Review Schedule

The FVTX upgrade project  Melynda Brooks
Silicon Sensor, Chip, Readout Jon Kapustinsky
Mechanics Walt Sondheim
Readout DAQ LANL/Columbia
Cost & Schedule Dave Lee
Electrical Integration Eric Mannel

Documents Provided:
FVTX Specification Document
Sensor specifications and quotes
Structural and Thermal Analyses Documentation
FPHX Chip Specification Document (LANL) and Conceptual Design Document (FNAL)
Radiation Environment Study (M. Prokop)
Wire Bonding Quotes
Cost Data Sheets
Forward Vertex Tracking Detector (FVTX)

Melynda Brooks, LANL
Forward Vertex Detector Review
BNL, 19-Feb-2007

Outline:

- Physics Motivation
- Design Requirements
- Detector Design
- Performance: detector and physics
- Efforts required
- Cost and Schedule Summary
- People
Physics Motivation

Silicon Vertex Tracker for Forward Rapidity:
- Tag displaced vertices to allow precision heavy flavor measurements
- Significantly enhances every aspect of the Muon Arms Physics Program
- Complements Barrel Tracker which will cover central rapidity

\[ y = 1.2 \]
\[ y = 2.4 \]
Physics Motivation

Measuring Charm and Beauty

- D, B mesons travel ~1 mm (with boost) before semi-leptonic decay to muons
- By measuring DCA to primary vertex, can separate D and B from prompt particles and long-lived decays like π, K
Detector Specifications

Enough planes to get 3 or more hits on most tracks within the Muon Acceptance → 4 planes with maximal r/z coverage

Good enough DCA resolution to find primary vertices and separate D, B from prompt and long-lived decays → 75 μm pitch strips

Low enough occupancy in Central AuAu to have efficient track finding → 75 μm pitch, with 3.75° phi

Ability to match tracks to muon system tracks → resolution, hits
Detector Performance

- Full PISA simulation
- Digitize strips, find clusters, get centroid
- Use Kalman Filter Fit to fit and project to z_vertex
- Get DCA components in r (good) and phi (less good)
- ~100 μm resolution in r and ~500 μm resolution in phi
- Multiple-scattering dominated resolution
- Sufficient resolution to separate prompt, heavy quark, and light meson decays.
Alternate Detector Configurations Under Study

Stereo angles for strips

DCA resolution vs. Momentum

- no strip tilt
- 11-degree

Phi resolution vs. Momentum

- no strip tilt
- 11-degree tilt 0 + 0

Phi staggering at each station

DCA resolution vs. Momentum (sigma)

- no strip staggering
- 1/4 strip staggering

Phi resolution vs. Momentum

- no strip staggering
- 1/4 strip staggering 1-2-3-4
- 1/4 strip staggering 1-4-2-3

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PHoenix

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Heavy Quark Signal Extraction with FVTX

Signal:Background for heavy-quark:decay muons+punch-throughs <1 before FVTX

Place cut $DCA_{\text{min}} < DCA < DCA_{\text{max}}$

Signal:Background>1 over all pT after FVTX DCA cuts (each background reduced by $\sim 10$)
Heavy Quark Signal Extraction with FVTX

- Improved S:B \(\rightarrow\) smaller statistical and systematic errors
- Heavy quark cross section \(\rightarrow\) \(R_{AA}\) become viable with FVTX
- Same for p+p asymmetry measurements

\[ \frac{d^2 \sigma}{dp_T^2} \text{ (GeV)} \]

![Graphs showing data with and without FVTX corrections]
Separating Charm and Beauty

Beauty measurements by:
- $B \rightarrow J/\psi$
- event topology cuts in single muon events
- kinematic cuts ($p_T$, DCA fits)

Direct Beauty Measurement

*Michael Malik

Los Alamos National Laboratory

M. Brooks, LANL
**W physics**

W signal enhanced by: DCA cuts, isolation cuts, match track in FVTX (removes neutral → μ)

- Deep track *3
- Quality cuts *2
- Isolation, Neutral, and DCA Cut *6
- Shower Cut in MuID *5

