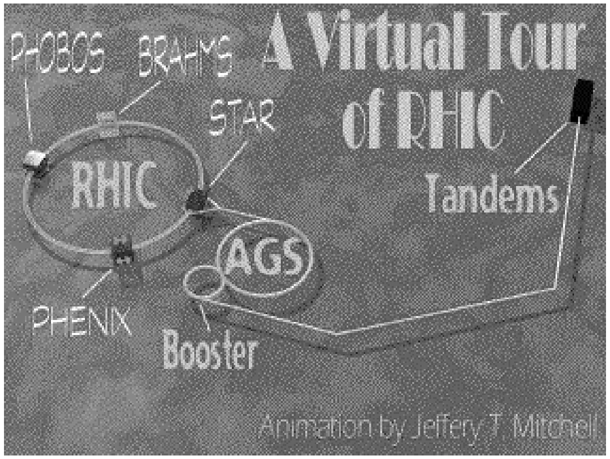
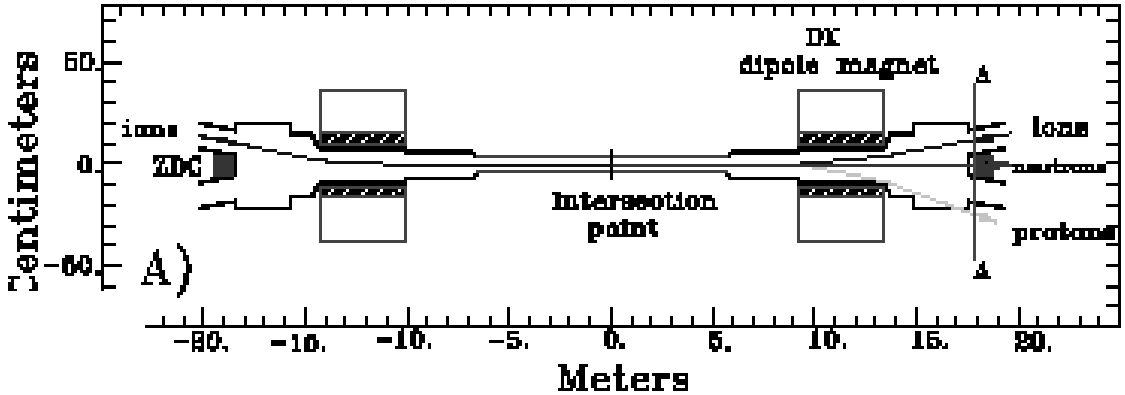
RHIC Plans

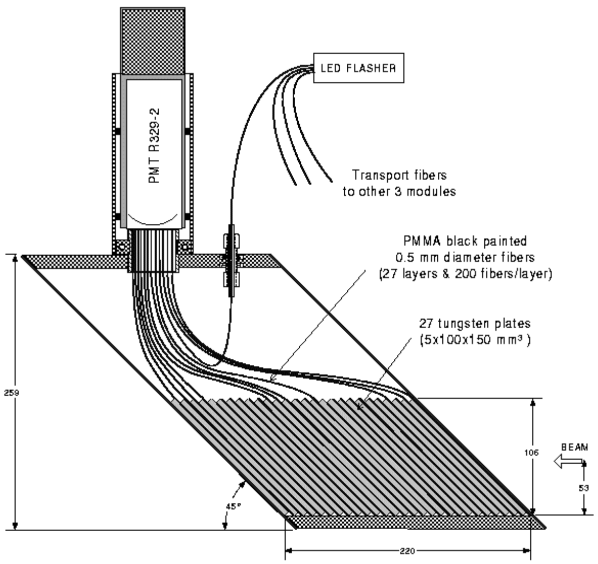
- Instrumentation(Machine and Experiments)
- Heavy Ion environment
- Highlights
  - Machine Performance
  - RHIC results
- Machine Evolution
- Detectors
- ‘the process”

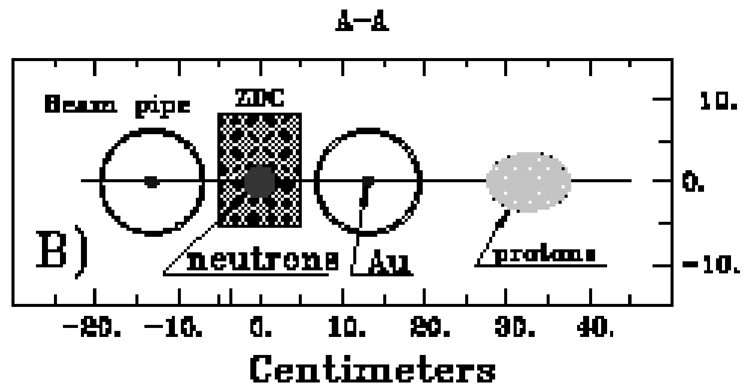
RHIC injector and Collider



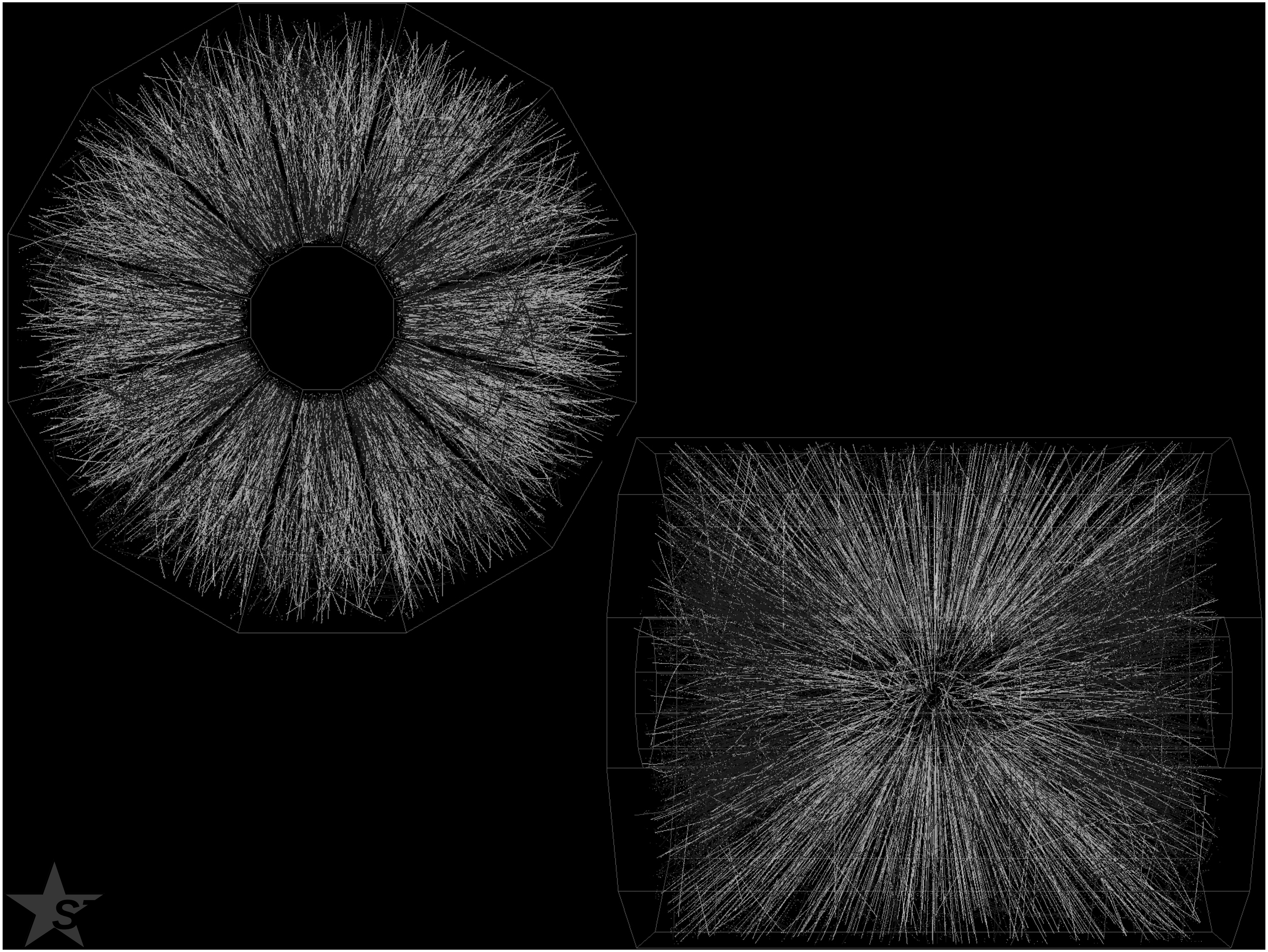
Interaction Region Geometry





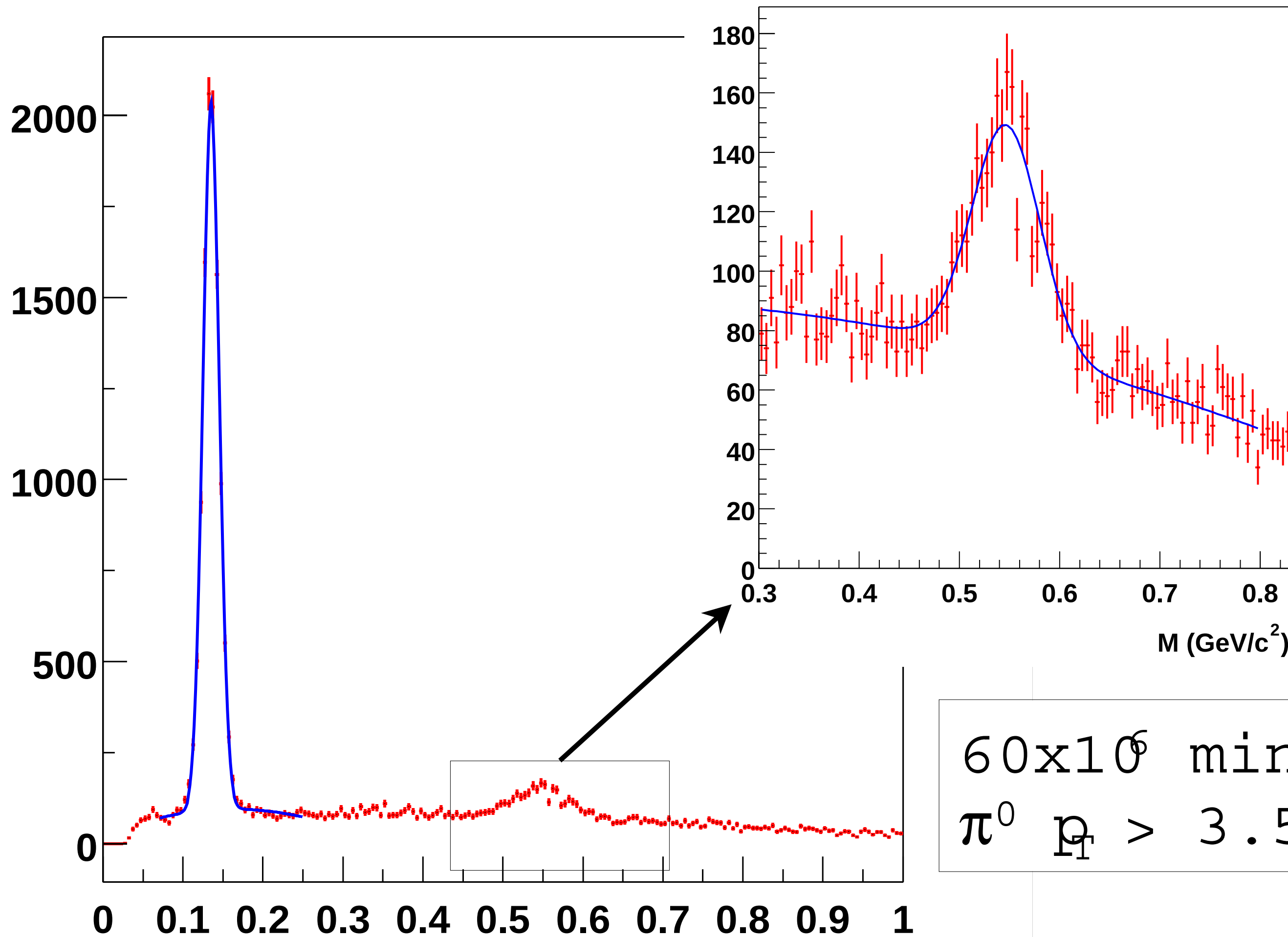


Common design for vacuum chambers and forward (ZDC) Instrumentation to 18 m.



