MVTX Status Overview
WBS 3.2

Ming Liu
LANL
For the MVTX Group
sPHENIX Collaboration Meeting @FSU
Outline

• MVTX science & technology

• MVTX project update

• Reviews and R&D progress

• Highlights from 1st day’s MVTX workfest

• Near term plan
MVTX Enables the 3\textsuperscript{rd} Science Pillar

1. Jets
2. Upsilons
3. Open Heavy Flavor

- Bottom quarks are heavy (4.2 GeV)
- Produced in initial collision, probe QGP evolution
- Well controlled in pQCD
- Access fundamental transport properties of QGP
MVTX Physics Highlights

• Heavy quarks – new scales, $m_c$, $m_b$
  • Study mass dependence
    • Jet quenching & energy loss
    • Flow – interaction with medium

• Access QGP properties
  • Density, coupling, transport coefficients etc.

12/7/18
MVTX Overview, FSU sPHENIX Collaboration Mtg
Monolithic Active Pixel Sensors (MAPS)

The Next-Generation, State-of-the-Art Pixel Tracker

Advantages of ALICE Pixel DEtector (ALPIDE) sensor:

- Very fine pitch (27μm x 29μm), for superb spatial resolution
- High efficiency (>99%) and low noise (<10^-6), for excellent tracking
- Time resolution, as low as ~5 μs, for less pileup
- Ultra-thin/low mass, 50μm (~0.3% X₀), for less multiple scatterings
- 0.5M channels with on-pixel digitization, for zero-suppression and fast readout
- Low power dissipation, 40mW/cm², for minimal service materials

An ideal detector for QGP physics!

ALPIDE design

Flexible Printed Circuit (FPC)

9 Chips

Cold plate

A 9-chip MAPS stave, 1.5cm x 27cm

ALPIDE sensor:
1.5cm x 3.0cm, 0.5M channels
MVTX Detector – Modified from ALICE/ITS Design

Service cone: signal, power, cooling and mechanical support

Extended power FPC

CYSS: Cylindrical Shell Structure

End-Wheel

3-layer sensor barrel
- 48 staves, 432 chips

### MVTX parameters

<table>
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<tr>
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<th>Layer 0</th>
<th>Layer 1</th>
<th>Layer 2</th>
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<td>Length (sensitive area) (mm)</td>
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<tr>
<td>Active area (cm²)</td>
<td>421</td>
<td>562</td>
<td>702</td>
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<tr>
<td>Number of pixel chips</td>
<td>108</td>
<td>144</td>
<td>180</td>
</tr>
<tr>
<td>Number of staves</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
</tbody>
</table>
Scope of the MVTX Project

- **MAPS Staves & Electronics**
  - Readout Integration R&D (LANL LDRD)
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Reprogram RU & FELIX into RCDAQ/sPHENIX
  - Production @CERN: $1.36M
    - 84 ALICE/ITS-IB staves from CERN
      - Acceptance test @LBNL, 48+spares(36)
    - 60 ALICE/ITS-RU from CERN
      - Acceptance test @UT-Austin, 48+spares(12)
  - Production @US
    - Final detector assembly in US
      - LBNL half detectors
      - BNL full detector
      - FELIX test & integration @LANL/BNL, 6+spares(2)
  - Ancillary systems
    - “adopt” ALICE ITS system
    - Power, slow control & monitoring etc.

- **Mechanics & Cooling**
  - Changes to ALICE/ITS inner tracker mechanical structures
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Detector and Service half barrels
  - Mechanical system integration,
    - Conceptual design (LANL LDRD)
    - Prototyping sPHENIX R&D
    - Design integration frames, MIT/LANL/BNL
    - Composite structures, LBNL
    - Non-composite structure, MIT
    - Installation tooling etc., BNL/LANL/MIT/LBNL
  - Adopt ALICE cooling plant design
    - Modifications to fit sPHENIX, MIT/BNL
    - Much smaller heat load than ALICE ITS

Installation & commissioning (BNL + MVTX group)
ALPIDE pixel:
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

MVTX Detector Electronics consists of three parts

Sensor- Stave (9 ALPIDE chips) | Front End- Readout Unit | Back End- FELIX/DAM

Interaction Region | Experimental Hall | Counting House
MVTX Full Readout Chain Demonstrated (3/2018)

Fermilab Test Beam: Feb-Mar, 2018

Tracking spatial resolution achieved: <5 um

120 GeV proton beam

4-hit track
Stave and RU Procurement Readiness
BNL Director’s Review, 7/19-20, 2018

https://indico.bnl.gov/event/4729/

• To produce RU and staves as part of ALICE production
  • Reduce technical risks
  • Cost saving

• To meet sPHENIX installation & run schedule.

