PHENIX Upgrade Plans for RHIC II

Axel Drees, SUNY Stony Brook

GSI, May January 15th 2002

Overview of baseline PHENIX detector

Physics goals of RHIC II upgrades

Upsilon spectroscopy

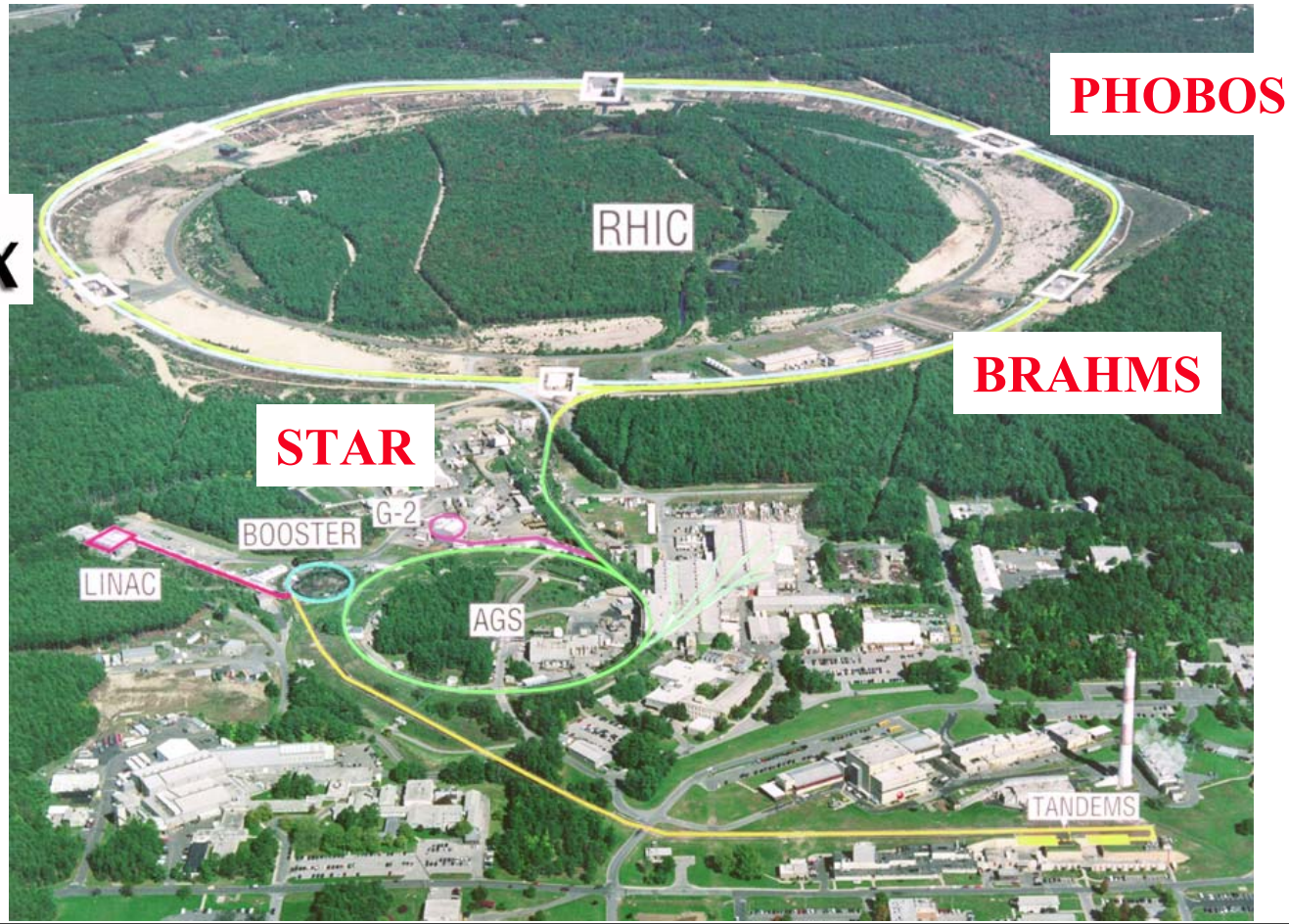
Lepton pair continuum ⇒ **Dalitz rejection**

Heavy Flavor ⇒ **Silicon vertex tracking**

High pt phenomena ⇒ **particle ID to 10 GeV**

Timeline for upgrades

The RHIC Accelerator Complex



$\sqrt{s}$	RHIC design luminosity		(reached in Run 2)
200 GeV	Au-Au	$L \sim 2 \times 10^{26}\ cm^{-2}s^{-1}$	(peak)
500 GeV	p-p	$L \sim 1 \times 10^{31}\ cm^{-2}s^{-1}$	(~ 1/10)

PHENIX Physics Capabilities

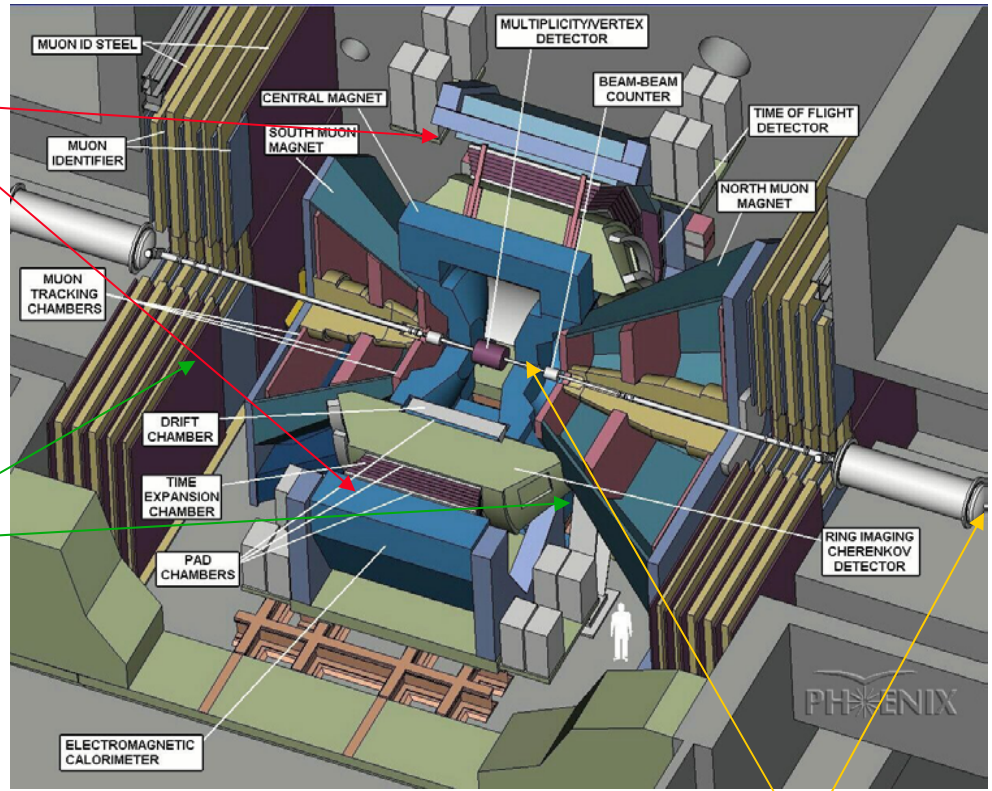
designed to measure rare probes:

Au-Au & p-p spin

+ high rate capability & granularity
+ good mass resolution and particle ID
- limited acceptance

- **2 central arms:**
  electrons, photons, hadrons
  - **charmonium** $J/\psi, \psi' \rightarrow e^+e^-$
  - **vector meson** $\rho, \omega, \phi \rightarrow e^+e^-$
  - **high** p_T π^o, π^+, π^-
  - **direct photons**
  - **open charm**
  - **hadron physics**

- **2 muon arms: muons**
  - **"onium"** $J/\psi, \psi', \Upsilon \rightarrow \mu^+\mu^-$
  - **vector meson** $\phi \rightarrow \mu^+\mu^-$
  - **open charm**



