Silicon Vertex Upgrade for PHENIX

- A+A: from discovery to characterizing properties dense phase
  - Need broad range of early probes: charm, beauty
- p+p: what carries the proton spin
  - $\Delta G(x)$ from polarized p+p, over broad range in x

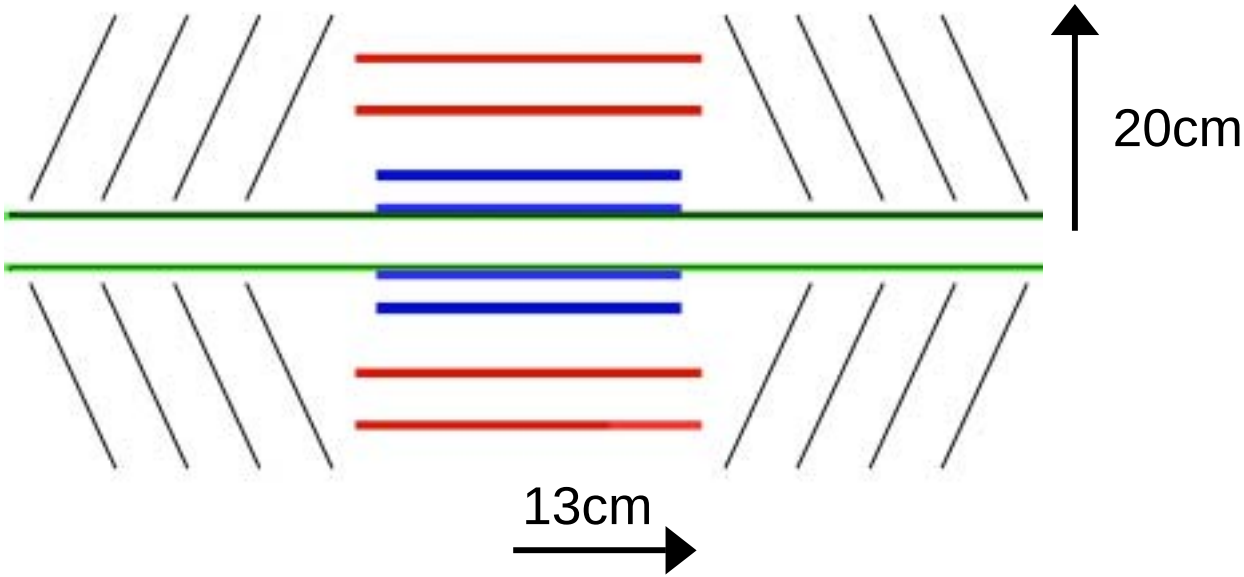
VTX Group within PHENIX

65 people, 14 Groups
From USA and Japan

Brookhaven National Laboratory, Chemistry Department,
Brookhaven National Laboratory, Instrumentation Division,
Brookhaven National Laboratory, Physics Department,
Florida State University, Iowa State University,
High Energy Accelerator Research Organization (KEK),
Kyoto University, Los Alamos National Laboratory, Niigata University,
Oak Ridge National Laboratory, RIKEN, RIKEN BNL Research Center
Stony Brook University, University of New Mexico

Proposal submitted to BNL

Sketch of VTX



Terms used in following physics plots

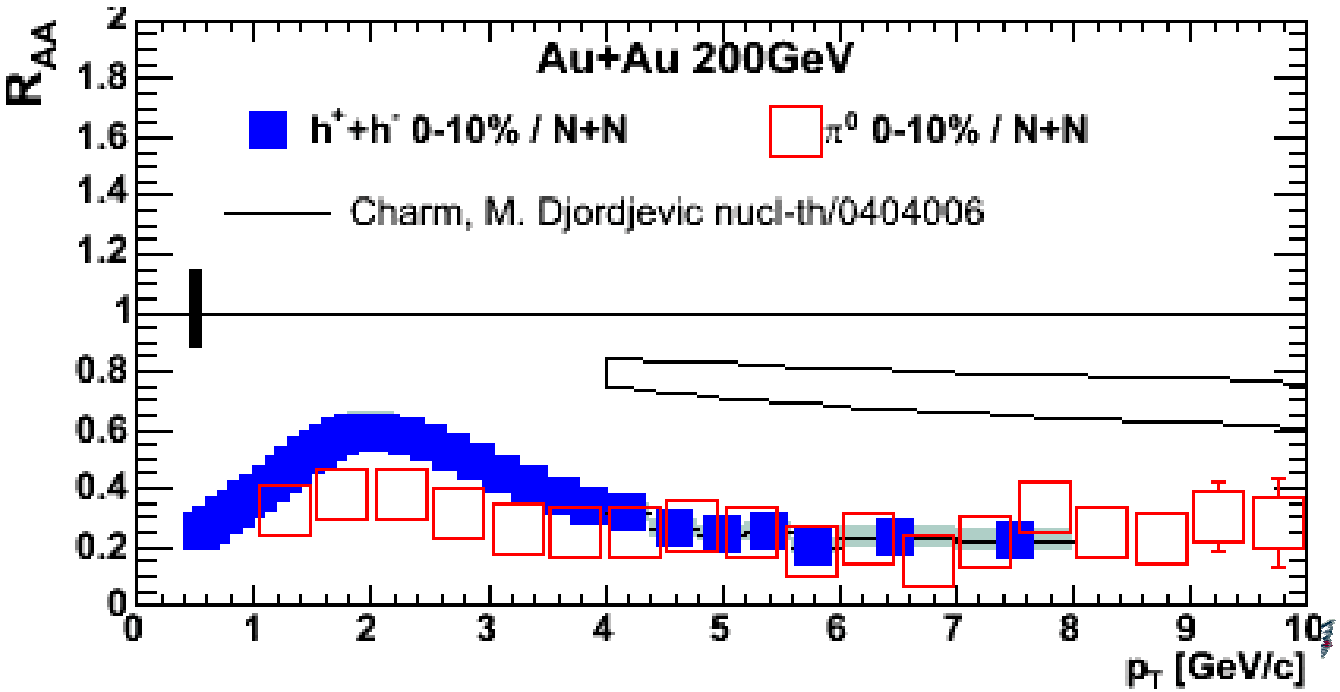
Barrel: Two layers of pixels (2.5, 5cm)
Two layers of strips (~10, 14cm)
Endcap: Four sets of mini-strip lampshades

Probing Properties of Dense Matter (Au+Au)