DAY-1 PHYSICS

Recommendations:
1) RU, proceed with production
2) Resolve MVTX/INTT space conflict
   1) modify stave design, longer power cables
   2) build a 3-D model
   3) Simulation TF to optimize INTT layers
3) Stave radiation hardness

Christof, Mickey, Walt’s talks ..
This MVTX model shown with 40cm flat power extension cables.
Confirmed HIC with Extended 40(60)cm Power FPC

• Built and tested two HICs at CERN in the week of 9/17/2018
  • No change in sensor performance (noise, threshold) observed, as expected;

Details presented by Dr. Sho Uemura at the sPHENIX general meeting on 9/23/2018

Followed identical ALICE IB QA test procedure, with a 8m SamTec cable!

Nice work by Alex and Sho et al!
MVTX + 4-layer INTT 3-D Mockup Demonstrated

Mickey, Rachid’s talks

Office of System Integration – led by Mickey & Bob, a team of engineers and physicists

MVTX and INTT
Space conflict resolved!
Sensor Irradiation Test – OK at 2.7MRad

- Continuous effort by ALICE (@NPI, Czech)
- BNL review recommendation: test sensor up to 1MRad

https://indico.cern.ch/event/758048/

Conclusion

Irradiated ALPIDE sensor (2700 krad) over a large range of threshold settings has:

1) good efficiency up to threshold ~190 e⁻ (Ithr = 100 DAC units) at Vbb = -3 V, Vcasn = 90, Vcasn2 = 102

2) fake hit rate remains orders of magnitude smaller than the requirement ($<< 10^{-6}$)

For non irradiated 2 noisy pixels were masked out. No pixel was masked out for the 2.7Mrad chip.
Address July MVTX Review Recommendations

Stave and RU procurement readiness review

- Completed sensor/HIC/stave evaluations at CERN
  - Built and tested two HICs with 40cm and 60cm long power FPC
  - Confirmed sensor performance same as the ALICE default configuration
  - Sensors irradiated up to 2.7MRad, no issues (updated 9/18/2018).

- Addressed all recommendations on stave/sensor R&D
  - Cost are set for staves/RU, UTK has started procurement paperwork
    - Technical specs document completed for production, BNL/DOE agreed
    - RU, Staves, sPHENIX production starts ~January 2019, expect to last ~12 months
  - MVTX/INTT mechanical integration
    - Mechanical design being updated and 3-D mockup demonstrated
    - Inner tracking task force completed evaluation, preferred INTT-layers ~2
  - Cables
    - BNL approved the use of SamTec blue cables
      - Electrically better & mechanically compact
      - ALICE confirmed signal performance with 8m long readout cables. For MVTX, 10m very likely works (30AWG/sPHENIX vs 32AWG/ALICE), to be confirmed by on-going R&D
    - Samples ordered for system integration mockup and test

https://docs.google.com/document/d/1vsm_G7Lgqv-kBZqK0jF69T_Nx2Uwk0Zxv86jRVxybw/edit?usp=sharing

Christof’s talk
MVTX Global Mechanical System Integration

- MVTX service barrel preliminary design, with two parts:
  - Part-1: from MVTX to PP-1b, all power PCB, 40cm
  - Part-2: length TBD later, from PP-1b to PP-2
MVTX Design Interim Review
11/19/2019, led by John Haggerty

https://indico.bnl.gov/event/5351/

- Detector assembly & installation in sPHENIX
  No evident showstoppers

Recommendations

Interim design review report, draft

1. The outline of the step-by-step assembly procedure for the MVTX showing installation of the barrel staves, power cables, and signal cables, should be written down and summarized in one or two slides. This does not have to be the final, more comprehensive assembly procedure, but should show the installation of major components and at what point tests are conducted.
2. The cables to the racks probably need to be longer than 8m, and this should be assessed conservatively.
3. A memo approving the halogenated cables should be on file from the fire protection group.
4. A proposal for extending the beam pipe to move the flanges further from the IP should be discussed with CAD and sPHENIX, as well as beginning a discussion of the beam pipe support.