- **combined central and muon arms:**
  charm production $DD \rightarrow e\mu$

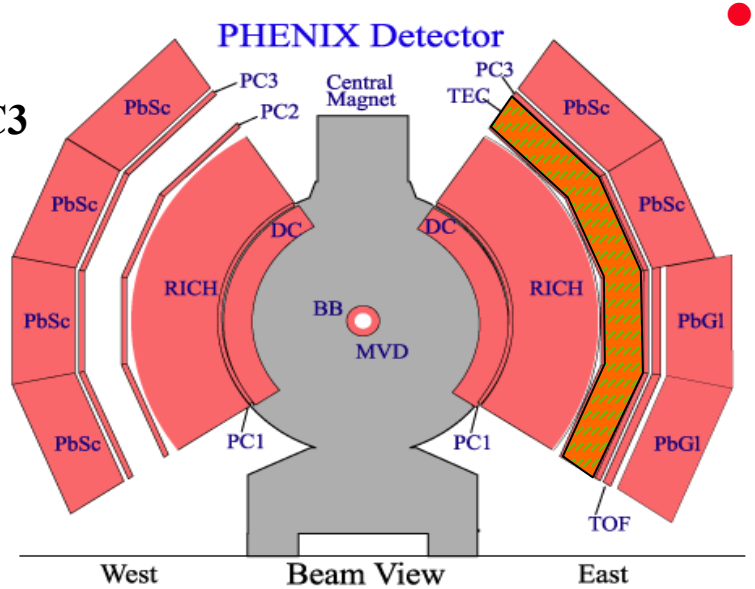
- **global detectors**
  forward energy and multiplicity
  - **event characterization**

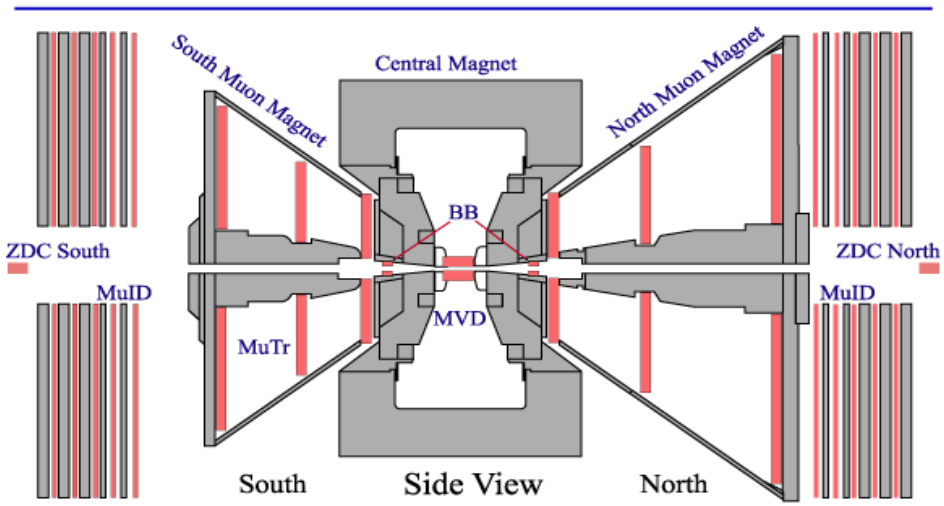
PHENIX

Axel Drees

PHENIX Setup Completed in 2003

- **West Arm**
  - **tracking:** DC,PC1, PC2, PC3
  - **electron ID:** RICH, EMCal
  - **photons:** EMCal
- **South & North Arm**
  - **tracking:** MuTr
  - **muon ID:** MuID
- **Other Detectors**
  - **Vertex & centrality:** ZDC, BBC, MVD





- **East Arm**
  - **tracking:** DC, PC1, TEC, PC3
  - **electron & hadron ID:** RICH,TEC/TRD, TOF, EMC
  - **photons:** EMCal

Run 1: 2001
3 10^6 Au-Au events

Run 2: 2002/2003
90 10^6 Au-Au events
+100 10^6 Au-Au sampled
~ 10^8 p-p sampled

Beyond the PHENIX Baseline Program

- **Heavy Ion Physics**
  - **shift of focus from establishing the existence of QGP and first studies of its properties to systematic study of QCD high T**
  - **focus on key measurements not or only partially addressed by original PHENIX setup:**

upsilon spectroscopy, Y(1S), Y(2S), and Y(S3)

lepton pair continuum: low mass to Drell Yan

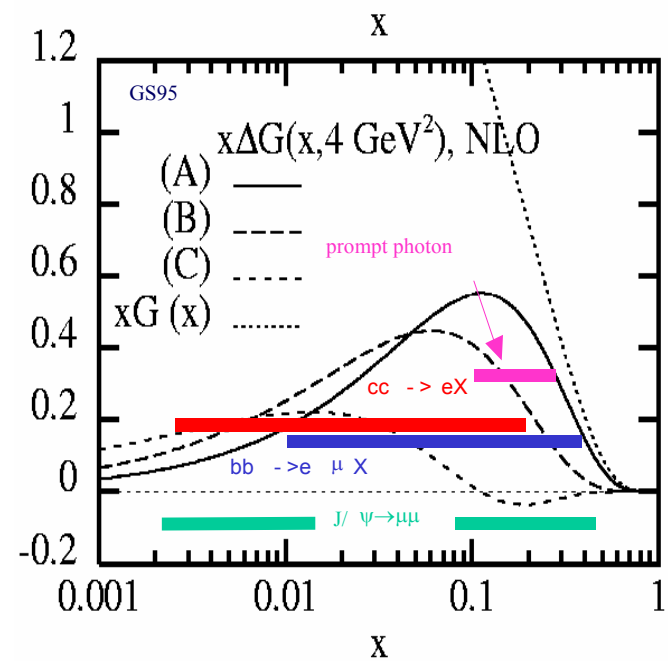
heavy flavor

high p_T phenomena

for these measurements
the PHENIX central and muon spectrometer are essential
but not sufficient !

PHENIX Beyond the Baseline

- **Spin Physics**
  - gluon spin structure over large x range
  - heavy flavor
  - W-Boson
  - transversity
- **p-A Physics**
  - parton structure of nuclei
  - diffractive processes



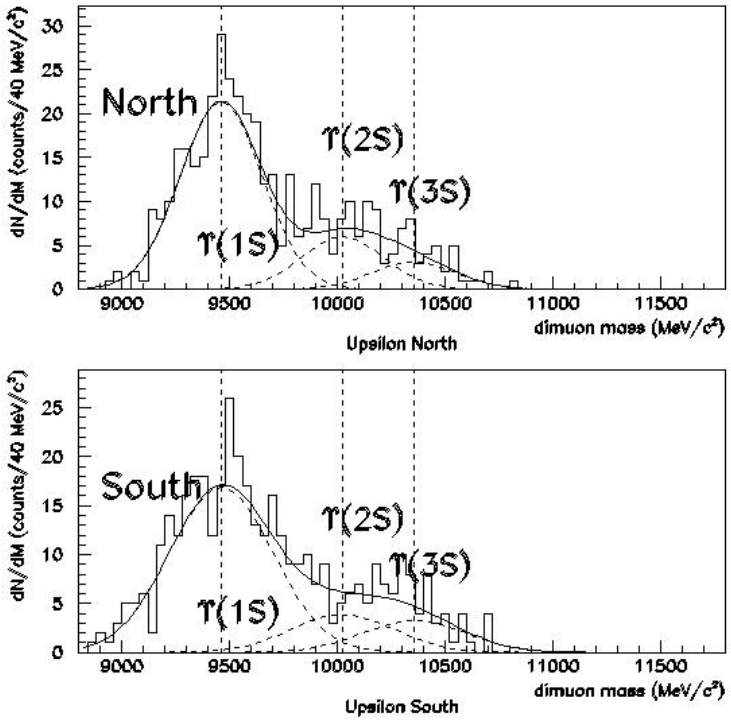
Measurement focus on rare processes ⇒ requires high luminosity

Expected luminosity upgrades at RHIC (RHIC-II)

