PHENIX Beam Use Proposal for Runs 12 & 13

run	species	$\sqrt{s_{NN}}$	weeks	$\int L\,dt$ $|z| < 30$ cm	$|z| < 10$ cm	pol.	comments
12	$p+p$	200	5	$13.1\,pb^{-1}$	$4.7\,pb^{-1}$	60% (T)	HI comparison, $\perp$ spin
	$p+p$	500	8	$100\,pb^{-1}$	$35\,pb^{-1}$	50% (L)	W program + ΔG
	Au+Au	200	7		$0.8\,nb^{-1}$		heavy flavor (F/VTX)
	U+U	193	1.5		$0.03\,nb^{-1}$		explore geometry
	Au+Au	27	1	$5.2\,\mu b^{-1}$			energy scan
13	$p+p$	500	10	$200\,pb^{-1}$	$74\,pb^{-1}$	60% (L)	W program
	$p+p$	200	5	$20\,pb^{-1}$	$4.7\,pb^{-1}$	60% (T)	HI comparison
	Cu+Au	200	5		$2.4\,nb^{-1}$		control geometry
	U+U	193	5		$0.57\,nb^{-1}$		explore geometry

Barbara Jacak for the PHENIX Collaboration

http://www.phenix.bnl.gov/WWW/publish/jacak/sp/presentations/BeamUse11/BUP11.pdf

PHENIX

The PHENIX Experiment

- **An excellent track record for**

Major upgrade(s) most years

Sustained scientific productivity

Handling >1pbyte data sets

- **Fully utilize RHIC luminosity**

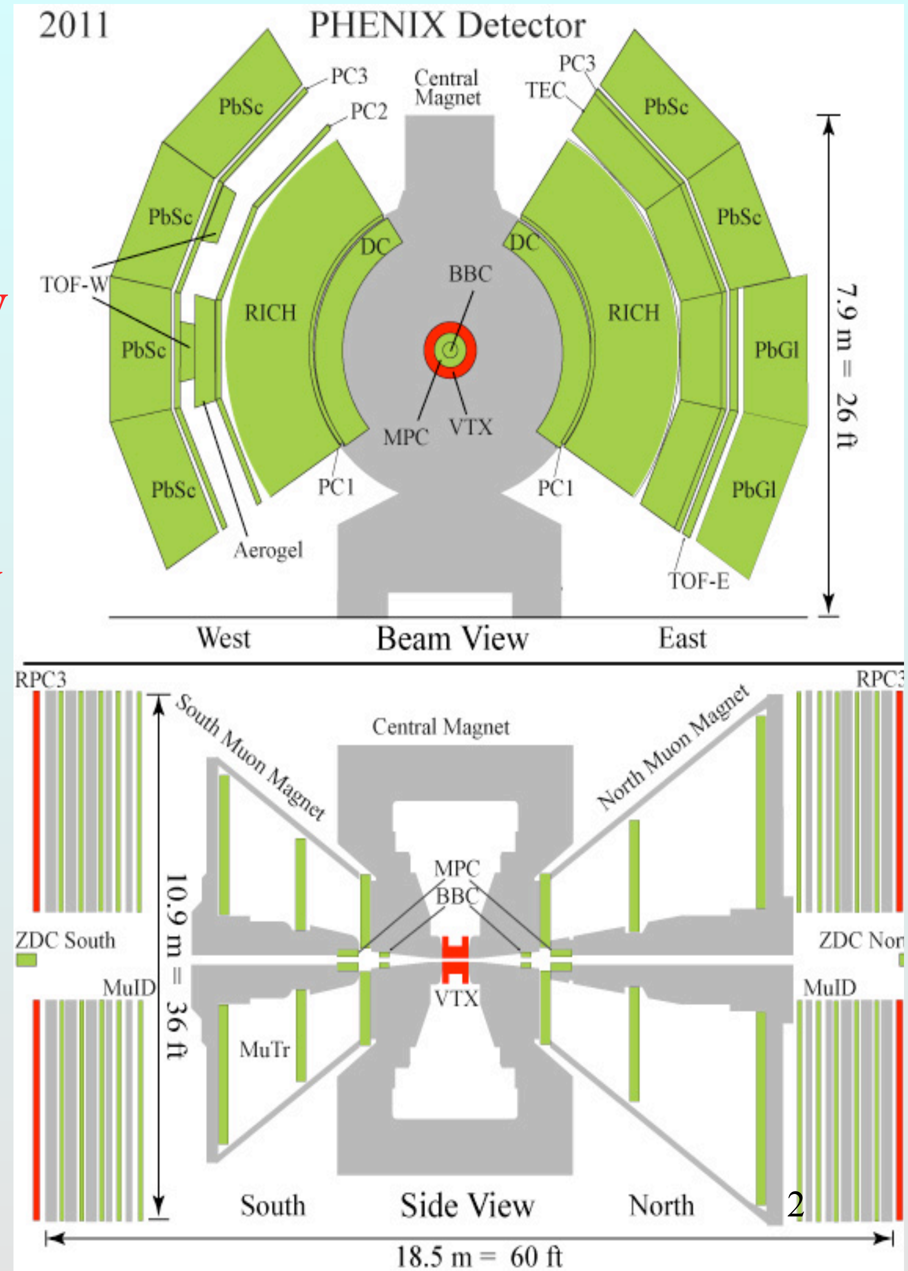
Data rate maintained w/VTX

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

- **Timely reconstruction**

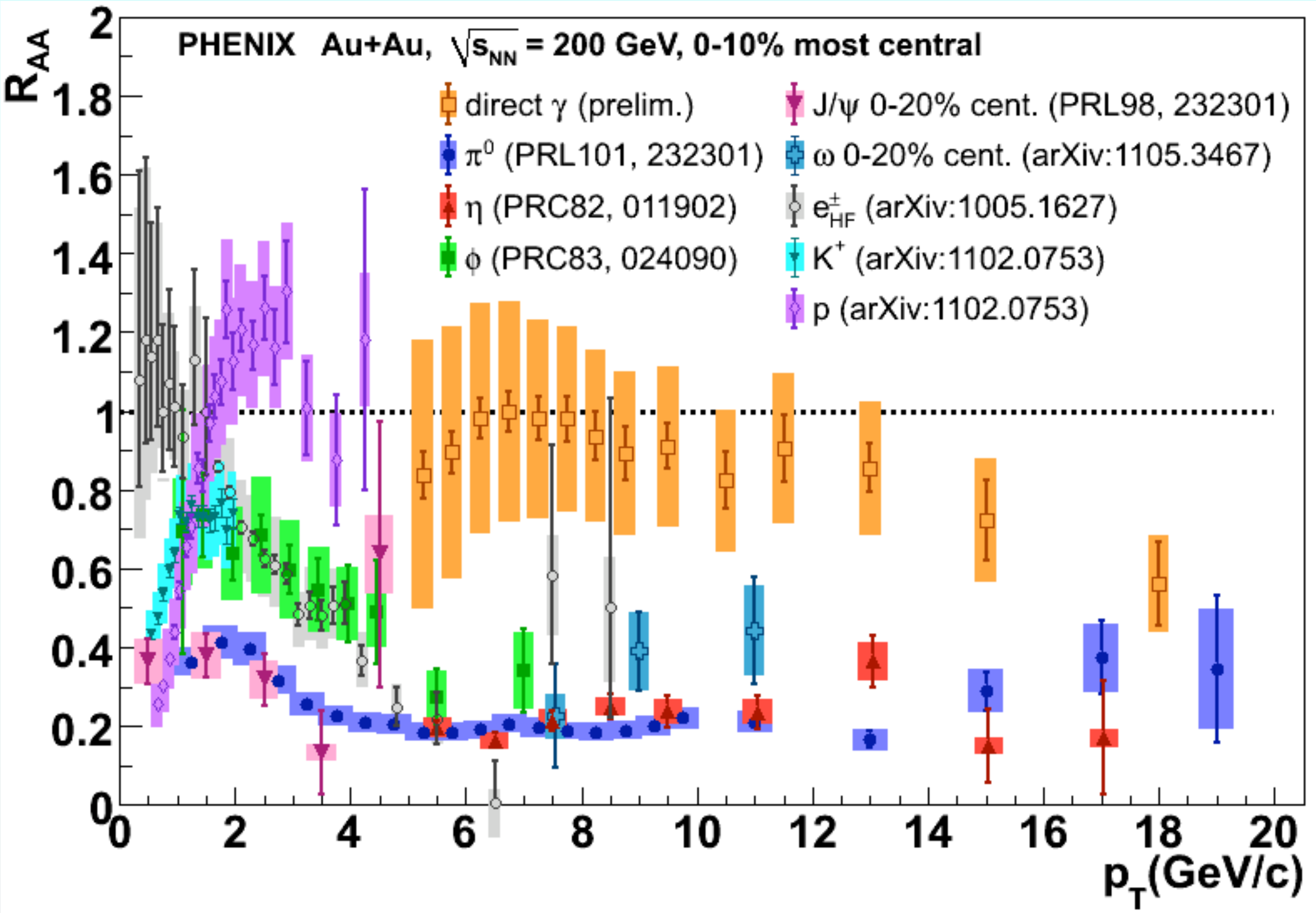
calibrate within ~1-2 days

data sets produced by next run



PHENIX

Unprecedented Reach and Precision



Superb particle ID, high rate capability and excellent trigger: broad physics capabilities over a large kinematic range

Recent Physics Accomplishments

New papers and preliminary results*

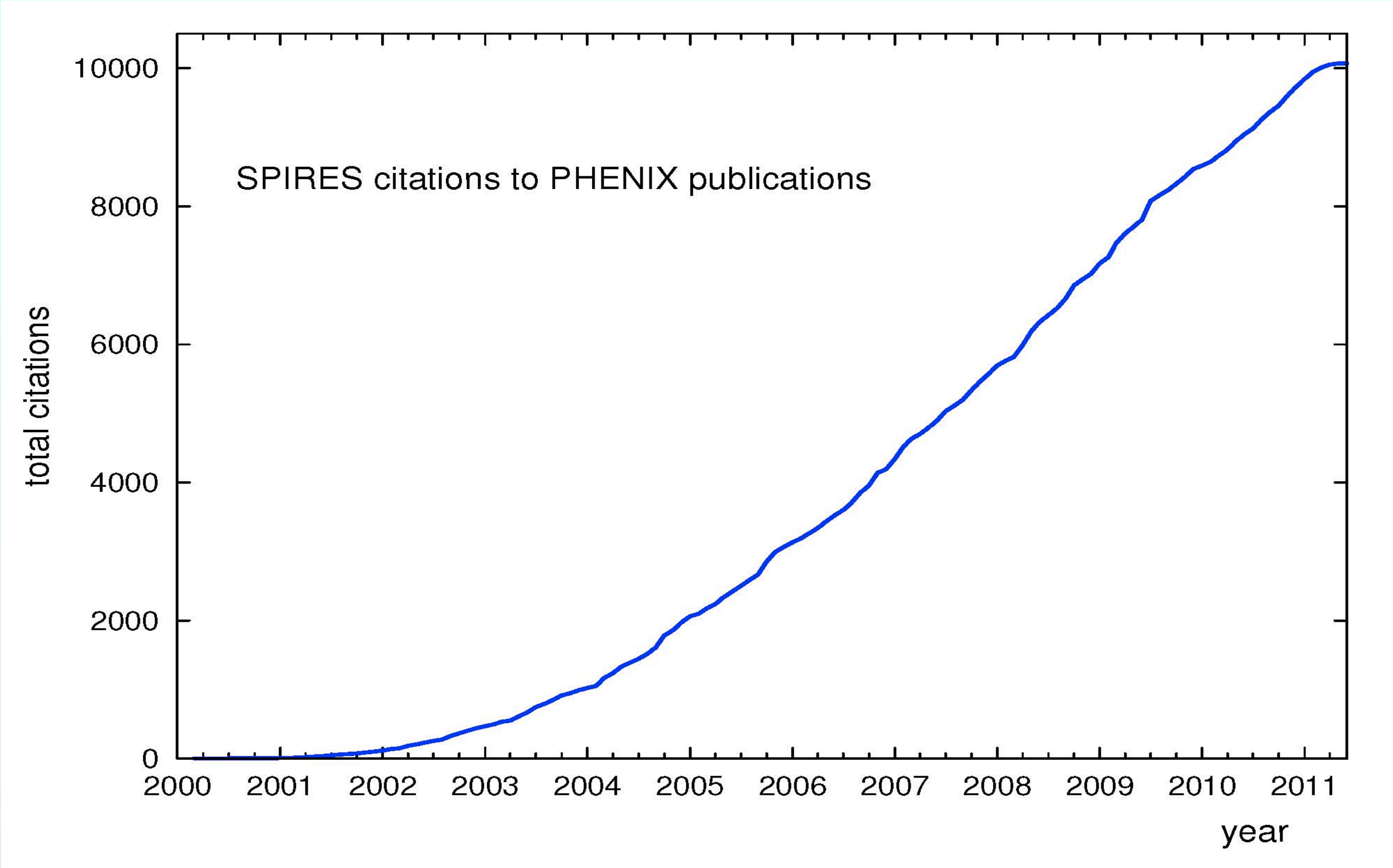
- Pin down initial state using d+Au collisions
- First new constraints on η/s
- Discovery of direct photon flow
- Measure W cross section, first look at A_L
- J/ψ suppression at 62 GeV

- PHENIX submitted 16 papers for publication in the past 12 months
- We published 12 + 1 in proofs
- ~35-40 preliminary analysis results

** More details to follow*

PHENIX

Over 10K citations of PHENIX papers

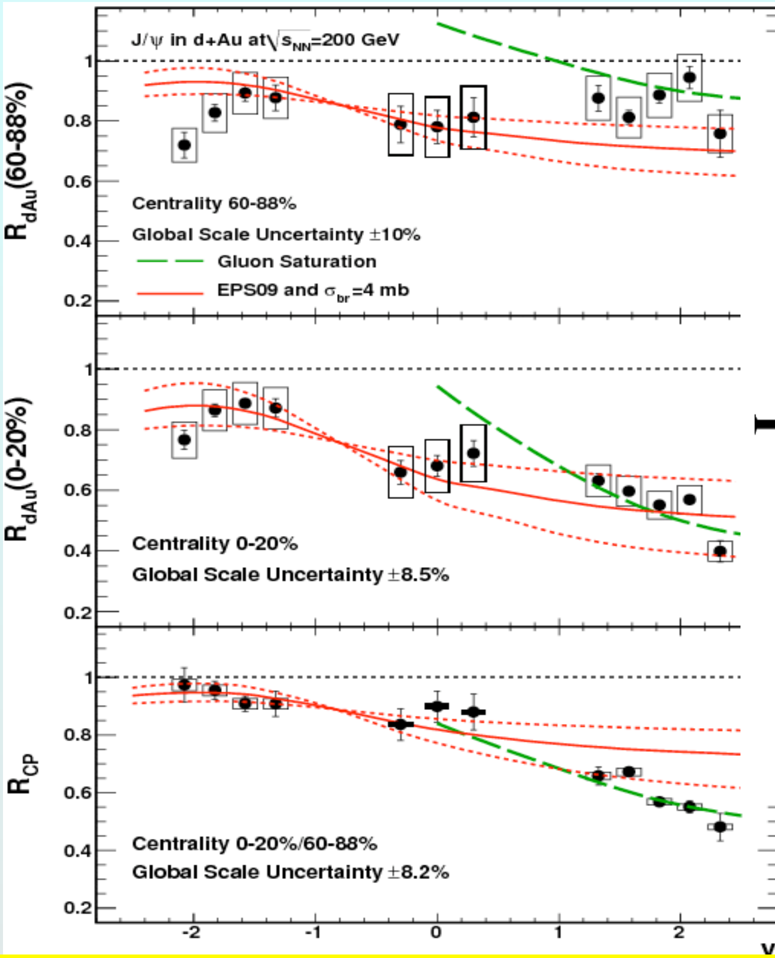


Citation *rate* remains high, as in past years

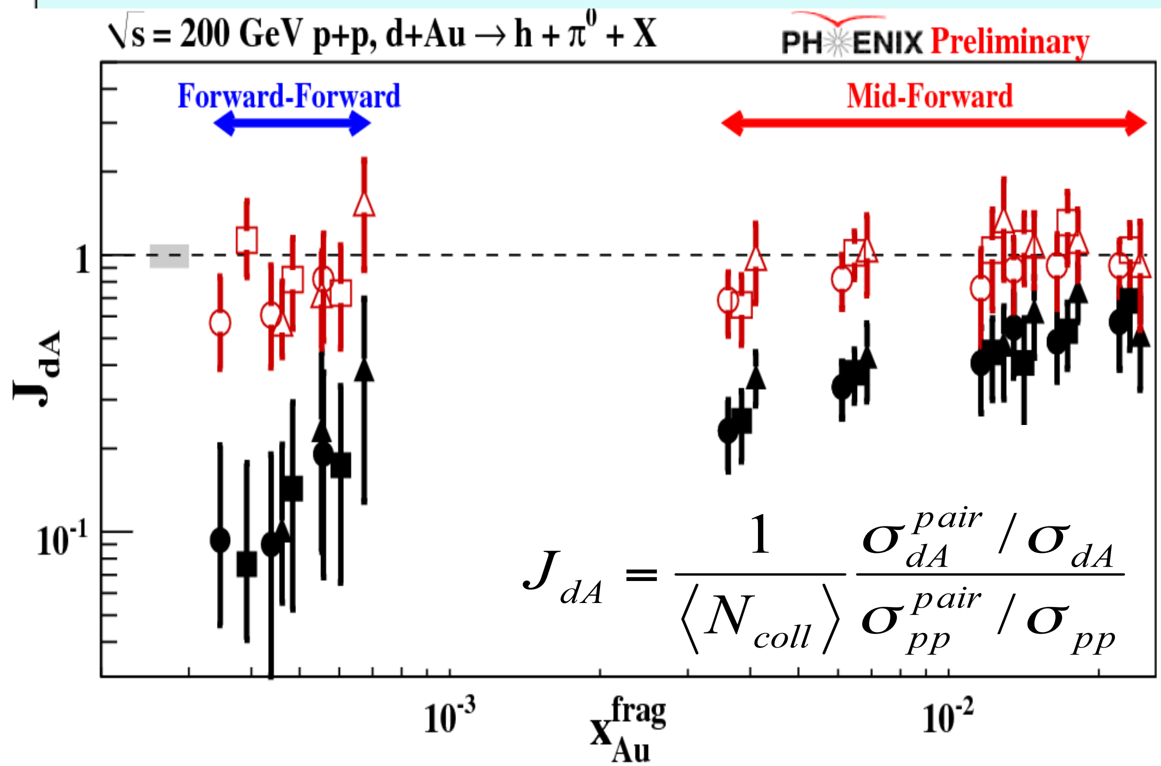
NB: White paper has 1079 citations; jet quenching discovery paper has 584

Dense gluonic matter (d+Au, forward y): large effects observed

arXiv:1010.1246



arXiv:1105.5112



Di-hadron suppression at low x

pocket formula (for 2→2):

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

Shadowing/absorption stronger than linear w/nuclear thickness

PHENIX Toward NSAC milestone DM8

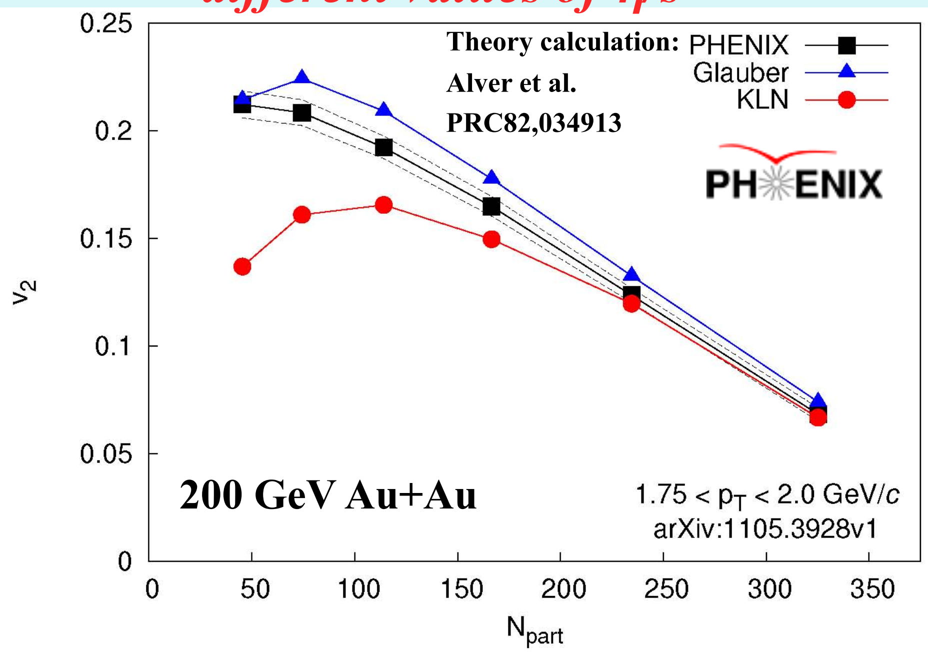
trend as, e.g. in CGC …

Fluctuations, flow and the quest for η/s

arXiv:1105.3928

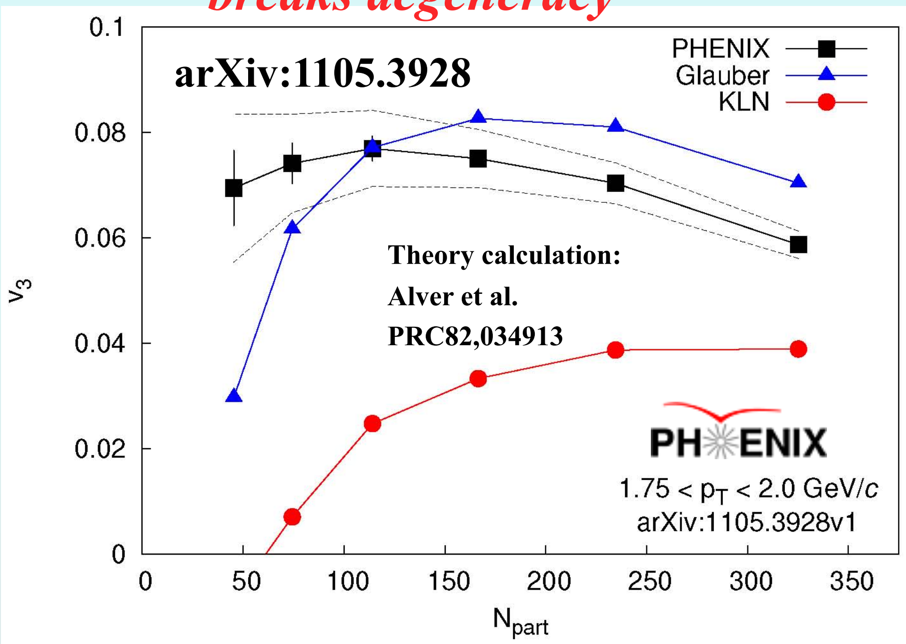
***v_2* described by Glauber and CGC**

different values of η/s



***v_3* described only by Glauber**

breaks degeneracy



Lappi, Venugopalan, PRC74, 054905
Drescher, Nara, PRC76, 041903

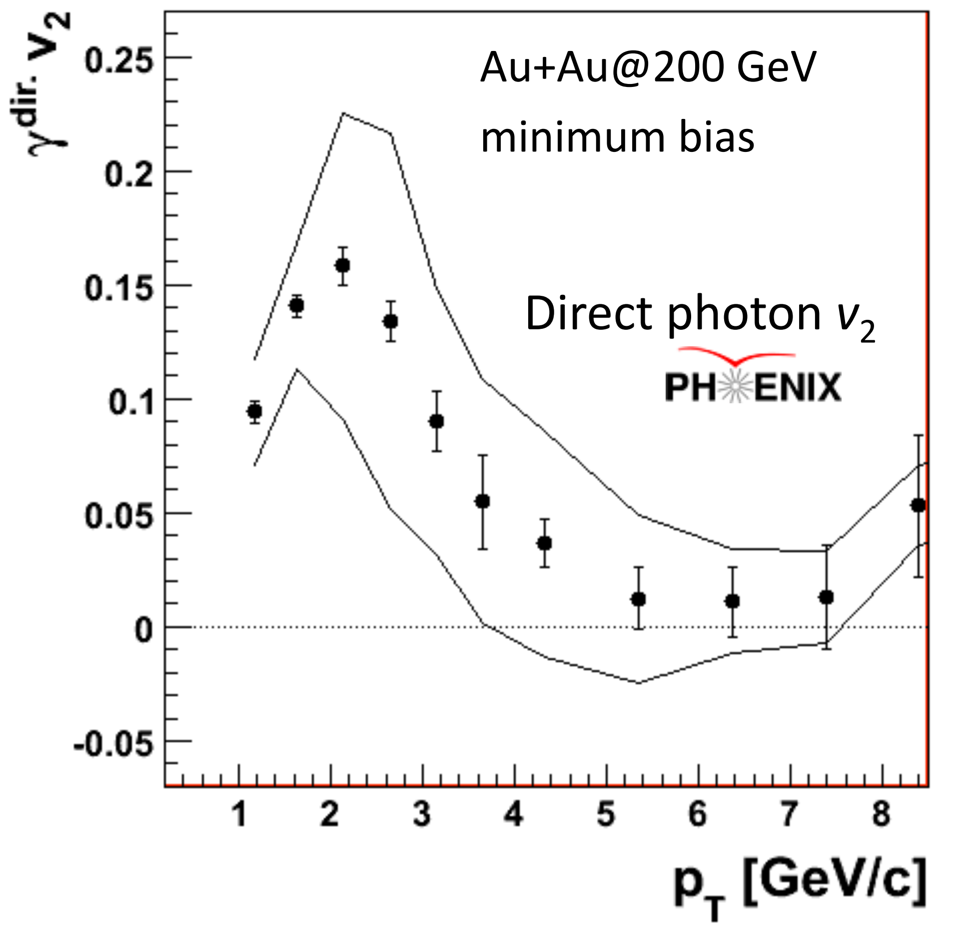
- Glauber
  - Glauber initial state
  - $\eta/s = 1/4\pi$