PHENIX Movie(quicktime)

π^0 in p+p at $\sqrt{s}$ = 200 GeV

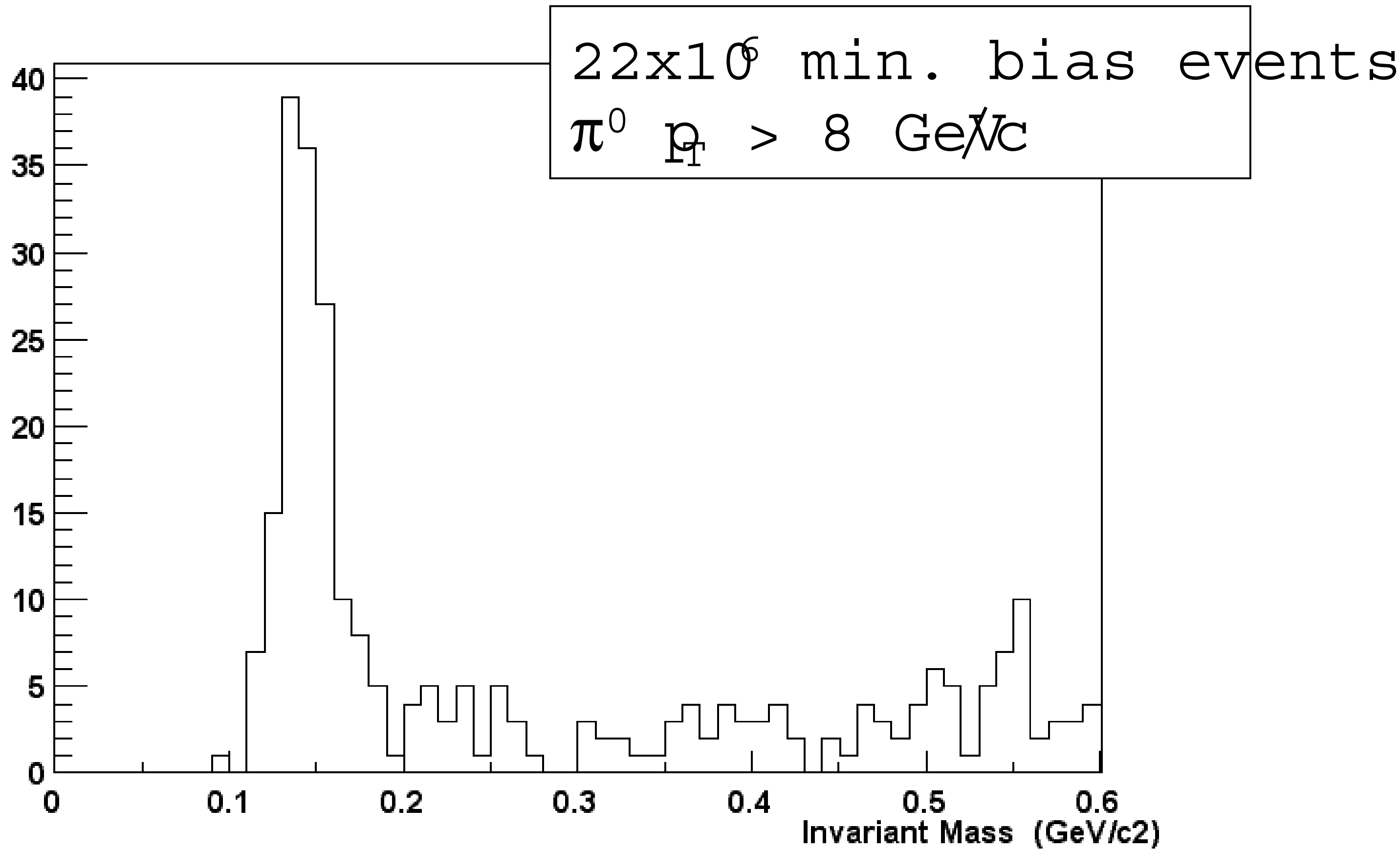


60x10^6 min. bias eve

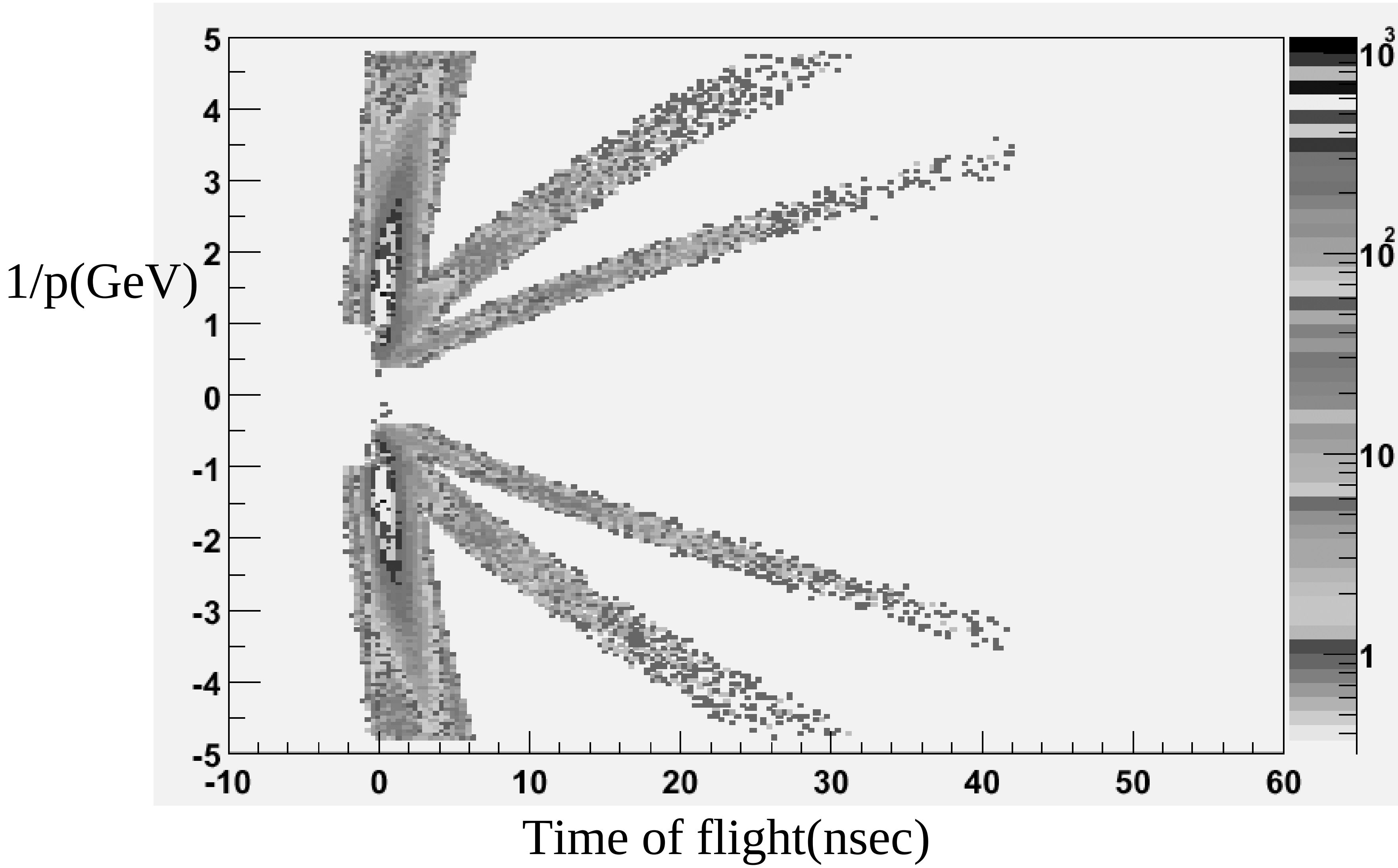
π^0 p_T > 3.5 GeV/c

Jur

high p_T π^0 full energy Au+Au



Particle id w. PHENIX Pb/Sc EMCAL t.o.f.



The Heavy Ion Environment:

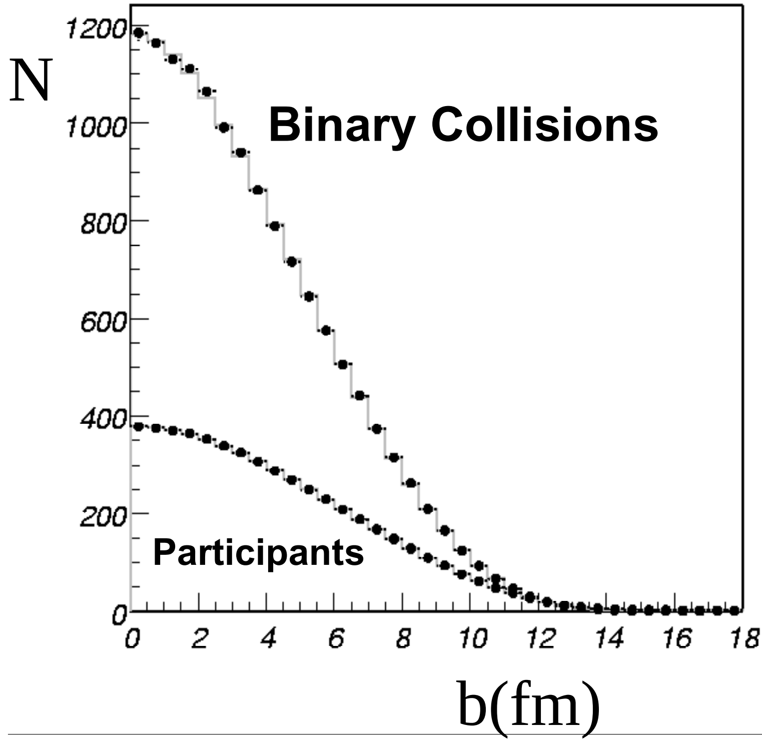
•Intra-beam scattering dominates luminosity lifetime@RHIC

•Luminosity determination easier than p-p:known to ~5%@RHIC
-> ~2% @LHC

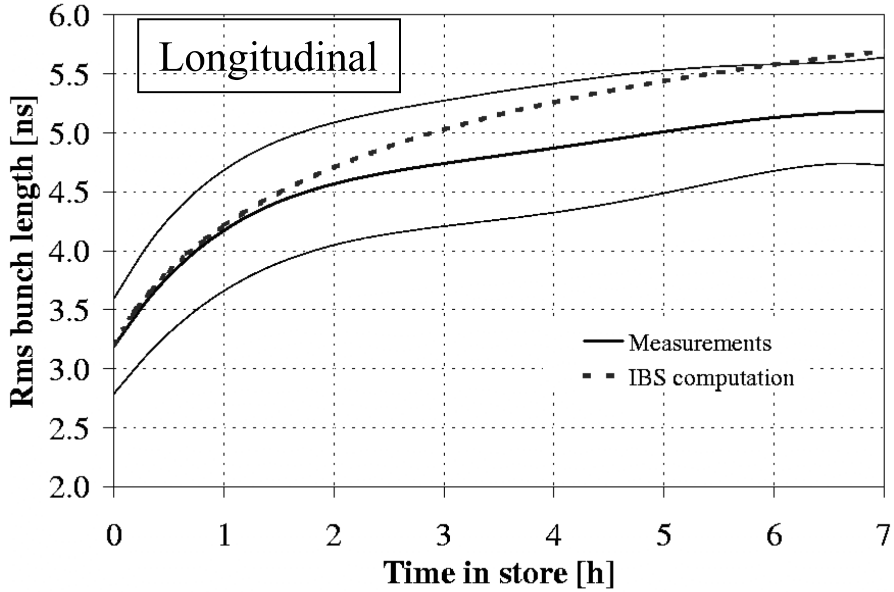
L(b) vs. b known a priori

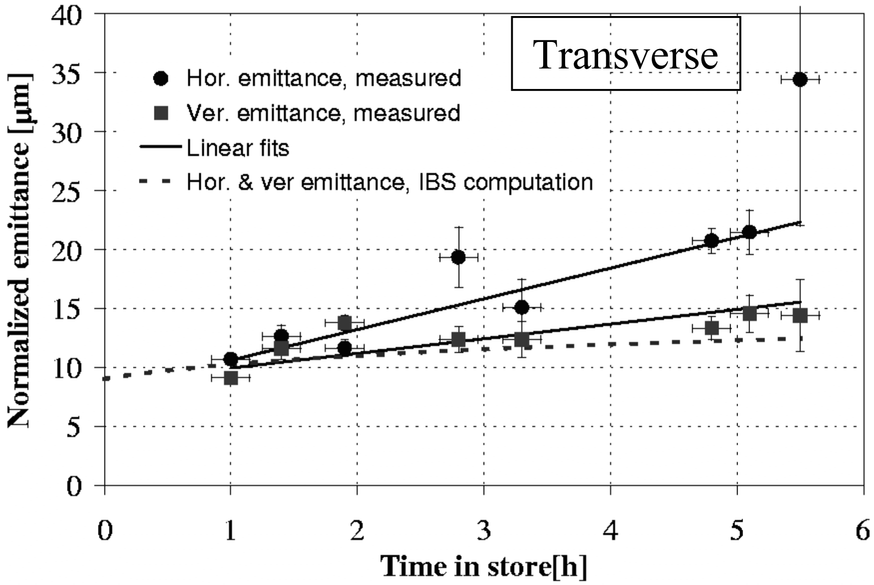
$$\frac{\int_0^b b' db'}{\int_0^\infty b' db'} \Leftrightarrow \% Centrality$$

N_{part},N_{bin} from Glauber model



Intra-Beam Scattering (IBS) in RHIC





Longitudinal emittance growth agrees well with model

Additional source of transverse emittance growth (Beam-beam, dynamic apert.)

IBS determines RHIC Au performance

Eventually will need electron cooling (see below)

RHIC RUN-2 Gold Parameters

–**55 - 56 bunches** per ring (110 bunches per ring tested, intensity limited)

–**7.5×10^8 Au/bunch @ storage energy** (intensity limited during acceleration)

–**1×10^9 Au/bunch achieved @ injection**

–**Longitudinal emittance**: 0.5 eVs/nucleon/bunch (0.3-0.6 Design)

–**Transverse emittance** at storage: **15 π μm** (norm, 95%)

–**Storage energy: 100 GeV/ amu (γ = 107.4)** **10 GeV / amu (γ=10.5)**

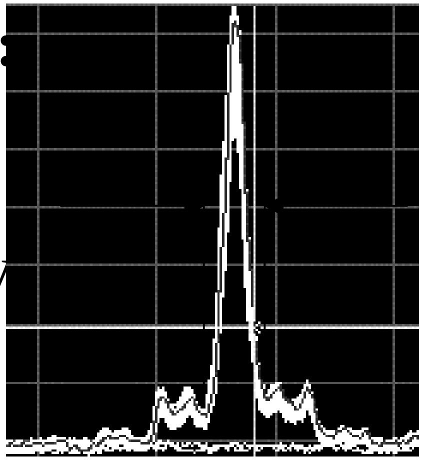
–**Lattice with β^* squeeze during acceleration ramp:**

