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# PHENIX Silicon Detector Upgrades

RHIC & AGS Annual Users' Meeting

Workshop 3

*RHIC Future: New Physics Through Upgrades*

27 May 2008



David L. Winter

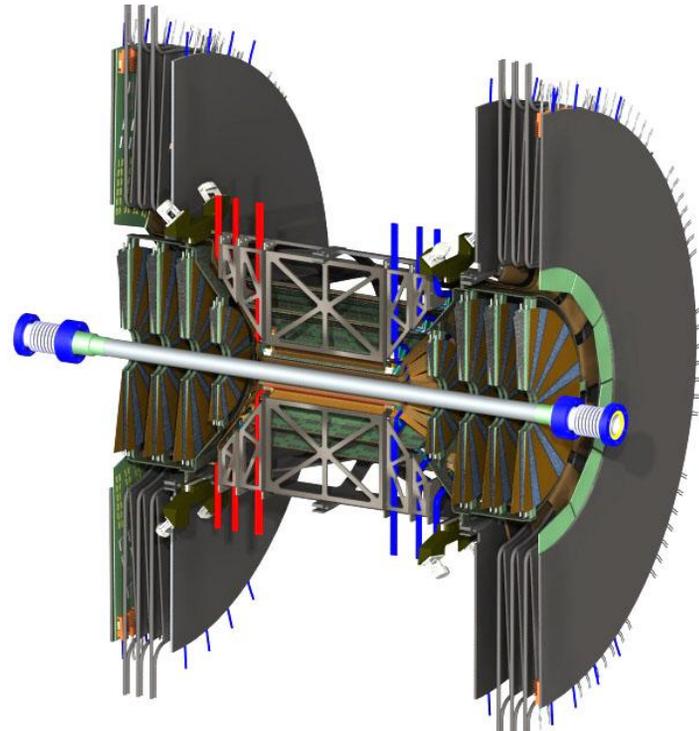
*for the PHENIX Collaboration*



COLUMBIA UNIVERSITY  
IN THE CITY OF NEW YORK



- Motivation
- Design
- Schedule and Status
- Summary



# Motivation

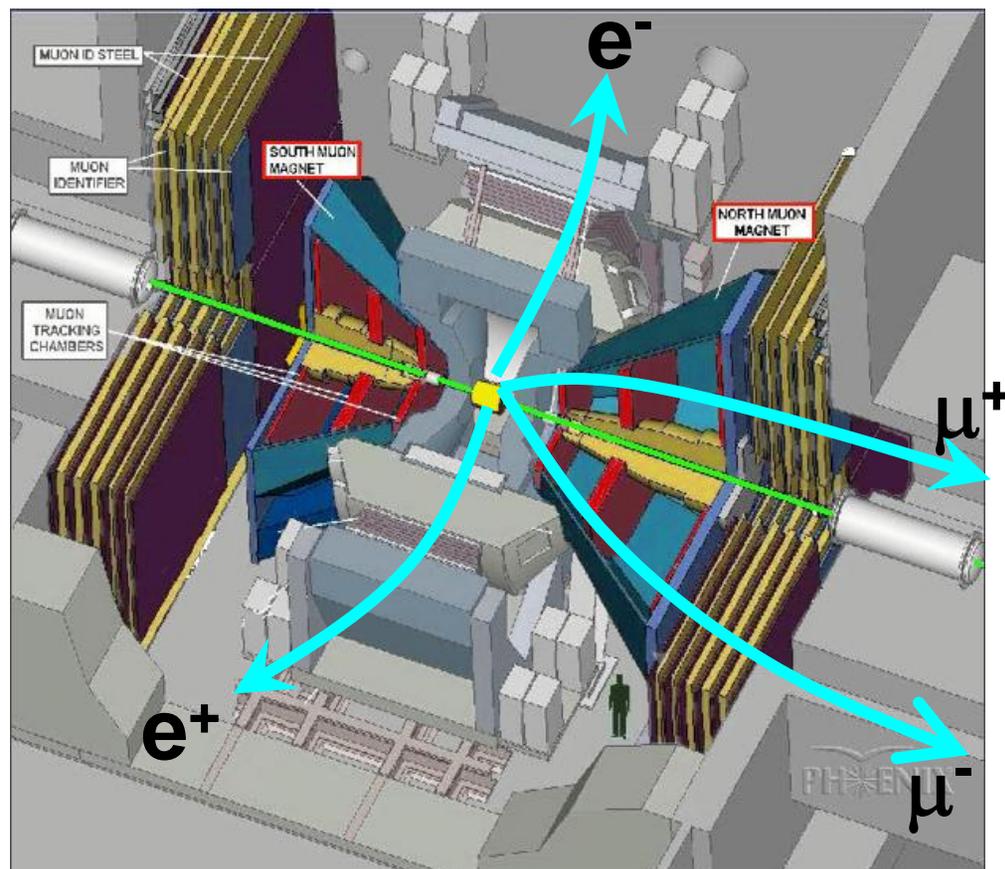
- Improve vertex resolution
- Improve  $p$  resolution
- Improve high- $p_T$  tracking
- Measure reaction plane
- Suppress background

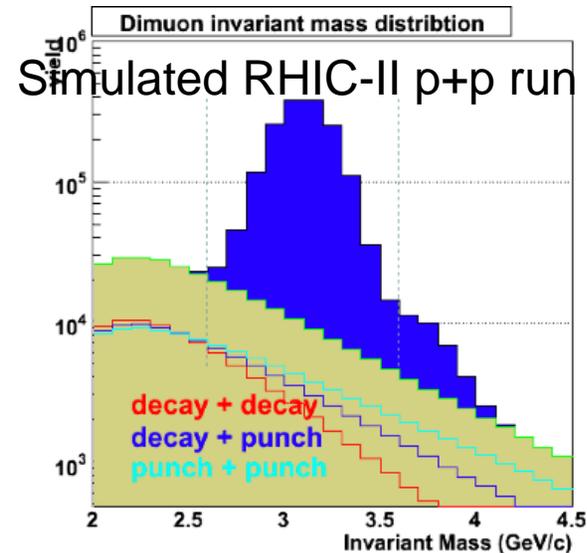
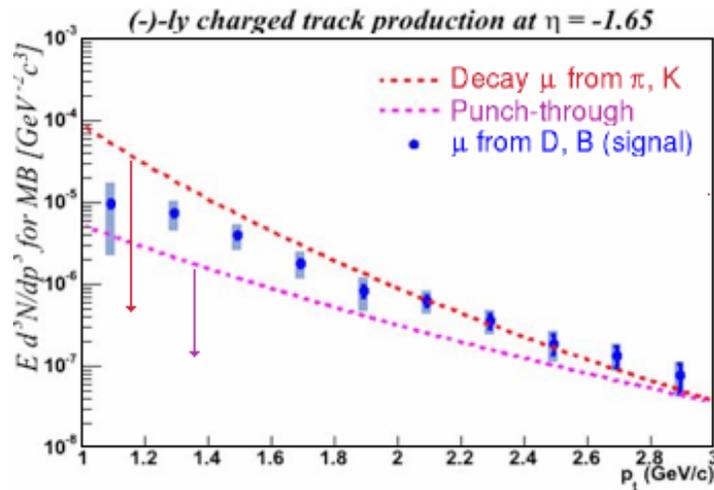
## Enabling:

- Separate measurement of production and flow of charm and beauty
- Study of production and suppression of quarkonia
- Study of  $q, g$  contribution to proton spin

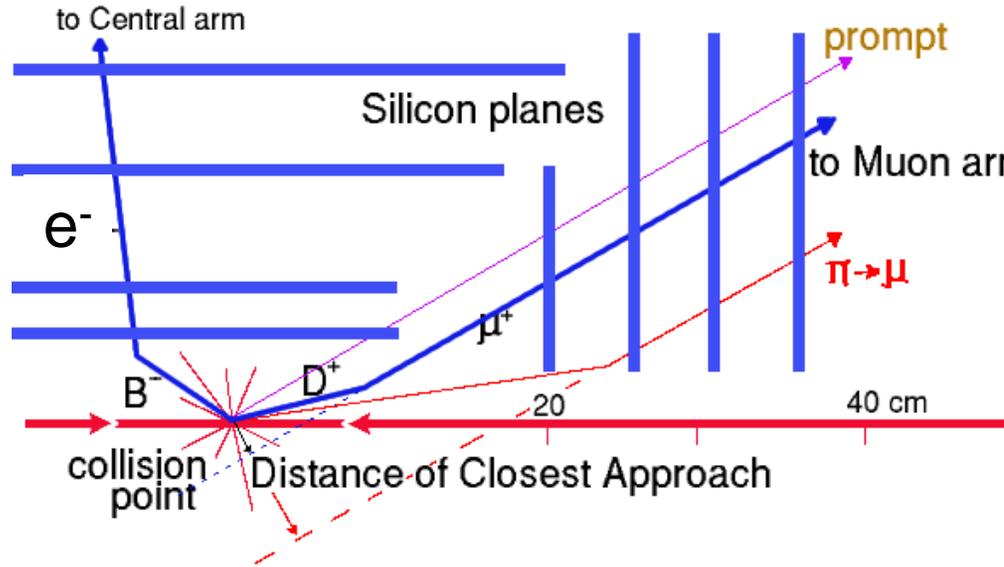
## Using signals:

- $b \rightarrow B \rightarrow \mu, e$
- $c \rightarrow D \rightarrow \mu, e$
- $J/\Psi, \Psi' \rightarrow \mu^+\mu^-, e^+e^-$
- Hadrons





- The problem(s):
  - Backgrounds ( $\pi, K \rightarrow \mu, e$ ) dominate the signal
- Cannot easily distinguish single leptons from those produced from charm, bottom
  - Central arms: electrons
  - Forward arms: muons



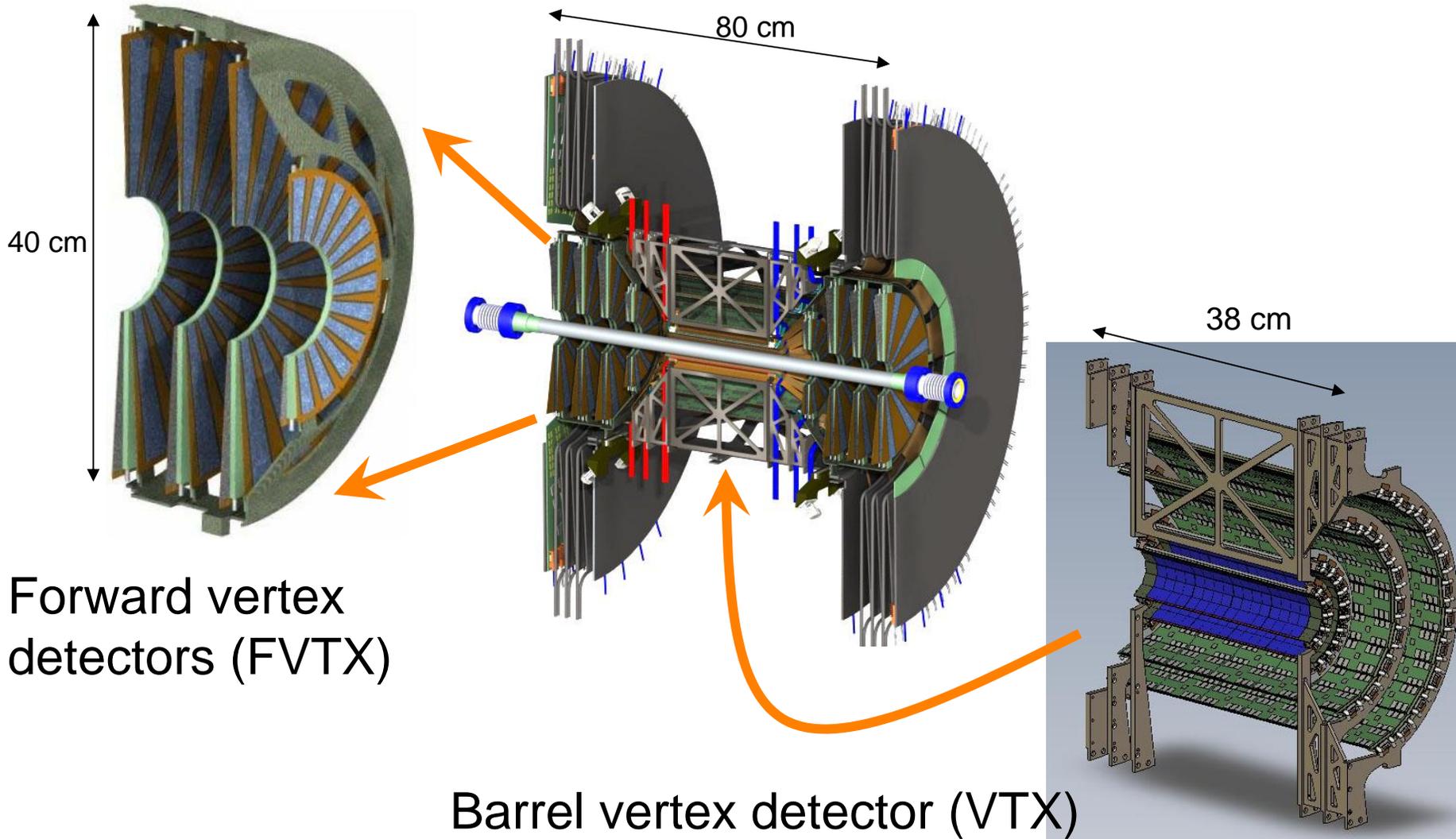
	$c\tau$ :	
$D^0$	125 $\mu\text{m}$	$B^0$ 464 $\mu\text{m}$
$D^\pm$	317 $\mu\text{m}$	$B^\pm$ 496 $\mu\text{m}$
$K^\pm$	3.7 m	$\pi^\pm$ 7.8 m

- Mean  $\pi$ ,  $K \rightarrow \mu$ ,  $e$  decay distance is large
- $D$ ,  $B$  mesons travel some distance before semileptonic decay to  $\mu$  or  $e$
- Prompt  $\mu$ ,  $e$  have 0 DCA

Separate  $D$ ,  $B$  decays from prompt leptons and from long-lived decays from  $\pi$ ,  $K$  by measuring the DCA to the primary vertex

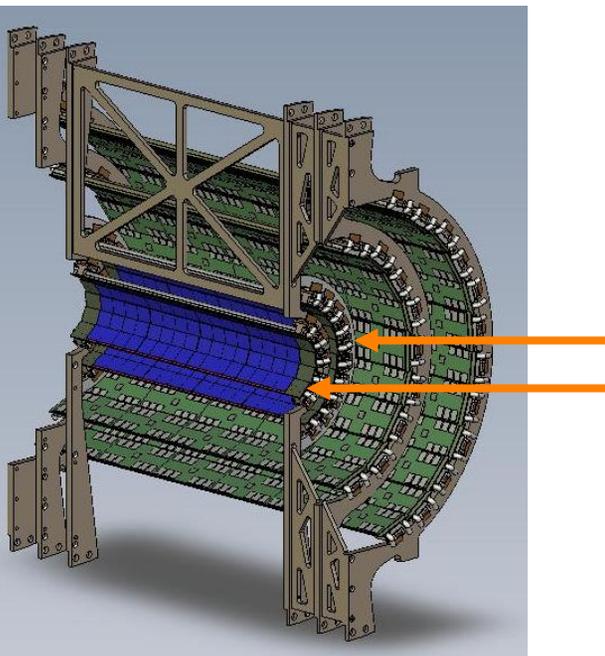
# Design

- Need sufficient DCA resolution
  - Central:  $\sim 50 \mu\text{m}$
  - Forward:  $\sim 100 \mu\text{m}$
- Need low enough occupancy to find tracks in central AuAu events (<few %)
- Need enough hits to reconstruct a track ( $\geq 3$  hits)
- Need to match tracks with
  - Central arm detectors:  $|\eta| = 0.35$
  - Muon system:  $|\eta| = 1.2 - 2.4$
- Large solid angle coverage



# Barrel Pixels (Layers 1 & 2)

- 2 Pixel buses per ladder
  - 30 ladders in 2 cylinders
- Pixels:  $50 \times 425 \mu\text{m}^2$
- $150 \mu\text{m}$  - thick Silicon
- $R = 2.5$  and  $5.0$  cm
- Length = 22 cm
- Readout:
  - 1.3 and 2.6M channels
  - ALICE1LHCb chip
  - Full bus readout in  $\sim 50 \mu\text{s}$
  - Fast-OR available for Lvl-1 trigger
- Rad Len 1.44% total