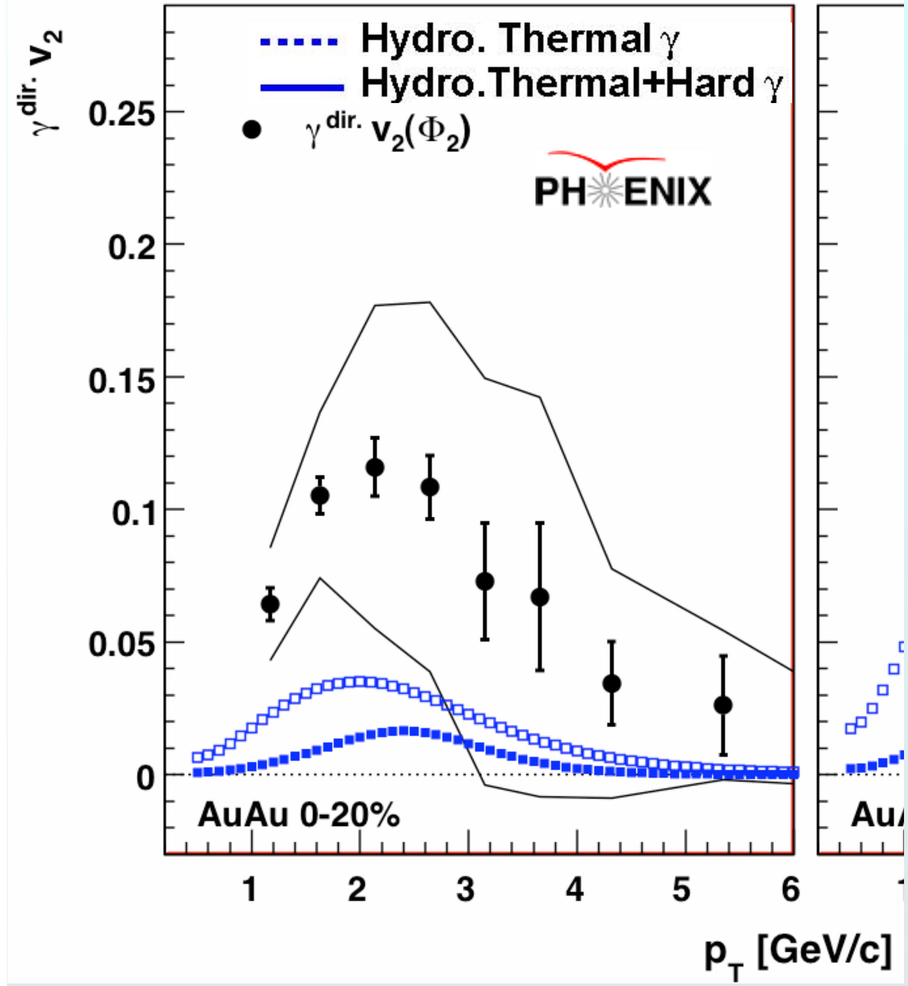
← **Two models** →

- MC-KLN
  - CGC initial state
  - $\eta/s = 2/4\pi$

Direct photons flow!

arXiv:1105.4126

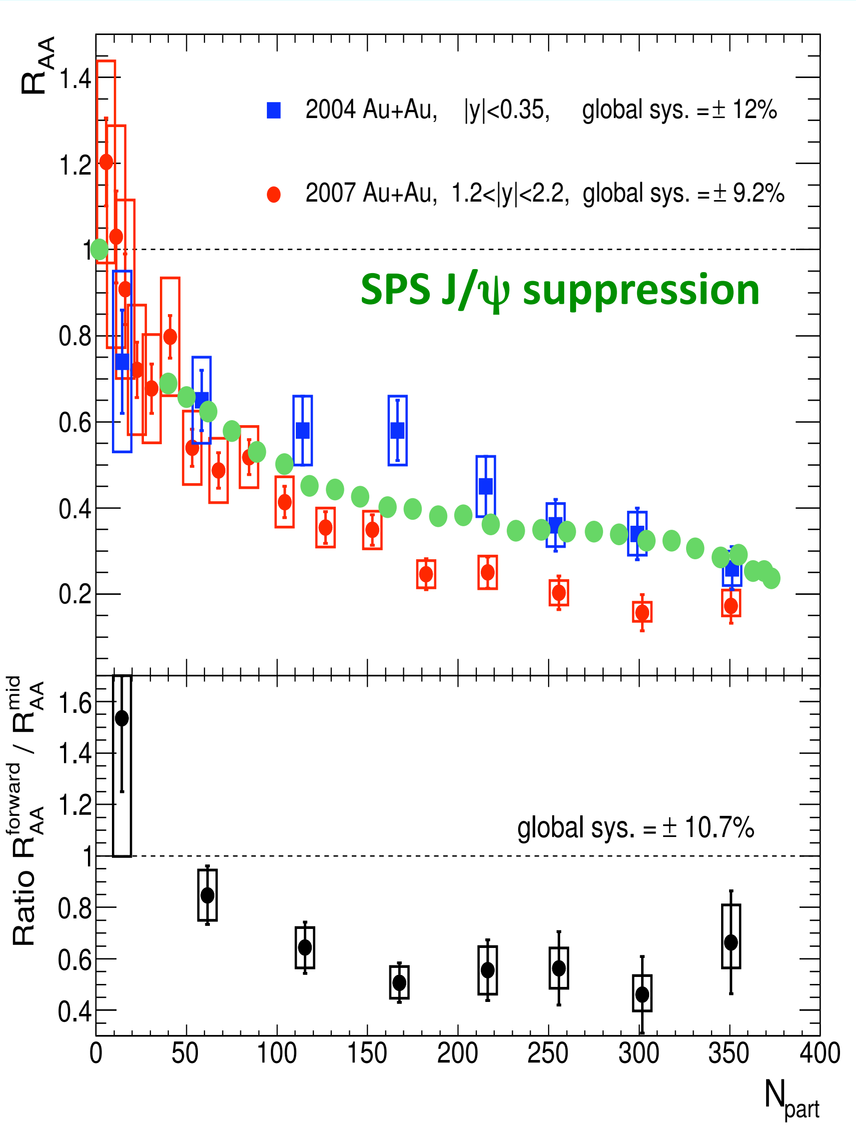


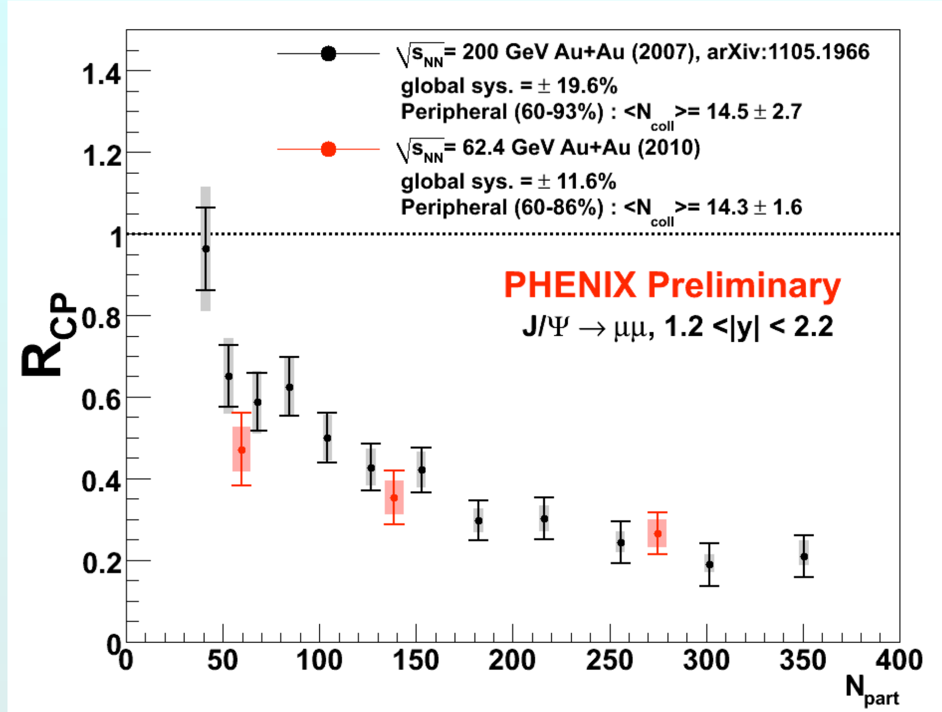


Flow magnitude is a real surprise!

J/ψ suppression at 62 GeV!

arXiv:1103.6269





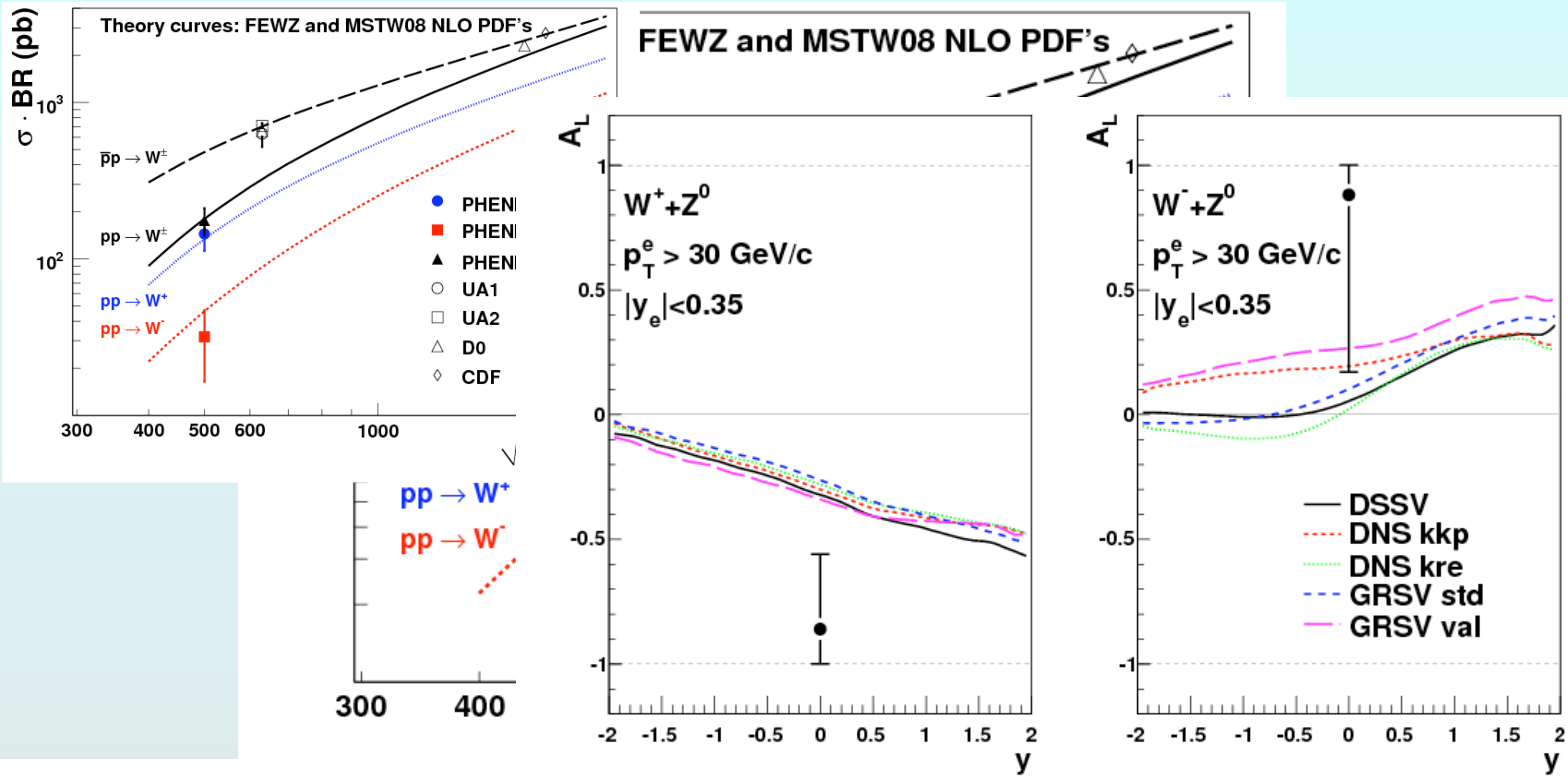
No obvious pattern of the suppression with energy density.

To understand color screening:

see as function of √s, p_T, $\mathbf{r}_{onium}$ +

d+Au to disentangle cold matter effects

First publication of W's at RHIC



PRL106, 062001(2011)

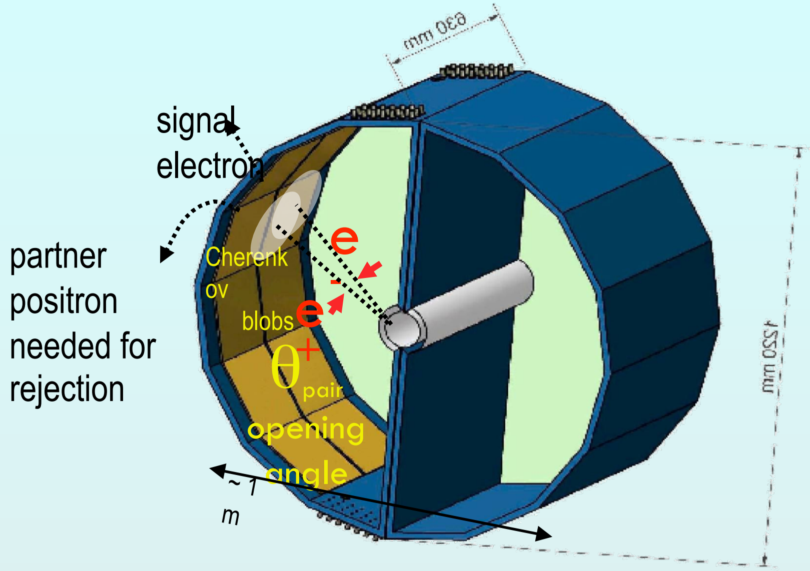
- Measure σ, first look at A_L with electrons in Run-9
- Starting with Run-11: precision W-> μ

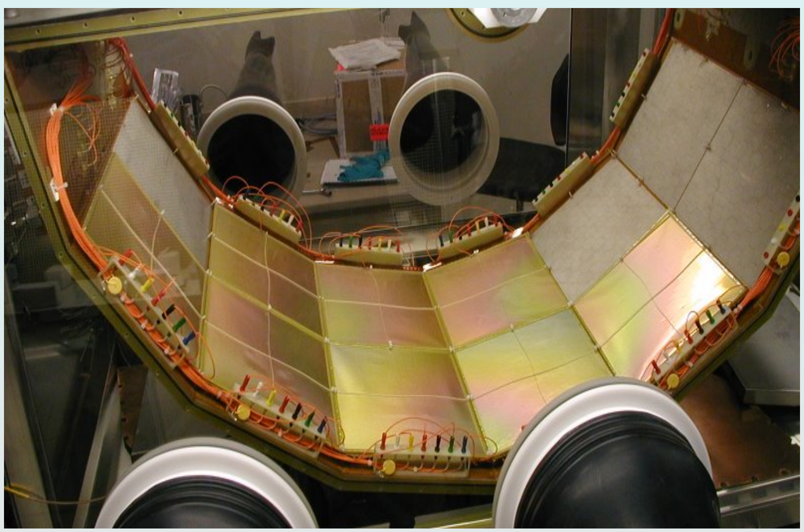
Other papers in the past year

- J/ψ, ψ', χ_c *1105.1966*
- ω production in pp,dAu, CuCu, AuAu *1105.3467*
- J/ψ suppression at high p_T *1103.6269*
- Identified hadron spectra in p+p *1102.0753*
- Away jet suppression vs. reaction plane *1010.1521*
- J/ψ supression in cold nuclear matter *1010.1246*
- hadron cluster A_{LL} *1009.4921*
- electron-hadron correlations *PRC83, 044912 (2011)*
- meson m_T scaling in p+p *PRD83, 052004 (2011)*
- ϕ R_{AA} *PRC83, 024909 (2011)*
- η σ and A_{LL} *PRD83, 032001 (2011)*
- J/ψ A_N *PRD82, 112008 (2010)*
- γ-h correlations in p+p *PRD82, 012001 (2010)*
- π^0 vs. reaction plane *PRL105, 142301 (2010)*

Where we are now?

HBD analysis is underway





N_0 ideal value	714 cm^{-1}
Optical transparency of mesh	88.5 %
Optical transparency of photocath.	81.0 %
Radiator gas transparency	89.0 %
Transport efficiency	80.0 %
Reverse bias and pad threshold	90.0 %
N_0 calculated	328 +/- 46 cm^{-1}
N_{pe} expected	20.4 +/- 2.9
N_{pe} measured	20
N_0 measured value	**330 cm^{-1}**

The highest ever measured N_0!
Maintained for 2 years

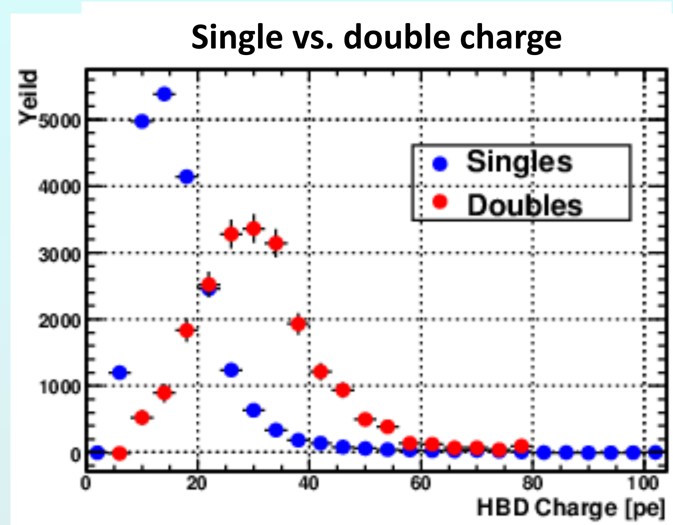
- **Single electron charge peaks at 20 pe**
- **Double electron charge peaks at ~40 pe**

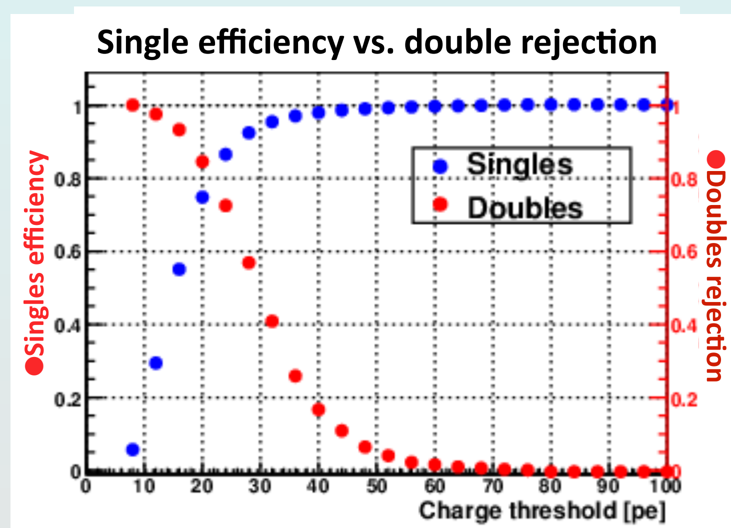
→Good single to double separation

In central Au+Au, must deal with scintillation light.
rejection of π^0 Dalitz electrons and upstream conversions

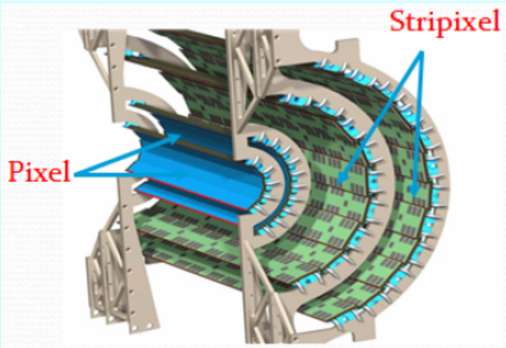
- Subtract <pe> to reject scintillation γ
- Then, can reject upstream conversions and π^0 Dalitz pairs with single/double charge cut
- This requires good gain calibration throughout the entire run
- Single electron hits studied w/ MC
  $\phi \to e^+e^-$ emebedded in Au+Au data
- Double electron hits studied using MC $\pi^0 \to \gamma\gamma$ emebedded in Au+Au data
- Background normalization is underway

Run 10 Au+Au ***e+e- pair spectrum soon***



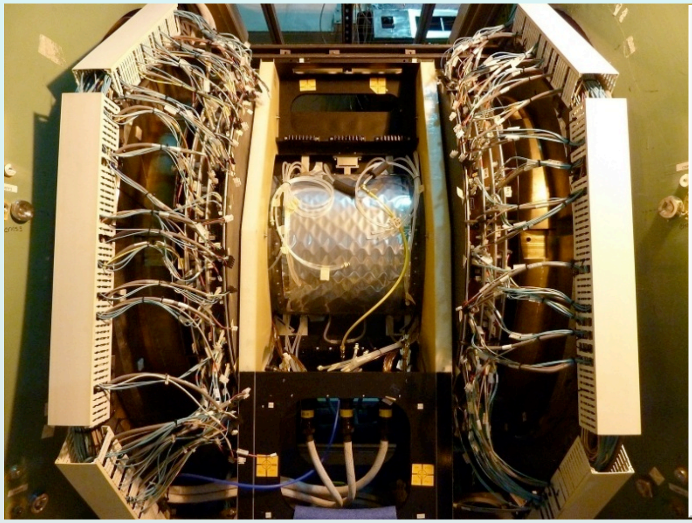


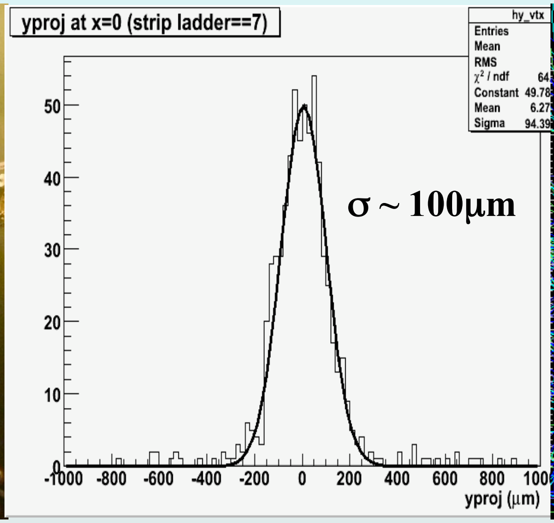
VTX is installed and commissioned



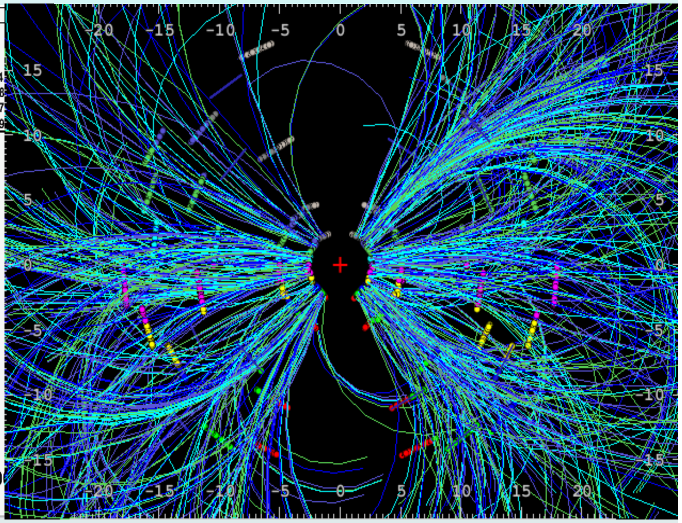
- Successfully commissioned in 2011 p+p run
- Taking data in Au+Au now

  Opens era of c/b separated R_{AA}, v_2 at RHIC !