∀ β^* = 3 m and 10m @ all IP at injection

∀ β^*= 1 m @ 8 and 2 m @ 2, 6 and 10 o'clock at storage

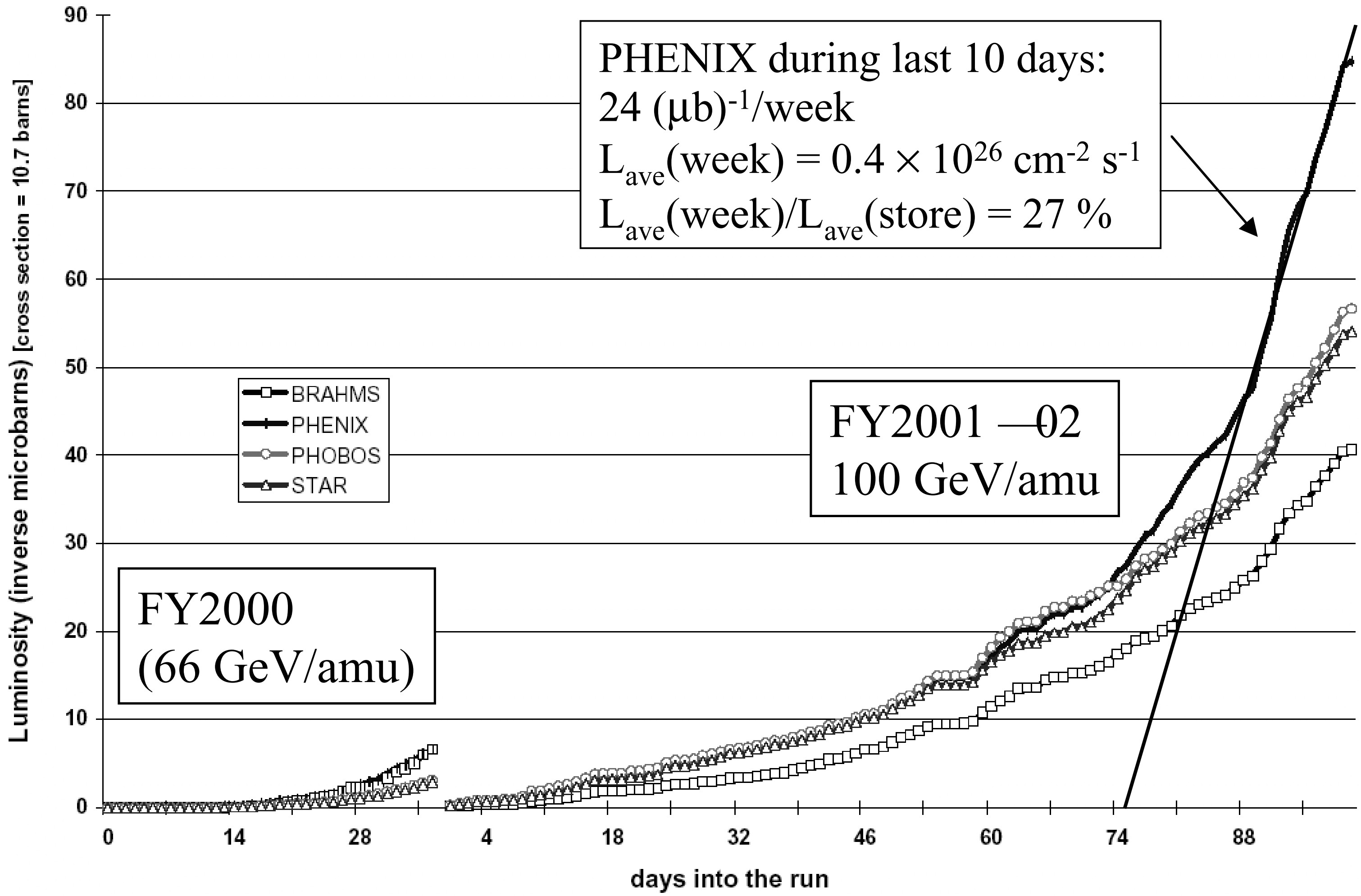
–**Peak Luminosity: 5×10^{26} cm^{-2} s^{-1}** ($2.5 \times$ design av

–**Bunch length: 5ns** with 200 MHz storage rf system (diamond length: σ = 25 cm)

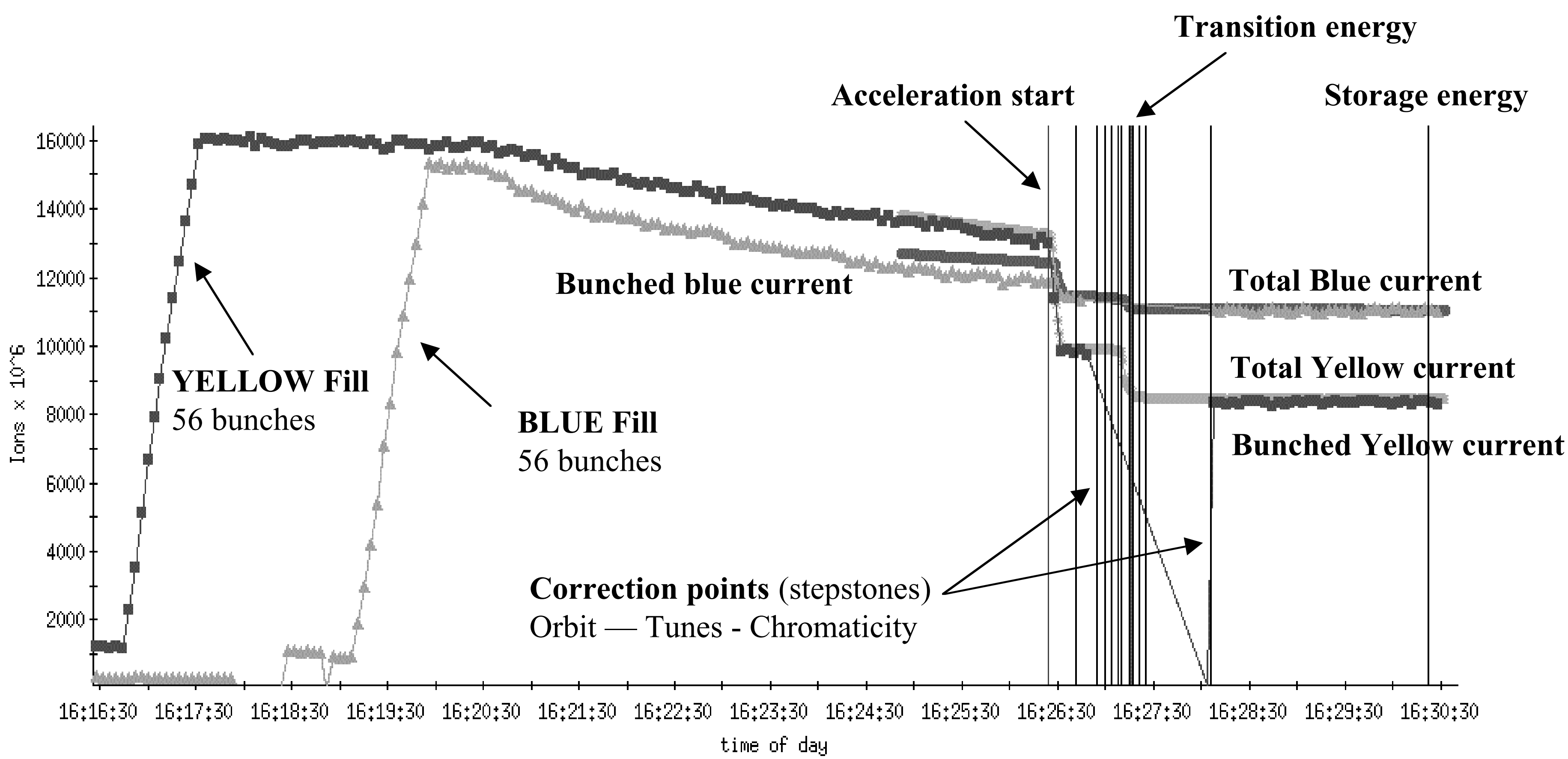


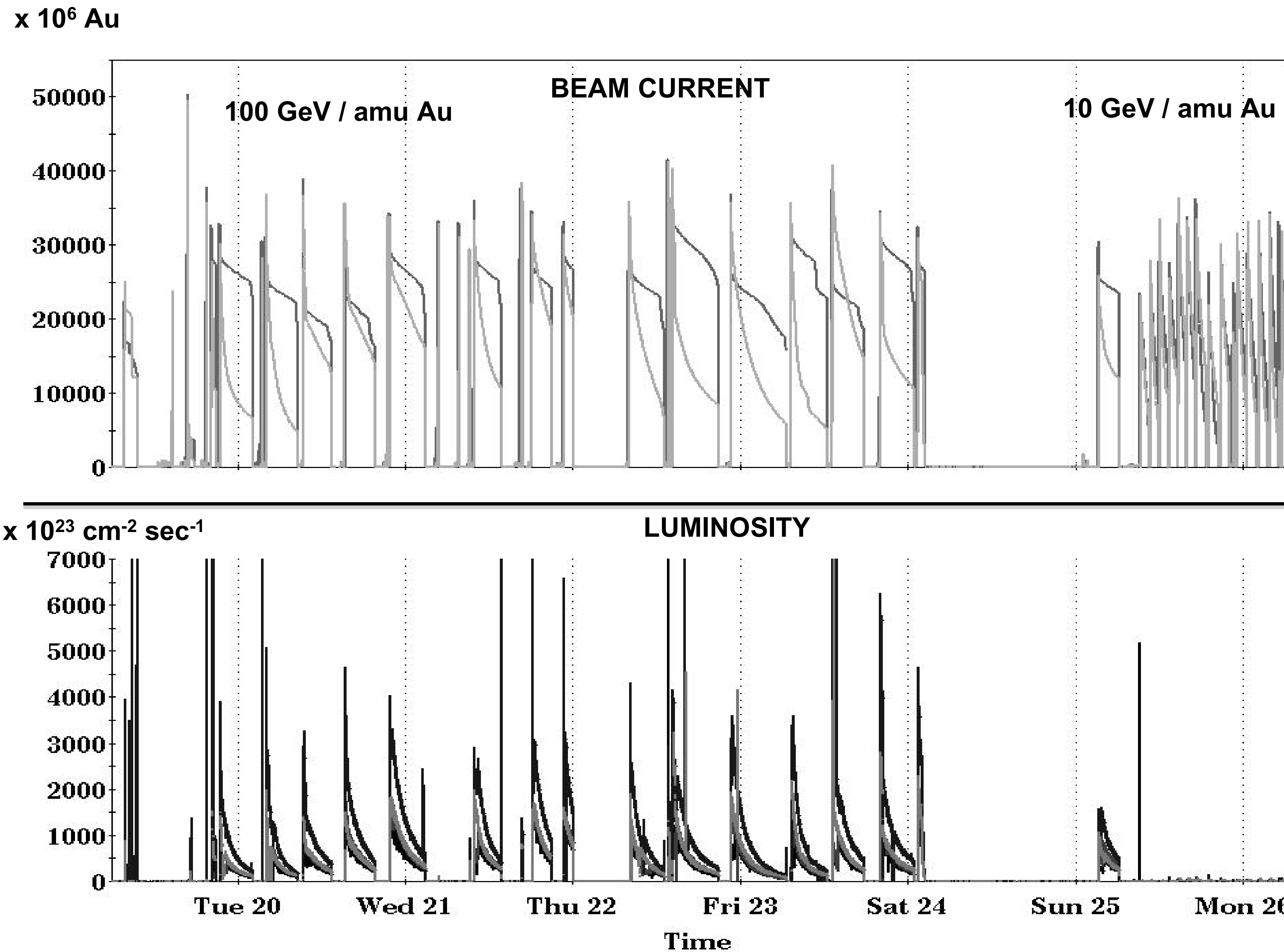
RHIC bunch profile

Integrated Au-Au luminosity



Example of RHIC ramp with 56 bunches



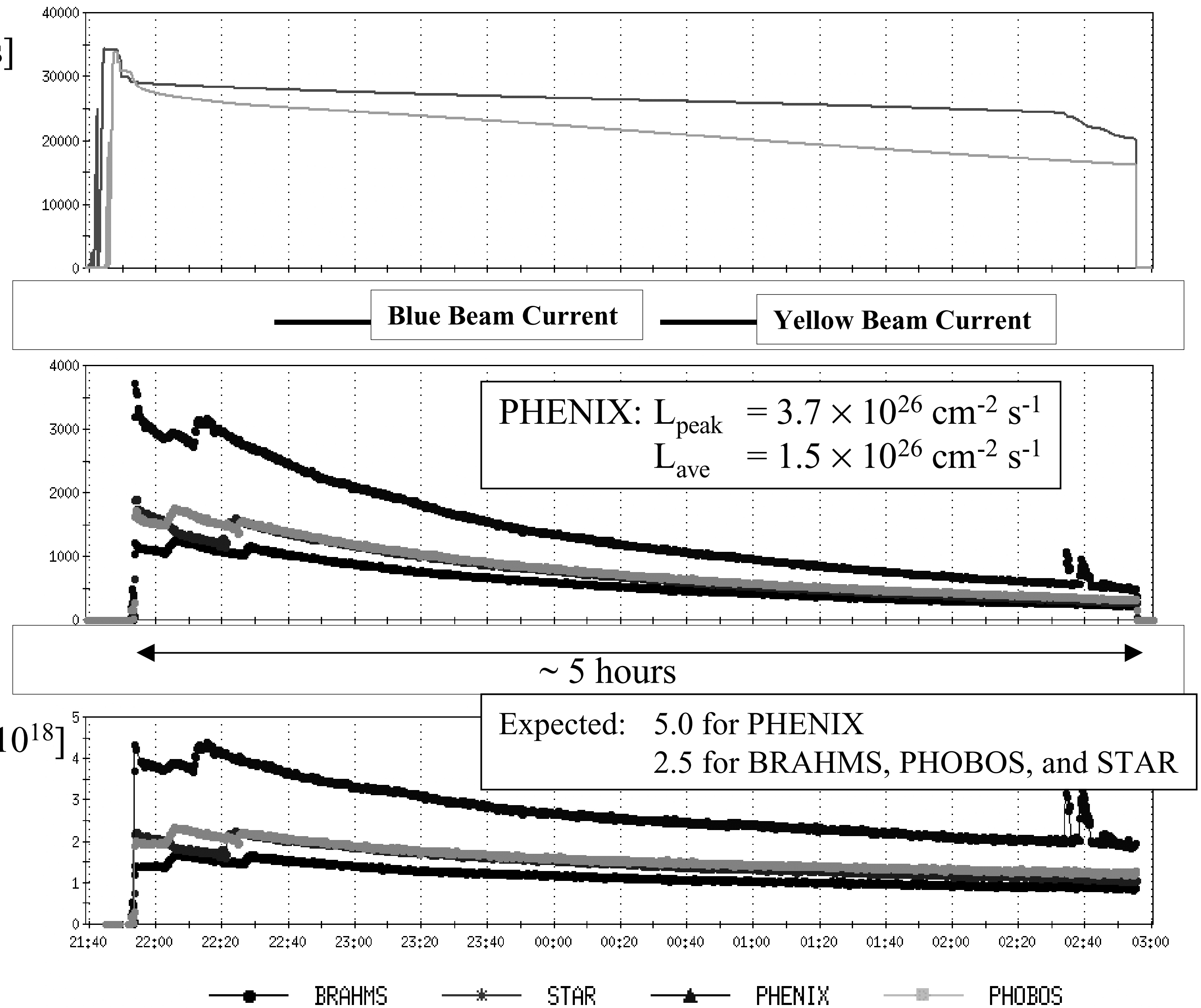

x 10^6 Au
BEAM CURRENT
100 GeV / amu Au
10 GeV / amu Au
50000
40000
30000
20000
10000
0
x 10^23 cm^-2 sec^-1
LUMINOSITY
7000
6000
5000
4000
3000
2000
1000
0
Tue 20
Wed 21
Thu 22
Fri 23
Sat 24
Sun 25
Mon 26
Time