Hard-scattered partons radiate gluons => lose energy

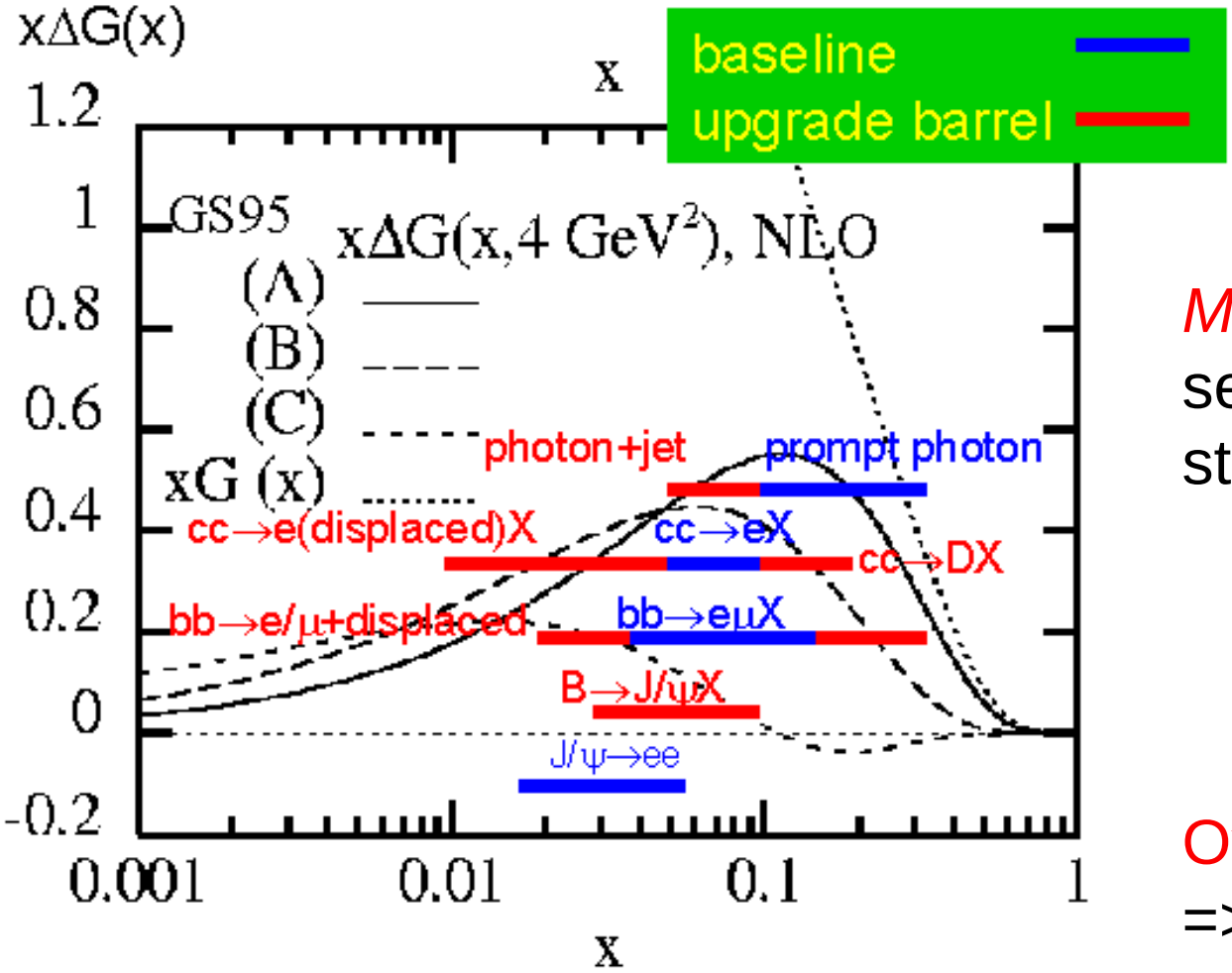
1. Density of color in medium
2. Interference of radiated gluons from multiple scattering

Balance between these effects depends on mass of quark
stronger interference for heavy-quarks => dead-cone



Measure:
1) suppression of high-pt charm
2) Elliptic flow of charm

Spin Structure Function: Broad Range in x (p+p)



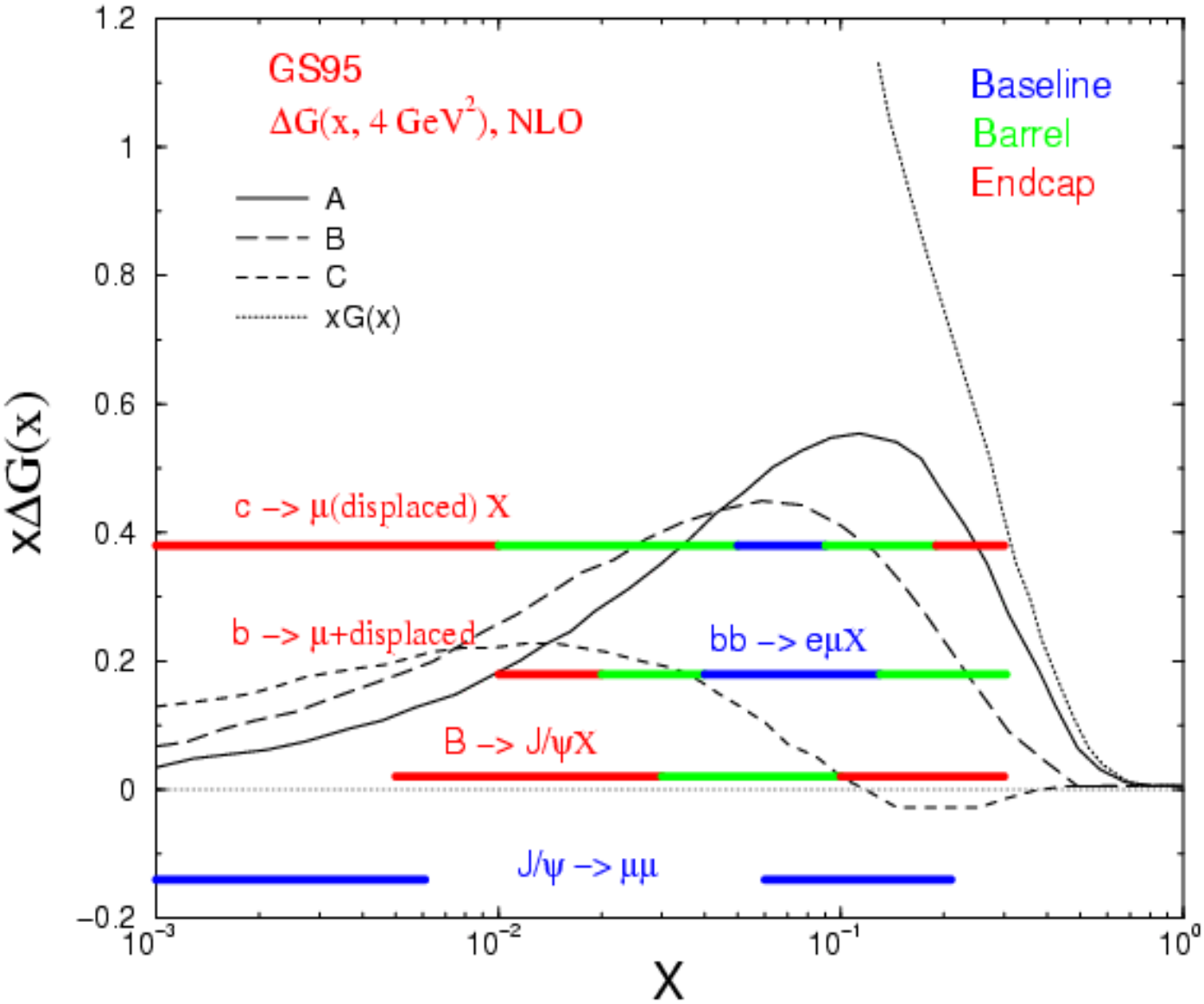
Multiple channels sensitive to gluon structure function

