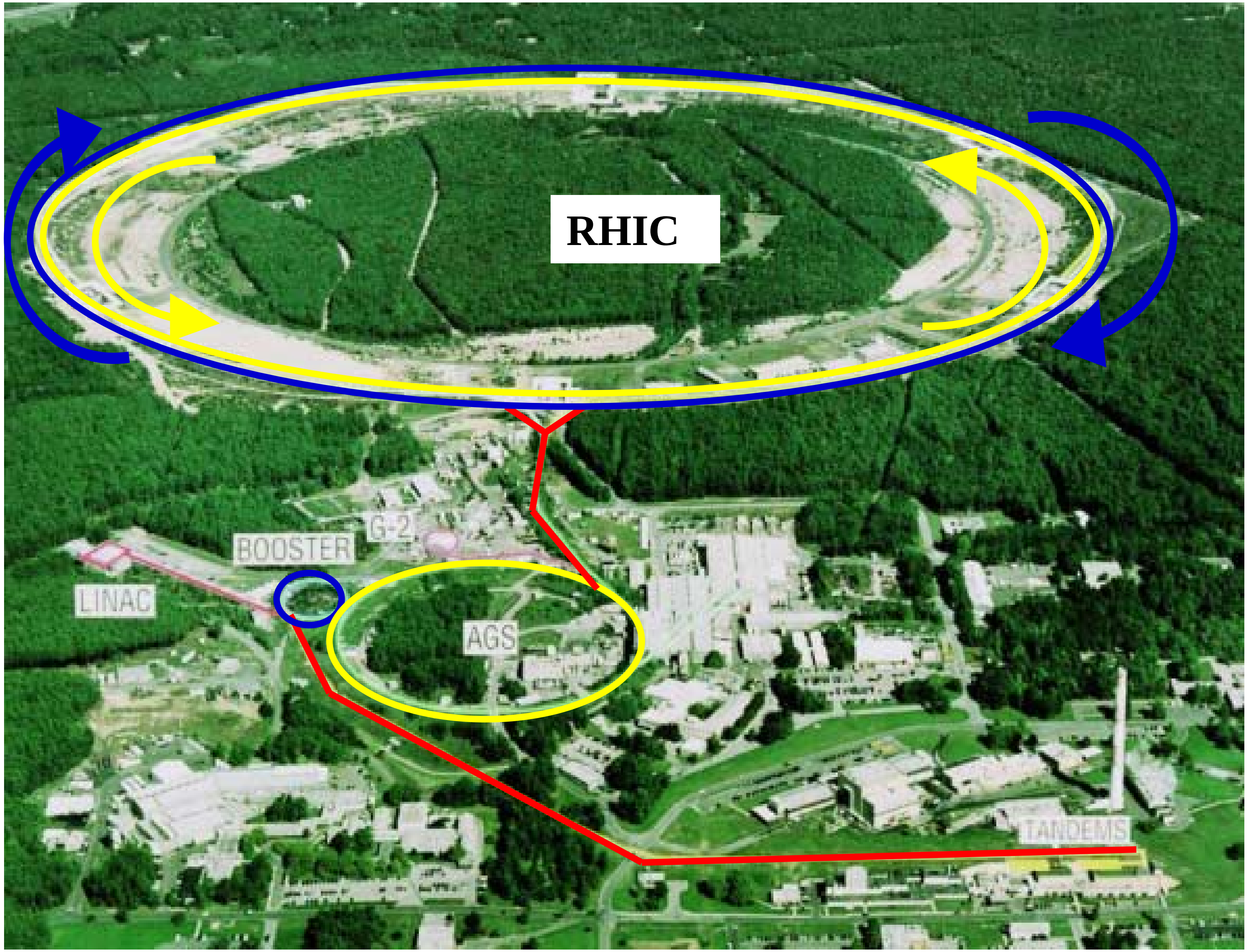
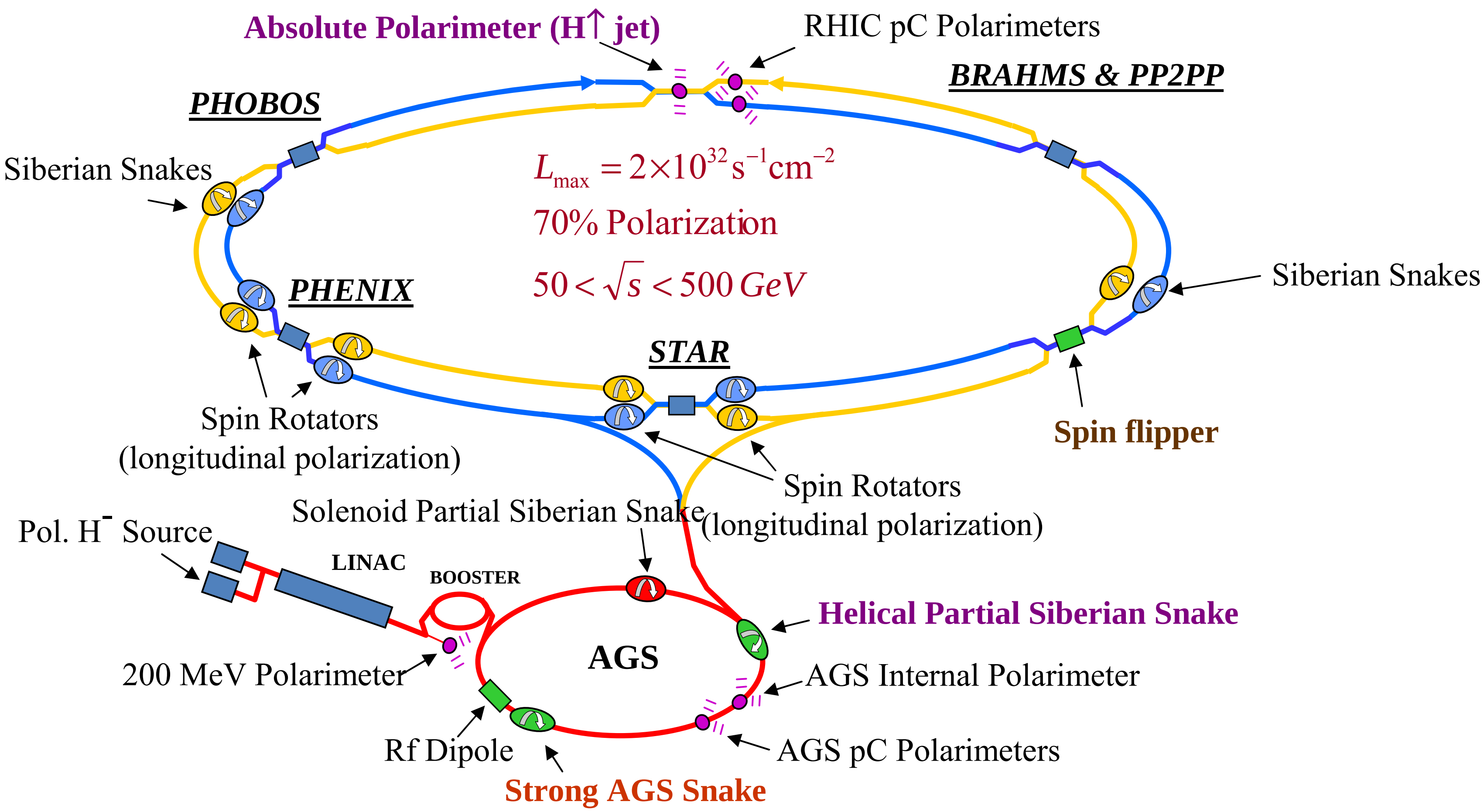
Physics of Heavy Ions Collisions with PHENIX detector @RHIC (BNL)

Alexei Denisov, IHEP (Protvino)
For PHENIX collaboration

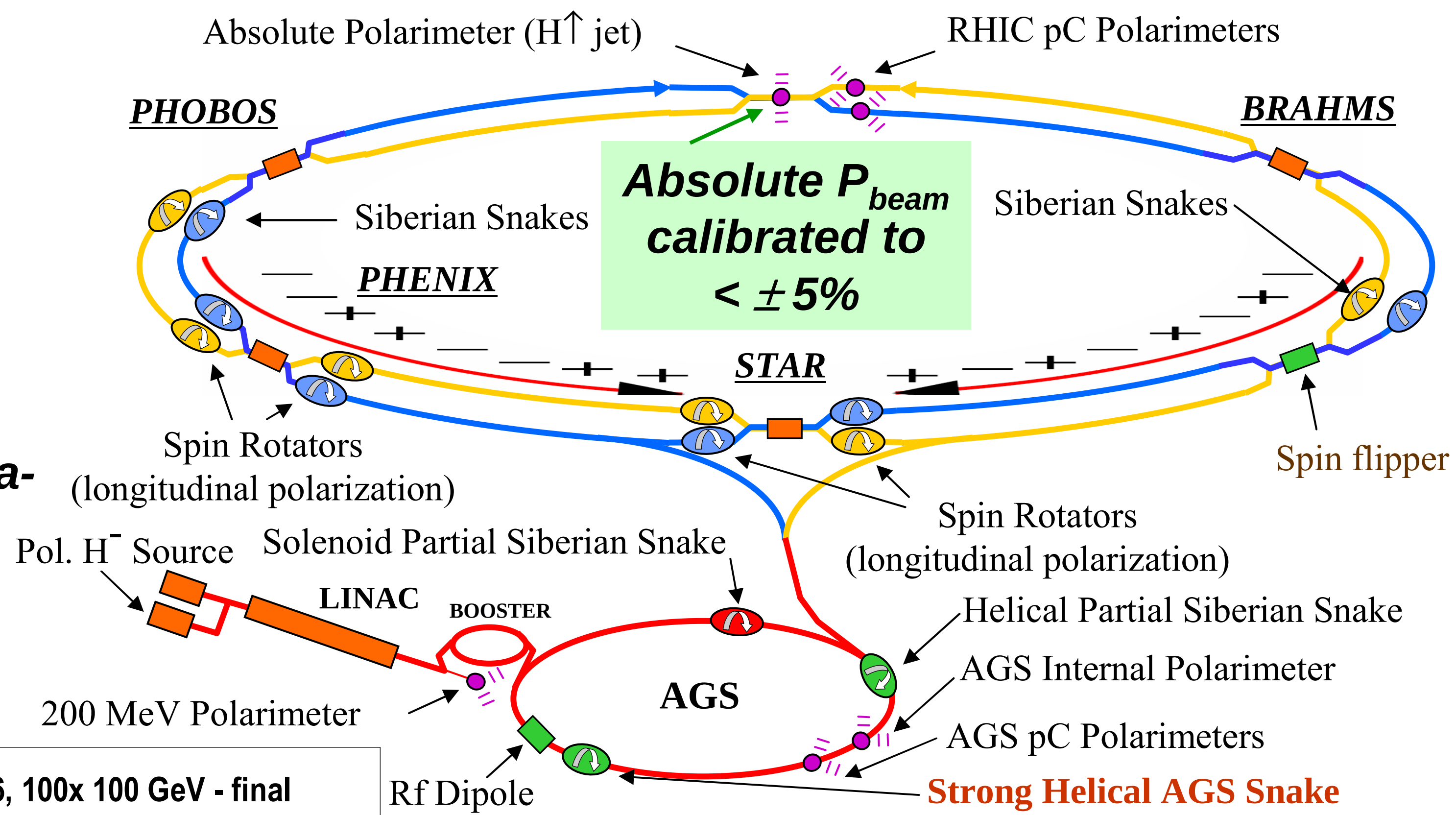
The RHIC Accelerator



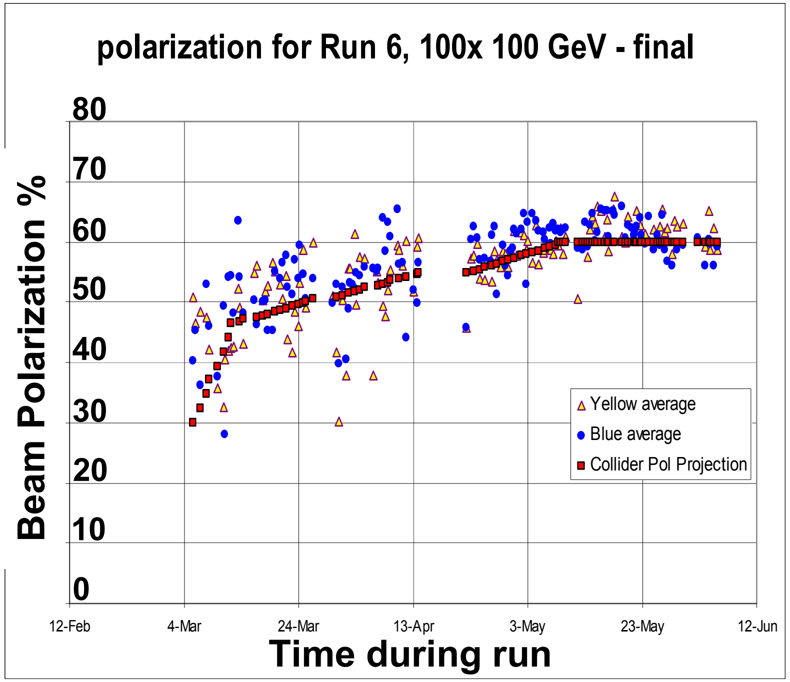
RHIC: RHI+polarized p-p collider



BROOKHAVEN NATIONAL LABORATORY

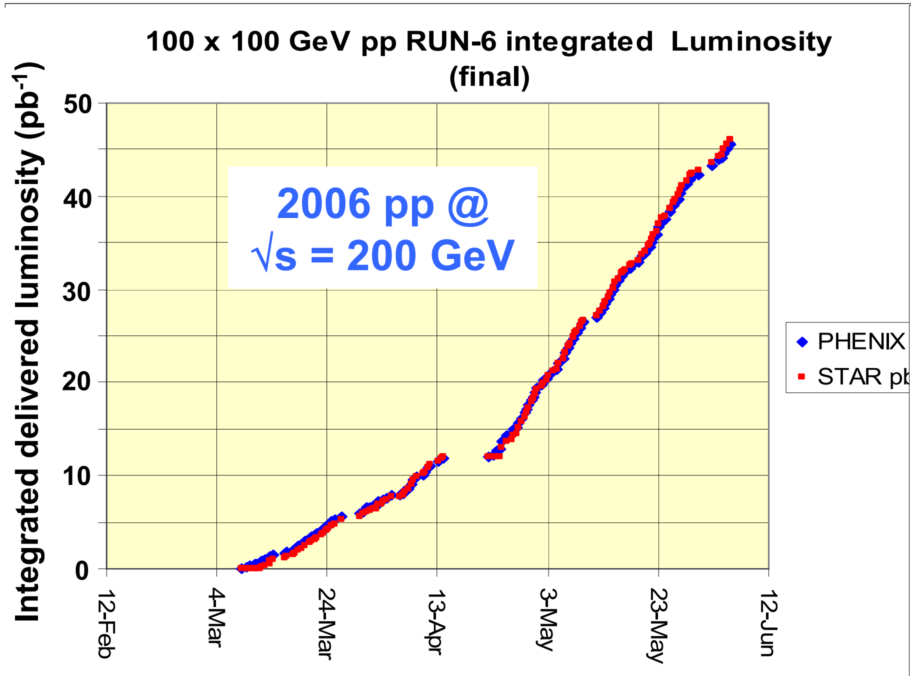


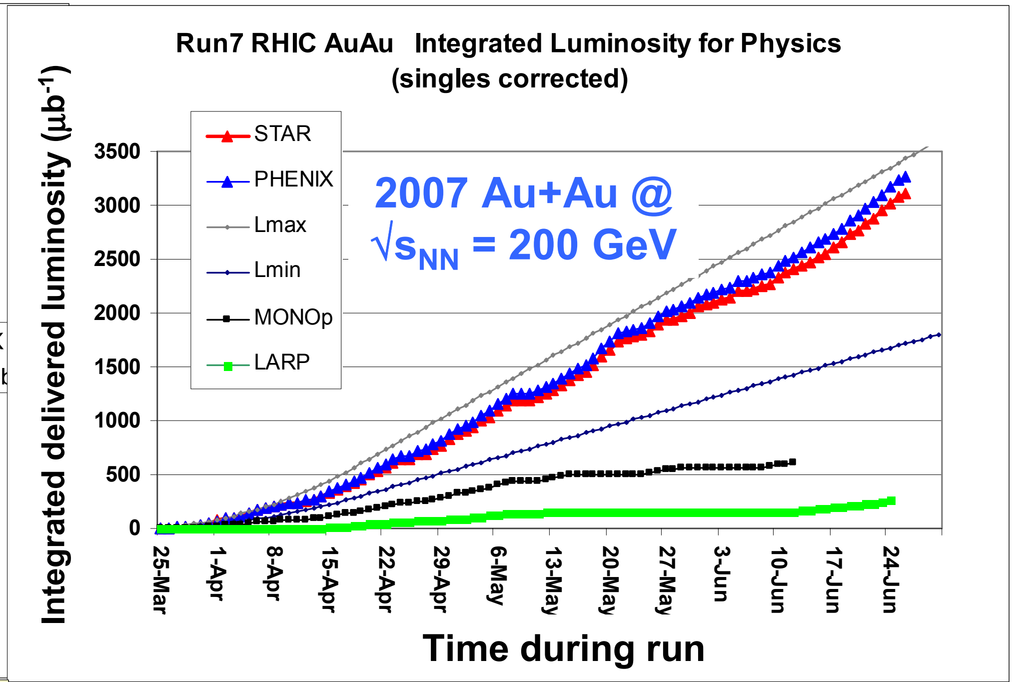
Significant learning curve with unique & complex polarization-preserving equipment in AGS & RHIC

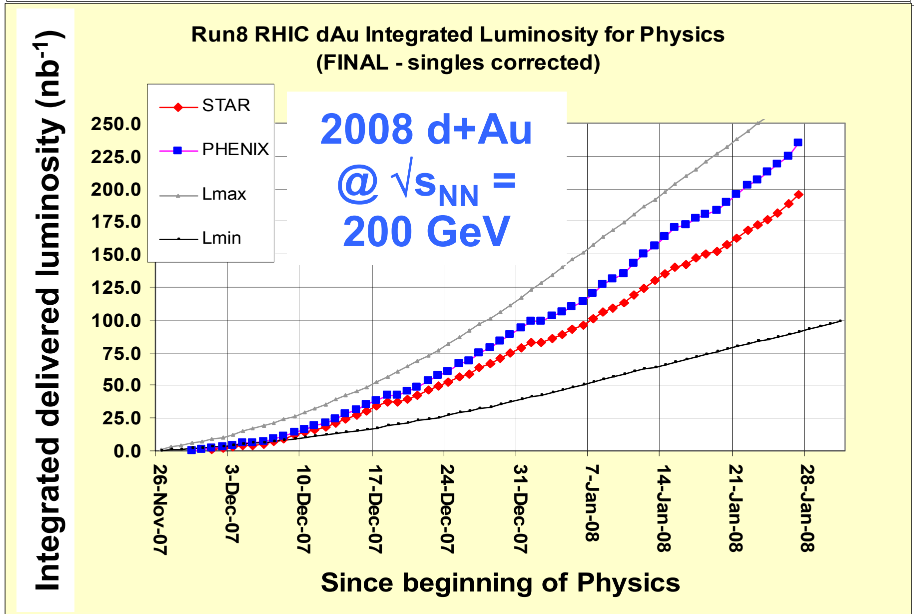


- *60% beam polarization achieved reliably in 2006, compared to 70% goal*
- *Absolute calibration of beam polarization to better than design goal accuracy achieved*
- *Polarization survival to 250 GeV maximum energy demonstrated*

Improved Collision Luminosity 2006-8







- ***Delivered luminosity each year has come close to maximum projected***
- ***Full energy Au+Au in 2007 already exceeded RHIC design goal luminosity***
- ***Another factor ~3 over 2006 L needed to reach enhanced pp design goal***
- ***d+Au completed in 2008 ⇒ x 30 over previous ∫L dt***

The PHENIX Collaboration: 550 Scientists, 69 Institutions, 14 countries

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PHENIX

14 Countries; 69 Institutions

July 2007

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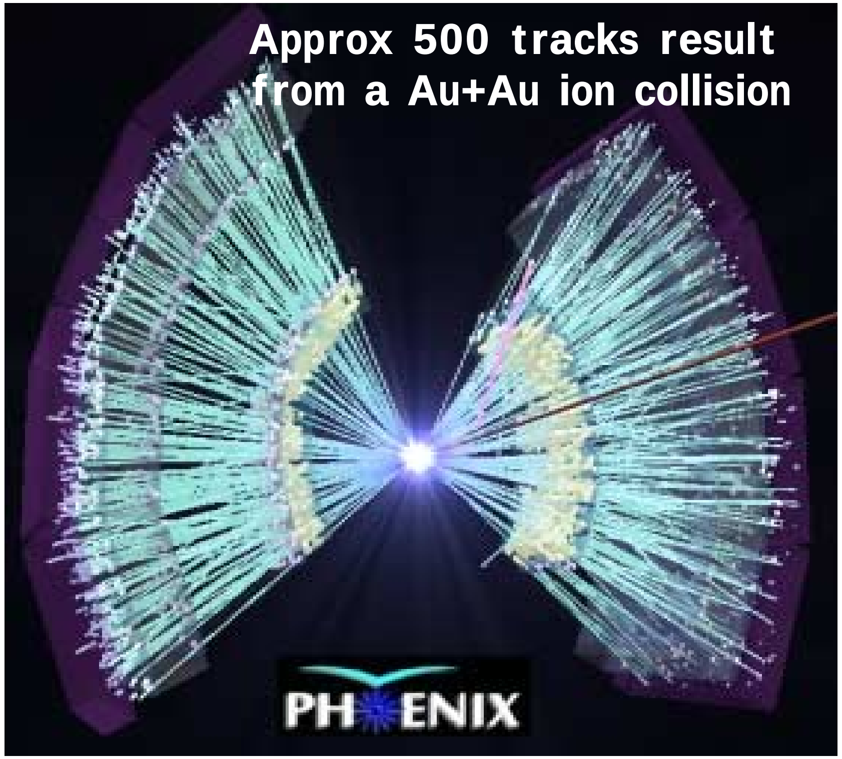
The PHENIX Experiment

Tale of the Tape:

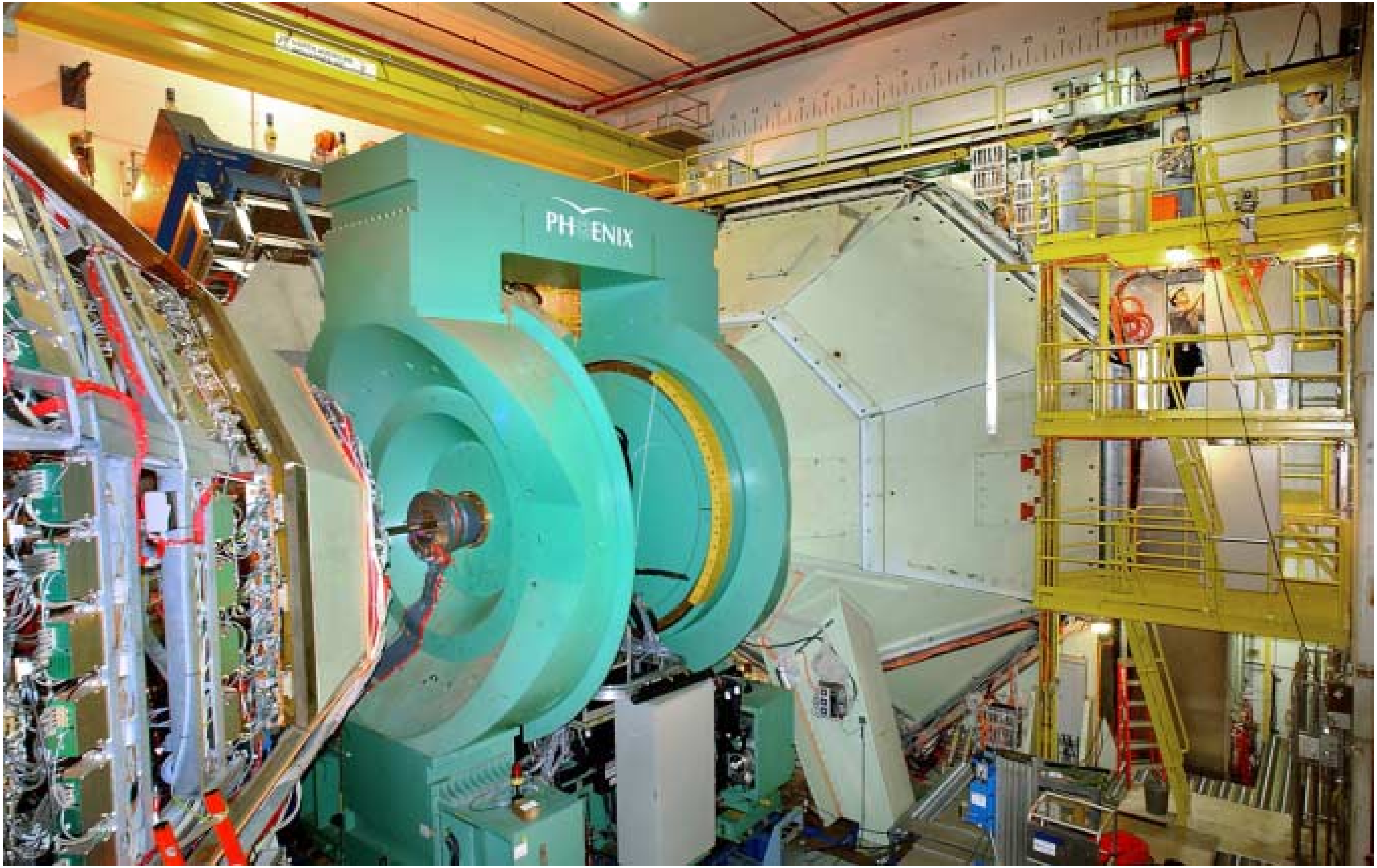
- Begun Operation June 2000
- 550 Scientists, 14 Countries, 69 Inst.
- 18 Detector subsystems
- 4 Spectrometer arms
  - Large electromagnets
- Total weigh = 3500 Tons
- >300,000 readout channels now
- >3,000,000 channels w/Upgrades
- >125 Varieties of custom printed circuit boards
- We can take 16 Terabytes of data/day
  - Fills One 100 GB computer hard disk every 3 ½ minutes
- Operate 7-8 months/year (24/7)
  - Maintain/repair 4-5 months/yr
- Major components built everywhere
  - US, Russia, Japan, Brazil, Israel, France, Sweden, Germany, Korea
- It takes ~110 people/wk to operate PHENIX while taking data

PHENIX is designed to probe fundamental features of the strong nuclear force, Quantum Chromo Dynamics (QCD)

- PHENIX took approx. 10 years and $120M to design, build & commission
- We are finishing our 8th year of operation

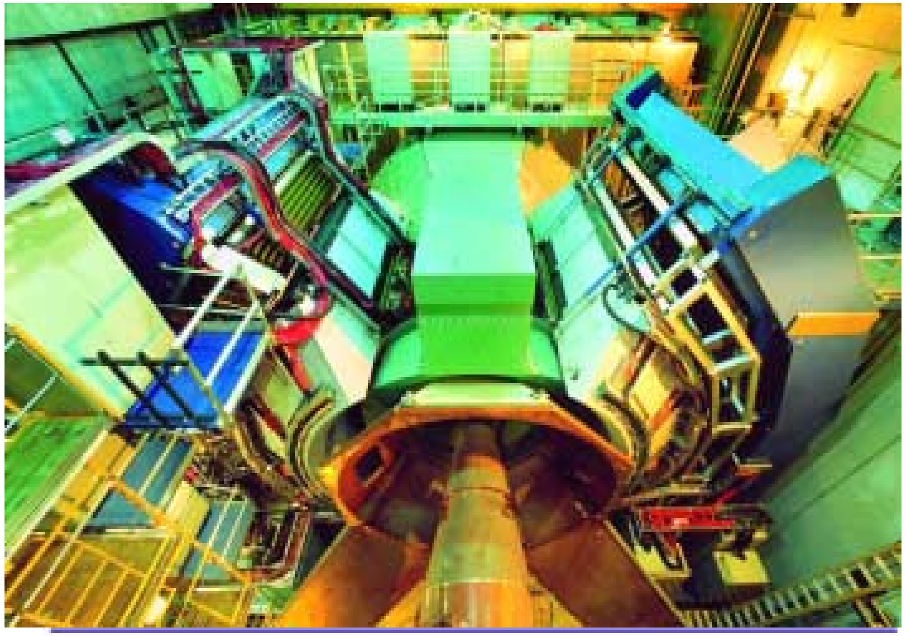


PHENIX maintenance



The PHENIX Detector

- Detector Redundancy
- Fine Granularity, Mass Resolution
- High Data Rate
- Good Particle ID
- Limited Acceptance



Charged Particle Tracking:

Drift Chamber
Pad Chamber
Time Expansion Chamber/TRD
Cathode Strip Chambers(Mu Tracking)

Particle ID:

Time of Flight
Ring Imaging Cerenkov Counter
TEC/TRD
Muon ID (PDT's)
Aerogel Cerenkov Counter

Calorimetry:

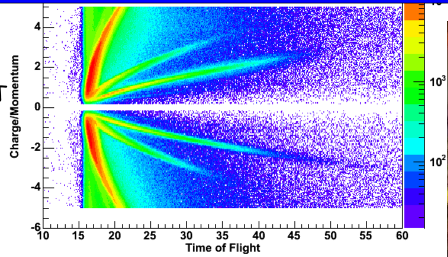
Pb Scintillator
Pb Glass
Muon Piston Calorimeter ($3<|\eta|<4$)

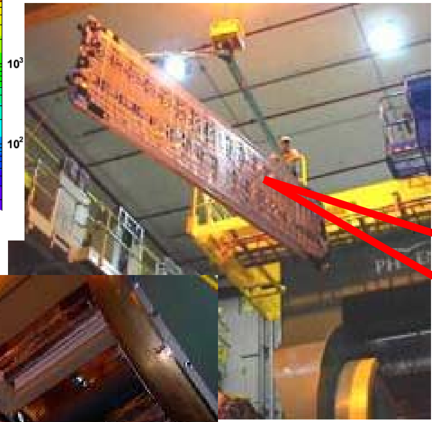
Event Characterization:

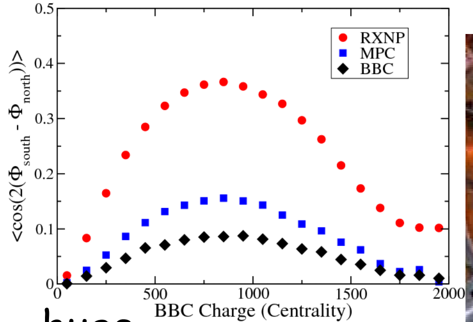
RxPN-Reaction Plane detector
Beam-Beam Counter
Zero Degree Calorimeter/Shower Max Detector
Forward Calorimeter

PHENIX Detector Configuration for Run8

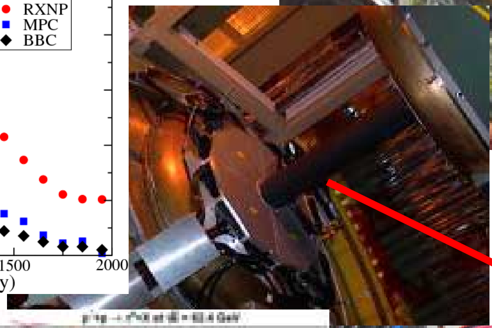
PID at higher p_T with TOF-W



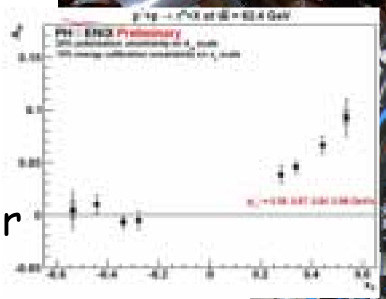


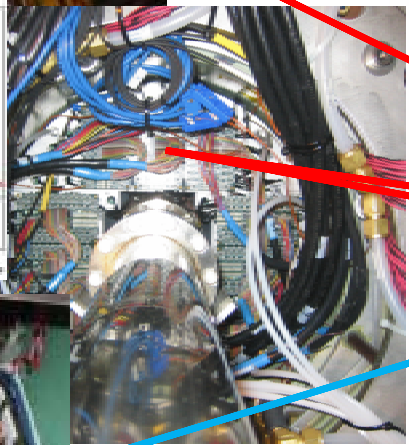


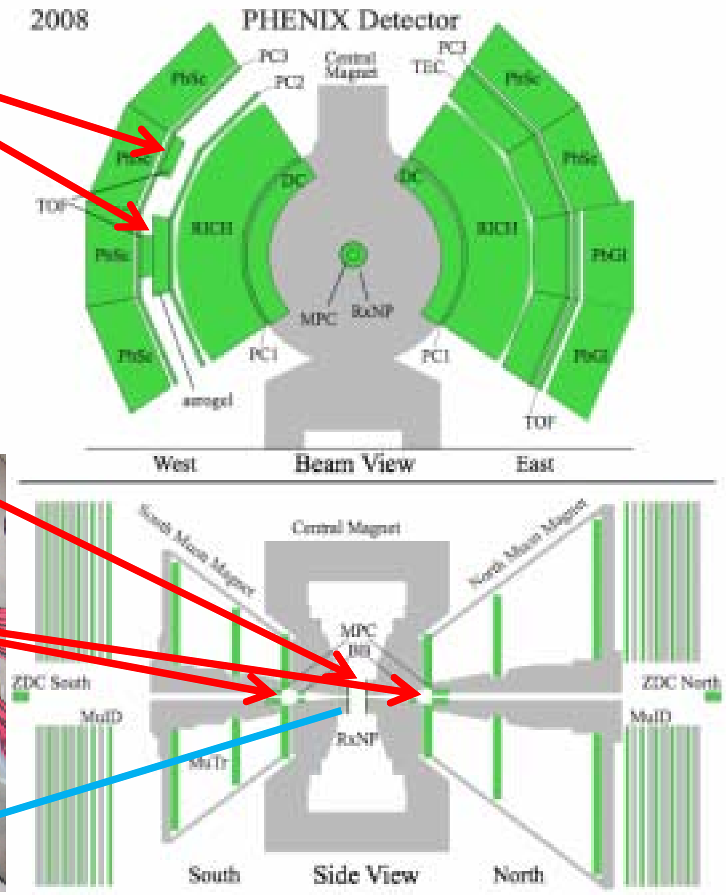
RXNP – huge improvement in AuAu reaction plane

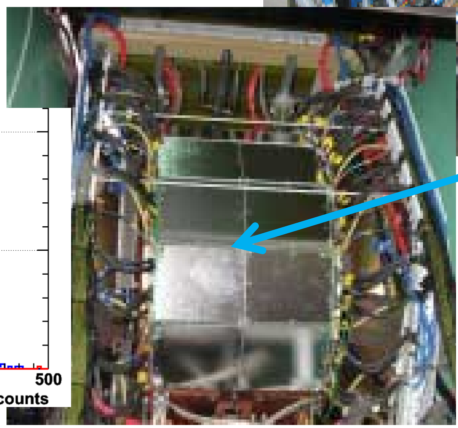


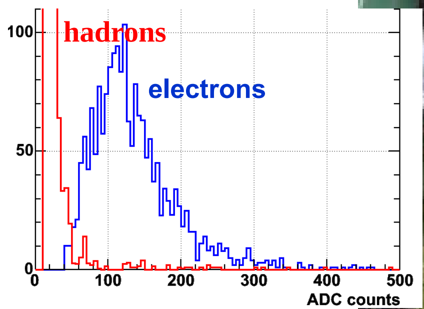
Two MPC's – nice for asymm dAu collisions











HBD was removed for rework until 2009

PHENIX Data Sets

Run	Year	Species	$\sqrt{s}$ (GeV)	$\int Ldt$	N_{tot} (samp.)	Data Size
Run1	2000	Au + Au	130	1 μb^{-1}	10 M	3 TB
Run2	2001/02	Au + Au	200	24 μb^{-1}	170 M	10 TB
		Au + Au	19		< 1 M	
		p + p	200	0.15 pb^{-1}	3.7 B	20 TB
Run3	2002/03	d + Au	200	2.74 nb^{-1}	5.5 B	46 TB
		p + p	200	0.35 pb^{-1}	6.6 B	35 TB
Run4	2003/04	Au + Au	200	241 μb^{-1}	1.5 B	270 TB
		Au + Au	62.4	9 μb^{-1}	58 M	10 TB
Run5	2005	Cu + Cu	200	3 nb^{-1}	8.6 B	173 TB
		Cu + Cu	62.4	0.19 nb^{-1}	0.4 B	48 TB
		Cu + Cu	22.4	2.7 μb^{-1}	9 M	1 TB
		p + p	200	3.8 pb^{-1}	85 B	262 TB
Run-6	2006	p + p	200	10.7 pb^{-1}	230 B	310 TB
		p + p	62.4	0.1 pb^{-1}	28 B	25 TB
Run-7	2007	Au + Au	200	813 μb^{-1}	5.1 B	650 TB
Run-8	2007/08	d + Au	200	80 nb^{-1}	160 B	437 TB
		p + p	200	5.2 pb^{-1}	115 B	118 TB
		Au + Au	9.2			

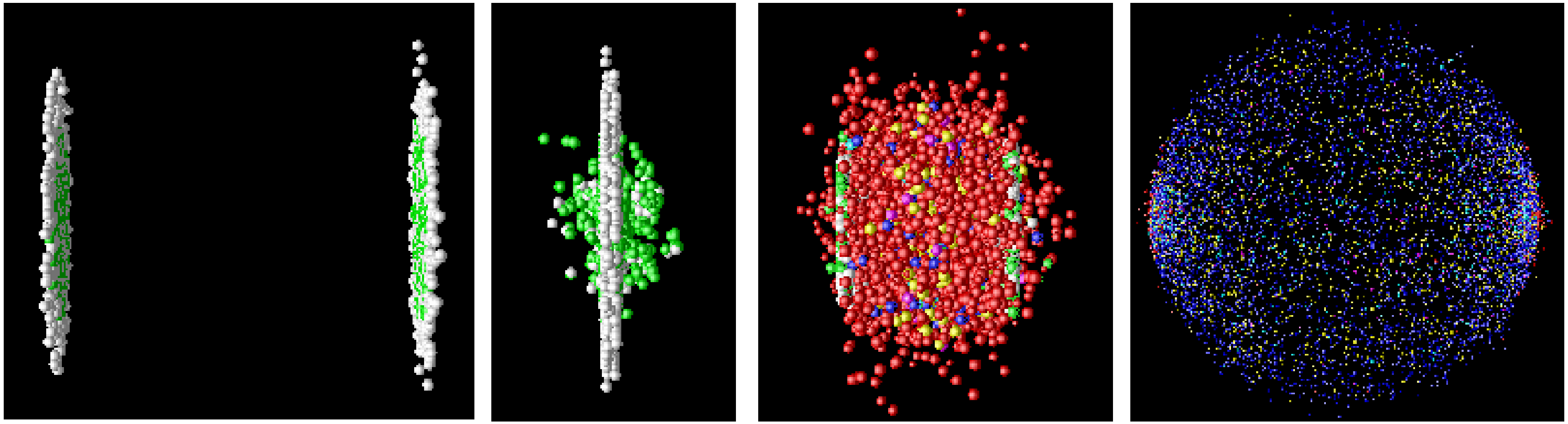
3 x AuAu

30 x dAu

Collided 4 different species in 8 years: Au+Au, d+Au, p+p, Cu+Cu
6 energies run: 9.2 GeV, 19 GeV, 22.5 GeV, 62.4 GeV, 130 GeV, 200 GeV

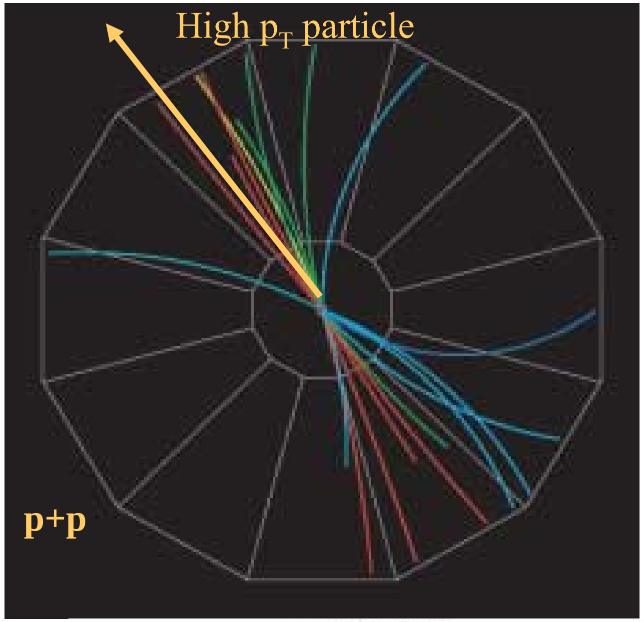
Three things are dramatically different in Relativistic Heavy Ion Physics than in p-p physics

- the multiplicity is ~A~200 times larger in AA central collisions than in p-p ⇒huge energy in jet cone: 300 GeV for R=1 at $\sqrt{s_{NN}}$=200 GeV
- huge azimuthal anisotropies which don't exist in p-p which are interesting in themselves, and are useful, but sometimes troublesome.
- space-time issues both in momentum space and coordinate space are important in RHI : for instance what is the spatial extent of parton fragmentation, is there a formation time/distance?