"Typical Store" # 1812

Beam currents [x10^6 ions]

Collision rate [Hz]

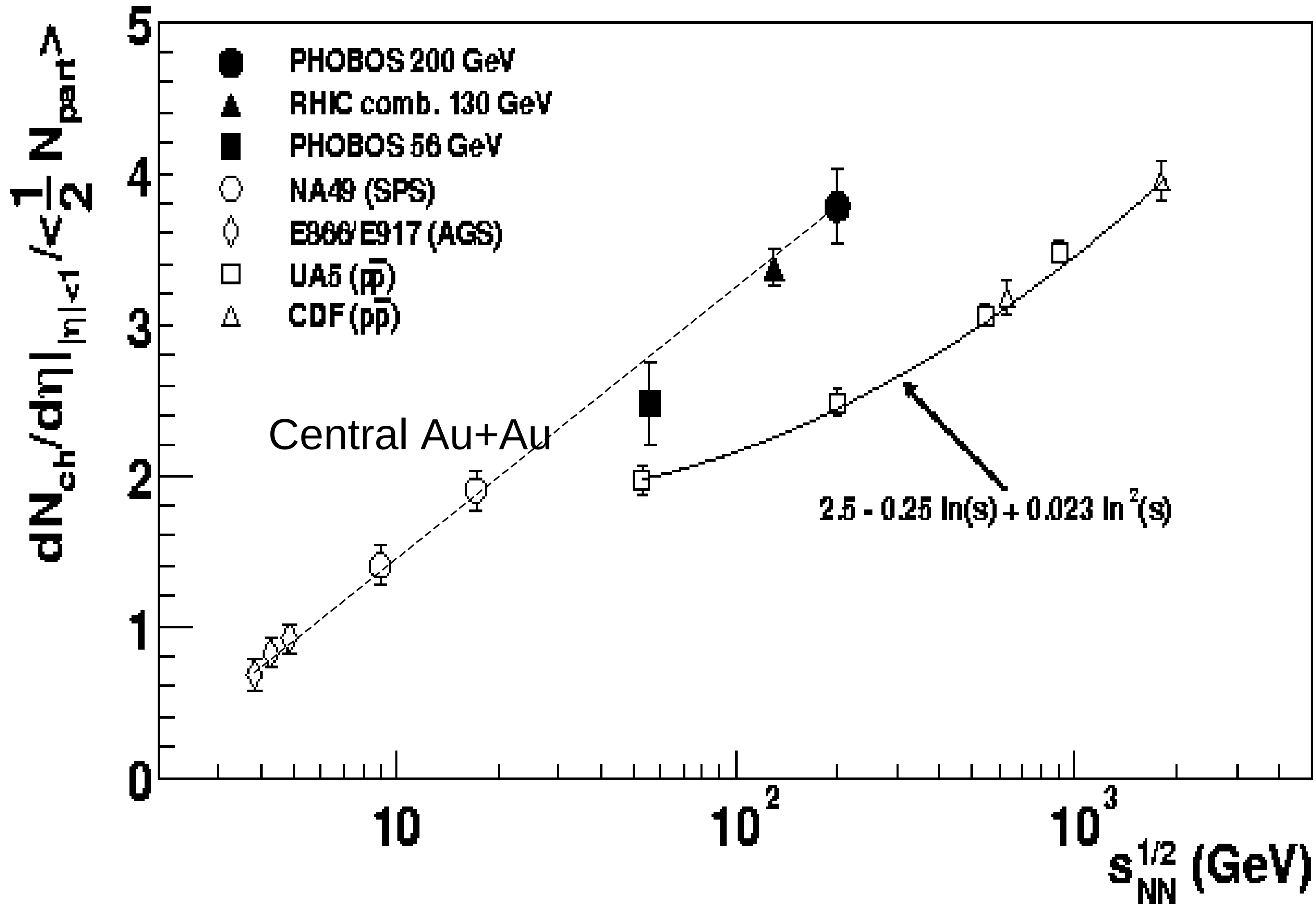
Specific luminosity [Hz/10^{18}]



June 28, 2002

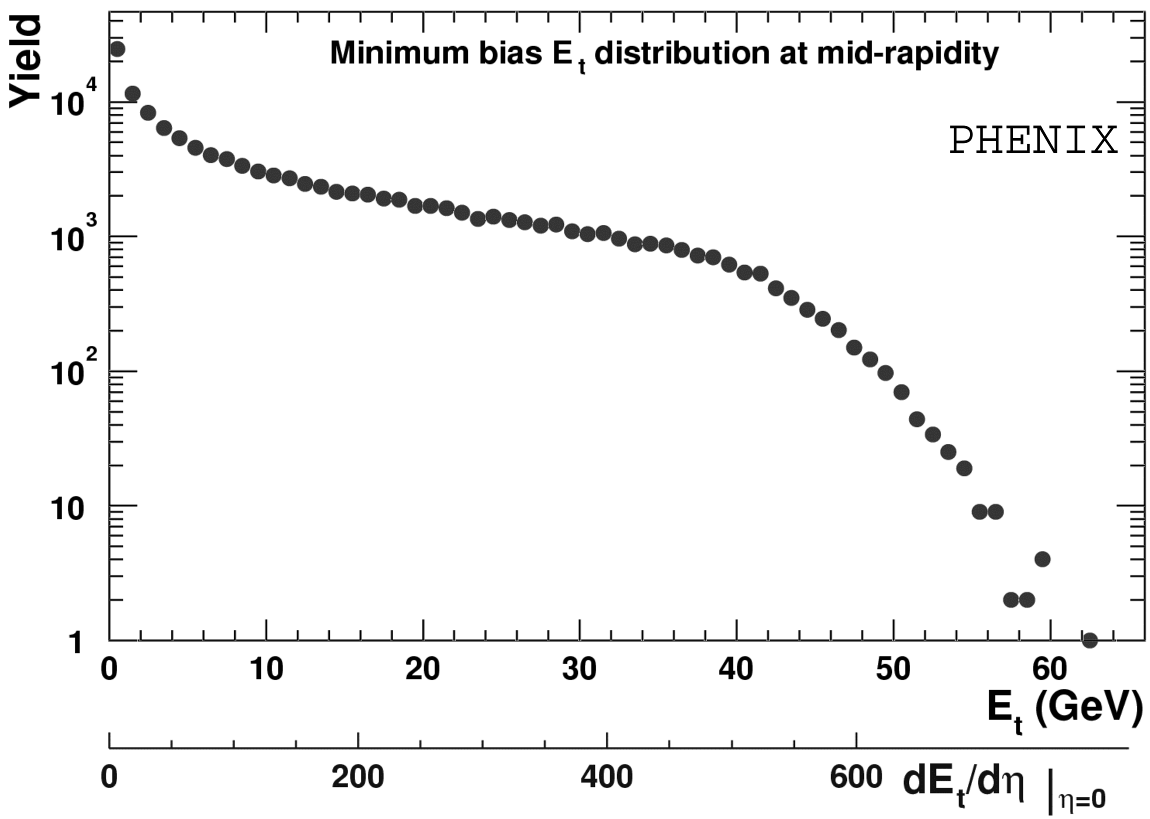
Highlights from Run 1(&2): Multiplicity distributions (PHOBOS et al.)

Extrapolation to LHC ~1/4 of “design” dN/dη



PHENIX

Energy density



$$\varepsilon = \frac{1}{\pi R^2 \tau} \frac{dE_T}{dy}$$

for top 2% of distribution

$dE_T/d\eta = 578^{+26}_{-39}$ GeV

ε = 4.6 GeV/fm^3 (τ = 1 fm/c)

cf. 405 GeV, 3.2 GeV/fm^3

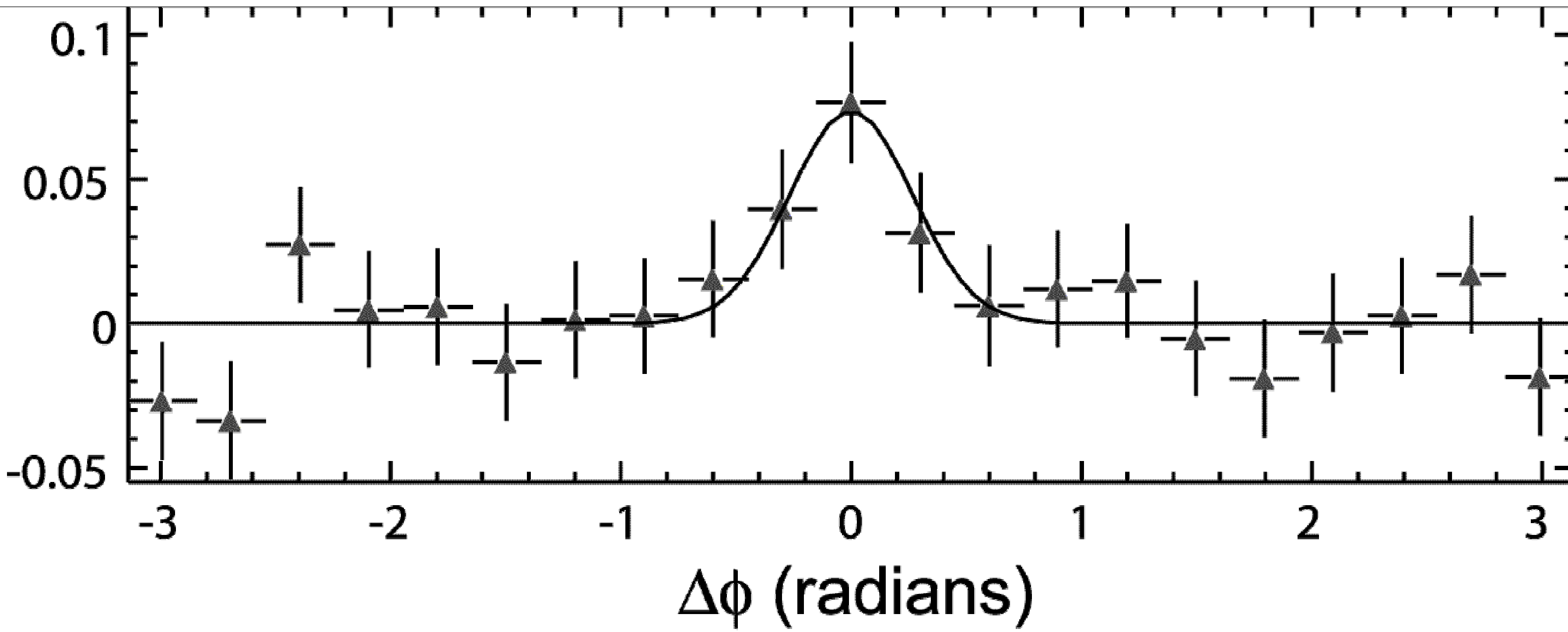
NA49 PRL 75, 3814, (1995)

ε = 15 GeV/fm^3 (τ = 0.3 fm/c)

STAR

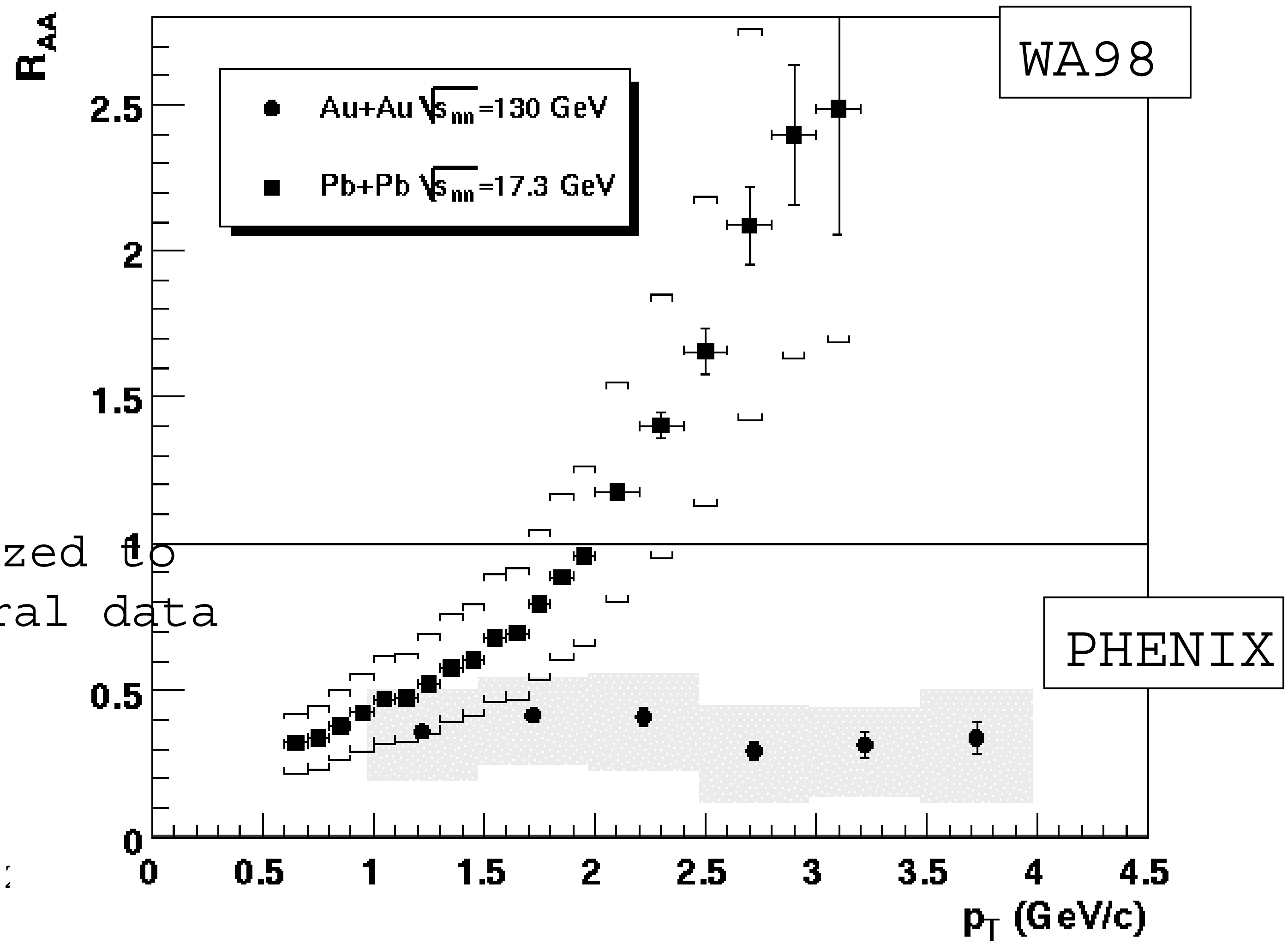
Two Particle Azimuthal Correlations at High-p_T