Au+Au@200 GeV, 2011



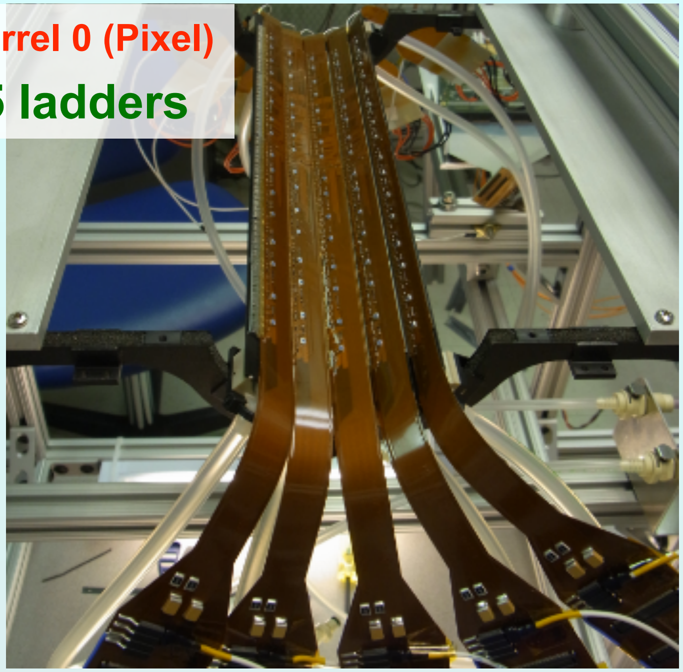
- DAQ upgrades (incl. DCMII, new EVB switch):

maintain same data rate! ~7 kHz p+p and 5 kHz Au+Au

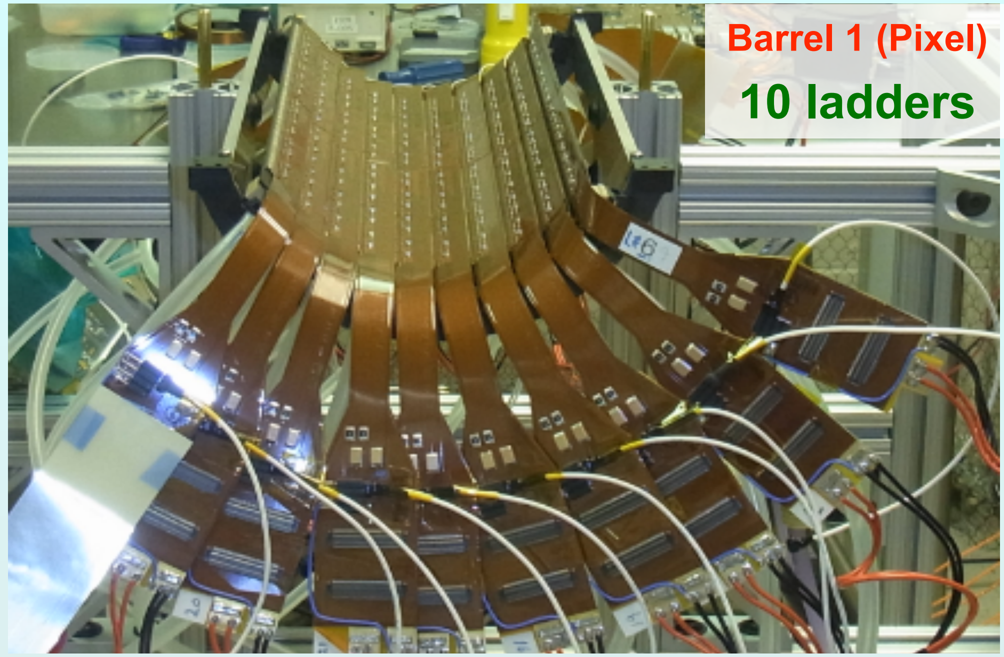
PHENIX

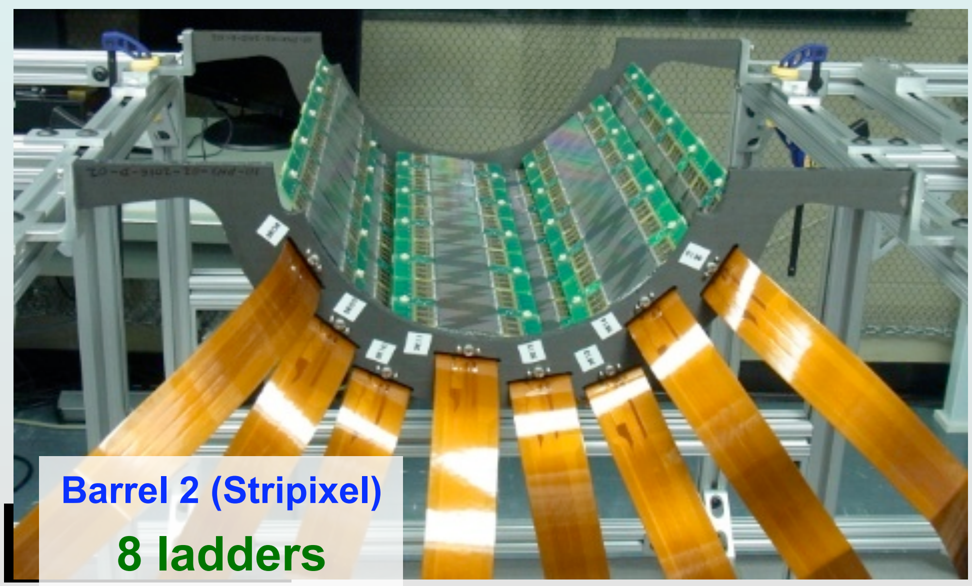
A peek inside the VTX

Barrel 0 (Pixel)
5 ladders

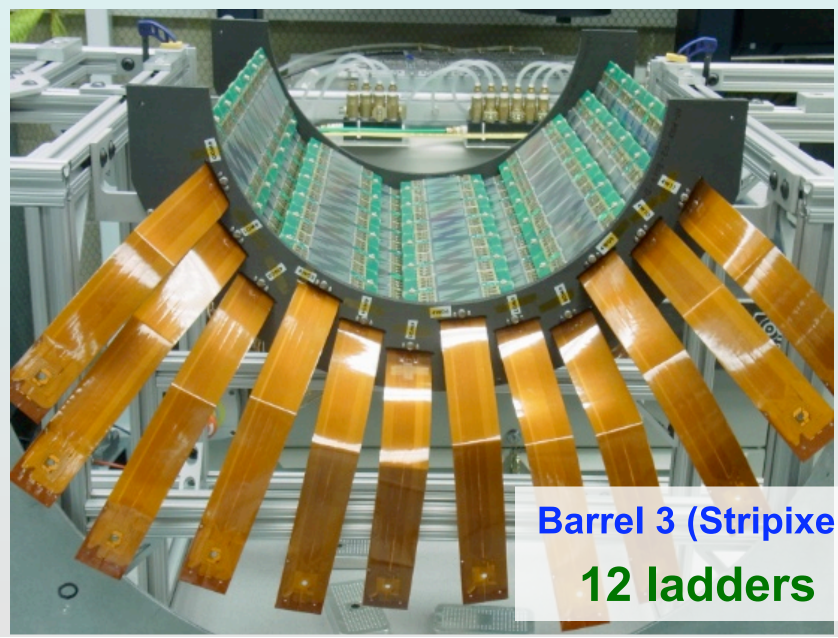


Barrel 1 (Pixel)
10 ladders





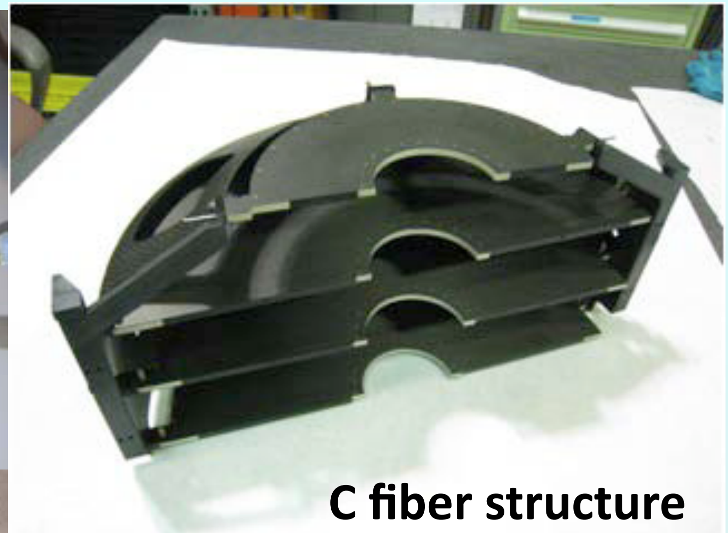
Barrel 2 (Stripixel)
8 ladders

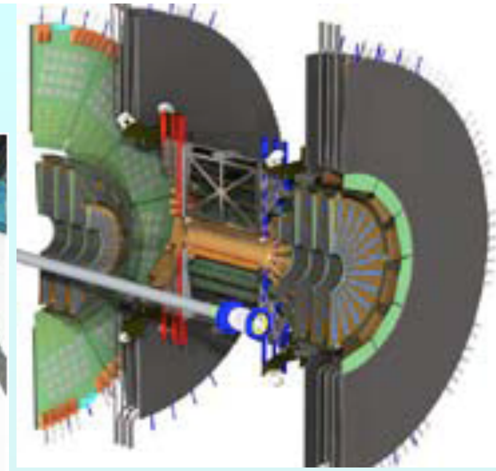


Barrel 3 (Stripixel)
12 ladders

FVTX construction underway


Fully Populated Small Disk


C fiber structure

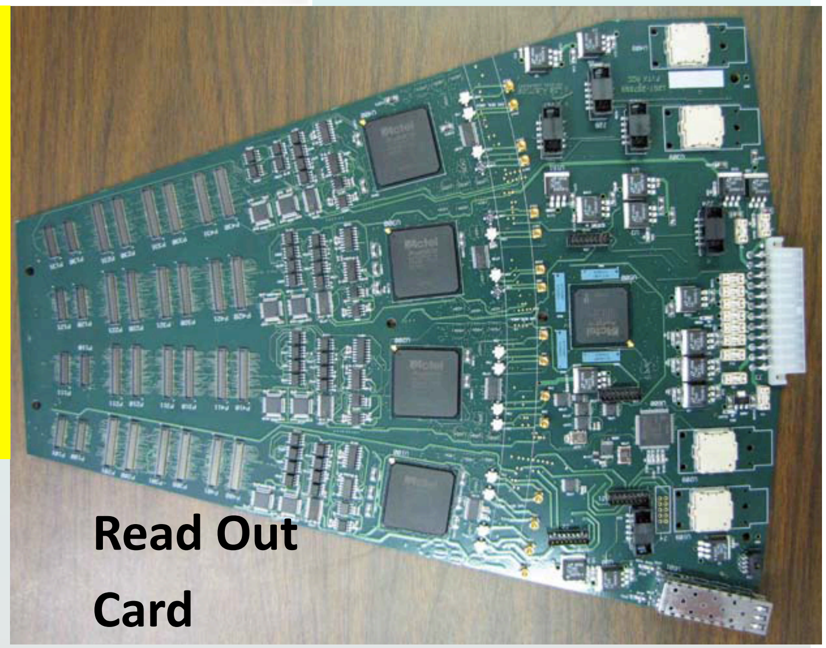



Fully Populated Large Disk


Wedge test

➔ Forward y

- open heavy flavor physics
- ψ' in AuAu & dAu


Read Out Card

On track

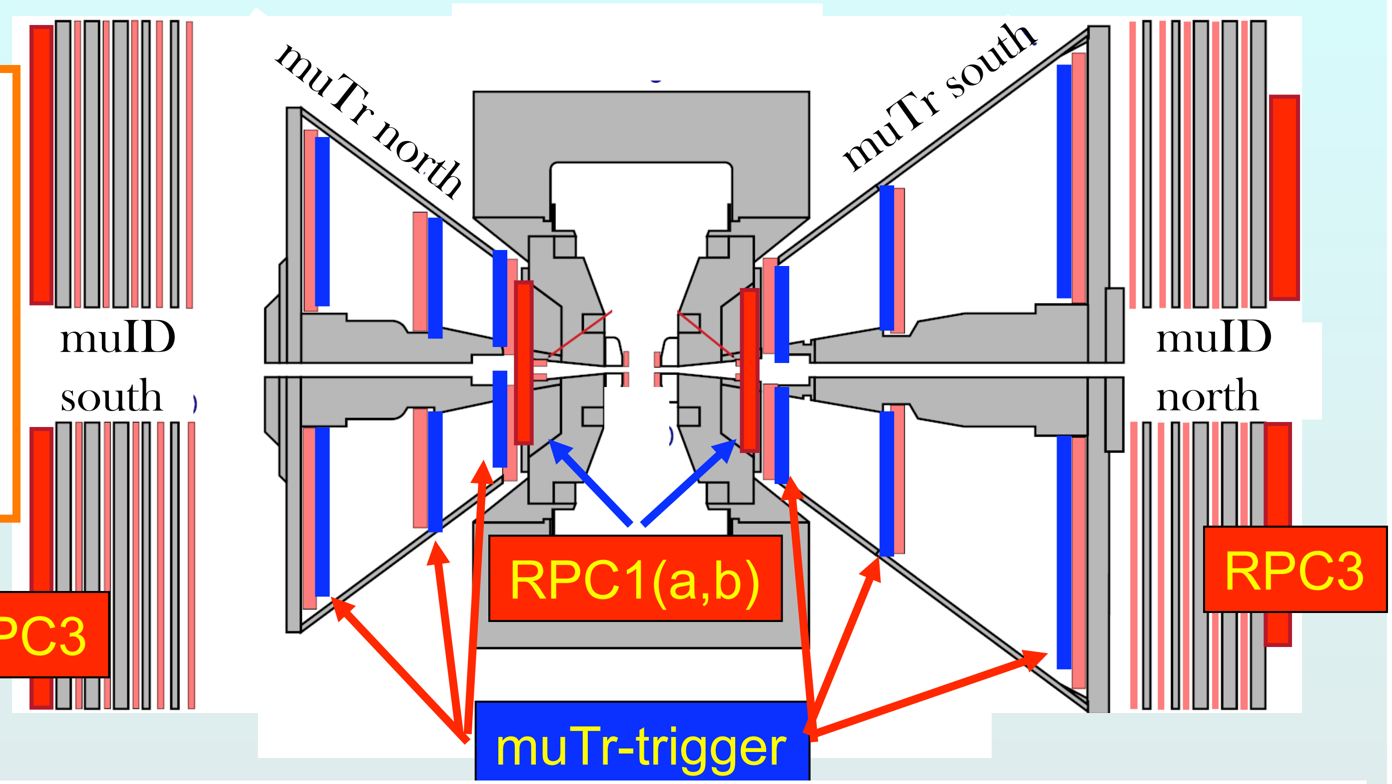
to install for Run-12

Muon Trigger Upgrade

Trigger idea:

Reject low momen-
tum muons

Cut out-of-time
beam background



Upgrade:

o muTr trigger electronics: muTr 1-3 ➔ send tracking info to level-1 trigger

o RPC stations: ... ger

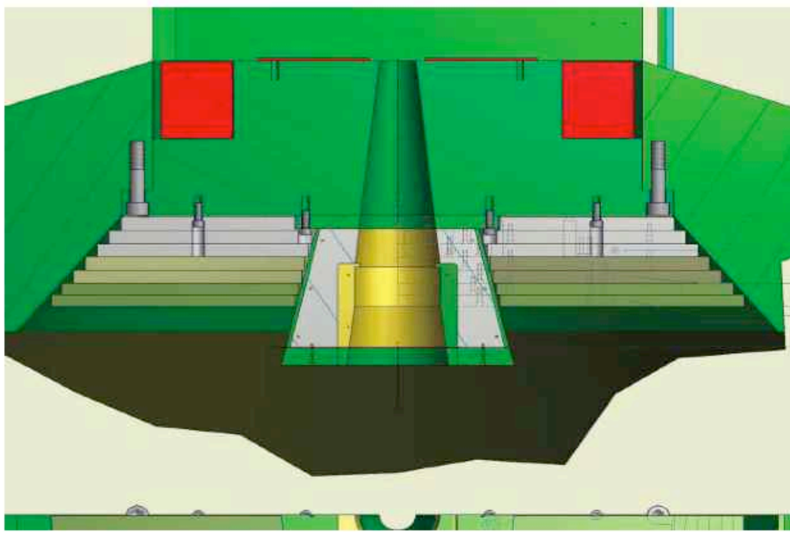
muTr FEE + RPC3 took data in Run-11

RPC1's to be installed for Run-12

Muon arm background reduction

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

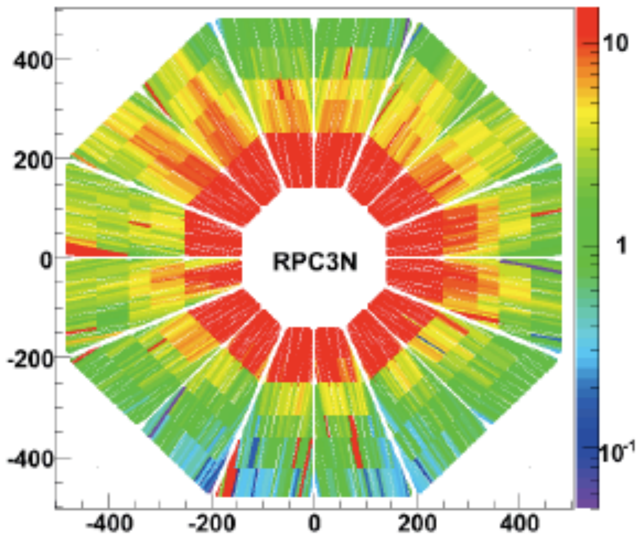
2 interaction lengths, based upon simulations



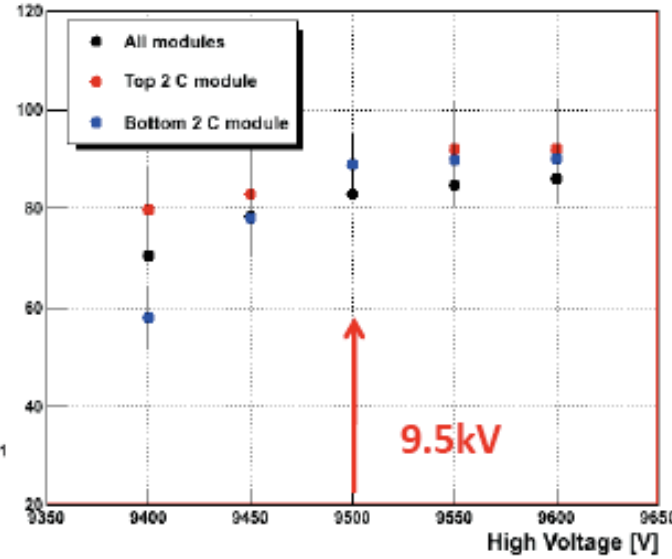
Installed on both muon arms during 2010 shutdown

Muon trigger status, first look at Run-11 data

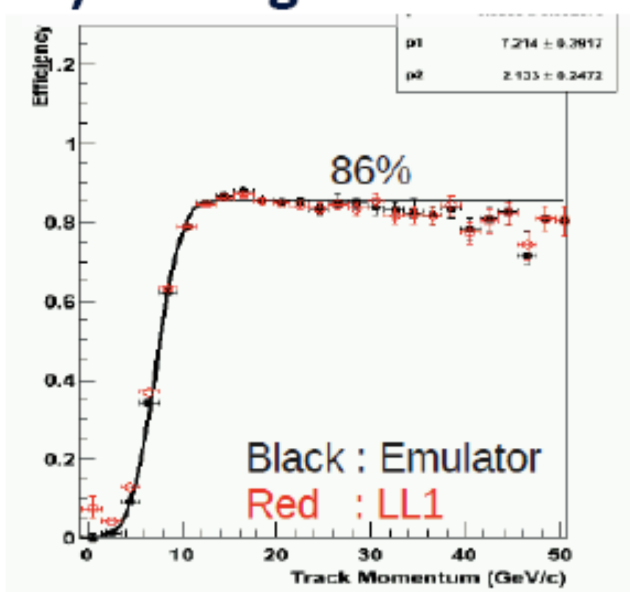
a) RPC Hit Map



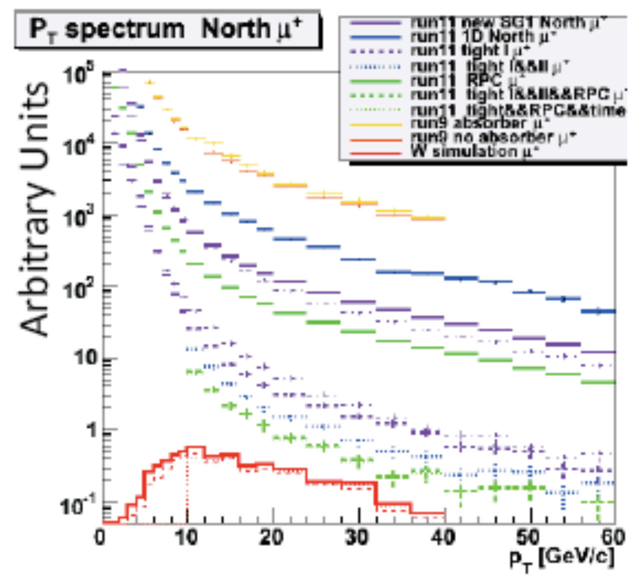
b) RPC-3 Efficiencies



c) MuTrig-Efficiencies



d) High p_T Background



Rejection power

~1100 @ 2.7MHz

S/B~1/2 first look

Anticipate 3/1 after tuning

Compelling physics questions*

* utilizing new PHENIX capabilities
+ RHIC luminosity (stochastic cooling)

* informed by new insights from RHIC & LHC

PHENIX

Mysteries in heavy ion physics

- **Energy loss mechanism** — NSAC milestone DM11, 12
  - @ LHC 40 GeV jets opposing 100 GeV jets look "normal"
    - no broadening or decorrelation
    - no evidence for collinear radiation from the parton
  - @ RHIC low energy jets appear to show medium effects
    - but, "jet" is defined differently
  - → c & b to probe role of collisional energy loss ***VTX, FVTX***
  - → quantify path length dependence ***U+U, Cu+Au***
- **J/ψ suppression and color screening** — NSAC milestone DM5
  - amazingly similar from √s=17-200 GeV; but initial states differ
  - not SO different at LHC
  - → Other states y & √s dependence (e.g. ψ') ***FVTX, statistics***
  - → d+Au for initial state; 130 GeV Au+Au eventually?