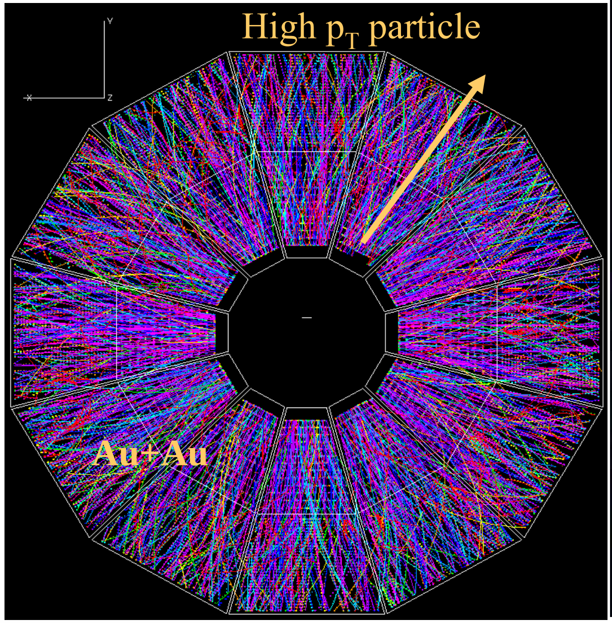


AuAu Central Collisions cf. p-p

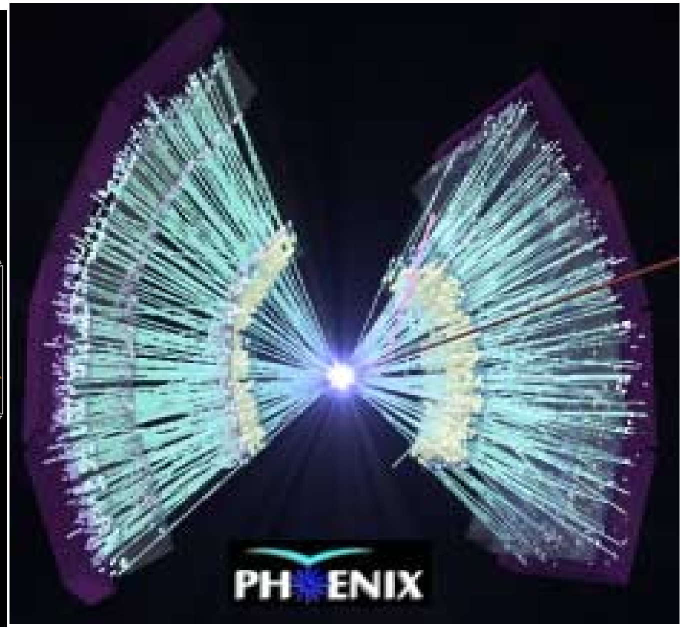
STAR-Jet event in pp

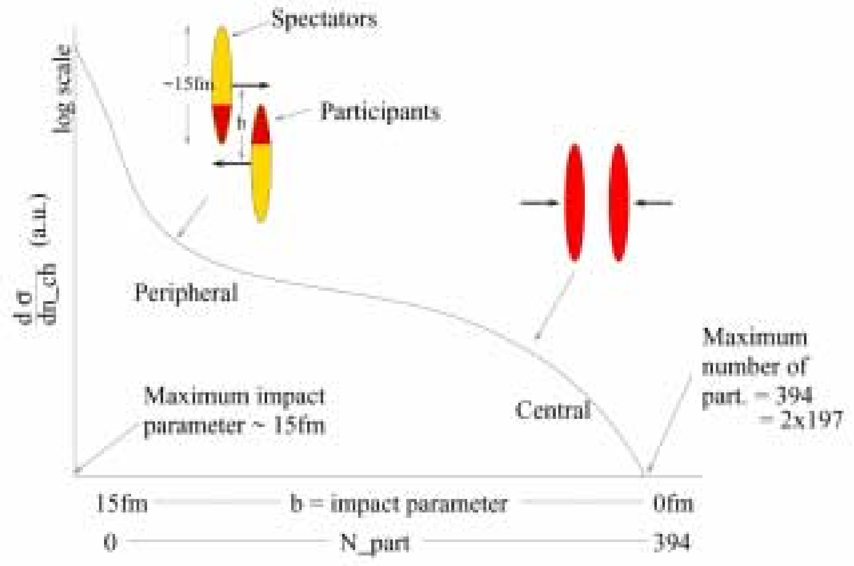


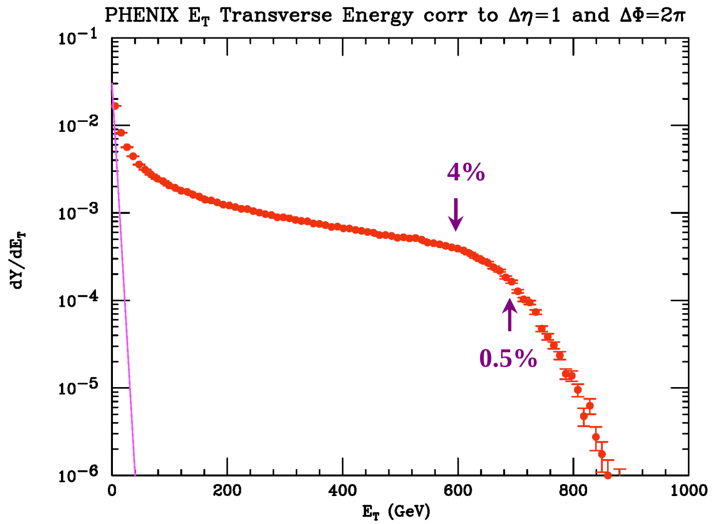
STAR Au+Au central



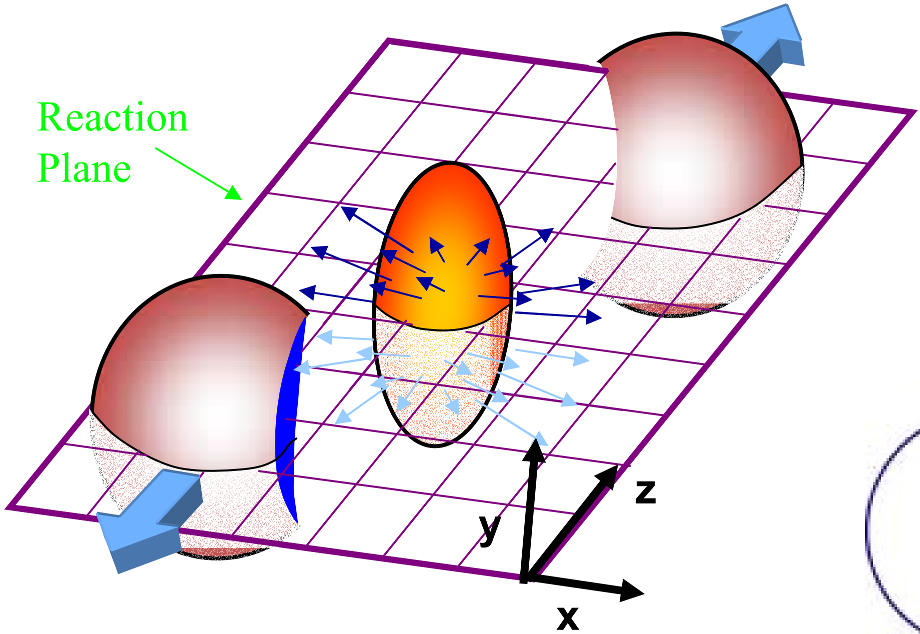
PHENIX Au+Au central



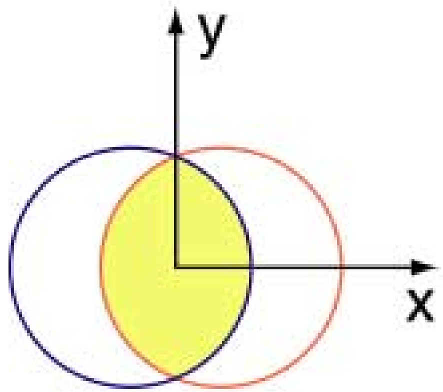


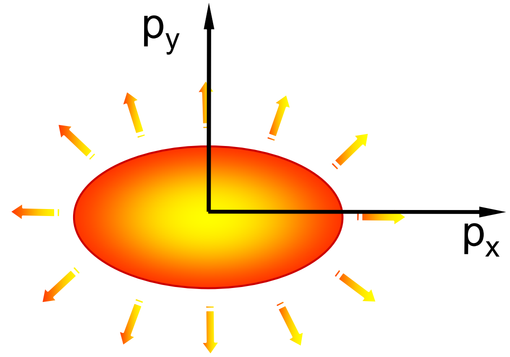


Anisotropic (Elliptic) Transverse Flow--an Interesting complication in AA collisions



• spatial anisotropy ⇒ momentum anisotropy





$$\phi = \text{atan}\frac{p_y}{p_x}$$

$$\frac{Ed^3N}{dp^3} = \frac{d^3N}{p_T dp_T dy d\phi} = \frac{d^3N}{2\pi\, p_T dp_T dy}[1+2v_1\cos(\phi-\Phi_R)+2v_2\cos 2(\phi-\Phi_R)+\cdots]$$

$$v_1 = \langle\cos\phi\rangle \qquad v_2 = \langle\cos 2\phi\rangle$$

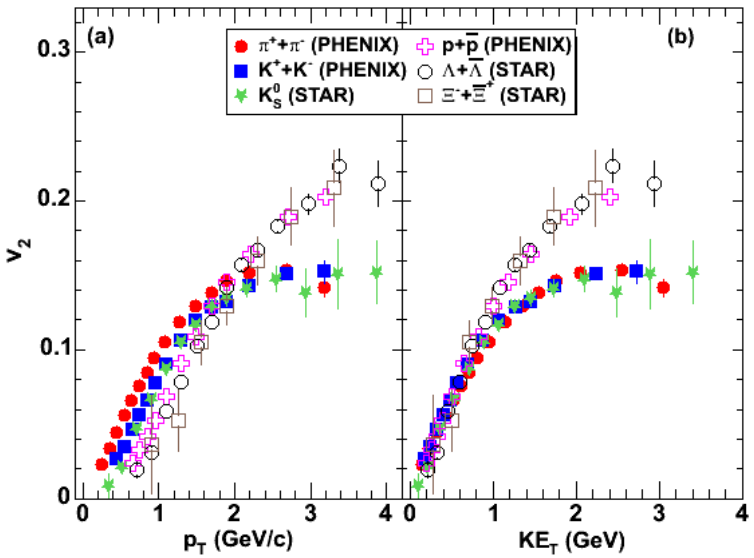
Directed flow zero at midrapidity	Elliptical flow dominant at midrapidity

•Perform a Fourier decomposition of the momentum space particle distributions in the x-y plane

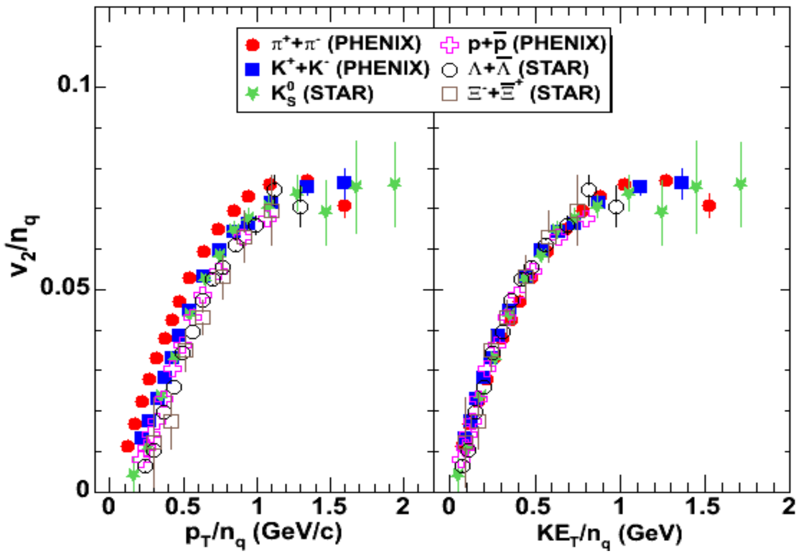
✓ v_2 is the 2nd harmonic Fourier coefficient

Elliptic Flow v_2 in AuAu Central 200 GeV Universal in constituent quark Kinetic Energy

STAR-PRC**72** (2005) 014904

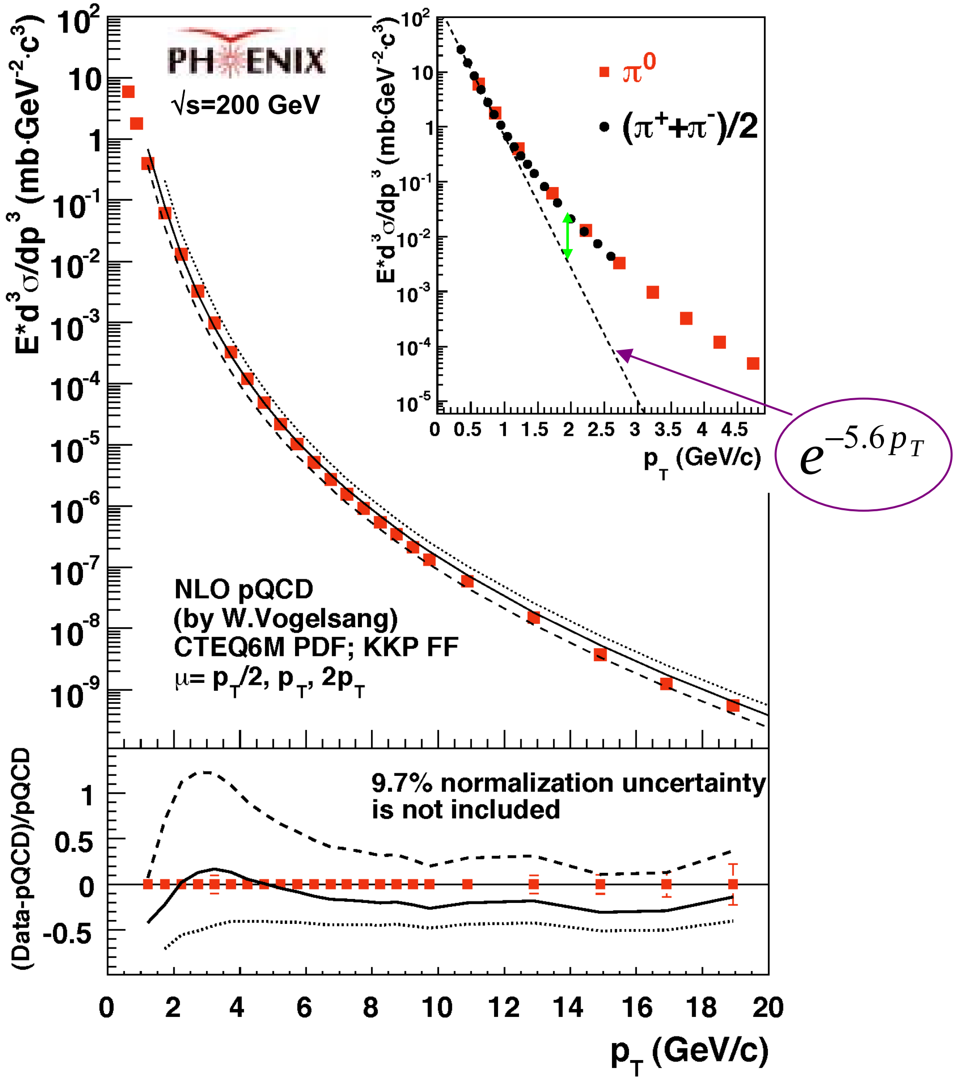


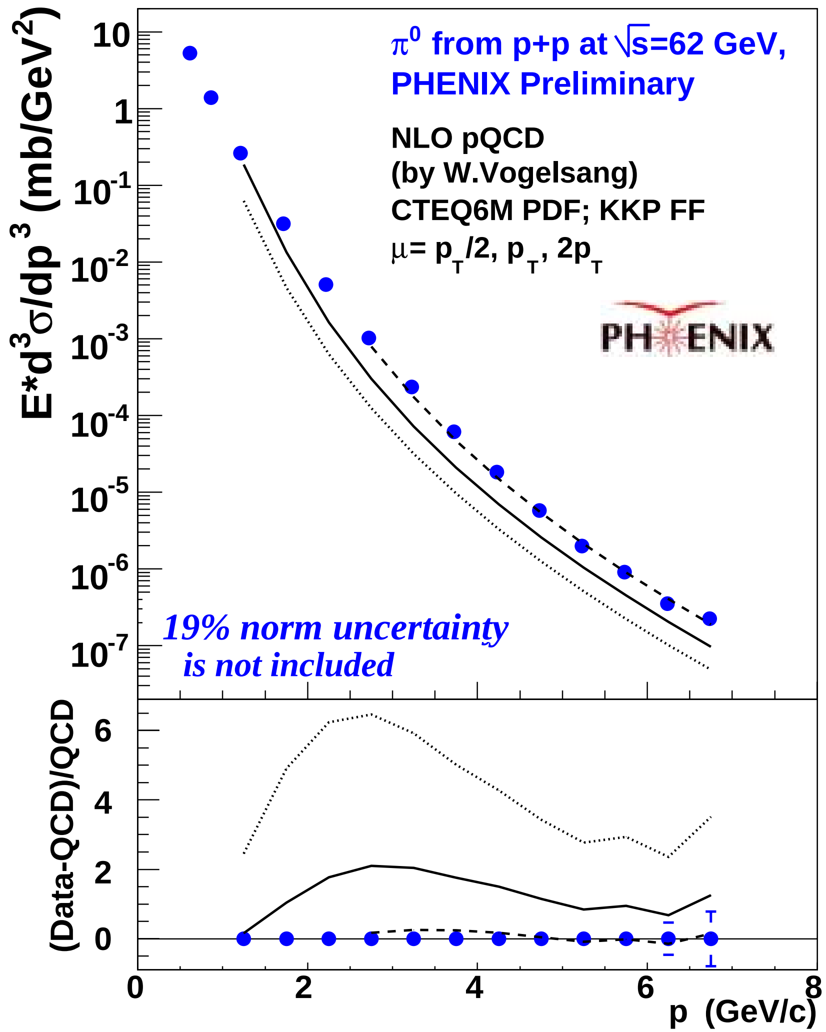
PHENIX PRL**98** (2007) 162301



- large v_2 for high and low p_T, plateaus for p_T>2 GeV/c for mesons, scales in KE/constituent quark
- ϕ-meson (not shown) follows same scaling: further implies flow is partonic not hadronic
- KE scaling suggests Hydrodynamic origin.
- v_2 for p_T> 1 GeV/c suggests low viscosity, D.Teaney, PRC**68** (2003) 034913, ``the perfect fluid''??
- Quantum Viscosity Bound from string theory reinforces this idea, Kotvun, Son, Starinets, PRL **94** (2005) 111601

p-p collisions at RHIC: π^0 production (PHENIX)

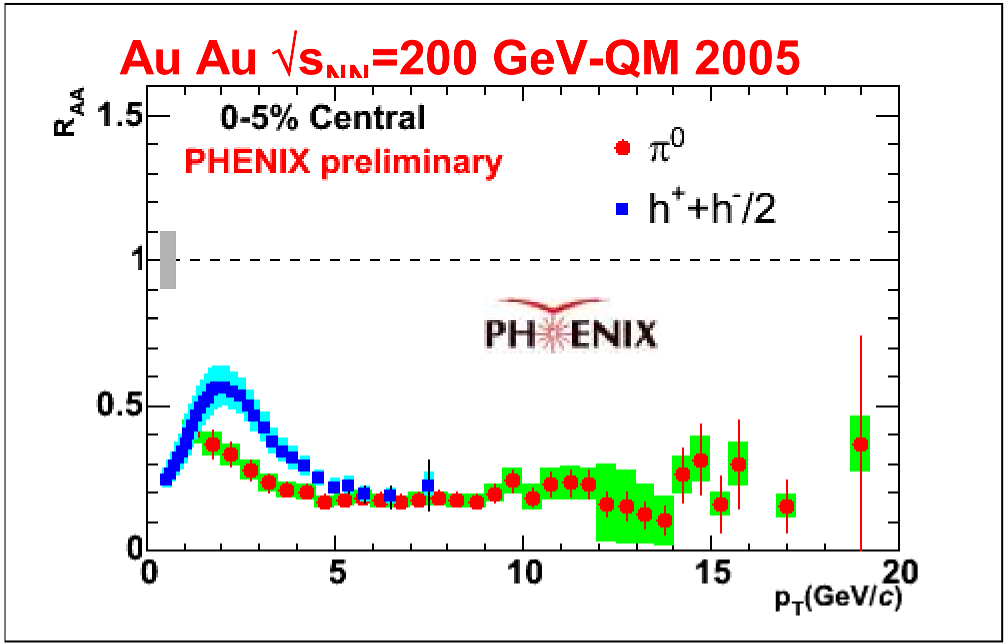




PRD**76**(2007)051006(R)

NLO pQCD agrees with data

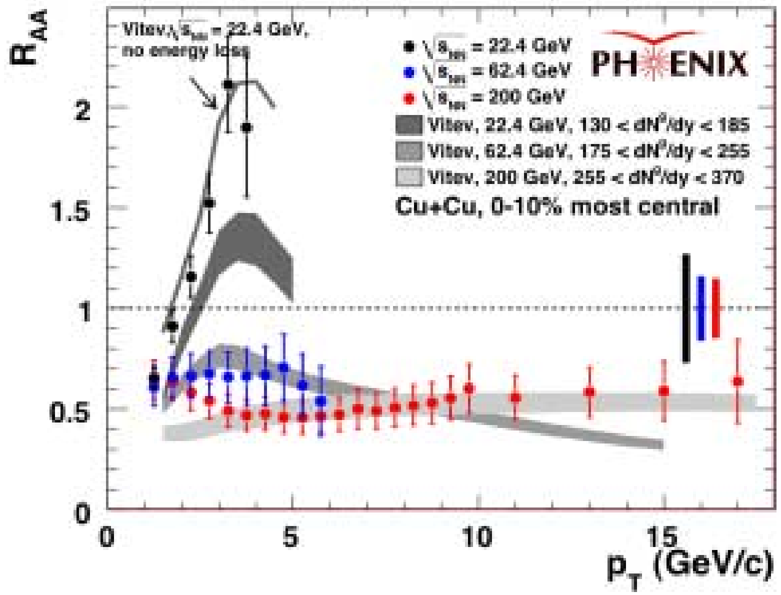
Suppression of π^0 is arguably the major discovery at RHIC. Energy loss in medium?



$$R_{AA}(p_T) = \frac{d^2N^{\pi}_{AA}/dp_T dy N^{inel}_{AA}}{\langle T_{AA}\rangle d^2\sigma^{\pi}_{pp}/dp_T dy}$$

CuCu central 10% R_{AA} vs $\sqrt{s_{NN}}$

PHENIX, arXiv:0801.4555 [nucl-ex]

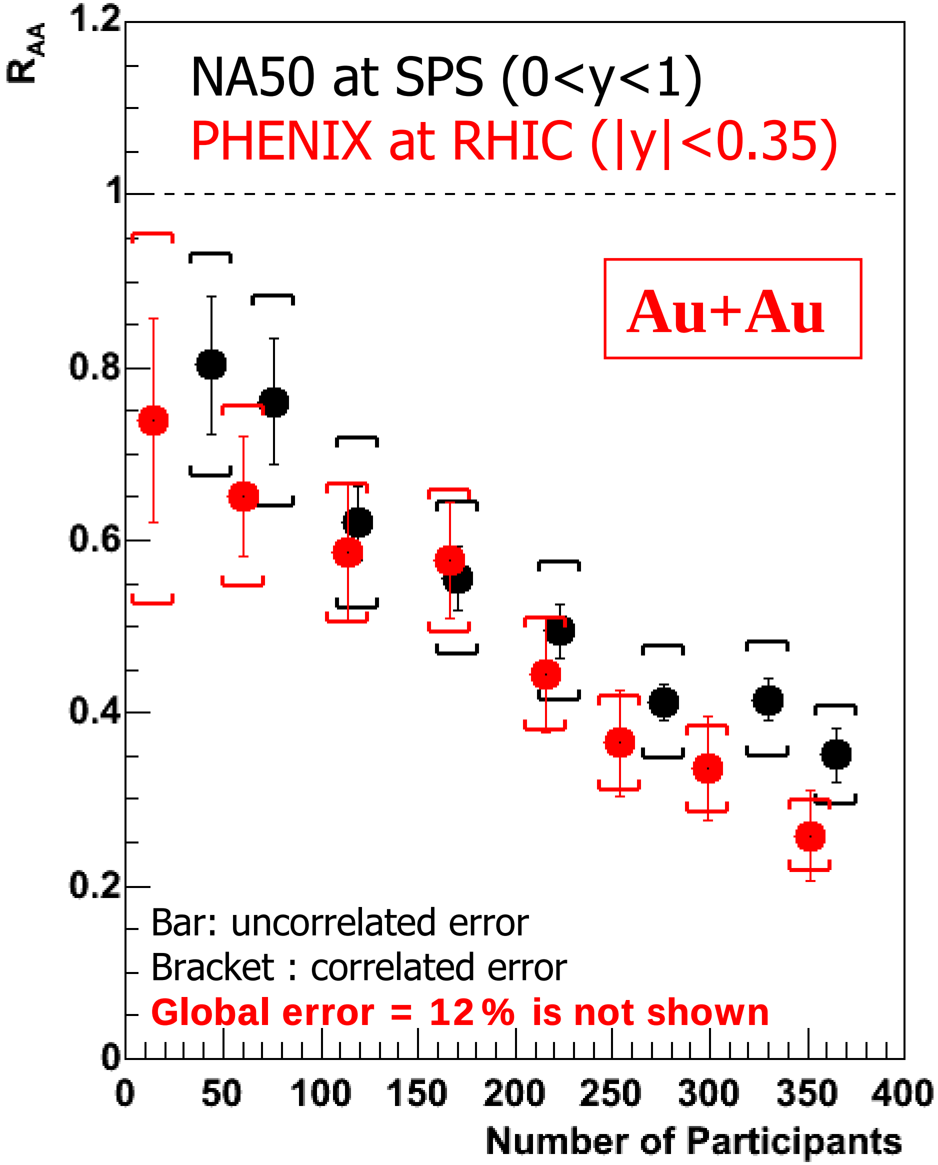


Suppression is unique at RHIC-**different** from low $\sqrt{s_{NN}}$ ($22.4 < \sqrt{s_{NN}} < 62.4$ GeV)

Non-identified $h^{\pm}$ and π^0 are different for $p_T < 6$ GeV/c⇒ particle ID is important.
π^0 suppressed by a factor of 5 compared to point-like scaling for $3 < p_T < 20$ GeV/c!