“Conduct a technical review with subject matter experts for the installation of the MVTX into sPHENIX (conduct before November 14, 2018). The details of the installation need to be understood and agreed upon before issuing the procurement for the power cables.”
Detector Assembly & QA Plan at LBNL

• Follow ALICE IB assembly procedures to build half-detectors for MVTX
• QA records in DB, travelers
• Modified jigs for MVTX
• Build two full half-barrel detector with the service structures

Install SamTec & power cables during half-barrel assembly with the service barrel at LBNL (under discussion)
IB Prototypes: Layer 2 Prototype

From ruby pads gluing to final stave installation procedure

Replacement of Dummy Stave with Final Staves

Dummy Stave installation

Ruby pads gluing
MXTX Model with Correct Length Power Cables:

New shorter 40 cm overall length for power extension cables from stave, more than 220. mm shorter than was shown in previous model, same length service-barrel – 1200.0mm, location for a new patch panel 1B.

Updated inner layer power extension cable – overall length 40.0 cm, as agreed to by ALICE at CERN.
MVTX Services - Work in Progress

- Service racks located close to MVTX detector
  - Electronics, power etc
  - “Minimal cable length”, 8m tested at CERN;
    - L~7.3m
    - R&D on 10m cables at LANL

- 48 RU and 24 PU
  - 1PU ->2RU
  - 6-U VME crates

- CAEN bulk power supply
  - located nearby

- Cooling plant
  - Location TBD
# MVTX Schedules and Milestones (11/2018)

**sPHENIX:**

<table>
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<tr>
<th>CY-2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tbody>
<tr>
<td>Stave &amp; RU production</td>
<td>FELIX production</td>
<td>Detector mechanics design &amp; production, global interface to sPHENIX</td>
<td>Service barrel design &amp; production</td>
<td>Global integration /interface design?</td>
<td>Half barrel #1</td>
</tr>
</tbody>
</table>

**MVTX**

- ALICE IB stave done; Facilities available for sPHENIX production;
- A window of opportunity:
  - Low technical risk
  - Cost saving

**sPHENIX: CD1/3a**

- CD2
- Installation
- 1st collisions

**Barrel Assembly & Testing @LBNL**

- Power system production
- Design & procure sPHENIX rails
- Half barrel #2
- Half barrels arrive @BNL
- MVTX installation & commissioning @BNL RU, FELIX, PS, cables etc.

**Half barrels arrive @BNL**

**Ready for beam; sPHENIX day-1 run**

**Dave’s talk**

To be updated @FSU 12/2018

Work in progress:
LANL/MIT/LBNL
Design and fabrication
**sPHENIX MVTX Group: Institution Roles**

- **Major institutions lead key tasks**

  **sPHENIX Project Office**
  - MVTX (WBS 3.2)
    - L2 Project Manager: M. Liu (LANL)
    - Deputy PMs: G. Odyniec (LANL), R. Corliss (MIT)
    - ES&H Liason: W. Sondheim (LANL)/A. Franz (BNL)

  **sPHENIX Integration**

  **Electronics & Power (M. Prokop)**
  - LANL - WBS - 3.2.2
    - Readout Units
      - UT Austin WBS 3.2.2.1
      - J. Schambach
    - Back-end
      - LANL WBS 3.2.2.2
      - S. Uemura/K. Liu
    - Power systems
      - LANL WBS 3.2.2.3
      - Y. Mei

  **Mechanics & Detector Assembly (G. Odyniec)**
  - LANL - WBS 3.2.3
    - Staves
      - LANL WBS 3.2.3.1
      - Y. Morales/C. da Silva
    - Carbon Structures Design
      - MIT/LANL WBS 3.2.3.3
      - J. Kelsey/W. Sondheim
    - Carbon Structures Fabrication
      - LANL WBS 3.2.3.2
      - Y. Mei
    - Barrel Assembly
      - LANL WBS 3.2.3.3
      - Y. Mei