- photon+jet
- charm
- beauty

Overlap, broad range x

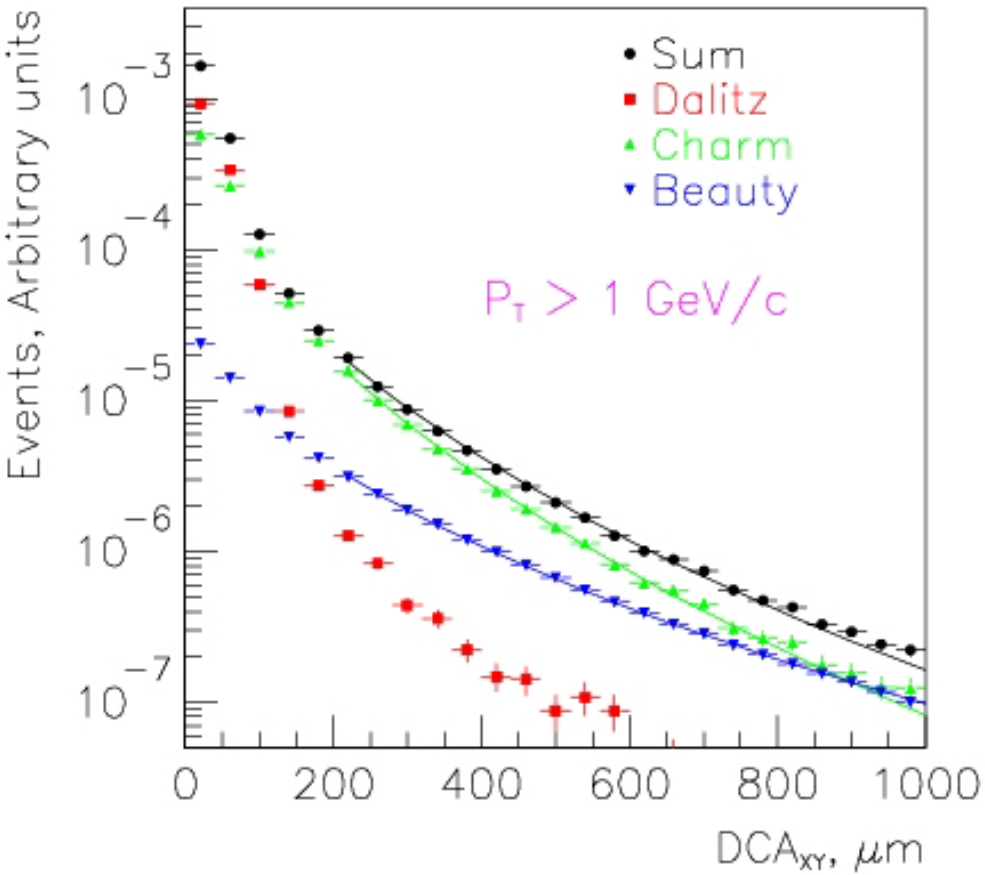
=> Robust Δg(x)

Endcap extends x-range (p+p)

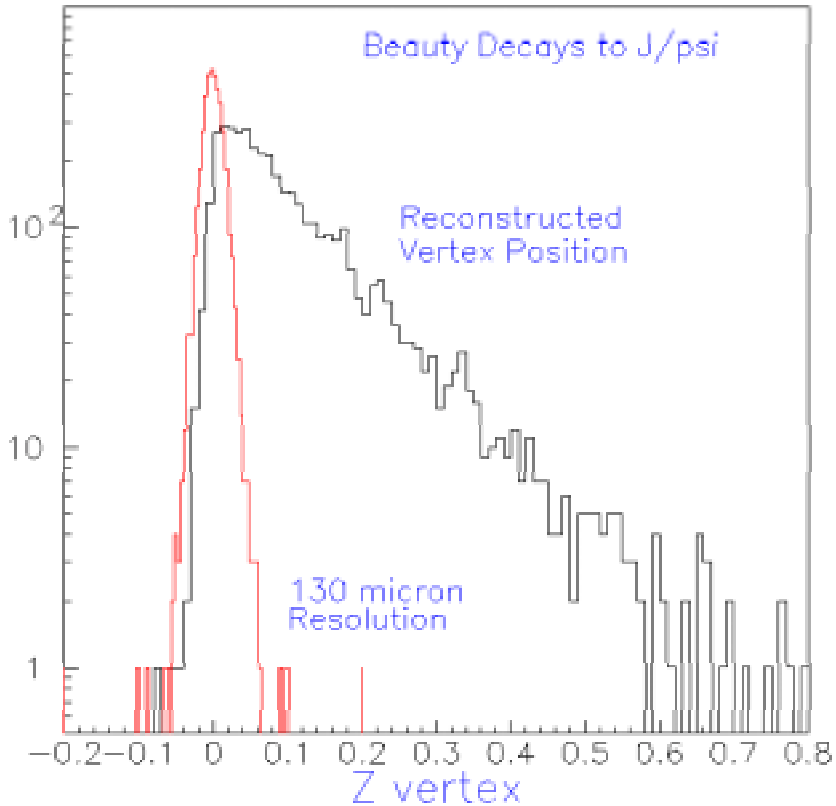


VTX Enables Measurement of Displaced Vertices

D => e



B => J/ψ=>$\mu^+ + \mu^-$



Other channels, D=>Kπ, B=>e

Additional Key Physics

- Open charm in A+A is vital baseline for J/ψ suppression
- Upsilon predicted not to be suppressed => control expt.
- Gluon structure function via d+A
- Use knowledge of charm => isolate thermal e^+e^- => T?
- Extend PHENIX's high-pt reach by confirming tracks

Physics Reach Au+Au (5+14 week * uptime)

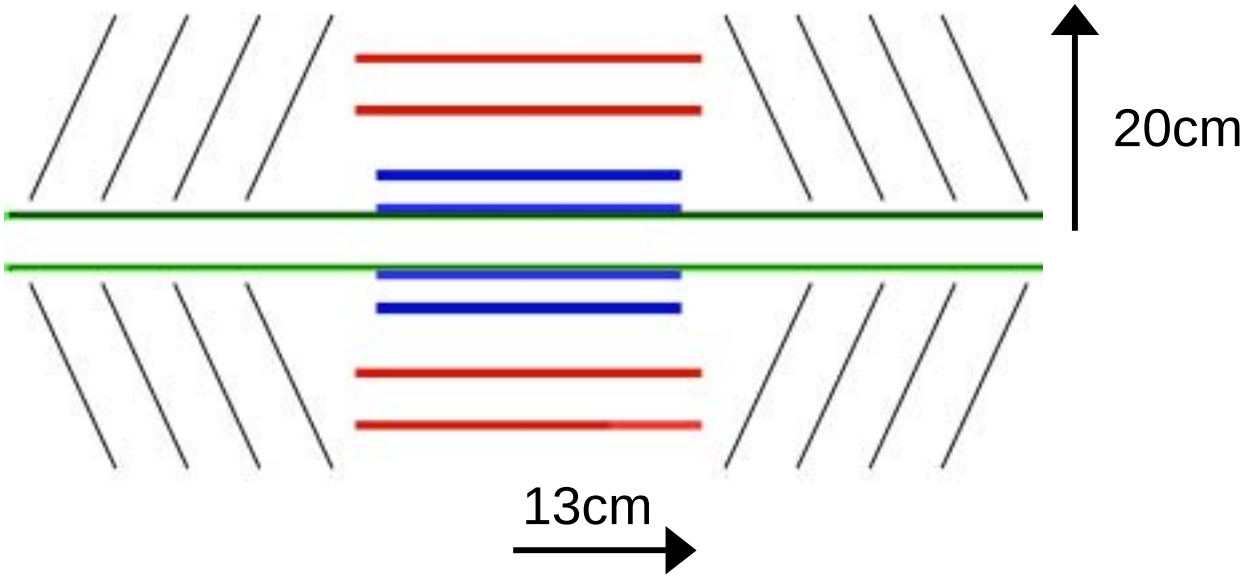
Observable	Trigger	RHIC-I counts/run	RHIC-II counts/run
D =>e pt >1 GeV/c + DCA	e-PID	200K	2M
D =>μ	μ-PID	>10M	>100M
D=>Kπ pt >2 GeV/c + DCA	Min-bias	15K	75K
B =>e pt >2 GeV/c + DCA	e-PID	7K	70K
B =>DCA J/ψ =>μ+μ–	μ-PID	800	8K
Υ =>e+e-	e-PID	16	160
Υ =>μ+μ–	μ-PID	43	430