Original π^0 discovery, PHENIX PRL **88** (2002)022301; latest preprint 0801.4020 [nucl-ex]

J/ψ Suppression (R_{AA}) is the **same** at mid-rapidity (PHENIX e^+e^-) as at lower $\sqrt{s_{NN}}$



- R_{AA} vs. N_{part} integrated over p_T
  - NA50 at SPS
    - 0<y<1
  - PHENIX at RHIC
    - |y|<0.35

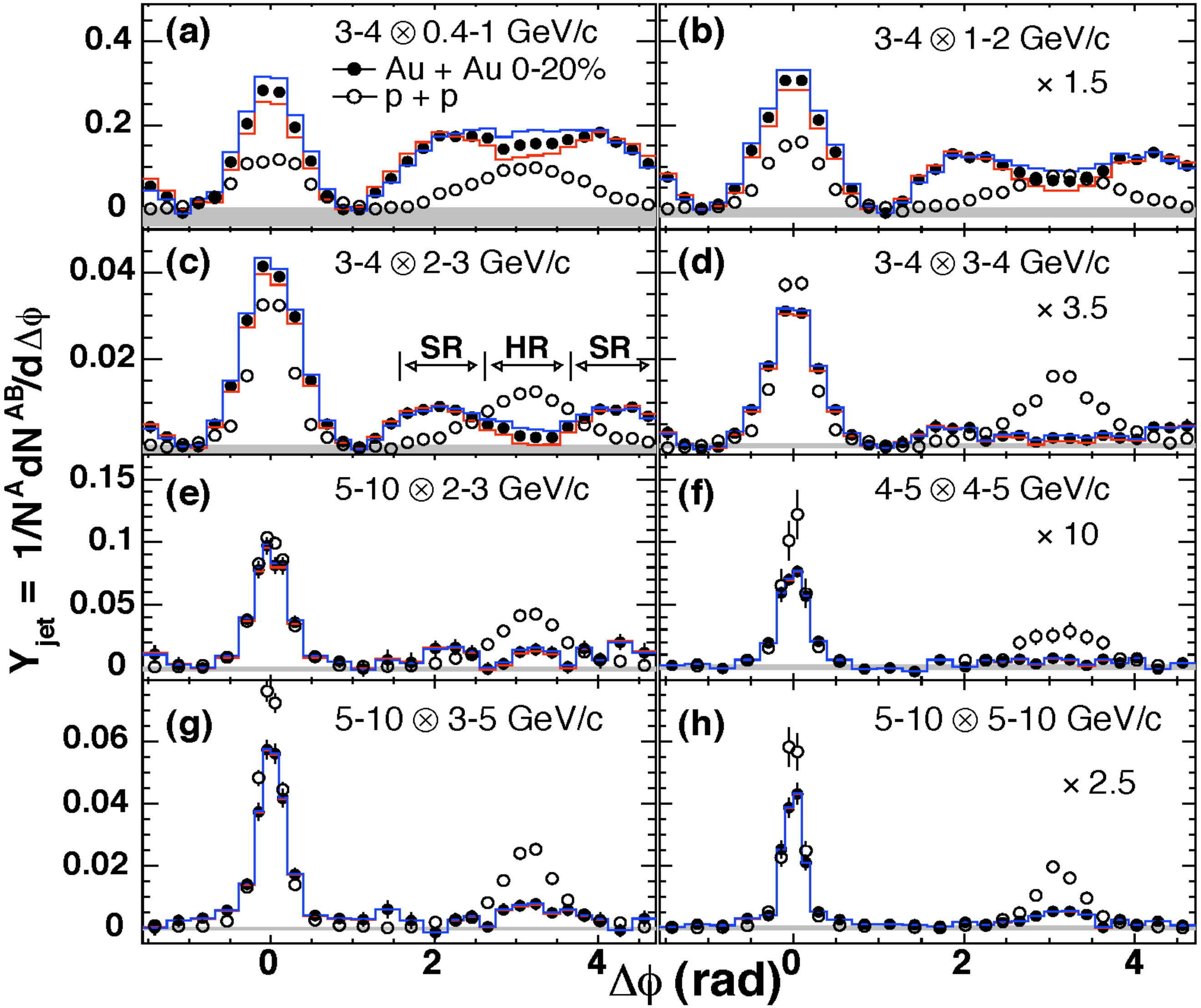
PHENIX PRL **98**, 232301 (2007)

This was CERN-Heavy Ion's main claim to fame in the infamous press conference of 2000 claiming observations ``consistent with the predicted signatures of a QGP.'' Will have to wait for LHC to find out whether J/ψ merely act like ordinary hadrons low p_T or whether they are actually probes of deconfinement .

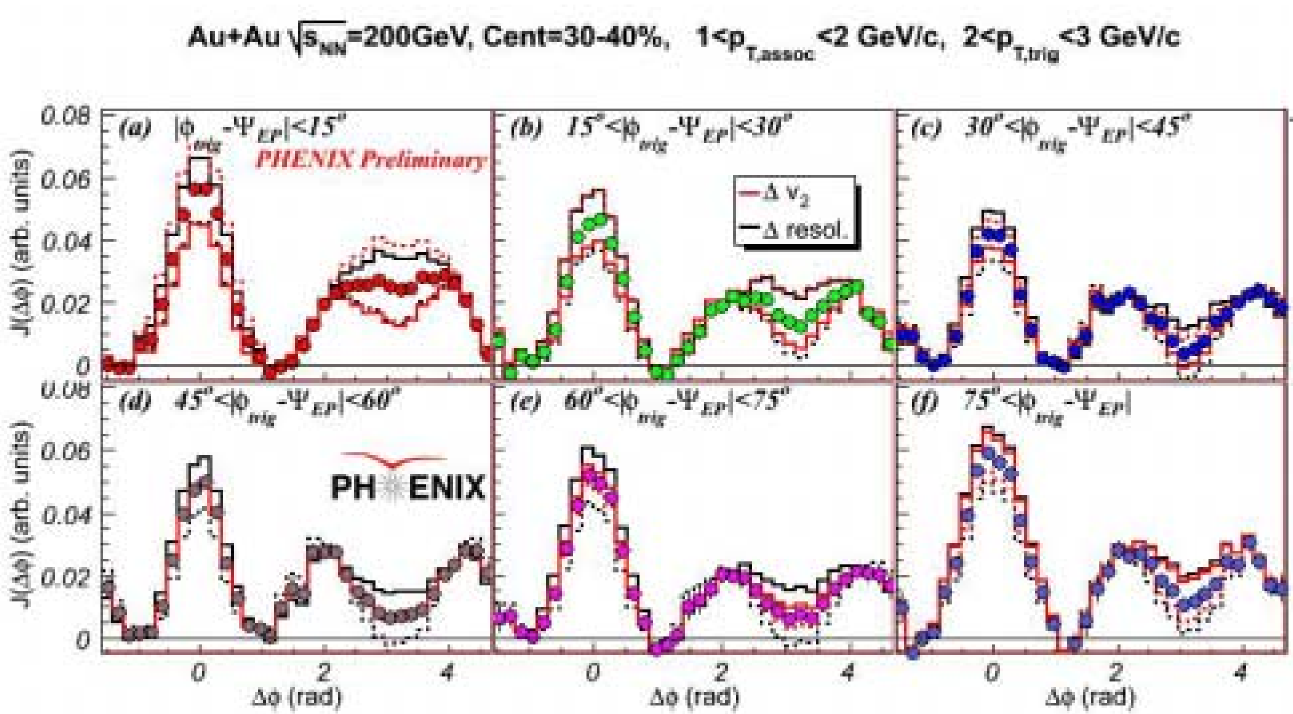
New PHENIX AuAu data

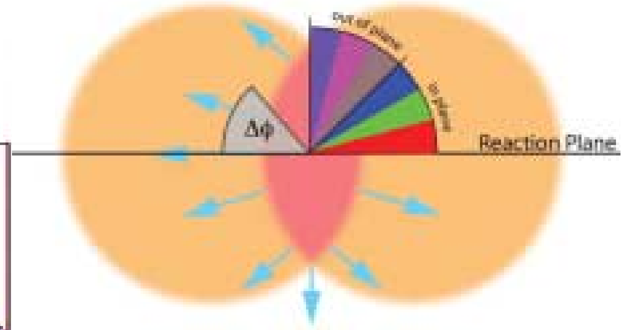
Away side correlation in Au+Au is generally wider than p-p with complicated structure

Define Head region (HR) and Shoulder regions (SR) for wide away side correlation.



$h^{\pm}$-$h^{\pm}$ correlations - Reaction plane dependence





PHENIX QM2008

We now see a nice jet shape without a dip at 0^{o}.

Allows improved background subtraction. 1) Acceptance correction does not depend on event plane, so use non-event plane selected mixed events for this. 2) The flow background, which is a non-jet correlation to the reaction plane, should then be given by mixed events as a function of event plane corrected for acceptance.

Conclusions

- the nuclear matter produced in central Au+Au collisions at RHIC appears to be a nearly perfect quark-gluon "liquid" instead of behaving like a gas of free quarks and gluons.

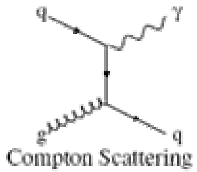
- No signs of a rapid phase transition have been seen---consistent with latest ideas that transition is a cross-over at RHIC energies.

- The medium at RHIC is characterized by very high energy densities, density of unscreened color charges ten times that of a nucleon, large cross sections for the interaction between strongly interacting particles, strong collective flow which implies early thermalization.

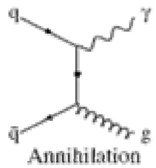
- This state of matter is not describable in terms of ordinary color-neutral hadrons, because there is no known self-consistent theory of matter composed of ordinary hadrons at the measured densities.

Sources of photons

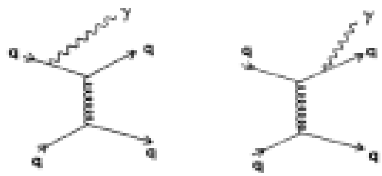
- In p+p collisions
  - Direct photons
    - Compton scattering
      - $q + g \rightarrow q + \gamma$



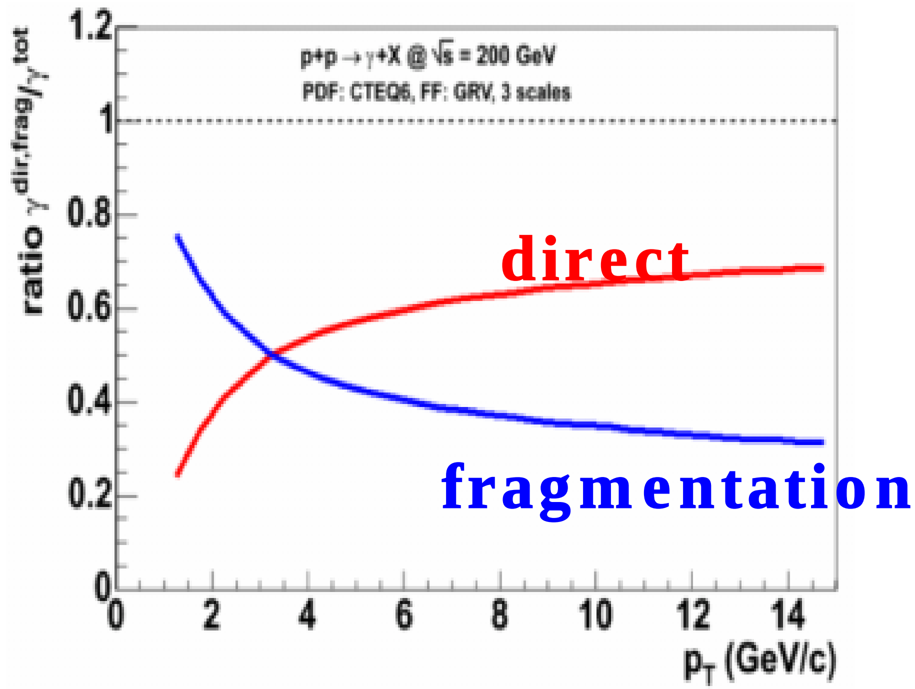
    - $q\bar{q}$ annihilation
      - $q + \bar{q} \rightarrow g + \gamma$



    - Bremsstrahlung

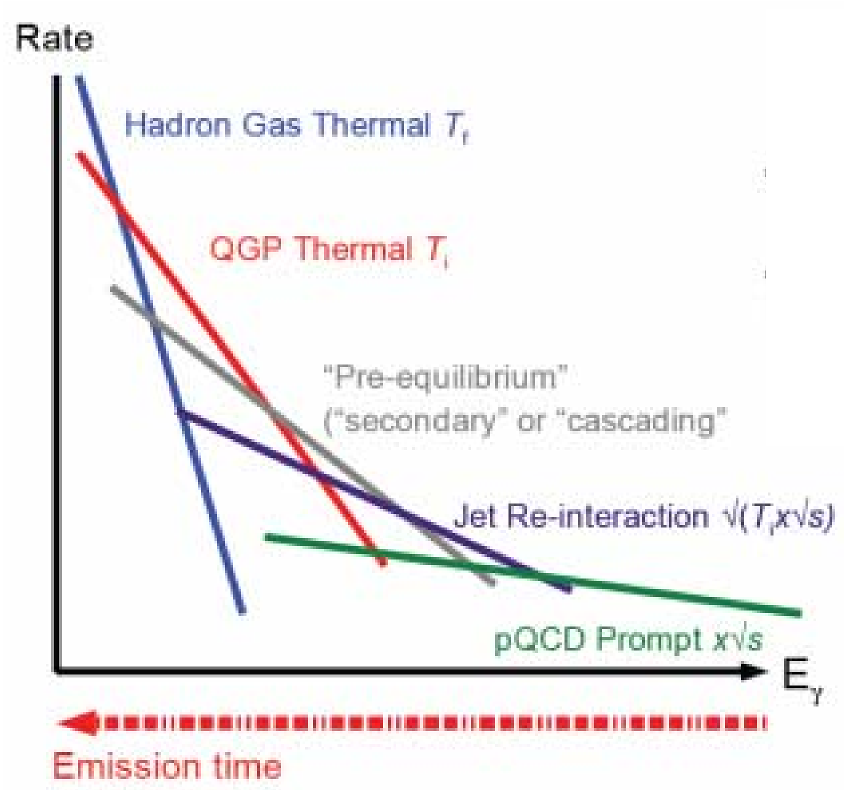


  - Fragmentation photons
  - Final state hadron decay (background)
    - $\pi^0, \eta, K^0, \ldots \rightarrow \gamma + \gamma$



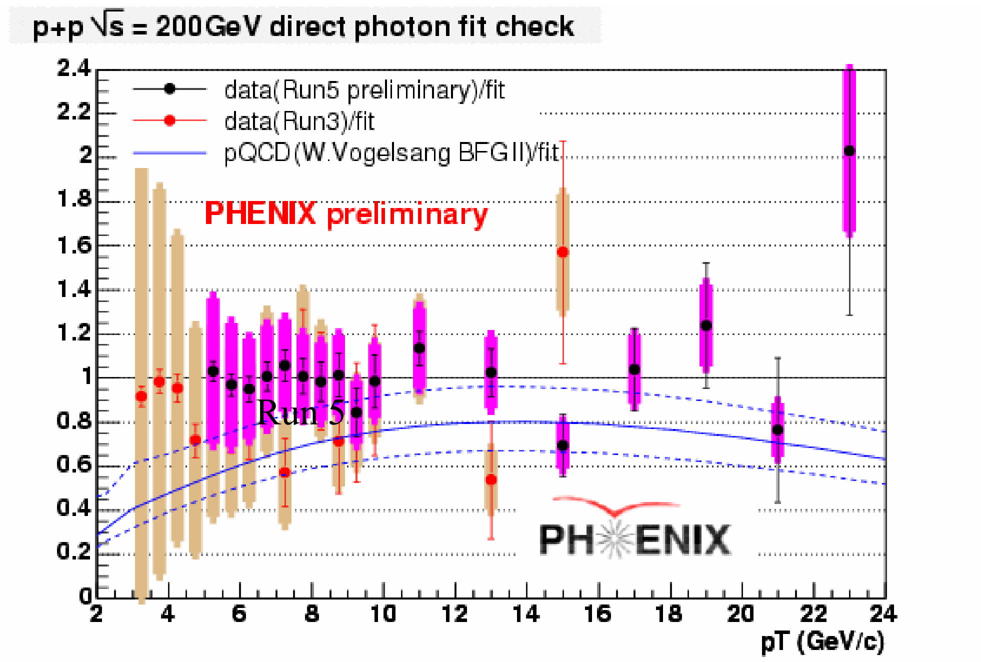
Sources of photons

- In A+A collisions
  - High pT photons (pT> 6 GeV): **non thermal**
    - **Initial parton-parton scattering**: as in p+p
    - not affected by Hot and Dense Matter ➔ test the theoretical description of A+A collisions with pQCD
  - Low pT photons (pT < 3 GeV) : **thermal**
    - **Come from the thermalized medium**
    - Carry information about the initial temperature of the Quark Gluon Plasma
    - Thermal photons are created in the QGP as well as in the hadron gas over the entire lifetime of these phases ➔ test hydro models
  - Low and intermediate pT photons (up to 6 GeV)
    - **Interaction of the quarks and gluons** from the hard scattering processes **with the QGP**
      - $q_{hard} + g_{QGP} \rightarrow q + \gamma$
      - γ get a large fraction of the momentum of q_{hard}

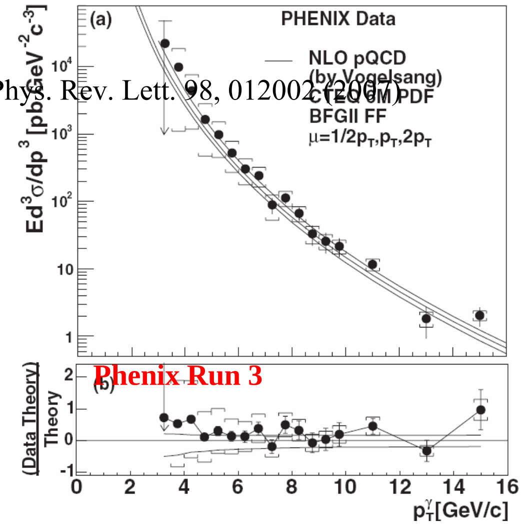


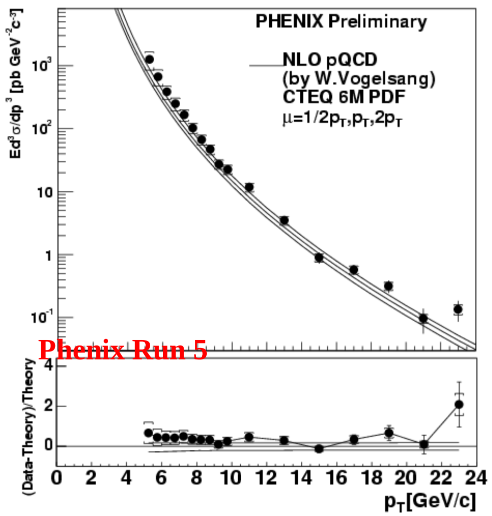
pQCD photons (High p_T) in p+p collisions

- Phenix year-3 and year-5 data set
  - Reference for Au+Au
  - **Measured p+p yield compatible with NLO pQCD calculations (tends to be higher by ~20%)**



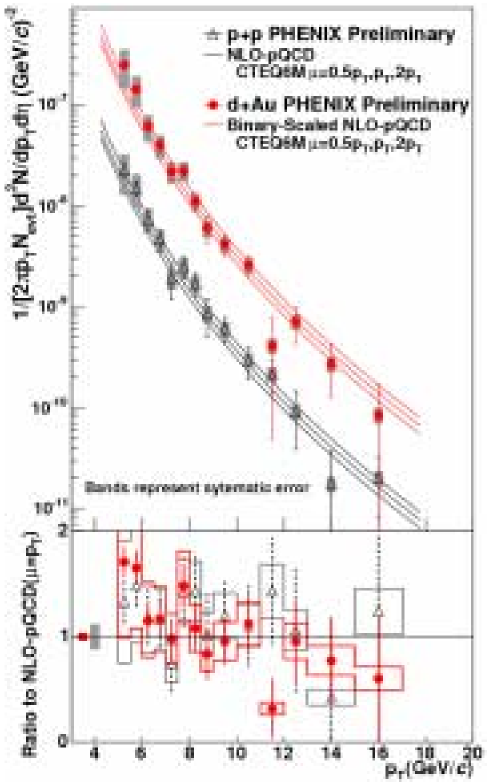
Phys. Rev. Lett. 98, 012002 (2007)



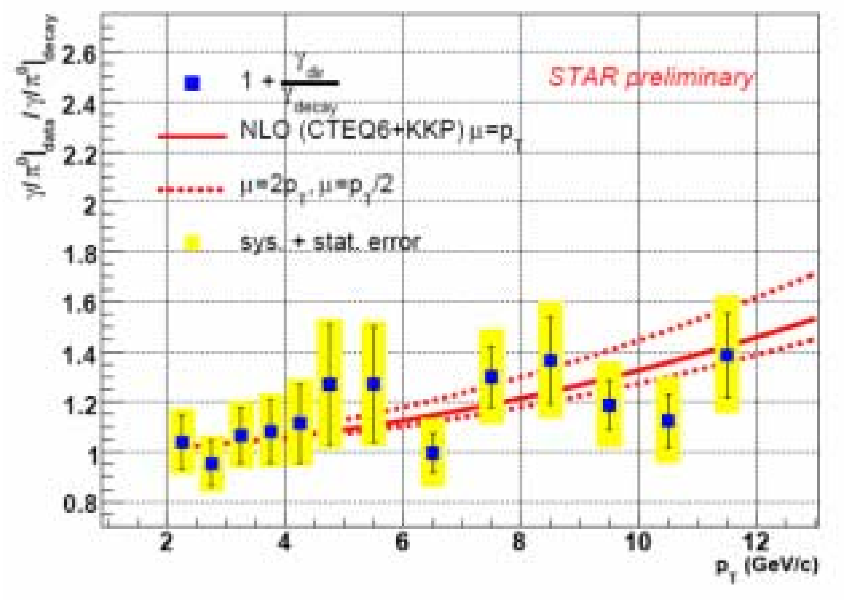


pQCD photons (High p_T) in d+Au

- Phenix
  - Consistent with NLO pQCD calculation



- Star
  - $\gamma_{dir} = \gamma_{incl} - \gamma_{decay}$
  - Plot $R = 1 + \gamma_{dir}/\gamma_{decay}$
    - Cancel systematic uncertainties
  - Signal consistent with pQCD NLO calculation