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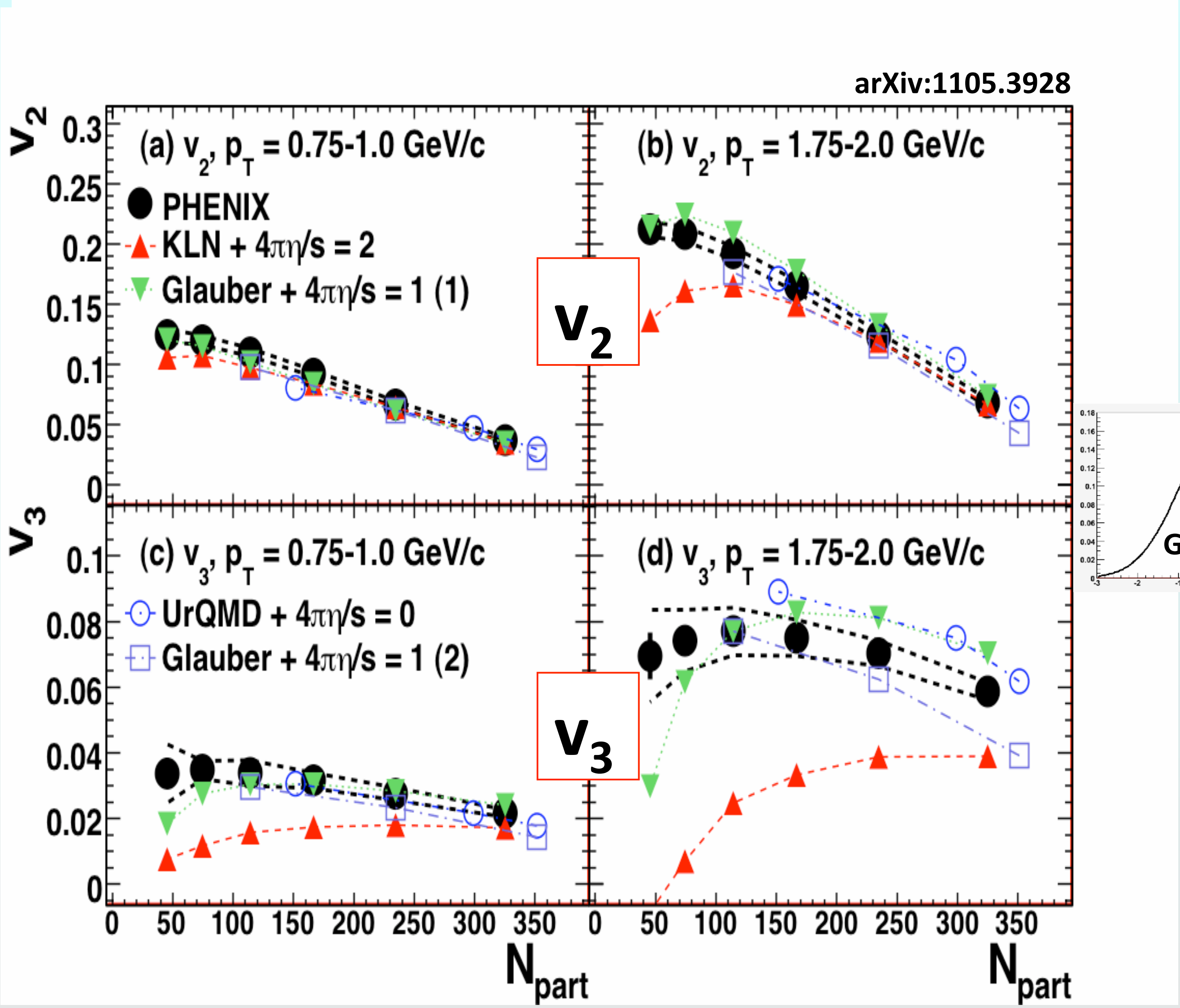
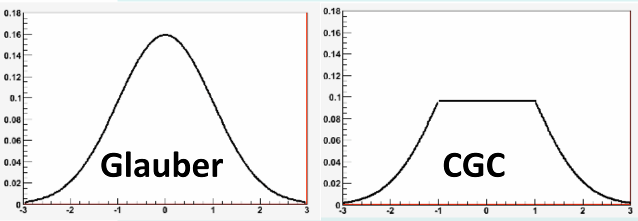
η/s vs. $\sqrt{s}$, using $v_2 + v_3$ + hydro



Energy scan driver for PHENIX

Will also need help from theory



Smaller eccentricity

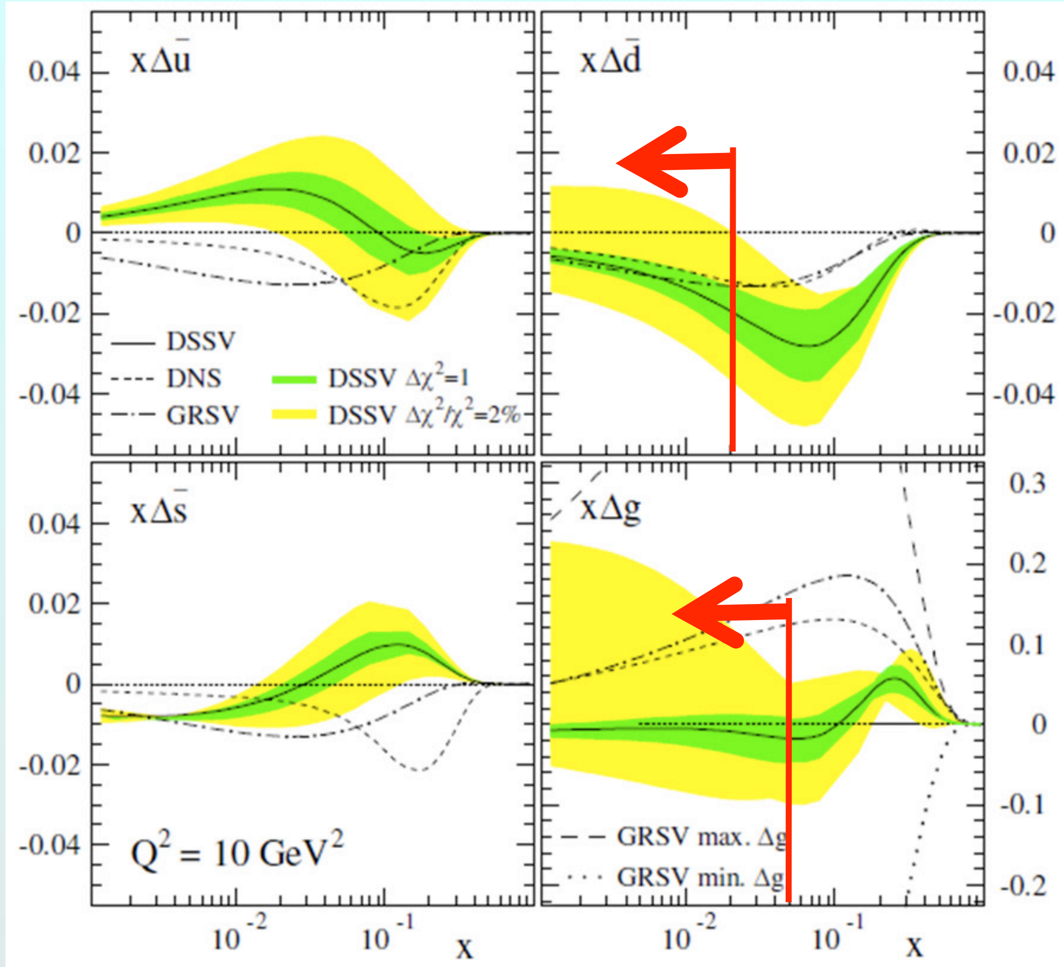
Larger eccentricity

NSAC milestone DM9

gluon & sea quark polarization

Current best knowledge from global fits

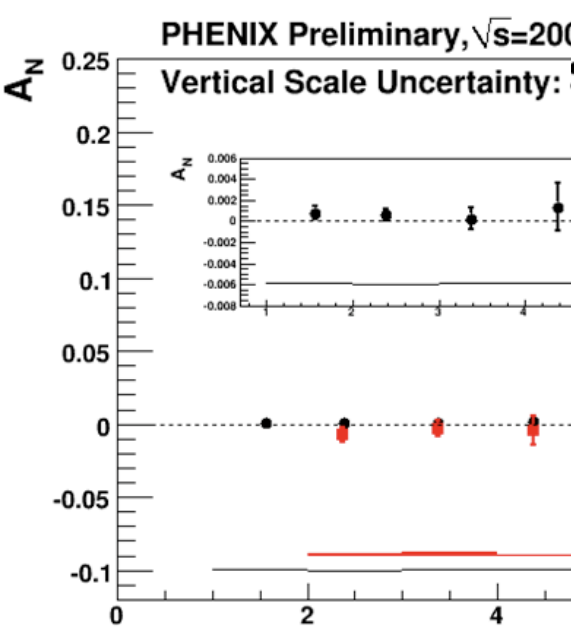
Still surprisingly small

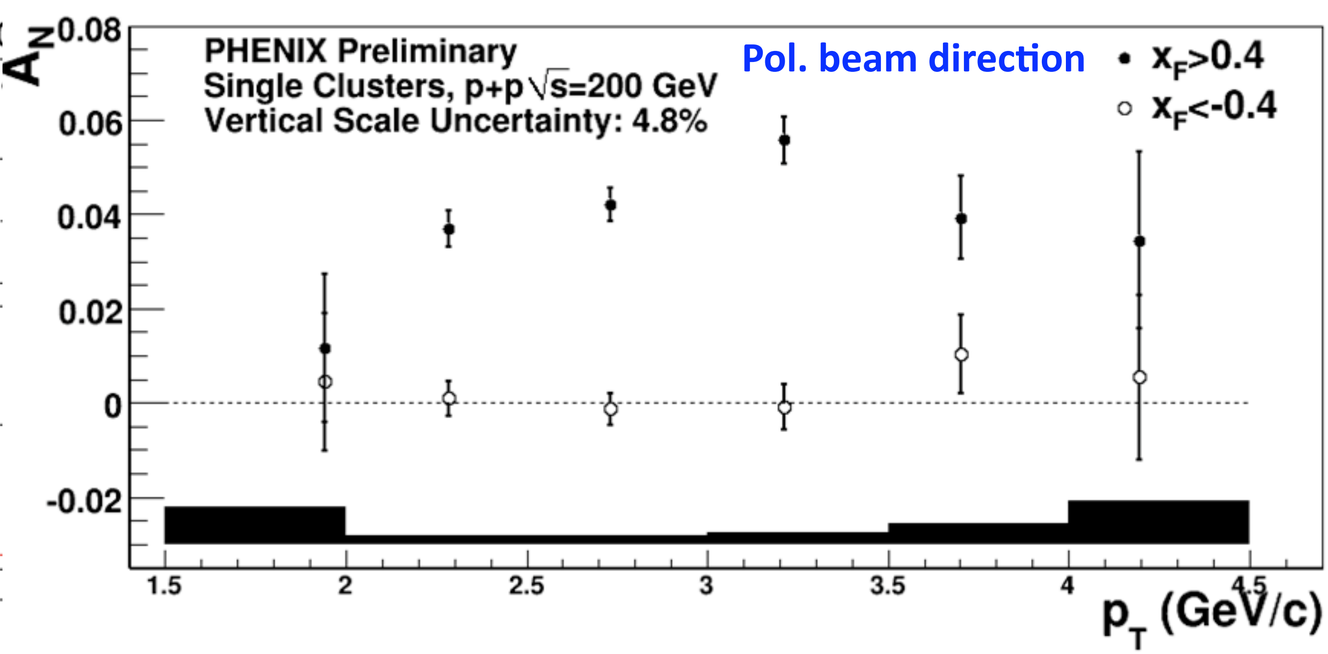


- **500 GeV p+p: π^0 A_{LL} to constrain Δg (0.01<x<0.3)** **NSAC milestone HP12**
  central/forward correlations tag kinematics **NSAC milestone HP8**
- **W A_L at forward, backward, mid rapidity for $\Delta\bar{u}$, Δu, $\Delta\bar{d}$, Δd**

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!

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

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
12	$p+p$	200	5	$13.1\,pb^{-1}$	$4.7\,pb^{-1}$	60% (T)	HI comparison, $\perp$ spin
	$p+p$	500	8	$100\,pb^{-1}$	$35\,pb^{-1}$	50% (L)	W program + ΔG
	Au+Au	200	7		$0.8\,nb^{-1}$		heavy flavor (F/VTX)
	U+U	193	1.5		$0.03\,nb^{-1}$		explore geometry
	Au+Au	27	1	$5.2\,\mu b^{-1}$			energy scan
13	$p+p$	500	10	$200\,pb^{-1}$	$74\,pb^{-1}$	60% (L)	W program
	$p+p$	200	5	$20\,pb^{-1}$	$4.7\,pb^{-1}$	60% (T)	HI comparison
	Cu+Au	200	5		$2.4\,nb^{-1}$		control geometry
	U+U	193	5		$0.57\,nb^{-1}$		explore geometry

***NB for Run-13** (Adds up to 30 cryo weeks)*

Relative priority of CuAu, UU, more AuAu TBD by Run-12 results

PHENIX

PHENIX beam use proposal

run	species	$\sqrt{s_{NN}}$	weeks	$\int L\,dt$ $\lvert z\rvert < 30$ cm	$\int L\,dt$ $\lvert z\rvert < 10$ cm	pol.	comments
12	$p+p$	200	5	$13.1\, pb^{-1}$	$4.7\, pb^{-1}$	60% (T)	HI comparison, $\perp$ spin
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	U+U	193	1.5		$0.03\, nb^{-1}$		explore geometry
	Au+Au	27	1	$5.2\, \mu b^{-1}$			energy scan

Additions if we get a longer Run-12 (in priority order)

1.5 week of 62.4 GeV p+p for J/ψ & open heavy q R_{AA}
1.5 week of 39 GeV p+p for π^0 R_{AA}
Add 1 week to 27 GeV Au+Au to improve reach

Ordering request

- We request to run 200 GeV p+p first
  - FVTX commissioning
    - avoid letting any downtime affect W program
  - RPC1 commissioning
    - be ready for the W measurement
  - Polarization development time (?)
    - may help optimize machine performance for 500 GeV
- Then 500 GeV p+p
  - Followed by low energy comparison running, if $ permit
- Switch to ions
  - Do 200 GeV Au+Au first
  - Probably should follow with 27 GeV Au+Au
    - lower priority for PHENIX than U+U test

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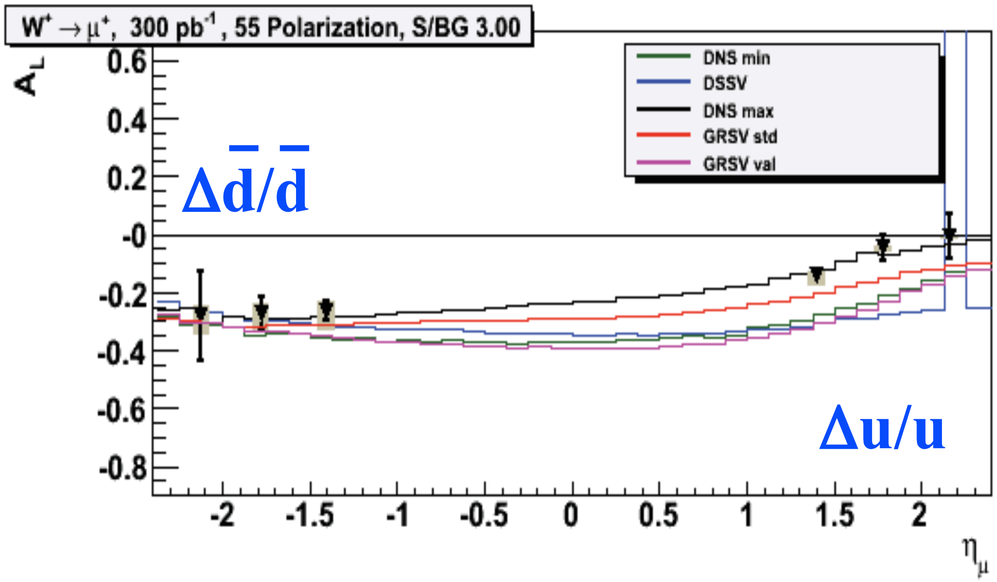
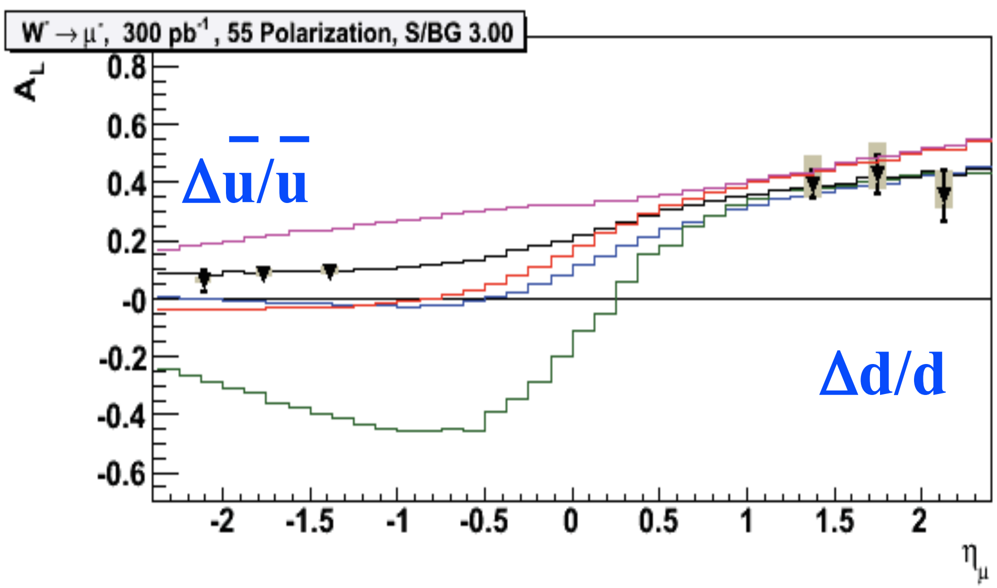
How well will we do?

Run-12 top priority: progress on W program



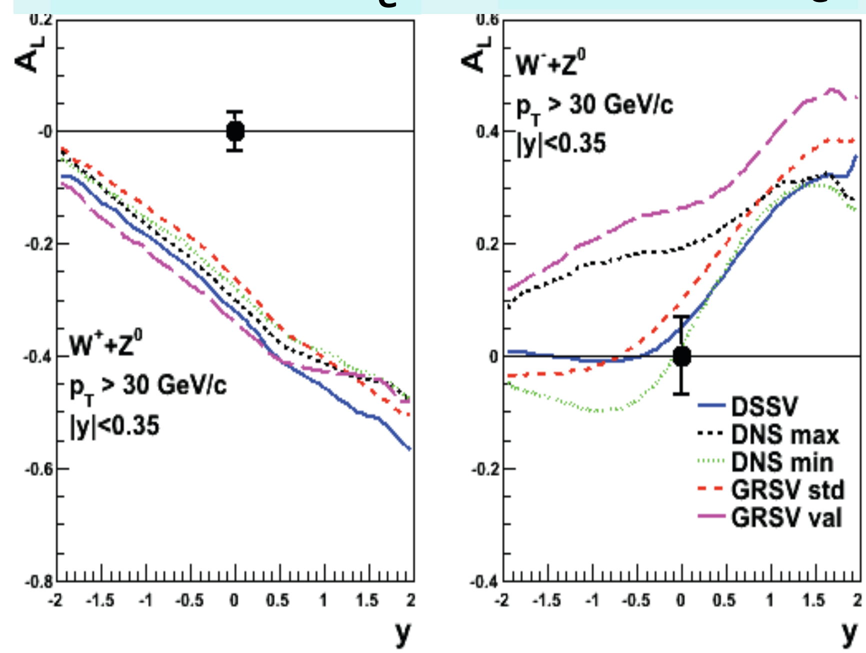


inclusive high p_T leptons

∫Ldt=300pb^{-1} in 30cm, P=0.55

Run-12 (100pb^{-1}) + Run-13

$W^+ \to e^+ + \nu_e$ **$W^- \to e^- + \bar{\nu}_e$**



Requires ∫Ldt=900pb^{-1} delivered in Run-12+13

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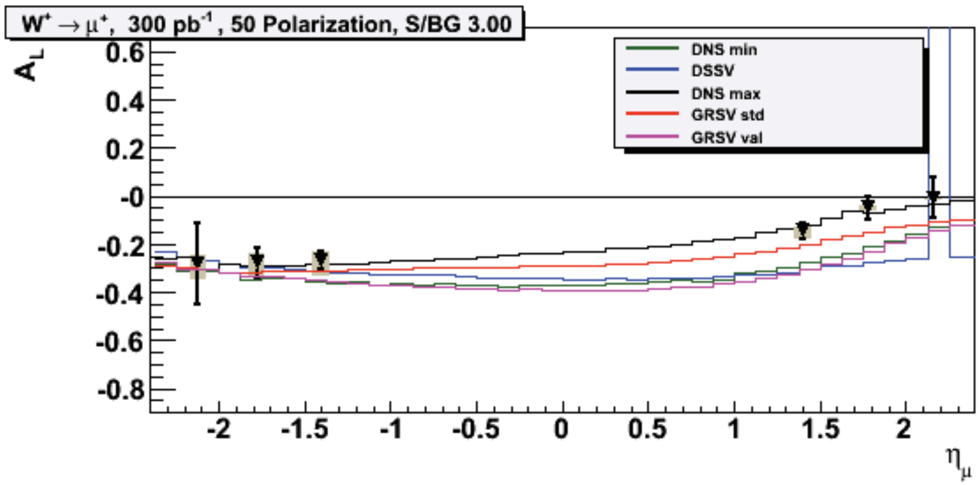
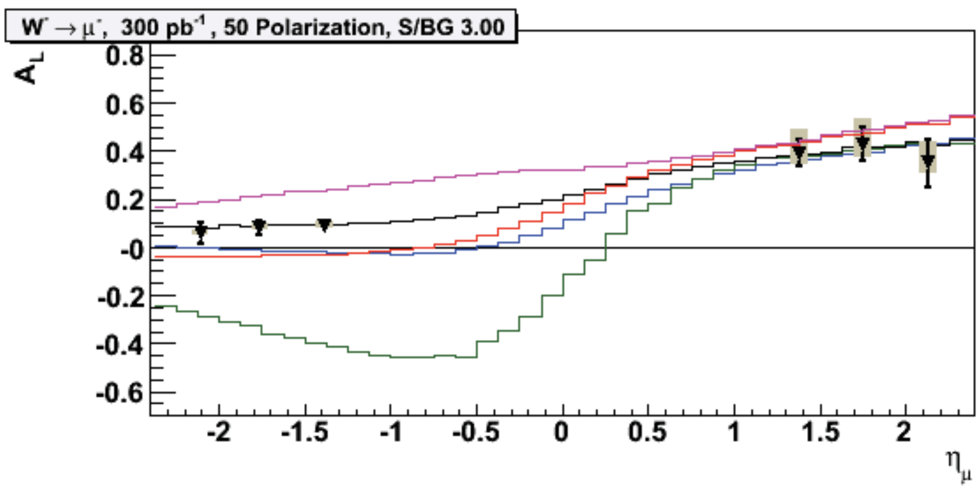
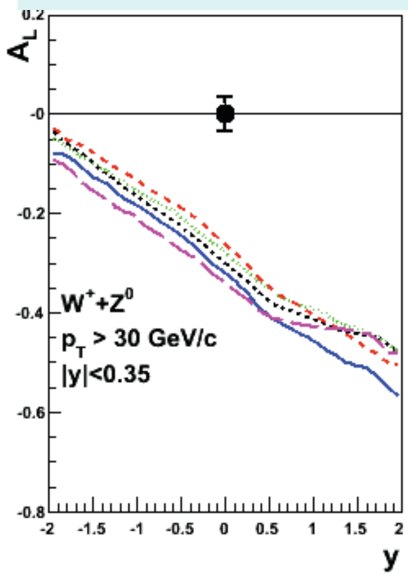
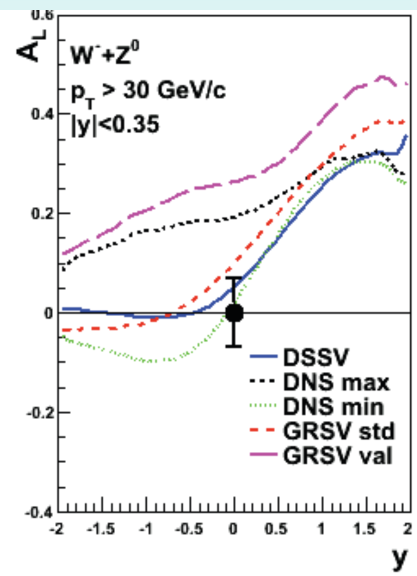
50% polarization performance

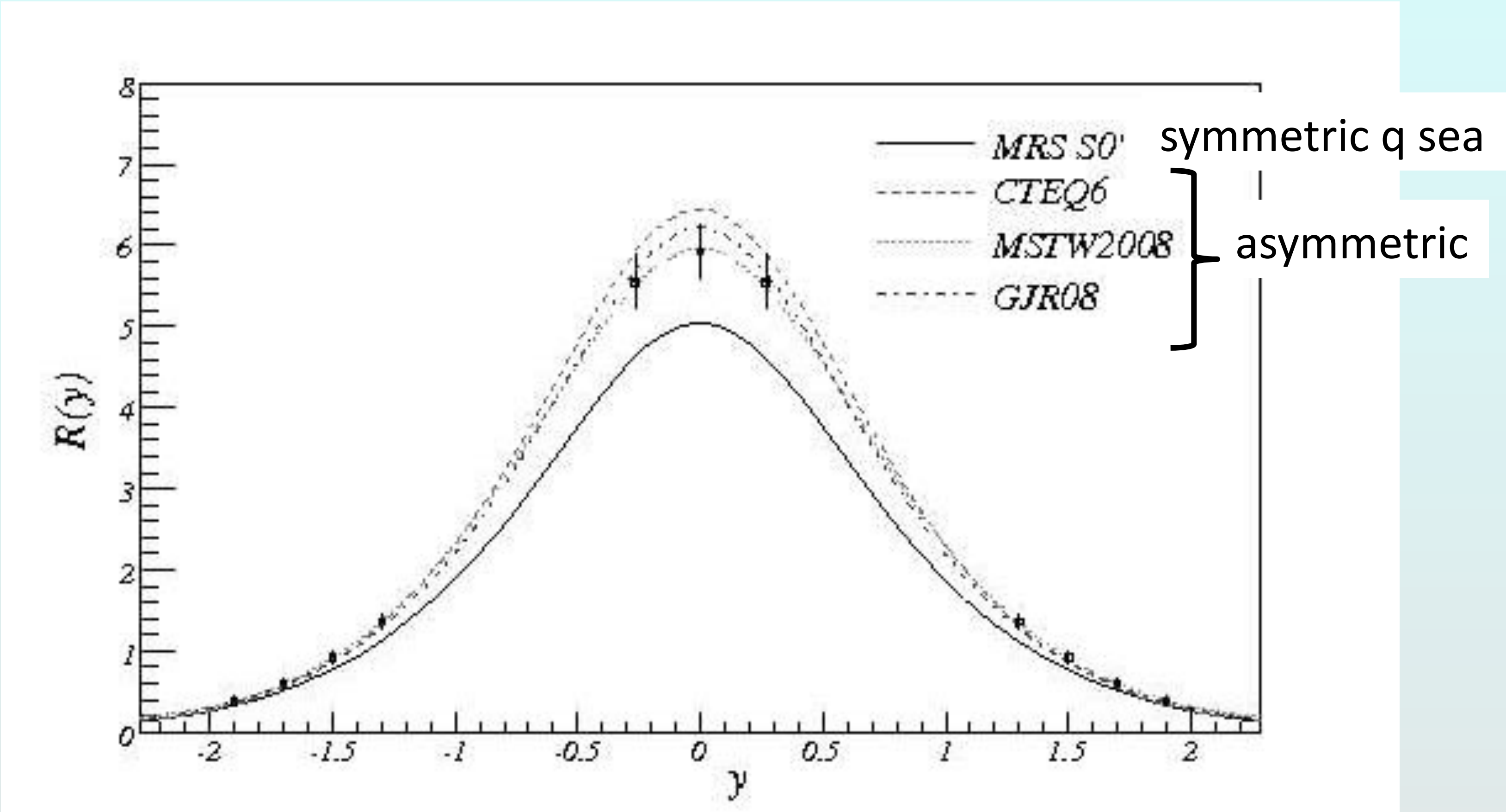








Constrain dbar/ubar with W+/W- ratio



A concern

- RHIC performance for 500 GeV polarized p+p
  - Not up to the usual RHIC standards
  - We only got $\int Ldt = 18 pb^{-1}$ within our vertex cut of 30cm
  - Polarization was ~ 50%
- 300 pb^{-1} in 30 cm is necessary for impactful measurement!
  - Plots are for 55% polarization; current performance is close to what's needed
- Can this program be completed in 2 years?
  - NSAC milestone HP8 is set for 2013
  - If we do not reach in 2 years, will request one more run