  **Integration & Infrastructures (R. Corliss)**
  - MIT - WBS 3.2.4
    - Cooling
      - MIT WBS 3.2.4.2
      - J. Kelsey
    - Safety System
      - MIT/NSF? WBS 3.2.4.3
      - R. Corliss/?
    - Global Mech. Support
      - MIT/LANL WBS 3.2.4.4
      - R. Corliss/W. Sondheim
    - Installation & Commissioning
      - BNL/all WBS 3.2.4.6

**Institutions and Roles**

- **Los Alamos National Laboratory (LANL)**: Overall readout electronics and mechanical system integration, project management.
- **Brookhaven National Laboratory (BNL)**: Global system integration and services, safety and monitoring, project management.
- **Lawrence Berkeley National Laboratory (LBNL)**: Carbon structure production, LV and HV power system, full detector assembly and test, project management.
- **Massachusetts Institute of Technology (MIT/Bates)**: Global mechanical system integration and cooling.
- **Massachusetts Institute of Technology (MIT)**: Stave assembly and test at CERN.
- **University of California at Los Angeles (UCLA)**: Simulation and readout testing.
- **University of California at Riverside (UCR)**: Detector assembly and test, simulations.
- **Central China Normal University (CCNU/China)**: Maps chip and stave test at CERN and/or CCNU.
- **Charles University (CZ/Czech)**: Maps stave production and QA.
- **University of Colorado (UC)**: B-jet simulations and future hardware.
- **Czech Technical University (CTU/Czech)**: Maps stave production and QA at CERN.
- **Florida State University (FSU)**: Offline software and simulations.
- **Georgia State University (GSU)**: Online software and trigger development.
- **Iowa State University (ISU)**: Detector assembly and test, simulations.
- **National Central University (NCU/Taiwan)**: Stave assembly and test, simulations.
- **University of New Mexico (UNM)**: Cabling & connectors.
- **New Mexico State University (NMSU)**: Tracking algorithm and physics simulations.
- **Purdue University (PU)**: Detector assembly and test, simulations.
- **Univ. of Science and Technology of China (USTC/China)**: Maps chip and stave test, simulations.
- **Sun Yat-Sen University (SYSU/Korea)**: MVTX detector and physics simulations.
- **University of Texas at Austin (UTA)**: MVTX readout electronics integration, Readout Units production and test.
- **Yonsei University (YSU/Korea)**: Maps chip production QA, readout electronics test and simulations.
MVTX Workfest, Day-1

https://indico.bnl.gov/event/5404/

• A very productive meeting
  • Physics update
  • Project tasks and schedules
    • production plan, sharing design work, cost reduction etc.
    • Global system integration
• Project cost & schedule plan
  • More follow ups from MIT & LBNL, on resources & cost
  • Update project plan by next week ~12/15
  • Update P-6, keep cost under 5M
  • Release fund for design/prod work soon

• MVTX related tracking discussion continues, 12/8-9
  • Global tracking, vertexing, pile up etc
New Topics being Explored – Charm Chemistry

Motivation

- Strong enhancement of \( \Lambda_c/D^0 \) ratio compared to PYTHIA calculations both seen in Au+Au collisions by STAR and p+p and p+Pb collisions at LHC.
  - Coalescence hardronization;
  - \( \Lambda_c \) contributes sizably to the total charm cross section.

- More precise measurement especially at low \( p_T \) is necessary to the understanding of \( \Lambda_c \) production.

Reconstruction of \( \Lambda_c \)
Design & Production Plan
Detector Assembly and Integration

LBNL Scope

- Stave reception from CERN and testing
- Power system
- Carbon composite structure production
- Half-barrel assembly and testing

Yuan Mei

MIT/Bates Responsibilities

- Cooling System (1.5.4.2)
- Modify ALICE design
- Safety system
- Mechanical model (1.5.3.2.1.1)
- Inner support structures (1.5.3.2.2.1, 1.5.3.2.3.2?)
- Service barrel (1.5.3.2.3.3?)
- Interface to sPHENIX exterior (1.5.3.2.1.1?)
- Installation procedure (1.5.3.2.1.1?)