*Zhengyun You, Ming Liu

Pythia Min. Bias and W events through full reconstruction

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Physics Programs Accessible With FVTX

Single Muons:
- Clean heavy quark and hadron measurements at forward rapidity
- Separation of charm and beauty measurements
- W measurement significantly improved (possible)

Dimuons:
- Drell-Yan becomes possible over large mass range
- Vector meson measurements much improved
- Direct measurement of c-cbar events becomes possible
- Direct measurement of B→J/ψ becomes possible

Physics:
- Advance understanding of energy loss, flow in medium by adding precise heavy quark measurements of $R_{AA}$ and flow.
- More precise vector meson measurements plus heavy quark allow detailed understanding of vector meson production and modification
- Cold nuclear matter effects: energy loss, gluon saturation better understood
- Much more precise gluon polarization and sea quark measurements
Efforts Required for FVTX
Detector Development

• Standard silicon technology for silicon min-strip sensors
• Modification of existing FPIX chip for readout
• Must develop connection between readout chip and readout boards, “HDIs”
• Mechanical and cooling plans
• Simulation and Analysis
DAQ Development, Requirements

• 4320 chips/arm, 2 data pairs/chip, 6 download lines/chip, zero-suppressed data streaming out, 1728 Gbps streaming out per arm when all chips are firing (AuAu event)
• Need to reduce I/O lines coming out of enclosure
• Must fit within space constraints and have manageable cooling
• Must integrate with VTX detector
Lvl-1 Participation Highly Desireable

<table>
<thead>
<tr>
<th>Existing Trigger MuID</th>
<th>Achieved Rejection</th>
<th>Rejection needed 2008</th>
<th>Rejection needed RHIC-II</th>
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<tbody>
<tr>
<td>p+p</td>
<td>478</td>
<td>478*21</td>
<td>478*71</td>
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<tr>
<td>Au+Au</td>
<td>5</td>
<td>5*15</td>
<td>5*116</td>
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<tr>
<td>p+p 1-Deep 1-Shallow</td>
<td>23500</td>
<td>&lt; 23500</td>
<td>23500*1.4</td>
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<tr>
<td>Au+Au 2-Deep</td>
<td>15.7</td>
<td>15.7*5</td>
<td>15.7*37</td>
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**Beam Clock, Lvl-1 Decision and Fly-Back**

- Gives goal that we would like to deliver all FPIX/PHX data to FEM/Lvl-1 within 4 beam clocks
- But, PHENIX can accommodate Lvl-1 decision taking as long as 40 beam-clocks (could take up to 28 clocks more or 7* as much time?)
- Iowa State has verified p+p displaced vertex Lvl-1 algorithm
- From above, any participation in Au+Au should be pursued also
Efforts Needed, Institutional Commitments

Silicon Sensor: prototype production and testing, final production and testing
  Czech collaborators, UNM, LANL
Readout Chip: design, prototype, production and testing
  Ray Yarema’s group (FNAL), LANL oversight
HDI: design, prototype, production, testing and assembly
  UNM, LANL
Readout DAQ: design, prototype, production, testing and assembly
  LANL/Columbia
Detector Q&A, Assembly, Installation, Commissioning:
  Multiple institutions
Mechanical and Cooling: detector assembly, support, enclosure design prototype
  and production, analyses; cooling needs assessed, designed, production
  HYTEC, LANL
Integration:
  Mechanical Integration Robert Pak (BNL), Walt Sondheim (LANL)
  Electrical Integration – Eric Mannel (Columbia)
Simulation and Analysis: Supporting design, advancing simulation to offline
  analysis stage
  Saclay, LANL, NMSU, Peking, BARC, Finland
Critical Development Issues

**FPHX Development** – critical path
- Conceptual design completed
- Need R&D funds to take to layout and prototyping this year to maintain schedule.

**Silicon Sensor Development** – critical path
- Need prototypes this year to test with FPHX chip to maintain schedule.
- Czech collaborators providing prototype, expect to help with full production.