Au-Au	$L \sim 8 \times 10^{27}\ cm^{-2}s^{-1}$	(x40)
O-O	$L \sim 1.6 \times 10^{29}\ cm^{-2}s^{-1}$	
p-p	$L \sim 4 \times 10^{32}\ cm^{-2}s^{-1}$	(possibly -> $4 \times 10^{33}\ cm^{-2}s^{-1}$)

Upsilon Spectroscopy

- **original PHENIX capability:**



Upsilon	mass (GeV)	Br($\mu\mu$) %	relative yield
Y(1S)	9.460	2.48	1
Y(2S)	10.023	1.31	0.36
Y(3S)	10.355	1.81	0.27

north muon arm: $\sigma_m \sim 190$ MeV

south muon arm $\sigma_m \sim 240$ MeV

22 week of Au-Au at 2 10^{26} $cm^{-2}s^{-1}$

total of ~ 400 Y decays

(~ 1/10 in central arms)

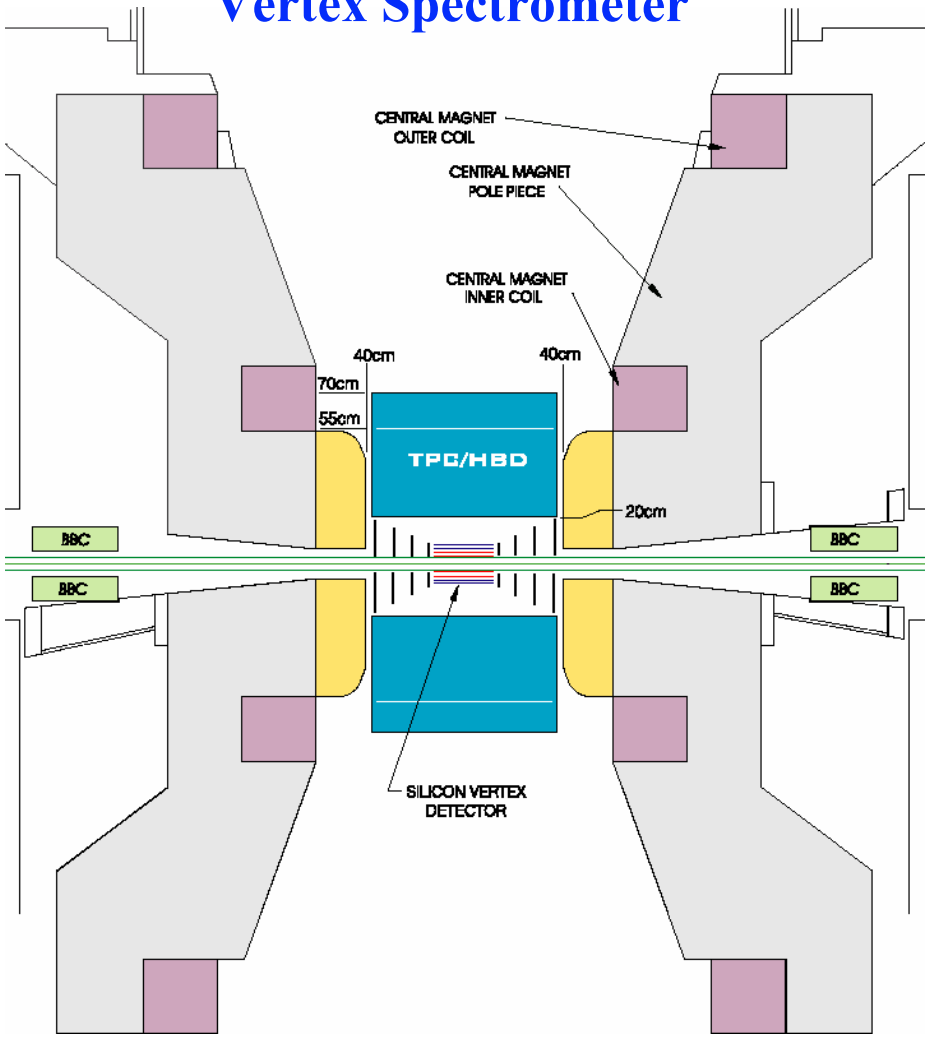
- **luminosity upgrade to 8 10^{27} $cm^{-2}s^{-1}$**

muon spectrometer: ~ 16000 Y

central spectrometer: ~ 1600 Y

PHENIX Detector Upgrades

Vertex Spectrometer



- **central vertex spectrometer**
  - flexible magnetic field
  - multi layer silicon vertex tracker
  - TPC/HBD
- **forward vertex tracking**
  - multiple layer silicon
- **enhanced particle ID**
  - TRD (east)
  - Aerogel/TOF (west)
- **enhanced muon trigger**
  - forward hodoscopes
  - forward calorimeter
  - station 1 anode readout
- **pA trigger detectors**
- **DAQ**

Rate and Yield Estimates for Low Mass Dileptons

Au-Au collisions at $\sqrt{s_{NN}}$=200 GeV

- **Luminosity** — **2×10^{26} cm^{-2} s^{-1}**
- **Interaction rate** — **1200 Hz**
- **10 weeks run** — **6.05 10^6 sec**
- **RHIC and PHENIX efficiency** — **0.25**
- **dN/dy (π^o) per min. bias event** — **100**

DAQ bandwidth limitation: ~ 330 Hz $\Rightarrow$ 5 10^8 events

	m=.2 - .5	ρ	ω	ϕ
Y(e^+e^-) per π^o (p_T > 200 MeV)	1.1 10^{-6}	1.2 10^{-7}	1.5 10^{-7}	1.7 10^{-7}
pair reconstruction efficiency	0.25			
Total yield (10 weeks run)	55000	6000	7500	8500
without trigger	11000	1500	1900	2200

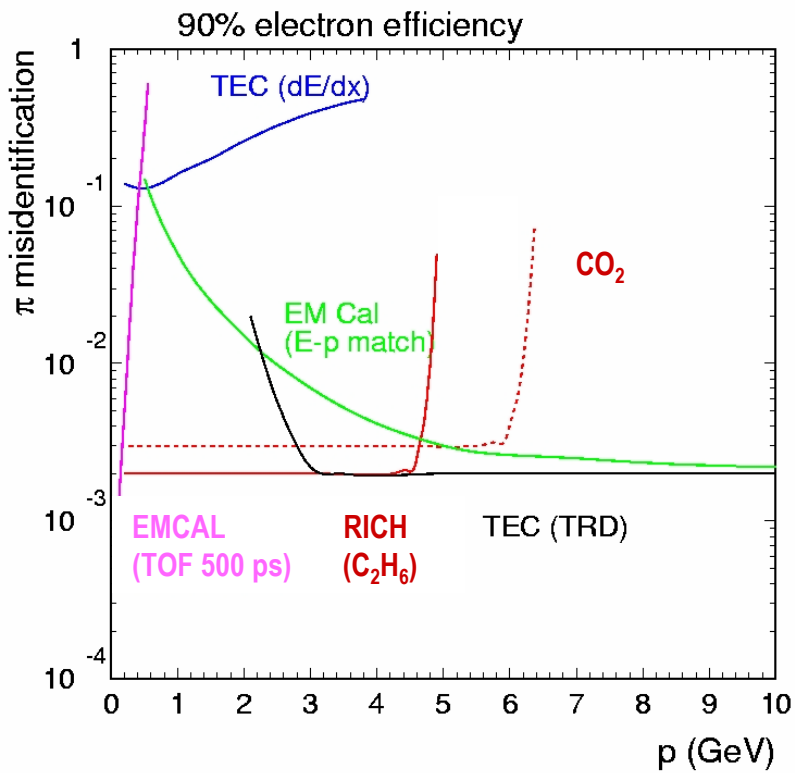
Au-Au pair trigger useful
p-p pair trigger mandatory

