## MVTX Status & Plan

Ming Liu Los Alamos National Lab For the MVTX Group

sPHENIX Collaboration Meeting, Santa Fe, NM

### Outline

- MVTX workfest summary
  - Plan for DOE submission
- Project status and plan
  - Physics and Simulations
  - Readout and Controls
  - Mechanical Integration
  - Budget and Schedule



A Monolithic Active Pixel Sensor Detector for the sPHENIX Experiment

### MVTX & HF-Jet Workfest @Santa Fe,12/5-7, 2018

- Goal complete full proposal, implement recommendations from last Director's Review
  - Expand the MVTX Science case
  - Update cost & schedule
- About 25 participants
- 4 working groups
  - Physics and simulations
  - Sensors and readout
  - Mechanical system
  - Budget and schedule

	More exit manage	US/Mountain Engli	sh Logged in as Liu, M. Logout
sPHENIX MV	ΓX proposal and H	IF-jet Topical G	roup Workfest
5-7 December 2017 <i>Sa</i> US/Mountain timezone	nta Fe, NM		Search
Overview Scientific Programme Timetable Contribution List Author index My conference	MVTX detector group and HF- NM. This is a pre-meeting of the Following the recommendation completion of the sPHENIX M the MVTX full proposal. https://www.overleaf.com/10 Workshop web page:	-jet topical group invites you t the sPHENIX collaboration me ons of the recent MVTX BNL Di VTX Detector proposal. The go 0919417bwssgrhhgryc#/41088	o this sPHENIX workfest @ Santa Fe, eting scheduled Dec 8-10. rector's Review, we proceed with the bal of this workshop is to complete 8978/
Registration Registration Form	http://cnls.lanl.gov/sphenix		

#### Updated the proposal with latest results & development!

https://www.overleaf.com/10919417bwssgrhhgryc#/41088600/

On track for DOE submission in late January 2018

## 4 Working Groups

- Physics and Simulations
  - HF-Jet TG, Jin, Xin, Tony, Chris, Sanghoon, Haiwang, Darren, Xiaolong, SukHyun, Cesar, Ming, Nu et al

#### Staves, electronics & power system

- Readout Mark, Sho, AlexT, Jo, Kun, Ming, Giacomo, Kai/BNL/ATLAS, Jin, Martin, JohnH, Eric ...
- Staves/Sensors- Cesar, Xuan, Maria, Ming ...

#### Mechanical system & Integration

- Integration Bob, Grazyna, Walt, Jim K., Giacomo, Chris O'...
- Carbon structures Grazyna
- Project Cost, Schedule, Risks
  - Dave, Maria, Ming, Bob, Grazyna, Giacomo, Jo, ...

#### \* Working group team leaders

#### 23 institutions, and counting!

#### A Monolithic-Active-Pixel-Sensor-based Vertex Detector (MVTX) for the sPHENIX Experiment at RHIC

A proposal submitted to the DOE Office of Science January 18, 2018

DOE Office of Science Program Manager: Dr. Jehanne Gillo

Los Alamos National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley National Laboratory
Massachusetts Institute of Technology
Univ. of California at Berkeley
Univ. of California at Los Angeles
Univ. of California at Riverside
Charles University (Czech)
Central China Normal University (China)
Univ. of Colorado
Czech Technical University (Czech)
Florida State University
Georgia State University
Iowa State University
National Central University (Taiwan)*
Univ. of New Mexico
New Mexico State University
Purdue University
Univ. of Science and Technology of China (China)*
Sun Yat-Sen University (China)*
Univ. of Texas at Austin
Yonsei University (Korea)
RIKEN/RBRC (Japan)

### Very productive workfest









MVTX Overview @sPHENIX Collaboration Mtg



### MVTX Full Proposal in Progress

- all key elements discussed and updated/to be updated soon

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63 pages now ... will be updated through out next a few weeks