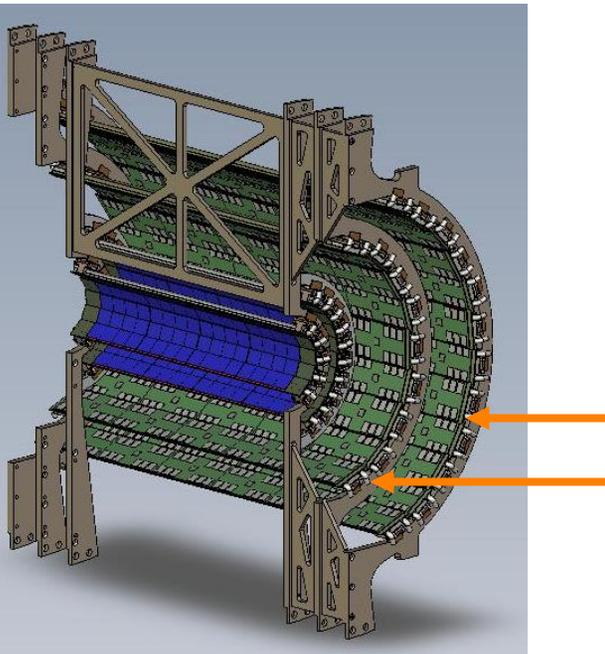


Ladder

SPIRO Board

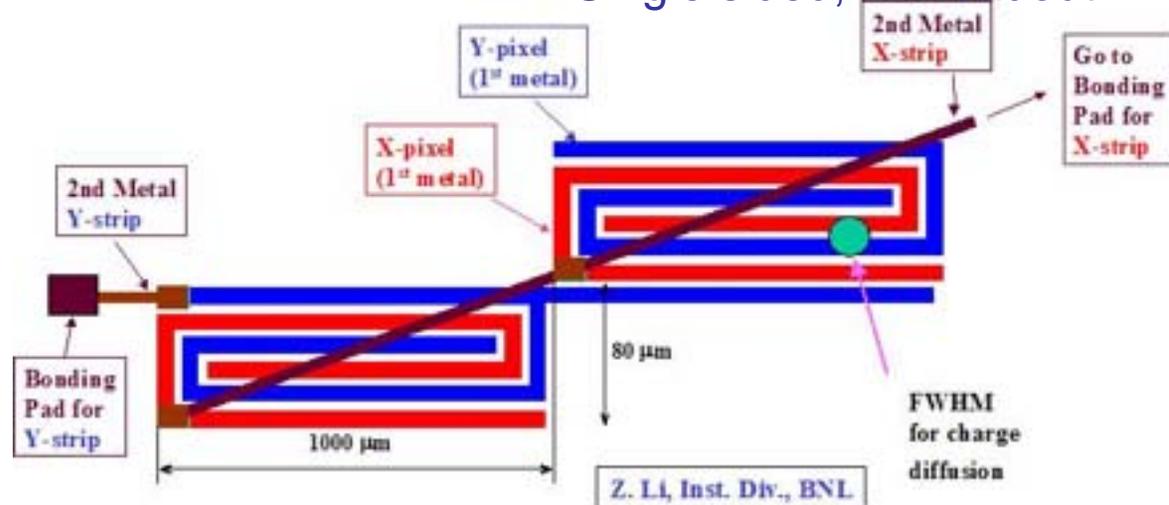
# Barrel Stripixels (Layers 3 & 4)

- Based on sensor design by BNL Instrumentation
- Effective pixels:  $80 \times 1000 \mu\text{m}^2$
- $650 \mu\text{m}$  - thick Silicon
- $R = 10$  and  $14 \text{ cm}$
- 44 Total ladders
- Length =  $32$  and  $38 \text{ cm}$
- 140K and 280K channels
- Readout with SVX4 chip
- Rad Len 2.7% total

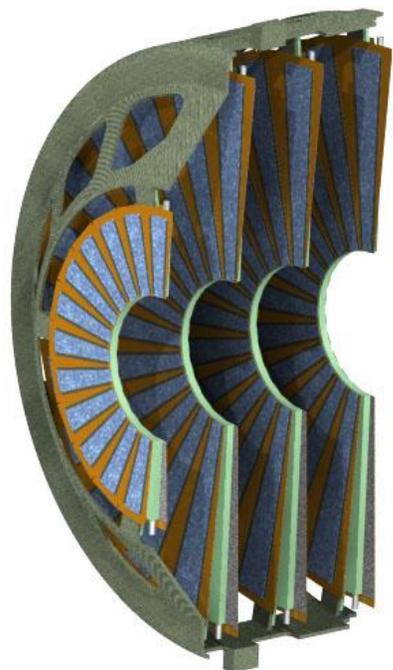


Strip pixel sensor wafer made by HPK

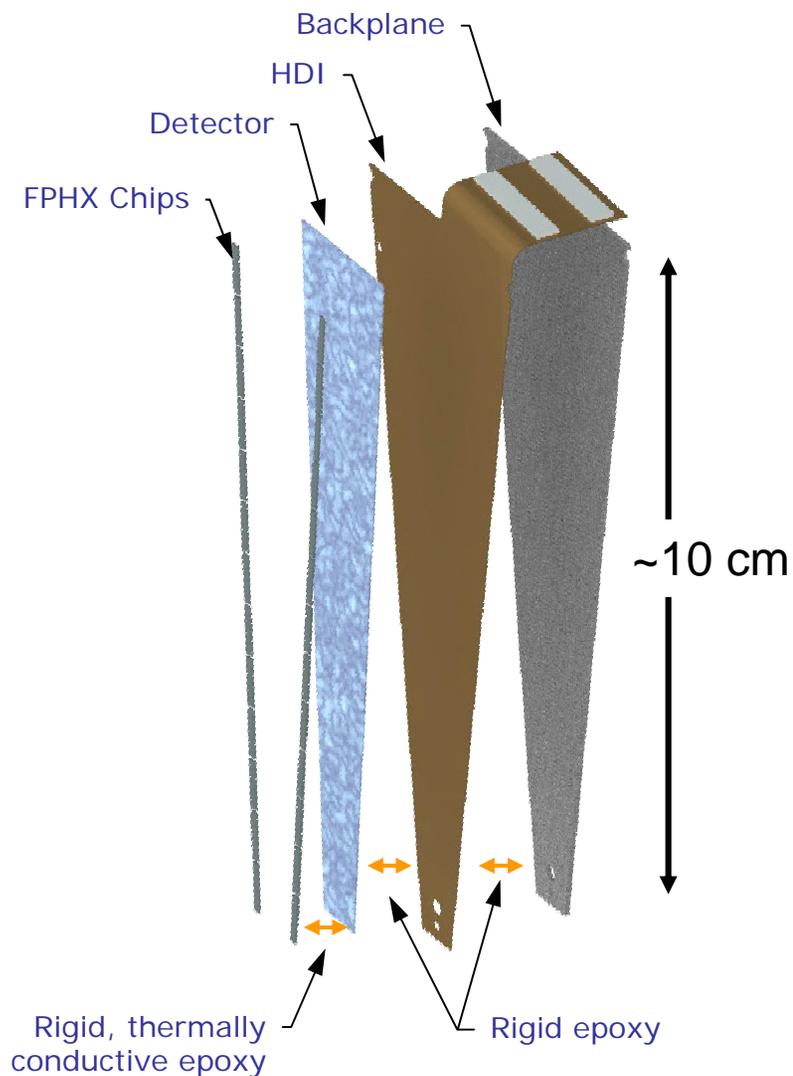
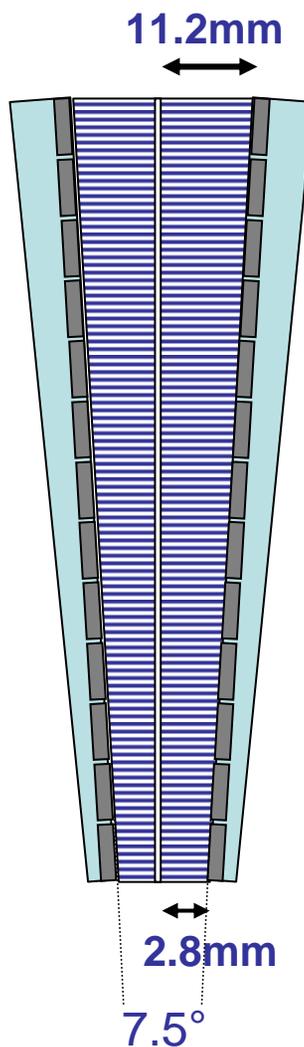
Single sided, 2D readout