PHENIX

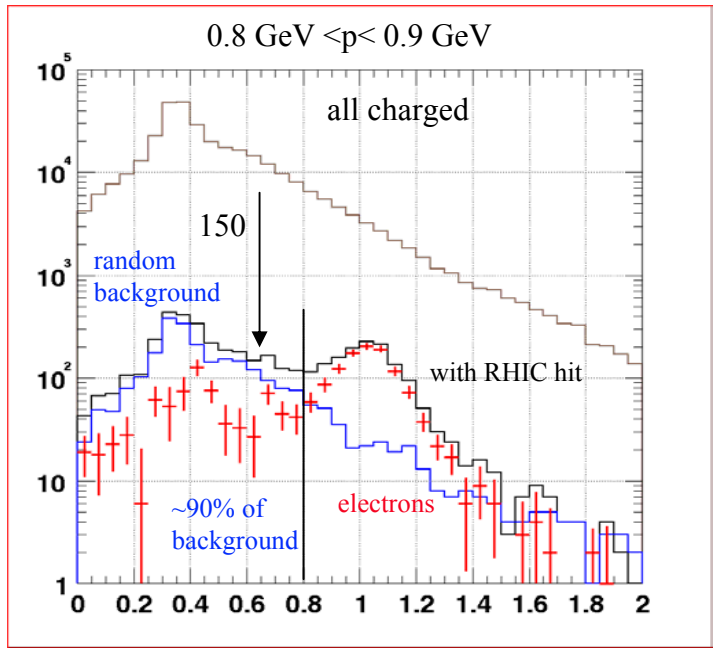
Electron ID in PHENIX central arms

Acceptance: p_t > 100-200 MeV/c
$\Delta\phi = 2x\ \pi/2$
$-0.35 < \eta < 0.35$

MC simulation (<1997)



Au-Au data 2001



E/P ratio

Electron ID at low momentum

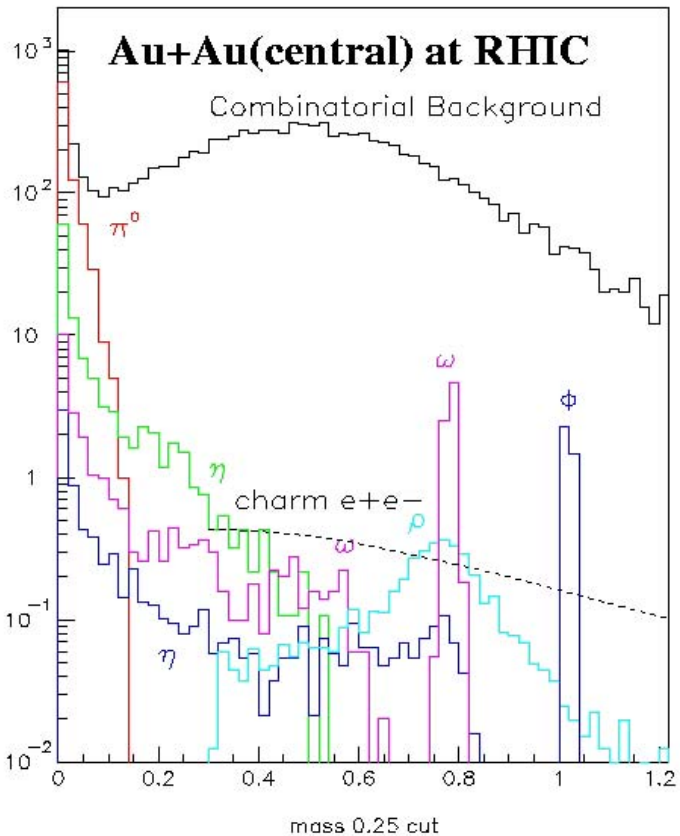
- **RICH**
- **EMCAL E-p matching**

$e/\pi \sim 7\ 10^{-4}$

at lower pt include TOF (400 ps)

Experimental Challenge

- **huge combinatorial pair background due to copiously produced photon conversion and Dalitz decays :**



photon conversion

$\gamma \rightarrow e^+ e^-$

Dalitz decays

$\pi^o \rightarrow \gamma \; e^+ e^-$

false "combinatorial pair"

In PHENIX:

combinatorial background factor > 250 larger than signal

Note: **ϕ and ω can be measured due to excellent mass resolution**

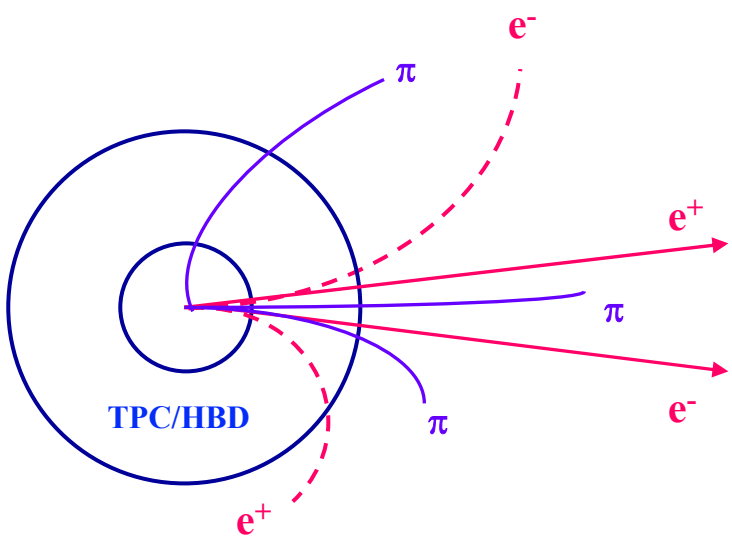
charm contribution is significant

- **need rejection of > 90% of $\gamma \rightarrow e^+ e^-$ and $\pi^o \rightarrow \gamma \; e^+ e^-$**
- **active recognition and rejection of background pairs**

Axel Drees

Strategy for Low Mass Pair Measurement

background pairs have low mass and small opening angle Θ



Opening angle not so small at collider

cut degree	rejection %	Pion pileup %	with e/π ~ 10	with e/π ~ 50
10	77	24	3	0.5
20	89	79	11	2
30	94	100	23	5
40	96	100	39	8

need e-ID to use opening angle

- Low inner B field to preserve opening angle with rough momentum measurement
- Identify signal electrons (p_t > 200 MeV) in outer PHENIX detectors
- Identify low momentum electrons (pt < 200 MeV) using Cherenkov light in Hadron Blind Detector (HBD) and/or dE/dx from TPC
- Measure momentum with TPC (few % δp/p)
- Use cuts on opening angle (or Θ < 350 mrad) and on invariant mass (m < 140 MeV) to reject background

Principle Monte Carlo Simulation

Efficiency - background rejection in ϕ mass range (20 MeV bin)

Without Dalitz rejection

S/B ~ 1/7

Assume for inner detector

- **perfect electron ID (ε_e = 100%)**
- **perfect π rejection**
- **perfect double hit resolution**