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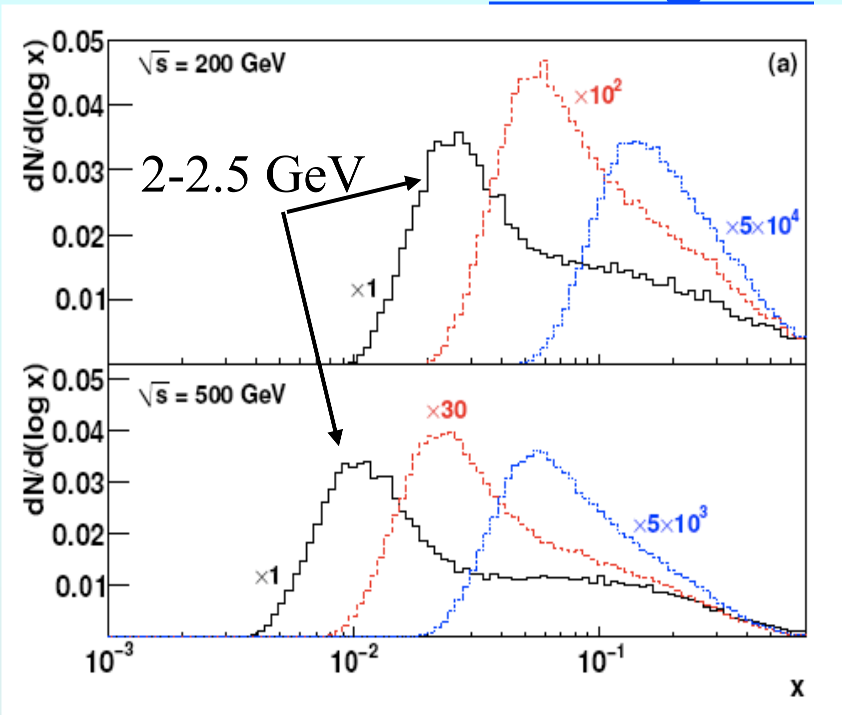
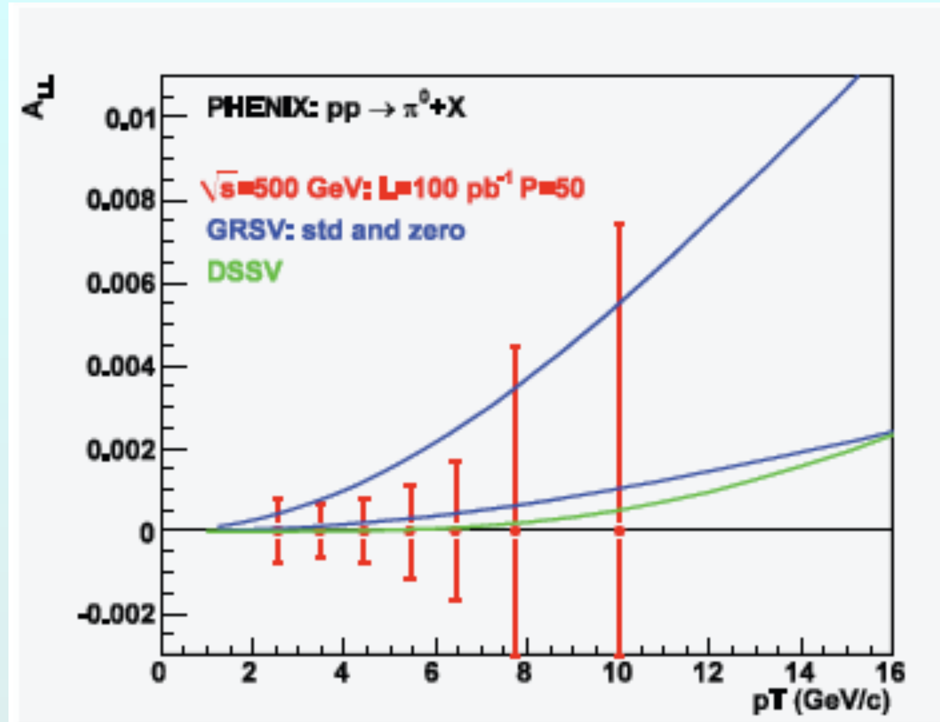
for Δg : π^0 A_{LL} at 500 GeV



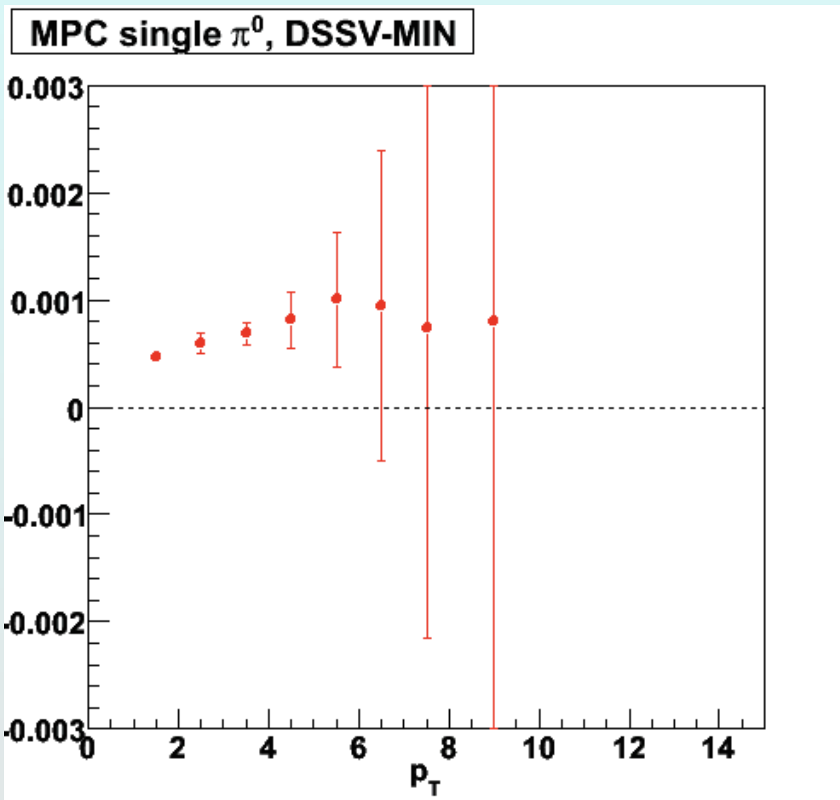


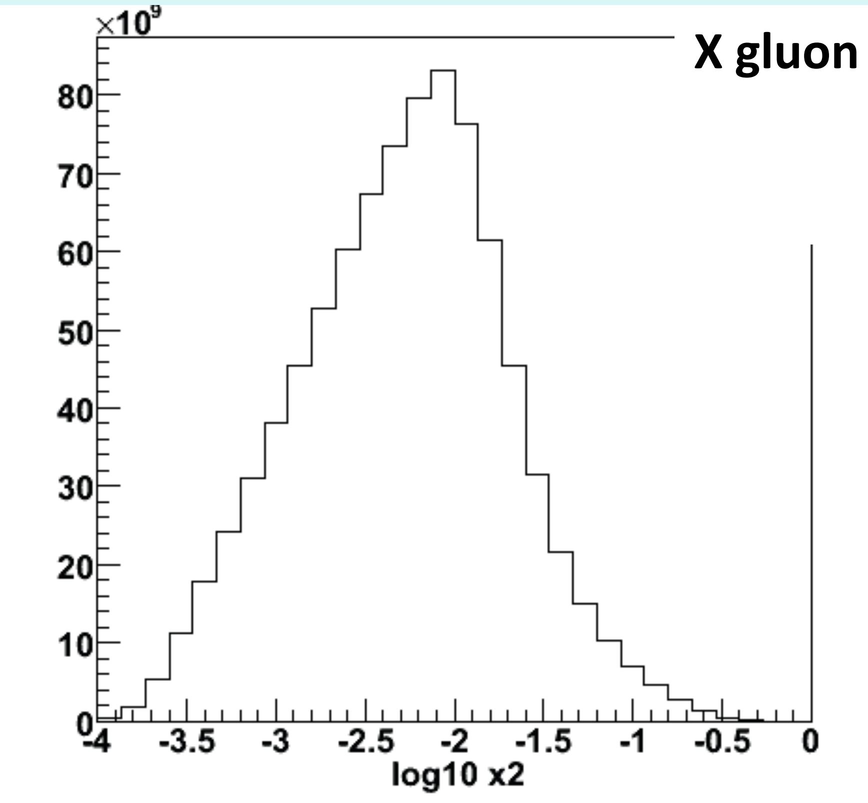
Small ΔG: a challenge!
500 GeV reaches lower x with higher luminosity

Uncertainties for Run-12 only; vertex cut of 10cm

For Δg: MPC π^0 and dihadron A_{LL}

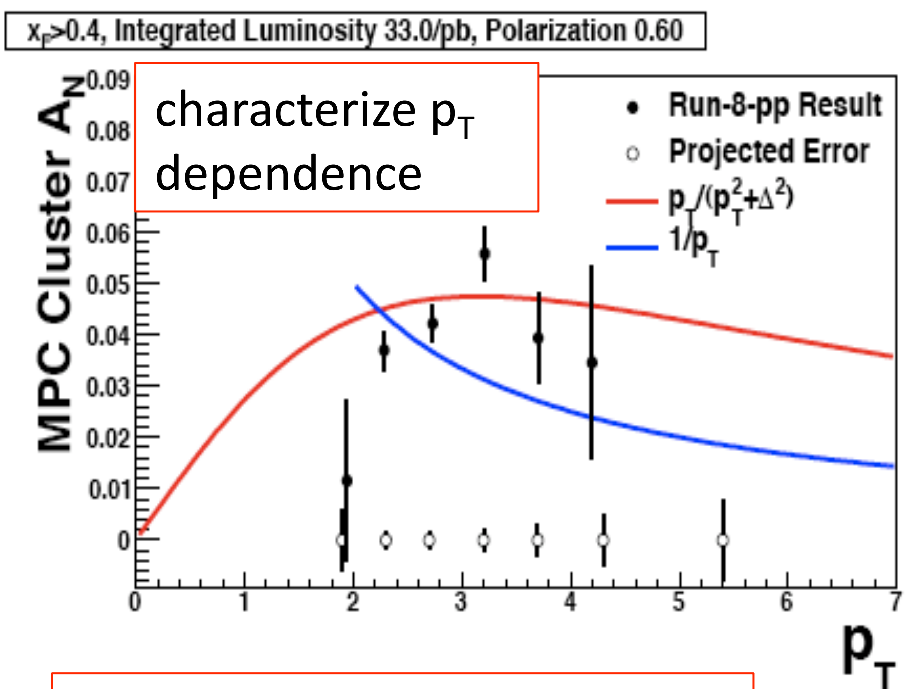
- For Run-12 + Run-13 500 GeV p+p run
- Plot: A_{LL} for single cluster in $3.1 < \eta < 3.8$
  will use dihadrons as in d+Au analysis, also





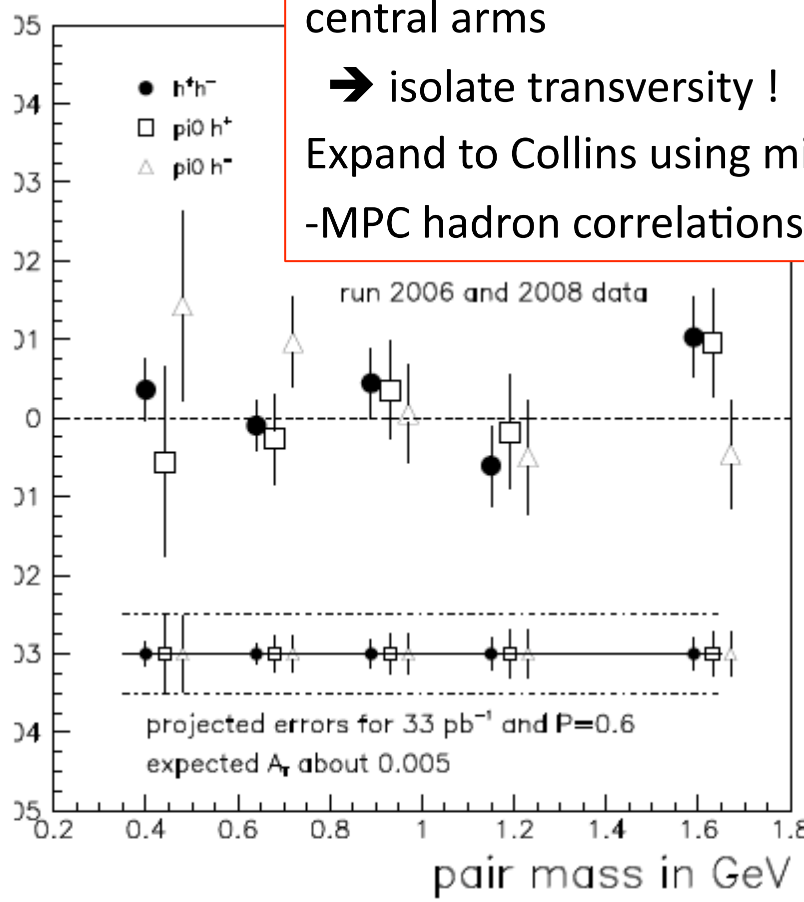
200 GeV p+p in Run-12+13

- **Double duty:**
  reference for c,b in AuAu + transverse spin physics
- **Assume $\int Ldt = 33 pb^{-1}$ in 30cm with P=0.6**
  (4 x existing lumi, better polarization)



characterize p_T dependence

Single particles at 3.1 < η < 3.8



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

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Run-12 next priority: 200 GeV Au+Au

- Utilize our new silicon detectors
  - Key data set with VTX – Au+Au and p+p comparison
  - First run with FVTX to look at forward rapidity
- The era of separated charm and bottom measurements
  - Help 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
    - (I don't believe in accidental cancellations…)

- 3rd priority: 200 GeV p+p comparison for c, b R_{AA}

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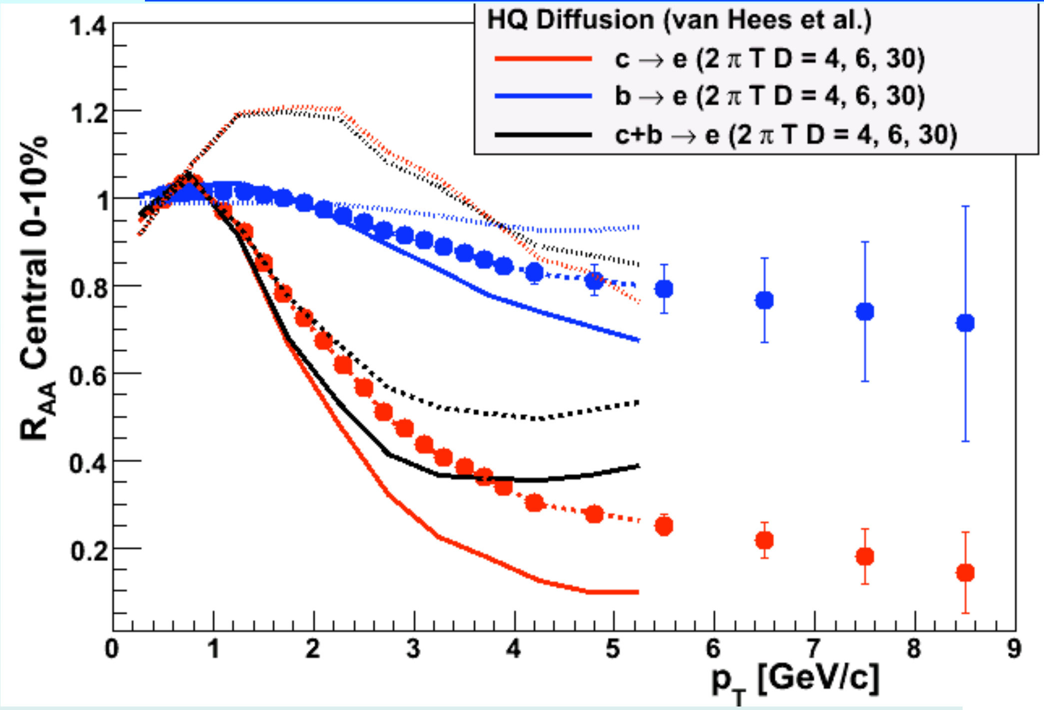
Run-12 next priority: 200 GeV Au+Au w/VTX



For 29M mb Au+Au events

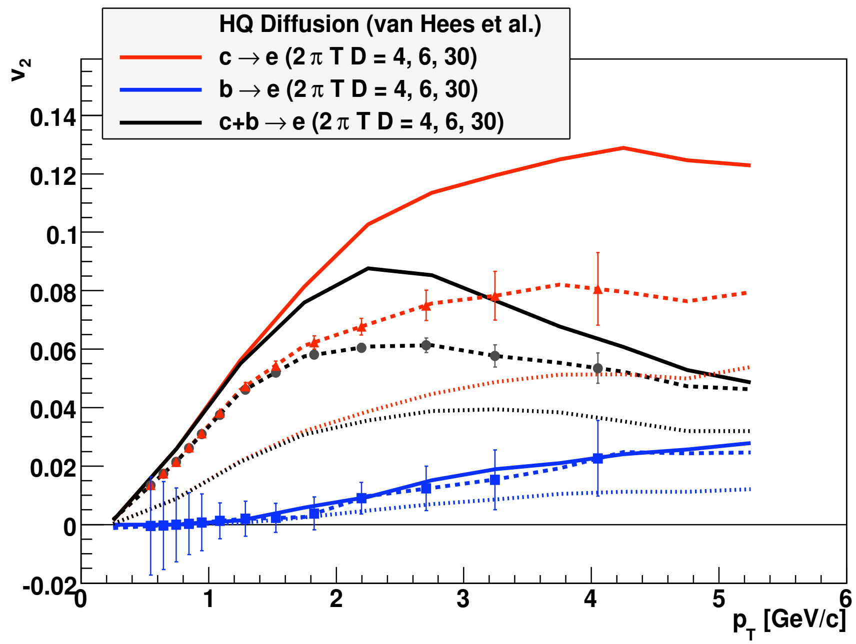
7 weeks in Run-12: 0.8 nb^{-1} (~4B events) in 10cm

Error bars Run-12 alone x √6

c, b R_{AA} to ~ 5GeV/c

b v_2 to ~ a few GeV/c

NB: Statistical power of VTX data from Run-11 is not yet known



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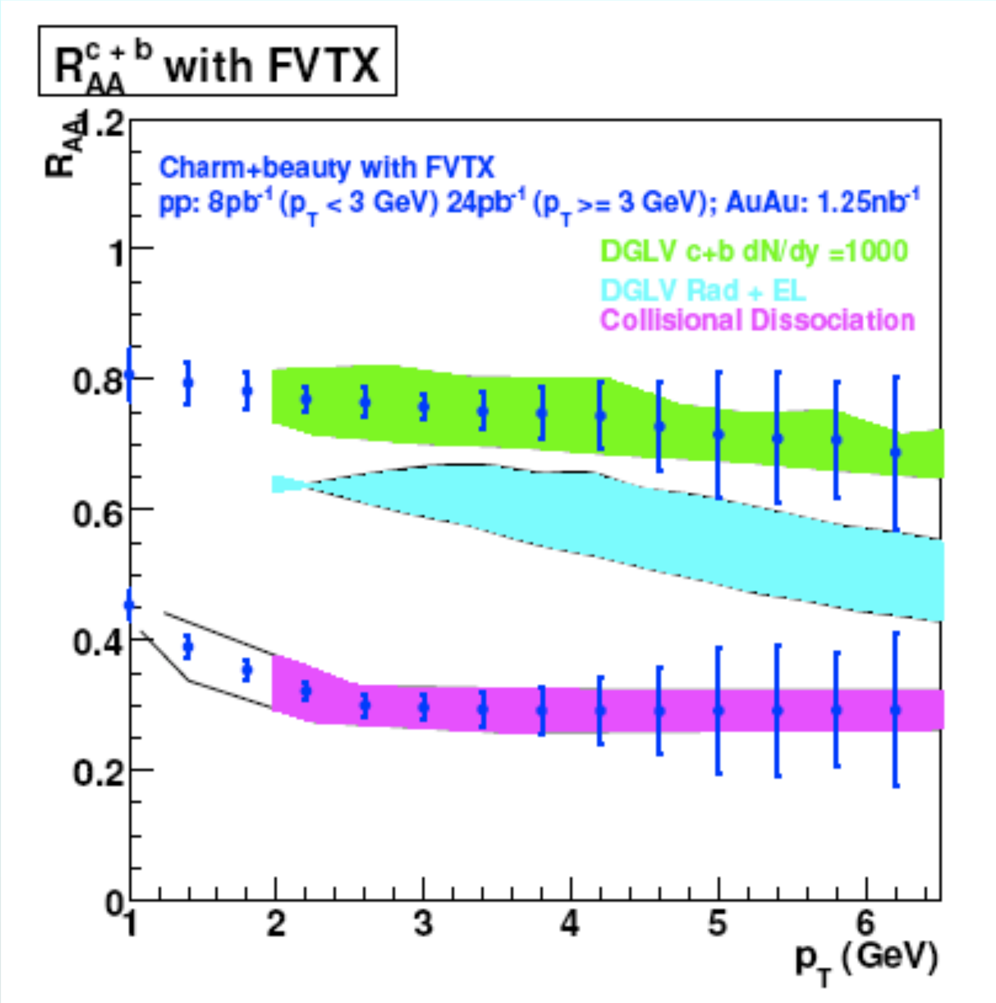
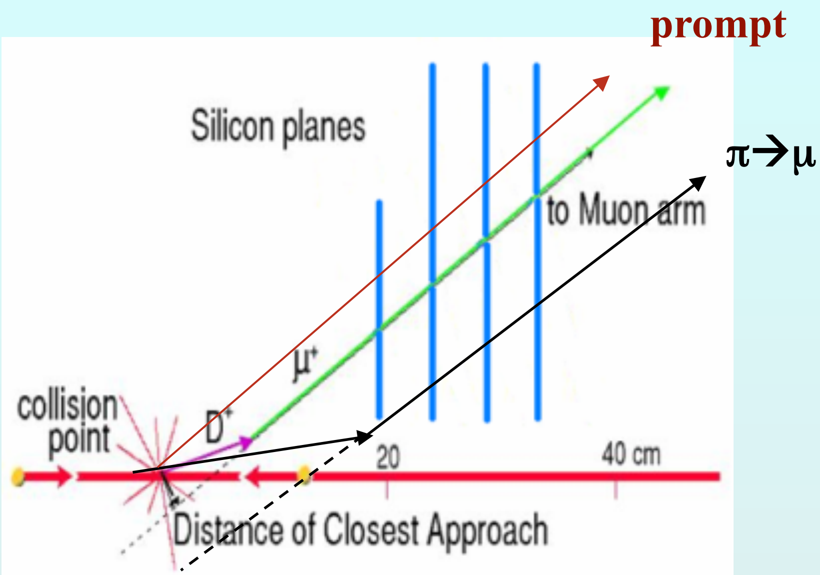
Run-12 FVTX physics