### Plan for the Proposal Submission – Draft Timeline

on-going discussion with ALD about the submission date and process

- Draft ready for sPHENIX collaboration comments:
  - Jan 3(Wed)-10(Wed), 2018, one week
  - Update document 1/11(Thur)-15(Mon), 2018
- For ALD review and feedback
  - Jan 15(Mon)-22(Mon), 2018
- Ready for DOE submission
  - Jan 22(Mon)-29(Mon), 2018, final editing, one week
  - Jan 29(Mon), 2018, ready for submission
- To be submitted before Feb 2018 DOE budget meetings
  - 2/22/2018 for LANL NP, similar timeframe for BNL and LBNL

### MVTX Project Status and Highlights

- Expanded science
- Sensor & readout system
- Mechanical system
- Budget & Schedule

Xin's talk

### Money Plots Updated: R\_AA and V\_2



Figure 1: Projected statistical uncertainties of  $R_{CP}/R_{AA}$  measurements of non-prompt/prompt  $D^0$  mesons and *b*-jet as a function of  $p_T$  in 0–10% central Au+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV from a dataset of 240 billion minimum bias Au+Au events.



Figure 2: Projected statistical uncertainties of  $v_2$  measurements of non-prompt/prompt  $D^0$  mesons and *b*-jet as a function of  $p_T$  in 10–40% central Au+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV from a dataset of 240 billion minimum bias Au+Au events.





To be updated with more model calculations

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## More Theoretical Inputs (I): B-meson v2

New calculations from PHSD for B-hadrons:

- Significant v2 suggested, but may NOT follow the scaling due to large bmass!
- 0.10 Ľ min-bias Au+Au @ 200 GeV STAR Au+Au @ 200 GeV ~\_0.15 > Ξ |n(B)|<1 Δ 0.08 10-40% **D**-meson **B-meson** ο Λ Parameter, w shadowing effect meson)  $\square K_s$ 0.06 0.1 I þ B 0.04 Anisotropy F ~ < 0.02 0.00 -0.5 1.5 2.5 2 0 5 10 15 0  $(m_{T} - m_{0}) / n_{a} (GeV/c^{2})$  $p_{\tau}$  (GeV)

STAR, PRL 118 (2017) 212301

- LANL model
- CUJET
- Duke model
- TAMU
- UrQMD
- AMPT
- PHSD
- Ads/CFT
- BAMPS
- HQ+EPOS2
- JetScape

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## More Theoretical Inputs (II): B-meson R\_AA

New calculations from PHSD for B-hadrons:

- Potential significant anti-shadowing effects
- Open b-bar in AuAu, very important baseline for Upsilon program!



### More Theoretical Inputs (III): HF-Jet Substructure

H. Li & I. Vitev @MVTX Workshop



QCD Splitting function in QGP

12/8/17

### Simulation Updated

• Fully implemented MVTX models used in performance projection



- Large jets production in full detectors, including detailed MVTX detector + full calorimetry
  - 250k MB jets in p+p collisions
  - 100k MB jet embedded into central Au+Au collisions

### Updated *p*+*p* and Au+Au *b*-jet Projections

- *b*-jet tagging projection re-evaluated with full tracking + calorimetry simulation
  - Tagging work point has been stable (60% Purity 40% eff for pp)
  - Central Au+Au Tagging work point has been stable (40% Purity 40% eff)
- Performance has been stable using truth jet finding or calorimetry reconstructed jet finding



## MVTX Readout and Control R&D



## Excellent Progress in LANL LDRD

- ALPIDE Evaluation and optimization
  - MOSAIC + Single Chip/Stave
  - Cosmic and source
  - Laser system
- Power unit tested
  - PU + MOSAIC
  - PU + RU
- Full readout chain demonstrated
  - ALPIDE + RUv1.0 + FELIX v1.5 + RCDAQ
  - Full stave + RUv1.x + FELIX v2.0 + RCDAQ
- Mechanical system integration
  - Conceptual design developed
  - MVTX+INTT integration

- A telescope under development
  - Mechanical frame, cooling etc
  - GEANT sim, alignment & tracking



### Single ALPIDE Chip Scan – Active Channel Fraction

- Scanned the available chips and stave at the LANL lab through digital scan to verify the dead channel fraction: the bad channel fraction is <1%.
- Similar results with different readout speeds.