Strong and direct evidence for hard scattering and parton fragmentation (jets) at RHIC



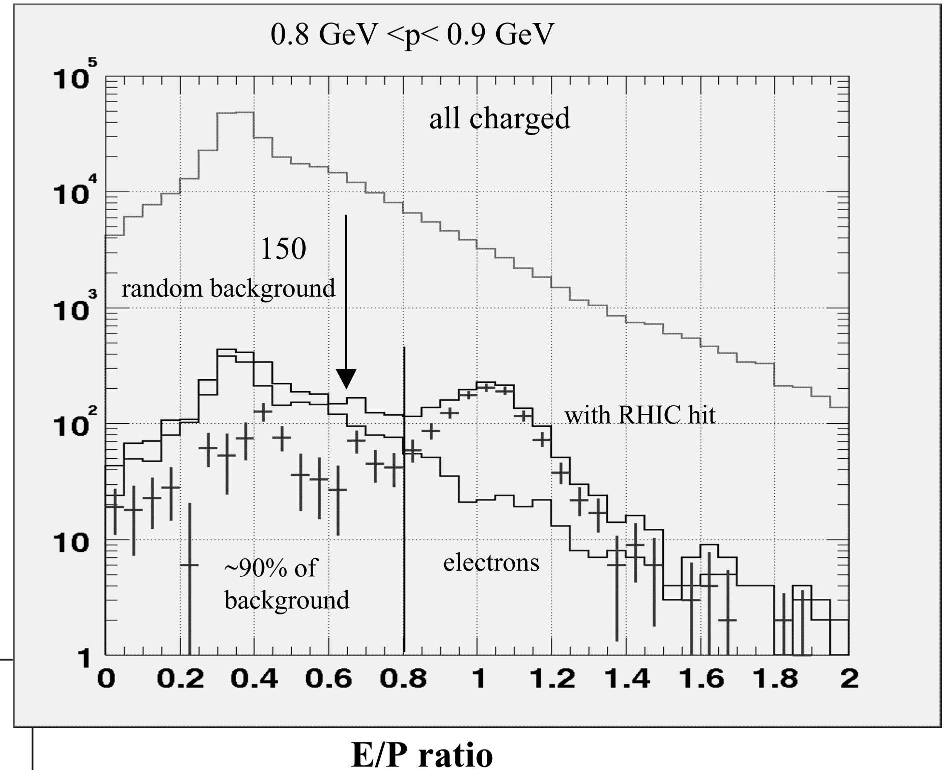
yield per nucleon-nucleon collision in cent

yield in p+p

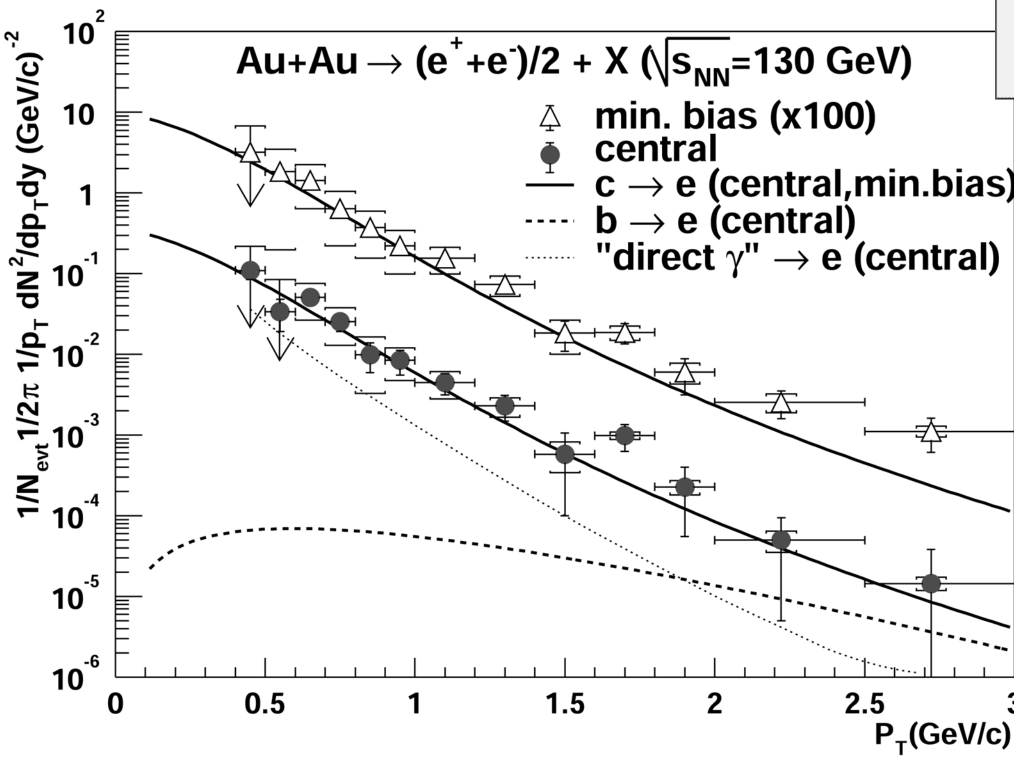


normalized to
peripheral data

Electron id using
Momentum and Ecal
+ RICH



PHENIX



data are well described using PY
cross-section multiplied by numb
binary collisions obtained from
nuclear thickness function, T_{AB}
(i.e., a Glauber model).

$$\sigma_{c\bar{c}}(0-10\%) = 380 \pm 60 \pm 200 \mu b$$

sion $$\sigma_{c\bar{c}}(0-92\%) = 420 \pm 33 \pm 250 \mu b$$

RHIC UPC Physics results from Run I.

published

VOLUME , NUMBER PHYSICAL REVIEW LETTERS

Measurement of Mutual Coulomb Dissociation in $\sqrt{s_{NN}}$ = 130 GeV Au + Au Collisions

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Michael Murray,[5] and Sebastian White[6]
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(Received 28 September 2001; revised manuscript received 19 November 2001; published)

submitted

Coherent ρ^0 Production in Ultra-Peripheral Heavy Ion Collisions

C. Adler[11], Z. Ahammed[23], C. Allgower[12], J. Amonett[14], B.D. Anderson[14], M. Anderson[5], G.S. Averichev[9],
J. Balewski[12], O. Barannikova[9,23], L.S. Barnby[14], J. Baudot[13], S. Bekele[20], V.V. Belaga[9], R. Bellwied[31], J. Berger[11],
H. Bichsel[30], L.C. Bland[2], C.O. Blyth[3], B.E. Bonner[24], A. Boucham[26], A. Brandin[18], A. Bravar[2], R.V. Cadman[1],
H. Caines[20], M. Calderón de la Barca Sánchez[2], A. Cardenas[23], J. Carroll[15], J. Castillo[26], M. Castro[31],
D. Cebra[5], P. Chaloupka[20], S. Chattopadhyay[31], Y. Chen[6], S.P. Chernenko[9], M. Cherney[8], A. Chikanian[33],
B. Choi[28], W. Christie[2], J.P. Coffin[13], T.M. Cormier[31], J.G. Cramer[30], H.J. Crawford[4], W.S. Deng[2],
A.A. Derevschikov[22], L. Didenko[2], T. Dietel[11], J.E. Draper[5], V.B. Dunin[9], J.C. Dunlop[33], V. Eckardt[16],

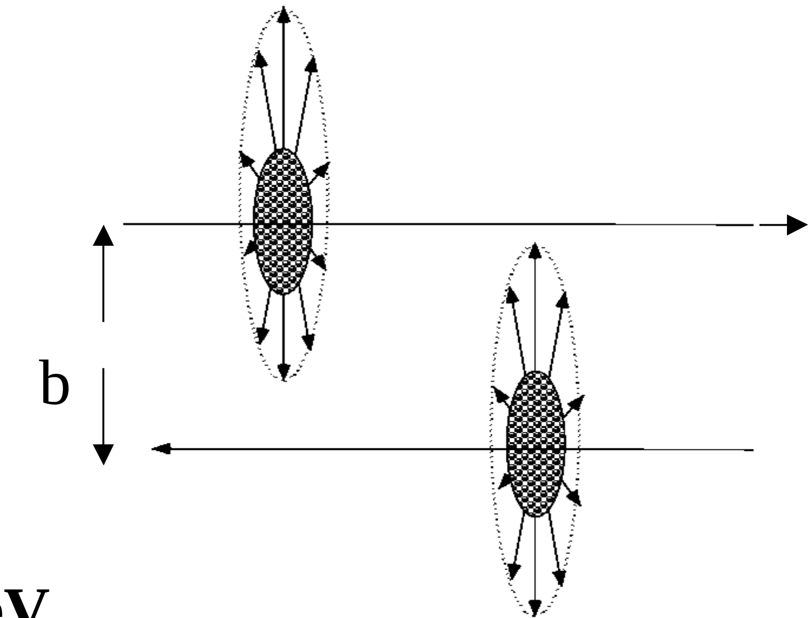
γ–γ

AuAu-> AuAu+e^+e^- 33 kbarns

-> AuAu+2(e^+e^-) 680 barns

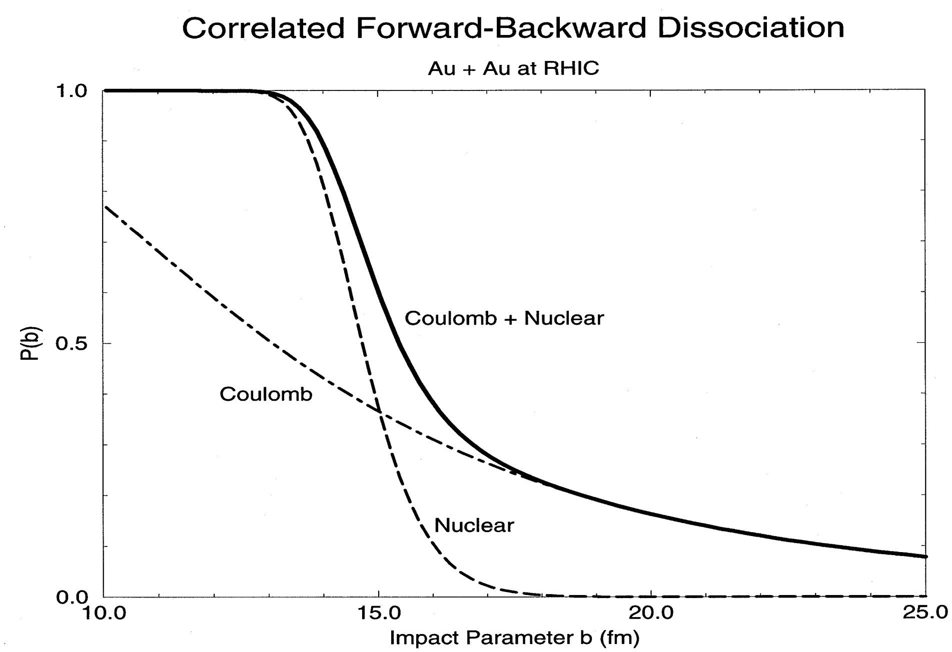
-> AuAu+3(e^+e^-) 50 barns

-> $AuAu^-$+e^+ 95 barns



$L(\gamma\text{-}N)=10^{29}\ cm^{-2}s^{-1}\ \ 2<E_\gamma<300GeV$

(At nominal RHIC running)



γ–N

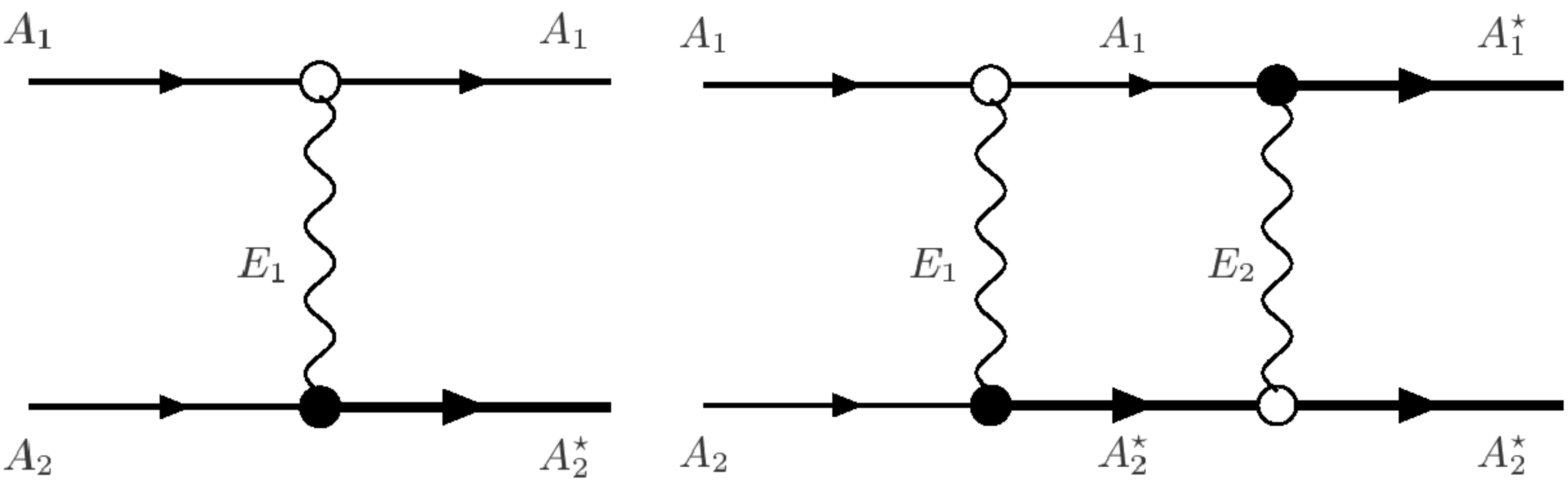
AuAu->Au+Au* 92 barns

→ X+neutrons

AuAu->Au*+Au* 3.6 barns

→ X+neutrons

→ Y+neutrons



Weizsäcker-Williams (WW) method

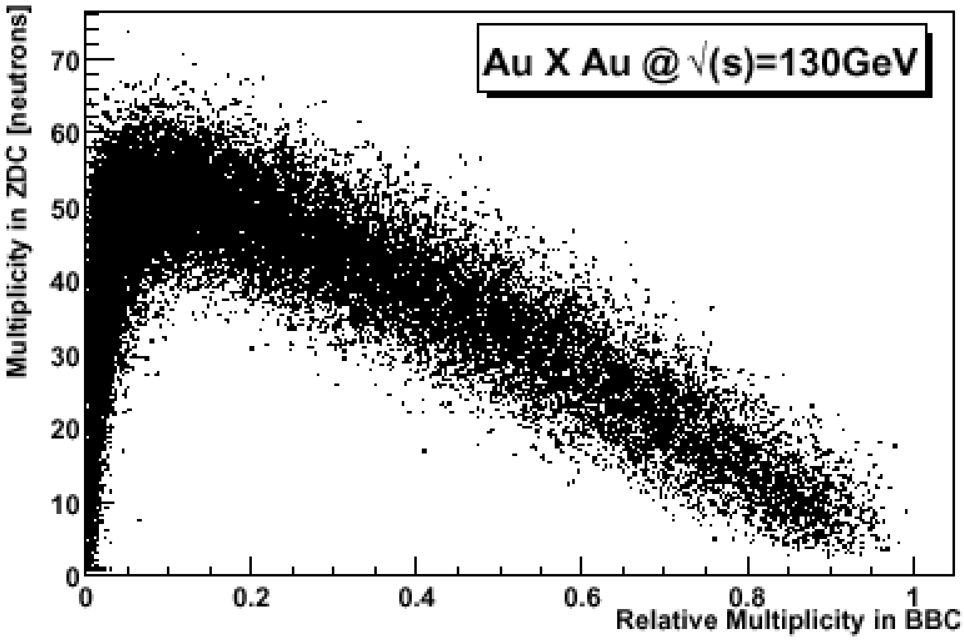
[1] A.Baltz, M.J.Rhoades-Brown, J.Weneser, Phys. Rev. E 54 (1996) 4233.