S/B ~ 10

Effect of increased acceptance

"veto region" : $|\delta\eta| < 0.40$
$\delta\phi < 100^o$

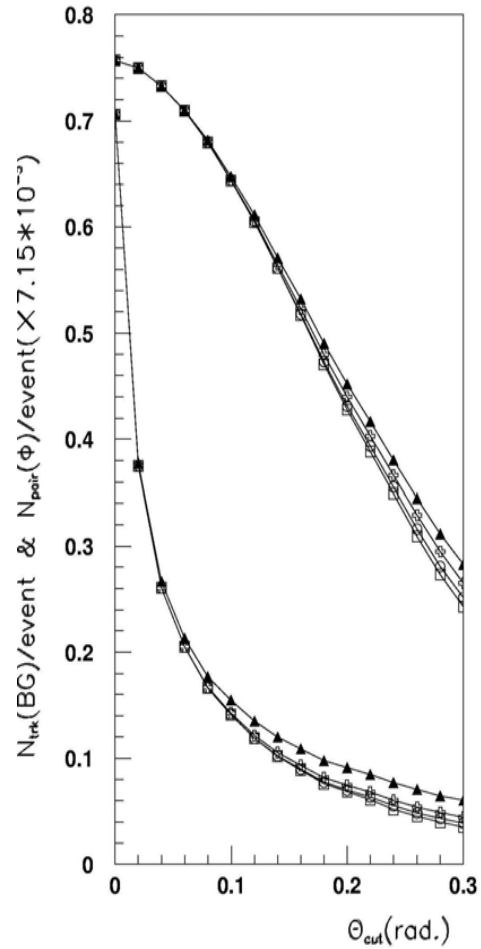
S/B ~ 30

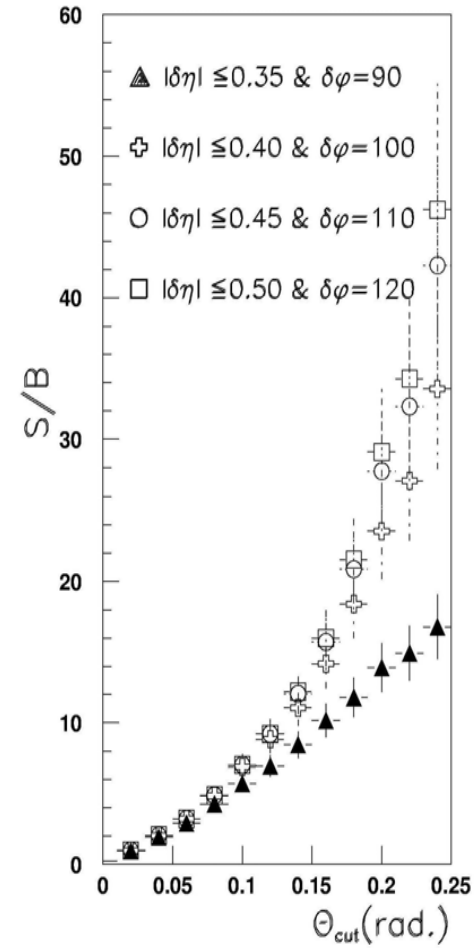
Include:

- **double hit resolution**
- **open charm contribution**

S/B ~ 1-3

Opening angle cut





+ additional rejection from mass cut

TPC/HBD Strawman Design

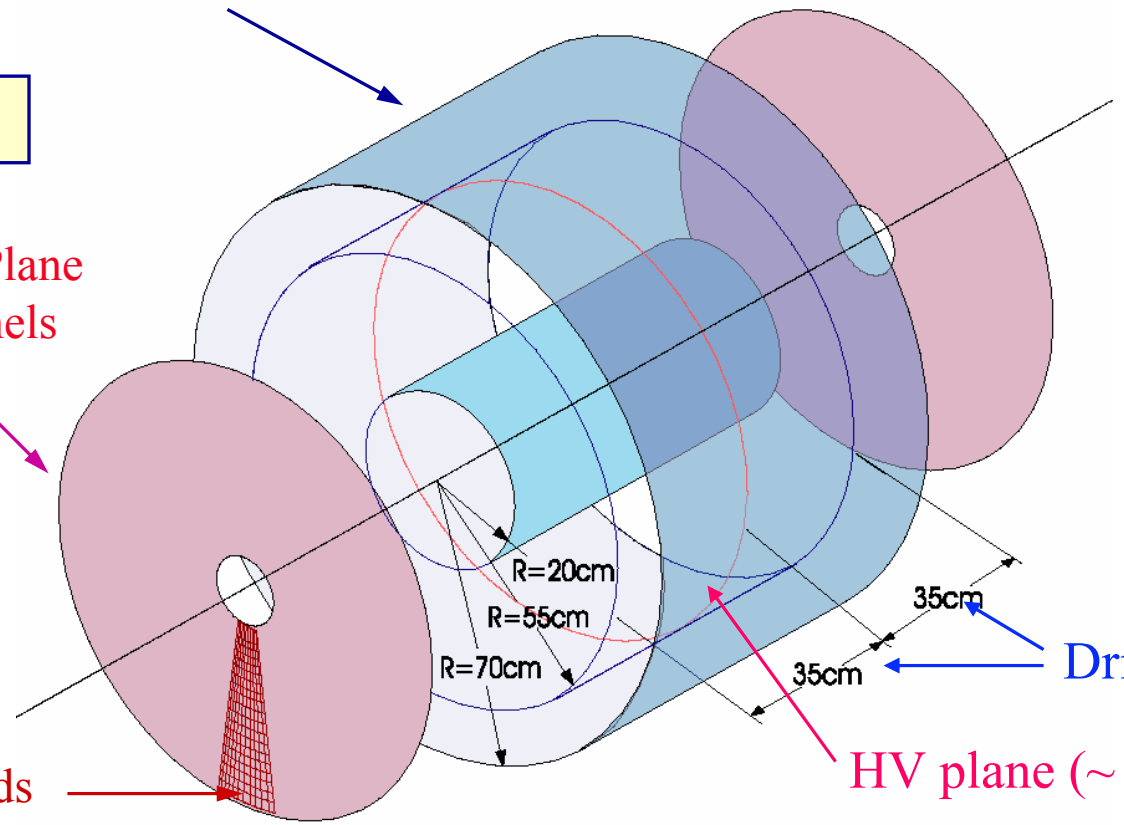
High rate capability: drift-time ~ 4 μs

CsI Readout Plane
5000-10000 channels

CF_4 or CH_4 drift gas
radiator gas
detector gas

GEM

TPC Readout Plane
~50000 channels



Drift regions

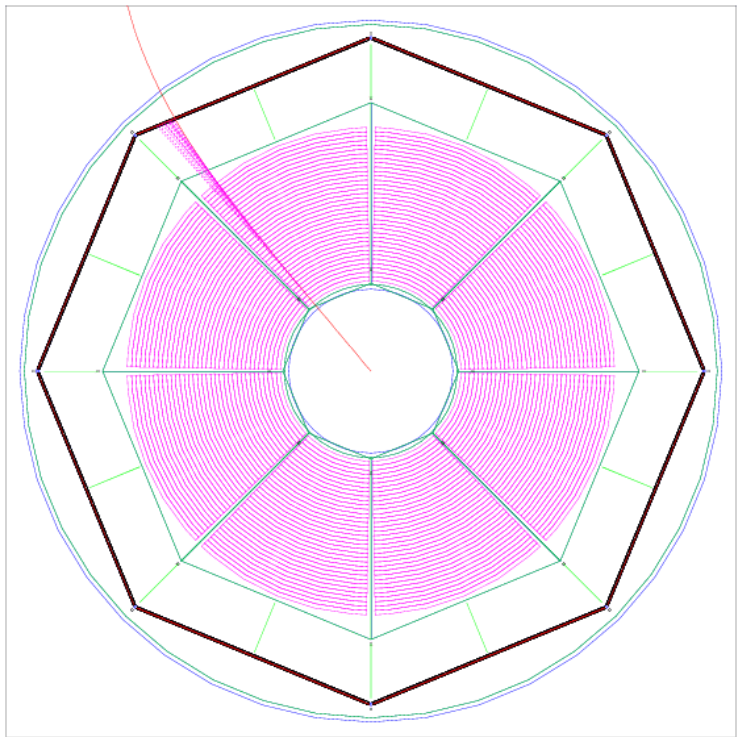
HV plane (~ -30kV)