Chip 1 test example

### Hit Pixel Cluster Distribution from Source Test (Sr<sup>90</sup>)



### ALPIDE Readout Optimization and Trigger Latency Study



- OUT\_A clipping: VCLIP. Decreasing VCLIP decreases clipping point.
- OUT\_A returns to baseline time: ITHR, VCLIP. Increasing ITHR decreases discharge time, and decreasing VCLIP decreases discharge time after clipping.
- OUT\_D return to baseline time: IDB. Increasing IDB increasing charging time hence decreasing pulse duration.

### **Trigger Latency Scan**

• Lower the OUT\_D threshold (IDB) increases the trigger duration time, but also increases the cluster size which might include more background hits.



## First Full Chain Readout: Success!



- Configured ALPIDE to accept triggers from FELIX using python software that came with the RU
- Configured GBT link to recover clock from FELIX and GT link (FGPA gigabit interface)
- 8 RU's emulated using 1 fiber link per RU on FELIX, 15kHz, 400 hits per RU
- Currently working the implementation of the above using a Stave

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**RUv1.0** 

### Parallel Effort at UT-Austin – Shared R&D

From Jo

ALICE ITS UPGRADE

### Test Setup at UT Austin

- RUv1 with transition bd + power mezz
- RUv0 as CRU emulator
- Single sensor on chip carrier board with interface board (only usable for IB tests, wrong pins for OB)

- Long (5m) FireFly cables
- Power board with single breakout board
- Now also tested with 9-sensor Inner Barrel module



Walt, Bob et al

### Mechanical Integration

Update from MVTX mechanics workfest

Incorporates the current INTT model and the TPC as components for the sPHENIX tracking system





### MVTX half detector assembly



MVTX layer break-out; three sensor layers with a carbon composite outer shell for mechanical stiffness



ALICE HALF-BARREL ASSY

## Model of MVTX with INTT inside TPC with the addition of two concentric composite cylinders;



## ALICE Inner Tracker Rail Support

The MVTX plus INTT half barrel assemblies location position is provided by the engagement of 4 rollers on the half-barrel, which would be previously measured and aligned, into four precise inserts housed in the "cage-rail" assembly.



In sPHENIX we will not use a "service cone, rail system" anywhere near the size of that planned for the ALICE detector, but we will use their concept.



## MVTX Schedule and new sPHENIX baseline Plan

- MVTX schedule align with sPHENIX plan
  - Stave production
    - Following ALICE production: ~8/2018
  - Readout units production
    - Be part of ALICE RU production:
      - FPGA & GTB cost saving
  - Ready for installation: late 2021
    - INTT ready for installation 4/2021
  - MVTX ready for beam
    - sPHENIX day-1

- New sPHENIX baseline schedule
  - CD-1 Review: 5/2018
  - sPHENIX installation
    - 4/2021 7/2022
  - sPHENIX ready for beam: 9/2022
  - First collision: 1/2023

### Cost and Schedule

- Total budget: 6.5M
  - Production
  - Assembly
  - Integration
- About 9 months schedule float



#### sPHENIX MVTX Cost Profile

Figure 42: MVTX Funding Profile.

Major Items	Cost (\$M)	Schedule
Staves (WBS 1.5.3.1)	1.3	8/2018-5/2019
Readout & Controls (WBS 1.5.2)	1.3	1/2019-6/2019
Mechanics & Detector Assembly (WBS 1.5.3)	1.8	2019-2022, TBO
Integration (WBS 1.5.4)	1.0	2021-2022, TBO
Project Management	1.0	8/2018-1/2023

### Major Cost Items

WBS	Task Name	Cost (K)	Cost with Contingency+ Passthru (K)
1.5.3.1.1	Produce 84 staves	\$966	\$1337
1.5.2.2	Readout Units(RDO)	\$480	\$664
1.5.5.3.2.3.2	CYSS Cylindical Structure	\$319	\$424
1.5.5.3.2.3.3	COSS Conical Half Shell	\$329	\$438
1.5.4.3	Safety Systems	\$139	\$191
1.5.4.4	Stave Support+ Global Interface	\$308	\$465