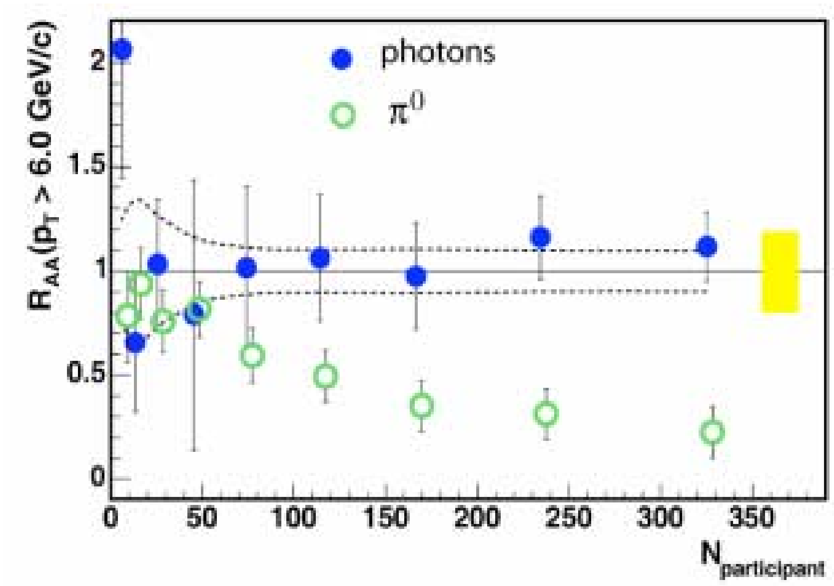


pQCD photons (high pT) in Au+Au

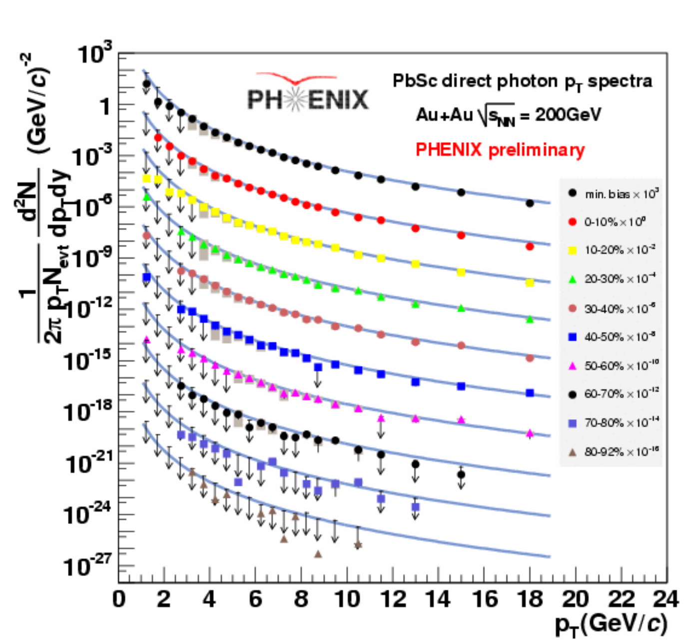
- PHENIX Run 2
  - Computing R_{AA}.vs.N_{part}

$$R_{AA} = \frac{dN^{\gamma}_{AA}}{<N_{coll}> \times dN^{\gamma}_{pp}}$$

  - π^0 are quenched
  - Direct γ are not



- PHENIX Run 4
  - Reach up to 18 GeV/c (12 GeV for Run 2)
  - Qualitatively well described by NLO pQCD calculations



pQCD photons (High p_T) in Au+Au

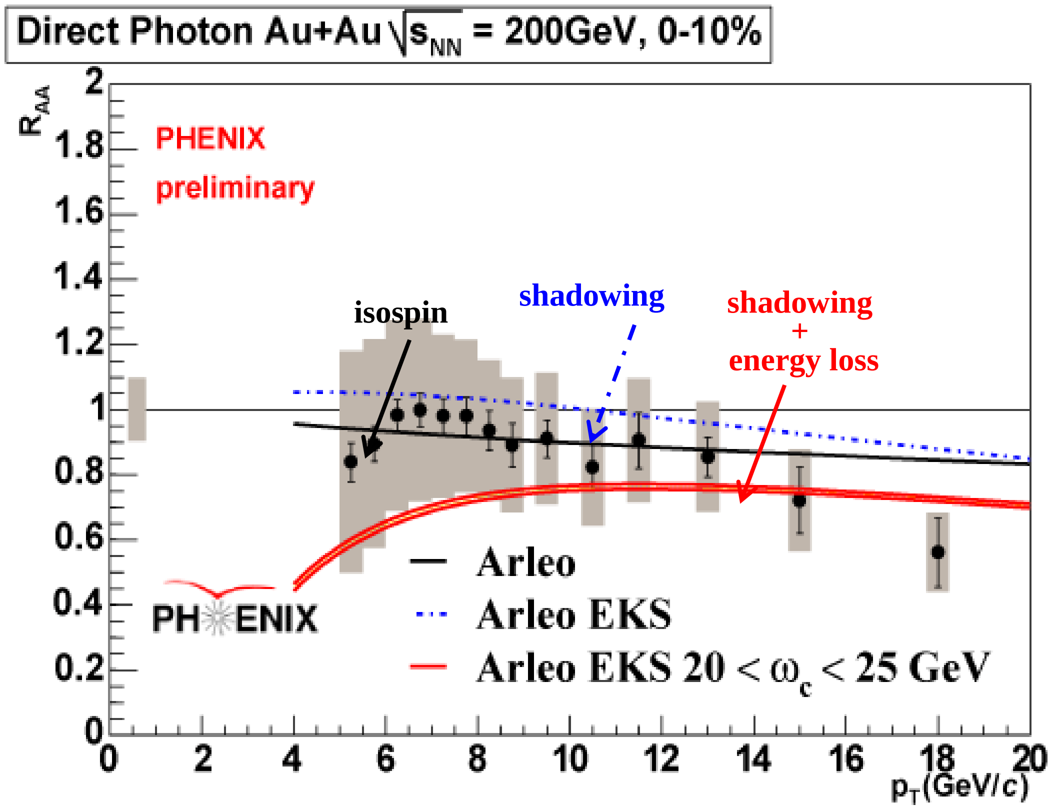
Au+Au run 4 compared with p+p

– Computing R_{AA}

- $$R_{AA} = \frac{dN^{\gamma}_{AA}}{<N_{coll}> \times dN^{\gamma}_{pp}}$$
- consistent with N_{coll} scaling below ~10 GeV
- Small decrease observed at very high p_T

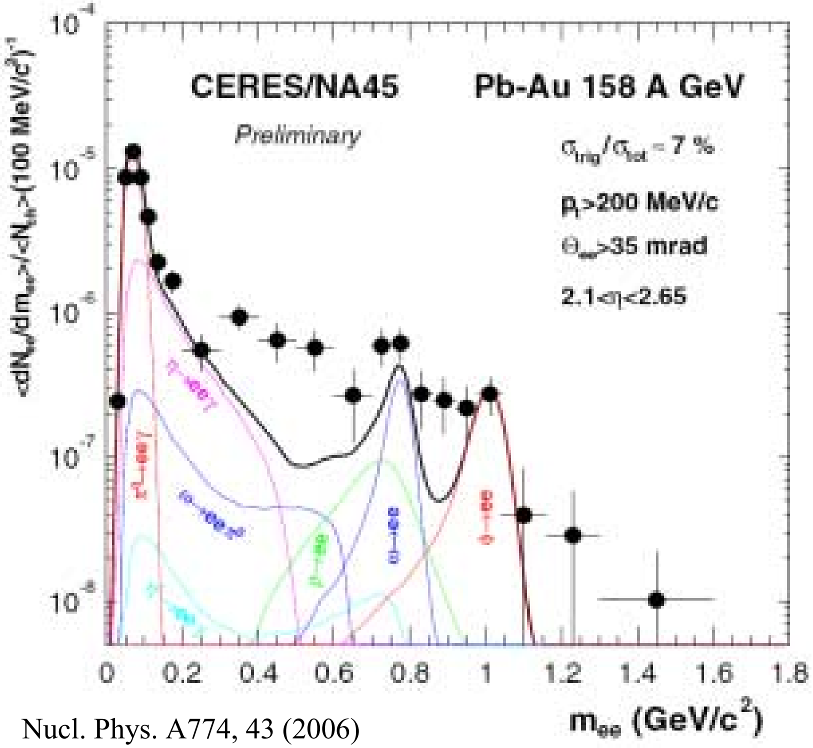
– interpretation

- F. Arleo : JHEP 0609 (2006) 015
- High-p_T suppression due to isospin effect, in addition to jet quenching and shadowing.

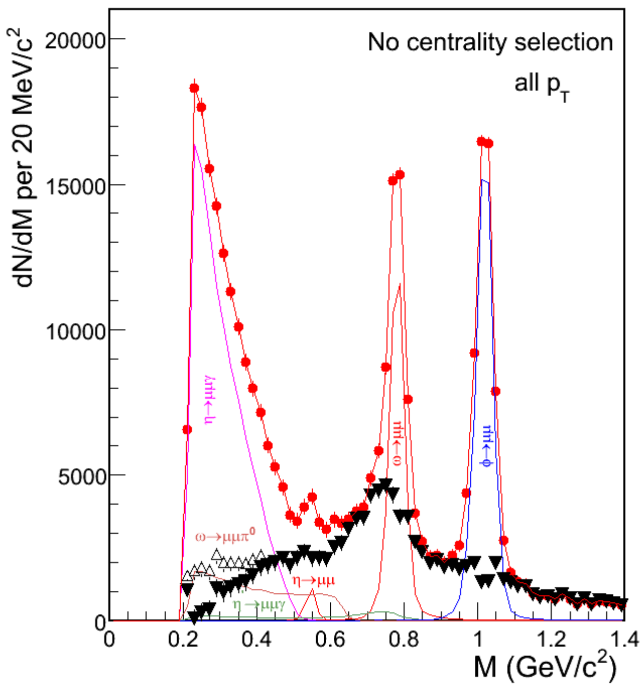


Dielectrons @ SPS

- Chiral Symmetry Restoration (?)
  - Adding mass term in QCD lagrangian brokes chiral symetry
  - Lattice QCD predicts that it is restored at T_c ~ 150 – 200 MeV
  - Experimentally expect mass drop and broadening of the ρ-meson
  - At SPS-CERN (~20 GeV), low mass excess observed by CERES in Pb+Au and confirmed by NA60 in In+In.

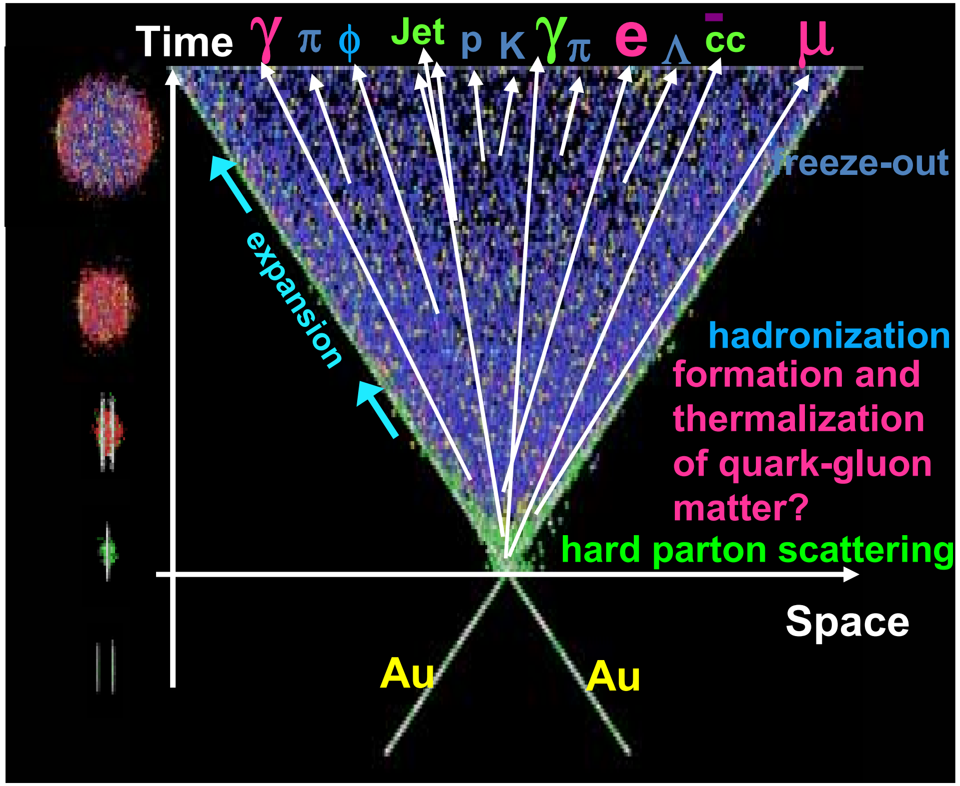


Nucl. Phys. A774, 43 (2006)

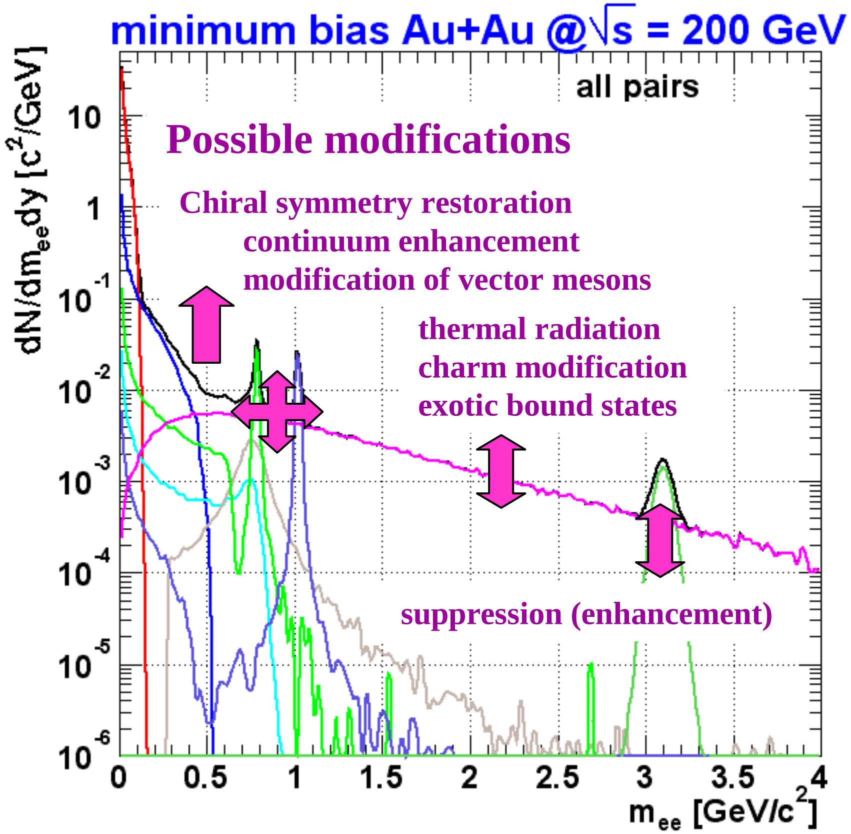


Phys. Rev. Lett 96, 162302 (2006)

Dileptons at RHIC



Expected sources
- **Light hadron decays**
  - Dalitz decays π^0, η
  - Direct decays ρ/ω and ϕ
- **Hard processes**
  - Charm (beauty) production
  - Much larger at RHIC than at SPS



- Photons and dileptons: radiation from the media
  - direct probes of any collision stages (no final-state interactions)
  - large emission rates in hot and dense matter
  - according to the VMD their production is mediated in the hadronic phase by the light neutral vector mesons (ρ, ω, and φ) which have short life-time
- Changes in position and width: signals of the chiral transition?

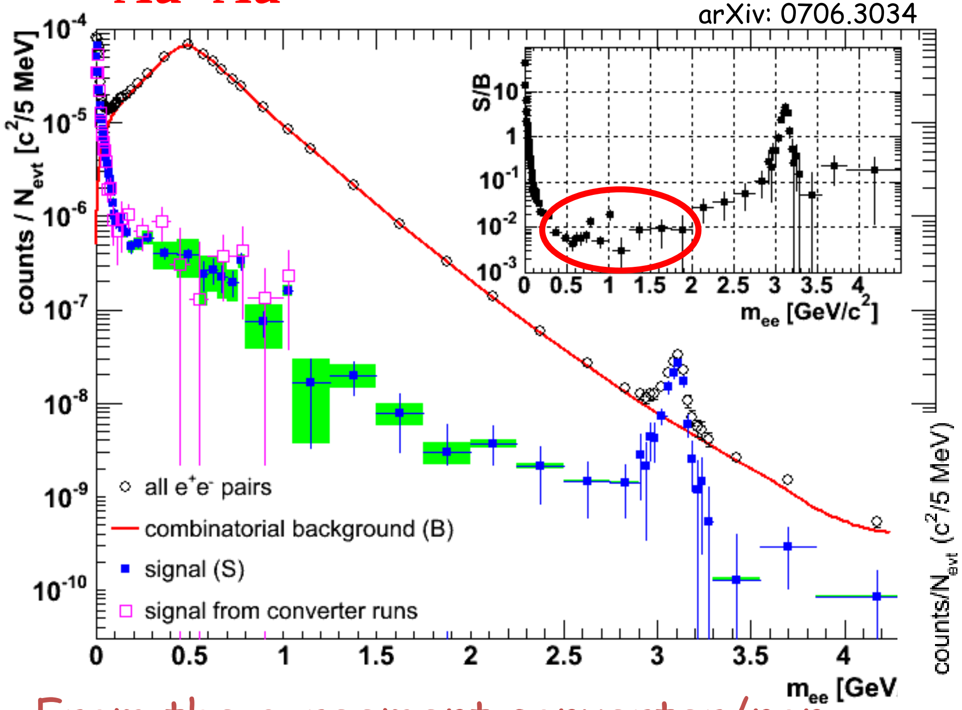
The raw subtracted spectrum

Same analysis on data sample with additional conversion material
→Combinatorial background increased by 2.5
Good agreement within statistical error

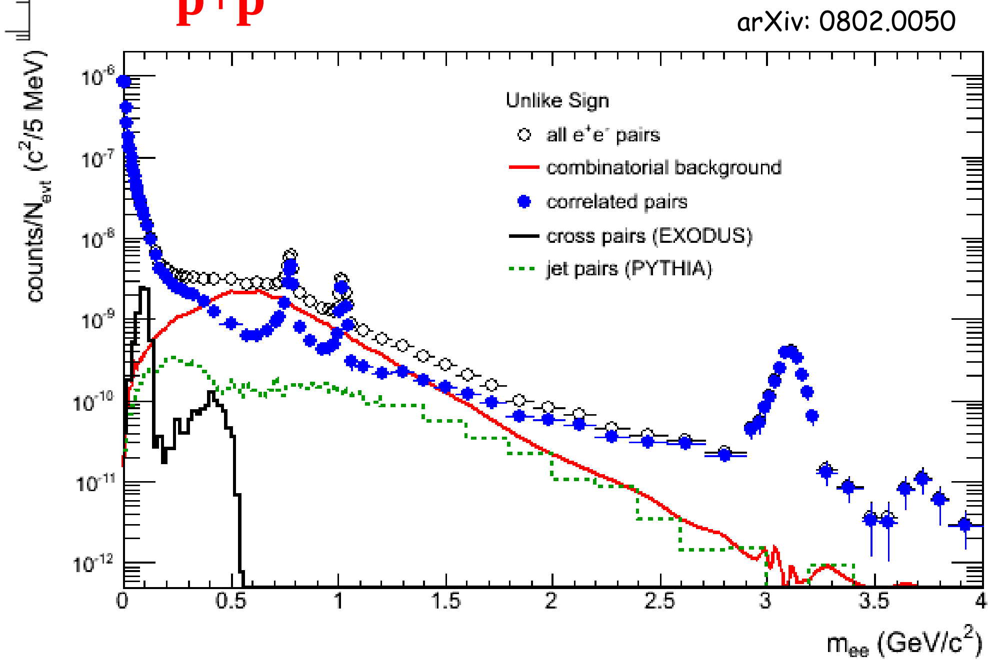
$$\sigma_{signal}/signal = \sigma_{BG}/BG * BG/signal$$

0.25% large!!!

Au+Au



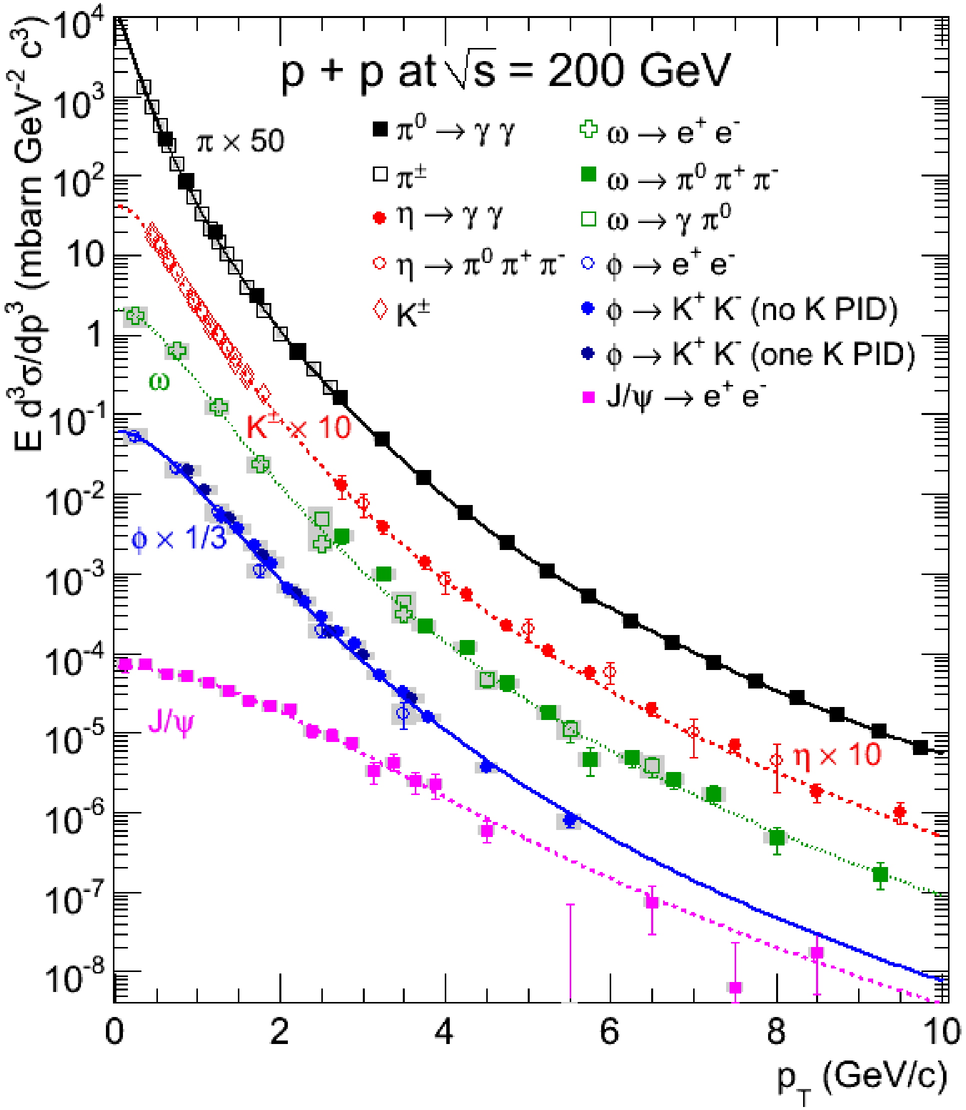
p+p



From the agreement converter/non-converter and the decreased S/B ratio scale error < 0.1%
(well within the conservative 0.25% error we assigned)

Meson p_T spectra pp PHENIX

PHENIX arXiv: 0802.0050



- Start from the π^0
- assume: $\pi^0 = (\pi^+ + \pi^-)/2$
- parameterize PHENIX pion data:

$$E\frac{d^3\sigma}{d^3p} = \frac{A}{\left(\exp(-ap_T - bp_T^2) + p_T/p_0\right)^n}$$

Other mesons well measured by many different detection and analysis methods, PHENIX is a very versatile detector.