Ross Corliss

Detailed sharing of engineering design, FEA/simulations, review and fabrication discussed

Engineering resources at LANL/MIT/LBNL
Project C&S being Updated

Dave, Glenn et al

12/7/18

MVTX Overview, FSU sPHENIX Collaboration Mtg

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Near Term Project Tasks & Schedule

- RU production through ALICE: 60 RUs
  - Being started at CERN, first batch of ALICE production ~ Dec., 2018
    - sPHENIX RUs available: ~Summer 2019
  - Acceptance test and QA at UT-Austin: starting ~summer 2019

- Stave production through ALICE: 84 staves (ALICE Gold/Silver QA)
  - sPHENIX sensor production ~Jan. 2019
    - Stave assembly starts @CERN, ~ April 2019, ~12 months to finish
  - Acceptance test and QA at LBNL, ~Summer 2019
    - Hand-carrying staves to LBNL, ~4 trips, ~20 staves each trip

- Mechanical system integration design
  - In good progress, under OSI

- Carbon and non-composite structure design and fabrication
  - Design & review – LANL/MIT/LBNL
  - Carbon structures fabrication @LBNL
  - Non-composite structure fabrication @MIT

- Half-detector assembly at LBNL: starting ~ summer 2019
  - To setup assembly & test lab as soon as fund available

- Safety, slow-control and monitoring

- MVTX detector commissioning at BNL: ~summer 2021
  - Setup lab, pre-installation commissioning
  - IR installation

- (Physics & detector simulations, tracking etc.)
Other Activities, Test Beam etc.

• CERN/ALICE visit planned ~end of January 2019
  • Walt, Ming, and MIT/Bolek, Jim, Ross et al
  • Mechanical design and integration
  • Produce 5 staves for MVTX telescope (Fermilab test beam)

• Preparation for MVTX stave production at CERN
  • One LANL PD hired at CERN
  • MIT student/postdoc/tech help at CERN, under discussion
  • LBNL will start preparing the MVTX detector lab as soon as fund transferred

• Fermilab beam test with INTT, ~May 2019
  • Waiting for HDI cables for INTT
  • MVTX telescope will be ready ~March 2019
  • A joint test beam proposal being developed
  • Test global tracking, timing etc.

• Possible MVTX beam test at LBNL
  • MVXT sensor and readout electronics characterization etc.
  • Details under discussion

Integrated MVTX+INTT readout?
- Event builder

12/7/18  MVTX Overview, FSU sPHENIX Collaboration Mtg
Summary: MVTX - WBS 3.2

- MS Project being updated, now in the sPHENIX P6
  - Stave and RU production through US-ALICE, moved out of the scope
  - The rest of tasks, being optimize for cash flow and production schedule
- Early procurements of staves and readout units (RU) through US-Ali
  - DOE and BNL agreed, DOE directly pays UTK/US-ALICE
  - Received signed letter from CERN on the cost of 60 RUs and 84 Stave, ~$1.3
  - Purchase paperwork in progress at UTK, aiming to complete by ~ December
- About $5M to be added to the sPHENIX Management Portfolio
  - Open MVTX accounts in progress
  - As a separated project from the MIE
    - Mechanical system design and fabrication
    - Update baseline cost and schedule by January 2019
    - Monthly report to sPHENIX and BNL upper management
  - Will NOT be part of CD-2/3 DOE review
    - Prepared for a separate DOE review in FY19
- LANL LDRD for early R&D and training!
backup
A Short Summary of the Project Status

• RU and Stave production – a separate direct procurement from ALICE/CERN
  • Technical doc and paperwork were prepared and sent to UTK from BNL in November
  • Paperwork in progress through OSP at UTK, aim for sign-off by December.
    • 60 RUs and 84 staves, production starts ~ January 2019.