Table 6: Major Cost Items

### **Project Organization**



#### MVTX Overview @sPHENIX Collaboration Mtg Figure 40: Organization chart of the MVTX project.

### Summary

- MVTX proposal document updated
  - Addressed recommendations from last Director's Review
  - Expanded science
  - Updated cost and schedule
  - To be submitted to DOE in Jan 2018
- Excellent progress in R&D
  - Readout and controls proof-of-principle demonstrated
  - Conceptual mechanical system design developed
- MVTX+INTT+TPC mechanical integration in progress
  - sPHENIX wide coordination needed
- Ready for sPHENIX Day-1 Physics

### Backup slides

### LDRD – MVTX/sPHENIX Key Tasks/Milestones



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### RC DAQ event Data Screen Shot

- Rcdaq receiving events from KC705 using ddump utility
- ffff0044ffffc0ff4ea0
- a0 Chip Header
- 4e bunch counter
- ff IDLE
- c0 Region Header
- 40 00 first Hit
- Second screen shot showing end of one event (b0..., f000f000) and the beginning of another

		maps : ddump - Konsole	maps : ddump - Konsole 🔍 💩 🕱
File E	idit View Bookmarks Settings Help	File E	dit View Bookmarks Settings Help
Eve	ent 1000 Run: 1 length: 974 type: 1 2000 965 1 (DNCS Packet) 98 (INKNOW)	1 (Data Event) 1508444542 39c	14cff01_14cff00_ff0350ff5c0150
Packet	2000 SOD -1 (UNUS PACKEC) SO (UNUNUM)	380	54TT01 TT0154TT TT000158 54TT0158 15cff00 60ff01 ff0160f 5f0164
0	B 0 4ea00000 ffffc0ff	3a8	164ffc0 ffc0seff ffc10188 6cff006c
8	48ffff01 48ffff00 ffff0101 ffff004c	38C 350	170ft01 120ft00 tt0074tt 620174 28ff01 ff0120ff ff00012c b0ff012c
с	1ff014c ff0050ff ff0150ff 601ff	364	1000000 0 0 640000
10	1005off 15offf 5offff 901ff	368	
18	ff0160ff ff0054ff 16401ff 68ffff	300	faceface
lc	168ffff 6cffff01 6cffff00 c0101	Eve	nt 1001 Run: 1 length: 974 type: 1 (Data Event) 1568444542
20	70TTTT 170TTTT 74TT01TT 74TTT00 1 1ffft01 ffff0078 fffff0178 f017c	Packet	2000 966-1 (DNCS Packet) 98 (UNKNOWN)
28	7cffff00 ffc1ff01 4001ff ff0140ff	9	8 p 3d=00000 ffffcoff
2c	1ff0044 48ff0144 148ff00 1201ff		1ff0040 ffff0140 ffff0044 30144
30	4ctf004c 50Tf01 15001tt tt0054tt		48/fff01 48/fff00 ffff0101 ffff004c
38	60ff015c 160ff00 6401ff ff0164ff	c 10	ITTOIAC THUSDIT TOISOFT COITT
Зc	1ff0068 6cff0168 16cff00 1801ff	14	1005eff 15effff 60ffff 901ff
40	70110070 741101 1740111 11007811	18	ffoieoff ffoosaff iskolff e8ffff
48	40ff0040 44ff01 14401ff ff0048ff	1c   20	IGSTITE GCTTTTOD GCTTTTOD COLOL ZOFFFFF 1ZOFFFFF ZOFFOLF ZOFFFFF
4c	1ff0148 4cff004c 50ff01 1e01ff	24	1ffffo1 ffff0078 ffff0178 f017c
50	54ff0150 154ff00 5801ff ff0158ff	28	7cffffco ffclffol 4001ff ffol40ff
58	64ff0064 68ff01 16801ff ff006cff	20	1TT0044_45TT0144_145TT00_1201TT deff004e_50ff01_15001fff005Aff
5c	1ff016c 70ff0070 74ff01 2401ff	34	Iffolds Selfoods Selfor ISolff