[2] A.J. Baltz, S.N.White, RHIC/DET Note 20, BNL-67127 (1996)

[3] S.N.White, Nucl. Instrum. Meth. A409, 618 (1998).

[4] A.J.Baltz, C.Chasman and S.N.White, Nucl. Instrum. Meth. A417, 1 (1998) nucl-ex/9801002.

[5] I.A. Pshenichnov , J.P. Bondorf , I.N. Mishustin , A. Ventura , and S. Masetti, nucl-th/0101035



<u>Efficiencies(hadronic):</u>

ε_{bbc}= (92 ± 2)% (HIJING)*

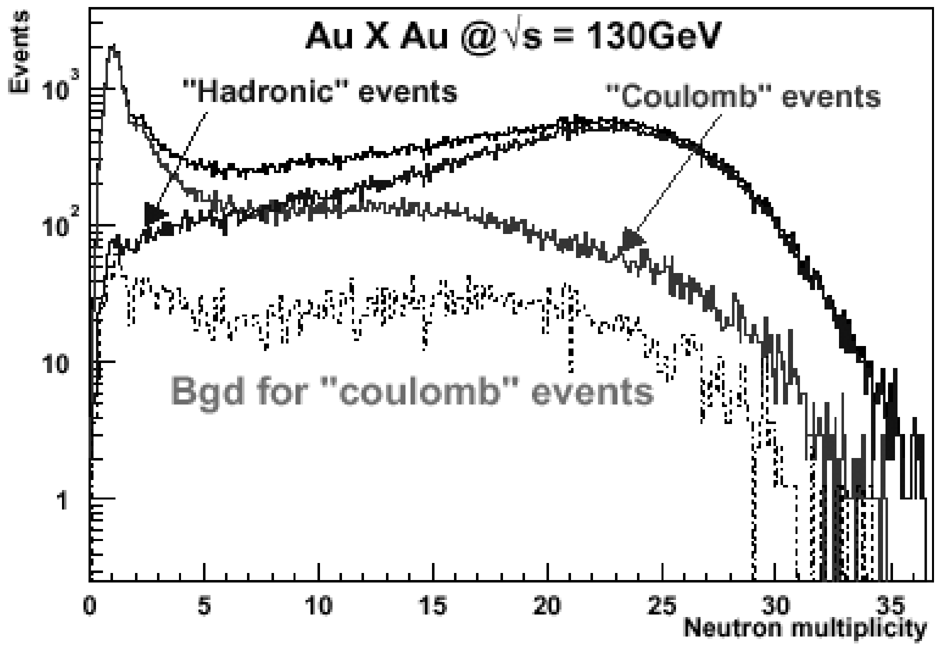
ε_{bbc} = (93 ± 2)% (JAM)

ε_{zdc} = (98 ± 2)% (conservative),

ε_{zdc} = (99.5 - 1.5)% (realistic)

*(in PHENIX Multiplicity PRL)

BBC ineff-> Coulomb bkg

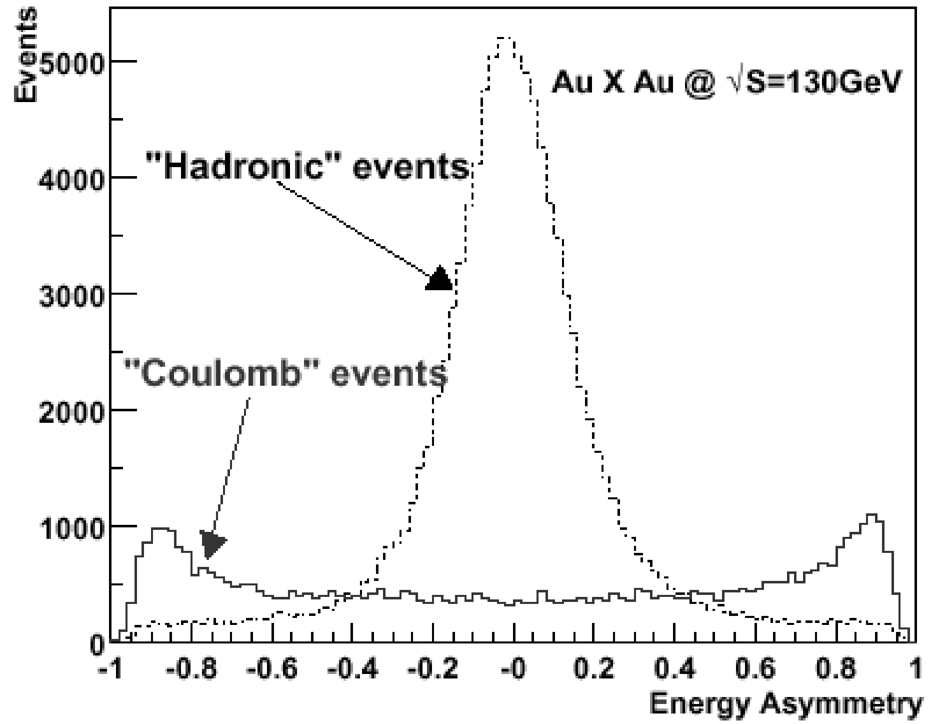


<u>Other corrections</u>

- Coulomb-> BBC hits
- Coulomb->ZDC miss
- Diffraction Dissociation

(all negligible)

Technology for tagging Photonuclear processes (and Pomeron mediated..)

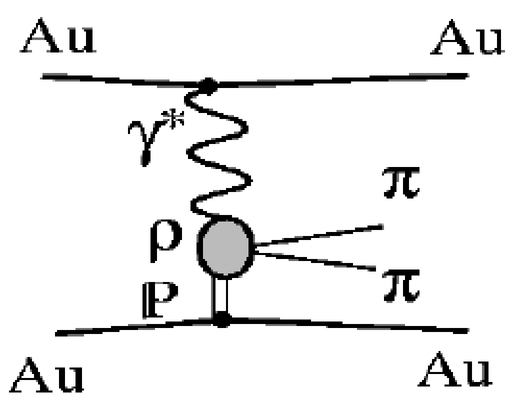


E asymmetry=$(E_{ZDCl}-E_{ZDCr})/(E+E)$

Exclusive Vector Meson Production $\gamma A \rightarrow VA$

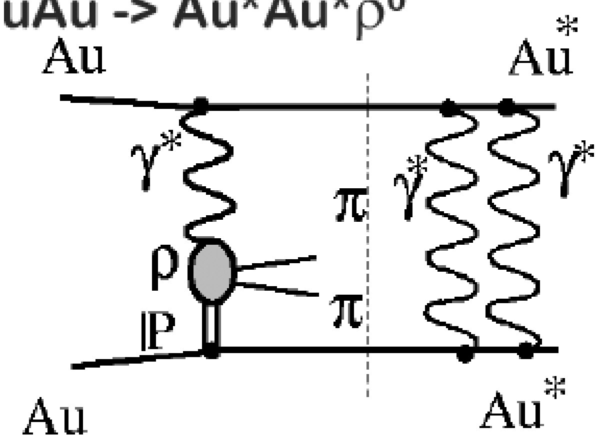
Exclusive ρ production

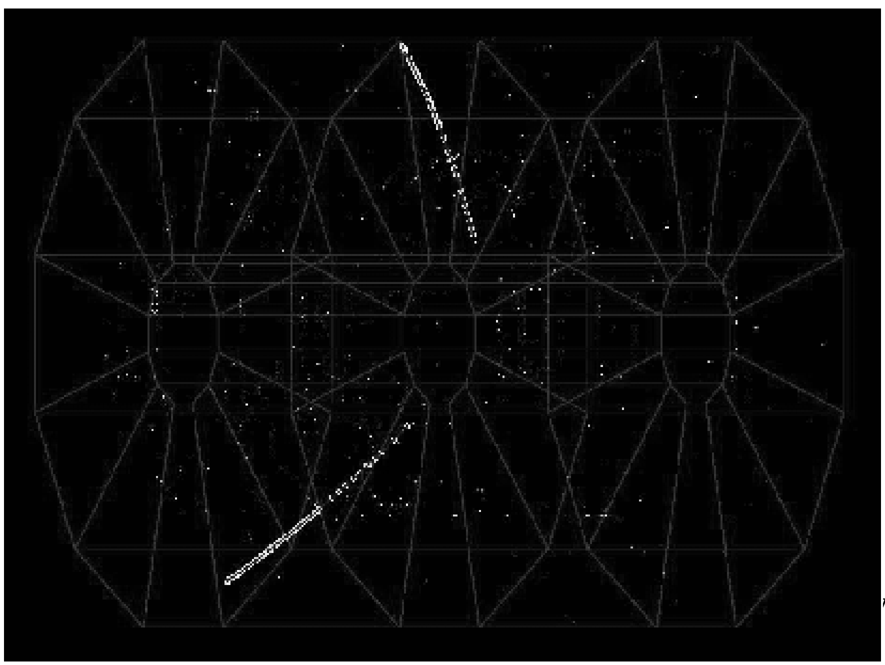
AuAu -> AuAuρ^0

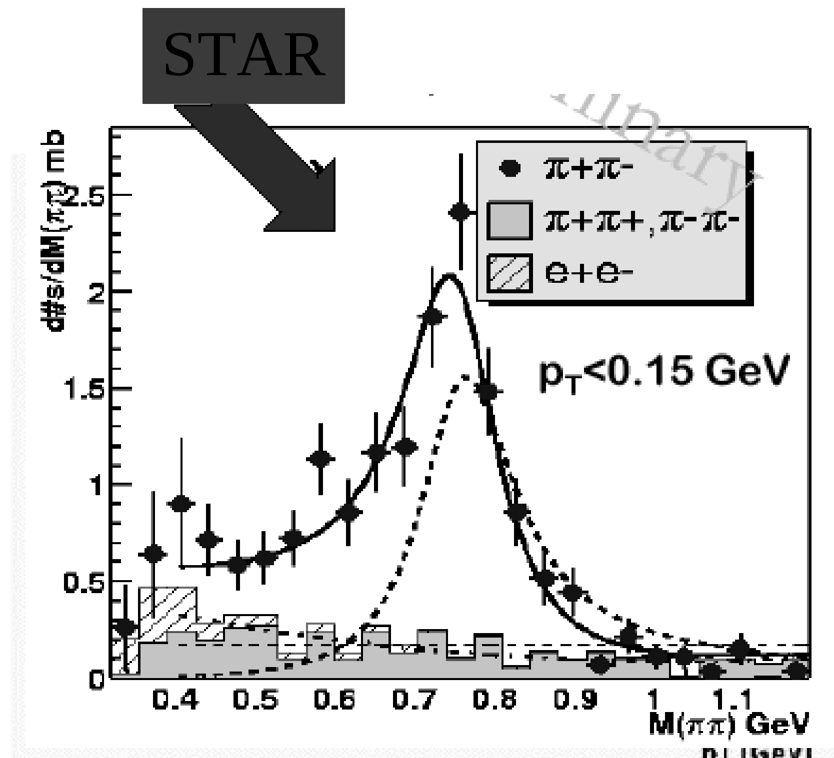


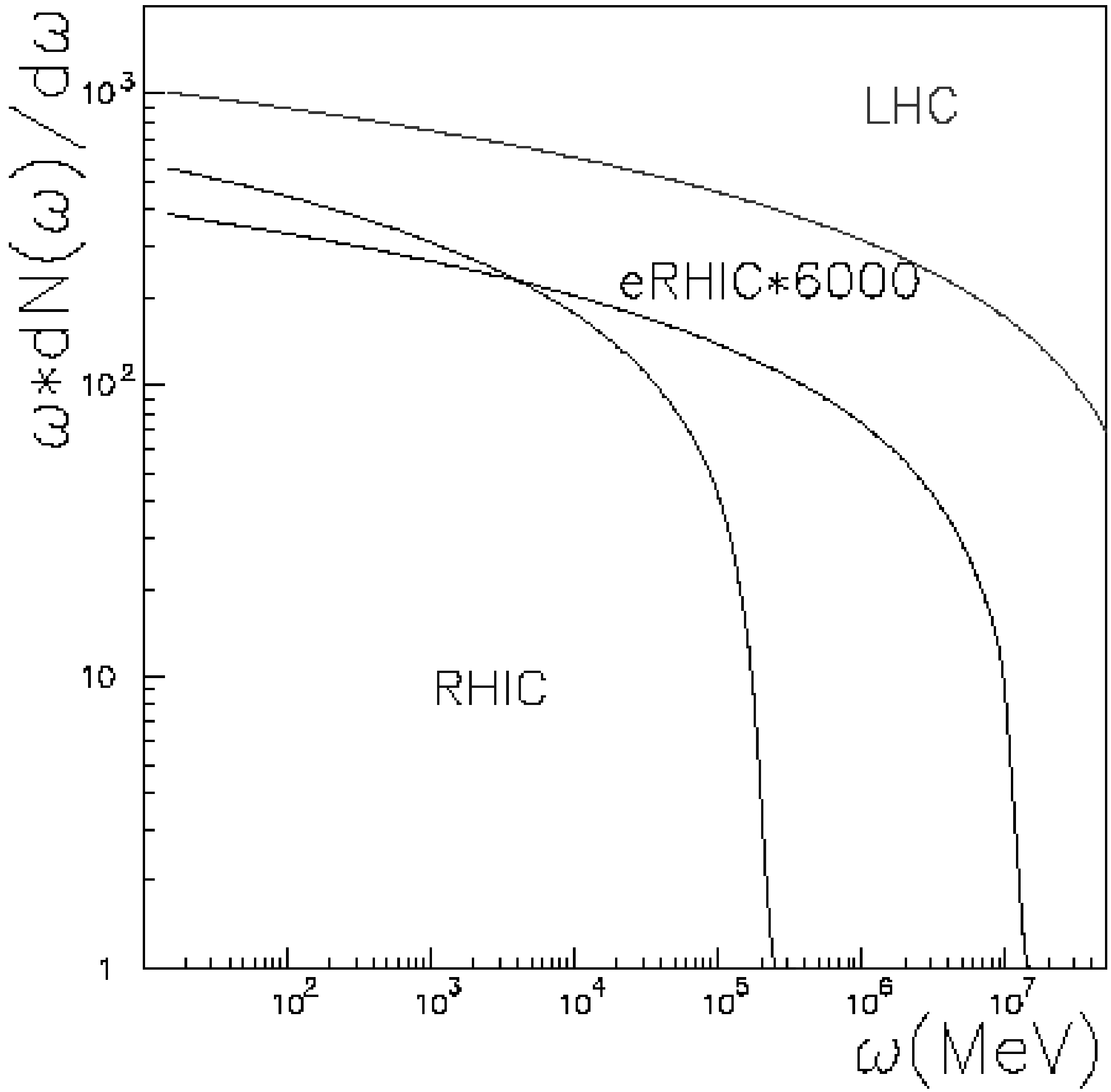
… with nuclear excitation

AuAu -> Au*Au*ρ^0









ω*dN(ω)/dω
10³
10²
10
1
LHC
eRHIC*6000
RHIC
10²
10³
10⁴
10⁵
10⁶
10⁷
ω(MeV)