• MVTX upgrade project in sPHENIX P-6
  • RU and stave production moved out from this scope
  • Work in progress on funding details
    • Split engineering/tech T&E among LANL, MIT, LBNL, BNL etc.
  • Adjustment in WBS scope (some moved to WBS 2.x) to keep the total cost under $5M
  • For discussion this week

• Recent reviews
  • MVTX Production Review 07/19-20, 2018
    • Stave and RU procurement readiness
    • [https://indico.bnl.gov/event/4729/](https://indico.bnl.gov/event/4729/)
    • Draft responses presented and discussed at PMG meeting
      • Review committee members, BNL and sPHENIX management
  • MVTX Interim Design Review, 11/19/2018
    • Mechanical system integration
    • Led by John Haggerty, draft recommendations being discussed
      • no evident showstoppers
    • [https://indico.bnl.gov/event/5351/](https://indico.bnl.gov/event/5351/)

Status at UTK: (12/6/2018):
1) Document in PAMS at UTK OSP, waiting for approval from UTK/ORNL, (target ~12/14/2018)
2) Approval in Germantown;
3) Approval in the Chicago office and negotiation of a grant funding document with the University.

All recommendations from July Review on stave/sensor R&D addressed

Recommendations
1. The outline of the step-by-step assembly procedure for the MVTX showing installation of the barrel staves, power cables, and signal cables, should be written down and summarized in one or two slides. This does not have to be the final, more comprehensive assembly procedure, but should show the installation of major components and at what point tests are conducted.
2. The cables to the racks probably need to be longer than 8m, and this should be assessed conservatively.
3. A memo approving the halogenated cables should be on file from the fire protection group.
4. A proposal for extending the beam pipe to move the flanges further from the IP should be discussed with CAD and sPHENIX, as well as beginning a discussion of the beam pipe support.

12/7/18

MVTX Overview, FSU sPHENIX Collaboration Mtg
Major hardware:

- 48 ALICE ALPIDE Staves + Interface Cables
- 48 Front End Electronics (ALICE RUv2)
  - 6 Back End Electronics (ATLAS FELIX v2)
  - 6 EBDC Linux servers
  - 24 Power Boards + CAEN Supplies + Cables
  - 48 Stave to RU cables
  - 144 data fiber optic cables (3 fibers x 48 FEE)

Stave production: total 84, 75% spares

- Two inner layers: 12+16=28
- 10% spares: 8 staves

RU production: 60 in total, 25% spares
Stave Production and Shipping etc.

- Hand carry staves from CERN to LBNL, 4 trips
- Preliminary design from CERN for stave transportation plates
  - To be produced at CERN, paid by LBNL/sPHENIX

Extended design from CERN for MVTX

12/7/18  MVTX Overview, FSU sPHENIX Collaboration Mtg
### Staves

- Purchase 84 staves from ALICE/CERN
  - 48 + 28 (spares for 2 inner layers) + 8 spares
  - Production following the completion of ALICE ITS/IB
  - Starting ~Oct. 2018, will last 6-12 months
  - Fully tested at CERN before shipping to US
    - All Gold/Silver staves (same as ALICE IB)
    - A LANL postdoc (Dr. Yasser Morales) oversees production QA at CERN
- Acceptance QA at LBNL
  - Full test and QA
    - Electrical
    - Mechanical
  - Detector assembly at LBNL

### Readout Units

- Purchase 60 RUs from ALICE/CERN
  - 48 + 12 spares (20%)
  - To be part of ALICE production
    - Cost saving
    - Minimize technical risks
  - Initial test at CERN
- Acceptance QA at UT-Austin
  - Full test
  - LANL as the 2nd test site

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https://indico.bnl.gov/event/4729/
Safety $\rightarrow$ MVTX $\rightarrow$ \[ \text{revise MVTX safety stem [cooling & power]} \]

1. stunned/PU \( \rightarrow \text{(I. V. T.)} \)
2. Cooling \( \rightarrow \text{flow, T. & T.)} \) \( \rightarrow \text{design for IB} \)
3. smoke, leakage...

\[ \text{Spheron: Global sys} \]
\[ \text{'ADAM-like' system.} \]

[John H.?]

\[ \text{online monitoring} \]
\[ \rightarrow \text{data} \]
\[ \rightarrow \text{safety data} \]
Collision Rates: PHENIX vs ALICE