RHIC-II needed for quality B measurement, feasible Υ

Figure of Merits: Baseline vs Upgrade NSAC Request

- Au+Au open charm
  - Current e measurement 40% systematic
    - » Reduce to ~10% systematic
    - » Necessary precision for e-loss physics
  - Current charm pt < 2.5 GeV/c
    - » DCA c,b and D=>Kπ , pt to several GeV/c
- Au+Au open beauty
  - Not possible without upgrade
- p+p spin
  - Current x-range, 0.02 < x < 0.3, extend to 0.01 < x < 0.3
  - Current one or two observables per x-range
    - » Extend overlap, three to four observables per x-range

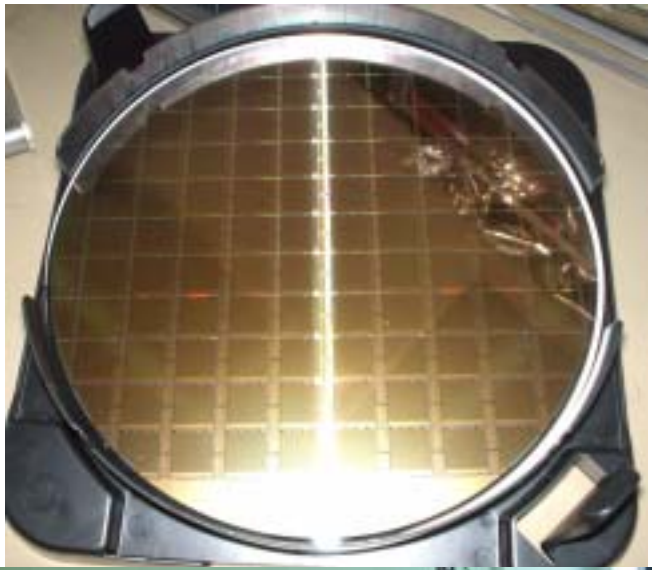
VTX



Joint Project between DOE and RIKEN-BNL, staged approach

- Japanese funding in place, construction started pixel layers
- DOE R&D for outer strip layers, endcaps
- Barrel strip layers DOE proposal, submitted to BNL
- Endcap DOE proposal, submit in 1-2 years

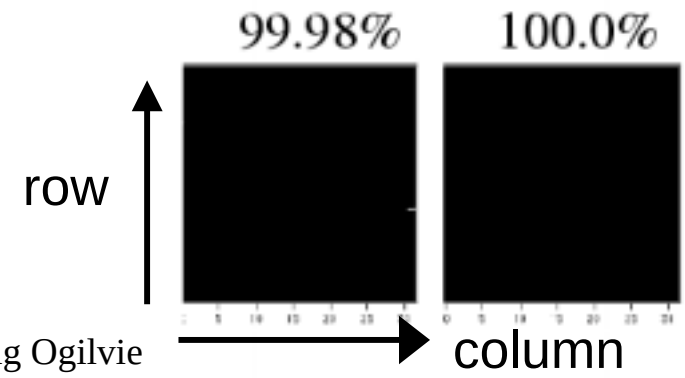
Barrel Inner Two Pixel Layers



Japanese construction started!!
ALICE1 Readout-chips
bump-bonded to
Pixel sensors 50x425 μm

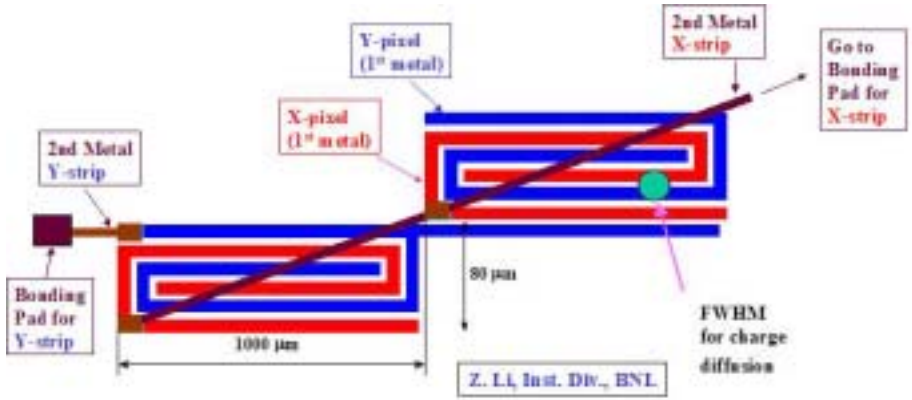
Sensors, chips summer 04
Bump-bonding 2004-2005

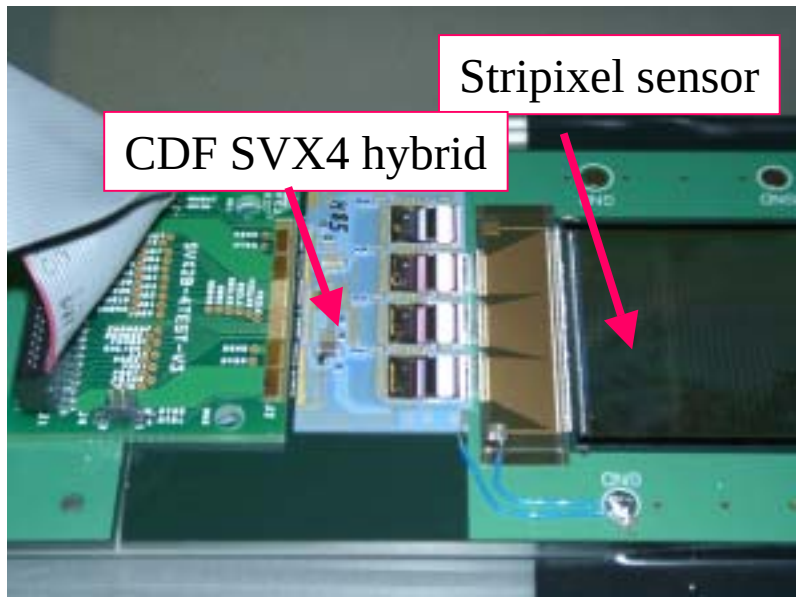
Validation of bump-bonding (VTT)
2D map, % good pixels