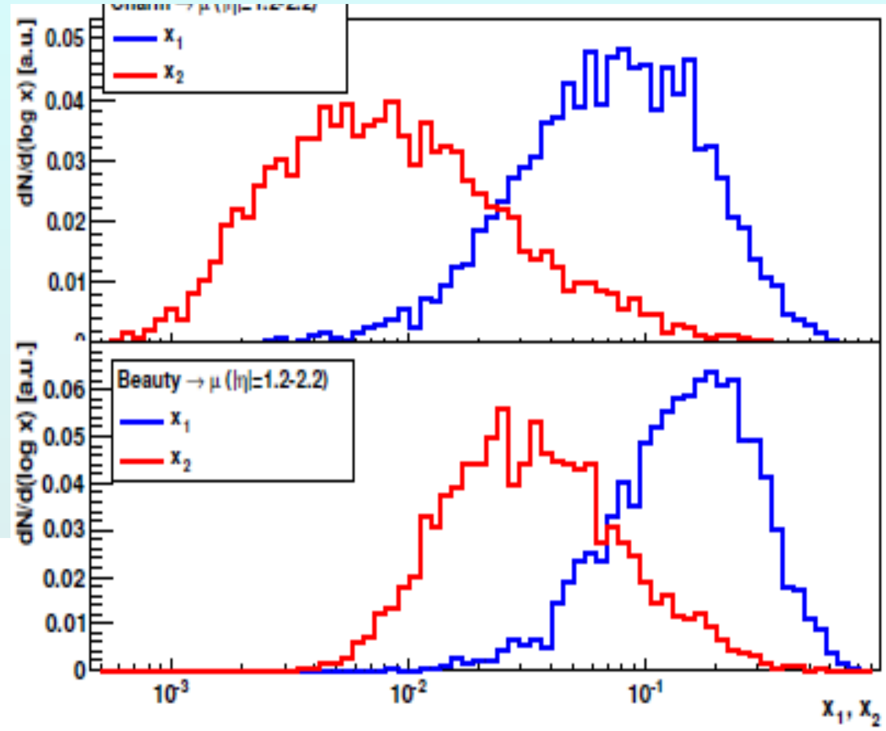
Run-12 Goals:

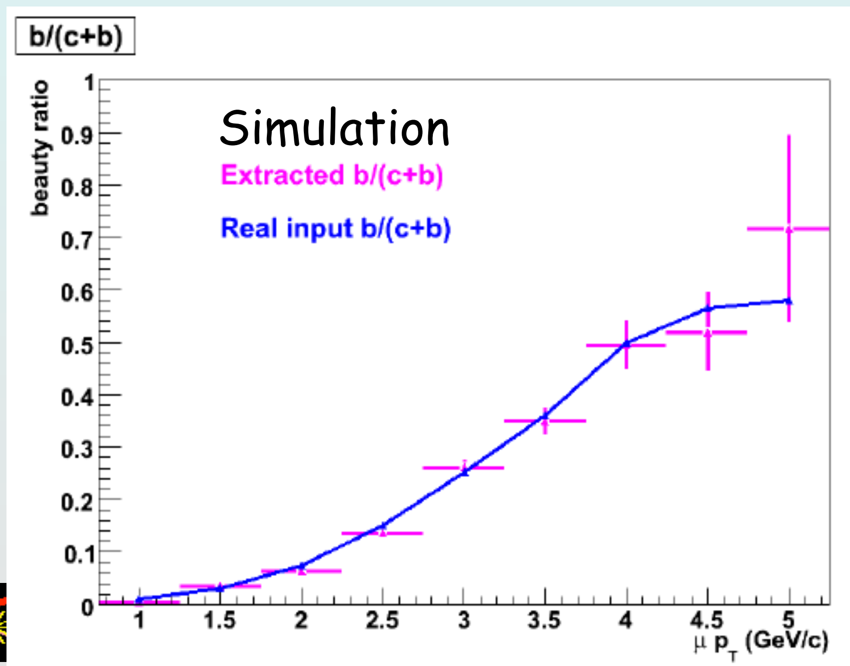
- Commission
- Collect first part of the data set at left ~1/6 of 4.6 nb^{-1} minbias
- One run already has discriminating power for energy loss models

FVTX performance simulations



c,b coverage





Fit DCA distribution in each p_T bin with sum of individual c, b contributions.

Iterate to constrain D and B p_T distributions.

4th priority: U+U "engineering" run: 0.5 + 1.5 wk

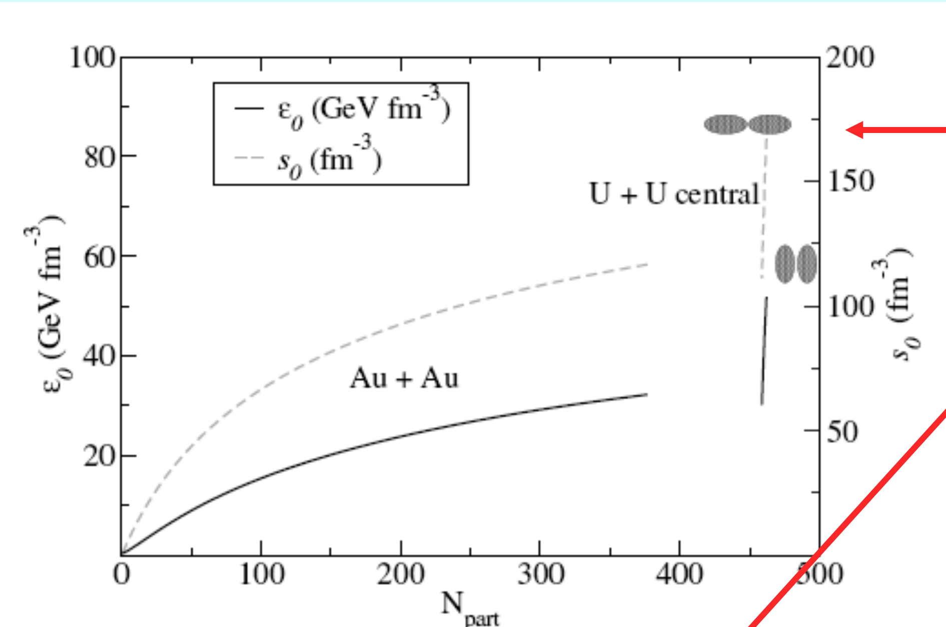
Glauber MC simulations show:

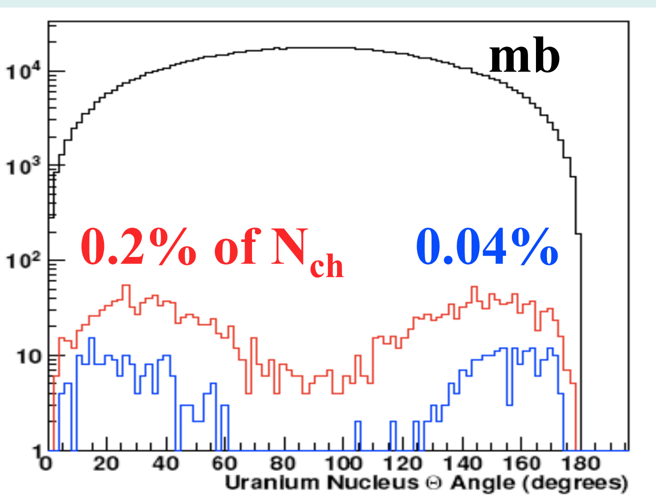
Goal: vary ε_0, eccentricity

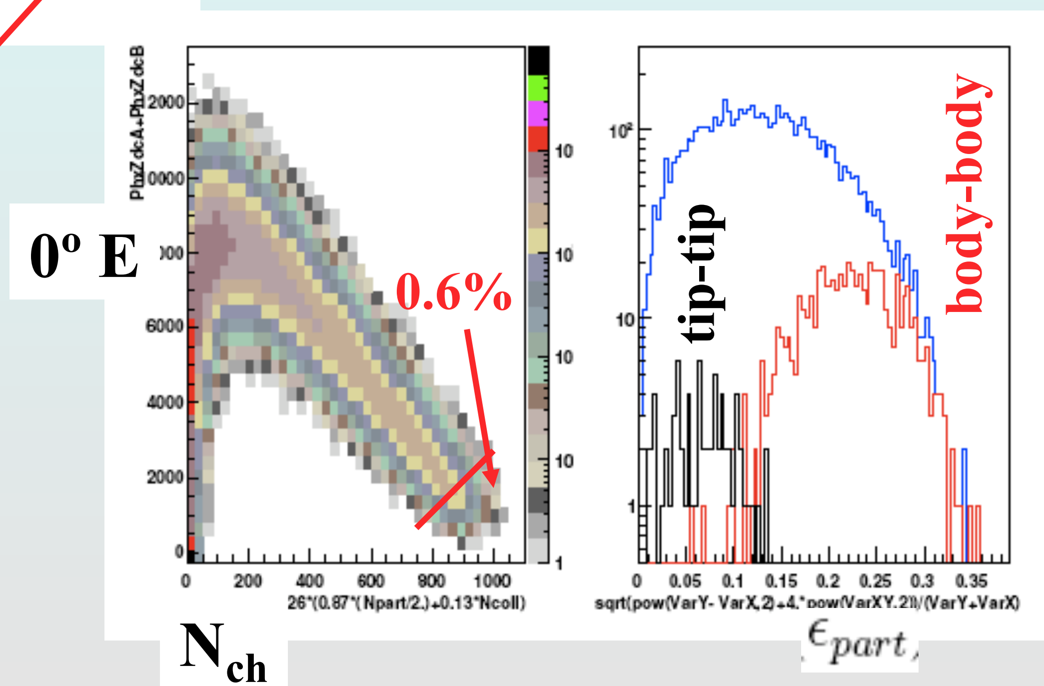
The problem

The solution: 200M evt

~ 400k tip-tip events







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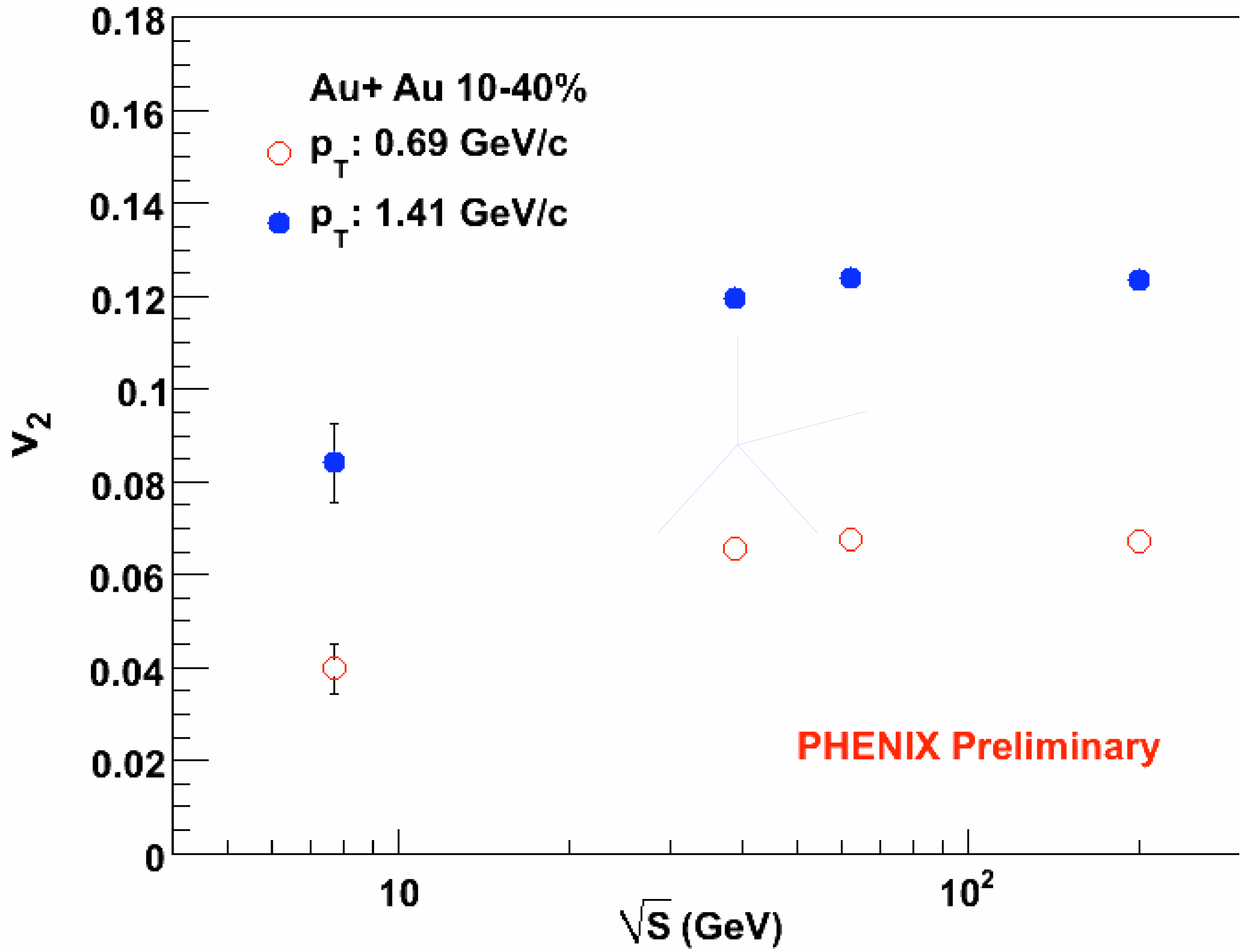
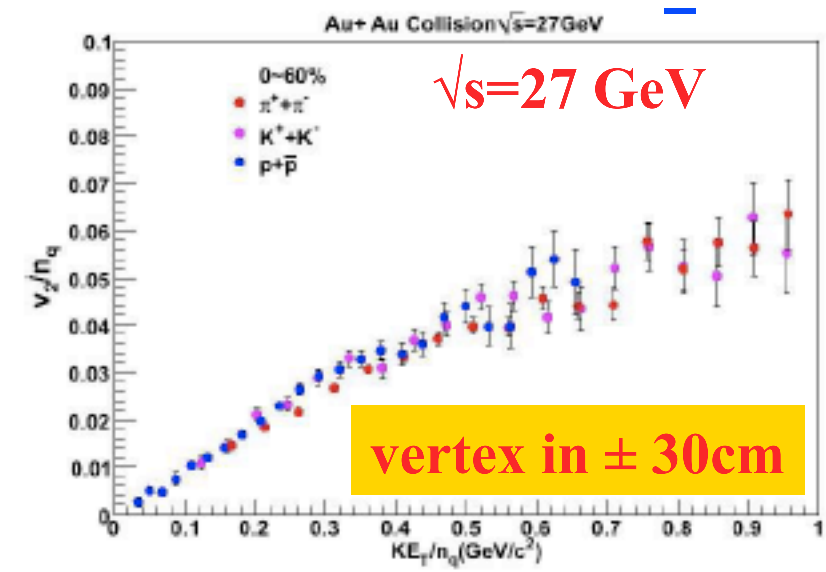
5th priority: 27 GeV Au+Au

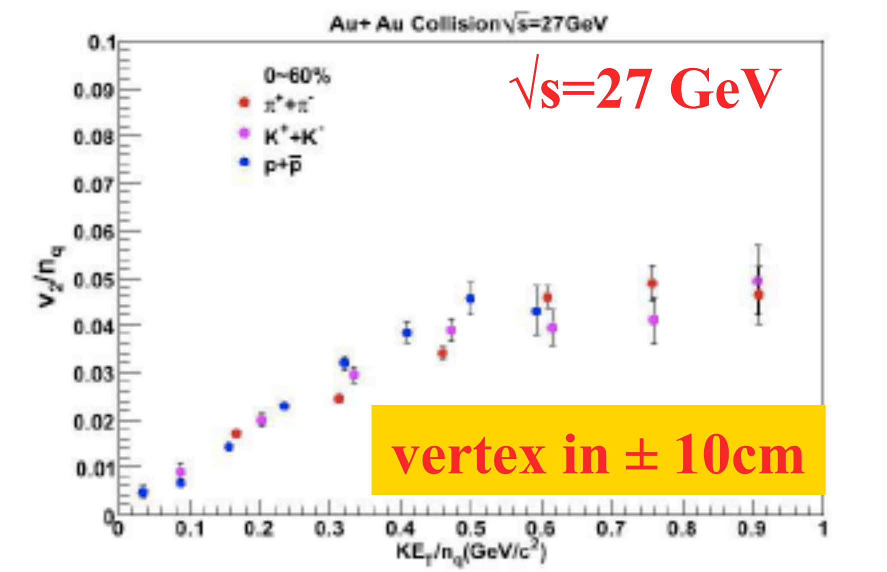


PHENIX beam energy scan goals:

- ***v_2 saturates where?***
- ***Constituent quark scaling?***
- ***v_3 vs $\sqrt{s}$?***
- ***$\sqrt{s}$ dependence of η/s?***
- ***R_{AA} reaches 1.0 where?***

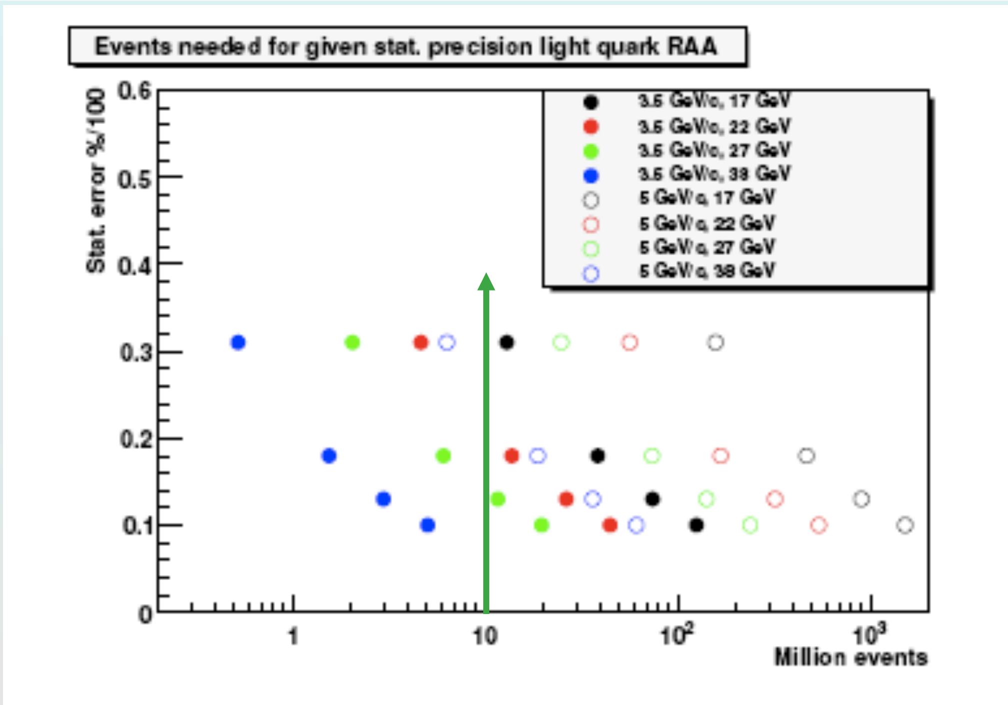
v_2 performance





Vertex cut

± 10 cm



1 week of running

(~11M events)

- uncertainty at p_T = 3.5 GeV: ~14% at 27 GeV
- Marginal for n_q scaling

5^{th} priority: low E p+p comparison

- Currently we rely upon extrapolation for 62 GeV
  - Considerable uncertainty for R_{AA}
  - Unavailable for heavy flavor electrons or J/ψ
- 62 GeV requirements
  - 4.5 pb^{-1} p+p equiv. Au+Au * R_{AA}=0.25 → 1.1 pb^{-1}
  - 4.8 $x10^{30}$ /cm^2/sec → 0.124 pb^{-1} per day → 9 days
- 39 GeV requirements
  - Rate is half as large; π^0 R_{AA}=0.4 @ p_T=3.5 GeV/c
  - 1.6 pb^{-1} p+p equiv. Au+Au * R_{AA}=0.4 → 0.64 pb^{-1} → 10 days
- NB: It may be preferable to live with interpolating 39 (and 27) GeV p+p if we pin down at 20 GeV

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Run-13 Physics goals

- Reach 300 pb-1 sampled for W in 500 GeV p+p
- 200 GeV p+p for VTX, FVTX comparison and transverse spin physics
- Control geometry to quantify path length dependence
  - U+U if successfully demonstrate selection cuts
    - 5 weeks for ∫Ldt=0.57nb^{-1} in 10cm (4B mb U+U events)
  - First Cu+Au collisions
- May replace one of these with full energy Au+Au
  - Depends on FVTX commissioning in Run-12

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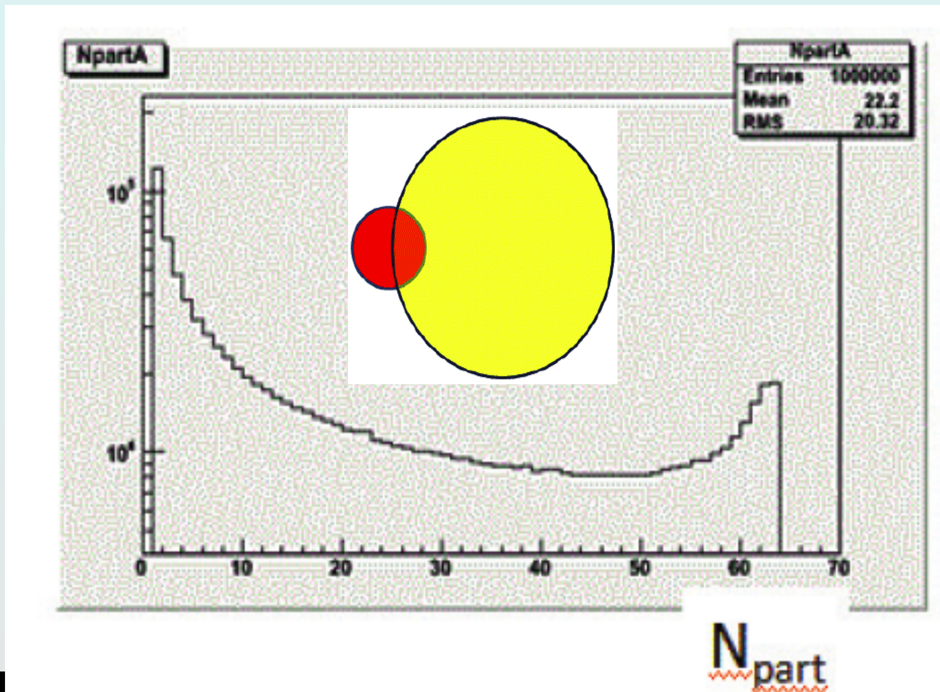
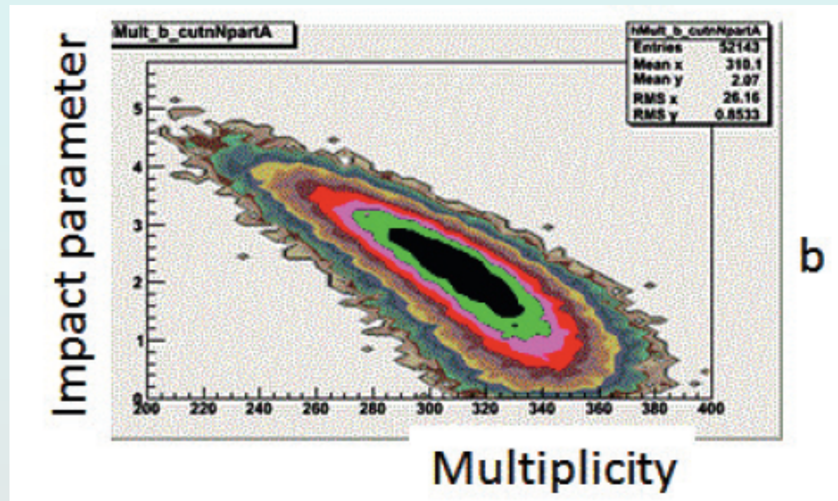
Cu+Au: 2.4 nb^{-1} into 10 cm vertex cut

- Cu buried inside Au for most central collisions
  - Minimize effects of the surface on hard probes
  - select top 3% centrality for this (300M events)
- Eccentricity without left/right symmetry for non-central collisions
  - Non-fluctuation source of odd harmonics