# Endcap Strips (Eight Stations)

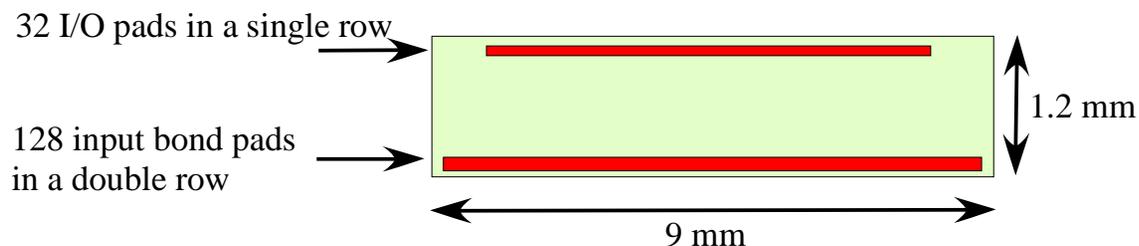


- 4 disks / side
- 48 wedges/disk
- 75  $\mu\text{m}$  strips,
- 2.8-11.2 mm long
- 1664 strips/column
- 1.1M channels total
- Readout with FPHX chip

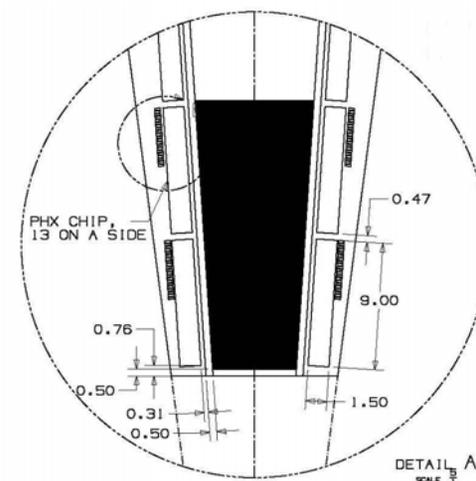


# Endcap Readout: FPHX chip

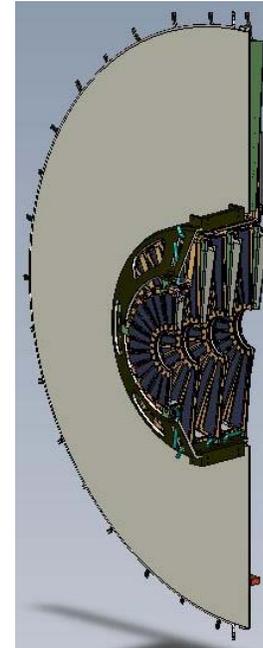
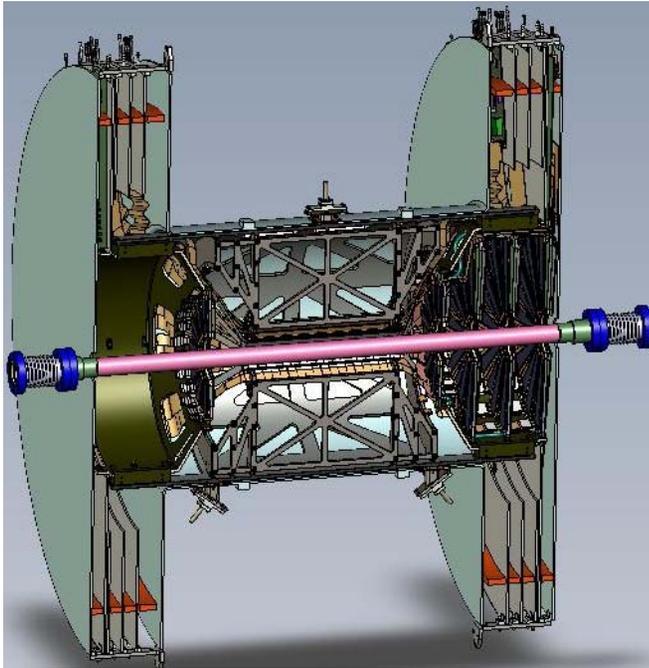
Development by FNAL,  
Based on FPIX design  
from BTeV



- 128 Channels (strips)
- Signal polarity: positive (holes)
- Gain at shaper output: 50 mV/fC
- 3-bit ADC
- Nominal peaking time: 60 ns
- Noise:  $110e + 196 e/pF$
- Data push architecture
- Output 4 hits in 4 beam clocks
- Power:  $\sim 600 \mu W$  per channel for maximum input transistor bias current



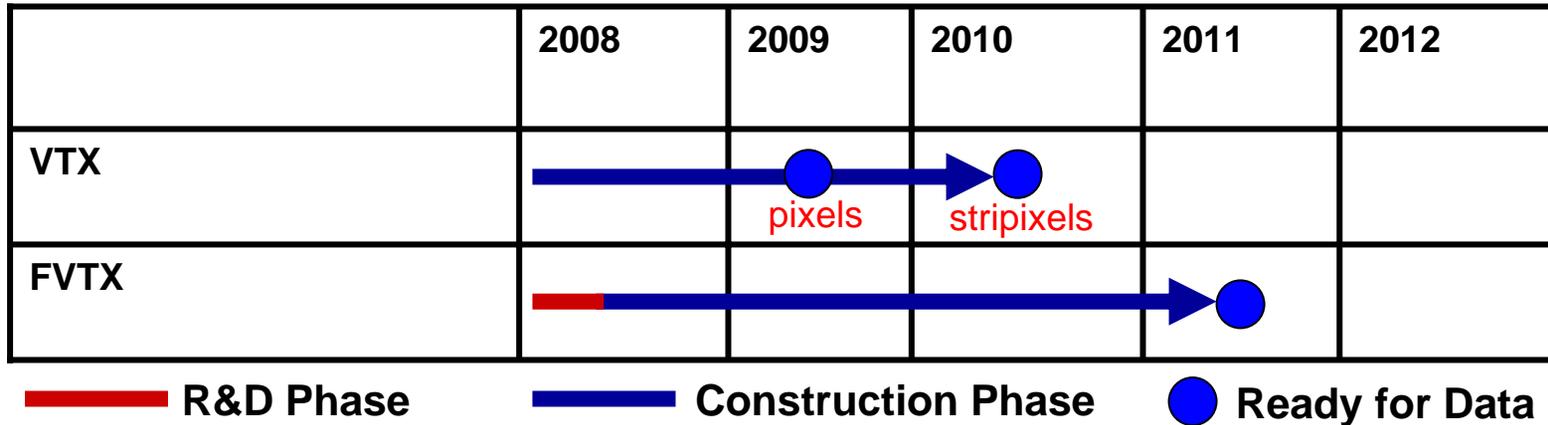
FPHX placement on wedge



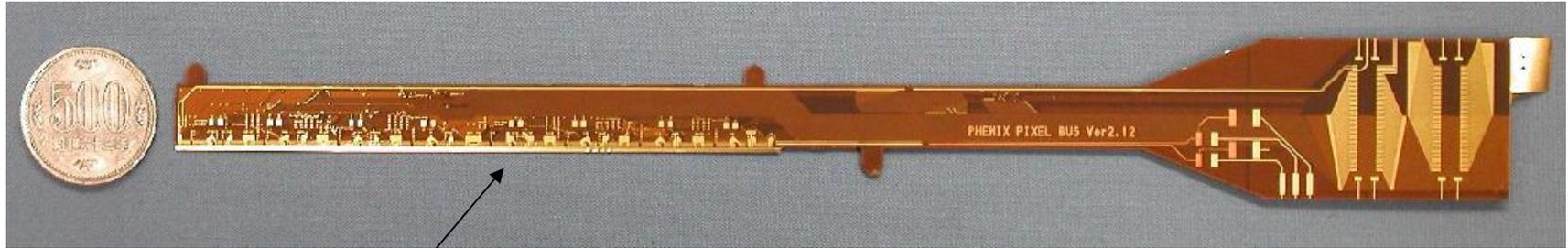
FVTX  
Big  
Wheel

- Single integrated VTX-FVTX mechanical structure being designed by HYTEC
- Two half-cylinder shells
- Services routed top/bottom (VTX) and out ends (FVTX)
- Electronics mounted on “big wheel(s)”
- New, smaller diameter beam-pipe