<table>
<thead>
<tr>
<th></th>
<th>ALICE (Run3)</th>
<th>sPHENIX (Max)</th>
<th>Ratio of data rates sPHENIX/ALICE</th>
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<tr>
<td>Pb+Pb / Au+Au</td>
<td>50 kHz</td>
<td>200 kHz</td>
<td>0.3</td>
</tr>
<tr>
<td>p+p</td>
<td>200 kHz</td>
<td>13 MHz</td>
<td>(1.6)</td>
</tr>
<tr>
<td>Trigger/Readout</td>
<td>50 kHz/(C.R.)</td>
<td>15 kHz</td>
<td>-</td>
</tr>
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- MB Event track multiplicity $dN/d\eta$
  - sPHENIX = 1/3 ALICE (pp)
  - sPHENIX = 1/5 ALICE (AA)

sPHENIX triggered data rate fits well within ALICE readout hardware specs
Projected Radiation Level after 5-year Runs

Projected sPHENIX integrated luminosities after 5-year operation

- **AuAu**: \( \text{Lum.} = 214 \text{ nb}^{-1} \)
- **pp+pAu**: \( \text{Lum.} = 1340 \text{ pb}^{-1} \)

Projected sPHENIX MVTX L0 fluence: \( \text{TID} = 1060 \text{ krad} \)
\[ \text{NIEL} = 6 \times 10^{12} \text{ N}_{\text{eq}}/\text{cm}^2 \]

Outer layers:
- \( \text{L1} = 0.6 \times \text{L0}; \text{L2} = 0.4 \times \text{L0} \)

Sensors tested to full MVTX NIEL and \( \sim 3 \times \text{TID} \) @ALICE (as of 9/18/2018)
Two HICs Produced and Tested at CERN w/ Extended Power Cables

NO noticeable difference in sensor performance, as expected, 9/2018
HICs Test Results from CERN (9/2018)

- Threshold and noise (from charge injection turn-on curve) are indistinguishable
- Other tests also see no change: supply currents, high-speed data transmission

15 cm: Before: 2 ALICE IB HICs

- Noise level: ~4 e’s; Threshold: ~180e’s; MIP: ~1000e’s

After: same ALICE HICs, replaced power FPCs
- top 40 cm, bottom 60 cm:

- Noise level: ~4 e’s; Threshold: ~180e’s; MIP: ~1000e’s
The connection to the service cables is achieved by a double FPC extension which is soldered to the HIC.
FPC Extension for Connection to Electrical Services

From Antonello Di Mauro

2-layer flex, PI: 50 µm, Cu: 35 µm, solder mask: 20 µm

The two flexes are connected together, AVDD is transferred from top to bottom.

The PWR extension is connected to the FPC by iron soldering and wings are cut.

Longer copper traces ~30cm for sPHENIX, no other components

Unchanged
LANL LDRD Activity Highlights

- MAPS evaluation
- Readout integration
- 4-sensor telescope
- Test beam at Fermilab
- Mechanical & cooling

4-ALPIDE Telescope: 5m-long SamTec cables

Signal integrity & cables

Cooling system prototype

Service cone R&D

FPC power extension R&D

Readout R&D
sPHENIX/MVTX IB Stave Assembly Procedure at CERN by ALICE ITS Group

1. Prepare sensors and FPC
2. Glue 9 sensors to FPC
3. Wire bonding 9 sensors to FPC
4. Solder power flex PCB to FPC
5. Glue HIC to coldplate/carbon space frame
6. A stave is ready for QA
7. CMM
B-Hadron & b-Jet Tagging

- Detected using the long lifetime of bottom quark hadrons:
  - Displaced tracks
  - Large 2nd vertex invariant mass
- Need high precision tracking and vertex determination – MVTX!
- Need excellent jet detection capabilities – sPHENIX!
sPHENIX@RHIC (2023+)

sPHENIX Inner Tracking: MVTX

Key integration tasks:
- Readout
- Mechanics

“Adopt” ALICE ITS/IB:
- Minimum risk
- Maximum physics

ALICE ITS Upgrade @CERN;
Inner Tracker System (2021+)

Leveraging on extensive R&D and design work by ALICE
Possible location for the two MVTX racks, from previous slide

Estimated 2D plane cable length 7.3 meters