Q:***Why not use p-p since higher Luminosity*Running time?***
A: ***Z^2(or Z^4) beats $A^{0.3}$ *$B^{0.3}$***

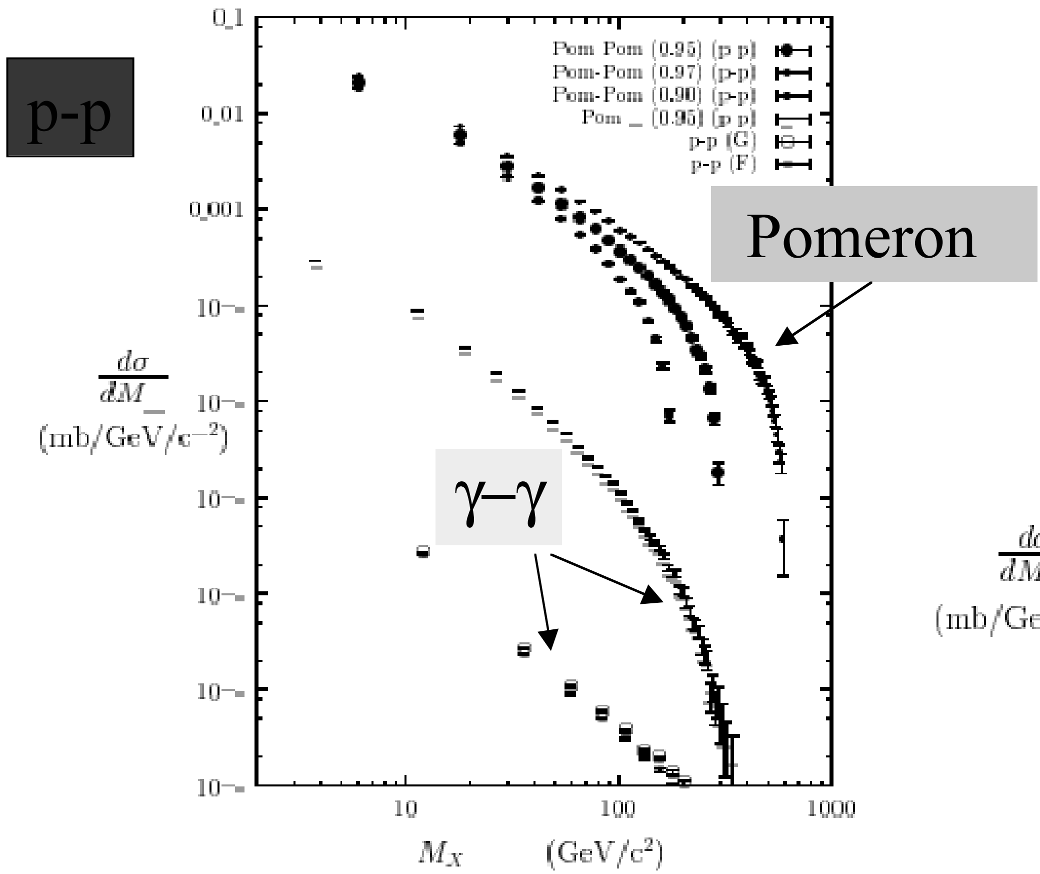


Fig. 4. We compare the cross section for the production of a hadronic cluster of invariant mass M_X via photon-photon interaction in proton-proton collisions using two different methods (F) and (G) to calculate the photon flux, described in the Appendix with the corresponding cross section for the diffractive reactions. The central diffraction cross sections (pomeron-pomeron collisions) are given for three different kinematical cuts $M_{cd} >$ 2 GeV/c^2, c = 0.90, 0.95 and 0.97. The single diffraction photon-pomeron cross section is given for $M_{\gamma\mathbb{P}} >$ 2 GeV/c^2 and c = 0.95

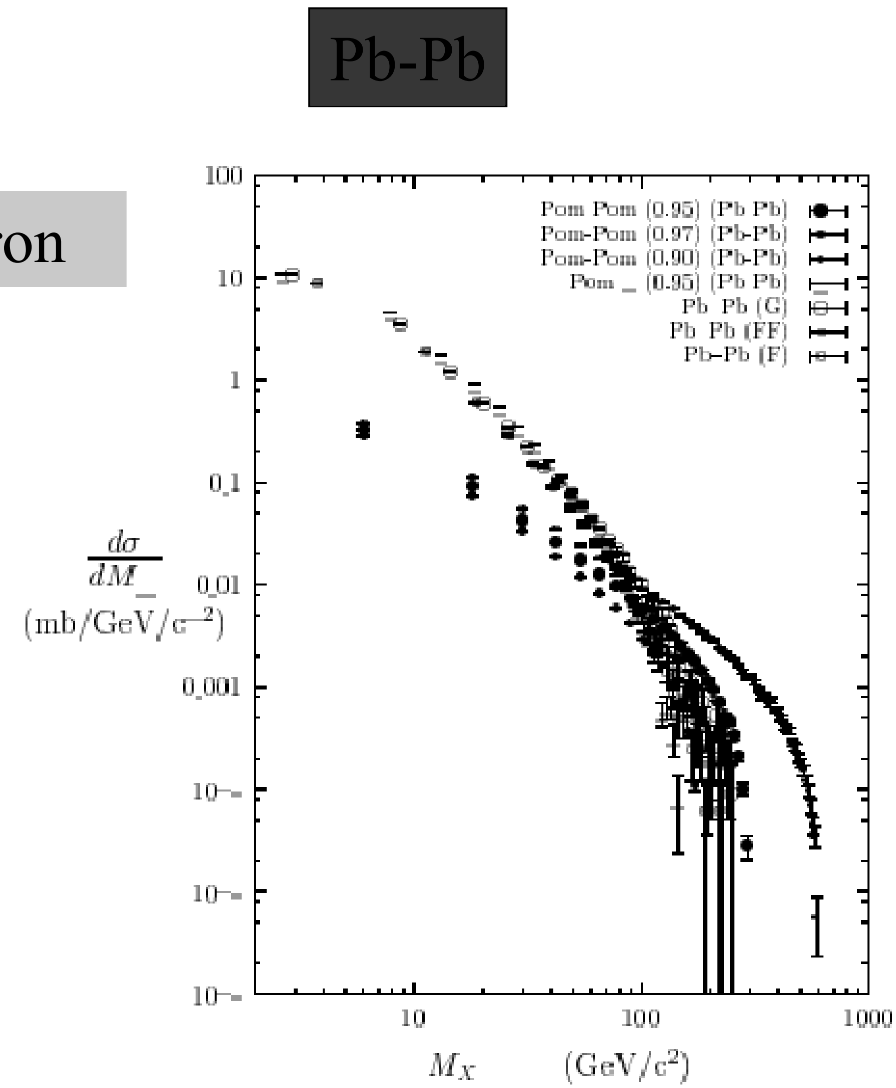


Fig. 9. As Fig. 4 but for heavy ion reactions Pb-Pb

Luminosity Measurement

1) Using "ZDC cross section"

TABLE I. Cross sections calculated and derived from the data. The errors quoted on measurements include the uncertainty of the BBC cross section [8]

Cross Section*	Calculated Value(1)	Calculated Value(2)	Measured
σ_{tot}	10.83 ± 0.5Barns	$11.19 \pm$	N.A.
σ_{geom}	$7.09 \pm xx$	$7.29 \pm$ xx	N.A.
$\frac{\sigma_{geom}}{\sigma_{tot}}$	0.67	0.65	0.661 $\pm$0.014
electromagnetic			
$\frac{\sigma(1n,Xn)}{\sigma_{tot}}$	0.125	xx	$0.117 \pm 0.003 \pm 0.002$
$\frac{\sigma(1n,1n)}{\sigma_{1n,Xn}}$	0.329	xx	$0.345 \pm 0.01 \pm 0.006$
$\frac{\sigma(2n,Xn)}{\sigma_{1n,Xn}}$	xx	0.327	$0.345 \pm 0.011 \pm 0.01$

*Definitions

$\sigma_{tot} = \sigma_{(\text{Mutual Coulomb Dissociation})} + \sigma_{(geom)} == \sigma_{(hadronic)}$

2)Machine based

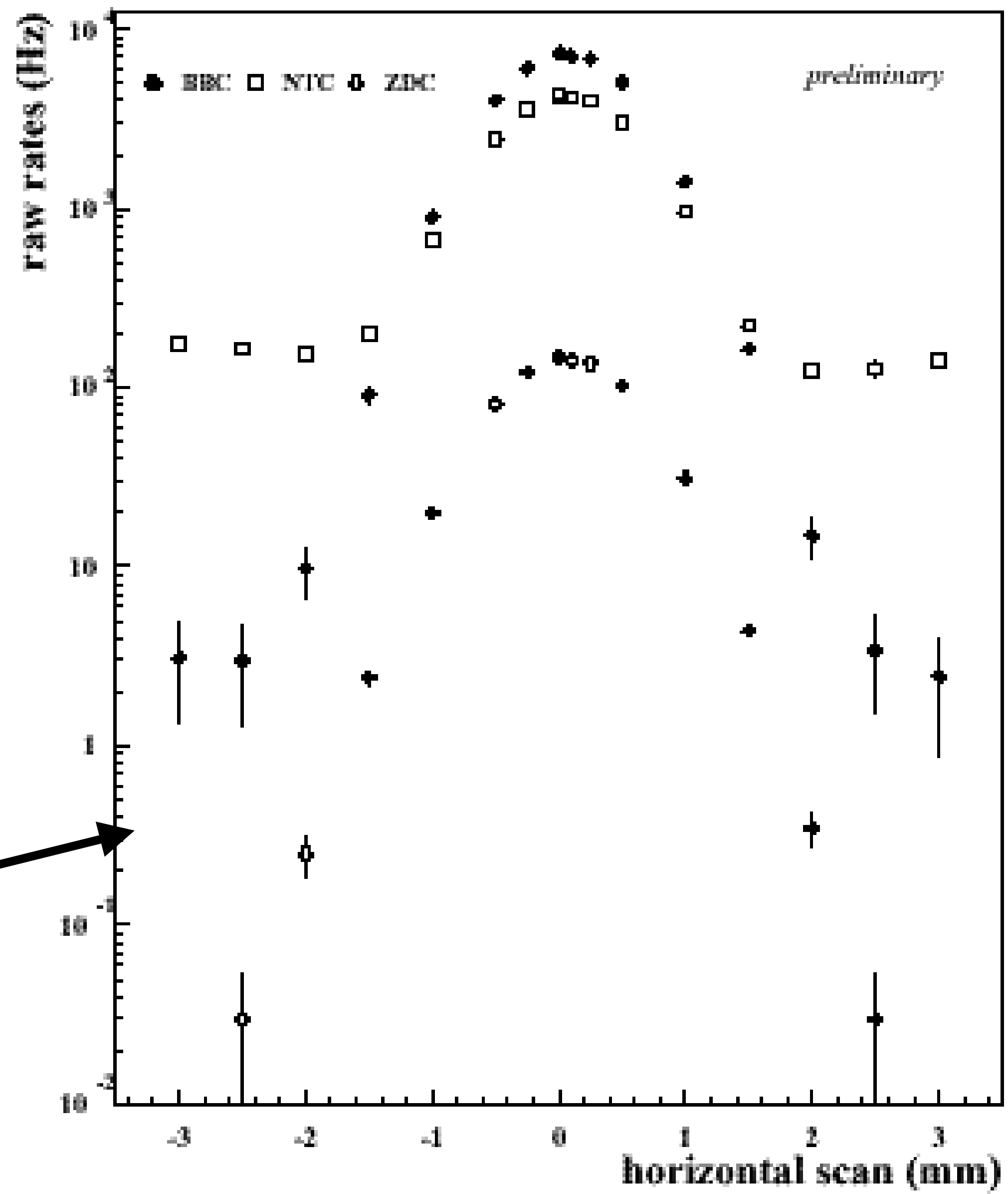
$$L = \frac{3 f_{rev} \gamma}{2} \frac{N_b N^2}{\varepsilon \beta^*}$$

$$N_b = 56\,; N = 1 \times 10^9;$$

$$\varepsilon = 15 \text{ to } 40\pi m\text{m};$$

$$\beta^* = 1 - 10\text{m}$$

Van derMeer scans to measure εβ*
(at PHENIX)



RUN2003 Goals (~ 3-4 weeks into run)

- Prepare for modes with:
  Energy/beam: 100 GeV/nucl., diamond length: σ = 20 cm, L_{ave}(week)/L_{ave}(store) = 40 %