60	78ff0174 178ff00 7c01ff ff017cff	38	eeffolse leaffoo e401ff ffole4ff
68	48ff0144 148ff00 4c01ff ff014cff	30	ITTOOEB COTTOISB ISCTTOO IBOITT
6c	1ff0050 54ff0150 154ff00 2a01ff	44	Iffolze zefforz ffczifol ibolff
70	58ff0058 5cff01 15c01ff ff0060ff	48	40ff0040 44ff01 14401ff ff0048ff
78	6cff0168 16cff00 7001ff ff0170ff	4c	1110148 4c11004c 501101 le0111 Saffaise isaffan seelf ffaiseff
7c	1ff0074 78ff0174 178ff00 3001ff	54	Ifforse Editise 150ffor 201ff
80	7cff007c ffc4ff01 4001ff ff0140ff	58	s4ff006458ff01 18901ff ff006cff
88	4cff004c 50ff01 15001ff ff0054ff	50	1++016c 70++0079 74++01 2401++ 25+f0124 128++01 7-01++ f+012c++
BC	1ff0154 58ff0058 5cff01 3601ff	64	lfffcg 40ff0ad 44ff01 270ff
90	60ff015c 160ff00 6401ff ff0164ff	69	48ff0144 _148ff00 _ 4c01ff ff014cff
96	70ff0070 74ff01 17401ff ff0078ff	5c	1110050 54110150 1541100 2a0111 55150055 551511 15-0115 7500515
9c	1ff0178 7cff007c ffc5ff01 3c01ff	74	10064ff ff0164ff 69ff0068 2d0101
aO	40ff0040 44ff01 14401ff ff0048ff	78	ffeeseff zeffelse zoffelse zeffel
a4 a8	54ff0150 154ff00 5801ff ff0158ff	7c	10174ft ft0078ft 7ctf0178 300100
ac	11f005c ff0060ff 64ff0160 420100	84	10144ff ff0048ff 4cff0148 330100
bO	<pre>t+0164t+ 68t+0068 6cff0101 15cff00 l 10070ff ff0170ff 74tf0074 450101</pre>	88	ff014cff 56ff0050 54ff0101 154ff00
ba i	ff0078ff 7cff0178 7cff0100 ffc6ff01	Bo	fooest fruissi stroose sector
bc	10040ff ff0140ff 44ff0044 480101	94	10168ff ffcc6cff 7offo16c 3S01C0
cO	1 10150ff ff0054ff 58ff0154 4b0100	98	ff0170ff 74ff0274 78ff0101 178ff00
c8	ff015aff 5cff005c 60ff0101 160ff00	90	foldeft adfinad adfinition lastfor
cc	10064ff ff0164ff 68ff0068 4e0101	84	1004cff ff014cff 50ff0050 3f0101
do	10174ff ff0078ff 7cff0178 510100	88	ff0054ff 58ff0154 58ff0100 Scff01
da	ff017cff 40ffffc7 40ff0100 44ff01	ac	forser russing services 42010
dc	10144ff ff0048ff 4cff0148 540100	64 64	10070ff ff0170ff 74ff0074 450101
eO	10058ff ff0158ff 5cff005c 570101	b8	ff0078ff 7cff0179 7cff0100 ffc6ff01
e8	ff0060ff 64ff0160 64ff0100 68ff01	bc co	1004011 11014011 4+110044 480101 fromstr definition 50ff01
ec	10168ff ff006cff 70ff016c 5a0100	c4	10150ff ff0054ff 58ff0154 4b0100
10 f.4	1007cff ff017cff 40ffffc8 5d0100	c8	ff01S8H Schlabs distinct Reafic
fø	ff0140ff 44ff0044 48ff0101 148ff00	- 33 - 0b	1000dr1 1010dr1 00 10000 440101
fc	1004cft ff014cft 50ff0050 500101	d4	10174ff ffcc78ff 7cffo178 5101cc
100	1 TT0054TT 58TT0154 58TT0100 5CTT01	49	

10144ff ff0048ff

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### Calculations

	<b>Collision Rate</b>
Au Au	200kHz
P P	10Mhz

### • Assume 10us window and cluster size 3

	Au Au	P P
# of collisions	<b>2</b> = 10us * 200kHz	<b>100</b> = 10us * 10Mhz
# of hits, hottest chip	<b>270</b> = 3 * 90	<b>75</b> = 3 * 25
# of hits in a stave	<b>1983</b> = 3 * 661	<b>543</b> = 3 * 181