# Schedule and Status

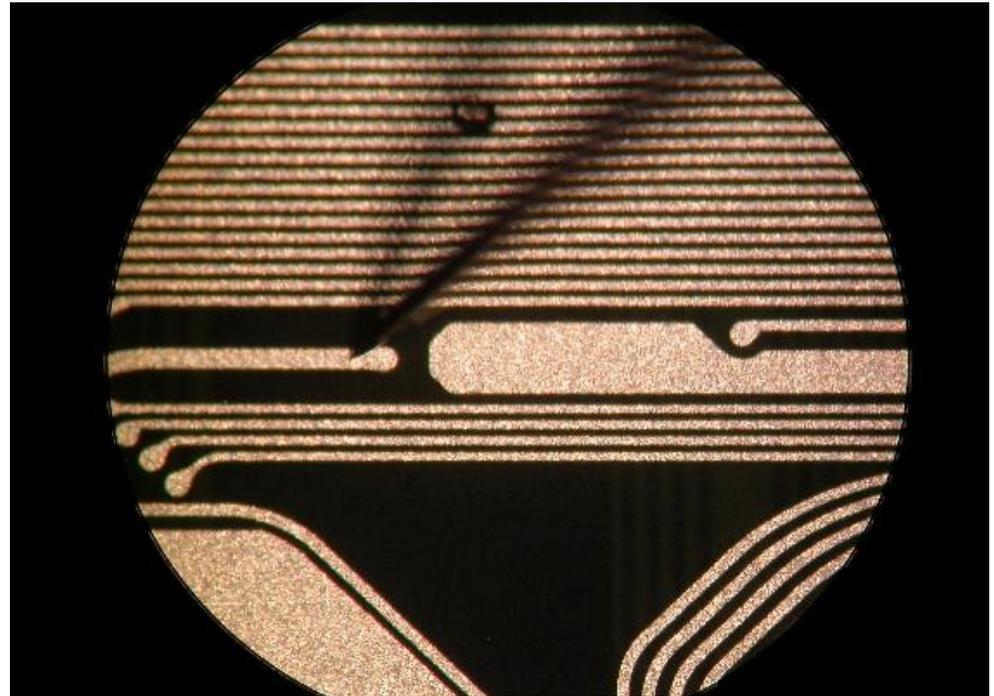


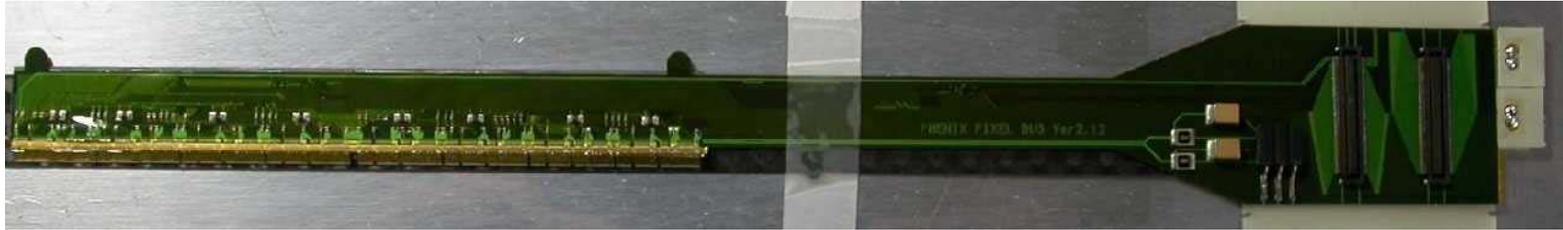
- Barrel construction well underway
  - pixel layers completion in 2009
  - stripixels completion in 2010 (first ladders)
- Forward detector construction started in FY08, installation to be in 2011