Other mesons are fit with:

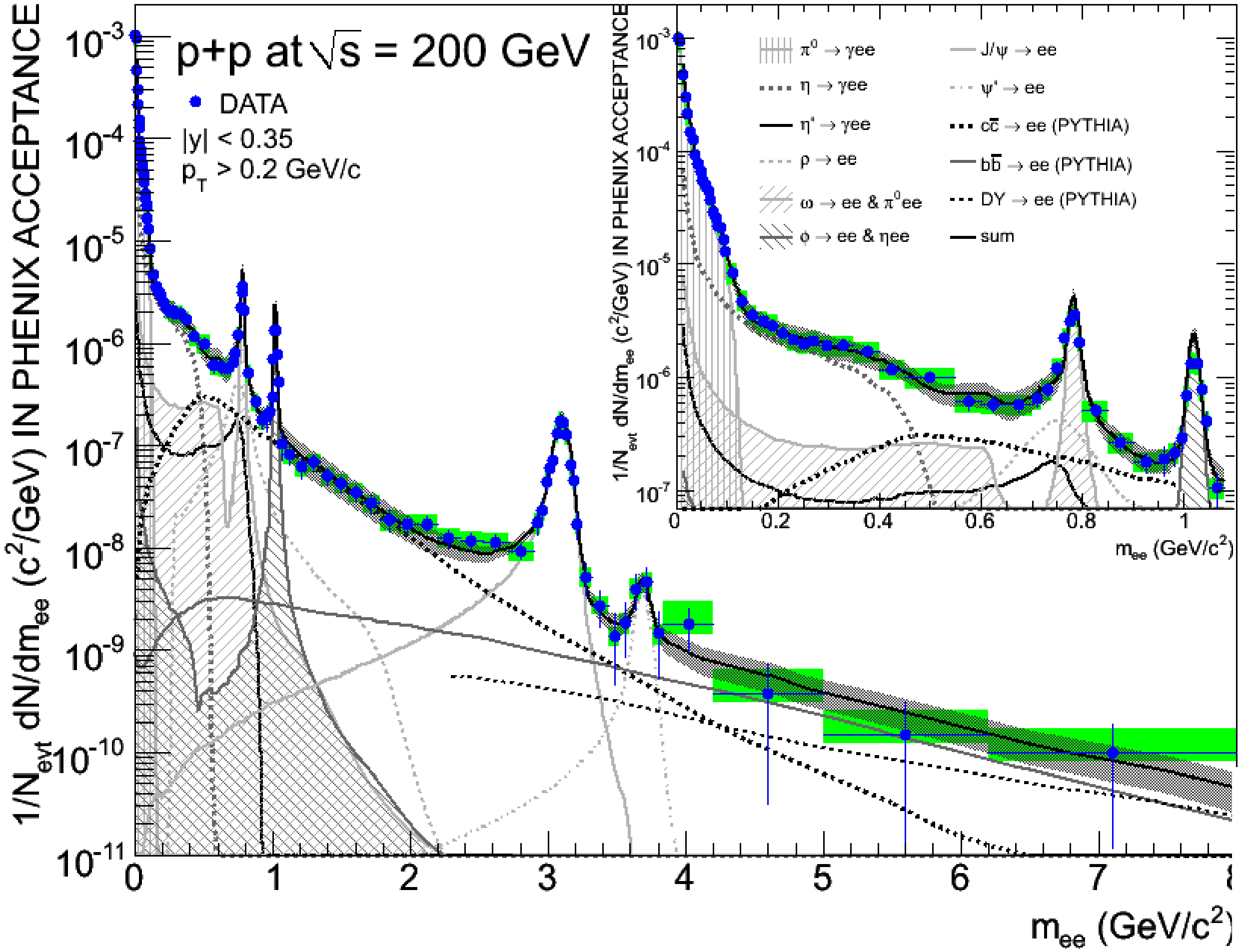
m_T scaling of π^0 parameterization

$p_T \rightarrow \sqrt{(p_T^2 + m_{meson}^2 - m_\pi^2)}$

fit the normalization constant

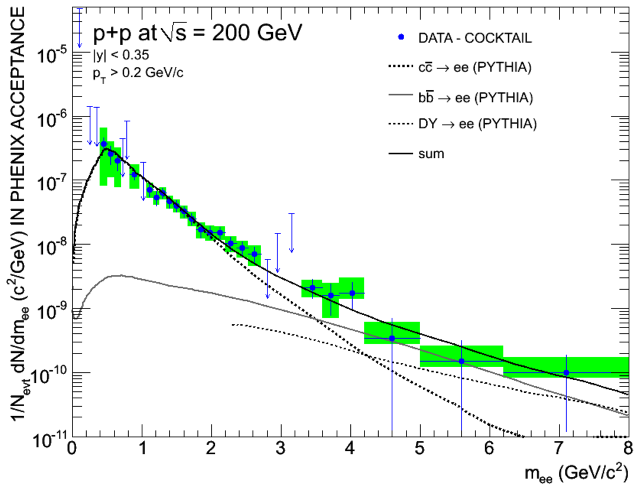
→**All mesons m_T scale!!!**

p+p Cocktail Comparison



- Data absolutely normalized
- Excellent agreement data-cocktail
- Extract charm and bottom cross section

PHENIX
submitted to Phys. Lett.B
arXiv: 0802.0050



Charm: integration after cocktail subtraction

- σ_c=544 ± 39 (stat) ± 142 (sys) ± 200 (model) μb

Simultaneous fit of charm and bottom:

- σ_c=518 ± 47 (stat) ± 135 (sys) ± 190 (model) μb
- σ_b= 3.9 ± 2.4 (stat) +3/-2 (sys) μb

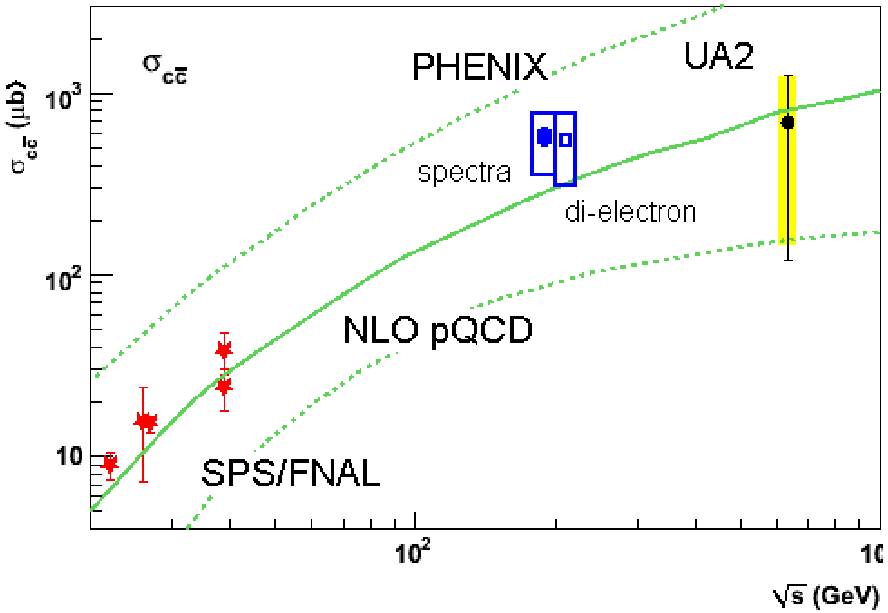
Charm and bottom cross sections

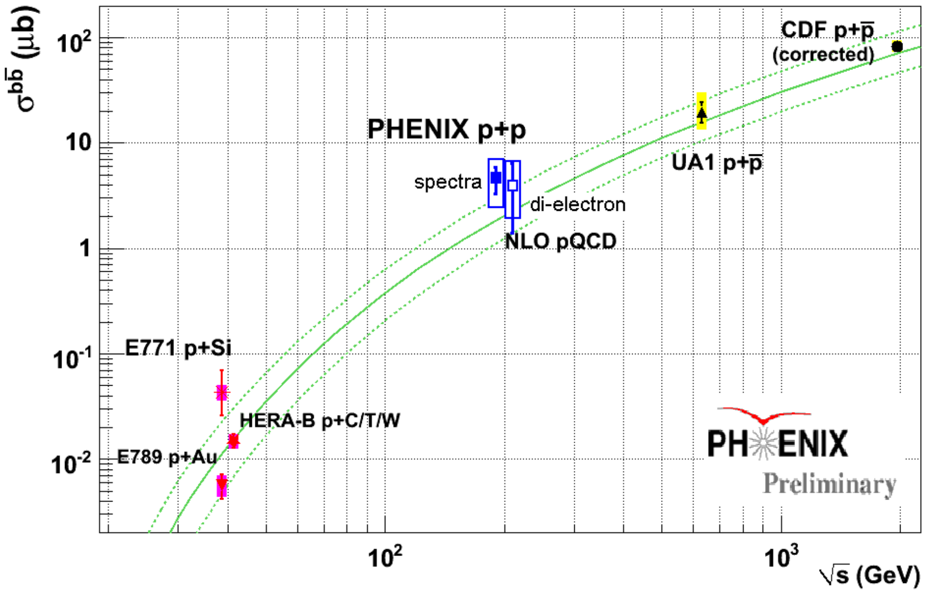
CHARM

Dilepton measurement in agreement with single electron, single muon, and with FONLL (upper end)

BOTTOM

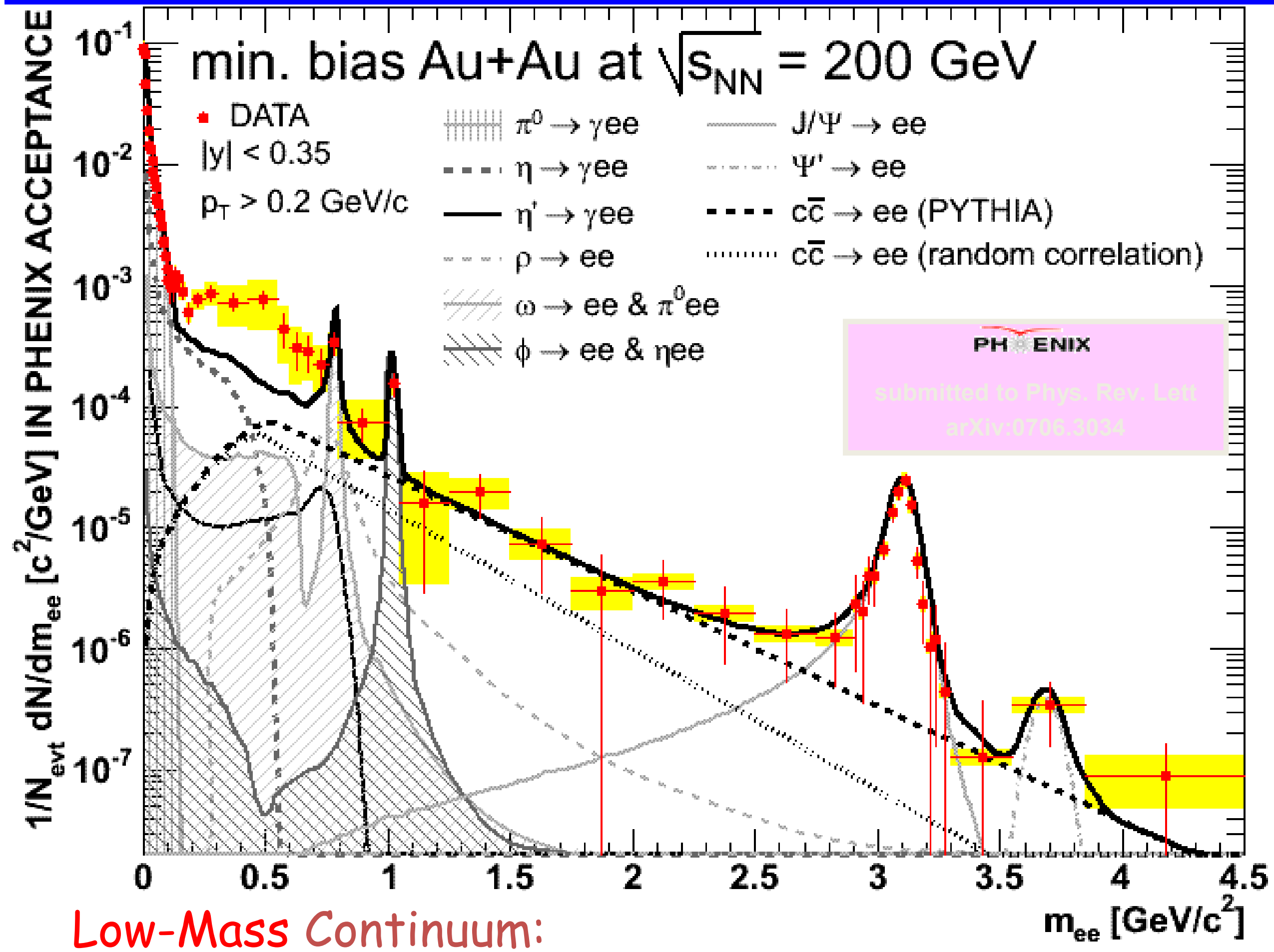
Dilepton measurement in agreement with measurement from e-h correlation and with FONLL (upper end)





First measurements of bottom cross section at RHIC energies.

Au+Au Cocktail Comparison



- Data absolutely normalized
- Cocktail filtered in PHENIX acceptance
- Charm from
  - PYTHIA
  - Single electron non photonic spectrum w/o angular correlations

$\sigma_c = N_{coll} \times 567 \pm 57 \pm 193 \mu b$

Low-Mass Continuum:

enhancement 150 < m_{ee} < 750 MeV: 3.4±0.2(stat.) ±1.3(syst.)±0.7(model)

Intermediate-Mass Continuum:

Single-e → pt suppression & non-zero v2: charm thermalized?

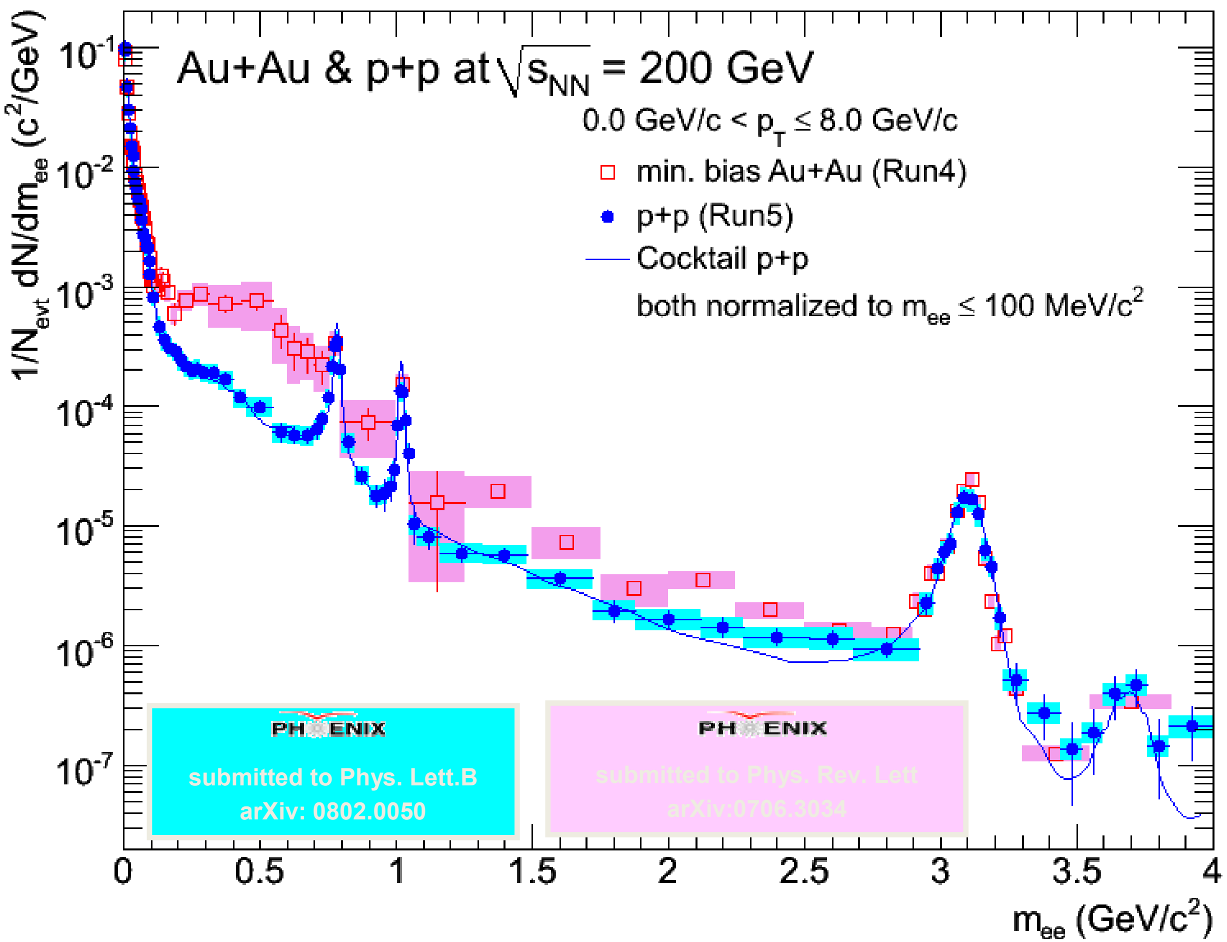
PYTHIA single-e p_T spectra softer than p+p but coincide with Au+Au

Angular correlations unknown

Room for thermal contribution?

pp – AuAu comparison

p+p NORMALIZED TO m_{ee}<100 MeV



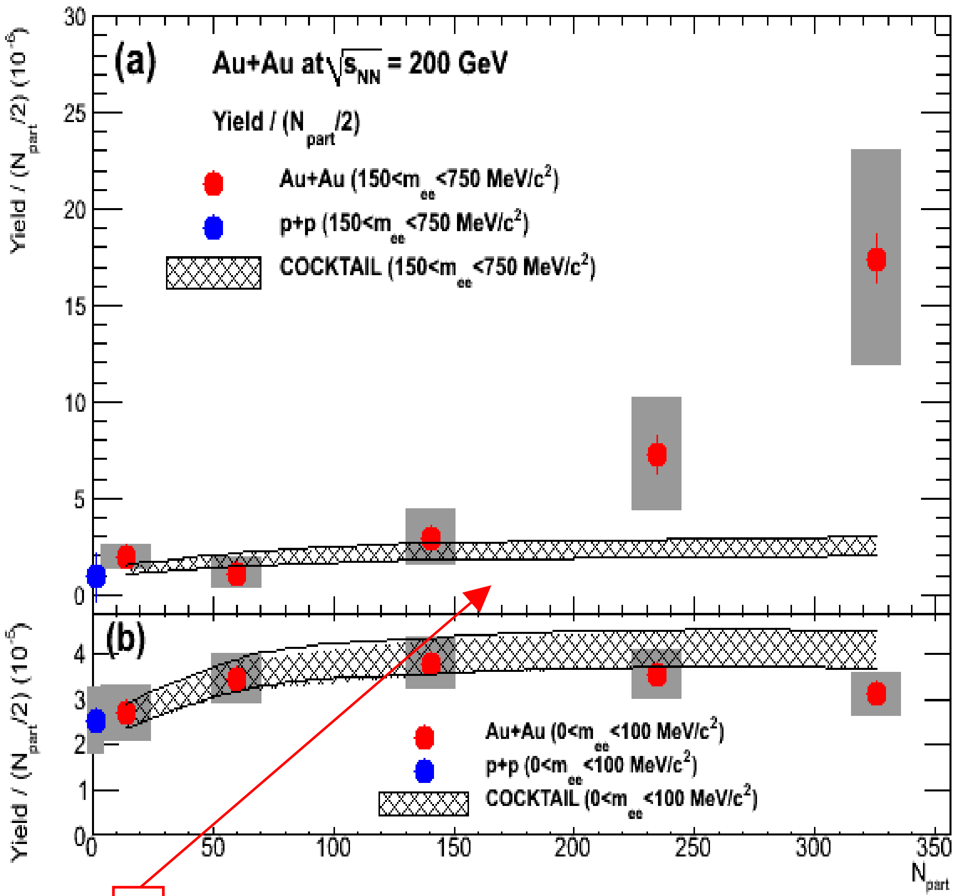
pp and AuAu normalized to π^0 region

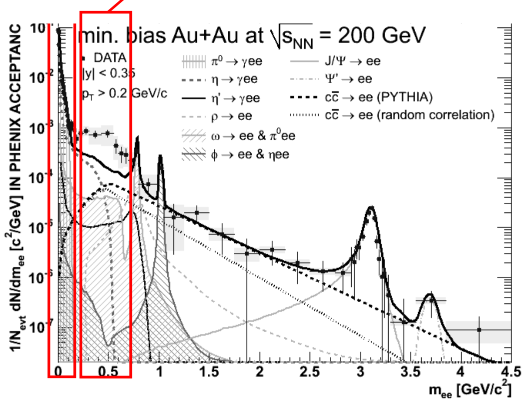
p+p: follows the cocktail
Au+Au: large Enhancement in 0.15-0.75

Agreement in intermediate mass and J/Ψ just for 'coincidence' (J/Ψ happens to scale as π^0 due to scaling with Ncoll + suppression)

Centrality Dependency

LOW MASS





PHENIX
submitted to Phys. Rev. Lett
arXiv:0706.3034

π^0 region:

- Agreement with cocktail

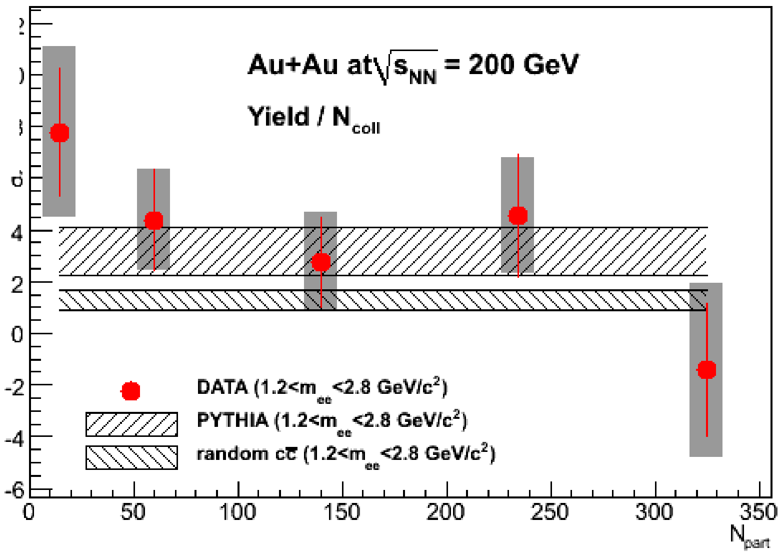
Low Mass:

- yield increases faster than proportional to N_{part}
  → enhancement from binary annihilation (ππ or qq) ?