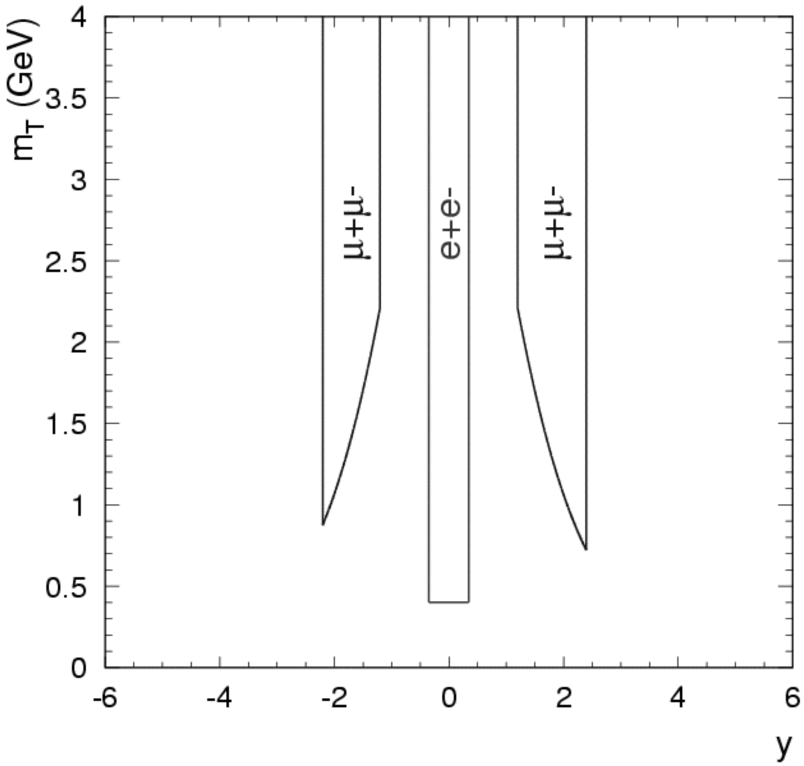
Mode	# bunches	Ions/bunch [$\times 10^9$]	β^* [m]	Emittance [$\pi\mu$m]	L_{peak} [$cm^{-2}s^{-1}$]	L_{ave}(store) [$cm^{-2}s^{-1}$]	L_{ave} (week) [$week^{-1}$]
Au-Au	56	1	1	15-40	14×10^{26}	3×10^{26}	70 (μb)$^{-1}$
d-Au	56	100(d), 1(Au)	2	20	5×10^{28}	2×10^{28}	5 (nb)$^{-1}$
Si-Si	56	7	1	20	5×10^{28}	2×10^{28}	5 (nb)$^{-1}$

Acceptance, Cross Sections and Resolution

central arms: $J/\psi \rightarrow e^+e^-$

p_t > 200 MeV/c
$\Delta\phi = 2x\ \pi/2$
$-0.35 < \eta < 0.35$

central arm	acceptance (4π)	σ_{pp}	$B_{ee}\ \sigma_{pp}\ A^{1.92}$ a Au-Au	resolution σ_m
J/Ψ	0.8%	3.3 μb	40 μb	20 MeV
Υ	1.7%	10 nb	110 nb	120 MeV



muon arms: $J/\psi, \psi', \Upsilon \rightarrow \mu^+\mu^-$

p > 2 GeV/c
$\Delta\phi = \pi$
$-1.2 < \eta < -2.2$
$1.2 < \eta < 2.4$

muon arms	acceptance (4π)	σ_{pp}	$B_{ee}\ \sigma_{pp}\ A^{1.92}$ a Au-Au	resolution σ_m
J/Ψ	8.6%	3.3 μb	430 μb	110 MeV
Υ	6%	10 nb	380 nb	200 MeV

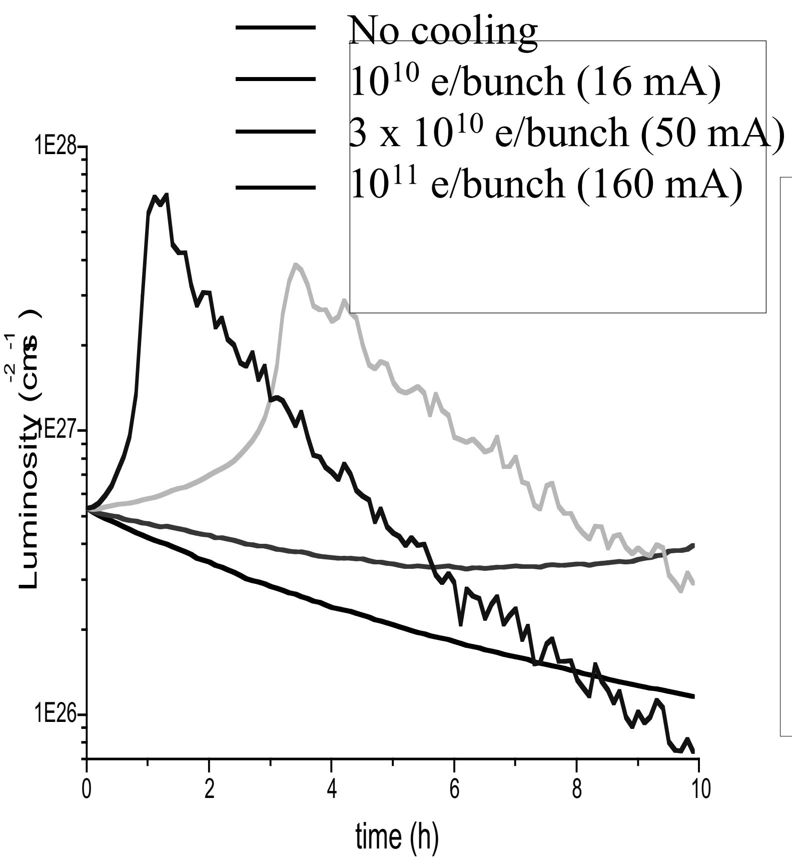
~ factor 10 larger acceptance for μμ

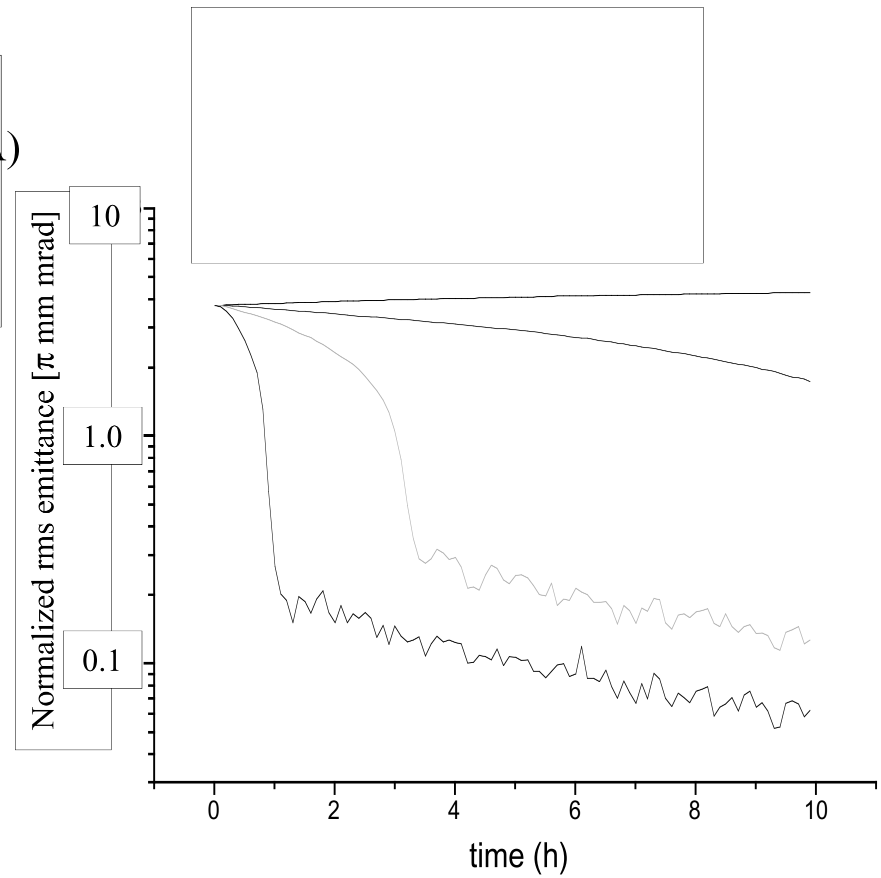
Heavy Ion Luminosity Upgrades

	RDM	RDM+	RHIC II	
Initial emittance(95%) πμm	15	15	15	
Final emittance (95%) πμm	40	40	3	
Beta function at IR [m]	2.0	1.0	1.0 → 0.5	
Number of bunches	56	112	112	
Bunch population [10^9]	1	1	1	
Beam-beam parameter per IR		0.0016	0.0016	0.004
Angular size at IR [μrad]	108	153	95	
RMS beam size at IR [μm]	216	150	95	
Peak luminosity [10^{26} cm^{-2} s^{-1}]		8	32	83
Average luminosity [10^{26} cm^{-2} s^{-1}]		2	8	70

- RDM and RDM+ assume 10 hr stores
- RHIC II includes electron beam cooling and assumes 5 hr stores since burn-off is high

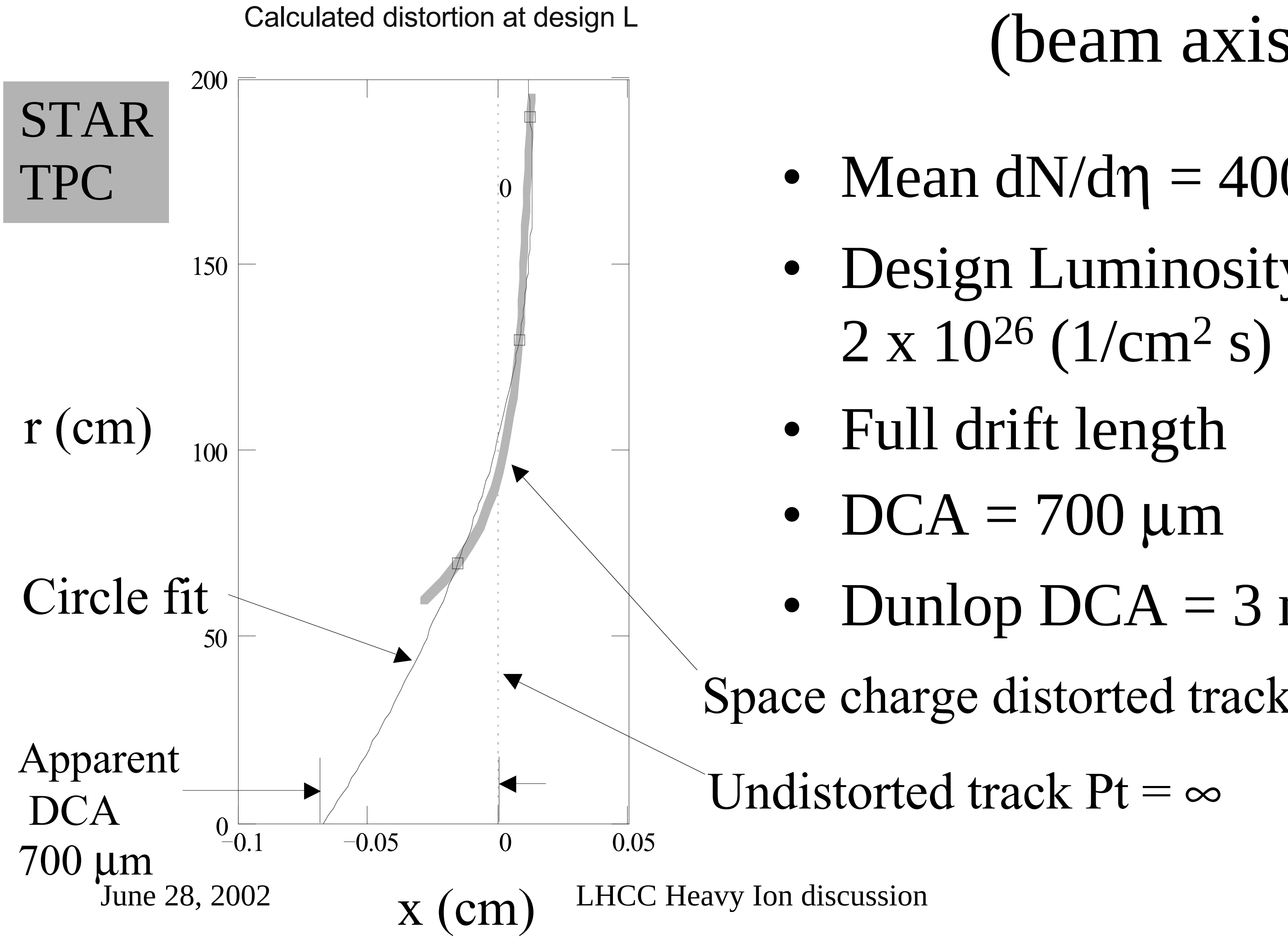
RHIC Luminosity and Emittance with Cooling





Calculated distortion from normal collisions (beam axis view)

STAR TPC



- Mean dN/dη = 400
- Design Luminosity – 2 x 10^{26} ($1/cm^2$ s)
- Full drift length
- DCA = 700 µm
- Dunlop DCA = 3 mm

STAR TPC performance with RHIC II under study

Space charge summary

	L	DCA measured (beam gas)	DCA expected (beam gas)	DCA calculated (normal collisions)
Year 1	$\sim 0.5 \times 10^{26}$	3 mm		0.2 mm
Design	2×10^{26}		3 mm	0.7 mm
Upgrade	80×10^{26}		3 mm	27 mm

Timeline for a major new project

DOE "Critical Decision" milestones

• BNL submits "Mission Need" statement (scientific justification):	Sept. 2002
DOE CD-0 (Mission Need)	Feb. 2003
• Prelim. CDR for electron cooling, detector upgrades	Sept. 2003
• BNL PAC scientific review of detector upgrade proposals	Oct. 2003
• NSAC Review	Jan. 2004
DOE CD-1 (Approve preliminary baseline range)	Mar. 2004
• Conceptual designs complete	Dec. 2004
DOE CD-2 (Approve performance baseline)	Feb. 2005
DOE CD-3 (Approve start of construction)	Sept. 2005
• e-Cooling complete	Sept. 2008
DOE CD-4 (Project operational)	Sept. 2009

Absorber and Beam Instrumentation (common design for CMS and ATLAS I.r.'s)-TAN