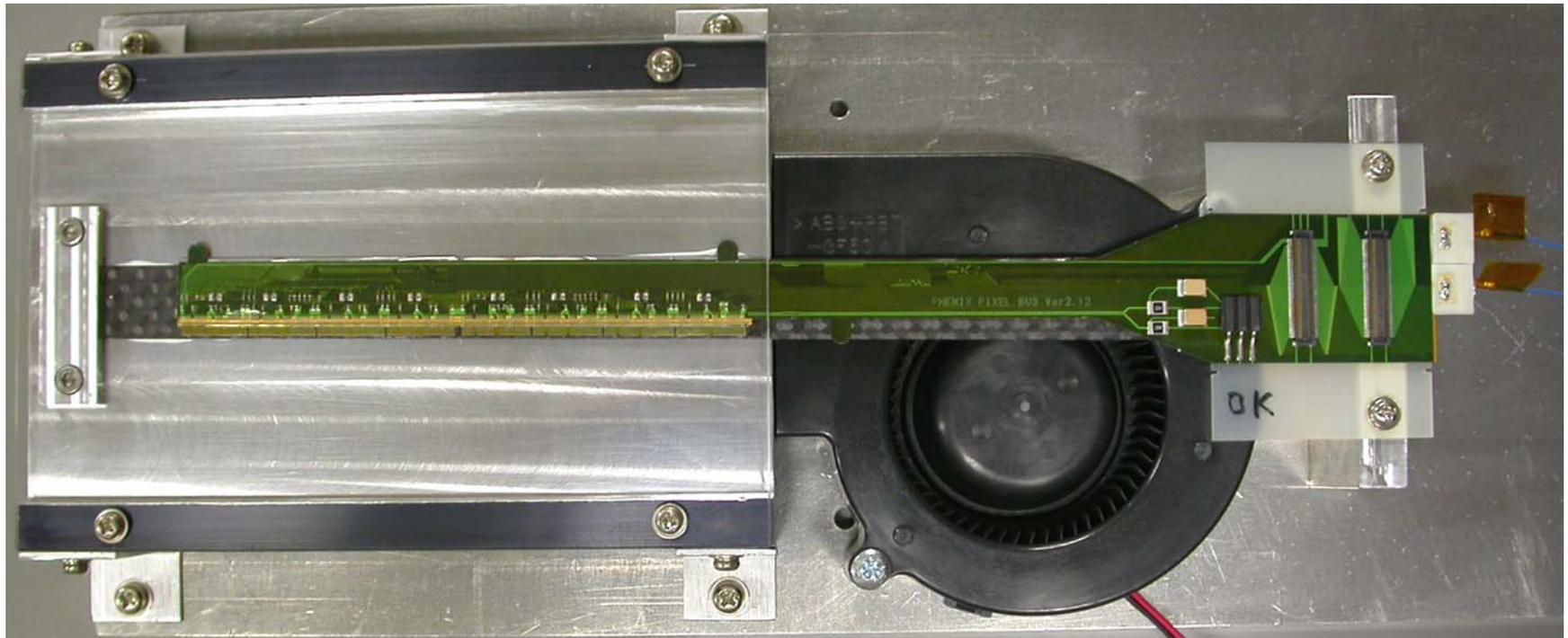
1.5cm bus before assembly

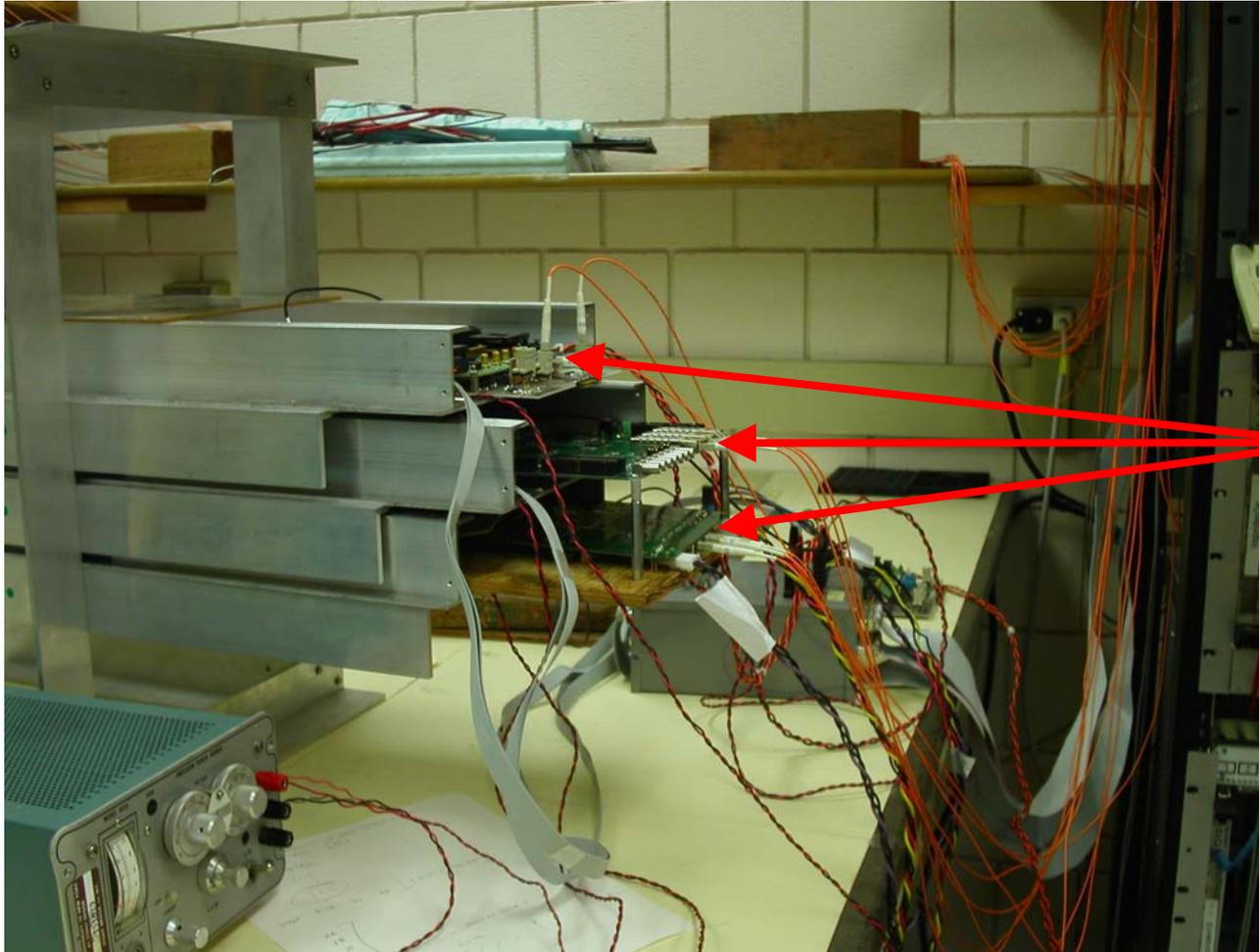
Fine pitch detail of the bus





Assembled Ladder

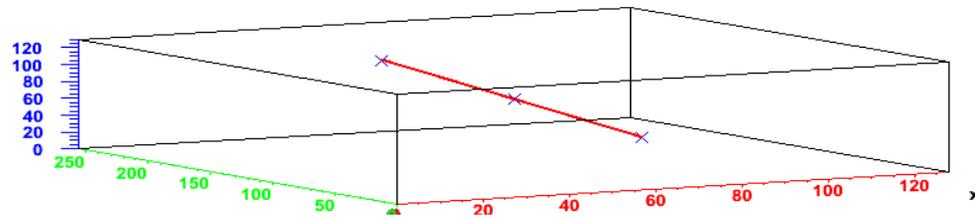
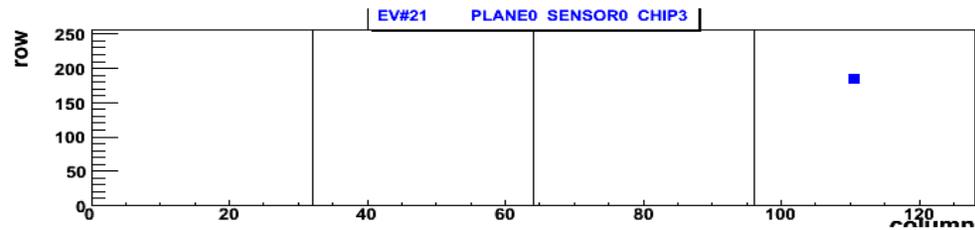
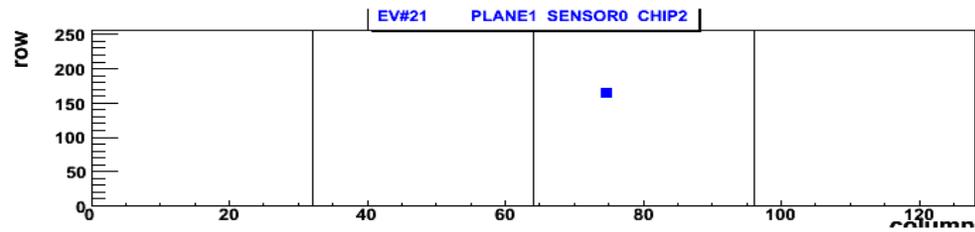
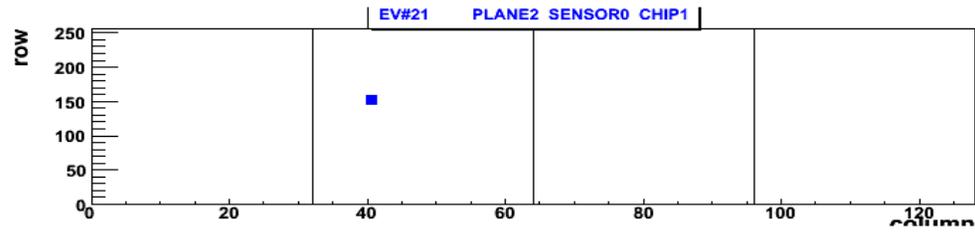




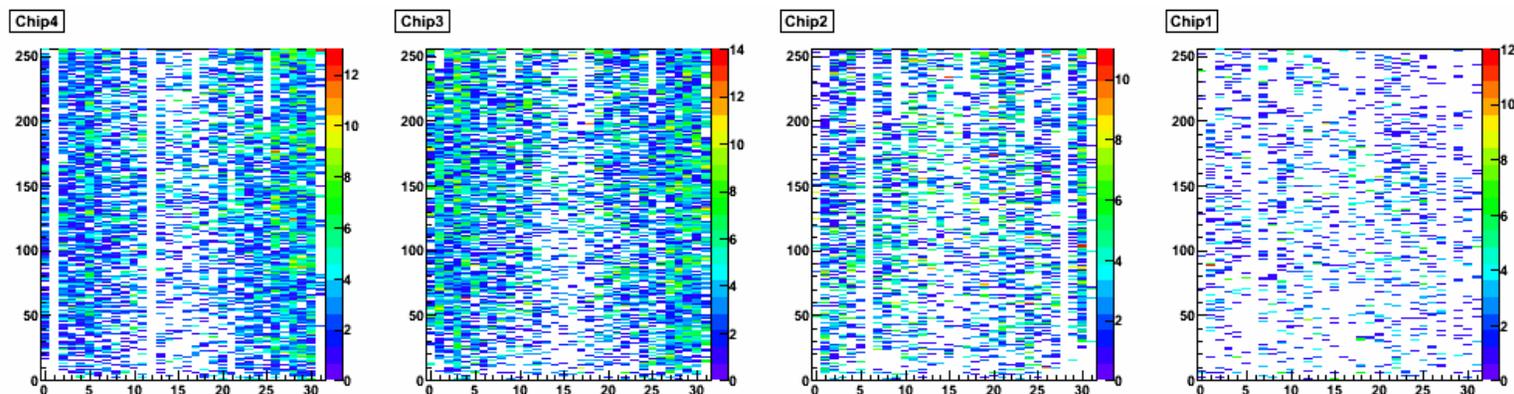
Ladders and  
SPIRO Boards

# Pixel Bus Cosmic Ray Tests

- Cosmic Ray telescope with 3 pixel buses
- Both external trigger and fast-OR trigger
- Used complete readout chain.
- Last test- Sept. '07



- Use source to illuminate sensor module on 1/2-ladder
- Self-trigger using readout chip Fast-OR
- 100K events

