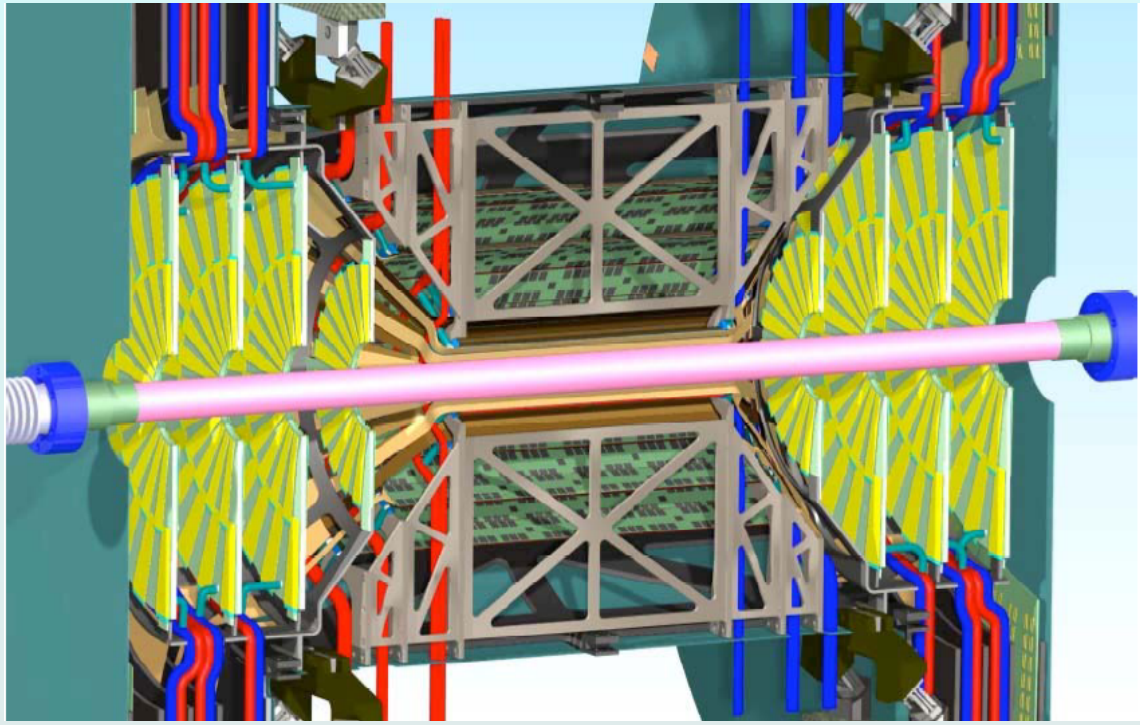
Forward Silicon Vertex Detector - FVTX

FVTX Specifications:

- 2 endcaps
- 4 pixelpad layers/endcap
- ~550k channels/endcap
- Electronics a mod of BTeV readout chip
- Fully integrated mech design w/ VTX
- 2π coverage in azimuth and $1.2 < |\eta| < 2.4$
- Better than 100 μm displaced vertex resolution



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