PHENIX beam use proposal

run	species	$\sqrt{s_{NN}}$	weeks	$\int L\,dt$ $\|z\| < 30$ cm	$\int L\,dt$ $\|z\| < 10$ cm	pol.	comments
	$p+p$	200	5	$13.1\,pb^{-1}$	$4.7\,pb^{-1}$	60% (T)	HI comparison, $\perp$ spin
	$p+p$	500	8	$100\,pb^{-1}$	$35\,pb^{-1}$	50% (L)	W program + ΔG
12	Au+Au	200	7		$0.8\,nb^{-1}$		heavy flavor (F/VTX)
	U+U	193	1.5		$0.03\,nb^{-1}$		explore geometry
	Au+Au	27	1	$5.2\,\mu b^{-1}$			energy scan

Additions if we get a longer Run-12 (in priority order)

1.5 week of 62.4 GeV p+p for J/ψ & open heavy q R_{AA}
1.5 week of 39 GeV p+p for π^0 R_{AA}
Add 1 week to 27 GeV Au+Au to improve reach

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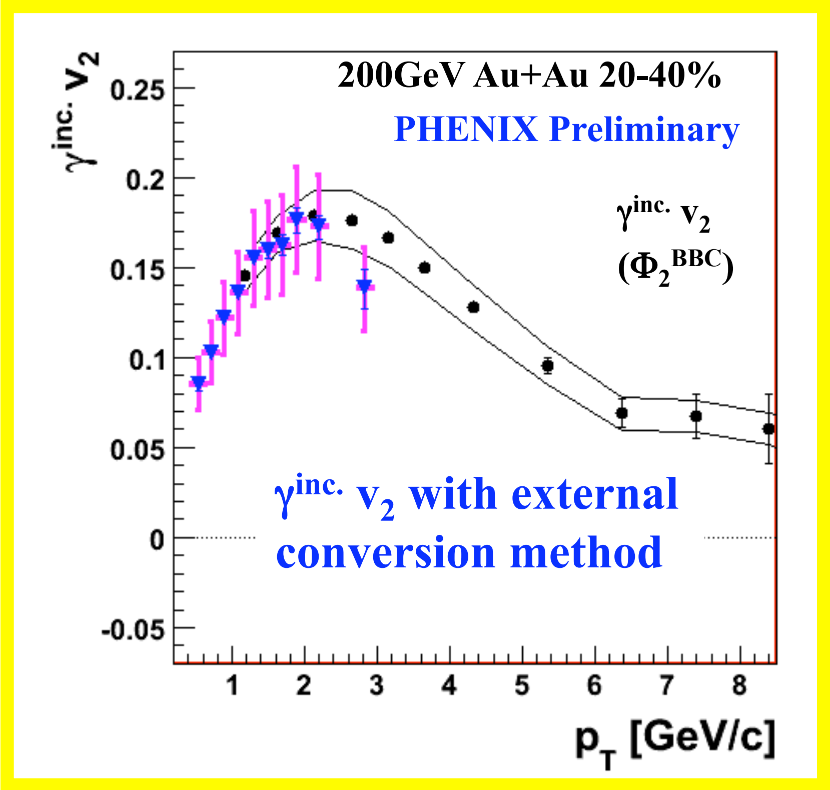
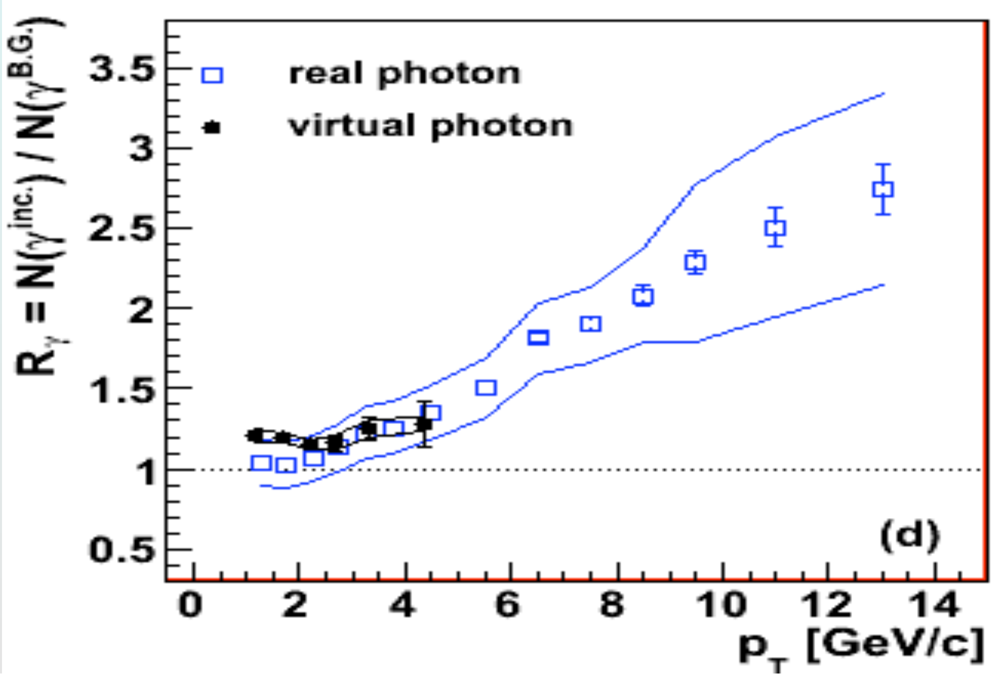
- **backup slides**

Direct photon flow ingredients



- Key cross checks:
  - γinc are really γ's:
    - check using γ-> e+e-
  - Rγ for virtual vs. real γ



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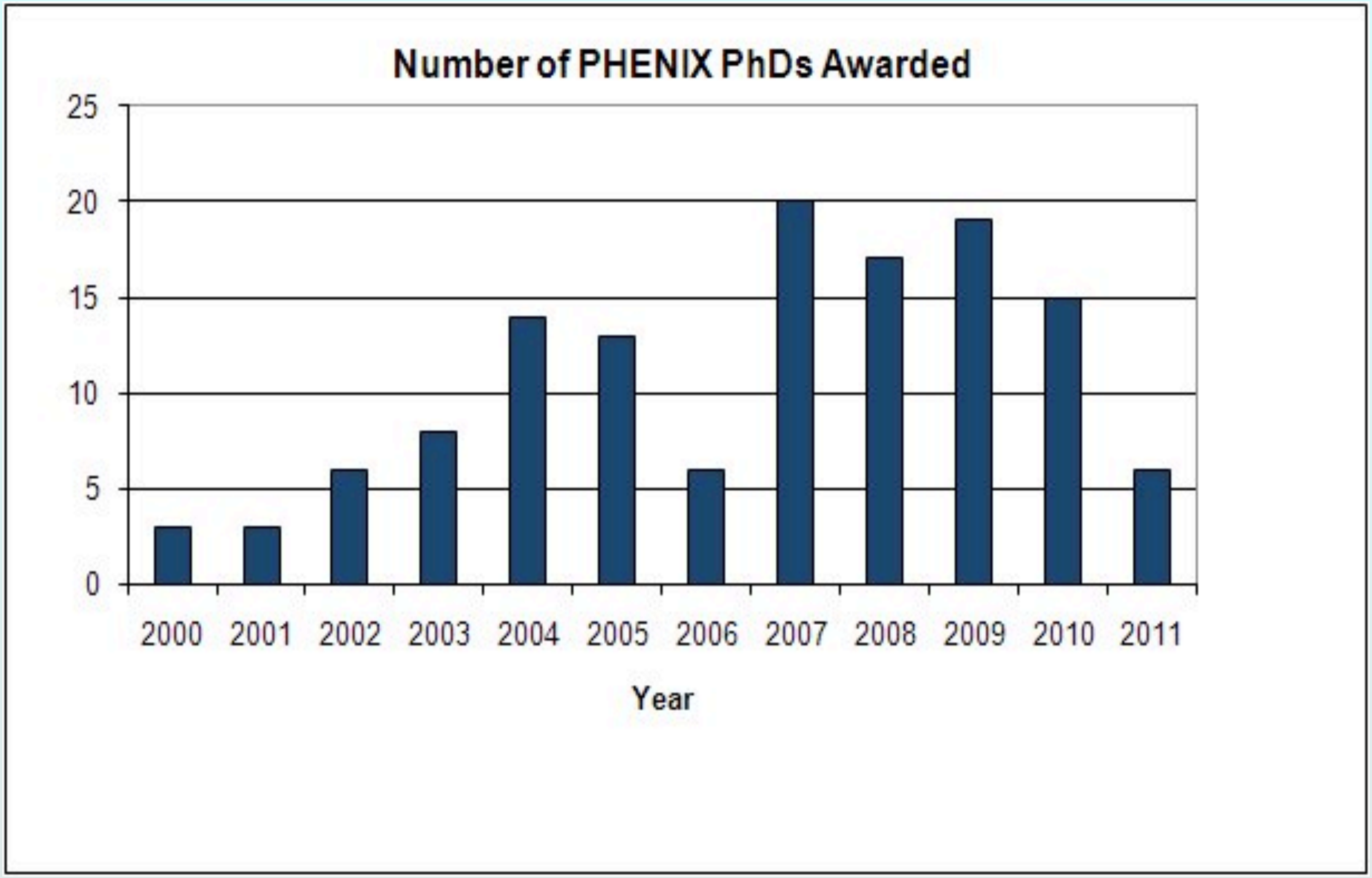
Ph.D. theses



Number of PHENIX PhDs Awarded
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year

Basis for time estimates

$\sqrt{s_{NN}}$	ave.lumi. $(cm^{-2}sec^{-1})$	σ (b)	Events/Day in 30 cm	Events/Day in 10 cm
Au+Au				
18	6.00 E+25	6.8	3.73 M	1.24 M
27	8.00 E+25	6.8	4.98 M	1.66 M
p+p				
22	2.50 E+29	0.03	68.6 M	22.9 M
27	6.00 E+29	0.032	176 M	58.5 M
39	2.40 E+30	0.033	724 M	241 M
62	4.80 E+30	0.0356	1.56 B	521 M

- Projections from W. Fischer

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HBD performance: figure of merit N_0 and single electron detection efficiency

- **The average number of photo-electrons N_{pe} in a Cherenkov counter:**

$$N_{pe} = N_0 L / \bar{\gamma}_{th}^2$$

with:

- $$N_0 = \frac{\alpha}{hc} \int \varepsilon(E) dE = 714 \text{ cm}^{-1}$$
- $$\bar{\gamma}_{th} = 29$$
- **bandwidth: 6.2 eV (CsI photo-cathode threshold) - 11.5 eV (CF_4 cut-off)**

N_0 ideal value	714 cm^{-1}
Optical transparency of mesh	88.5 %
Optical transparency of photocath.	81.0 %
N_{pe} measured	20
N_0 measured value	**330 cm^{-1}**

Quantum efficiency kept constant during the two years of operation!

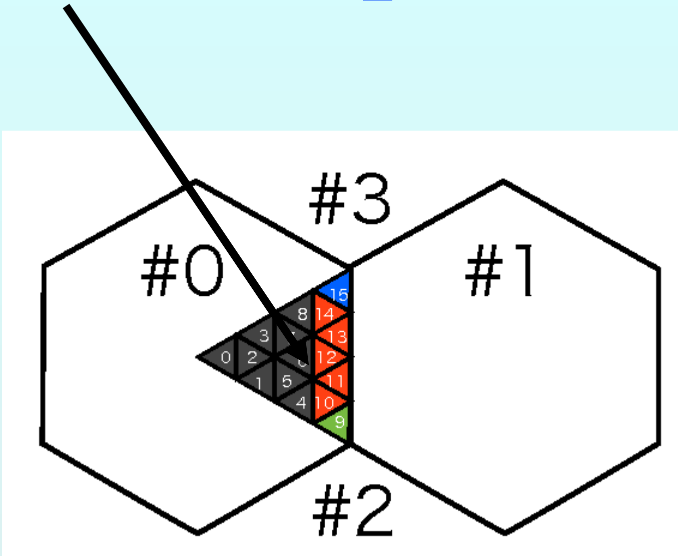
The highest ever measured N_0!

The high photoelectron yield → excellent single electron detection efficiency:

→ Single electron efficiency using a sample of open Dalitz decays: ε ~ 90 %

→ Single electron efficiency derived from the J/Ψ region: ε = 90.6 ± 9.9 %

CF_4: good N_0 but it also scintillates

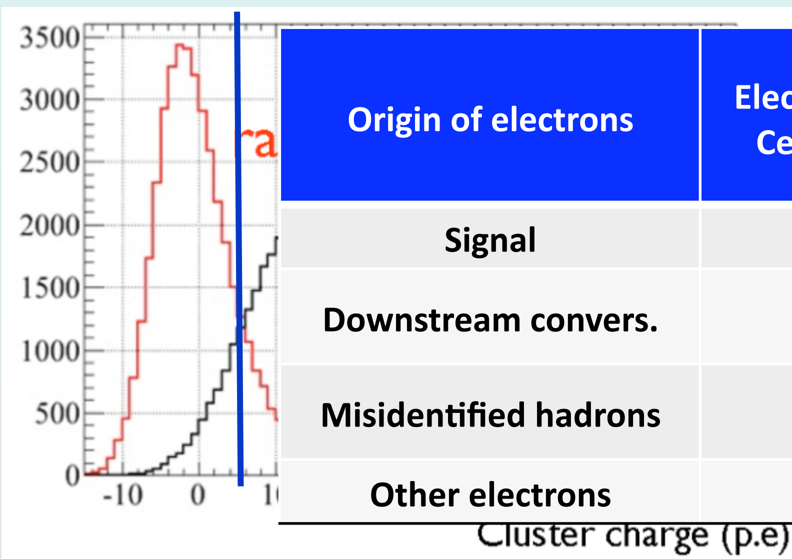


Analysis steps (being optimized now):

1. Subtract underlying event
2. Reject electrons created downstream of the HBD
3. Reject π^0 Dalitz, conversions created upstream

MC study: Matching to HBD only:

S/B → 8.4 S/B



Origin of electrons	Electrons/event Central Arms	Electrons/event Central Arms + HBD	Efficiency	Rejection
Signal	0.17	0.14	**0.83**	
Downstream convers.	0.85	0.09		**9.7**
Misidentified hadrons	0.33	0.07		**4.7**
Other electrons	0.22	0.15		**1.5**

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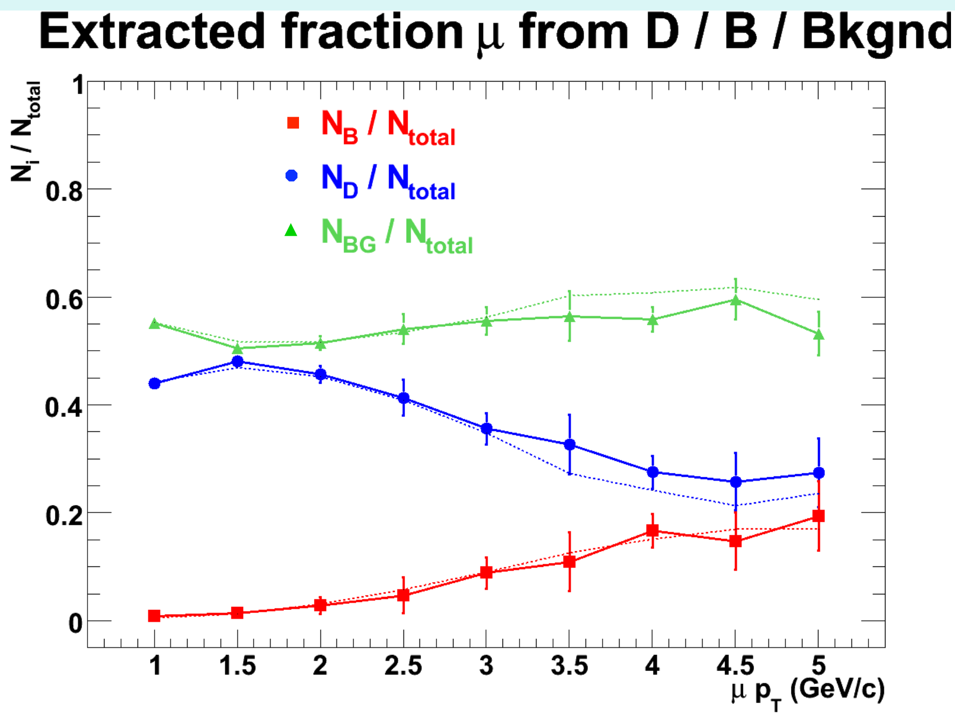
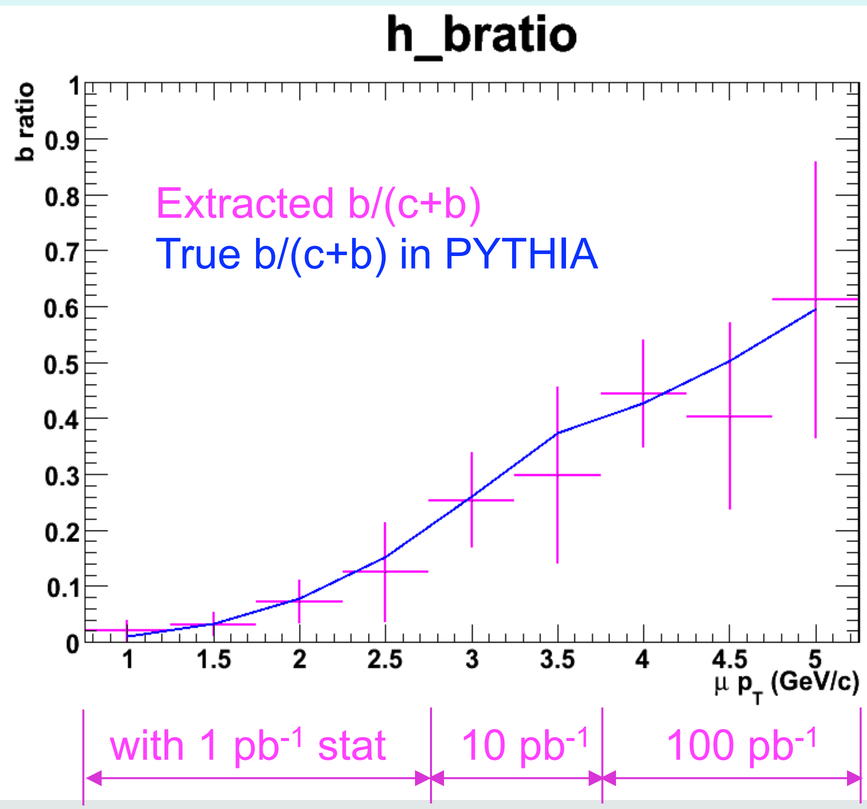
M. Makek, QM2011

Beauty & charm separation at different muon p_T





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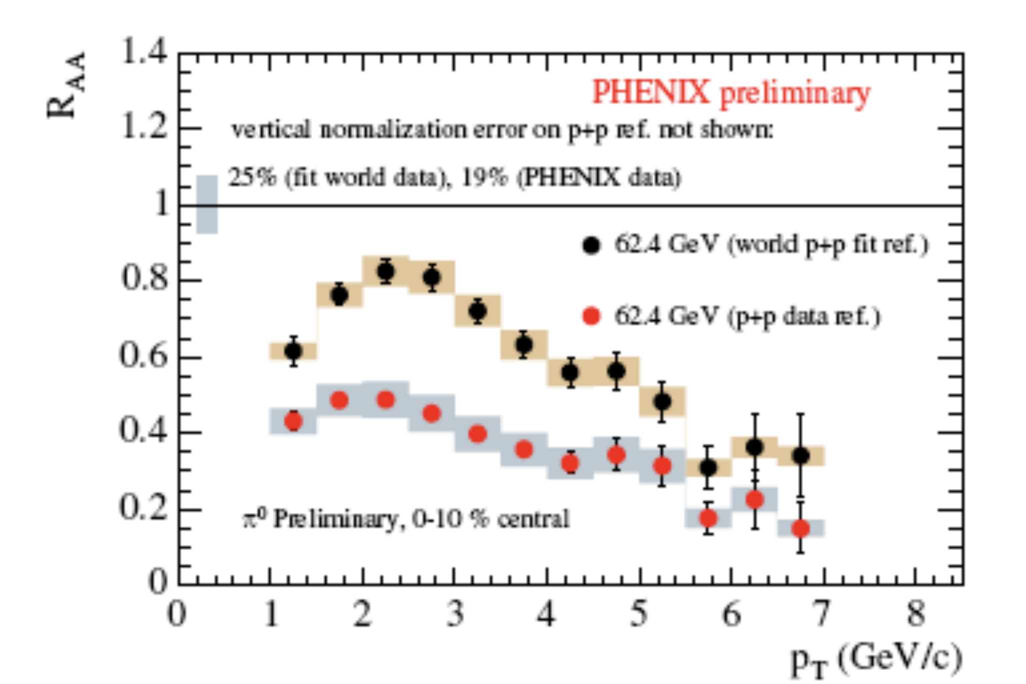
Low energy p+p comparison running



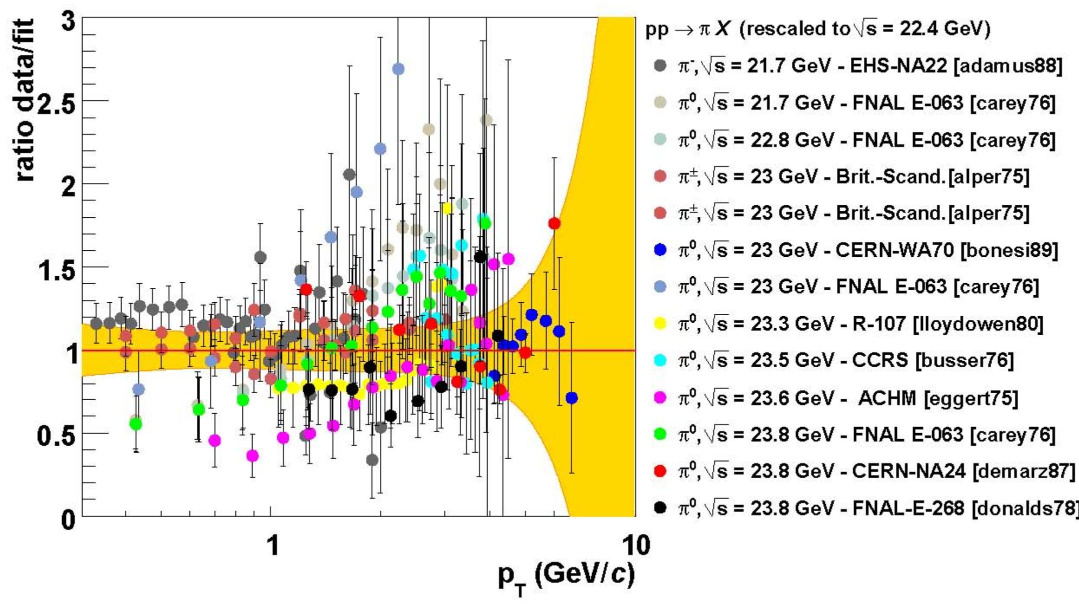
Measurement way better than fit!

But, p+p data run out at 7 GeV/c p_T so we request new run

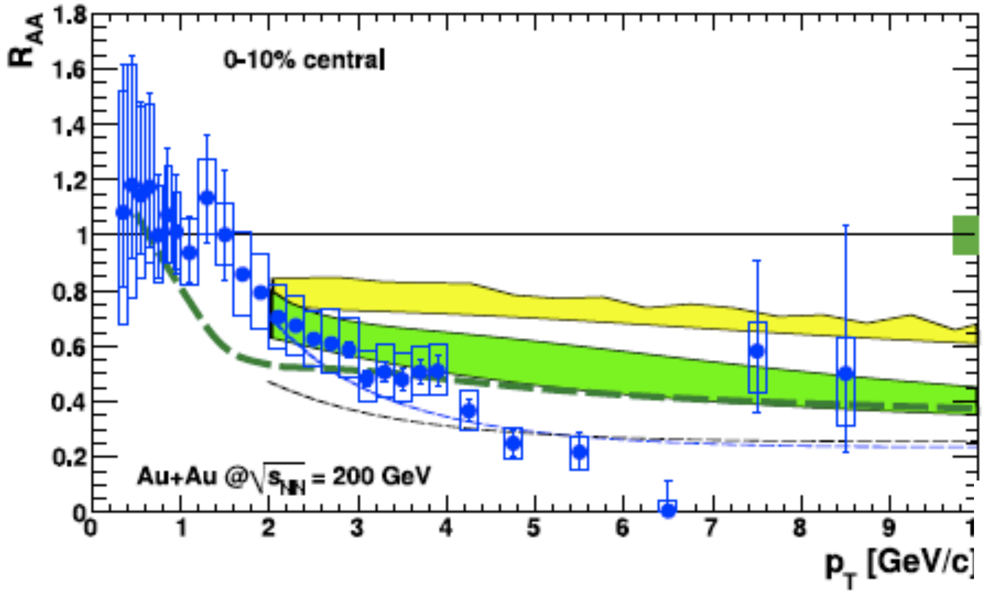
Arleo & d'Enterria, Phys.Rev.D78:094004,2008

- **Key: p+p data at √s = 22.4 GeV**
- **For Cu+Cu statistics, require 0.01 pb^{-1}**

  I.e. 6 days + changeover



heavy quark suppression & flow?