Intermediate Mass:

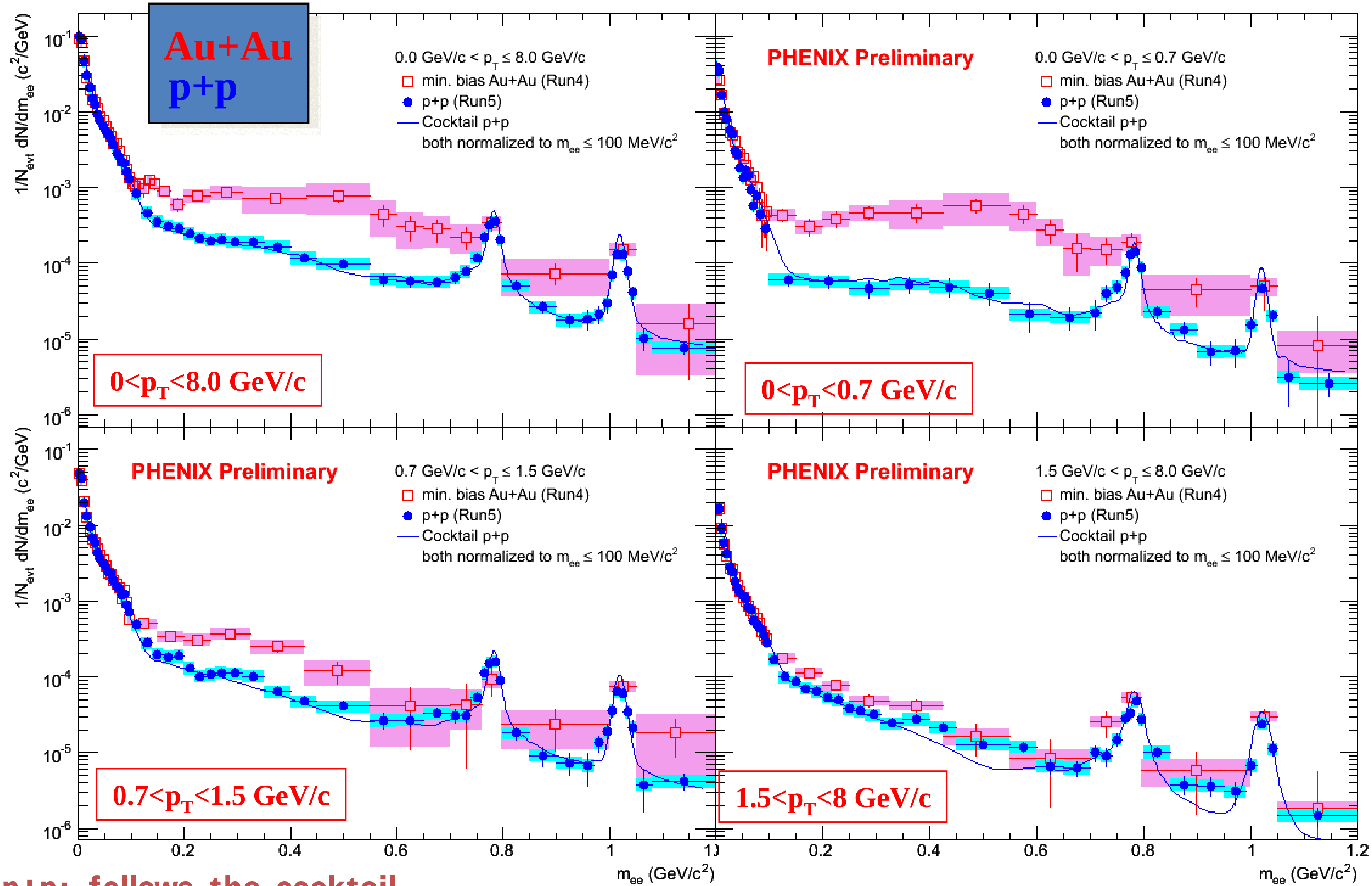
- yield increase proportional to N_{coll}
  → charm follows binary scaling

INTERMEDIATE MASS



p_T dependency

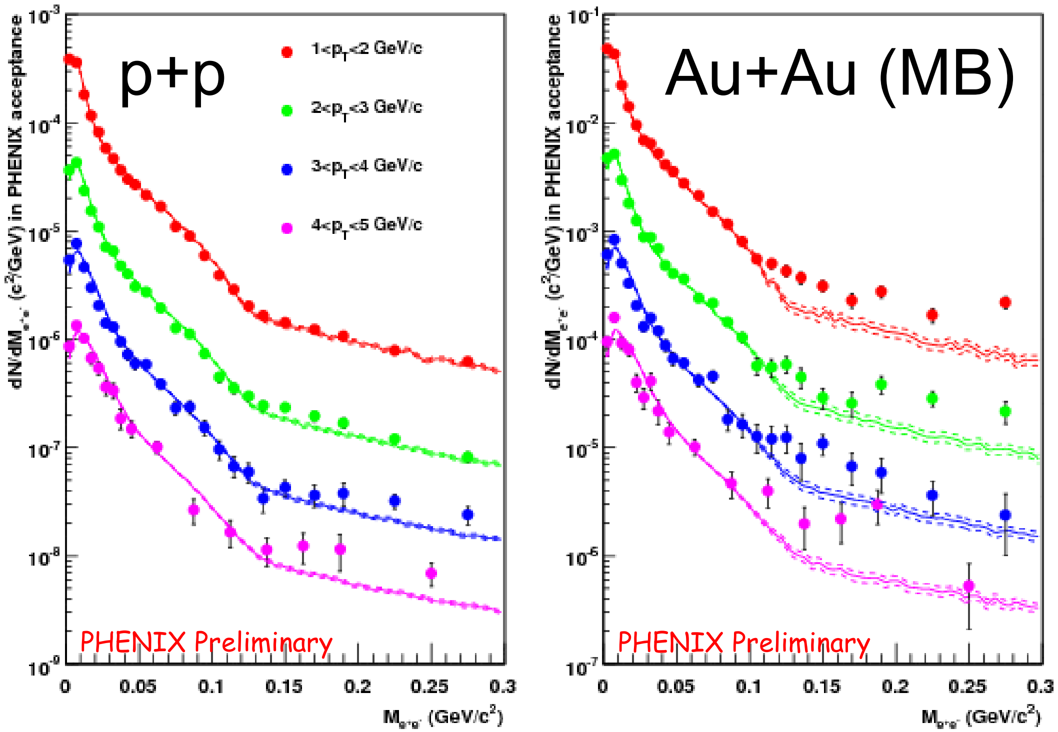
arXiv: 0706.3034
arXiv: 0802.0050

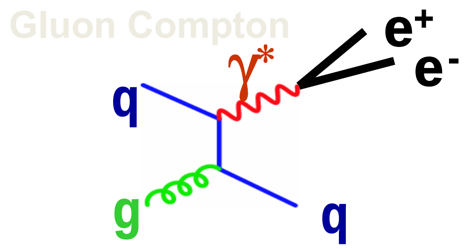


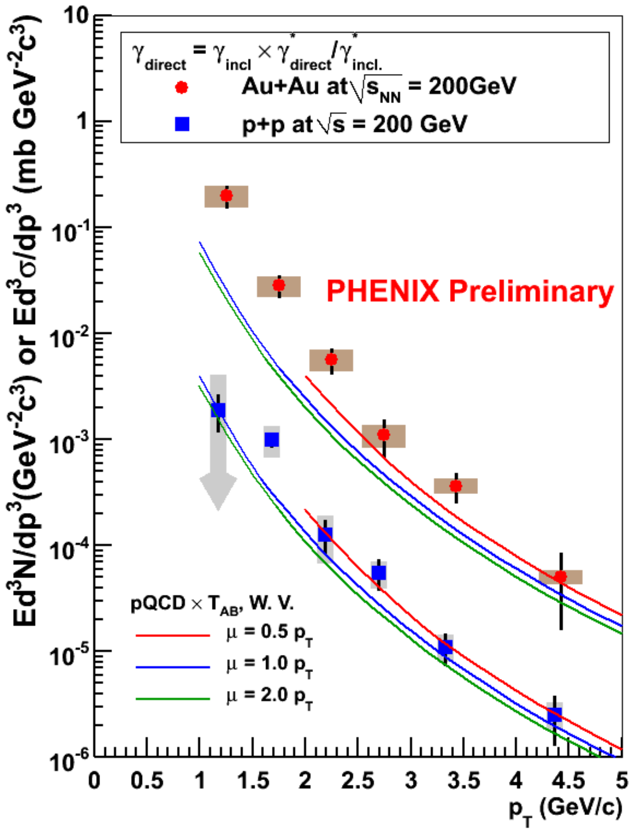
p+p: follows the cocktail

Au+Au: enhancement concentrated at low p_T

Dileptons at low mass and high p_T

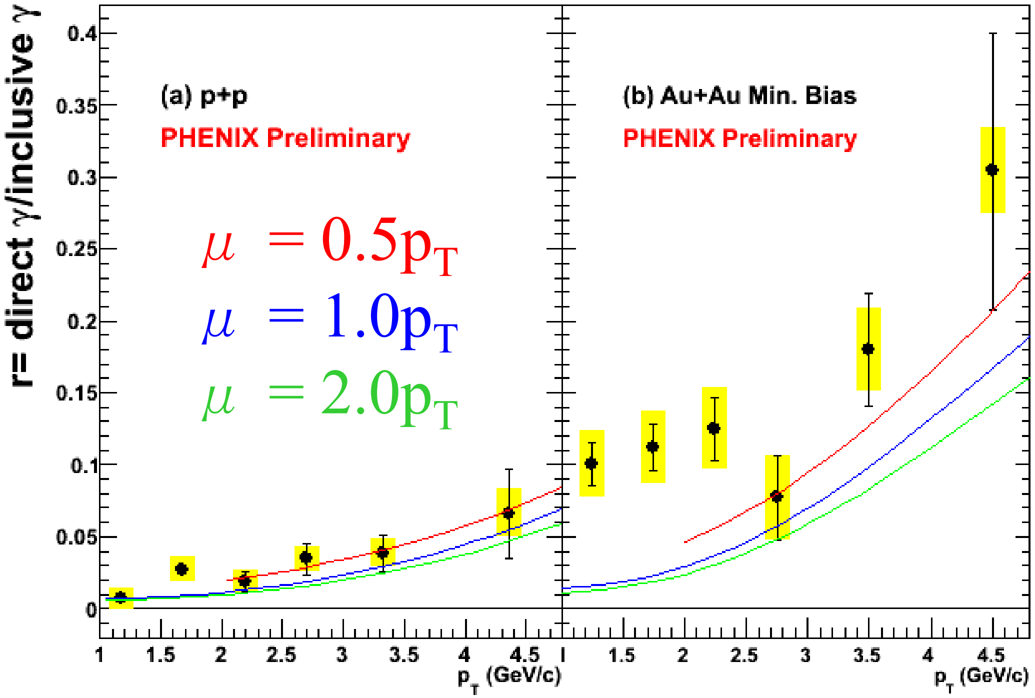






- m<2π only Dalitz contributions
  - p+p: no enhancement at low p_T
  - Au+Au: large enhancement at low p_T
- Any source of *real* γ produces *virtual* γ with very low mass
- Assuming internal conversion of direct photon → extract the fraction of direct photon
- p+p: follows pQCD
- Au+Au: clear **excess** above pQCD → signal of **thermal** photons?

direct γ*/inclusive γ*



Curves : NLO pQCD calculations with different theoretical scale done by W.

$$\left(d\sigma_\gamma^{NLO}/dp_T\right)/\left(d\sigma_\gamma^{NLO}/dp_T + d\sigma_\gamma^{hadron}/dp_T\right)$$

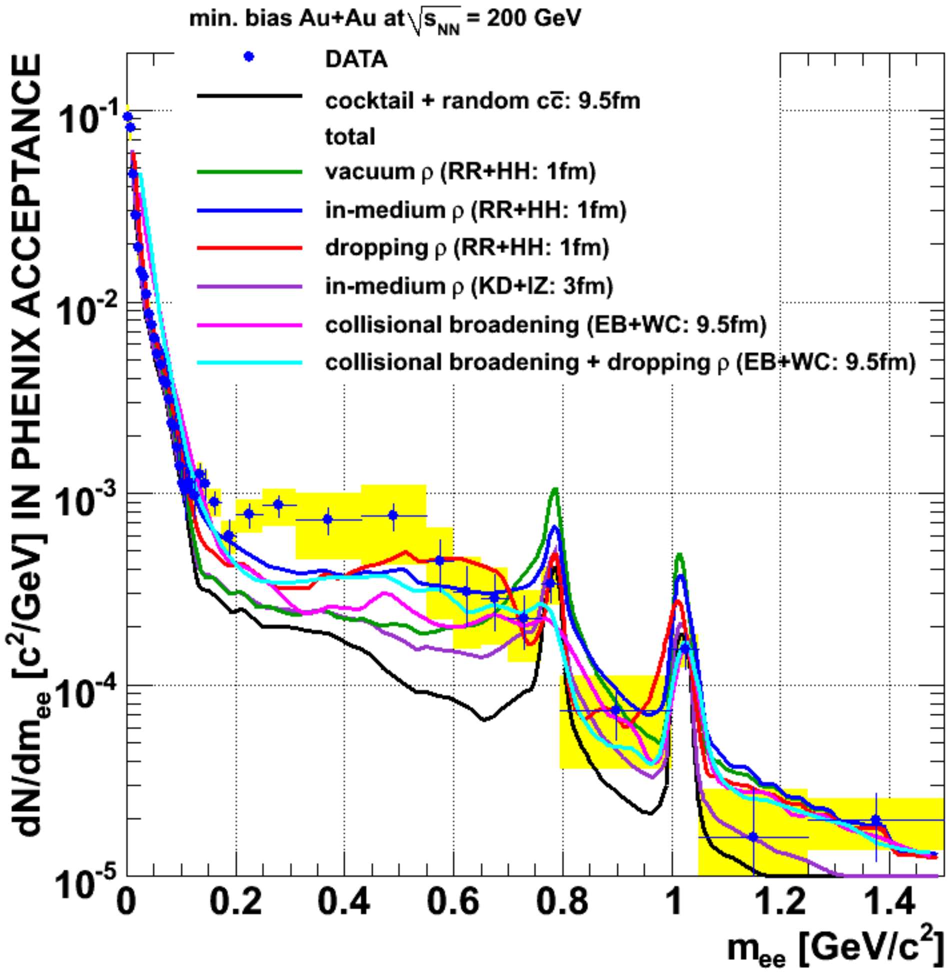
p+p

- Consistent with NLO pQCD
  - better agreement with small μ

Au+Au

- Clear enhancement above NLO pQCD

Theory comparison



- Freeze-out Cocktail + “random” charm + ρ spectral function

Low mass

- $M>0.4GeV/c^2$: some calculations OK
- $M<0.4GeV/c^2$: not reproduced

Intermediate mass

- Random charm + thermal partonic may work

Summary on dielectrons

- First measurements of dielectron continuum at RHIC

p+p

Low mass

- Excellent agreement with cocktail

Intermediate mass

- Extract charm and bottom
  - σ_c = 544 ± 39 (stat) ± 142 (sys) ± 200 (model) μb
  - σ_b = 3.9 ± 2.4 (stat) +3/-2 (sys) μb

Au+Au

Low mass

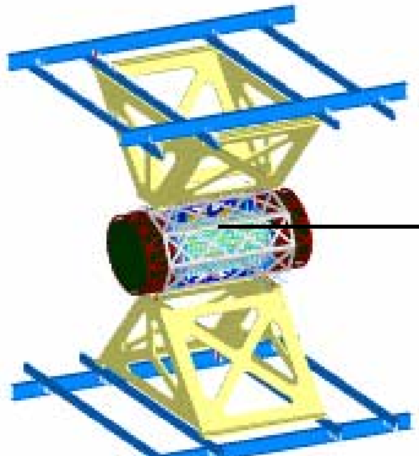
- Enhancement above the cocktail expectations: 3.4±0.2(stat.) ±1.3(syst.)±0.7(model)
- Centrality dependency: increase faster than N_{part}
- p_T dependency: enhancement concentrated at low p_T

Intermediate mass

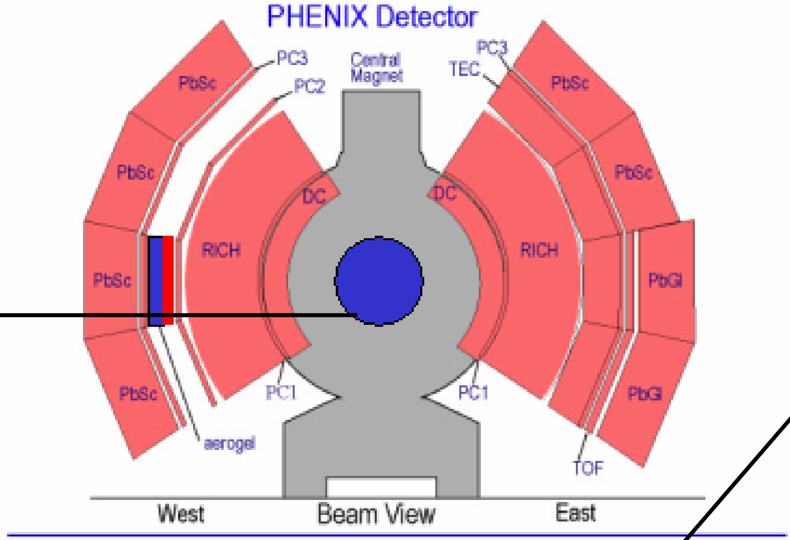
- Agreement with PYTHIA: coincidence?