Readout Pads
ΔR ~ 1 cm
rϕ ~ 2 mm

Need to develop integrated electronics

Monte Carlo Simulation of Hadron Blind Detector

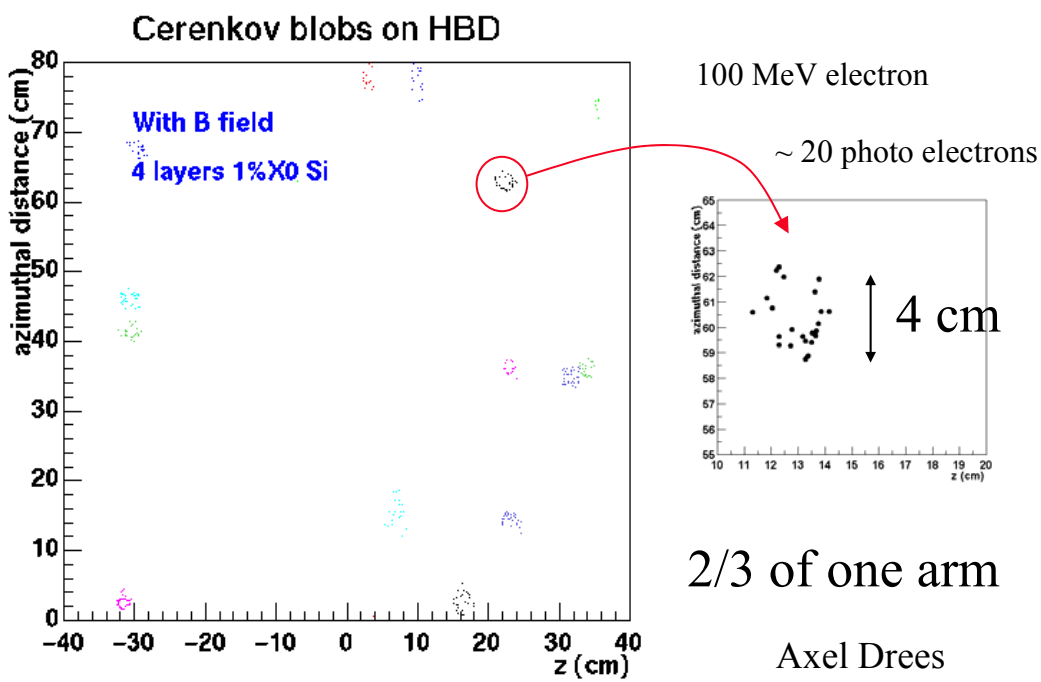
single 100 MeV electronxs



Central Au-Au collision
$dN/d\eta \sim 650$

4 layers of silicon vertex detector
$N_e \sim 25$ for one arm

~ 130 charged particle single hits
not shown



2/3 of one arm

Axel Drees

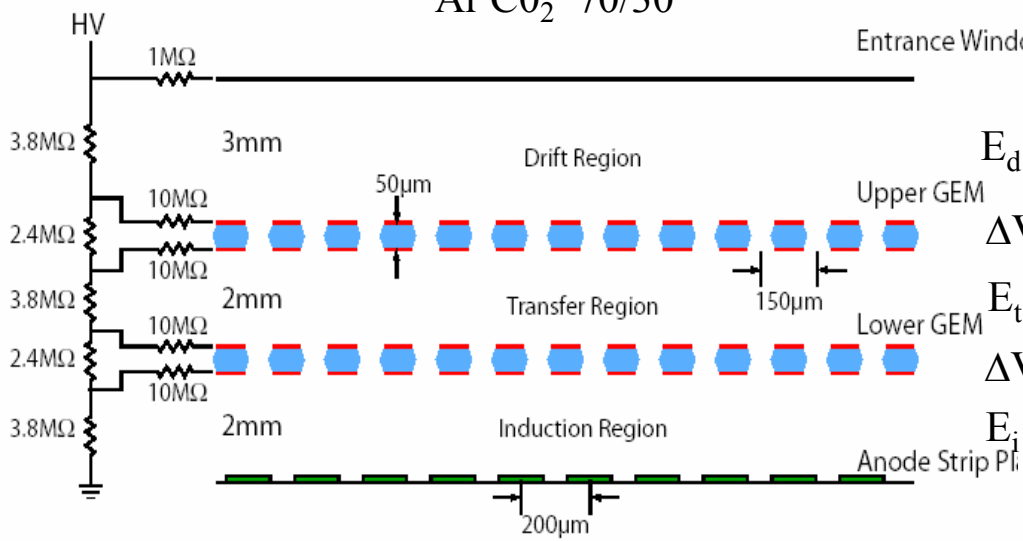
GEM Performance Studies

B.Yu, UWG, 4/16/02

Double GEM Detetor Schematic Cross Section

(with resistive divider)

Ar $C0_2$ 70/30



E_d ~200 V/cm

ΔV_{G1} ~ 260 V

E_t ~4 kV/cm

ΔV_{G1} ~ 440 V

E_i ~4 kV/cm

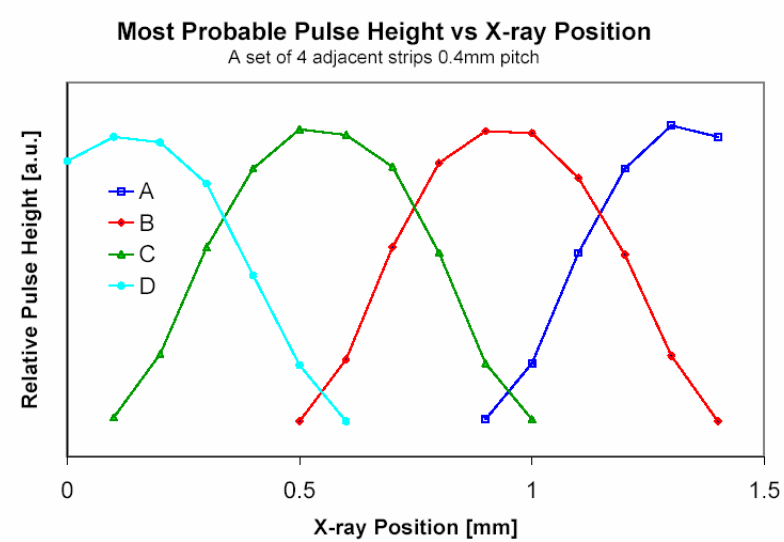
V_{GEM}~ 15% V_W

excellent spatial resolution

R&D effort at BNL/Weizmann:

- Study GEM performance
- design TPC readout plane
- develop readout electronics

- develop CsI photo-cathode
- design HBD readout plane
- develop readout electronics