**Readout DAQ Development**
- LDRD DAQ same as FVTX (and driven by FVTX) to get maximum benefit from LDRD ($ covers most all R&D, experience gained…)
- LDRD schedule requires that board layout begin now
- Many mechanical issues (VTX and FVTX) require detailed design now
- Full concept of DAQ at LANL
- Entirely parallel development has taken place at Columbia
- LANL board design for ROC (most critical item) should support either proposal seen today
- All subsequent talks (except Dave W’s) base cost, schedule, mechanical and cooling analyses on the “LANL design”
- Cannot afford to continue to support two designs
Collaborating Institutions

Los Alamos National Laboratory
Bhabha Atomic Research Centre
Brookhaven National Laboratory
Columbia University
Iowa State University
Charles University, Czech Technical University, Institute of Physics, Academy of Sciences, Prague
New Mexico State University
Saclay
University of New Mexico
University of Jyvaskyla
Yonsei University
Cost and Schedule for FVTX

Schedule:

LANL and BNL R+D required
• Design and prototype chip+ silicon now → 01/08
• Design and prototype DAQ interface now → 12/07

Construction:
• Production + assembly 01/08 → 06/10
• DAQ Interface, LV, HV… parallel
• Installed 10/10

Cost

LANL R+D: $714k
BNL R+D: $175k
Construction: $3.67M + 24% contingency = $4.57M

Details in Dave’s Cost and Schedule talk
# Review Schedule

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Backups
LDRD Forward Silicon Project from LANL

• Approximately one octant’s worth of silicon tracking provided within 3 years

• BTeV-designed silicon and readout chip used, but readout chip will have almost identical digital section to this project

• Much Shared R+D:
  • All DAQ interface efforts will be directly applicable to FVTX project
  • Pixels rather than mini-strips → similar number of channels and cards to deal with as FVTX project
  • Experience from data analysis will be directly applicable
“Bonuses” FVTX brings

Overall improvement in track resolution for muon physics

Overall background improvement using DCA and even topology cuts in all muon physics programs

e-γ separation for the NCC

Lvl-1 capability, Improvement in p+p event efficiency

Improved Reaction Plane measurement
Why?—Improvement of Forward Rapidity Muon Measurements

- Physics observables with Muon Arms plus FVTX:
  - Vector Mesons
  - Open heavy flavor
  - Hadrons

Each and every physics measurement from the muon arm will be improved with the addition of the FVTX and new measurements will become available.
Why?—Limitations of Current Measurements

- Many current measurements with PHENIX detector are quite limited because of large systematic errors associated with large backgrounds.
How FVTX Can Help

• Single muon components can be separated from each other, greatly reducing systematic errors on open heavy flavor measurements.

• Decay muons can be removed from dimuon background and dimuon mass resolution will improve. All dimuon measurements (vector mesons, Drell-Yan, correlated and uncorrelated open heavy flavor) will have less background.

Real Data
Why Forward Rapidity?

- Improvement in rich Muon-Arm physics program:
  - pp, dAu, AuAu programs all improved significantly

- Forward Rapidity brings critical kinematic extension with much better systematic errors than current measurements to:
  - Separate various cold- and hot-nuclear matter effects
  - Map out distribution functions over broader x-range
Last Gap == 4
Factor ~ 3

Quality cut
Factor ~ 2
SvxConeHit = 0
Factor ~ 6

Muid Show and ConeHit = 0 (r=50cm)
Factor ~ 5
Sigma of distance from all muid hits of track to the track (p>20GeV)
Lvl-1 Timing, or NOT

Beam Clock, Lvl-1 Decision and Fly-Back

- Gives goal that we would like to deliver all FPIX/PHX data to FEM/Lvl-1 within 4 beam clocks.
- But, PHENIX can accommodate Lvl-1 decision taking as long as 40 beam-clocks (could take up to 28 clocks more or 7* as much time?).
- IF there were no Lvl-1 participation requirement, requirement is that we get data to DCMs within 50 μs:
  - Chip, Roc Propagation
  - FEM Buffering, Propagation
  - ~400 clocks later data delivered to DCM

All data could be sent out serially on a single line, even for AuAu and a large number of chips, and get to DCM with no problem.

M. Brooks, LANL