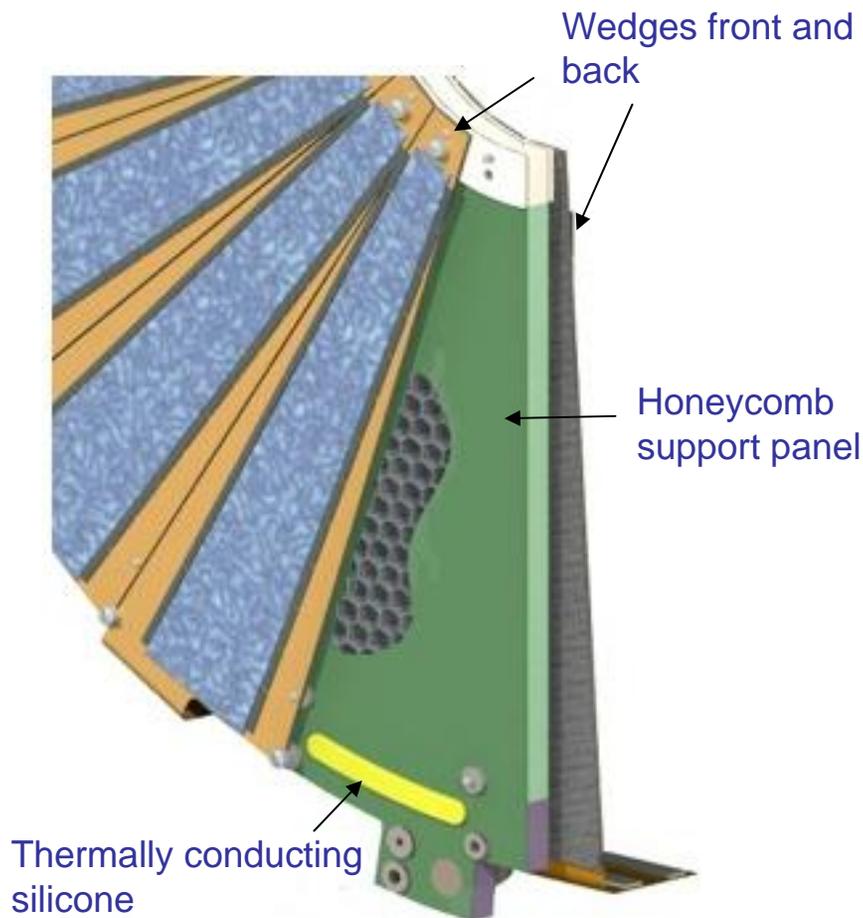


- PIXEL Ladders:

- Cosmic ray events observed, Sept '07
- Ladder production to start in 2008
- 2 Barrels ready for installation in 2009, Run 10

- STRIPIXEL Ladders:

- Readout-Card Prototyping in progress.
- First Ladders ready for installation in 2010, Run 11
- Full detector ready in 2011, Run 12

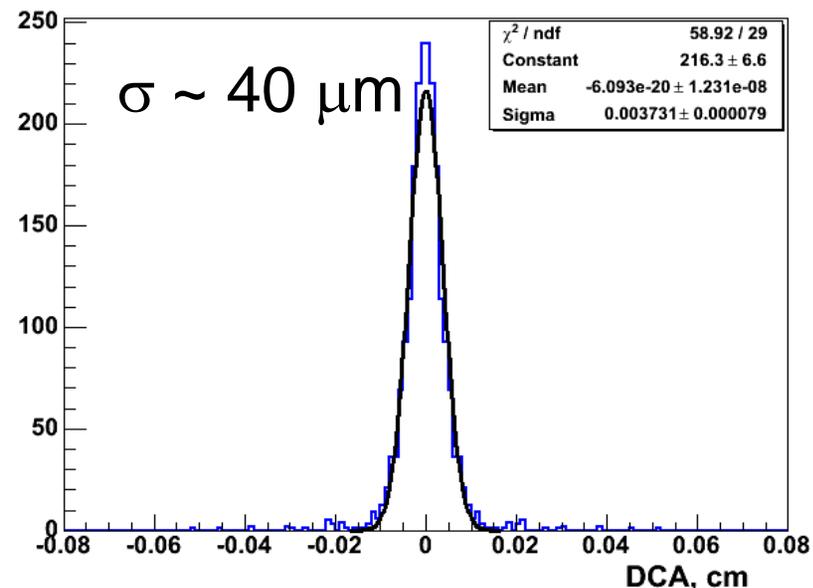
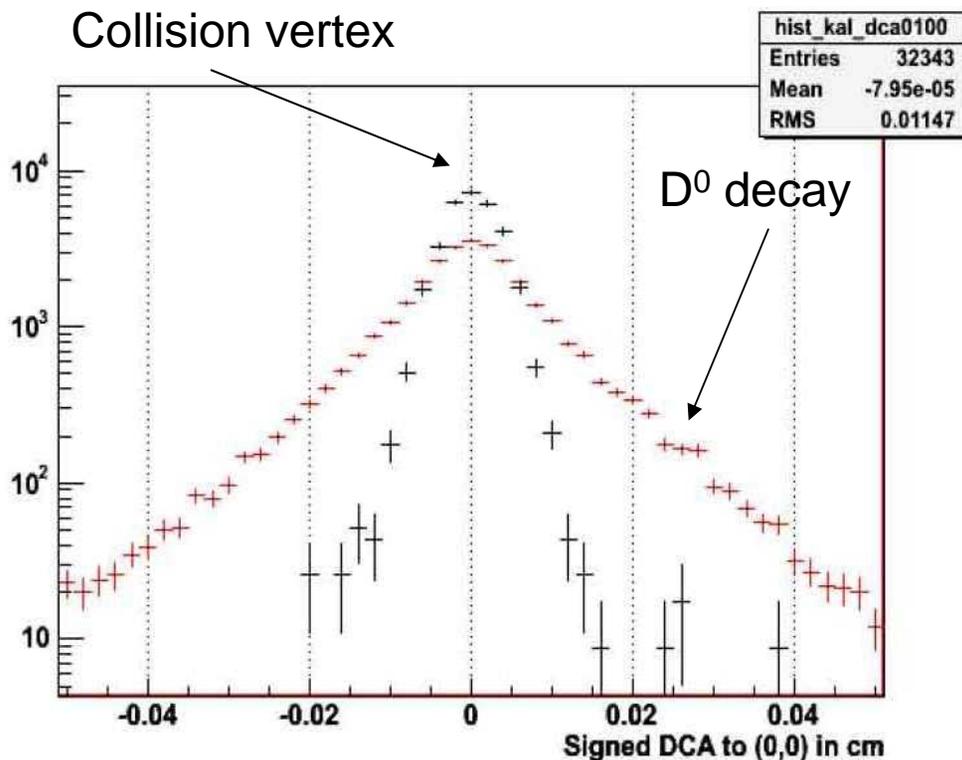


## Prototype DAQ Electronics



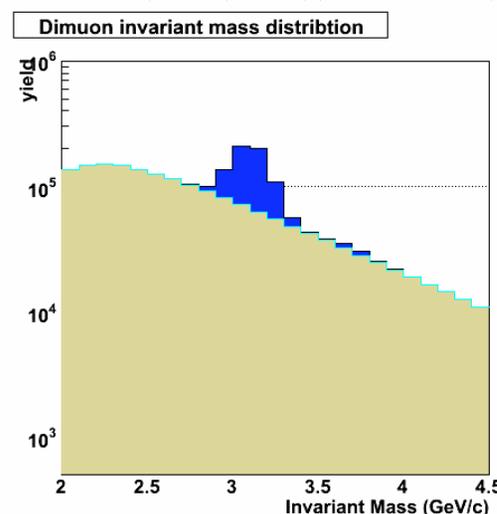
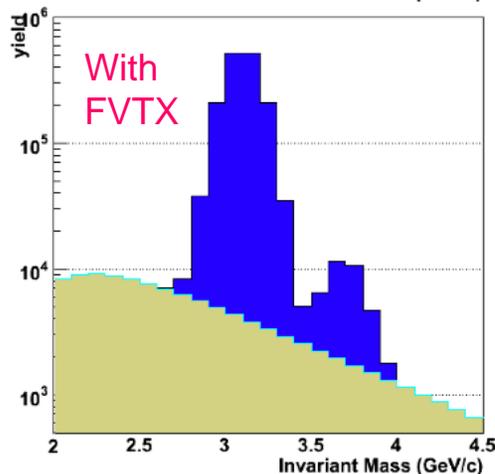
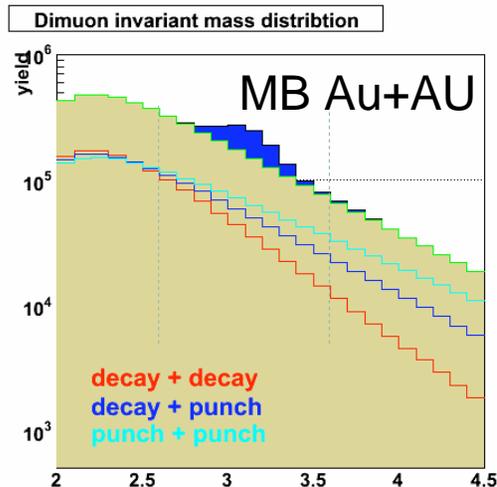
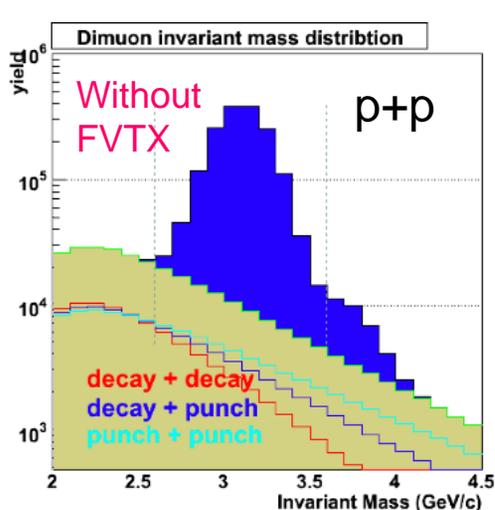
- Mechanical design ~ 80% complete
- First prototype FPHX submission is very soon (June)
- HDI under development
- DAQ readout electronics have been prototyped