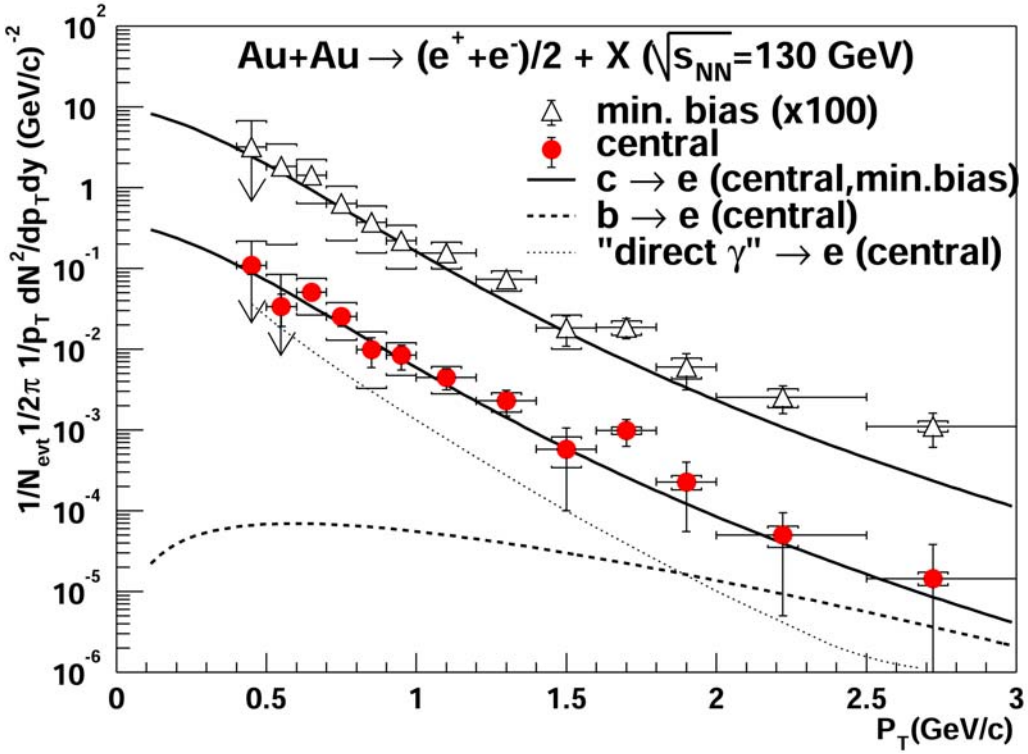


Charm and B Decays

open charm production from inclusive electrons

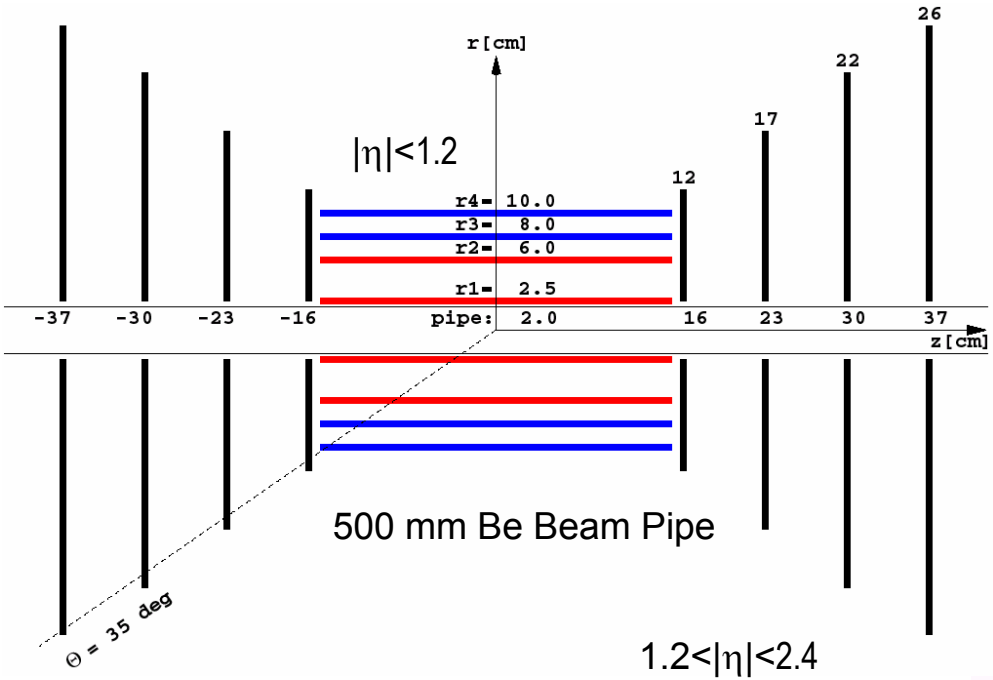
A high precision vertex detector will allow a clean separation of charm and bottom decays

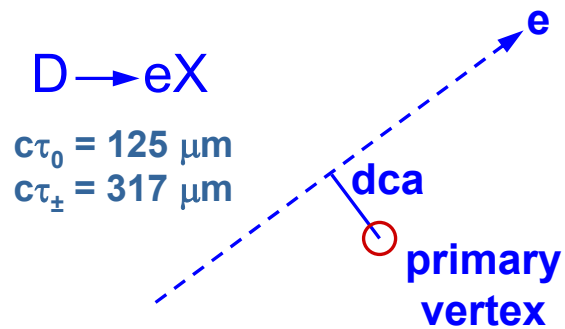
	m GeV	cτ μm	→ eX %
D^0	1865	125	6.75
$D^\pm$	1869	317	17.2
B^0	5279	464	5.3
$B^\pm$	5279	496	5.2