Central Au-Au collision with 2.0 pileup MB collisions: 661 clusters/stave in layer 0



p-p collision with 100.0 pileup collisions: 181 clusters/stave in layer 0

BNL control envelope drawing; Z location of the inner hcal is at 2175,0mm



12/8/17

## Adding the INTT to model of MVTX in sPHENIX



It is clear from this detail view the conical region of the MVTX detector barrel with the INTT that the MVTX will need to translate in Z by at least another 50.0 mm in addition to the 180.0mm that is seen in this model

Detail view of MVTX, where the conical region has been translated by an additional 50.9 mm, along with the INTT and two concentric composite cylinders



Cross-section view from CAD model of MVTX, INTT, TPC, beam-pipe, plus two composite conical shells



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Gap between conical shell of MVTX and inner layer of INTT is 11.58 mm



### 56.0 mm gap between INTT and inner radius of TPC



Earlier model for the INTT, chevron configuration, inner layer half ladders in width;



## Offset from OD of beampipe and innermost component of the MVTX



## Offset needed to install split MVTX into run location around beampipe, passing over 2.75 in conflat flange



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### INTT stave design with HDI



Latest configuration of ladders in the INTT, 4 layers where each is made from two layers for hermeticity



### New INTT model with HDI extensions;



# Some High Level Summary of Specs and Deliverables for MVTX

to be added to the proposal

### **STAR HFT Parameters**

### High-level CD-4 key performance parameters: instrument must be capable of:

Pointing resolution of HFT system	≤50 µm	sPHENIX:<50 um, w/ 2-layer hits reguriement
(750 MeV/c kaons)		
Single-track efficiency for HFT system	$\geq 60\%$	sPHENIX: >60%
(1 GeV/c pions)		
Compatible with STAR DAQ-1000 system	sPHENIX:	15kHz readout

Low-level CD-4 key performance parameters: experimentally demonstrated at Project Completion:

1	Thickness of first PXL layer	< 0.6% X <sub>0</sub> sphenix: <0.5%X0
2	Internal alignment and stability	$< 30 \ \mu m$
	PXL	
3	Internal alignment IST and	$< 300 \ \mu m$
	SSD	
4	PXL integration time	< 200 μs sPHENIX: <20uS
5	Detector hit efficiency PXL	> 95% sensor efficiency and noise from all
		sources $< 10^{-4}$
6 =	Detector hit officiency IST	> 060/ with 080/ purity
7	Live channels for PXL and	$>95\%$ sphenix: use ALICE OA? 90%??- $\rightarrow$ 80% seems OK
	IST	
8	PXL and IST Readout speed	<5% additional dead time @ 500 Hz average
	and dead time	sPHENIX: <5% additional dead time @15 trigger rate and simulated occupancy
9	SSD dead time	< 00/ at 500 Hz

### Table 3-1 HFT Key Technical Performance Parameters

#### 3.3.2 CD-4 DELIVERABLES

12/8/17

The HFT MIE project will be complete when all DOE deliverables (Table

3-2) have been tested and installed into the STAR detector at BNL.

Sub-system	Deliverable	
PXL		
	PXL insertion structure sPHENIX: mechanical interface structure and	tools
	PXL insertion tool to sPHENIX Global Rail System	-
	10 sectors with each sector consisting of :	
	One ladder at a radius of 2.5cm and 3 ladders at 8.0 cm.	
	Each ladder contains: 10 silicon detector elements, one readout	
	board sPHENIX: 3-Layer MVTX	
	40 ladders total	
	3 DAQ receiver Personnel Computers SPHENIX: 6 DAQ PC, hosting 6 FELIX I	oards
	Two clam shells, with five sectors integrated and aligned on each	*
	clam shell, installed on pixel insertion tool. sPHENIX: 3-Layer MVTX,	two clam shells
	Forty tested ladders to serve as spares and replacement components	
	to allow for any needed repairs to the existing sectors of the PXL	
	detectors sPHENIX:48 + (28 + 8 spares) = 84	
	Low Voltage, Cabling, and Cooling	
	A PC-based control and monitoring system MVTX Overview @sPHENIX Collaboration Mtg	54

Software	
	Online control software verification

Table 3-2 HFT Deliverables