Barrel Outer Two Strip Layers

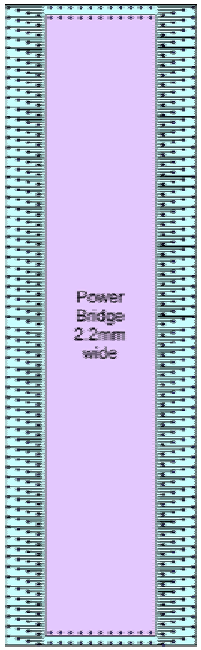
- Stripixel: single sided, two dimensional read-out (Z. Li BNL Inst. Division)
- Ionization collected by two “spirals”
- Each spiral connects to either U or X strip
- Readout chip SVX4
- Current R&D
  - S/N
  - board containing SVX4





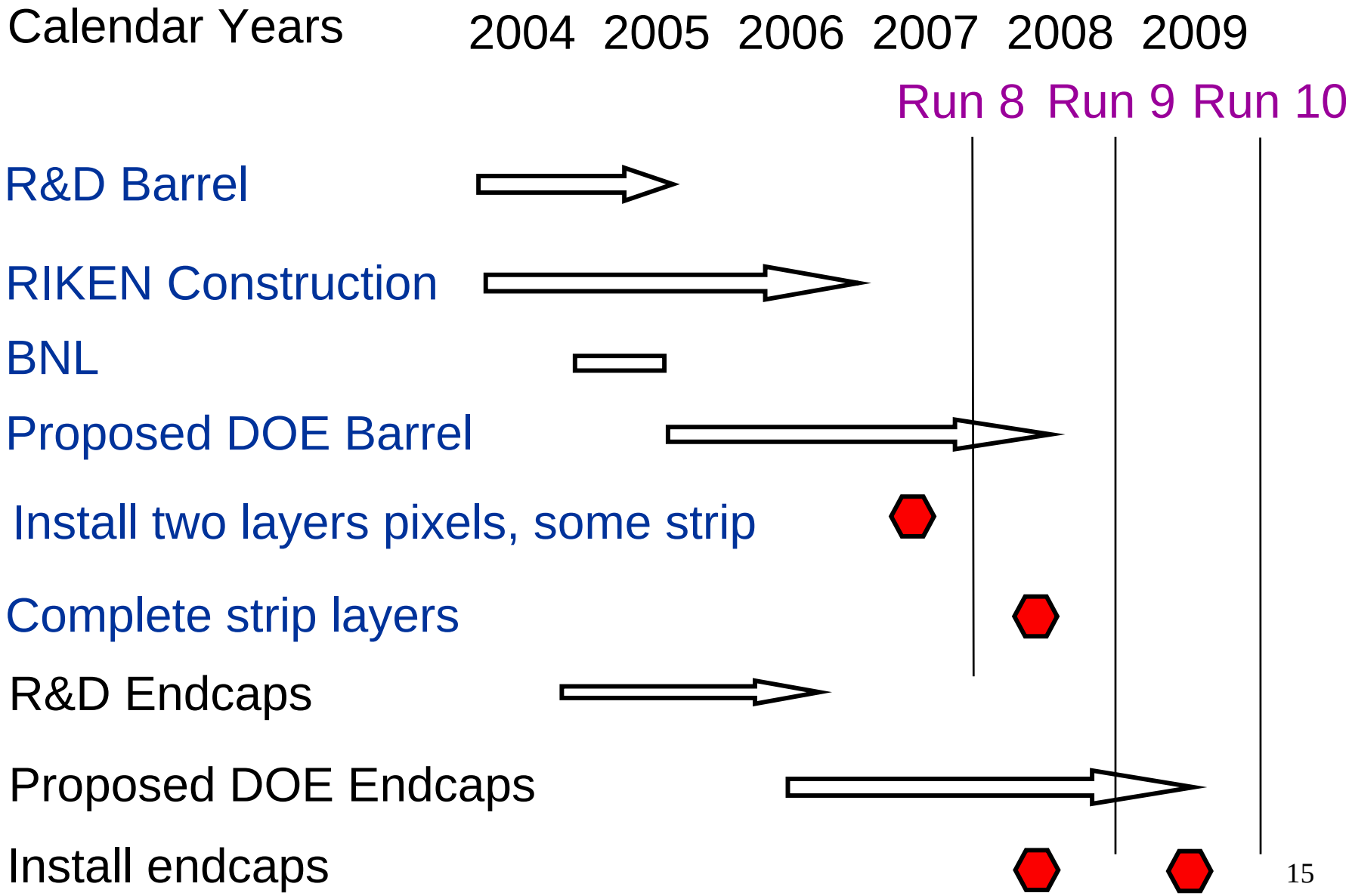
Endcap: Ministrips

- Mini-strip detectors
  - 50 x 2000 to 11000 μm
- Readout chip (PHX) adapted from FPIX2 (FNAL)
- Bump bonded assemblies
- R&D
  - FY05 PHX design/test



PHX

Schedule


Calendar Years
2004
2005
2006
2007
2008
2009
Run 8
Run 9
Run 10
R&D Barrel
RIKEN Construction
BNL
Proposed DOE Barrel
Install two layers pixels, some strip
Complete strip layers
R&D Endcaps
Proposed DOE Endcaps
Install endcaps

DOE Costs Per Year

	FY04	FY05	FY06	FY07	FY08	FY09
Barrel R&D	150K	200K				
BNL Operations Equipment		280K				
Barrel Proposed DOE construction			2800K	2000K	400K	
Endcap R&D	100K	250K	320K	150K		
Endcap Proposed DOE construction				2050K	2050K	2050K

Summary

- Heavy quark probes of early stage of Au+Au
  - Stronger gluon interference => smaller energy-loss
  - Baseline for suppression (J/ψ) / (open charm)
- Gluon spin-structure function in p+p
  - Broad-coverage in x
  - Overlap in x => robust global fits

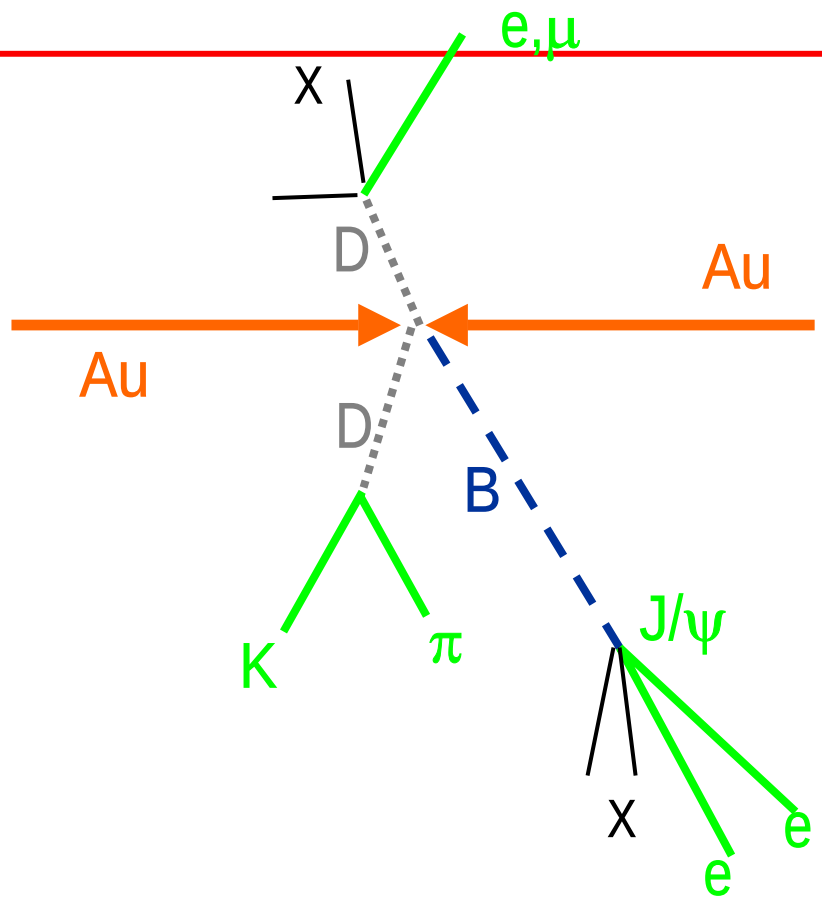
- Japan construction of pixel layers underway
- R&D finishing for strip layers
- R&D in progress for endcaps