Collision vertex

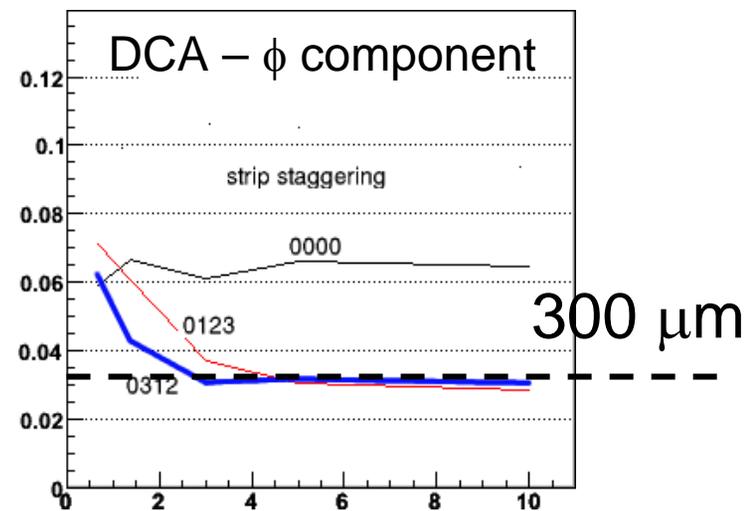
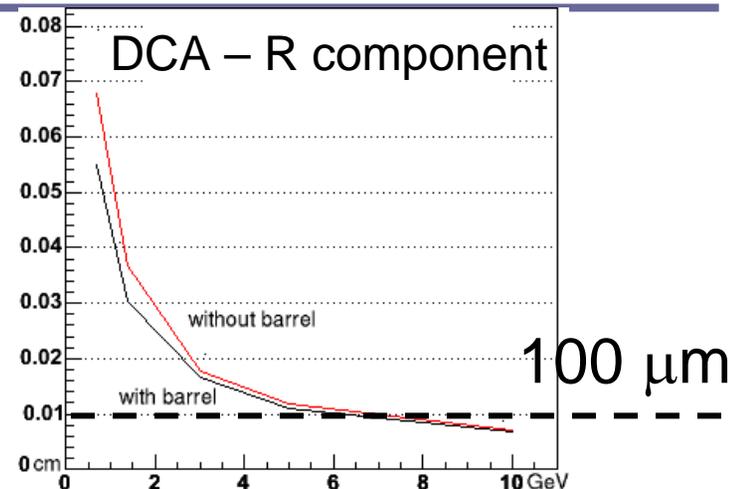


- Simulated Au+Au
- After  $\chi^2 < 1$  cut, DCA distributions of light hadrons and  $D^0$  decay are clearly separated

- Single  $\pi$  with  $3 < p_T < 4$
- 200  $\mu$  thick pixel layers
- 650  $\mu$  thick stripixel layers
- Passive material is:
  - 1.0% pixel
  - 2.75% stripixel

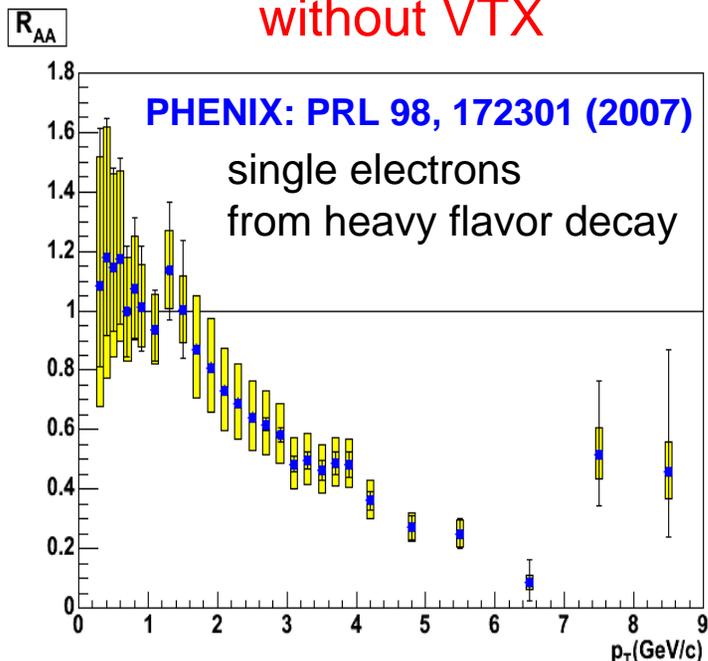


- improved background rejection
- Improved mass resolution
- Separate  $\psi$ ,  $\psi'$

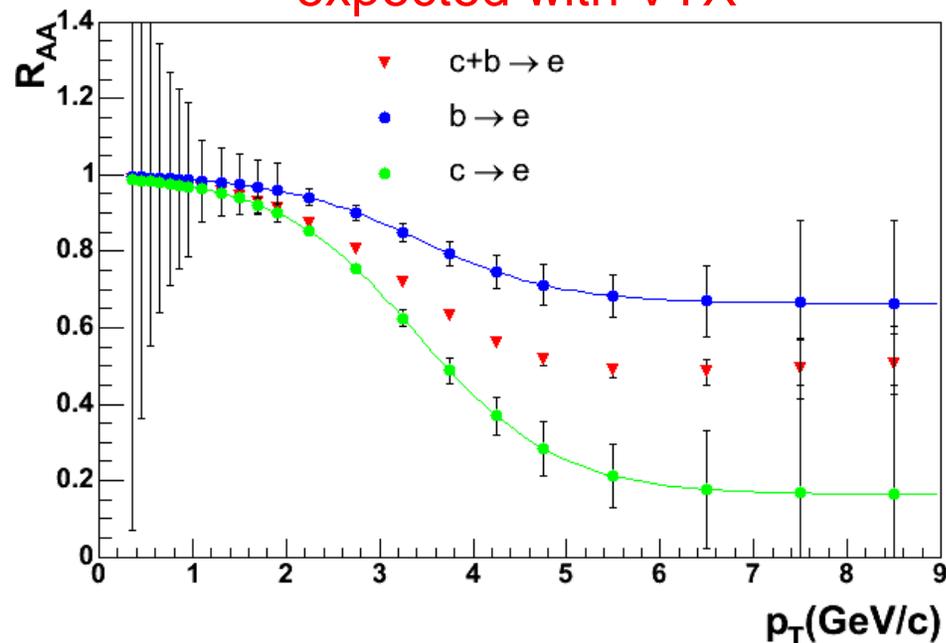


- DCA metric
  - “Perfect” track finding
  - Kalman filter fit
  - Includes VTX hits

## Nuclear Modification Factor without VTX



## Nuclear Modification Factor expected with VTX



- factor 4-5 suppression!(?!)
- perturbative QCD?

- VTX to separately measure  $R_{AA}$  of  $b \rightarrow e$  and  $c \rightarrow e$
- Same goal for FVTX ( $e \rightarrow \mu$ )

- The VTX and FVTX detectors have been proposed, approved, and being constructed to address heavy-flavor physics
  - Large coverage ( $2\pi$  @  $1.2 < |\Delta\eta| < 2.4$  and nearly  $2\pi$  @  $|\Delta\eta| < 0.35$ )
  - Improved tracking and resolution
- These projects will enable
  - Study of heavy-flavor production and flow (charm and bottom separately)
  - Study of quarkonia production and suppression
  - Study of contribution to proton spin
  - Greatly improved background suppression
- Construction is underway for both detectors
  - Inner barrels installed by 2009
  - Outer barrels installed by 2010/2011
  - Endcaps installed by 2011