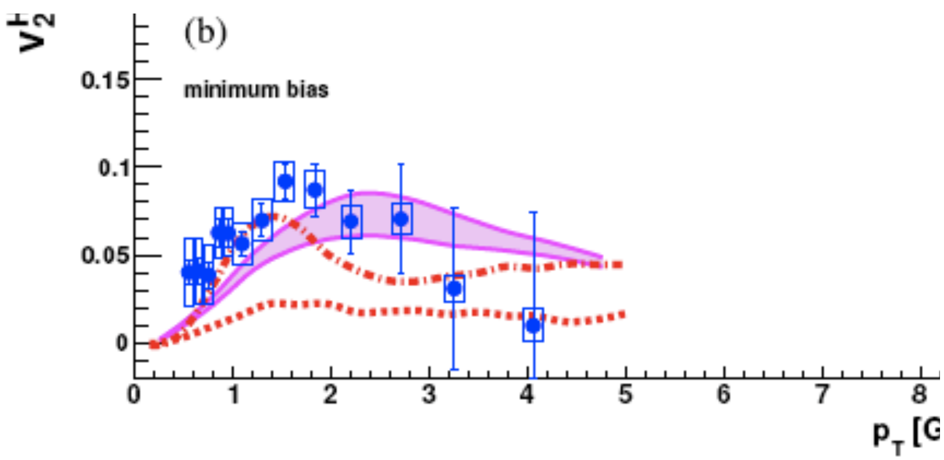
PRL.98: 172301,2007

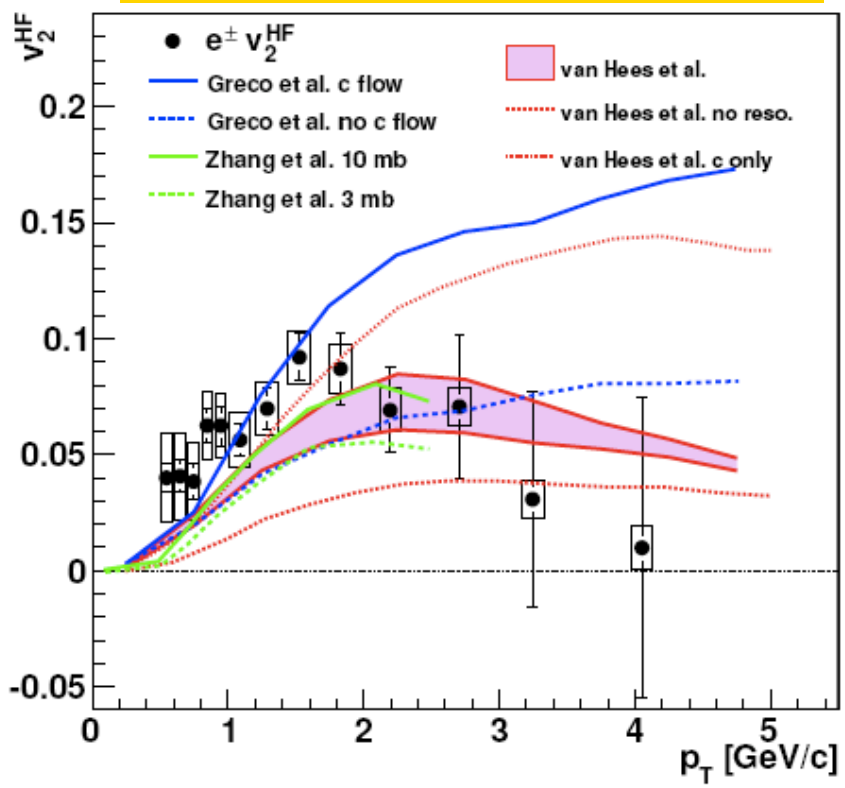
arXiV: 1005.1627

Collisional energy loss?

v_2 decrease with p_T?

role of b quarks?





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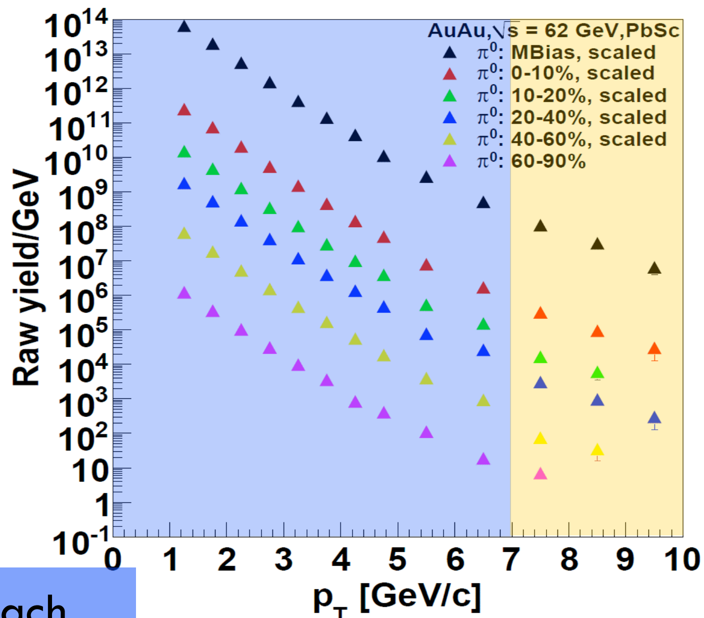
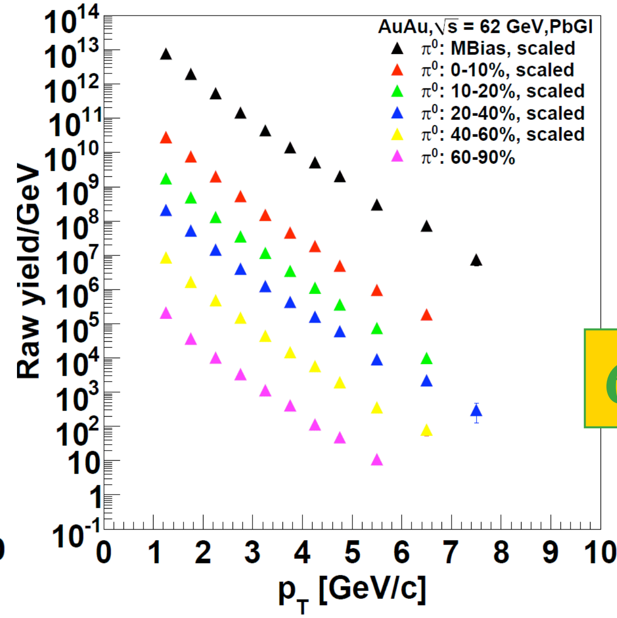
Jet suppression in Run-10



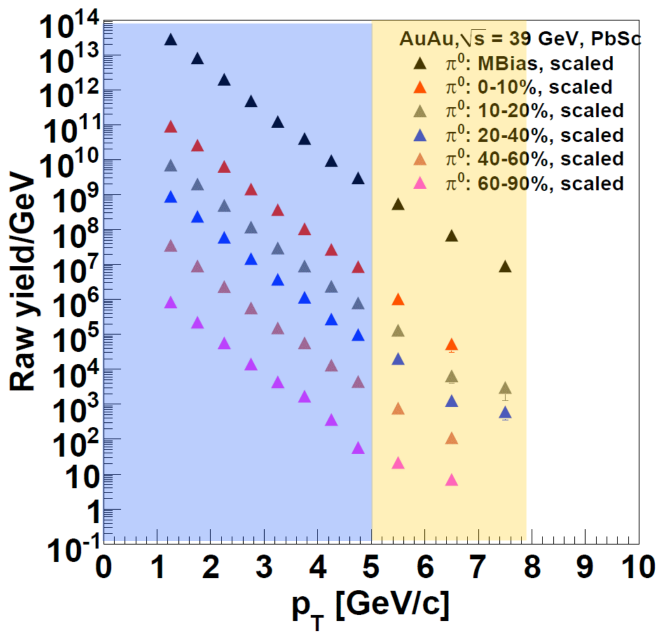


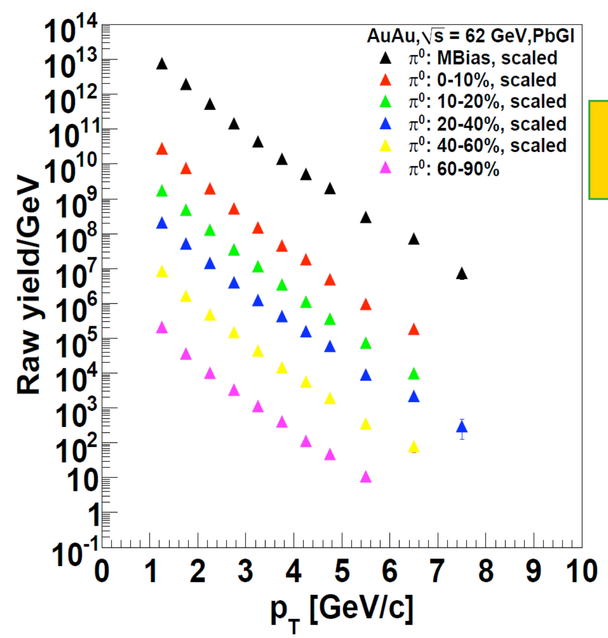
Run-10 Raw π^0 yields

62 GeV

Previous p_T reach (Run-4)

Enhanced p_T reach (Run-10)

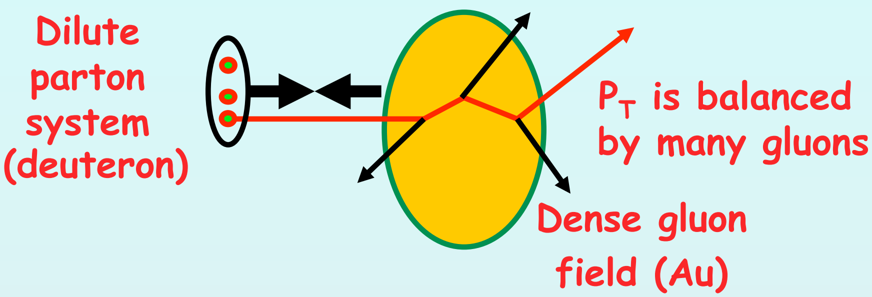


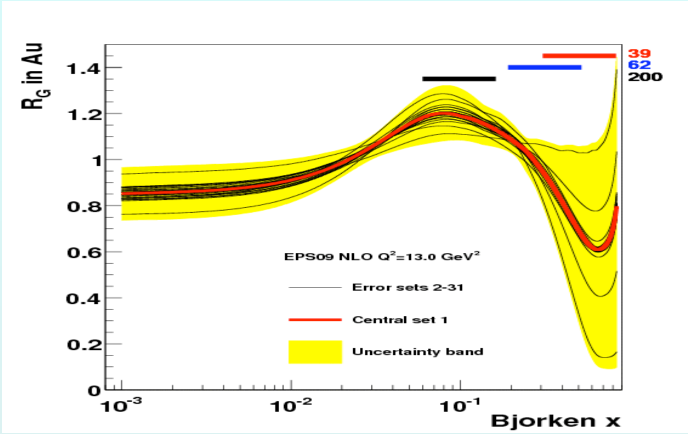


39 GeV

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

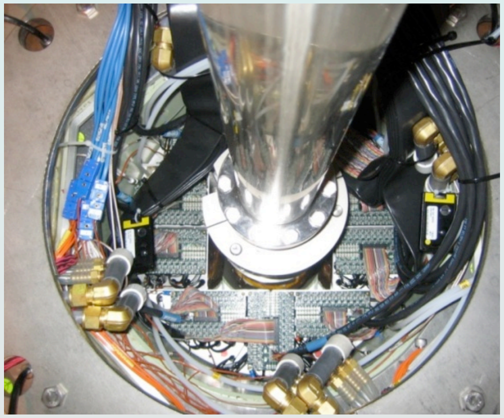
other probes of shadowing & gluon saturation – forward hadrons

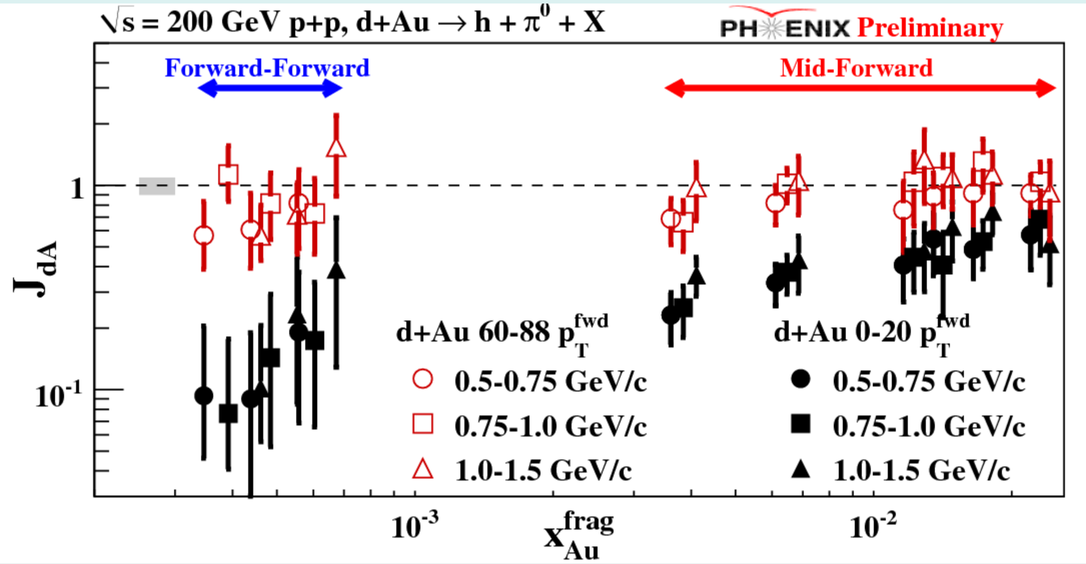




Mono-jets in the gluon saturation (CGC) picture give suppression of pairs per trigger and some broadening of correlation

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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Peking University, Beijing, People's Republic of China
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Czech Technical University, Zikova 4, 166 36 Prague 6, Czech Republic
Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2,
182 21 Prague 8, Czech Republic
Helsinki Institute of Physics and University of Jyväskylä, P.O.Box 35, FI-40014 Jyväskylä, Finland
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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 $500 \le m_{e+e-} \le 1000$ 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

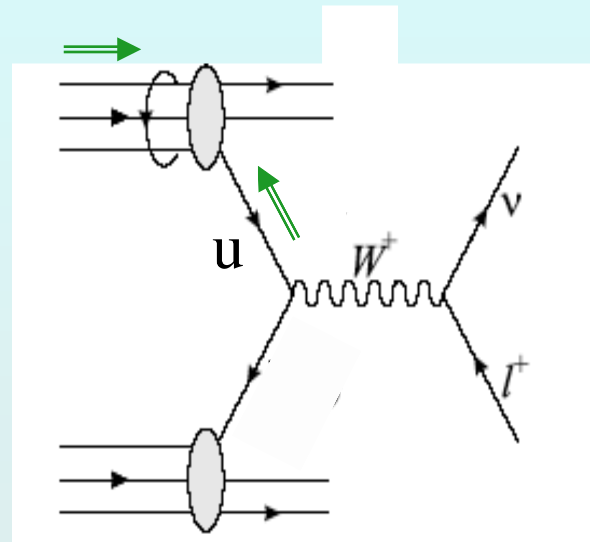
Year	#	Milestone
2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12	Determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized 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.

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

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

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

$\vec{p}$

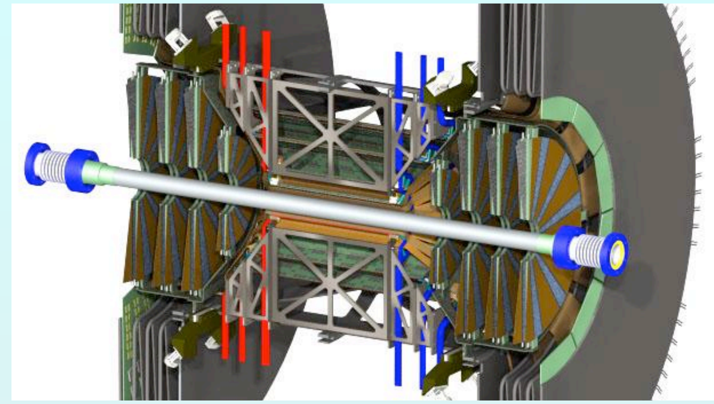


p unpol.

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

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

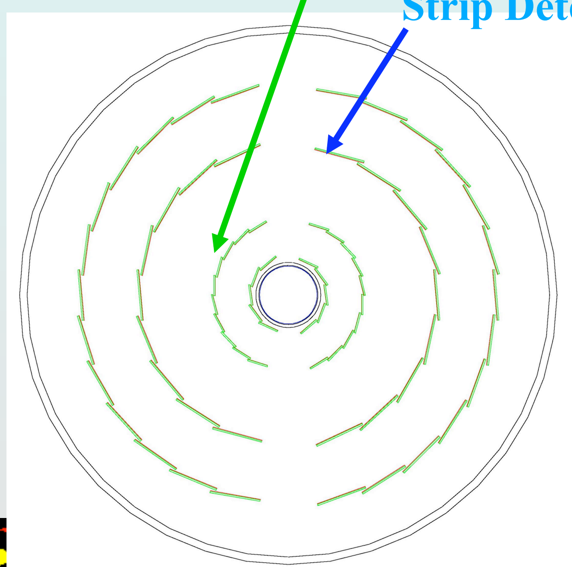
Barrel VTX Detector

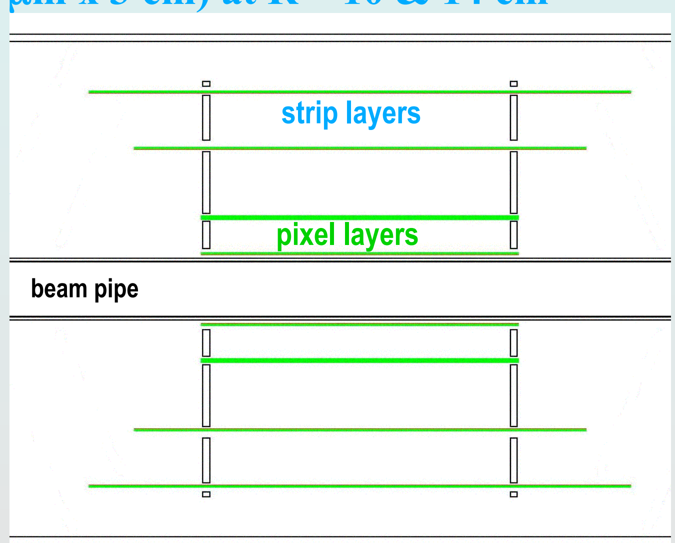


- **Specifications:**
  - Large acceptance ($\Delta\phi \sim 2\pi$ and $|\eta| < 1.2$)
  - Displaced vertex measurement $\sigma < 40\ \mu m$
  - Charged particle tracking $\sigma_p/p \sim 5\%\ p$ at high pT
  - Detector must work for both HI and pp collisions.
- **Technology Choice**
  - Hybrid pixel 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





$|\eta|<1.2$

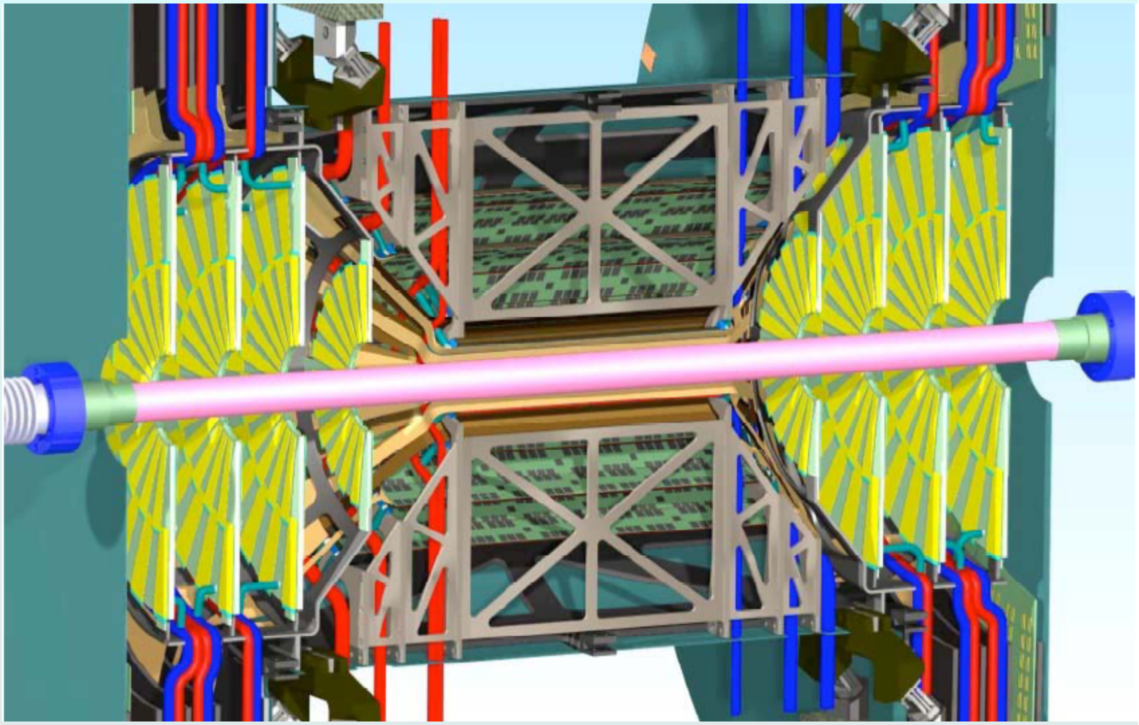
$\phi \sim 2\pi$

$z \sim \pm 10$ cm

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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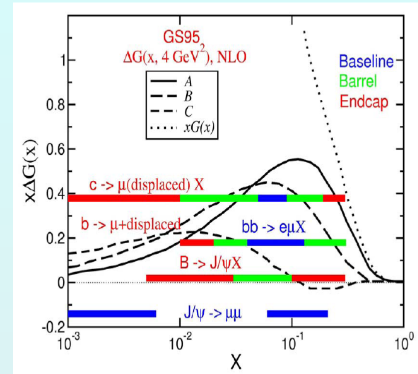
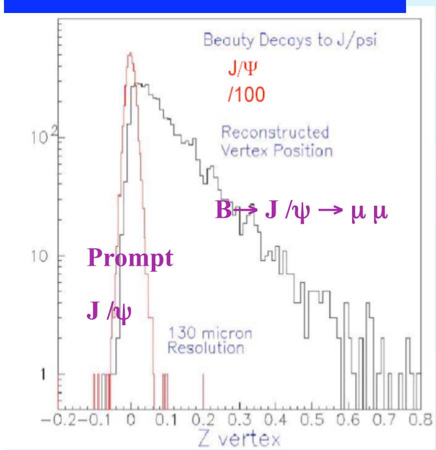
Forward Silicon Vertex Detector - FVTX

Enhanced x coverage



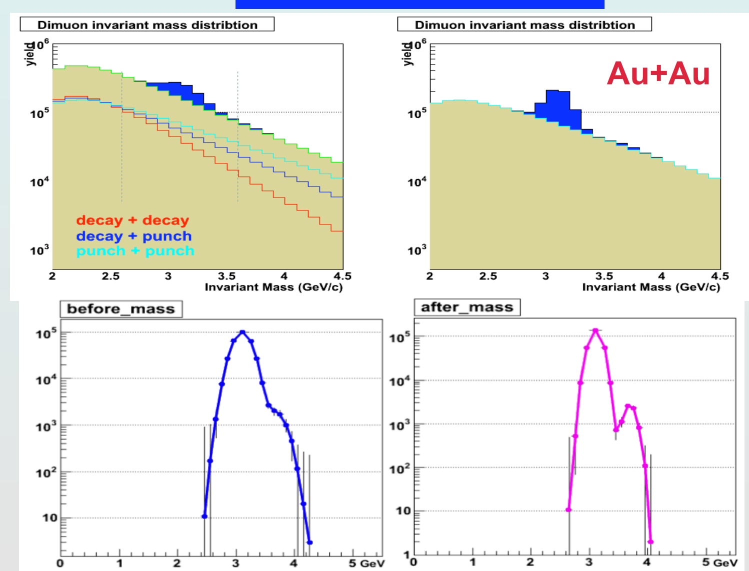
Direct measure of B



Physics Program of FVTX includes

- Resolving J/ψ and ψ' in Muon arms
- Resolving ϒ at y=0 using Muon arms
- Direct measure of B meson through displaced J/ψ
- Drell-Yan Measurements in dAu at both forward and midrapidities
- c, b ID for both HI physics & ΔG spin measurements
- Nuclear modification factor (CGC effects) in dAu using hadrons, c, b, and J/ψ

J/ψ, ψ' separation



c, b suppression at forward η