Backups

Direct Observation of Open Charm and Beauty

Detection of decay vertex
will allow a clean identifications of
charm and bottom decays

	m GeV	cτ μm
D^0	1865	125
$D^\pm$	1869	317
B^0	5279	464
$B^\pm$	5279	496



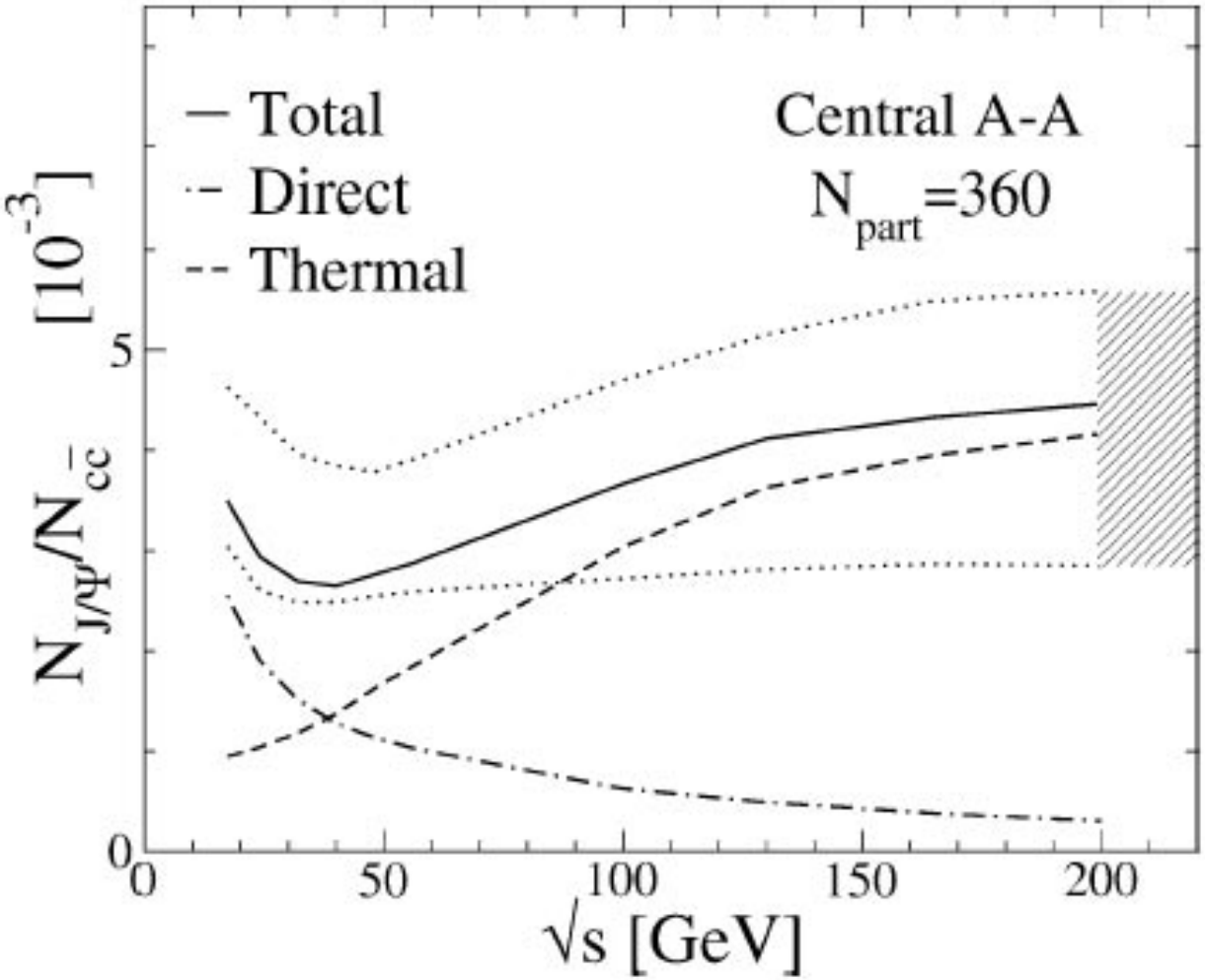
Detection options (PHENIX):

- **Beauty and low p_T charm via displaced e and/or μ** **$-2.7<\eta<-1.2$, $|\eta|<0.35$, $2.7<\eta<1.2$**
- **Beauty through displaced J/ψ → ee (μμ)** **$-2.7<\eta<-1.2$, $|\eta|<0.35$, $2.7<\eta<1.2$**
- **High p_T charm through D → π K** **$|\eta|<0.35$**

Rate Assumptions

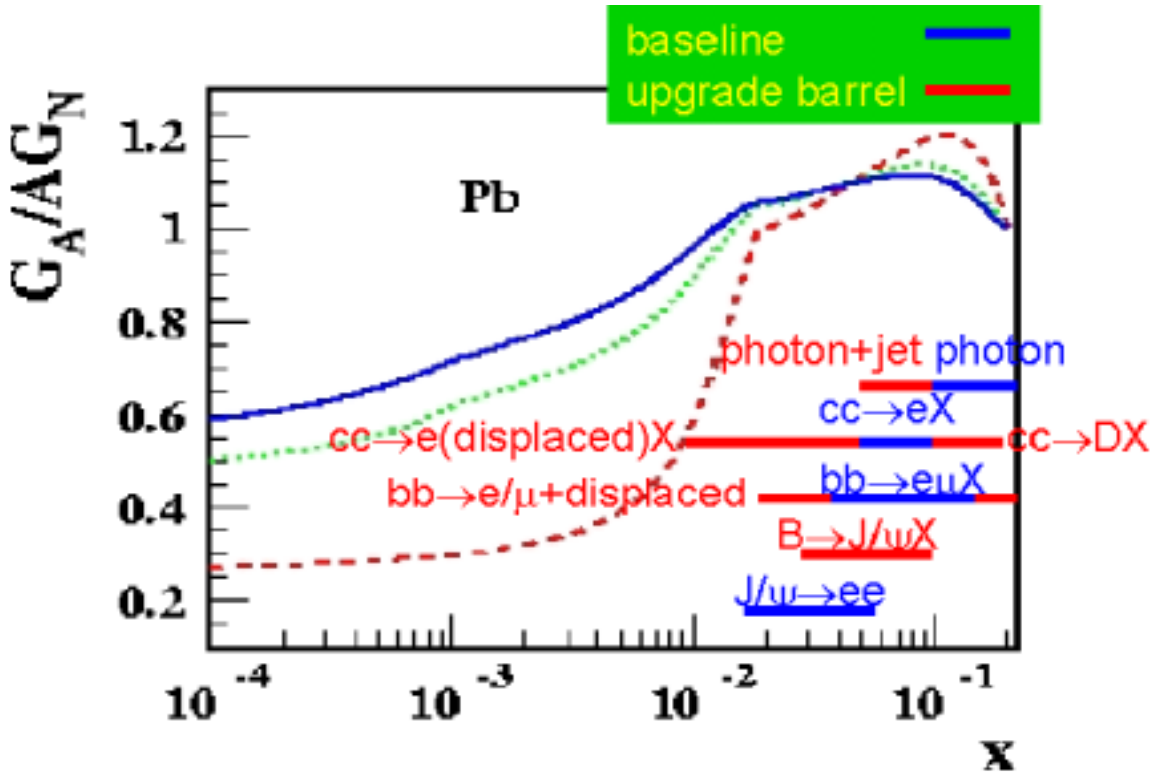
- Au+Au |z|<10cm, 5+14 week, RHIC 60%, PHENIX 60%
  - RHIC I, Integrated DAQ =0.76 pb^{-1}
  - RHIC II, Integrated DAQ = 7.6 pb^{-1}
  - 50% MB, 50% LVL1 triggers
  - Trigger electron threshold increased for RHIC-II