PHENIX detector future Upgrade & run plans

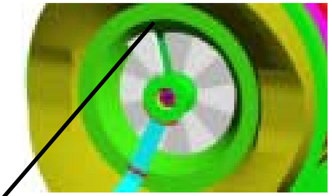
Future PHENIX Subsystems



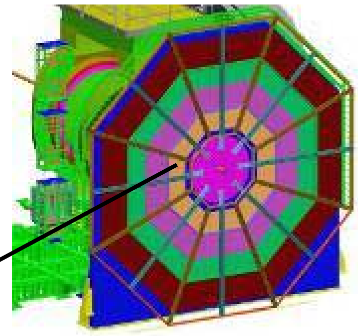
Silicon VTX and FVTX

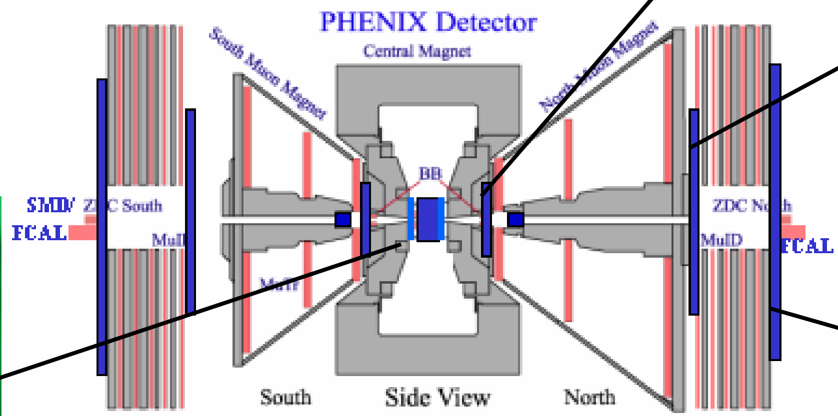


MuTrig Station 1

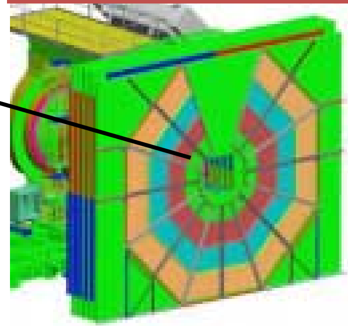


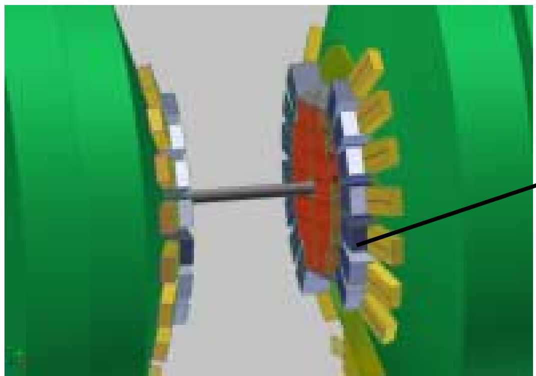
MuTrig Station 2





MuTrig Station 3

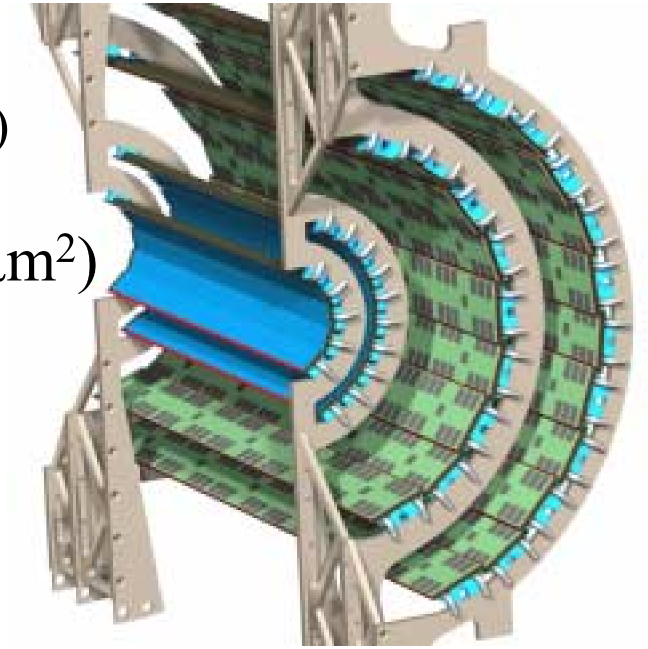


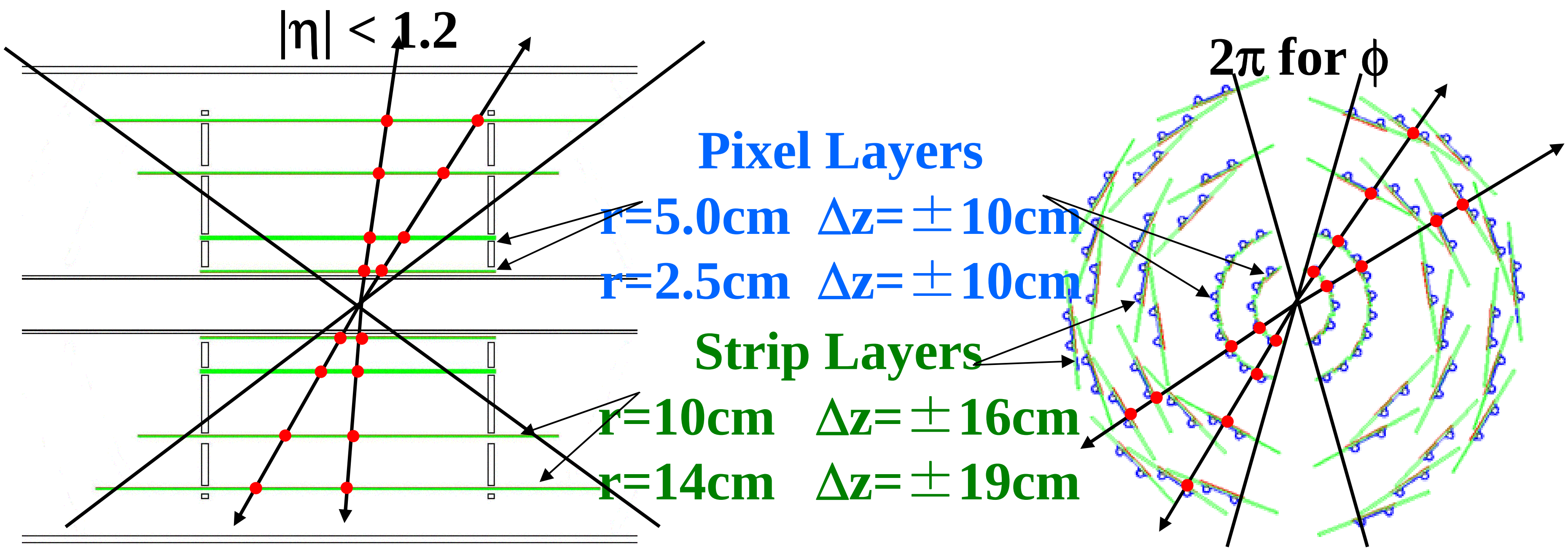


Nose Cone Calorimeter

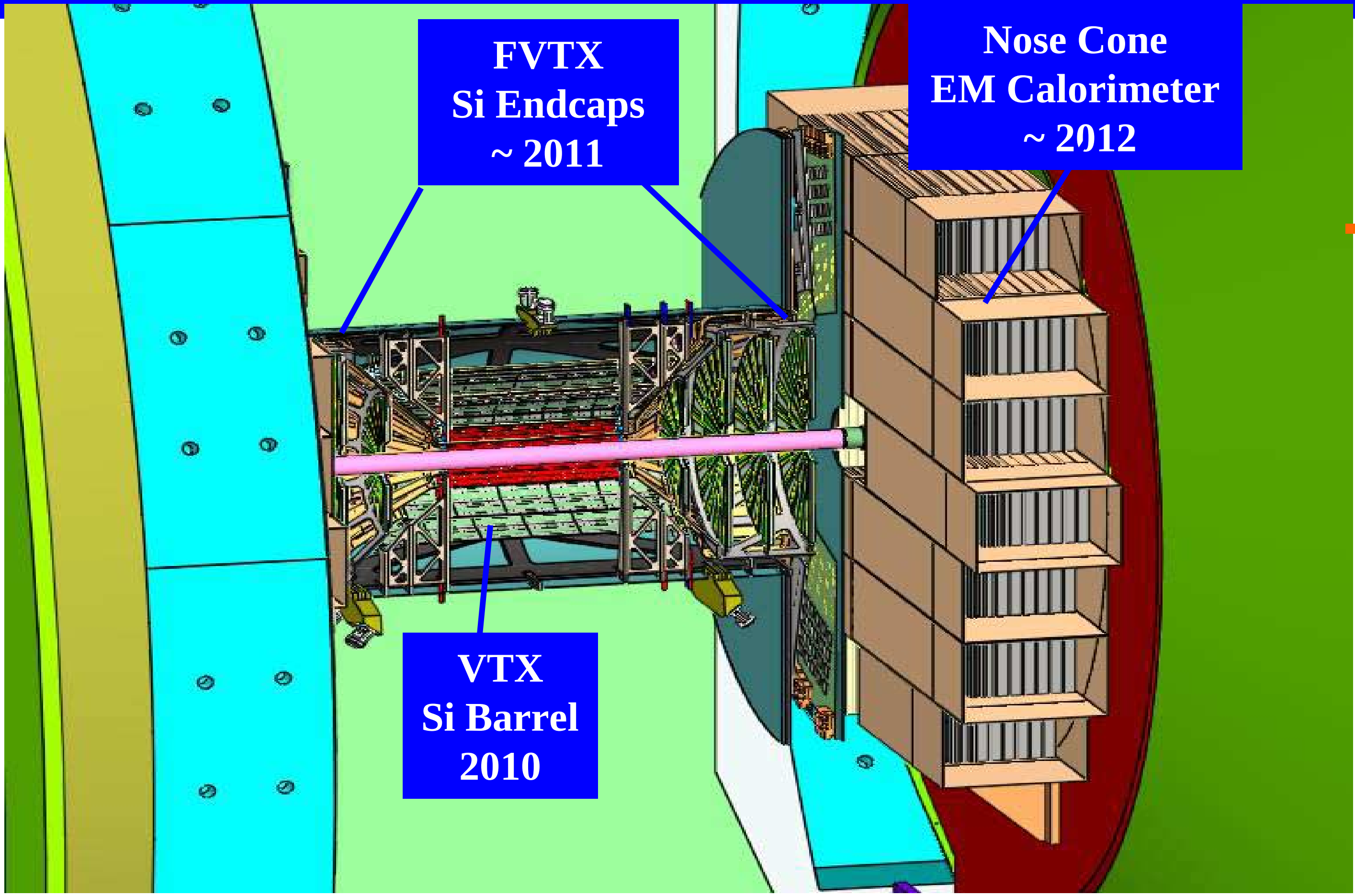
The PHENIX barrel VTX Detector

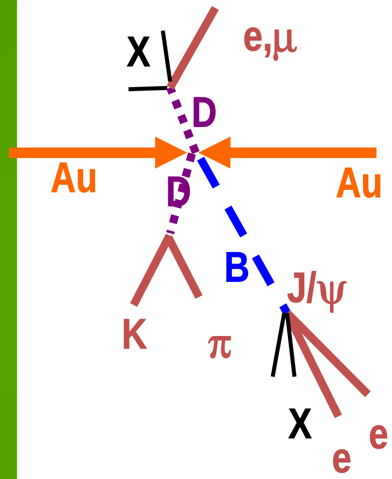
- Four-Layer Barrel Detector
  - **Pixel Sensor** (Inner 2 Layers) ($50 \times 425\ \mu m^2$)
    required for high occupancy
  - **Strip Sensor** (Outer 2 Layers) ($80 \times 1000\ \mu m^2$)
- Good DCA resolution
  $\sigma_{DCA} \sim 50\ \mu m$
- Large Acceptance
  $|\eta| < 1.2$, 2π for ϕ





Improved Vertex Tracking and Forward Acceptance

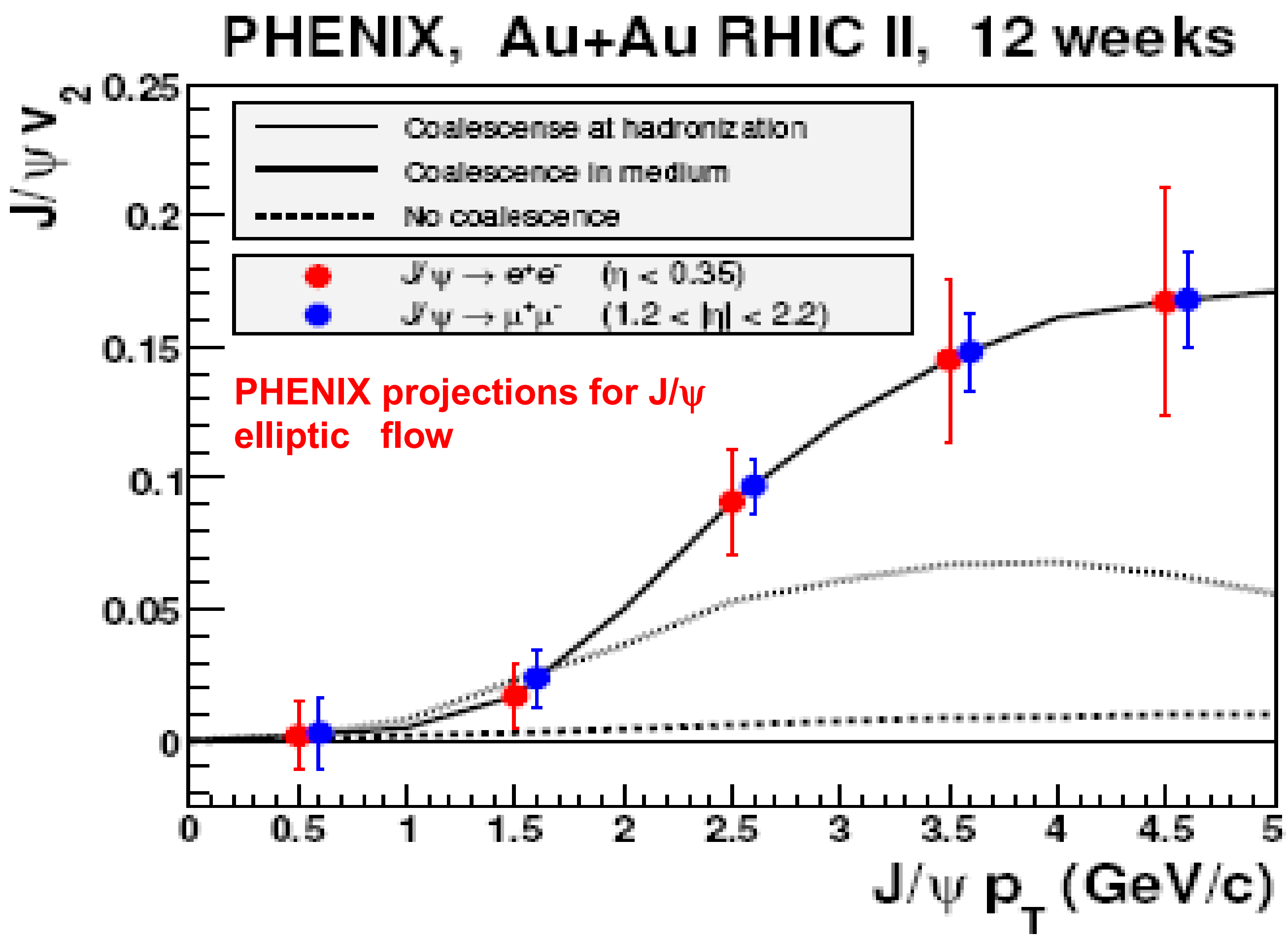




- ***PHENIX vertex upgrades provide resolution to reconstruct slightly displaced vertices associated with heavy flavor hadron decays ⇒ study heavy-quark flow & equilibration in "perfect liquid".***

- ***Improved forward calorimetry enhances γ- jet acceptance to study light quark E loss and gluon contribution to proton spin***

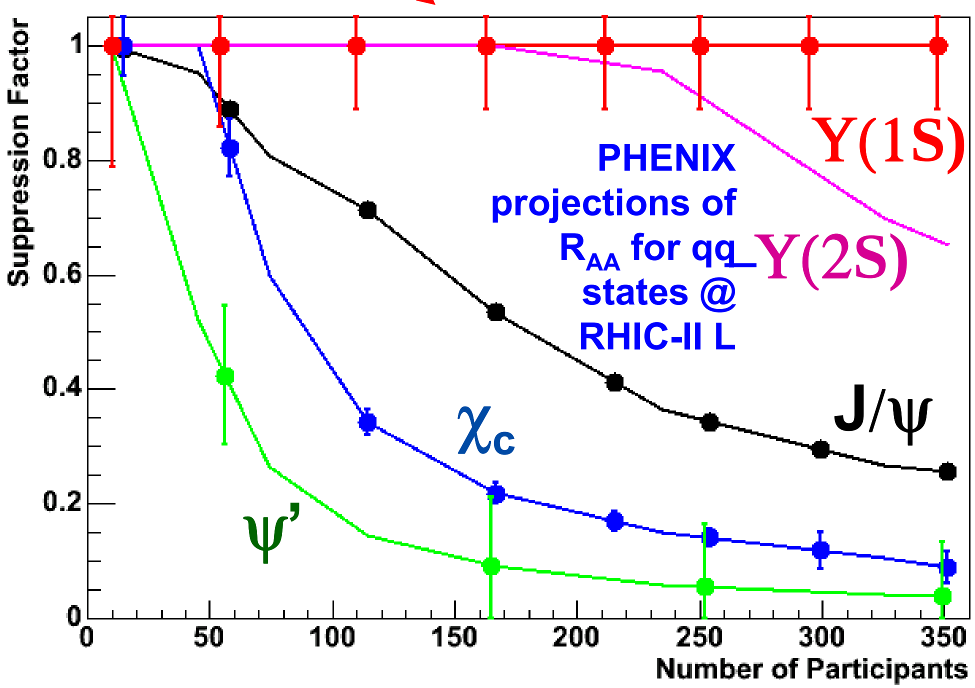
Detector & Luminosity Upgrades ⇒ New Physics Milestones



Measure hadron suppression and flow for identified heavy-quark mesons, possibly baryons (Λ_c)

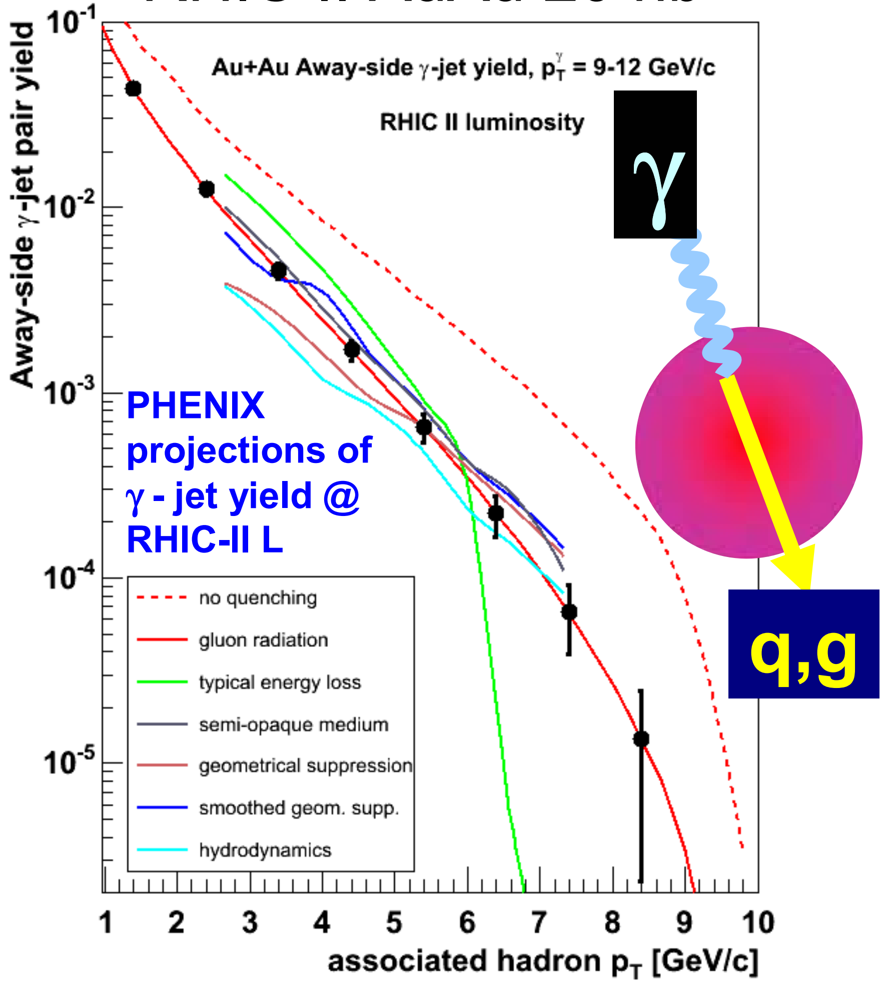
Detector & Luminosity Upgrades ⇒ New Physics Milestones

- ***Calibration of light-quark energy loss via γ- tagging***
- ***Definitive map of quarkonium melting***

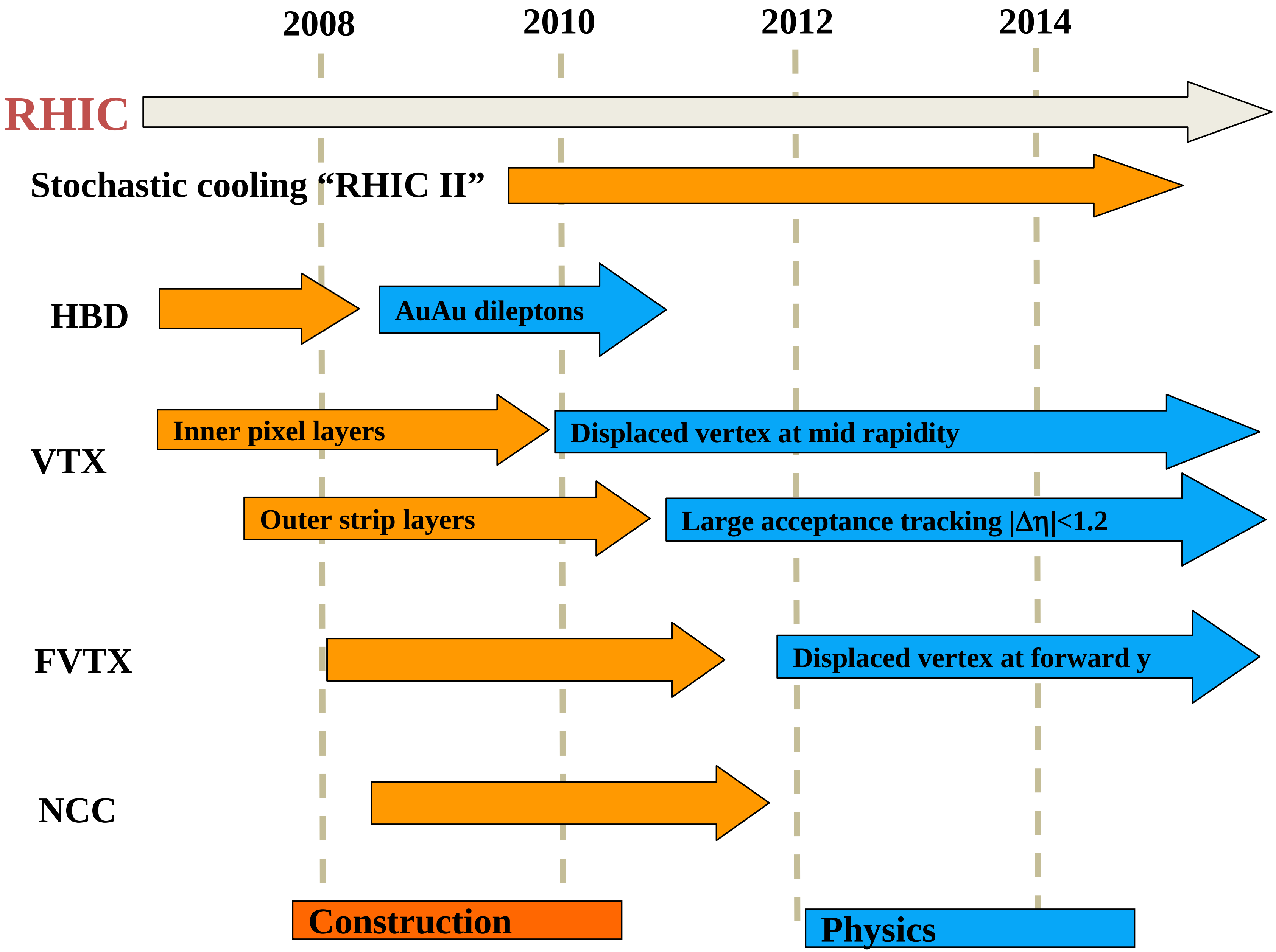


Reference model based on consecutive melting without regeneration
(Note: This results in small ψ', χ_C yields, other models like regeneration model will give similar yields for J/ψ, ψ', χ_C !)

RHIC II AuAu 20 nb^{-1}

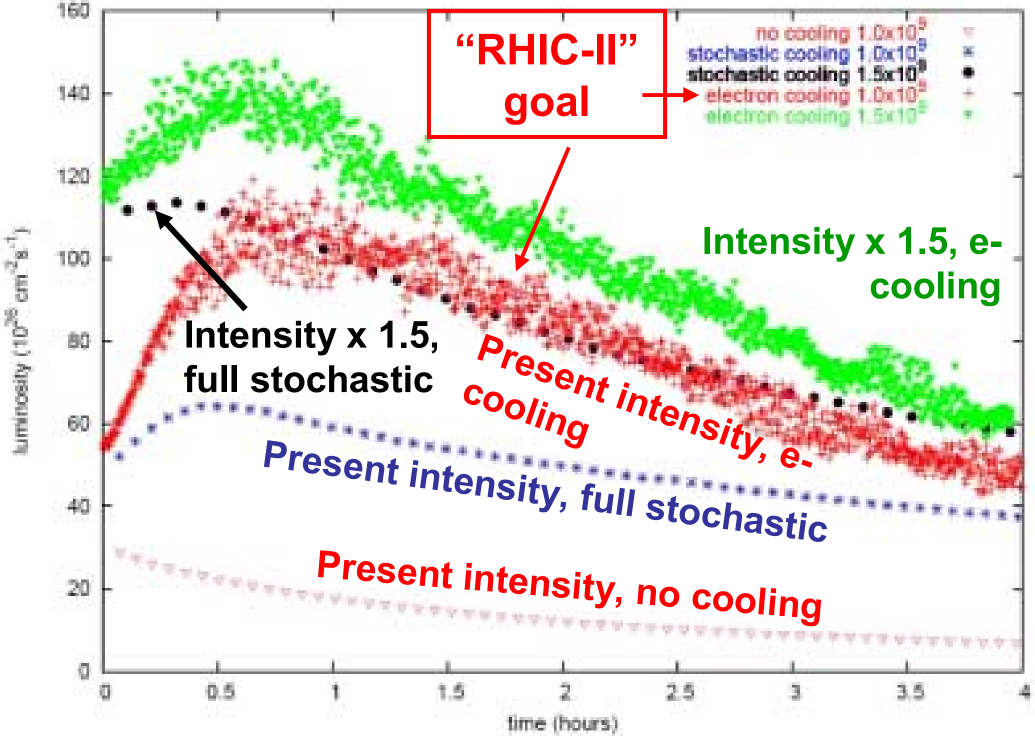


Timeline of PHENIX upgrades



Plan to Implement and Test Stochastic Cooling of Heavy Ion Beams at RHIC

Simulated effects of beam cooling for full-energy Au+Au



- ***Test combined effect of long. & transverse stochastic cooling for one beam in 2009 run.***
- ***If results follow detailed simulations, full implementation by 2011.***

- ***Simulations ⇒ long. + trans. stochastic cooling + 56 MHz SRF for both beam goes ~2/3 way (with present bunch intensity) to RHIC-II projected L at order of magnitude less cost, ~5 years quicker than e-cooling.***

Strawman 4-Year Run Plan (With Decent Budgets)

Fiscal Year	Colliding Beam Species/Energy	Comments
2009	200 and 500 GeV p+p	Complete longitudinal asymmetry measurements at 200 GeV and develop 500 GeV performance
	200 GeV Au+Au	Permits test of 1st plane of transverse stochastic cooling + additional J/ψ v_2 statistics + …
2010	500 GeV p+p	1st substantial 500 GeV run allows clear observation of W production signal
	Au+Au at assorted low E	STAR TOF upgrade fully installed; 1st part of energy scan to search for QCD critical point – focus on higher among scan energies, where luminosity sufficient
2011	200 GeV Au+Au	Full implementation of stochastic cooling in place, PHENIX VTX upgrade complete $\Rightarrow$ long run to reap benefit for rare probes
	200 GeV U+U ?	Utilize EBIS for first measurements with highly deformed nuclei, to increase energy density coverage
2012	500 GeV p+p	Long run in anticipation of 2013 DOE performance milestone on W production, sea antiquark polarization
	Au+Au at assorted low E	Complete energy scan with improved luminosity at very low E from low-energy e-cooling implementation

Physics priorities will determine machine upgrade priorities.

Extras

A Hadron Blind Detector (HBD) for PHENIX

- Dalitz & Conversion rejection via opening angle
  - Identify electrons in field free region
  - Veto signal electrons with partner
- HBD concept:
  - windowless CF4 Cherenkov detector
  - 50 cm radiator length
  - CsI reflective photocathode
  - Triple GEM with pad readout
  - Reverse bias (to get rid of ionization electrons in the radiator gas)
- Status
  - installed and taking data in RUN7
  - x3 more statistics