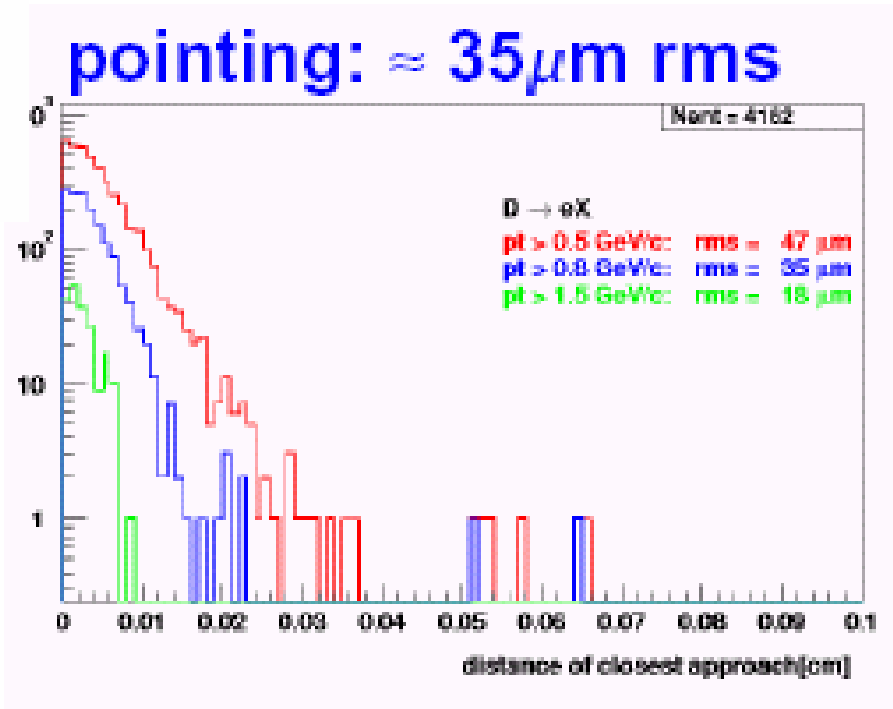


Need secondary vertex resolution
~ 30 - 50 μm

Proposed Silicon Tracker in PHENIX



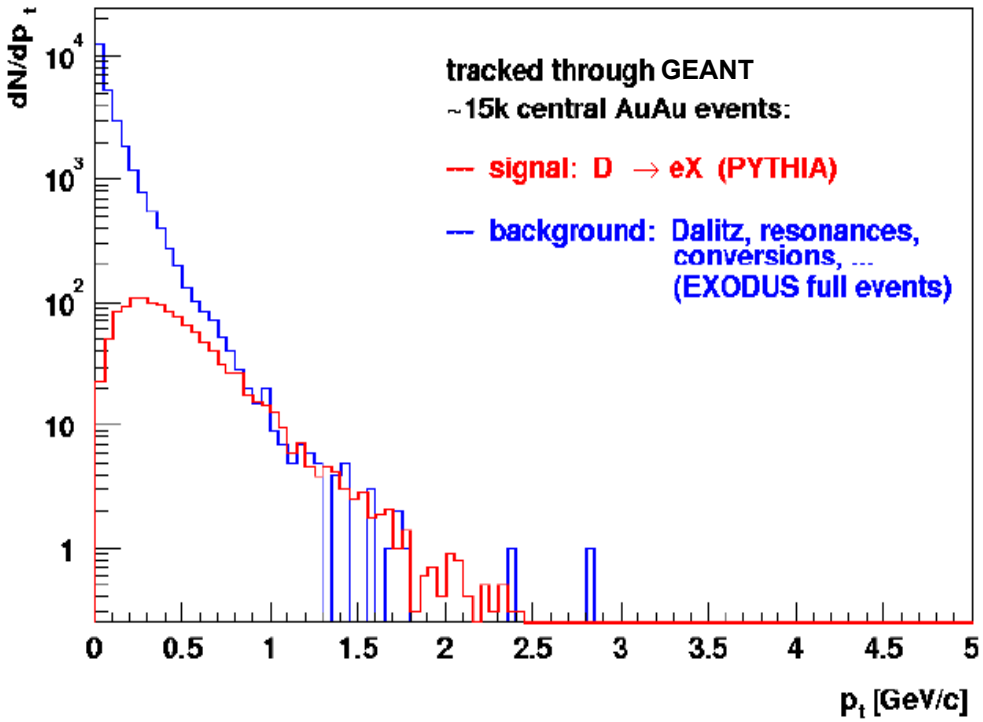




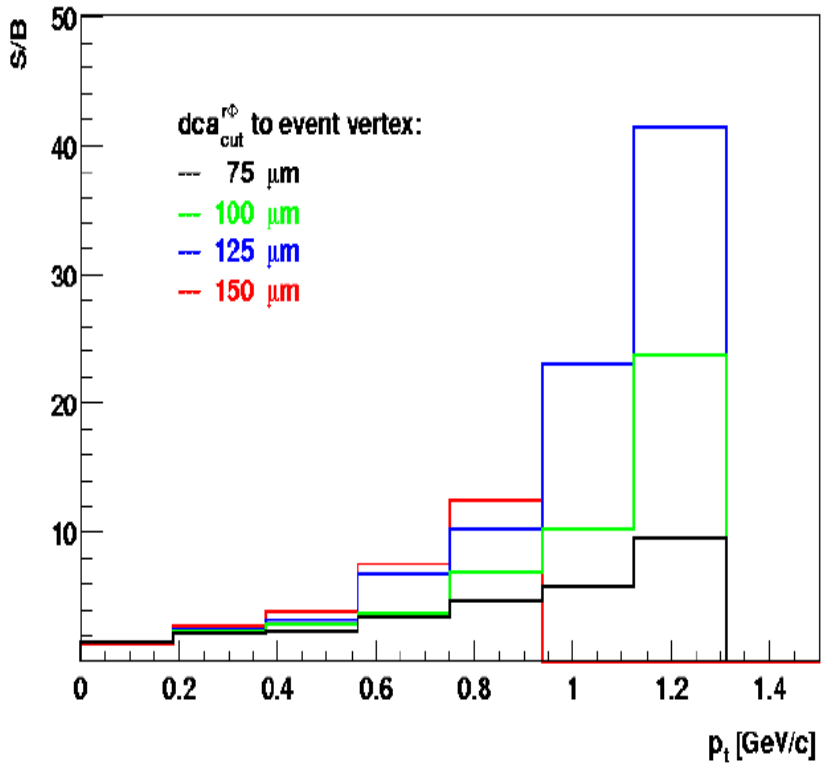
Pixel barrels (50 μm x 425 μm)
Strip barrels (80 μm x 3 cm)
Pixel disks (50 μm x 200 μm)

1.0% X_0 per layer

Signal/Background with DCA cut



S/B improves to > 10 for p_T > 1 GeV/c with DCA cut ~ 100 μm



Without cuts on displaced vertex

- **S/B ~ 1 for high-pt**
- **S/B ~ 0.1 p_T = 0.5 GeV/c**

Technology Choices for Silicon Vertex Tracker

target date for silicon barrel: 2004-2005

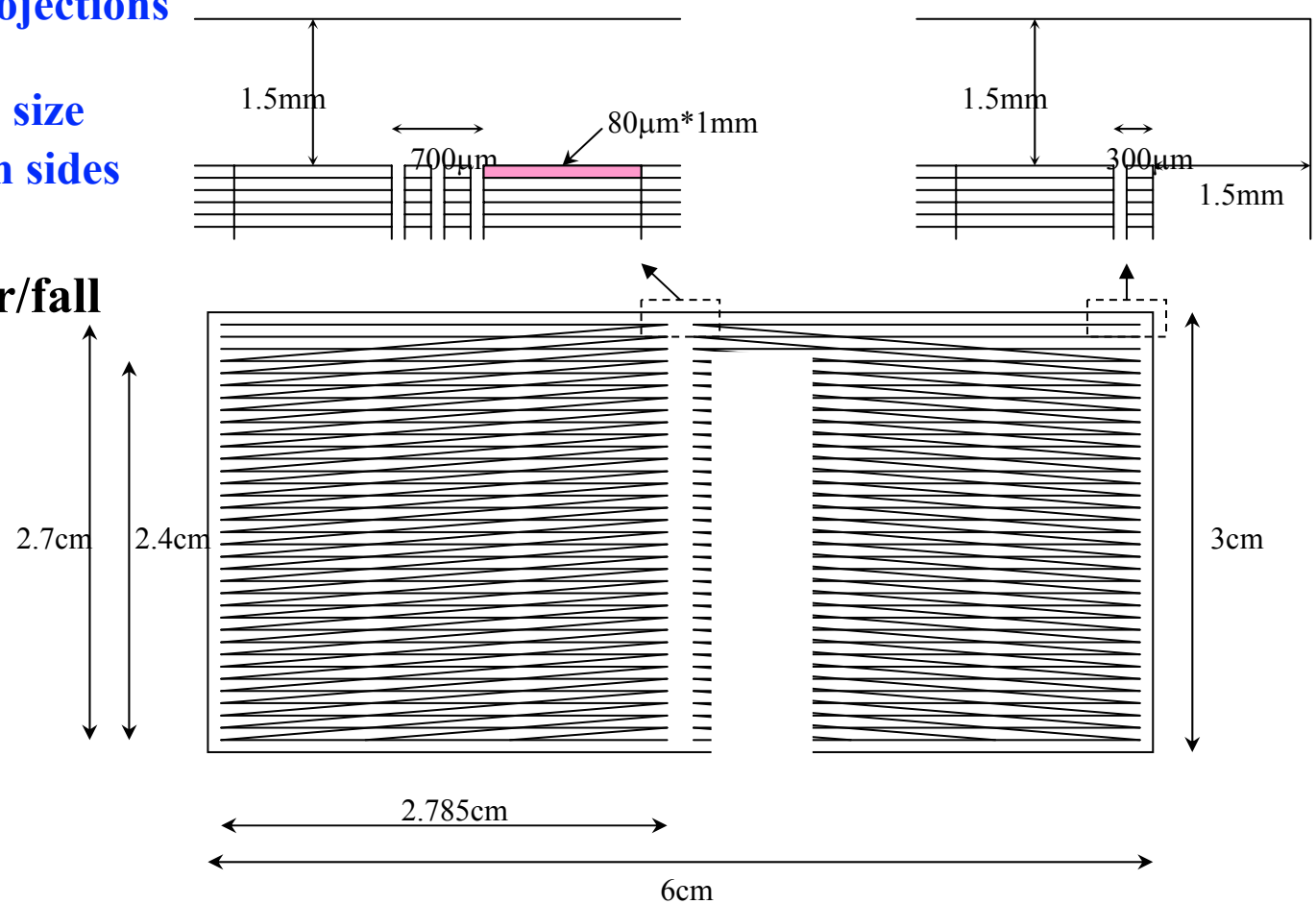
- **Silicon Strips**
  - **Prototype development at BNL**
  - **readout electronic options**

    ABCD chip (ATLAS)
    SVX4 chip (Fermilab)
    AP6 (CMS)
    ….
- **Hybrid Silicon Pixel**
  - **adapt ALICE (NA60) readout chip**
  - **R&D collaboration with NA60/ALICE**

    (two postdoc's at CERN)
  - **sensors for NA60 being developed at BNL**
- **Monolithic active pixels**
  - **Lepsi, LBL (STAR), Iowa State**
  - **longer time scale**

Silicon Strip Sensor Development

- **Prototype development at BNL**
  - 80 µm x 3 cm strips
  - 2x 375 strips
  - stereoscopic projections
  - 80 µm x 1 mm effective strip size
  - readout on both sides
  - 1500 channels
- **Tests this summer/fall**



Time Scale and Cost

2002 - Completion of Baseline Detector

Install North Muon Spectrometer
Upgrade TEC to TRD

2002-2004

Silicon strip detectors
Prototype silicon pixel detector
Prototype HBD (upgradable to TPC)
Prototype aerogel detector

2005-2007

Complete silicon pixel detectors
Complete TPC/HBD
Complete aerogel detector

R&D 2002-2005

- presently supported by various institutional funds (LDRDs,RIKEN)
- requires ~ 3-4 $M over 3-4 yrs
- needs DOE funding to continue

Construction 2004-2007

- Staged approach, with detectors requiring less R&D to be implemented first
- Rough estimate of detector construction costs ~ $10-15M
- NSAC plan shows $80M in RHIC II detector upgrades over 7 years starting in FY05