(J/ψ) / charm

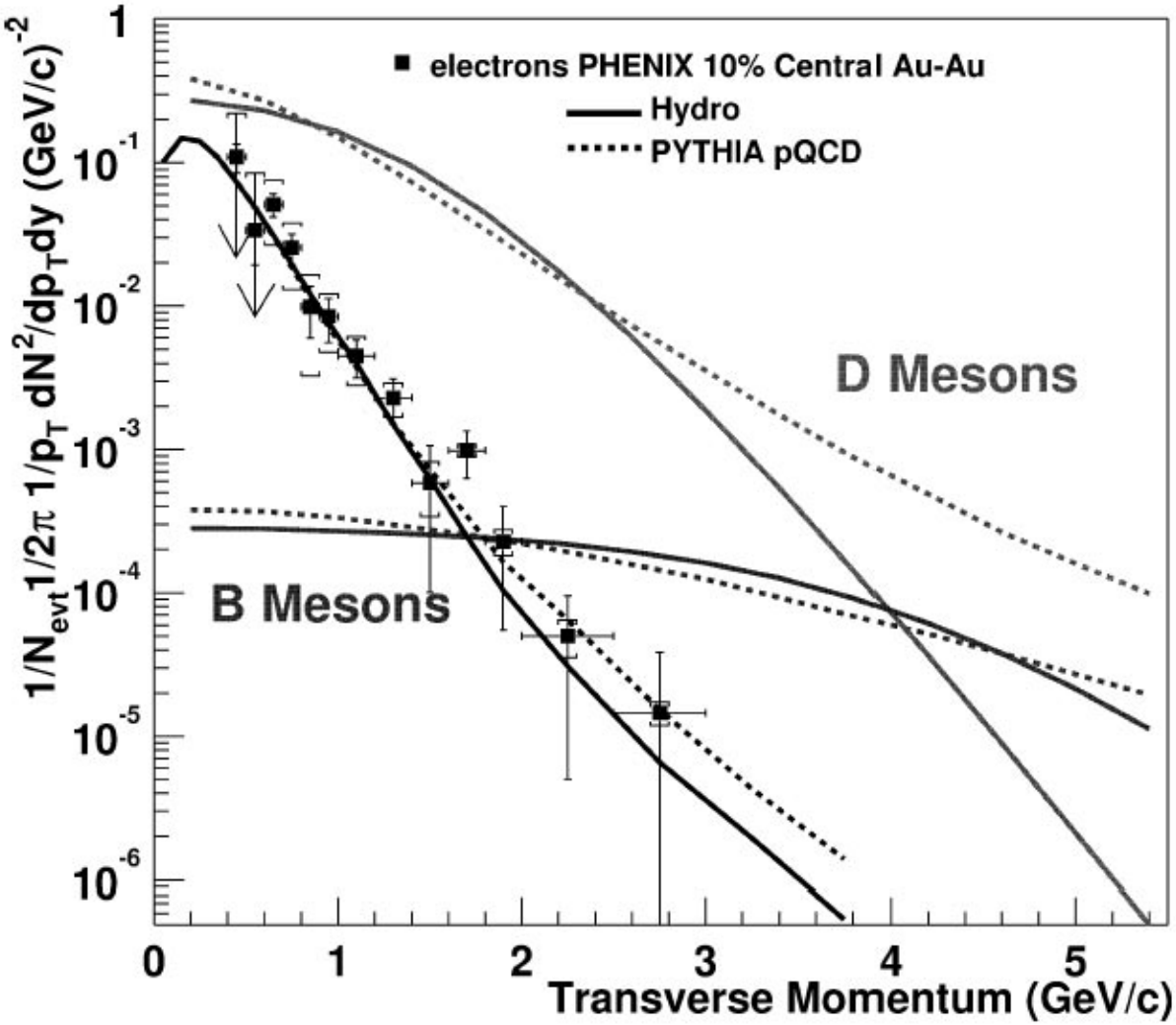

Total
Direct
Thermal
Central A-A
N_part=360
N_J/ψ/N_cc̄ [10^-3]
5
0
0
50
100
150
200
√s [GeV]

pA Physics with VTX

- Extracting gluon structure function in nuclei, shadowing

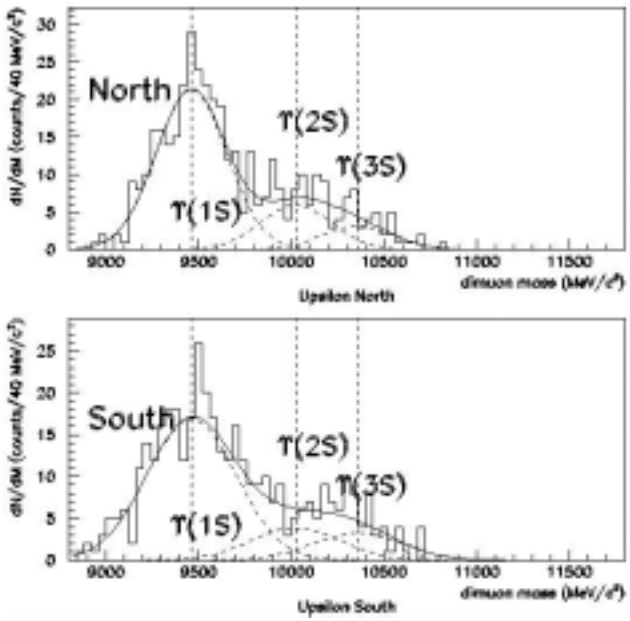


Spectra


electrons PHENIX 10% Central Au-Au
Hydro
PYTHIA pQCD
D Mesons
B Mesons
$1/N_{evt} 1/2\pi\ 1/p_T\ dN^2/dp_T dy\ (GeV/c)^{-2}$
Transverse Momentum (GeV/c)

Upsilon Spectroscopy with RHIC II Luminosity

- Muon arms:

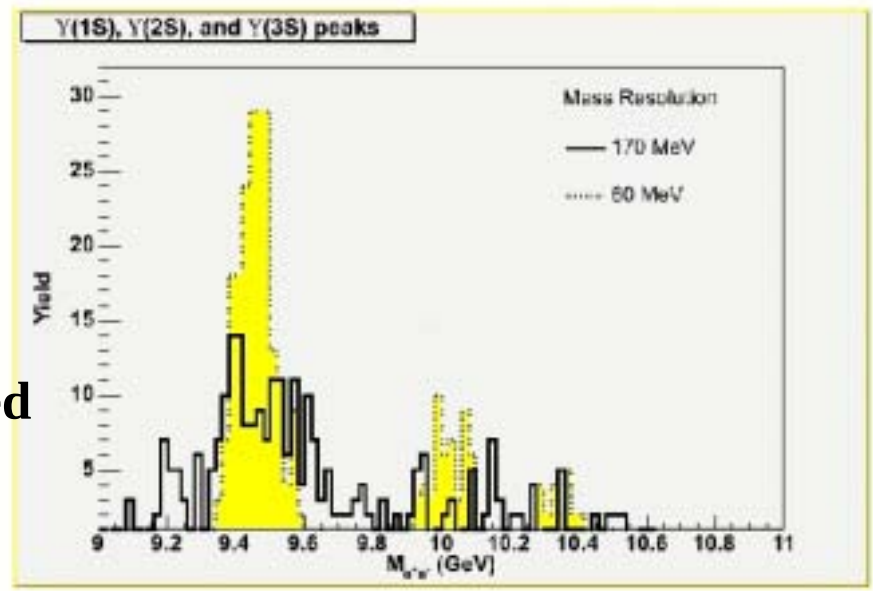


total of ~ 400 $\Upsilon \rightarrow \mu\mu$ reconstructed decays

north muon arm: σ_m ~ 190 MeV

south muon arm σ_m ~ 240 MeV

- Central arms:



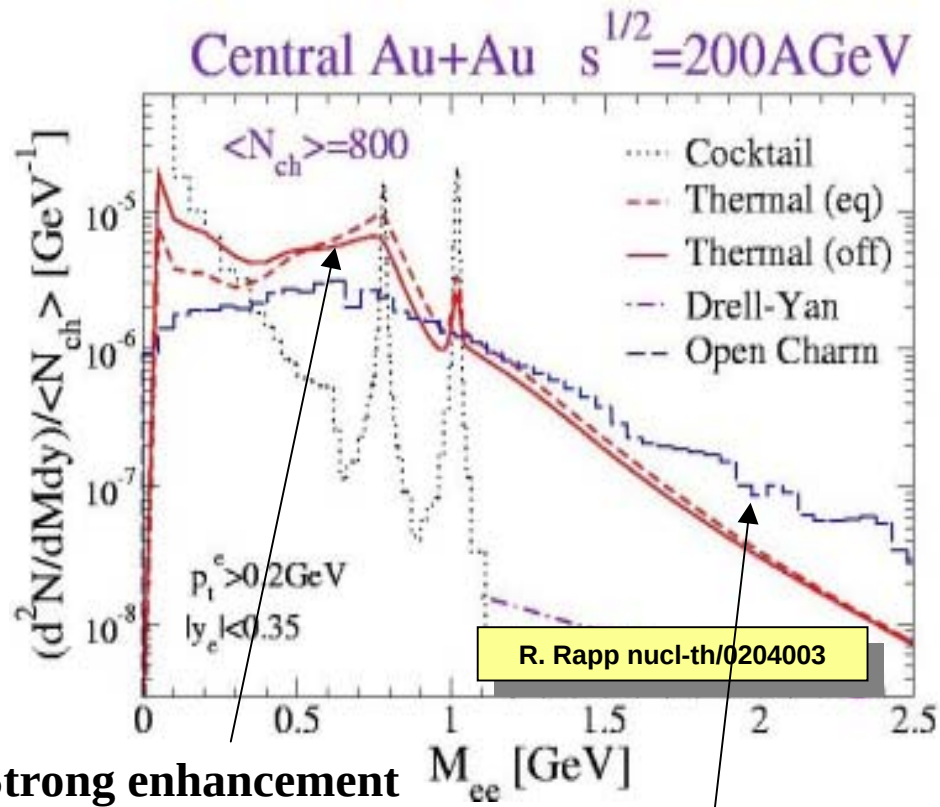
total of ~ 150 $\Upsilon \rightarrow$ ee decays reconstructed

original setup σ_m ~ 170 MeV

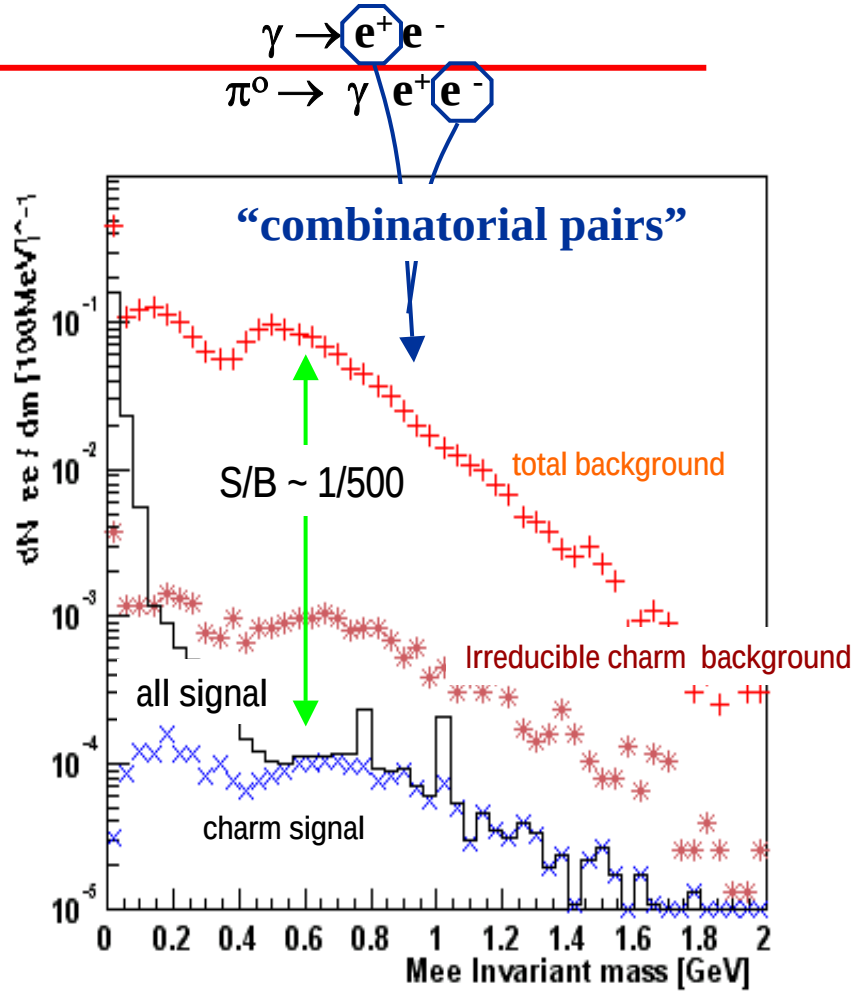
upgraded setup σ_m ~ 60 MeV

Low-Mass e^+e^- Pairs: Prospects at RHIC

Sensitive to chiral symmetry restoration



Strong enhancement of low-mass pairs persists at RHIC



Significant contribution from open charm

Need Dalitz rejection & accurate charm measurement